SCIENTIFIC PROGRAMME

E-BUSINESS
IN CE

A BUSINESS PROCESS REENGINEERING FRAMEWORK FOR ANALYZING E-COMMERCE EFFECTIVENESS

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ABSTRACT

The world of business is being revolutionised by the Internet and the World Wide Web. Information technology (IT) opportunities constantly emerge in this new environment. Despite the financial meltdown of e-commerce companies, and their operational difficulties, companies are still increasingly turning to the Internet as commercial gateway. This has given rise to different e-business formats and platforms, covering a wide range of business processes, such as sales, procurement, design and manufacturing.

This paper describes a model, which is based on the Davenport functions used in BPR methodology. It analyzes the different e-business formats and identifies which of the Davenport functions they support. From this their effectiveness (or lack thereof) is derived.

The model is inspired on the fact that effective e-business portals should be integrated seamlessly into the business processes of the parent company. Therefore, BPR methodologies could be effective in (re-)designing e-business portals and their functions. The paper illustrates the model with different case studies.

1. INTRODUCTION

E-Business or e-Commerce includes electronic trading of physical goods and of intangibles such as information, between companies and/or private persons. E-Commerce has already existed for over 20 years, mainly as strictly formatted information exchange protocols, such as EDI. However, only recently it underwent an explosive development because of the Internet and the Word Wide Web (WWW).

The key enabling characteristics of the Internet and the WWW are (Timmers, 2000):

- Availability: 24-hours per day and immediate access;
- Ubiquity: global information networks offer worldwide, large-scale and low-cost access to e-commerce everywhere;
- Global: no physical borders for access;
- Local: paradoxically, the Internet reinforces local physical presence and local content;
- Digitisation: the real business will increasingly be happening in information space;
- Multimedia: long-awaited combination of technologies;
- Interactivity: appears to overcome the virtuality of the business relationship, as well as an opportunity for greatly improving traditional customer service and lower price;
- One-to-one: it becomes possible to perform individual customer profiling;
- Network effects and network externalities: low cost and fast growth in the number of relationships and;
- Integration: add value-combining information across steps of the value chain.

E-Business uses connected marketplaces, the Internet and IT opportunities. It has changed the rules of the market and the role of information technology to create value for customers and for the firm.

2. IT OPPORTUNITIES

If one cuts through the hype and technological jargon of many e-business platforms, what remains is a new "toolbox" of communication and information processing techniques. Just as any other business support technology, such as ERP, successful use will depend heavily on the extent to which companies can introduce these technologies seamlessly into their business processes (Van Landeghem et al, 1999). It is therefore useful to analyze e-business technology as another ICT tool, with respect to the opportunities it could provide. A good analytical framework of the ICT impact on business processes has been described by Davenport

(1993). In Table I we list the 9 basic impact formats of ICT, and we provide for each format examples of companies, whose WWW platform is particularly designed for the specific function. These examples have been described at length in (Bergareche, 2002). Due to space limitations, we include only excerpts in this paper.

IMPACT	EXPLANATION	EXAMPLES (Bergareche, 2002), (Timmer, 2000)
Automational	Eliminating human labor from a process	Caesma S.L., Amazon, Virgin
Informational	Capturing process information for purposes of understanding	eBay, Cydesa, Frape Behr
Sequential	Changing process sequence, or enabling parallelism	Team Center, Kodak, Phoenix Mutual Life
Tracking	Closely monitoring process status and objects	MRW, Johnson&Johnson, DHL
Analytical	Improving analysis of information for decision making	Storm (Linear Systems), Amazon, Progressive insurance of Cleveland, American Express
Geographical	Coordinating processes across distances	Hewlett Packard, Frape Behr, Ford, General Motors, United Parcel Service
Integrative	Coordination between tasks and processes	Centre CIM, Hospitals,Comercial Loans, Insurances
Intellectual	Capturing and distributing intellectual assets	Ford, American Airlines, The Big Six and other accounting firms
Disintermediating	Eliminating intermediaries from a process	Pefa, Virgin Express

Table I. Davenport functions of ICT, with examples from WWW platforms

3. E-BUSINESS MODELS

An e-business model is defined as the organisation of product, service and information flows, with specific sources of revenues and benefits for suppliers and customers. Suppliers and customers interact, sometimes throughout intermediaries, using technology to attain better communications and lower transaction costs.

Information and communication technology enable a wide range of business models. Timmer (2000) has written a landmark book describing different e-business models, with some examples. In table II we provide an overview of these models, which we subsequently will match with the Davenport functions of Table I.

4. RELATIONSHIPS BETWEEN IT OPPORTUNITIES AND E-BUSINESS MODELS

Referring to Table II, E-Shops open a new channel of advertisement, promotion, and more and more the possibility of purchasing with low transaction costs. Cost does not increase because human labour is not needed to offer a 24-hour service throughout the Web. Land's End, an online clothing shop, uses this opportunity, "automational", although the firm is also still sending letters by traditional mail.

In some cases we can also see the impact of the informational opportunity. For example, Land's End captures customers' behaviour to improve its services. This online store offers the opportunity to their customers to have access to their order status, which implies the use of the tracking opportunity. When e-shops allow ordering and paying online, co-ordination across distances is needed to assure customers satisfaction. For instance, Fleurop, which sells and distributes flowers, co-ordinates sales and logistic processes across several places. Land's End uses the integrative and the sequential functionality in a basic way. They co-ordinate tasks with UPS. However, the firm should improve the use of the geographical impact because nowadays orders from outside of the U.S cannot take advantage of all the Web offerings.

An e-mall is a group of e-shops, therefore, like in the e-shop model, human labour is reduced, and even more than in the e-shop model, the geographical opportunity is exploited. A lot of shops work from different locations sharing some features. However, in most cases co-ordination between the e-shops has to be improved. An e-mall has to work in an environment of security. Quality and delivery reliability has to be guaranteed, often by third parties, if we want to gather the best suppliers. In this regard, the e-mall concept adds value to the e-shops by providing a brand-like quality guarantee to its customers.

E-BUSINESS MODELS	EXPLANATION	EXAMPLES
E-Shop	Electronic form of a traditional shop. Basic Web presence, sometimes with possibilities to order.	Lands' End, Fleurop, Travelocity, Merck-ltd.
E-Mall	Collection of e-shops, usually enhanced by a common feature or theme.	Industry Net, Abalone Web, EMall, Browser Mall.
Third Party Marketplace	Portal function to create a marketplace with multiple buyers and sellers, often within a specific industry sector.	Tradezone, Amazon Associates Programme, Citius.
E-Procurement	Electronic tendering and procurement of goods and services. A purchasing portal widens the supplier base and reduces transaction costs.	Autochain, Japan Airlines, Epylon.
E-Auction	Offers an electronic implementation of bidding mechanisms also known from traditional auctions.	eBay, Fast Parts, Pefa, Eauction Room.
Information Brokerage, Trust and Other services	Information services are emerging to add value to the huge amounts of data available on the open networks. Trust services provide basic security technology to Net parties.	Google, Verisign, Belsign, Tiaa Cref, Fulton Financial Advisors.
Value-Chain Service Provider	Specialised in a specific function for the value chain.	CheckFree, FedEx.
Virtual Community	Gathering different parties with the same interests to add value sharing these common interests.	Amazon, Indconnect, Apparelex, Yahoo.
Collaboration Platform	Provides a set of tools and an information environment for collaboration between and within enterprises for trade, design or manufacturing purposes.	Vastera's Collaborative Platform, Commerce One Collaborative Platform, VA Linux, Colaboris.
Value-Chain Integrator	Integrates multiple steps of the value chain, with potential to exploit the information flow between those steps as further added value.	Marshall, Commerce Quest formerly known as Advanced Network Solutions, TRANS2000, UPS.

Table II. e-Business Models, as defined by Timmer (2000)

Third Party Marketplaces gather a wide range of suppliers and customers, assuring security often applying sophisticated algorithms. Processes should be co-ordinated across distances. Interaction between participants has to be co-ordinated too. In Tradezone, for instance, the key issue is to achieve the co-ordination between multiple catalogues to assure satisfaction of both suppliers and buyers. In some cases we can distinguish the informational and analytical impact. For example, Amazon Associates captures consumers' behaviour, buying patterns and suggests substitute products. Furthermore, customers can access their order status. Third Party Marketplaces offer a wide range of services almost without human labour; Tradezone offers complete processes online, enabling processes parallelism. The firm should improve the use of the disintermediating opportunity bypassing some middlemen by adding online information, but this will only be possible if trust in e-business increases.

An important feature of e-procurement is the wide choice of suppliers. Customers can purchase online customised items from the selected suppliers. To achieve a time reduction it is necessary to automate requests and bids. As in Epylon, the quality of service is enhanced allowing control of the process status with the tracking opportunity. If a company wants to develop this model correctly it has to use the sequential functionality. Workflow has to be allowed between customer and supplier and also between different departments of a firm. Parallelism between processes has to be enabled. For example, in Epylon customers ask for quotations from different suppliers at the same time and then they can compare responses on a single screen.

E-auction enables a true disintermediation, for instance with PEFA (an online fish auction) fishermen can sell their catch directly to the final retail consumer. However, not all of the intermediaries are bypassed in this model. Some people are needed to assure the quality because consumers cannot see what they are going to purchase. To achieve profit applying this model, co-ordination between all the participants, and their roles in their different locations, has to be assured. In the eBay example we can see the impact of the informational opportunity. eBay is an online consumer-to-consumer auction that collects customers' behaviours, information about the duration of each auction, etc. to improve its service. E-auctions often allows consumers to monitor process status and even to have them alerted (through paging or email) when the price on selected items reaches a certain threshold.

Information Brokerage, Trust Services, and Consultancy add value to the available data. They aim to help consumers, firms or people, to achieve better financial results, services, information, etc. These firms should capture customers' behaviour. To optimise the obtained results one should use complicated algorithms and distribute them to all the interested parties, as for instance, Fulton Financial Advisors does. Offering universal services increases the company's benefits and the customer's trust. For example, we have studied the case of Verisign that offers security services around the world endorsed with its worldwide brand. The automational opportunity can reduce errors.

The Value-Chain Service Provider model has to enable the co-ordination between several tasks. We have seen that FedEx co-ordinates shipment requests and carriers. To offer a complete service firms should offer an easy access to the transport status around the world. It could be useful to apply computer programmes to optimise services. FedEx is also applying a sophisticated programme to select the most suitable routes to deliver an item. Sometimes Value-chain Providers capture and distribute intellectual assets. For instance, FedEx provides training about logistics.

Virtual Communities gather different parties around the world that share knowledge and interests. These companies can increase the quality of their services offering the possibility of monitoring process status. Participants can review their last operations. In this model processes can be done simultaneously. The order of traditional business' processes often changes. Virtual Communities offer a complete service where different process must be co-ordinated. Furthermore, we have seen the analytical impact in Amazon where the firm collects information about its customers and then is able to offer customised products.

Collaborative Platforms link applications co-ordinating tasks and processes across distances. For instance, the design of different parts of a car can be done in different departments or even in different countries that work co-ordinated. Some

	AUTOMATIONAL	INFORMATIONAL	SEQUENTIAL	TRACKING	ANALYTICAL	GEOGRAPHICAL	INTEGRATIVE	INTELLECTUAL	DISINTERMEDIATING
E-SHOP	⇧	⇨		⇨		⇧	⇨		⇧
E-MALL	⇧					⇧	⇨		⇨
THIRD PARTY MARKETPLACE	⇧	⇨	⇧	⇨	⇧	⇧	⇧		⇨
E-PROCUREMENT	⇧		⇧	⇧		⇨	⇨		⇨
E-AUCTION	⇨	⇧	⇨	⇧		⇧	⇧		⇧
INFORMATION BROKERAGE	⇧	⇨			⇧	⇧	⇨	⇧	
VALUE CHAIN SERVICE PROVIDER	⇧			⇧	⇧	⇧	⇧	⇨	⇨
VIRTUAL COMMUNITY	⇧		⇧	⇧	⇨	⇧	⇧	⇨	⇨
COLLABORATION PLATFORM	⇨	⇧	⇧	⇧	⇧	⇧	⇧	⇧	
VALUE CHAIN INTEGRATION	⇧		⇧	⇧	⇨	⇧	⇧	⇧	⇨

Legend of figure 1:

⇧ NECESSARY/CRUCIAL

⇨ RECOMMENDED/USEFUL

Figure 1. Ideal Davenport functions for each e-Business Model.

processes that usually were sequentially developed can be done in parallel. We recommend the use of the tracking opportunity in collaborative platforms; it can make the work easy. Intellectual assets have to be captured and distributed between participants to enhance the efficiency. We have identified, for example in the case of VA Linux, that engineers share information during product and process development. Engineers can capture process information. Knowledge is distributed throughout the firm.

Finally, Value-Chain Integrator co-ordinates multiples steps of the value-chain capturing information. Application systems among trading partners and customers are integrated. Parallelism between tasks, processes and files broadcast is enabled. Workflow is secure and reliable. The distribution of intellectual assets is possible. For example, we have studied the case of Advanced Network Solutions. They offer training to customers and share knowledge and experience with them. The model has to co-ordinate a complete service, along the different steps of the value-chain, across distances.

	AUTOMATIONAL	INFORMATIONAL	SEQUENTIAL	TRACKING	ANALYTICAL	GEOGRAPHICAL	INTEGRATIVE	INTELLECTUAL	DISINTERMEDIATING
LANS' END	●	●		●		▲			●
BROWSER MALL	●	▲		▲		▲	▲		
TRADEZONE	●	▲	●	●	▲	▲	▲		▲
EPYLON	●	▲	●	●	●	●	▲		
eBay	▲	●		●		●	●	●	●
PEFA	●	▲		●		●	●	●	●
GOOGLE	●	▲	●		●	●	▲	●	
VERISIGN	●	▲		▲	●	●			
FULTON FINANCIAL ADVISORS	▲	●		●	●	●	●	●	▲
CHECK FREE	●	▲		▲		●	●	▲	
AMAZON	●	●	●	●	●	●	●	●	
VA LINUX	▲	●	●	●	●	●	●	●	
MARSHALL	●	▲	●	●	●	●	●	●	

Figure 2. ICT Opportunities for selected e-business examples

● **They are doing it.**

▲ **They should do it.**

We have combined the results of the above analysis in two figures. Figure 1 shows, for each e-business model, the "ideal" set of Davenport functions that are necessary and useful. Figure 2 shows for a selected set of examples, which opportunities they have left open.

5. CONCLUSIONS

From inspection of figures 1 and 2, while paying attention to the relationship found between e-business models and the opportunities offered by the information technology, we conclude that:

- The automational and the geographical opportunities are the most used in current e-business models. But alone, they cannot achieve competitive leadership of e-business in the world.
- The use of the informational, the intellectual and the analytical functions has to be improved, nowadays they are the least applied. The use of information has to increase. Sharing information should add value to achieve true improvements, customer satisfaction and benefits.

By incorporating the proposed framework in the design of new e-business platforms, one should be able to achieve more effectiveness and enhanced customer value.

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New businesses on The Net: the digital object handling services

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KEYWORDS

E-enginering, digital object handling, e-engineering, e-marketplace, virtual incubator of enterprises.

ABSTRACT

This paper presents the results achieved in the scope of the IPS029077PR-TEMA project "*TElematic MArket of services related to Digital Objects*", co-funded by the European Commission in the framework of the "Innovation & SMEs" programme. Two aspects have been deeply studied in this project: the first is the growing profitability of online computational services that grouped in an Internet portal can build a real market of digital object handling services. Digital object handling in the scope of the manufacturing has the meaning of engineering activities based on digital models of parts and assemblies. The nature of the cited activities makes Internet the ideal channel to run the business, nevertheless the new online marketplace needs to reach a critical mass in order to be trusted and become a successful business.

For this reason, the second aspect faced by the TEMA project concerned the support to the creation of new companies capable to join the e-marketplace and contribute to the creation of a virtual community, reaching the required critical mass for the marketplace. TEMA developed a methodology for strengthening the business idea of applicant entrepreneurs wishing to operate in the digital object handling market, also making them available some web-based tools useful in analysing their idea of digital object handling service.

By the project end, TEMA is achieving two results: an Internet portal representing the first prototype of e-engineering marketplace, used for testing some experimental services of Digital Object Handling. The second result is the TEMA Virtual Incubator of e-services, a web-site publishing the TEMA methodology and a bundle of services for the market analysis and the financial planning of any new business idea that could launch a new digital object handling service.

INTRODUCTION

The term "digital object handling" can be used to embrace a wide range of activities related to the computation, exchange and management of digital information, namely digital objects. The Engineering-oriented companies are the principal users of computer-based technologies supporting the best in class treatment of their product data. Plenty of computations are the core of software tools useful to improve the quality of the product life-cycle, in particular during the design phase. There are different kinds of simulations, modelling, translations and analysis, reducing the time to market of the new products, the costs of the development, the quality and the accuracy of the results necessary to move from the idea to the target good.

All the digital object handling techniques contributing to the development, validation and test of digital models have a potential market in the development of Internet services addressing the satisfaction of the demand of manufacturing companies, despite of their location. Since digital object handling services are just requiring digital data to produce their results, they find in the Internet based technology a unique business chance for the marketing and the service delivering to customers all over the world, actually operating in the global marketplace. From the other hand, any company wishing to take advantage of latest computational technology for the development of their products, even lacking competencies for that, can outsource the desired computation by purchasing the proper online service.

Actually a virtual market of digital object handling services is not yet operating, but new providers appear on the market, while connectivity problems and bottlenecks in Internet are falling. In other worlds, it can be perceived the potential of the e-engineering market while the technology is more and more mature for supporting it. Apart from the benefit of a virtual market collecting the different offers of services, a problem exists in the approach of the small enterprises. Potential customers of the digital object handling services should not be large companies, which should have internal resources and departments in charge of the required digital object handling. Potential customers can be likely identified in middle and small companies developing their own products and capable to perceive the importance of the computational services related to the products design and engineering, but hindered in their use.

As a matter of fact, small and very small companies are not used to get advantage of digital object handling services, they face difficulties in approaching such technologies and they can not devote resources to purchase them or to train employees to use them properly. Also, most of them are not used to search and buy services and goods in Internet.

It is feasible to depict a scenario where the Information Society is ready to satisfy the demand of the companies, but many target users, in particular very small SME, are distrustful. Partially this situation is due to the difficulties of the so called new economy, that demonstrated the weakness of an economic system where investments, speculations, profits and bankruptcies have been reiterated at a ceaseless rate. Even so, the new economy is just the present economy and companies started to perceive the potentiality and the benefits of the Internet-based economy. No businesses can neglect the expectancies of customers more and more attracted by the Internet world, as a consequence no companies can just wait for the next events.

Internet is strongly committed to become the more convenient and effective media providing information to the widest and heterogeneous public. Yesterday Internet was a *competitive advantage* for the pioneers of the new economy who survived, today and in the future it represents a *competitive requirement* for any company that will make a proper use of The Net.

Digital Object Handling services (DOH)

In the world of small and very small companies, where it is not easy to introduce ICT support systems, the entrepreneurial associations play the major role of stimulating the entry of the Information Society. These associations are starting to provide online services to their associated, for example systems to automate payrolls and invoicing.
Managers in any company are conscious about the importance of being in time for the meeting with the Information Society and get advantage of the numerous opportunities for the best run of their core activities. Missing the appointment should be harmful, in particular in the coming years, since acting in the global marketplace necessarily imposes the companies to be dynamic and highly competitive. In this days it is already clear that information is even more precious than physical assets, in particular for networked organisations that are founded upon collaborative activities co-ordinated thanks virtual value networks of information. The opportunity of the e-engineering is enhancing the perception of the higher information value, thanks to the chance that every company has for improving its overall business.

In this panorama the digital object handling is promising functional and qualitative improvements to products and processes of the customers, namely a competitive advantage previously almost exclusively owned by leader companies of given markets. Industries should pay attention to the digital object handling services delivered online and the benefits they offer. There are many reasons justifying this:

- Internet is the most suitable media to sell and get the results of the digital object handling computations. Why renouncing the best ones if they are just one click far and they allow to recover or reduce the delay with respect to market leaders?
- Even if the digital objects contain company know-how, they can travel on the Net in a secure and easy way, being protected from hacker attacks. Latest security technologies allow companies to trust the e-business.
- Any company can take advantage of the DOH for maintaining or improving the desired level of competitiveness, establishing partnerships with companies that are specialised in the required DOH services. The market would create competition among service providers, making more profitable the use of the services.
- Customer companies get the possibility of outsourcing the required DOH processes to service providers, neglecting their location in the world.
- Finally, Internet allows any enterprise to gain access to competencies and technologies of specialised experts, with the lowest costs.

This opportunity can be collected not only by companies already used to exploit DOH processes, but also by companies not used to do so. In particular it is an opportunity for many SME used to work just as subcontractors of larger firms. They can acquire a major control of their processes, improve and differentiate them, increasing their competitiveness and their offer, also supporting their entrance in new markets.

THE TEMA PROJECT

The TEMA project aims at proving applicant entrepreneurs with support tools for the start-up of their innovative firms, in particular companies delivering online DOH services, besides stimulating the creation of a virtual marketplace hosting the new created services. The objective of the e-marketplace is to make easier for customer to identify the desired services, besides guaranteeing the quality and the earnestness of the hosted DOH providers.

As a matter of fact, virtual communities are the premier sites where building and fostering the necessary business trust. The birth of an actual virtual market of digital object handling services is more hindered by the culture of people than by the technology. This is particularly true for SMEs, where entrepreneurs dislike changes, in particular concerning the introduction of new ICT tools in their company. The biggest potential of the DOH services is actually here. Companies can verify and test or make an extensive use of the desired services, without side-effects on their core business. In other words, they can get the maximum benefits, the best technologies and competencies just paying for the lower costs.

The TEMA project started in September 2000 and it finishes in April 2002. Major result of the project is made of two guidebooks for DOH companies start-up. These guidelines are available on the project website, together interactive tools for business planning and market research. Both guidelines and tools are available for registered users and registration is free of charge.

The guidelines

The guidelines are aimed at strengthening the entrepreneurial spirit and the business idea of people, being the objective of TEMA to stimulate and support the creation of new DOH services. The themes discussed in the guidelines belong to two main fields: (i) the DOH company start-up path discussed step by step; (ii) the creation of the market interface, that is the Internet portal supporting the DOH business run.

Selling services online is typically a business-to-business activity, even if differentiation in the applied business models could be revealed for services focused on different areas. To start up a digital object handling business means to launch new services that are very innovative in the actual market. For this reason, even if the DOH company performs an online business that is a particularly risky activity, such a company should also have a big advantage: *it offers a range of services whose importance is well known by the target customers, namely a market made of companies that can not be unsteady and seasonal. The services are not accessory, they can support the core business of the customers for the benefits of their competitiveness.*

In order to ensure expressiveness to the guidelines and their most effective and widest use, they are published in the TEMA Virtual Incubator website in hyper textual format, besides being integrated with interactive tools allowing the user to easily apply the guidelines to his business case. The interactive tools support the market analysis and a financial planning for any DOH business. The TEMA Virtual Incubator is now published at the address

http://www.tema.democenter.it.

The TEMA guidelines presents the start-up path of a DOH service by taking into account its peculiarities, discussing specific arguments like the technological requirements of the market interface, the European directives regulating the online business, the business process and many other topics. The start-up path is subdivided in the following main steps (see also Figure 1 and Figure 2):

- *Market analysis*: the debate concerning the opportunity of performing a market investigation before entering the market with a new product or service is far to be concluded. Market researches are expensive, they take time, also sometimes a market research has been wrong affecting the good results of a business, in particular when new technologies were involved. TEMA wishes to help people in identifying their potential market and it suggests a methodology to evaluate the market niche of a given DOH service, using data aggregated at the European level.

- *Planning*: the creation and management of a new business must be carefully evaluated from the financial point of view. Not all people having a business idea can study by himself the financial implications of his idea, that's why TEMA provides two different approaches: a budgetary analysis that can be used also by people not used to deal with financial planning, and a second level of analysis providing more detailed results but requiring more effort and experience from the user.

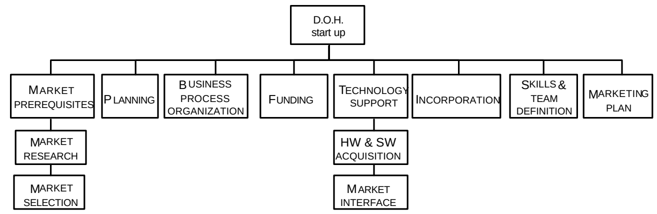

Figure 1 – Breakdown structure for DOH start-up

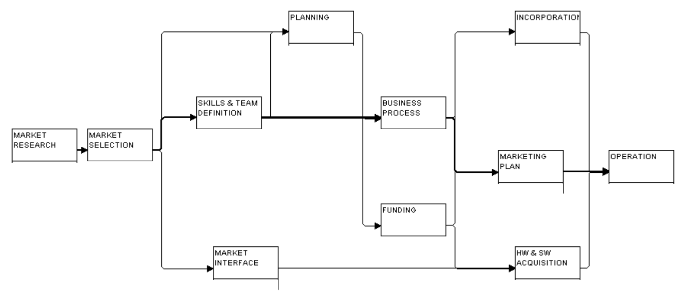

Figure 2 - Pert diagram of the DOH start up

- *Skills and team definition:* any DOH service is a business requiring a range of capacities and skills in many different fields. Even if a small team can carry out the business, its members must sum up the full range of roles required to ensure the proper management, quality and performance of the DOH service.

- *Business process*: providing online a DOH service requires to follow a proper business process, also taking into account a set of rules coming from the regulation of the e-businesses.

- *Incorporation*: there are different opportunities for creating a new company. Different models exists in any European member state, having different requirements and providing different opportunities. According to these, entrepreneurs can reason about the incorporation model that is better fitting its requirements and possibilities.

- *Marketing plan*: even before starting to operate on the market, a DOH company must set up its marketing plan. In this era Internet is providing big chances to the businesses and is completing a marketing mix that must still take advantage of traditional media, in order to provide the proper company image and service marketing to different categories of audience.

- *Hardware and software acquisition*: a DOH business is based on the ICT technologies, both for providing and delivering the DOH services. It is necessary to evaluate and select the proper communication platform, implement all the functional services necessary to guarantee the performances required by the customers, besides to procure the application-specific platform to carry out the process of digital object handling.

Relevance has been given to the *Market Interface* analysis, as it is fundamental for the effectiveness of the online business wishing to sell in Internet the services. Actually Internet is the unique channel to reach the customers and the setting up of the market interface must take care of many elements to fit the requirements of an e-business.

The matrices complex

In order to help users in applying the methodology developed in the guidelines, the Virtual Incubator has been enriched with two active applications. One of this is the matrices complex. By means of this tool, the user is guided through a Market analysis, helping him to find interesting market data, about the particular kinds of manipulation he is interested in and about the different industrial sectors which use them. This analysis is done through the combined reading of given matrices: Relevance matrix; Present use matrix; DOH matrix; Segmentation matrix; Prospect niche matrix. Scope of the tool is not just to provide data for a sample of DOH services, it is also promoting a research methodology that allows the users to learn the principles of the investigation.

The business plan builder

This application aims to assist the future entrepreneur along the path from the conception of his business idea to the conscious definition of his future business activity. The result of the interaction between the customer and the application consists of a preliminary Business Plan and a user exercise in understanding the requirements of his business.

The importance of writing a good Business Plan is universally recognized and almost all the traditional incubators supply documents recommending contents, document structure and style of this milestone of the business creation. The business plan builder empowers the applicant entrepreneurs combining the *editing functions* for their own business plan with the evaluation of the achieved results, providing *benchmarking parameters*, *visual indicators and aids* to understand results of their financial drafting.

As such a document laying out economic and financial programming can be very complex and it is a vital element for the profitable start-up of a firm, the document resulting from the use of the application can not be considered a final plan. The virtual incubator will allow the users to build their own *preliminary business plan.* Such a document will be a reliable base from which to start writing the final BP, maybe with a professional adviser. The preliminary Business Plan is composed of several main sections, such as:

1. Entrepreneur presentation and business introduction.
2. Strategic planning and Market analysis.
3. Operative planning, Cost analysis and Financial considerations.
4. Projection of the estimated economic results.

The third Section "Operative planning, Cost analysis and Financial considerations" allows the preparation of several sectional budgets: Sales budget; Direct Costs budget; Employees budget; Capital budget; Amortizations budget; General Costs budget; Financial budget.

This set of budgets is easy to draw up and to understand by any user of the virtual incubator, but the counterpart of this easiness of use is a financial analysis not very deepened. Stopping to this level, a prospective entrepreneur misses detailed information that would be relevant in the following, when facing the final business plan. Nevertheless, the user has available schemes to get projections of the cash flow and analysis of financial index variations. The tools made available by TEMA are:

- *Variations Analysis*: an instrument that enables the user to do a rapid and direct comparison among the economic results obtained with the data put in the sectional budgets, and the ones derived by some specified percentage variations on the different items.

- *Cash Flow Analysis*: a facility with the aim of displaying to the user possible Cash Flow series for the first twelve months of operation of his company, in order to discover lacks of money.

For users being already used to deal with financial planning, TEMA proposes also the forth Section "Projection of the estimated economic results" (in depth analysis). In this section a user will get available a more exhaustive and detailed tool to perform the financial analysis. The deeper level of financial investigation forces the user to do a hard work for the financial parsing and the tracing of the proper data. As obvious, this hard work lead the user to more detailed data and indicators.

The showcase

The last phase of the project has been dedicated to the preparation and execution of a showcase aimed at simulating a marketplace of digital object handling services. The experimentation concerned four services where the handling of digital objects plays a fundamental role in the achievement of the final result: reverse engineering; simulation of plastic injection, CAD format translation and rapid prototyping. The prototype of the market portal is published at the address

http://tema.tekniker.es/temas.php

Thanks to the experiment it has been feasible to verify each function of the marketplace devoted to the business run, besides testing the market interface of each service and the related management functionality.

The experiments concerned two real industrial cases involving a sequence of DOH services for reaching the desired goal. A first trial concerned the reshaping and restyling of a perfume bottle, a second case lead to the production of a prototype of plastic gear. For the first trial the sequence of required services has been reverse engineering, CAD translation, rapid prototyping. During the second trial the service involved were CAD translation, plastic injection simulation, rapid prototyping. For each service the proper market interface has been used to agree the terms of the business, collect the problem requirements and perform the service. By the end of the experiment phase it has been possible to collect all the strength and weakness point of the market portal, with the aim of reducing the time to market of a real Internet marketplace of e-services.

CONCLUSION

The TEMA project has investigated a very promising market, that is the market of engineering-related services. Such services find their natural business channel in Internet, but despite of the effort spent for the transaction from the old economy to the new economy, a number of cultural and trust-related problems hindered so far the online business soar, compromising the survival of many dot-com companies. This can be the main reason why only few providers are delivering DOH services online. Nevertheless there is a strong commitment of governments and a growing desire of companies and citizens to improve and consolidate their relation with the Information Society. Technology is mature to support the widest implementation of the new online business, with continuous effort to ensure the desired level of security and the reduction of bottlenecks in connectivity.

It is according to this perception and to the impossibility of renouncing to the technical and cultural progress gained so far that TEMA acts for stimulating the creation of a Internet DOH marketplace. The digital object handling has the opportunity to become a profitable online business, both for skilled providers and customer companies outsourcing specialised computational services. TEMA verified the feasibility of the online DOH business and implemented a measure for supporting the development of new services.

The use of the achieved results and the lesson learnt from the trial will be addressed toward the integration with complementary competencies and tools, so that to succeed in fostering the DOH marketplace. First of all the virtual incubator would be integrated with traditional business development measures, building a support framework capable to act from the business idea development to the company start-up. Second, partners of the TEMA consortium are capable to initiate a marketplace by means of their own services, giving reason to the first run of the market. Finally, such a marketplace would represent the entry market for any new DOH provider company developed through the TEMA guidelines and supported in its development.

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Practical Experiences with B2B Applications

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INTRODUCTION

For the requirement of shorter development times it becomes more and more important for the automotive industry to offer simple possibilities of direct EDM access on bill on materials, [i]CAD geometries, assemblies, standards and specifications. As the variety of different information systems is enormous (in many cases historically grown), this becomes one the of most important tasks which automotive enterprises have to deal with in order to remain competitive and innovative.

This abstract explains the process to offer all information necessary for the development and production of a vehicle in a simple WebBrowser GUI using the example "*Integration of Product and Process Description*" of the Mercedes-Benz development process at DaimlerChrysler. Through this, benefits such as increased process reliability, early data provision and reduction of costs will result.

PROJECT DESCRIPTION

Currently, the design of body in white parts with the CAD system CATIA in the Mercedes-Benz development process at DaimlerChrysler is completely digital. This means, that single parts and assemblies are designed three-dimensional on the computer and not, as in former times, exclusively on the drawing board as a 2-D drawing. Up until now, technical drawings which had been derived from the 3-D data files, were required as obligatory documents for the documentation and release of components and thus also for those of the design of further organisational ranges, such as prototypes, production planning and plants. In many areas today, such as by the generation of operation equipment/facilities and test specifications of free form surfaces in raw parts, for example, 3-D data files are more frequently used directly. However, the 3-D data file does not contain all the process-relevant information. Only the drawing contains all necessary information.

The project "*Integration of Product and Process Description*" has the goal that all information necessary for the development and production of a vehicle is contained in the 3-D data file. All participants in the process will have access to this data, whereby the technical drawing can then be omitted. For the development/design and documentation without drawings, it will be ensured that all geometrical, process-relevant and organisational information of the components will be filed structurally in the 3-D data file. The implementation of the "drawingless" procedure in the following ranges, such as prototype construction, production planning and plants, makes new demands on the working processes. With the omission of drawings, the information for the design of operating equipment/facilities and workshops, for example, will be derived from the 3-D data files. A web-based eEngineering portal with integrated visualisation tools which are harmonised with the working processes must be employed. In order to ensure a reliable implementation, the requirements on the use of 3-D data files will be accommodated with detailed process analyses.

EXPECTED BENEFITS

- ❖ Efficient CAD-Methods in the design
- ❖ Faster Release Process – earlier availability of Product Information
- ❖ Faster Engineering Change Process
- ❖ Less redundant work "One-Source-Principle"

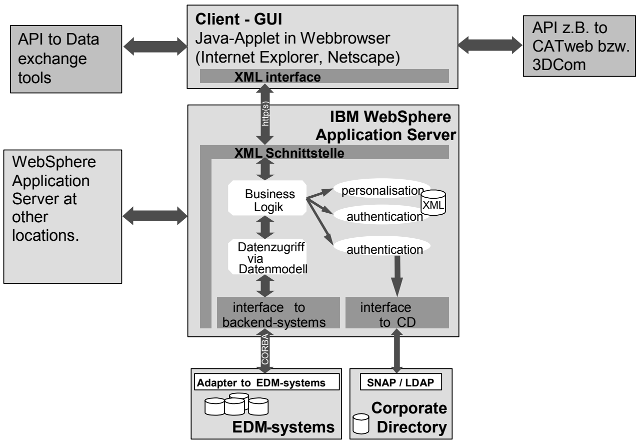
System description

The main component of the *Integration of Product and Process Description*[ii] process is the eEngineering portal with the integrated visualisation system.

An engineering portal can be imagined as a more horizontal portal which gives access to the information of several EDM/PDM systems and eBoM systems and display them in operating system independent graphical user interface. Main features are a SingleSignOn mechanism, a structured data model which contains the important informations of all available systems, the operating system independent GUI which is built in JAVA or HTML and a visualizing tool with more or less possibilities to handle the visualized geometry.

With these features the EDM/PDM systems and eBoM systems are opened for totally new user groups inside the OEM like purchaser, people involved in the production with little or no experience in the CAD/CAM area, people which are only interested in a special combination of information which has to be gathered from different systems like the combined information of part and price for example.

SYSTEM STRUCTURE OF THE EENGEERING PORTAL

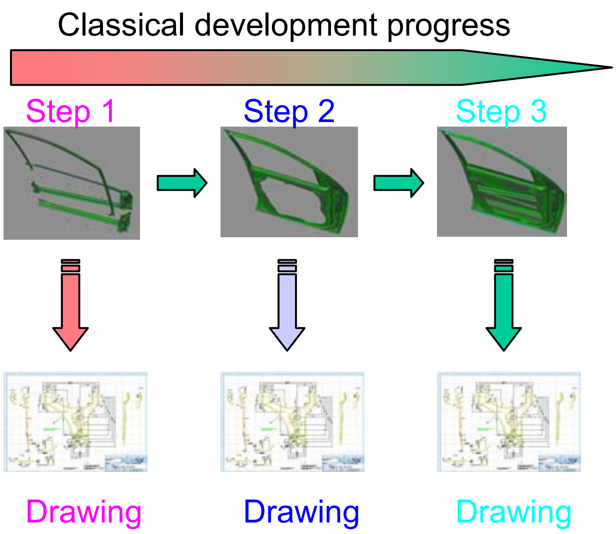


NECESSARY COMPONENTS

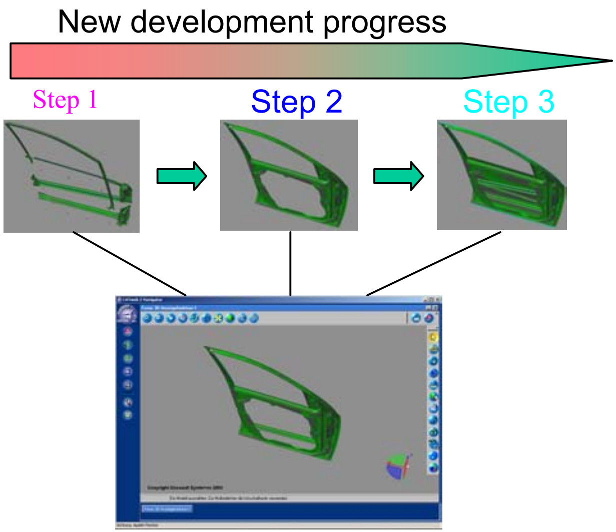
1. Presence of a working Corporate Directory (CD)
2. Non-aging UserID's on Legacy systems will reduce system administration
3. Powerful visualisation software if required with realtime visualisation
4. Exact definition of the data file model
5. Powerful Middleware (e.g. WebsphereApplicationServer)

INTEGRATION IN THE DEVELOPMENT PROCESS

The actual development process is described in the following drawing. At every step from the 3D model a 2D drawing has to be made for the pre-series research and the workshop departments. This is not only expensive but also increases development costs and slows down the whole development process.



When the new process is completely established the development process looks like displayed in the following chart:



eEngineering Portal

During the dynamic process the technical departments have access on the actual data in every moment of the project.

SYSTEM INTRODUCTION

The system started productive service in December 2001. 200 users in Stuttgart and Tuscaloosa /Alabama were trained in using the system. Most of the users came from the BIW production area and they were no CAD users. For them, it was a big step to become familiar with a completely new way of working with parts.

The system introduction is still in progress and will be finished at the end of 2002.

FIRST EXPERIENCES

- In general, experience has shown that the eEngineering Portal is easy to handle. The access to the different EDM-system takes place with good performance.
- Noticeably increased access possibilities to the EDM/PDM systems by an access via several databases at the same time with only one user interface. Integrated manoeuvrability both via parts list trees and also to part number levels.
- The possibility of a Single Sign on principle is especially important for large-scale enterprises and saves a lot of time at the administration of users.

- ❖ Users from the production line sometimes need an extensive training program.
- ❖ The importance of the CAD-viewers is considerably higher than expected.
- ❖ For an enhancement of the performance it would be desirable, to store the CAD geometry immediately in a pretesselated (already prepared for the CAD Viewer) format.
- ❖ The user are requested to have knowledge about the EDM/PDM systems to find the right version of the CAD geometries.

Overall, it can be said that the establishment of the eEngineering Portals has proved to be an important step into the right direction. Together with the project "*Integration of Product and Process Description",* it has demonstrated to be an important module, approaching the digital factory/plant.

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ORGANIZATION AND MANAGEMENT

PRODUCT PROGRAM DEVELOPMENT
– A CASE STORY FROM A KITCHEN MANUFACTURER

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KEY WORDS
Product development methodology, Multiproduct development

ABSTRACT

Development of product programs or variety of products instead of single products has been of interest for many researchers over the last years. Going from a mass-production strategy to a variety strategy have caused problems for many companies. Platform development and modularization are examples of results of these efforts.

Designing a totally new product program for a company that also needs to make a smooth transition from old to new products, is a major challenge. A kitchen cabinetry manufacturer shows how it can be done by separating the products into functional and aesthetic parts, and by designing the program so that variability is achieved where it counts for the customers and held down where it doesn't. The paper outlines the product program strategy – both regarding internal process efficiency and external market adaptation – the tools and methods applied, and the resulting product program.

INTRODUCTION

"The management challenge of the 1990s is to reduce costs- and increase the perceived value of the product." (Galsworth 1994)

In many companies there is a steady growth of the product assortment. This growth is a key characteristic of mature product areas, areas where customers have come to take working functionality of the product for granted. In these product areas, properties other than the basic functionality may mean the difference between a sale and a lost sale. The consumer products market is full of examples of this. Mobile phones, for instance, are no longer sold on their ability to place and to receive calls, or to send and receive text messages; these properties are so obvious, that they are not worth mentioning. The attractive features of new mobile phones are things like PC connectivity, time manager software interfacing, voice command, text typing assistance, etc, etc; none of them functional in a narrow sense, but all adding to the complexity and the variability of mobile phone models and variants. And since they are not necessary or intrinsic properties of the product and each of them usually add cost to the product, each will appeal to different customers, and thus product variants will easily appear (Aasland 2001).

The manufacturers' ability to attract a large percentage of the potential market will therefore depend – among other things – on the width of the variant assortment.

On the other hand, production and other internal stakeholders want less complexity and more economies of scale. Flexible production is a key to efficient handling of product variety, but no flexibility can match the efficiency of repeated production of identical products.

Standardisation, product platforms and modularization are ways of coping with the internal complexity. Better ways of handling the complexity (with product modelling or configuration) is often presented as an alternative solution, but will in our experience only work if based on a sound product program.

A product program should be a planned product portfolio for a company, which considers both internal and external impacts on the product portfolio. An oversimplified way of presenting this, is to say that we want to keep or improve positive variety (variety which is important in the market), while changing negative variety into commonality to achieve internal benefits.

In this paper we present a case where an effort was made to develop a new product program based on variety effectiveness in production and logistics while retaining and even improving market opportunities. And as an added complication, a number of factors – including the heavy investment in exhibition cabinetry in the shops – say that the transition from old to new should in part be hidden from customers.

The result is a more efficient and flexible product program achieved by introducing a later differentiation point in the production.

GOAL

The goal of the project has been to apply new methods to the development of new product portfolios, and to develop a new product program for the company with clear benefits regarding internal processes (reduced complexity, increased efficiency) and increased possibilities regarding the market.

BACKGROUND – PROBLEMS AND CHALLENGES

The company in question is one of Norway's leading suppliers of kitchen cabinetry. Ever since factory-made kitchens took over for carpenter-made, the company has been an important participant in the market. They are, however, limited to the small Norwegian market, with very limited export.

The company started out as an efficient mass-producer some 30 years ago. But the variety of products (both in fronts and bodies) that have emerged have complicated the production processes and made the company less efficient and less profitable.

One major asset, according to the company, that it has, is a distribution and delivery model which they believe is superior to the competition. This means that they have shorter delivery times than most competitors, and that they should be able to deliver anything to anybody with a very short lead time.

Over the last few years, the company has not been able to make a profit. They have been on a downward trajectory profitwise, and they have experienced that ever increasing product variety seems to make profitability ever more difficult. The delivery time and precision is also affected as they have problems to keep the promised.

They have also felt the growing competition. From below, especially Ikea has been aggressive, and gains market shares all the time. From above, Italian exclusive kitchens are carving out a niche for themselves, although this has not, so far, had real economic impact.

Recently, the company merged with a number of other kitchen manufacturers to form an international group.

SEPARATION OF FUNCTIONAL AND AESTHETIC PART OF PRODUCTS

Kitchen cabinetry is a mature product group. This means that serious, well-established companies dominate the market, and that they all have achieved a technical quality that is "good enough" by customer standards. There are also certain industry standards, formal or informal, that make products from different manufacturers very similar. This is even more so, since some manufacturers buy cabinet body elements from others, and even those who produce themselves often copy those of market leaders.

Our company was different because they had their own body elements, with dimensions and technical solutions that made them non-interchangeable with those of all other manufacturers. This difference was however not really captured by the customers.

The kitchen is probably the most important room in most peoples' homes, since it has evolved into a working area in which many different activities take place. This means that it is extremely important that people like the environment of the kitchen. The appearance is therefore very important, not only in a sales situation point of view, but for the entire lifetime of the product.

Kitchen design is dominated by certain parts of the cabinetry. Whereas the bodies only contribute to the appearance when they are used in untraditional ways, doors, drawer fronts and worktops (commonly referred to as fronts) are what people see and what they have to relate to. We can say that the fronts are the aesthetic parts whereas the cabinet hulls are the functional. There are numerous examples of the same cabinets changing "personality" completely by exchanging the fronts for a different design.

Figure 1 shows how the fronts, dark in the figure, cover and "hide" the cabinet hulls (grey).

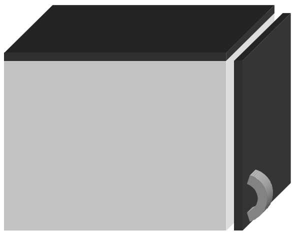

Figure 1 Cabinet hull and front

Our company's solution to its problems was to redo its entire product range. This means that they decided on a transition date, after which all products would be different from any product before the transition.

They decided to adopt the cabinet standard and principal body design of other members of the new, international group that they now belong to. To a large extent, this means that the functional part of the products will be identical to competing products from other members of their group. The reason for this, is that they decided that this was an area where they did not compete, even before they standardized. Not that the quality of the products were inferior, the customers simply did not see the subtle differences in these functional parts.

The appearance of the products and the delivery system are where they wanted to compete and differentiate themselves from the competitors.

One way of competing, is by retaining the best of their previous designs. Kitchen cabinetry is not an area dominated by fashion and trends coming and going rapidly, so retaining well-known, popular front designs was important. There is also the important investment in exhibition kitchens in the shops. If these were to become obsolete overnight, and needed to be replaced by new kitchens from the new program, independent shops would go bust, and company-owned shops would need years to recoup the investment. Therefore, retaining designs that make exhibits from the old line still usable, is important. This way, renewal in the shops will come when new designs that are really new and add a new customer experience are introduced, facilitating a step by step renewal in the shops.

But keeping the design does not mean retaining the technical aspects of the fronts. This was identified as a major potential area of increased efficiency, especially since it was and is obvious that the future will hold more variants. Being prepared for this is important to ensure that the big shift pays off in the long run.

DESIGN FOR MANUFACTURING

The company needed to design a new generation of kitchen cabinetry that should be designed for manufacture. They needed to:

- reduce cost
- improve manufacturing reliability
- prevent that every introduction of a new front design reduces manufacturing efficiency

The first issue was resolved by outsourcing the manufacturing of body elements to one of the sister companies, and using – with a few notable exceptions – the elements already in production at this company. The supplier is large and efficient in this production, and production volumes contribute to lower costs.

Development and introduction of a redesigned assortment of fronts addressed the latter two issues. This re-design meant that common technical solutions and production processes were identified across front designs, even where no commonality existed earlier. The issue was increased manufacturability and production reliability.

DESIGN FOR MARKET SUCCESS

“The market is driven by the consumers’ demand for choice” (Galsworth 1994).

Efforts to improve performance of a company by creating increased efficiency in internal processes, can be a failure if this leads to a reduced market appeal (Aasland 2000). Since saving money is not the overall objective of the company, it must design its products for market success, and this must not be compromised by a single-minded focus on efficiency. The company in question was facing a number of problems and challenges, among which can be mentioned:

- Market share is falling. This leads to reduction in beneficial large-scale effects, and lack of economy in shops, where costs are mostly independent of volume.
- Introduction of new front designs causes problems regarding manufacturing efficiency and production reliability. An obvious effect of this is that the company is reluctant to introduce new models, which again has given them a conservative, somewhat old-fashioned image.

The cure for this, was identified as a major simplification of the existing front program. A number of old front design, that had never been great sellers, was deemed outdated, and scrapped. By doing this, few sales were lost, and major simplification both in logistics and production was achieved.

The next step was to study the remaining fronts with simplification in mind.

Since most door designs are based on a frame with a filling, adaptation of profiles to a common set of manufacturing processes were possible. For most fronts, this was achieved without changing the visual appearance of the front, and in those cases this was not possible, the modifications were small, and tended to appear as timely updates.

In the design of the common production processes, design for manufacturing was emphasized like never before. Since there was only one production line remaining, and only one chain of processes, optimization was much simpler than would have been the case with the old front designs. Consequently, processes were chosen that gave fast through-put and high reliability.

METHODS

The experience at Norema has prompted the development of methods for design of product programs. As a part of this, the academic field has been surveyed for applicable methods and tools.

There is no room to go into any details here, but table 1 lists the most important tools applied in the different phases of the development.

As will be clear from the table, we have found that there are quite a few methods available for use in product program development. They are, however, mostly isolated islands, and setting them into an overall system which ensures good results, is the challenge. Some experience in this respect has been gathered in our project.

The one overwhelmingly important guideline, is to strive for late variant proliferation. If this is achieved, everything will be much more efficient and cost effective. The other important thing to keep in mind, is that expertise in design of production systems and in design for manufacture is essential to success, and that no method for product program design can replace this. The same goes for design for market success. The product program techniques do not ensure

Phase:		Tools:	References:
Observe	internal	Variant tree (“Variantenbaum”)	(Schuh 1999)
	product	Part index	(Galsworth 1994)
	external	“Merkmalbaum”	(Schuh 1999)
Analyse	internal	SWOT Commonality plan ABC (activity based costing) VAT (Variety effectvieness process analysing tools)	 (Robertson 1998) (Galsworth 1994)
	product	Product family master plan (PFMP)	(Mortensen 2000)
	external	Differentiation plan Competitor analysis	(Robertson 1998)
Relate		Relationship matrices	(Robertson 1998)
Restrict			
Generate		Traditional concept generating tools MFD (Modular Function Deployment)	 (Ericsson 1999)
Evaluate		QFD, evaluating indexes	

Table 1 Summary of tools applied in development phases of new product program

market success, and unless knowledge and methods for this purpose are applied, failure is likely (Stormo 2000).

THE RESULT

At the time of writing, it is too early to present final results from the project. The transition has not yet taken place, and the new production lines are only being tested. Market effects will not be clear until late in the year. The internal effects in the company, however, can be predicted and partly reported upon.

Manufacturing

The redesigning of the front assortment resulted in a T-shaped production line. The previous lines did not have much commonality between them (see figure 2). In the new line, most of the variety did not occur until the last production steps (see figure). Also the stock could be kept down since the painting did not occur until after the delivery order had taken place.

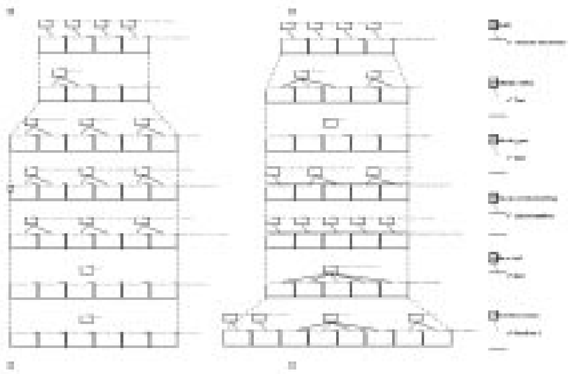

Figure 2 Situation before transition, with 3 separate lines and a wide variant tree

After the transition, we had a much “narrower” variant tree, see figure 3. This means that production processes are common up to a certain point in the chain, and that variants appear at a later point.

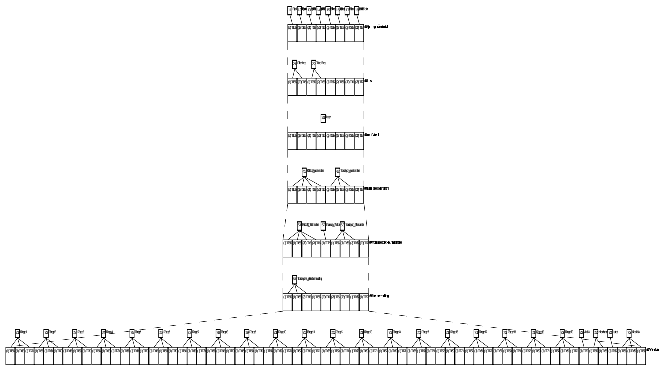

Figure 3 Variant tree after transition, with only one line and late variant branching

As should be obvious from the figures, the new situation means that the flexibility in production regarding which fronts will be in demand, will increase dramatically.

Since the company already operated with a 3 week delivery time, there was little possibility of improvements in this respect. There was, however, the issue of delivery accuracy – that is, they had a problem with delivering on time – and this should be improved upon. At the time of writing, we do not know if this result will be achieved.

Market

The company had to cut away some of the existing doors. These were doors that should have been phased out anyway. Others had to be redesigned to fit the new production line. The variety achieved in the front assortment increased after the redesign.

The new production line increased the company’s flexibility regarding shifts in the market. They could now introduce new colors or designs according to the demands of the market without too many internal hassles.

CONCLUSIONS

This case story has shown some effects of improving a product program:

⇒ more variety in the market (both present and future)
⇒ more commonality in the production lines

increased market share
reduced costs
increased profit

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CONCURRENT ENGINEERING: COGNITIVE SYSTEMS AND KNOWLEDGE INTEGRATION

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ABSTRACT

The concept of knowledge has become a key aspect in the consideration, concurrent engineering and definition of intelligent, cognitive, learning agents, since agents must have knowledge capabilities to perform the tasks. Knowledge capability defines the degree of an agent's autonomy, its reactivity and ability to adaptation. In this paper, we present formal approach to concurrent engineering of a cognitive system, which consists of knowledge-interrelated agents. Knowledge integration is considered as a critical task in concurrent engineering the cognitive systems, since it directly impacts cognitive processes and influences the formation of cognitive systems. A formal approach to the concurrent engineering of cognitive structure is presented.

INTRODUCTION

Many definitions and types of agents have been introduced in research literature in order to define a common understanding of this phenomenon in modern virtual environments. In fact these definitions reflect a variety of viewpoints, problems and applications of the agents, and, therefore, they outline the major directions in this important research and practical field. It is recognised that general characteristics of intelligent agents are an agent's character, reasoning and learning capabilities, autonomy, reactivity, pro-activity, goal orientation, mobility, communication, and co-operation (Wooldridge and Jennings 1995). In this work we consider human resources as a cognitive system. We define a cognitive agent as an intelligent agent who is capable of peer learning, integrating to another agents, and defining flexible cognitive structure with respect to the practical needs. The cognitive agents can be self-organised and can be integrated into the cognitive system that performs the tasks and solves the problems.

The content and formation of cognitive systems is dependent on *cognitive structures* and *cognitive processes*. We consider *cognitive structures* that represent the way in which knowledge is stored in the cognitive system. *Cognitive processes* describe manipulation of knowledge during the formation and utilisation of the cognitive system, for instance, the representation of mental models in (Lindsay and Norman 1977; Johnson-Laird 1983). A cognitive system consists of knowledge-interdependent agents. In fact, a cognitive agent has to have knowledge in order to be autonomous, adaptive, reactive, etc. In order to oversee a task, an agent has to possess a number of key knowledge factors, the integration of which allows the completion of the task. There is a need to make a formal analysis of the available knowledge of cognitive agents in order to ensure the performance of the tasks at a desired performance and technology levels while utilising the available knowledge capabilities effectively and efficiently. That is, we consider concurrent engineering the knowledge capabilities and compatibility factors and their impact on the formation of the cognitive system and its performance. We recognise that capabilities and compatibility factors influence the integration of knowledge of cognitive systems, since agent availability issues do not contribute much to the success of performance. Furthermore, there is a risk of inappropriately selecting agents to do work because they are available and not because they have their correct particular combination of key knowledge factors. Moreover, agents can be both available and capable of overseeing cognitive tasks, but factors such as knowledge and technical/technological, may be *incompatible*. Agents also have to be compatible with each other in order to perform the tasks. Hence, an evaluation of agents' capabilities and compatibilities has to be an important task of knowledge integration.

KNOWLEDGE PROFILE

Knowledge factors are considered as basic factors in the modelling of cognitive agents/systems, since agents must have knowledge capabilities to perform their tasks. A cognitive agent is described by a set of knowledge factors, each factor may be defined by multiple characteristics. A set of such factors forms a knowledge profile. We represent a factor by qualitative and quantitative information. Quantitative description of the ith profile factor is defined by indicator characteristic, property, and weight. In particular,

- $\boldsymbol{e}_i$ - indicator characteristic, that expresses by factor presence in the description of a cognitive agent. In particular,
  - – $\boldsymbol{e}_i$ may be defined as a time characteristic of the ith factor $\boldsymbol{e}_i = \boldsymbol{e}_i(t)$
  - – $\boldsymbol{e}_i$ may represent a binary case, e.g. Boolean variable
- v_i - property of the ith factor: $v_i \geq 0$, $v_i = v_i(t)$.
- w_i - weight of a factor which defines either the factor importance or the factor priority: $w_i \geq 0$, $w_i = w_i(t)$. Weights of the factor can be determined in the context of practical applications.

We define a *profile b* as a set of factors $b_1, b_2,..., b_n$: $b = \{ b_i,\ i = \overline{1,n} \}$, where the ith factor b_i is represented by a pair $b_i = (\boldsymbol{i}_i, e_i)$ with

- $\boldsymbol{i}_i$ - an identification of the ith factor, i.e. a name of the ith factor
- e_i - the 3-tuple of the ith factor: $e_i = \langle \boldsymbol{e}_i, v_i, w_i \rangle$
- n - a number of factors.

Available and Required Profiles

Knowledge of cognitive agent can be described from two viewpoints: availability and requirements. We define *required* knowledge as a requisite set of knowledge factors that are required for performance of given task with expected outcome(s). An *available* knowledge is a set of the knowledge factors that are available to perform a given task. Thus, we consider *required* $b^{(0)}$ (as a set of required factors $b_1^{(0)}, b_2^{(0)},..., b_n^{(0)}$) and an *available* b (as a set of available factors $b_1, b_2,..., b_n$) profiles

Profile Superposition

A factor itself may have multiple properties that may be presented by a profile. In this case, we define *profile superposition* as a set of profiles:

$$Ps = \{ (u(b^{(j)}), \langle e(b^{(j)}), b^{(j)}, w(b^{(j)}) \rangle),\ j = \overline{1,N} \}$$

- $u(b^{(j)})$ -name or identification of the jth factor
- $e(b^{(j)})$ - profile-factor existence
- $b^{(j)}$ - the jth factor profile
- N - number of factor profiles

Concurrent Engineering: Cognitive System Modelling via Knowledge Integration

The incorporation of knowledge capabilities of the cognitive agents into modelling frameworks of cognitive systems may effectively solve the concurrent engineering problems relevant to cognitive agents: their capabilities, compatibility evaluations and management, and their optimal structure determination. In this section a formal approach to cognitive system modelling is presented. In particular, we consider knowledge profile and cognitive tasks as key elements in a framework for concurrent engineering of cognitive system. We show how profile and integration of the profiles may be used for cognitive system modelling in conjunction with tasks. We believe that autonomy of cognitive agents is possible when a cognitive agent/system has required knowledge capabilities to oversee the tasks. When we allocate a cognitive agent to a cognitive task, we compare available knowledge with required knowledge and clearly define criteria for their comparison (Plekhanova, 1999). That is we define some relations between these knowledge profiles.

KNOWLEDGE INTEGRATION

Let us consider two cognitive agents and represent their capabilities by knowledge profiles: $b^{(1)} = \{b_1^{(1)}, b_2^{(1)}, ..., b_n^{(1)}\}$ and $b^{(2)} = \{b_1^{(2)}, b_2^{(2)}, ..., b_n^{(2)}\}$.
Denoting by:

- $\mathrm{I} = \mathrm{I}(b)$ - a set of all names or identifications of the profile b: $\mathrm{I}(b) = \{i_i : i_i \; i(b_i), i = \overline{1,n}\}$
- $\boldsymbol{i}_i$ - name or identification of the *i*th factor
- $\boldsymbol{i}$ - a subset of identifications of the factors: $\boldsymbol{i} = \{i_i : i_i = i(b_i), i \in \{1,2,...,n\}\}$, $\boldsymbol{i} \subset \mathrm{I}(b)$

we define knowledge integration via union of knowledge profiles.

The *union* U_p *of two knowledge profiles* $b^{(1)}$ and $b^{(2)}$ we define as the set of all pairs $(\boldsymbol{i}_i, e_i(b^{(1)} \cup b^{(2)}))$, the factor identifications of which belong to $b^{(1)}$ or to $b^{(2)}$ or to both

$$\boldsymbol{i}_i \in \mathrm{I}(b^{(1)}) \cup \mathrm{I}(b^{(2)}) = \{\boldsymbol{i} \mid \boldsymbol{i} \subset \mathrm{I}(b^{(1)}) \text{ or } \boldsymbol{i} \subset \mathrm{I}(b^{(2)})\}$$

and the 3-tuple for the *i*th knowledge factor is defined as

$$e_i(b^{(1)} \cup b^{(2)}) = \begin{cases} < e_i, \max[n_i^{(1)}, n_i^{(2)}], w_i >, & \text{if } n_i^{(1)} \neq n_i^{(2)} \\ < \max[e_i^{(1)}, e_i^{(2)}], n_i, w_i >, & \text{if } n_i^{(1)} = n_i^{(2)} \end{cases}$$

e_i takes the value from a profile with $\max[n_i^{(1)}, n_i^{(2)}]$, if $n_i^{(1)} \neq n_i^{(2)}$; and n_i from a profile with $\max[e_i^{(1)}, e_i^{(2)}]$, if $n_i^{(1)} = n_i^{(2)}$; $w_i = \max[w_i^{(1)}, w_i^{(2)}]$ (Plekhanova, 2000).

Then, the union of two knowledge profiles is

$$U_p = b^{(1)} \cup b^{(2)} = \{(\boldsymbol{i}_i, e_i(b^{(1)} \cup b^{(2)})) \mid \boldsymbol{i}_i \in \mathrm{I}(b^{(1)}) \cup \mathrm{I}(b^{(2)})\}.$$

That is, the set U_p represents an *integration of available knowledge profiles* $b^{(1)}$ and $b^{(2)}$.

On the Cognitive Structure of Cognitive System

A knowledge structure (or cognitive structure) is an essential element in modelling, design, development and management of cognitive systems. The internal properties of knowledge factors are changed with time and they effect the cognitive system structure.

At the present time, heuristic approaches are used for structure formation of complex systems. As a rule, heuristic approaches to concurrent engineering the system structure address only the performance characteristics (e.g. *productivity, cost*) *without correlation to corresponding internal properties of* *elements of the complex system.* However, the same performance characteristics of a cognitive system may be obtained by different knowledge that can be integrated into a cognitive system and which may form different structures. Since different knowledge may have different variable internal property constraints (e.g. capabilities, compatibilities), they will also possess different performance constraints. The possibility of formal modelling the cognitive system structure provides an opportunity for the management or modification of the cognitive system structure towards the desired direction and/or within given boundaries. In turn, this influences the formation of cognitive systems. Therefore, there is a need to develop formal approaches to structure function definition and to consider the impact of the knowledge properties of cognitive agents on the formation of the cognitive system structure.

We describe a number of cognitive agents by a *cognitive* system, which is defined as a complex system B, in which the elements are interrelated knowledge profiles. That is, a cognitive agent is represented by knowledge profile and a cognitive system by a set of N interrelated *available* knowledge profiles. We use notion of the relational structure function $b = b(h(B))$ of order N (Kaufmann et al. 1977) to describe profile's relationships that, in fact, define the cognitive structure. Thus, a cognitive system is represented by a profile superposition and their cognitive structure: $B = \{(b^{(1)}, b^{(2)}, ..., b^{(N)}), \mathbf{b}\}$.

We associate with each available knowledge profile a variable (as a state) $h^{(j)} = h(b^{(j)})$, $j = \overline{1, N}$ such that:

$$h^{(j)} =$$

$$\begin{cases} 1, \text{if } b^{(j)} \text{ knowledgeprofile exists in a cognitivesystem} \\ s, \text{if } b^{(j)} \text{ knowldgeprofile has criticalknowldgefactors} \\ 0, \text{if } b^{(j)} \text{ knowldgeprofile doesnot exist in a system} \end{cases}$$

The N-tuple $h(B) = (h^{(1)}, h^{(2)}, ..., h^{(N)})$ will be called an *indicating set* whose elements show if certain profiles in a cognitive system exist or not. Notice that the same sets of profiles can form alternative structures. In order to select all combinations of the available knowledge profiles we should define how they satisfy the required knowledge profile for a task. We use capability measurements to compare and analyse the available knowledge profiles with respect to each other and/or to the required profile. The values of the ith factor capability can be determined by the following formula (Plekhanova 1999):

$$V(b_i) = p \ w_i \left(\frac{e_i}{e_i^{(0)}} \right) \left(\frac{v_i}{v_i^{(0)}} \right)^2$$

where v_i, $\boldsymbol{e}_i$ are available level and time/existence, respectively; $v_i^{(0)}$, $e_i^{(0)}$ - are required level and time/existence. Assume that we need to determine the distance between available and required knowledge profiles. A "deviation" of available knowledge profile $b \in$ B from a required knowledge profile $b^{(0)}$ can be measured by any L_p metric, which can be used as a distance between profiles. That is, the distance between an available knowledge profile and a required knowledge profile is defined as:

$$\left\| b - b^{(0)} \right\|_p = \left[\sum_{i=1}^{n} \left| V_i - V_i^{(0)} \right|^p \right]^{1/p}, \ p \in \{1,2,3,...\} \cup \{\infty\}$$

where n is a number of required knowledge factors for a task; $b \cap b^{(0)} \neq \varnothing$. We define the *distance* from the knowledge profile $b^{(i)}$ to the knowledge profile $b^{(j)}$ as: $d_p(b^{(i)}, b^{(j)}) = \left\| b^{(i)} - b^{(j)} \right\|_p$. It can be easily shown that such a defined distance on B satisfies the metric definition. This distance we call a *capability-compatibility metric*. Thus, B can be defined as a metric space (B, d) with the metric $d_p(b^{(i)}, b^{(j)})$. A given or required distance we call a *radius* $r = r(b)$. An available knowledge profile b

covers the required knowledge profile $b^{(0)}$ if the distance is less or equal to the given radius: $d_p(b, b^{(0)}) \leq r(b)$.

Knowledge Integration Models

We determine an integration model, which encompasses *integration criteria* (e.g. with respect to capability and compatibility and/or performance factors), *priorities of the knowledge profiles* and *knowledge integration goals*. Knowledge integration goals are improvement of available knowledge or generation of new knowledge for better performance. Result of knowledge integration can be represented by profile superposition. We may identify different requirements (e.g. integration criteria, preferences) for knowledge integration that define a *set of integration models*. In the following sections we introduce examples of knowledge integration models representing different integration criteria. The goal of knowledge integration is to define the satisfaction of available knowledge from the cognitive system to the required knowledge.

Model 1: Series Cognitive Structure

We define the available knowledge profiles $b^{(1)}, b^{(2)}, \ldots, b^{(M)}$ as *mutually complementary with respect to factor identifications* if the factor identifications of a union of the available knowledge profiles belong to a set of *required* knowledge factor identifications (Plekhanova, 2000).

The available knowledge profiles are defined as mutually complementary with respect to the available knowledge factors if a union of M available knowledge profiles satisfies the given metric d (the integration criterion): $d(\bigcup_{j=1}^{M} b^{(j)}, b^{(0)}) \leq r$. That is, a union of available knowledge factors represents the required knowledge factors for a given task performance, i.e. the required knowledge profile is covered by a union of available knowledge profiles and this union is a non-empty set: $\bigcup_{j=1}^{M} b^{(j)} \neq \varnothing$. Then, we represent a relational structure defined by the function $\boldsymbol{b} = \boldsymbol{b}(h(B))$, whose components are M mutually complementary profiles *distributed in series*, in the following way: $\boldsymbol{b}(h(B)) = \prod_{j=1}^{M} h^{(j)}$. This relational structure function corresponds to a system that is represented by all required knowledge factors for a given task:

$$(\forall j : h^{(j)} = 1) \Rightarrow (\boldsymbol{b} = 1);\ (\exists j : h^{(j)} = 0) \Rightarrow (\boldsymbol{b} = 0);$$

$$(\exists j : h^{(j)} = s) \Rightarrow (\boldsymbol{b} = \tilde{s} :\ \tilde{s} \neq 0, \tilde{s} \neq 1).$$

When $\boldsymbol{b} = \tilde{s}$ ($\tilde{s} \neq 0$ and $\tilde{s} \neq 1$) or $\boldsymbol{b} = 0$, improvement or new knowledge of cognitive system is needed for the performance of the task. The system is obtained by placing in series the available knowledge profiles that are mutually complementary with respect to the available knowledge for a given task. Each profile takes its turn in the chain of tasks.

Model 2: Parallel Cognitive Structure

We define the available knowledge profiles $b^{(1)}, b^{(2)}, \ldots, b^{(M)}$ as the equivalent profiles *with respect to* factor identifications if they have the same intersections of factor identifications with the required knowledge factor identifications. We define the available knowledge profiles $b^{(1)}, b^{(2)}, \ldots, b^{(M)}$ as equivalent profiles *with respect to* the available knowledge factors if they satisfy the given metric d for the required knowledge profile (Plekhanova, 2000):

$$d(b^{(1)}, b^{(0)}) \leq r,\ d(b^{(2)}, b^{(0)}) \leq r,\ \ldots,\ d(b^{(M)}, b^{(0)}) \leq r$$

We represent the relational structure function of a cognitive system B with M equivalent profiles in the following way (Kaufmann et al. 1977):

$$\boldsymbol{b}(h(B)) = 1 - \prod_{j=1}^{M} (1 - h^{(j)}).$$

This relational structure function corresponds to a cognitive system that has at least one of the available knowledge profiles with the required knowledge factors:

$$(\exists j : h^{(j)} = 1) \Rightarrow (b = 1)\,;\ (\forall j : h^{(j)} = 0) \Rightarrow (b = 0)\,;$$

$$(\exists j : h^{(j)} = s) \Rightarrow (b = \tilde{s} :\ \tilde{s} \neq 0, \tilde{s} \neq 1).$$

If $b = 0$, there are no profiles with required knowledge factors and a task cannot be performed by a given cognitive system. If $b = \tilde{s}$ ($\tilde{s} \neq 0$ and $\tilde{s} \neq 1$) there are critical knowledge factors in a cognitive system. Hence, improvement or new knowledge of cognitive agents/system is needed for the performance of the task. The cognitive system is obtained by placing in parallel the available knowledge profiles that are equivalent to each other with respect to the available knowledge for a given task.

Model 3: Discretionary Cognitive Structure

We say that the available knowledge profiles form a discretionary cognitive structure in a cognitive system when there are different combinations of the parallel and series cognitive structures of those profiles that cover the required knowledge profile, e.g. series-parallel, parallel-series. This type of cognitive structure provides the presentation of *combinations of parallel and series cognitive structures.*

CONCLUSIONS

We consider knowledge integration as a task of knowledge engineering, where knowledge integration addresses the following problems:

- inconsistency analysis via capability and compatibility factors with respect to available and required knowledge
- allocation of knowledge to the performance of the tasks or problem solutions
- roles definition via knowledge priority for the tasks
- self-organisation of cognitive systems based on knowledge capabilities with relevance to the given tasks
- autonomy relevant to the uncertainties in requirements and required knowledge for the task

We have presented a formal approach to knowledge integration that is based on the application of the profile theory and is used for the modelling and concurrent engineering of (new) cognitive systems, where the cognitive structure is defined by structure of knowledge profiles and is flexible; and the cognitive process is a sequence of applications of different knowledge profiles with different structure. This approach provides for the consideration and analysis of the impact of knowledge factors and their properties, on the formation/performance of the cognitive systems. That is, we consider the concurrent engineering of the cognitive systems via engineering of cognitive structure and knowledge integration. In fact, by knowledge integration we can generate new/novel cognitive systems that can be used as a tool for solutions of (new) problems.

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THE ENGINEERING-BRIDGE PROJECT

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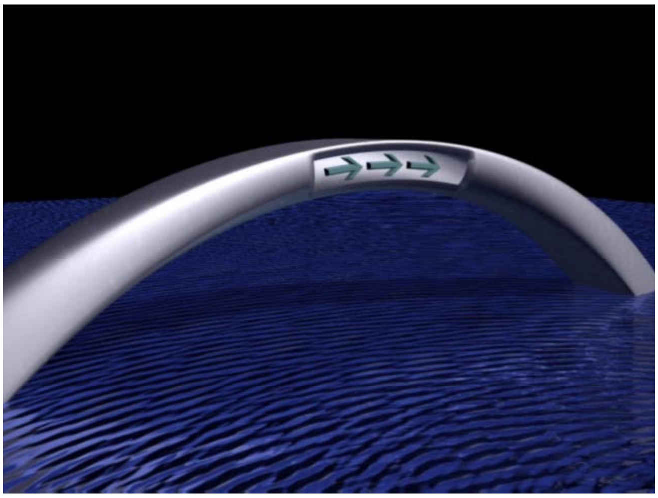

KEYWORDS

Engineering-Bridge, engineering collaboration, engineering portal, business process management, process, partner management

ABSTRACT

The Department of Computer Integrated Design (DiK) of the Technical University of Darmstadt in cooperation with T-Systems ITS GmbH is developing concepts for an engineering portal (eBridge) which supports enterprise and department spanning business processes. The concepts are shown and validated in a functional demonstrator.

Due to the decreasing vertical range of product development, particularly in huge enterprises and the integration of small and medium sized enterprises (SME) into the product development processes of their partners there is a need to extend the product development process to business partners.

For project leaders and management it is important to have more detailed and certain information about process progress and quality of such processes. In eBridge processes shall be monitored Quality Gate and Sync Point oriented.

For the participating enterprises, the advantage of the Engineering-Bridge concept in a product development process is the use of the same communication platform for different projects with different development partners, which gives an overview about the process progress and offers an environment for the common business process in a particular project.

PROJECT GOALS

The following description summarizes the goal of the eBridge project in a very short way:

The Engineering-Bridge is a technique and service to manage and control processes in a customer-supplier-relationship with a high degree of automation in order to accelerate the adding value and improve process quality. (Pfeifer 2001, Pfeifer-Silberbach 2002)

In an enterprise and department spanning product development process there are two kinds of processes: internal processes and spanning processes. For the management of the spanning processes no satisfying solution exists yet. This problem is improved little. There exist many engineering portals. Most of them take care of data exchange, project management, and supply chain management. This is not what Engineering-Bridge wants to do. Only if the entire process between the cooperating business partners is well known and transparent, it can be optimized iteratively and the maximum on added value can be reached with teamwork of the business partners. (Schmelzer 2001)

This is the reason why in this project an engineering portal (Engineering-Bridge) that tries to support management and staff making decisions within a product development process has been developed.

The approach of this project is to collect and develop concepts that support this idea by monitoring the business process, its evaluation by theory, and validation of the concepts in cooperation of business partners within real scenarios. Therefore Engineering-Bridge tries to use proved standards (such as STEP and SADT) as far as possible. This ensures the interoperability between international business partners and facilitates the data import, export, and the use of product data and product information from other software systems as well as future extensions in functional capability.

MAIN CONCEPTS

The main concepts have been implemented in a functional demonstrator allowing to show the functionality of this engineering portal. The following paragraphs describe the main concepts very briefly.

Project view

Usually staff is not only involved in a single project but in several projects. A reason why Engineering-Bridge deals after login only with one main project, wich can be divided into further relating sub-projects.

Any information (e.g. messages, documents and specifications, as well as contract related information) depends on access rights of the user and are bind with his project or sub-projects.

Projects and sub-projects in Engineering-Bridge are defined and selected within the ‘Project-Navigator’ (see Figure 1).

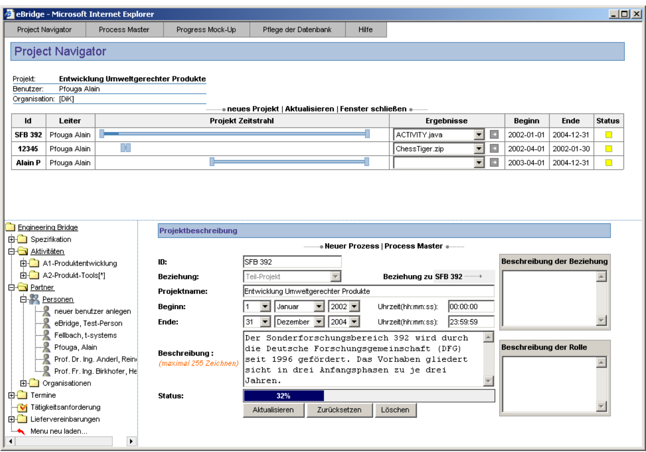

Figure 1. Project Navigator

Process view

Processes within Engineering-Bridge are managed in the ‘Process Master’, which is the control center for all processes in a project or sub-project. A process is defined according to the Structured Analysis and Design Technique (SADT) with input, output, controls and tools (Anderl 2001) in order to control the flow of informations and aggrements through the development cycle. Additionally planned dates have to be defined.

Monitoring view

The concept for monitoring processes in Engineering-Bridge is to define Quality Gates (QG) and Sync Points (SP) within processes. QG and SP are defined as follows:

Quality Gate

Quality Gates are result-oriented checkpoints within the development- and business processes. Achievements that have been made between customer and supplier are validated concerning their degree of fulfillment.

Sync Point

Sync Points are dates defined in advance to validate sub-processes. Therefore it is necessary to synchronize the data.

A likely answer and question form, which can be configured within the Engineering-Bridge for each Quality Gate and Sync Point is defined in advance. This form is to be answered by the supplier and validated by the customer at least at the date defined for the associated QG or SP. (see Figure 2)

The question and answer form shall be the comittment between customer and supplier about delivery and quality. All questions should be asssigned to previously defined catagories as e.g. ‘quality’ and ‘adherance to delivery dates’. Answers are evaluated arithmetically. Depending on the percental fulfillment the status of the processes is set to ‘critical’, ‘needs attention’, ‘not critical’, or ‘finished’. The status is provided as colored icon in ‘Process Master’.

In order to make monitoring and evaluation easier, the form is presented in an ‘magical eye’ that provides a graphical presentation of a comparison between customers expectations and suppliers responses.

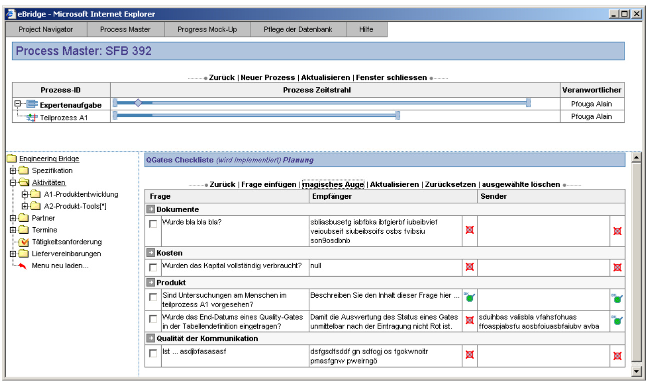

Figure 2. Process Master with answer question form

Business model

The underlying very simplified business model in Engineering-Bridge is that two firms are committing to cooperate in product development. Therefore they need a common environment to manage their spanning business processes and provide an information plattform for the development progress and all other important information for both – customer and supplier. An additional service starting with first contact, defining the contract and setting up the way to communicate, collecting information about the development progress and bringing the right persons together, to avoid any trouble within processes, which are coupled with loss of time and money, shall be provided.

This tasks shall be supported by the Engineering-Bridge portal as well as by a third party service provider, that all administrative work (as well as organizing meetings, teleconferencing etc.) relies on.

DEMONSTRATOR ARCHITECTURE

The Engineering-Bridge functional demonstrator exists of a J2EE architecture that allows perfect process management over the worldwide wide web (www). Its structure is composed of three main layers, built by a presentation layer, a communication layer and a link layer. (see Figure 3)

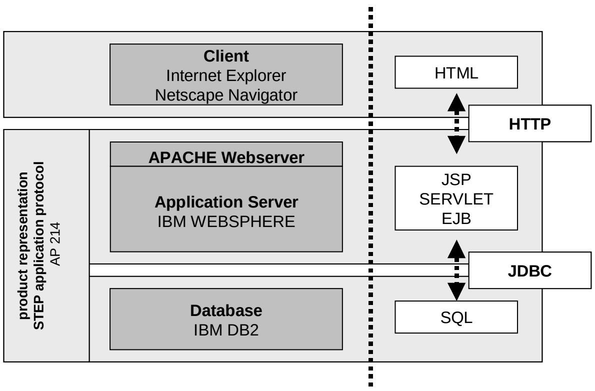

Figure 3. eBridge software architecture

The first layer represents the user's environment, where single data dumps from the database (IBM DB2) will be represented after a defined query of the user. This layer communicates by the HTTP-protocol over a web server with an application server, which administers server-laterally the entire composition of information.

The application server IBM Websphere forms the communication layer. This layer is responsible for the processing of queries between arriving queries from presentation layer, data composition from the link layer and the production of data in the form of HTML pages for the presentation layer. All resources are supplied in the form of servlets and jsp applications, which create an appropriate response for inquiries.

The link layer is built by the relational database DB2, where information about user, projects, dates activities and all process related information are stored. (Pfeifer-Silberbach 2002)

FURTHER PERSPECTIVES

In further project steps the possibilities for extensions of Engineering-Bridge to support managers with mobile communication systems using UMTS (Universal Mobile Telecommunications System) by providing information and data dealt within Engineering-Bridge can be investigated.

The monitoring can be support more efficiently by indexes, that collect information from existing PDM systems and other supporting systems automatically. Additionally a weighting for answers and indexes can be introduced.

At least the Engineering-Bridge portal shall be validated in some development processes in different business lines.

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ORGANISATIONAL REQUIREMENTS FOR SMART BIDDING ORGANISATION

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KEYWORDS

Cooperative Problem Solving, Project and Team Co-ordination, Information & Application Sharing, Business Process reengineering, Multi-Disciplined Team-Working.

ABSTRACT

The paper aims to present the methodological and ICT requirements for the constitution and operation of *smart bidding organisations (SBO)* made of SMEs belonging to the bio-medical sector. These requirements have been collected and formalised during the first part of the IST – 2000 –28618 BIDMED project, taking into account a real case involving three Small-Medium Enterprises (SMEs) from the bio-medical district of Modena province (Italy). To co-ordinate and facilitate the SBO behaviour, the project identifies an independent entity, the Bid Manager (BM), that plays the role of unique interface with respect to the customers, anyway allowing the partners SMEs to protect their own know-how and maintain their direct customers. In the case under study, CNA-Modena acts as BM.

INTRODUCTION

The concepts of Virtual Organisation, holonic system, distributed enterprise, multi-site and multi-business organisation, network organisation, and similar, are becoming increasingly important at a national and international level, and the need of new methodologies and planning tools for the SMEs is even more urgent. New global market opportunities and the development of innovative products require financial and technical capabilities that individual SMEs can hardly provide (Hirsch et al.1995).

The new market trends, mainly due to the globalisation of the economy and the formalisation of large economic common space blocks like the European Union, force companies to look for high flexibility, reactive systems and high quality standards. The need to cluster each other and to co-operate constituting smart organisations, supported by opportune technological tools and organisational methodologies, is the challenge that SMEs, especially of very small size, must face since now in several sectors. The real problem is that the single SME is able to fulfil only a small portion of every single customer order.

In the bio-medical sector this situation is particularly evident. The peculiar aspects of this sector are, among others, the following:

- It produces components for complex equipment (e.g. dialysis machines) and disposable materials for health-care activities (e.g. syringes, catheters, dialysis membranes).
- Many enterprises in this sector are small sized and highly specialised.
- Their customers are hospitals and health-care organisations that, usually, purchase huge quantity and variety of products, typically to satisfy requirements on a time horizon of several months.

In this environment, SMEs must learn how to organise complete and competitive bids, in particular for public calls for tender, being at least free from the intermediaries that now wrap them with respect to the market.

A possible approach is to group together SMEs of the same sector, creating an organisation that allows them to prepare integrated offers, behaving as a unique supplier, and to guarantee convenient prices. The *bidding organisation* should be s*mart*, which means able to adapt itself to market and rules evolution, in condition to dynamically re-configure whenever a new business opportunity occurs, capable to revise its behaviour on the basis of a systematic measure of its performances in supplying products and services. At the same time it should be "*glocal*", that is, global with respect to the market but also local for the possibility of reducing overheads and transportation costs by taking advantage of partner proximity.

Here we intend to present the results achieved in the field during the participation in the European project IST-2000-28618 BIDMED (Co-operative Bidding in the Medical Sector).

BIDMED main objective is to define and experiment a *best practice* to support the collaboration among SMEs of the bio-medical sector, up to the constitution of their *smart bidding organisation* (SBO), with the role of unique interface with respect to the customers. During the project, the *best practice* is experimented in three different regional contexts: the bio-medical district of the Modena Province (Italy), a group of Hungarian health care service providers and a group of French enterprises also active in the bio-medical sector.

The paper is organised into five main sections: the first introduces the Related Works of the BIDMED project, whereas the other ones are more focused on the Italian business case. In particular; the second section presents the Methodological Requirements; the third section contains the Operative Scenarios and the fourth one puts in evidence the Requirements on ICT tools. Finally some considerations are reported in the Conclusions.

RELATED WORKS

Virtual organisations are not just a new object of studies. As SMEs need to collaborate because of the global competition, they are increasingly interested in dynamic networked and virtual organisations (Erastos Filos et al. 2000). In spite of this interest, few SMEs have adopted IT tools to support their collaboration (Bonfatti et al. 1996). The level of integration and the enabling ICTs used, are often not adequate: many activities are still performed manually and in a complicated way, with the associated high costs (Filos et al.2000).

DemoCenter and the University of Modena and Reggio Emilia have been working for several years on different projects of the ESPRIT and IST programme, (COWORK, GNOSIS, PLENT, VIVE, BIDSAVER, TEMA, PROVE-SME, UCANET), focused on the support of SMEs joined in Virtual Organisations. The work done is always targeted to study, prototype and integrate cheap, easy to use ICT tools characterised by a low learning curve that can be adopted with a minimum of additional work. The purpose is to enable SMEs to join easily, without a big organisational and financial impact on their organisations.

CNA, being an association of SMEs, is continuously working in collaboration with its associates, on the field of every day SMEs problems and opportunities. CNA ICT-based new services are more and more often consequent to projects concerning the new technology sector. CNA has recently collaborated with DemoCenter also to another EU project (Prove-SME) in the field of SMEs networks.

METHODOLOGIACL REQUIREMENTS

The BIDMED project is involving three Italian SMEs acting in the bio-medical field and producing disposable sterile materials and components for hospital departments and machines for dialysis: RIMOS, MEDICA and PROBIO. These enterprises are of small-medium size. They completely own the know-how to realise their products. Their customers are hospitals and health-care organisations that usually purchase huge quantity and variety of products, typically to satisfy their needs on a year based time horizon. They are already associated in a Consortium, named CONSOBIOMED, promoted by CNA, together with other 20 companies of their industrial district, to rationalise quality assurance procedures.

At the moment, each SME works independently (like most SMEs in the Biomedical sector) producing the above mentioned kinds of medical components and products. As a result, they are not able to directly participate to tenders where hospitals require big amount of different components.

The BIDMED approach will allow the three enterprises to find out a standardised frame of co-operation and to have an effective ICT support in bid preparation, and, in case of success, work execution.

From a preliminary assessment of the company needs, they are very interested in taking part in a SBO without losing their direct customers: each SME, involved time by time in the SBO, will keep on doing also its own business. On the bidding side, the consortium could bring an essential success factor: a 30% reduction of current prices. In fact, this is the overhead that is usually applied by those mediators that now prepare the bid, and of which the manufacturers SMEs are subcontractors. The price is the third evaluation criteria that the hospitals apply when comparing bids, after the product technical evaluation and the company profile.

In the following of the paper are presented the *methodological requirements*, concerning the organisation and operation of the SBO.

Analysing the information collected during the interviews with the three enterprises (RIMOS, MEDICA, PROBIO), we discovered that one of the most relevant aspects is the need of realising a two levels architecture. The first level refers to the existence of a preliminary Consortium including several enterprises of the biomedical sector, interested in co-operating to be able to participate to big tenders, and at the same time to become a qualified supplier for direct orders. The second level becomes operative only when a set of enterprises (not necessary all the members of the consortium) agrees to participate to a business opportunity, making a partnership which is in charge of preparing the bid for a specific tender, taking into account how their competencies meet market requests, and creates the partner team. To clarify, the first level will be named Consortium, whenever the second level will be identified as *dynamic SBO*.

Consortium Statute framework

Enterprises express clearly the need to regulate all the aspects of the Consortium life with a specific and detailed set of rules (Statute), signed by each partner. This contract, expressing the consortium policy and settling the general aspect of the consortium life, must be considered as the base over which every other aspect will take place.

It should also be highlighted that the Statute has also to control both the relationships among the members of the Consortium and external entities, such as healthcare institutions, selling agents, the market (for publicity), banks, etc. Thus, the Statute must contain two different sections: Internal rules and External rules. Internal rules cover several aspects: common catalogue; competition among partners; competition between a partner and the consortium in the same tender; constraints relative to the territory and its exclusion; enterprises selling agents; products and country registrations; new registrations; prices policy, discounts, samples; costs; logistic and warehouse management; products recall; budget for publicity; tenders in foreign country; purchasing of product not directly produced by the consortium; norms management. External rules concern aspects such as enrolment in professionals and trade registers; publicity; technical assistance; rules for new throwing.

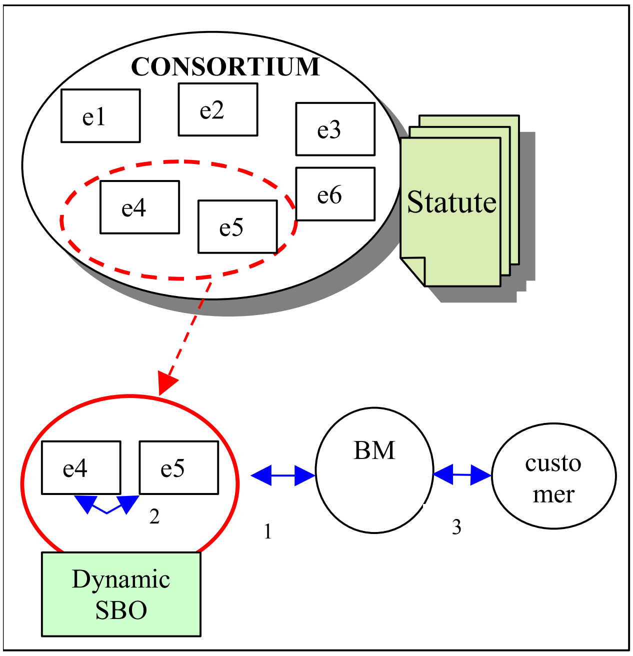

Figure 1 – SBO architecture

SBO architecture

The enterprises suggest the need of identifying an independent entity, the Bid Manager (BM), in order to co-ordinate and facilitate the SBO behaviour, playing the role of unique interface with respect to the customers. During the period of best practice implementation, CNA Modena will be the Bid Manger for the Italian pilot case.

The BM role is to support during all the *SBO* life cycle the engaged SMEs: starting from the constitution to the real operation (organising the bid process). The Bid manager acts as an intermediate between the Dynamic SBO and the customer, as shown in Figure 1.

The SBO architecture is based on three different kinds of communication, as highlighted in Figure 1:

- Communication between partners and Bid Manager: it refers to the messages, meetings and documents exchanged during all the phases of the Dynamic SBO life cycle, from the constitution to the operation.
- Communication between partners: for the Italian case this type of communication has not a strong importance because it rarely occurs.
- Communication between customers and Bid Manager: it refers to the messages, meetings and documents exchanged for the aspects of tender, new throws, payment.

The common catalogue

One of the main requirements of the enterprises is the implementation of a unified product catalogue.

The on-line catalogue groups products of different company, presenting the consortium to the customer as a single entity. Each enterprise needs to manage its products on the common catalogue, but some constraints are put, concerning the frequency of the modifications or products elimination. For each product, beyond the traditional information (code, description, picture), it is useful to indicate: the possibility to customise the product; the list of certifications per country; territory where it is possibly to sell the product (constraint due to commercial agreements with selling agents) and other important information relative to the biomedical sector.

Catalogue main functionality are the following: to present commercial information to customers, to present further information to the BID Manager (helping him to organise the bidding process), to allow the customer to request estimations on costs and due date.

The archive of Norms

Requirements on legal aspects concern the management of the set of norms that has to be followed, in order to participate to a call for tender in a specific country (some norms are often added by regional administration). At a first analysis a set of tools useful in this context could be: a searching engine to find norms (by country, by title, and so on), tables with links to norms and a thematic check list, driving the user to prepare bids.

OPERATIVE SCENARIO

Starting from the current way of working of each enterprise and from their needs, the most common situations (scenarios), that describe relevant events and activities occurring in the collaboration, have been analysed in detail. These scenarios, that cover a wide spectrum of the SBO life cycle, are: *SBO constitution and configuration, Co-operative bid preparation, Customer order management*.

SBO constitution and configuration

This scenario, which is repeated for every new tender, associates the companies of the Consortium to the SBO, taking into account how their competencies meet market requests, and creates the partner team (*Dynamic SBO*) which is in charge of preparing the bid for the tender.

This scenario is obtained through the following phases:

<u>First evaluation of the Announcement of the tender</u>

The Bid Manager (BM) receives the information on a call for tenders and makes a first evaluation mainly concerning the feasibility. In case he decides to go on he asks to the healthcare organization for the complete Announcement of the tender. Once he has the Announcement, he asks to partners their opinion on the actual business opportunity.

<u>Team constitution</u>

If the consortium decides to go on with the participation to the tender, the BM searches for candidates (partners required to produce the goods requested by the tender). Basing on the technical requirements expressed in the Announcement of the tender and on the common catalogue data, the BM assigns production tasks among the partners. Each partner must declare if he intends to participate to the tender or not. In case of competing partners, it is necessary to decide some criteria to select the right partner (since detailed technical specifications are not yet available, the low price criterion is not sufficient and the data on past performances could be an useful criterion). If some products requested by the tender are not manufactured inside the consortium, the BM has to organise their purchasing, asking some partners to take care of the procurements. The process ends with the team constitution.

<u>Request to be invited to the tender</u>

The team already exists, thus the BM simply asks to partners the documents (usually proving the technical and economic capability) to be sent to the healthcare organization in order to receive the Invitation to the tender. If the request is accepted, the BM will receive the Invitation, including the detailed articles and specifications of the tender.

Co-operative bid preparation

This scenario concerns the detailed specification of all the co-operative activities the partners have to perform to submit the common bid.

The BM has to coordinate the co-operative bidding. Each partner must prepare a bid for the products he is in charge of. The co-operation aspect of the process concerns the communications between the BM and the partners and the documents exchange. The BM collects documents prepared by partners in accordance with the tender requirements and guarantees that all the legal issues are accomplished. He is also in charge of the financial aspects. The final step of this scenario concerns the communication to the partners of the competition result.

Customer order management

This scenario describes the customer order execution phase.

As soon as the BM knows the due date (usually indicated into the tender specifications) he prepares the plan of the purchasing process (from partners) and issues to them the time limit of their tasks. The planning of the manufacturing process is in charge of each enterprise: they have to respect the due date requested by the BM planning.

The BM has in charge of controlling the progress state of the customer order and of organizing the transport of all requested materials (when ready) to the healthcare institution. In order to allow this, each partner must communicate to the BM the progress and conclusion of the task it is in charge of. If some exceptions (e.g. delays) arise, partners have to advice the BM so that he tries to recover the problem.

As a consequence of task progress communication the BM knows when all the items are ready (each partner keeps its finished items inside its warehouse) to be moved to the healthcare institution warehouse. The BM has in charge the organization of the delivery: he advices the partners involved in the customer order execution on the conclusion of all the tasks; contemporarily he contacts a delivering company and agrees with them about the date of the transportation. After that, he communicates the date to the partners.

Periodically, the Bid Manager can evaluate the performances of each partner (e.g. the medium delivery time) to obtain a synthetic indication of partner reliability. This information is used when the Bid Manager decides which are the partners to involve in a new bid.

ICT TOOLS REQUIREMENTS

One of the main aims of the BIDMED project is to supply an ICT infrastructure to facilitate the communications among the partners and to cover all the above listed needs: realise a unified products catalogue, support the co-operative work of bid preparation, interact with the customer in every phase of the SBO life cycle.

All the Italian SMEs participating to the project are already using basic Internet tools such as browser and e-mail. Thus they are supposed to have no problems with the introduction of web services following the Application Services Provider paradigm.

In particular, the required tools should manage the following aspects:

- *Common catalogue*. The catalogue needs to be accessible via Internet to customers, partners and public with different grants. Its peculiarity is to manage data specific to the biomedical sector, in particular considering technical, commercial and legal constraints on products.
- *Common workspace*, to exchange data and information.
- *Monitor of task progress*. This functionality has the twofold aim of recovering exceptions (such as delays) and allowing the Bid Manager to manage the relations with customers (such as organising the delivery of products). Therefore, a specific tool is required to allow the partners to update its own task progress and to enable the Bid Manager to have a global view of the whole process.
- *Repository for normative aspects*. The sets of normative need to be shared among partners. This means to build an archive easily accessible, secure, up datable with an user friendly interface. Fast and flexible searching instruments are considered very useful.

CONCLUSIONS

In this paper we tried to give an overview of the complex and wide set of methodological and ICT infrastructure requirements, that have to be taken into account while defining and trying to set up a real SBO. It is taken into account the Italian perspective of the problem, that is an SBO providing biomedical products.

From a preliminary assessment of the company needs, the major problem they feel is the lack of proper ICT tools for starting the collaboration and for bid preparation and negotiation.

Another relevant problem to face is connected with the normative aspects: the tenders, especially in the public sector, are subject to complex regulations that depend on the country where the customers operates.

Finally, also the financial support matters are very important for the SBO success.

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AUTHOR BIOGRAPHY

GIULIA PIGNEDOLI graduated in Informatic Engineering at the University of Modena, October 1999. Since October 1999, she has worked at DemoCenter as researcher for the ICTs Research department, mainly carrying out European Projects relating to virtual enterprise constitution and operation and industrial resource planning. In particular, she has followed the IST-1999-14095 **UCANet** (Understand the Consequences of the adoption of tools and systems to support dynamic networked and virtual organisations) project. The study aimed at:

- Contributing to reduce the lack of wide survey about IT tools and organisational models suitable to SMEs willing to constitute and participate in dynamic networked and virtual organisations.
- Giving to tool developers and services suppliers indication on how to develop tools, systems and services on the basis of the requirements defined in the analysis of SMEs needs.
- Suggesting adequate societal and organisational models to SMEs and to those consultant societies that support collaboration among enterprises.

Official Web site: www.democenter.it/ucanet

Since September 2001, she has also been in charge of a recent project related to the virtual enterprise concept: IST-2000-28618 **BIDMED** (Co-operative Bidding in the Medical Sector).

The main objective of the project is to define and experiment a best practice to support the collaboration among SMEs of the bio-medical sector, up to the constitution of their smart bidding organisation (SBO). This entity plays the role of unique interface with respect to the customers, anyway allowing the partners SMEs to protect their own know-how and maintain their direct customers.

During this period she has actively participated in organising and managing DemoCenter demonstrative activities (seminars and conferences). She is also involved in activities related to the transfer of technologies and innovations towards small and medium enterprises of Emilia Romagna region and America Latina countries such as Argentina and Brazil.

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COLLABORATIVE WORKFLOW IN DISTRIBUTED TEAMS – MANAGEMENT AND IMPLEMENTATION ISSUES

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KEYWORDS
Workflow, process modeling, distributed teams, enactment theory

ABSTRACT

Organizations are increasingly forced to manage and coordinate their product and service development processes, to make their products and services available as quickly as possible, and to involve employees, customers, suppliers, and partners in different stages of the processes. To accomplish this, organizations focus on coordination across their distributed teams. One of the fundamental problems IT-Management has to deal with in this regard is the lack of continuous business process support for distributed teams across a variety of corporate information systems: from electronic brainstorming tools up to collaborative workflow management systems (WfMS) for enactment of business processes activities. The contribution of this paper is the development of a framework to identify management and organizational variables relevant to collaborative workflow management systems for distributed teams and to provide IT-management with the required understanding to implement collaborative workflow systems successfully.

INTRODUCTION

The interdependences among Information Technology (IT) Management and information assets have never been greater than in the area of the networked global economy. Efficient use of technology and communications-infrastructure are key factors to the success and viability of modern and flexible organizations. Organizations increasingly manage and coordinate their product and service development processes, to make their products and services available as quickly as possible, and to involve employees, customers, suppliers and partners in different stages of their business processes. To accomplish this, organizations are increasingly more focused on coordination issues across departments, cultures, project groups, applications, customers, partners, suppliers, distributors, retailers, and employees. One of the fundamental problems IT-Management has to deal with in this regard is the lack of continuous business process support across a variety of corporate information systems.

Information Technology in general and business process modeling tools, Workflow Management Systems (WfMS) (e.g. Bussler 1999), and Groupware (Ellis and Nutt 1980) systems in particular have been used to automate or to augment business processes in organizations (Bussler 2001; Schal 1996). Groupware has been defined as "technology based systems that support groups of participants working on a common task or goal, and that help provide a shared environment" (Ellis et al. 1991). It naturally includes technologies such as electronic mail, video conferencing, and shared group document editors. Groupware typically does not contain any knowledge or representation of goals or processes of the group, and thus cannot explicitly help to forward the group process. Groupware systems are not organizationally aware. On the other hand, workflow systems are typically organizationally aware because they contain an explicit representation of organizational structure and processes. WfMS have been defined as "technology based systems that define, manage, and execute workflow processes through the execution of software whose order of execution is driven by a computer representation of the workflow process logic" (WfMC 1995). Whereas Groupware has been criticized because it is not organizationally aware, WfMS have been criticized because of its typically inflexible and dictatorial nature compared to the way that office workers really perform tasks (Grudin 1988). Future WfMS will cover inter-organizational activities and processes including product value-chains on the Internet (Bussler 2001; Casati et al. 2001; Chen et al. 2001; Christophides et al. 2001; Kafeza et al. 2001; Krithivisan and Helal 2001; Papazoglou and Jeusfeld 1998; Puustjärvi and Laine 2001; Zeng et al. 2001). With this in mind, management and implementation issues regarding collaborative WfMS for distributed teams will naturally become even more relevant.

In recent years there has been considerable attempts to merge workflow and groupware technologies. Industrial research labs and product teams have made significant steps forward (Chen et al. 2001; Hausleitner and Dustdar 1999). While most successful commercial WfMS have been developed in the United States, it is interesting to note that most academic research on the subject has been conducted in Europe. This might reflect a tendency of "low-context" cultures (O'Hara-Devereaux and Johansen 1994) to plan, control, and monitor the information flow of business processes.

A WfMS can impose a rigid work environment on users, which often has consequences. One example is among users who perform time-consuming manual "work arounds": the consequence is lower efficiency and dissatisfaction with the system. Therefore, for distributed teams it is of paramount importance to provide a less rigid workflow; one in which the users can, within limits, define the flow of work. Workflow automation provides unique opportunities for directing information flow and monitoring work performance. As a consequence WfMS enable continuous loops of sub processes such as goal setting, working, monitoring the work, measuring performance, recording and analyzing the outputs, and evaluating the "productivity" of personnel. Users of WfMS often consider the controlling and monitoring possibilities as a "dark side" of these systems, which results in demotivating employees.

Generally speaking, *business processes* have well defined inputs and outputs and serve a meaningful purpose either inside or between organizations. Business processes and their corresponding workflows exist as logical models. When business process models are executed they have specific *instances*. When a workflow is instantiated the whole workflow is called a *work case* (WfMC 1995). The WfMS enacts the real world business process for each process instance. A business process consists of a sequence of activities. An *activity* is a distinct process step and may be performed either by a human agent or by a machine. Any activity may consist of one or more *tasks*. A set of tasks to be worked on by a user (human agent or machine) is called *work list*. The work list itself is managed by the WfMS. The WfMC calls the individual task on the work list *work item* (WfMC 1995). To summarize, a workflow is the instantiated (enacted or executed) business process, either in whole or in parts. During enactment of a business process documents, which are associated to tasks are passed from one task participant to another. In most cases this passing of documents or executing applications is performed according to a set of *rules*. A WfMS is responsible for control and coordination such as instantiating the workflow, assigning human or non-human agents to perform activities (staff-assignment), generating work lists for individuals, and routing tasks and their associated objects such as documents between the agents.

Recent advances in the area of Internet Computing and collaborative WfMS are often seen as essential for supporting distributed, often cross-cultural, teams. Workflow systems generally aim at helping organizations' team members to communicate, coordinate, and collaborate effectively as well as efficiently. Therefore WfMS possess temporal aspects such as activity sequencing, deadlines, routing conditions, and schedules (Chinn and Madey 2000). In other words, collaborative process coordination systems such as WfMS inherently are related with "cultural" issues such as peoples' attitude towards time and people (Dustdar and Hofstede 1999). Cooperative tasks in distributed teams are increasing and as a consequence, the use of collaborative systems is becoming more pervasive. WfMS and project management systems are prototypical for this need in organizations. Knowledge work requires the interaction of many individuals, groups, and project teams. It is recognized that information systems supporting collaborative business processes (e.g. where teams collaborate on various sets of tasks) require some sort of "cultural awareness" to succeed in cross-cultural teams (O'Hara-Devereaux and Johansen 1994).

To fully understand the context of collaborative WfMS it is important to first analyze the dimensions of current systems. In this paper we analyze process supporting systems along two orthogonal dimensions: task automation and process structure as shown in Figure 1 (Dayal et al. 2001). Tasks in business processes are performed automatically by an application (application centric tasks) or by involving human judgement or manual processing in general (human centric tasks). Business processes may have different levels of structure. A process is highly structured when business rules and sequences that tasks have to follow are pre-determined and pre-modeled. In a semi-structured process only parts of the rules are pre-modeled. Other parts of the rules may be modified on the fly (ad hoc process). In an unstructured business process no repeatable patterns of rules or any sequences among the tasks exist. Unstructured processes are often performed by participants when they meet at the same time. In the upper right corner business process modeling systems, production WfMS, and Enterprise Application Integration (EAI) Systems are to be found. This space is called Design center for Process Management Systems (Dayal et al. 2001). In this paper our focus is on integration aspects of collaborative WfMS, therefore this paper concentrates on the design center for computer-assisted collaboration systems, which involves human-centric tasks and unstructured and semi-structured processes mainly found in distributed teamwork.

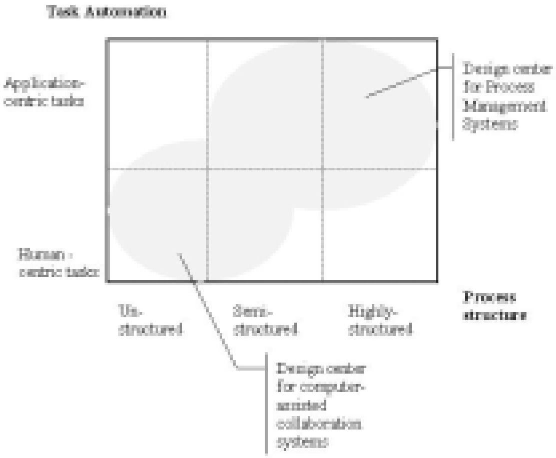

Figure 1: A two-dimensional framework for WfMS

Figure 2 illustrates a high-level process map of "New Product Development" (NPD), a collaborative business process common in most product companies. On the left side are the functional departments or skill sets that have to be applied to various NPD tasks. The business process map itself portrays the manner in which tasks relate to one another through time, as the product moves from concept to development, to manufacturing, and then to distribution. This NPD example is a typical collaborative workflow: it requires the interaction of diverse skill sets usually found in cross-departmental structure and in most cases many cultures (organizational cultures such as Marketing and Engineering, as well as national cultures as it is often the case with manufacturing and distribution partners located in different countries) are involved throughout this processes.

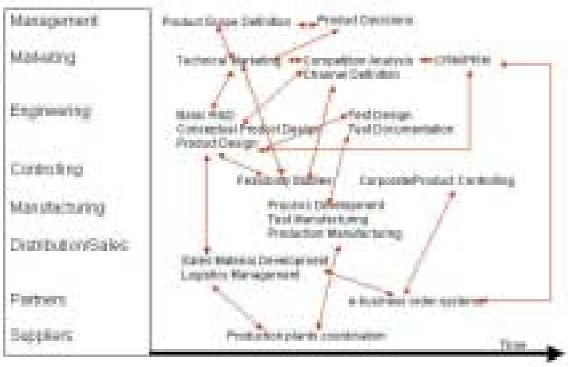

Figure 2: "New Product Development" - a collaborative Workflow

This paper argues that IT-Management, researchers and practitioners alike, should be aware of qualities of collaborative WfMS they implement and relate those to management and implementation variables in order to efficiently and effectively utilize systems and in order to provide transparent support for distributed team work.

The reminder of the paper is structured as follows: Section 2 investigates characteristics of business processes, tasks, and teams. Section 3 introduces the enactment theory framework for analyzing the phases, steps, and software supporting business processes. Section 4 discusses some fundamental requirements for continuous support for collaborative business processes as elaborated in the enactment theory framework. Finally the concluding section discusses implications for IT-Management and future work.

CHARACTERISTICS OF PROCESSES, TASKS, AND TEAMS

Before we analyze teams and their usage of business process systems we need to take a look at some of the characteristics of self-managed teams and review some of the critical success factors for work teams. Those factors include (Mintzberg 1979):

1) an organizational culture which facilitates team-building and collegiality;
2) clear aims and objectives for the team in the context of the larger organization;
3) a strong commitment to the team by individual members;
4) frank and open communications to promote constructive criticism among team members;
5) a reward system which encourages creativity, innovation and risk taking.

Collaborative WfMS substantially support and enable those critical success factors for teams. For example clear goals and objectives are required to model tasks as part of business processes. Research shows that team performance is positively affected by communications between team members, as shown in (Mc Donough et al. 1999). Literature stresses the importance of the formal and informal communicative aspects of WfMS, which reflect the underlying structural dependencies in work settings (Chinn and Madey 2000; Mc Donough et al. 1999; Flores et al. 1988). Working in organizations is often characterized as "networks of commitments", as people in the organization send work through the systems (Winograd and Flores 1986). In this context it is important to note, that with business process reengineering, activity based costing, and total quality management challenging the traditional division into separate functional departments, and their associated task support systems, such as negotiation support systems, project management systems, decision support systems, and WfMS, a need for integrative systems arises to span the whole task/process continuum (e.g. Craven and Mahling 1995). Mintzberg (1979) listed five fundamental ways of coordinating tasks in an organization:

1) Mutual adjustment
2) Direct supervision

3) Standardization of output
4) Standardization of work processes
5) Standardization of skills

Collaborative WfMS aim at supporting mutual adjustment (coordination), standardization of output (modeled tasks and the associated applications to perform tasks), and the standardization of work processes (modeling of business processes).

Tasks in organizations have a purpose. Both projects and workflows have explicit and implicit goals. The explicit goal of a project is its objective or final product, such as a software product or a service. Implicit goals include successful achievement of explicit goals and possibly include personal goals as well. Enhancing the efficiency and effectiveness of office work is an example for an implicit goal (Ellis and Nutt 1980). Workflow systems use tasks on the lowest level called executable steps in process engineering. Sets of sequential or parallel steps form a business process. Processes can be linked to form process chains. Projects on the other hand are per definition unique and can be decomposed into sub-projects (often called activities) but eventually executable steps must be performed to bring the project to completion. To summarize: A workflow process such as ordering of a product could be decomposed into the tasks of checking the inventory, evaluating the customer, approval, shipping, and billing. Hence, as there are process hierarchies, activities, and steps within tasks, each of these has corresponding goals.

ENACTMENT THEORY FRAMEWORK

This paper suggests an enactment theory approach to the study and design of collaborative WfMS that entails different phases, steps, and maps current software product categories to them. Enactment theory (Mahling 1993) operates at a higher level of abstraction than either speech act theory (Winograd and Flores 1986) or planning theory (Mahling 1993). The interesting work and products of Winograd and Flores based upon speech act theory suggest that any interaction can be viewed as a "conversation" with a protocol structure that can be modeled as a workflow (Winograd and Flores 1986). The coordinator was a product emerging from this work that had this protocol notion built in.

In enactment theory, the enactment is considered the basic building block of human activity (Mahling 1993). Persons and their context are connected via enactments. In acting, people affect their context, yet simultaneously comply with contextual constraints. In short, enactments are processes of behavioral patterns meant to purposefully transform states of reality incrementally in the direction of a goal (Mahling 1993). The enactment process as depicted in Figure 3, has different phases consisting of steps. It is crucial for IT-Management to be aware that software products such as brainstorming tools, project management tools, or WfMS aim at different phases and steps of the enactment of business processes. This awareness is important for several reasons: When business processes are enacted they pass through different phases and steps. Each of those steps requires different tools for their support.

Management of Engineering teams, for example, focus on "Engineering" sub processes (see Figure 2). When results of their tasks are passed onwards to the next process step, the context of the Engineering work gets lost, due to the use of a different software system. A common example of this dilemma is the conflict between Engineering (R&D) and Marketing (see Figure 2). When engineering work is finished and the results are passed to Marketing for creating marketing material for the product, the marketing department does not have access to the knowledge and context of Engineering. Marketing might produce collateral, which the Engineering departments are not satisfied with. This might result in conflicts between those departments. Currently each of the enactment steps utilizes their specific software tools. It remains a challenge for IT-management to "glue" those systems together in order to provide a collaborative business process support in all process stages. Collaborative WfMS have the goal of providing support for all steps in business process enactment. The following paragraphs explain the enactment phases as depicted in Figure 3 in detail.

Figure 3: Enactment theory framework

The **orientation phase** comprises steps such as matching the needs to affordances (goal refinements) and building motivation. For those steps software systems used in Electronic Meeting Rooms, such as systems supporting the brainstorming process may be utilized. The **anticipation phase** builds on the motivation developed before and includes steps such as setting up the organization, assigning agents (people) with tasks, and scheduling tasks. The **action phase** consists of the actual execution steps of the tasks necessary for achieving the goals as well as monitoring their success. During those steps collaborative WfMS software may be used. Finally, in the **evaluation phase** results, efforts, and exceptions are evaluated. Business Process Simulation software is a companion technology during this phase.

Currently software systems supporting the integrated and continuous enactment of business processes as a whole (as depicted in Figure 3) do not exist. The requirements raise a number of research questions typical for the area of Computer Supported Cooperative Work (CSCW). Some of the design issues of the architecture of collaborative WfMS are:

- Supporting collaborative definition of tasks and their mapping to goals and business processes
- Supporting sharing of artifacts (objects and resources) in all phases and steps of business processes
- Monitoring the distributed execution of steps

COLLABORATIVE WFMS REQUIREMENTS

This section seeks to clarify the requirements for software systems supporting the full enactment cycle as depicted in Figure 3. To better understand the implications for a continuous enactment support, we will provide examples of software usage during the respective phases with the goal to specify some requirements for integrating the systems discussed.

In the "*Orientation*" phase the main driving force is the desire to build consensus on the availability of resources and regarding motivational issues. Figure 4 shows one example of an electronic meeting room, where this phase is supported by software and hardware. Following the idea presented in Figure 3, it is one goal of the orientation phase to specify the requirements of the project under discussion. Ideally, these requirements and the artifacts created during this phase, will be stored in a repository accessable for distributed team members. A repository provides a persistence store for artifacts, such as text-documents, multimedia files (audio, video) taken from the meeting itself, and the communications flow (questions, answers, reasons) of the team members.

Figure 4: NTT Electronic Meeting Room (InterPOD)

The "*Anticipation*" phase focuses mainly on organizational-setup for the projects. Most frequently tools for project management are used for this purpose. The artifacts created with tools in this phase comprise project plans, resource plans, and work breakdown structures. Project management systems focus mainly on a view for the project manager. They seldom provide support for different "views" on a project (e.g. depending on the team members' role) and also provide no support for enactment (execution) of project plans, as required in the next (Action) phase or simulation as required in the "Evaluation" phase of the enactment lifecycle.

The "*Action*" phase is mainly concerned with the actual project dynamics, the instances of projects. In most cases (collaborative) workflow management systems are used to first model the required activities of a project and then to enact the model. Collaborative WfMS provide software support for the execution of the modeled activities. Therefore it is possible (e.g. for project/process managers) to analyze any instance of a process (project). This means that the information and communications flow of the participants may be monitored and traced. Figure 5 depicts a model of a simple directed workflow graph, which is enacted during a software development project.

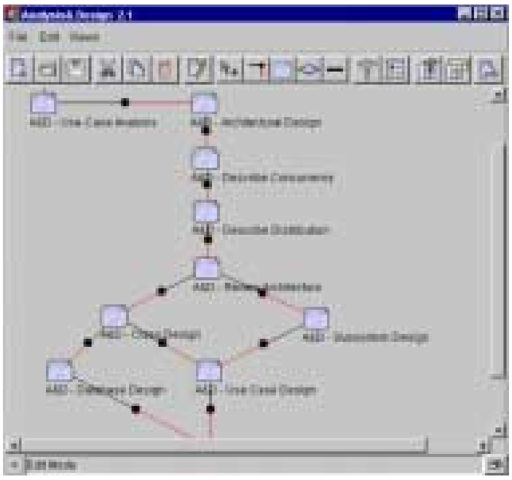

Figure 5: Caramba Process Modeler

Finally the "*Evaluation*" phase is concerned with the overall evaluation of the project or process flow itself. The main questions one is interested in this phase are: Did we reach our goals? Are we on time and within our budget constraints? What would happen if we would enact this project differently (e.g. through simulation of alternative process models based on various criteria)?

CONCLUSION

This paper presented a two dimensional framework for collaborative technologies enacting business processes for distributed teamwork. Based on current software systems in those categories, we presented a theoretical enactment framework, elaborated the requirements, and discussed the current shortcomings of software systems required to fully support the enactment framework "life-cycle". Our future work will comprise detailed analysis of systems interfaces between electronic brainstorming tools, project management systems, business process modeling systems, collaborative workflow management systems, and process simulation systems. Further research is also needed on how collaborative workflow systems can be designed, not only to execute the logic of a workflow, but also to satisfy human, cultural, and organizational needs.

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BIOGRAPHY

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ADOLog: AN IMPLEMENTATION OF THE SUPPLY-CHAIN OPERATIONS REFERENCE-MODEL

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KEYWORDS

SCOR, Implementation, ADOLog®, Process oriented supply-chain management

INTRODUCTION

The success of a manufacturing company mainly depends on the performance of its supply-chain. The rapid evolution of new technologies during the last years and the development of forward-looking business models cause massive changes in procurement and distribution and make new approaches in managing supply-chain issues available. Companies use intelligent technologies for managing inventory, collaborating with upstream and downstream partners or making outsourcing decisions. The traditional linear supply-chains are transforming into highly dynamic supply-webs. Therefore, supply-chain management (SCM) is one of the most discussed topics in management during the recent years.

SUPPLY-CHAIN MANAGEMENT

The main purpose of managing supply-chains is enabling effective communication among supply-chain partners to improve the whole spectrum of material-, information and financial flows. SCM - considered in the traditional way - was local optimisation within our own company. But the current challenge is to find a global optimum for the whole network and to create – as far as possible – a win-win situation for all companies throughout the entire supply-chain. Actually in global inter-company collaboration you have to deal with a wide range of problems, which starts with local company specific specialisation, continues with individual software solutions, and ends with problems in trusting the partner concerning the exchange of supposed to be confidential data.

One approach to ease SCM is a to lead to a basic change in form of transformation of present functional organisation into integrated process-chains by implementing the SCOR-Model into the supply-chain processes.

THE SUPPLY-CHAIN OPERATIONS REFERENCE-MODEL (SCOR)

The Supply-Chain Operations Reference-Model (SCOR) has been developed and endorsed by the Supply-Chain Council, an independent not-for profit global corporation of companies and organisations with more than 700 members world-wide (Supply-Chain Council 2002). As a practitioner's model it rapidly gains growing importance as a cross-industry standard for supply-chain processes. SCOR is a process reference model, which integrates the well known concepts of business process reengineering, benchmarking, and process management into a cross-functional framework. It contains standard descriptions of management processes and standard metrics to measure process performance. SCOR defines a system of relationships among the standard processes and recommends proven management practices, that produce best-in-class performance. Using the SCOR-model you are able to describe, measure, and evaluate end-to-end supply-chain configurations. The model spans all customer interactions (from order entry through paid invoice), all product transactions (from your supplier's supplier to your customer's customer), and all market interactions (from the understanding of aggregate demand to fulfilment of each order). Defining five distinct management processes (Plan, Source, Make, Deliver, and Return) the SCOR-Model is a standard language designed for effective communication among supply-chain partners.

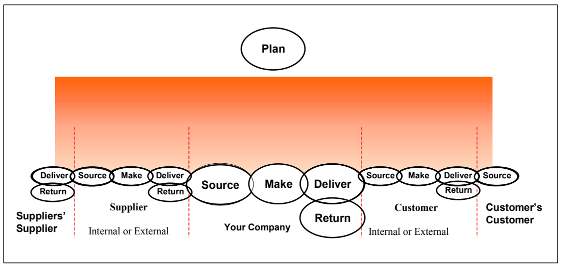

Figure 1: SCOR is organised around the five major management processes

SCOR pre-defines three levels of modelling. Level I serves to define scope and content for the Supply-Chain Operations Reference-Model distinguishing between the five major management processes. The actual configuration of a supply-chain takes place in Level II using thirty core process categories. This way companies a able to implement their operations strategy, e.g. by choosing a "configured-to-order" layout. The more detailed process element -Level III defines the companies ability to compete successfully in its chosen markets and serves for fine tuning of the operations strategy. At the following Level IV, which is not pre-defined by SCOR, companies implement their supply-chain management practices to achieve competitive advantage and to adapt to changing business conditions (Supply-Chain Council 2002).

However, the SCOR-Model does not aim to fix all details of a company – which would of course be impossible. But the obvious fact, that there is world-wide no implementation of this reference-model with negative return on investment (ROI) argues for its proven benefits.

IMPLEMENTATION

The basis for the implementation of the SCOR-Model concerning the creation of an appropriate software tool was the modelling platform ADONIS®. ADONIS® is a successful business modelling tool with distinctive customising capabilities (Junginger et al. 2000). These features met the development-requirements of a process oriented supply-chain management solution. Based on the Supply-Chain-Council's SCOR-Standard there has been created a special configuration of ADONIS® for process oriented supply-chain management called ADOLog® ("ADONIS® for Logistics").

Corresponding to the SCOR-Model three different model types, one for each SCOR-Level, were defined. Using online customising the exceptional capabilities of the ADONIS® meta modelling concept made it possible, to create all modelling objects, concerning layout and functionality the way defined by the SCOR-Model.

Level I is solely used for definition of the five major management processes and not available for modelling specific supply-chains. Using pre-defined process categories the model type Level II serves for illustration and configuration of product specific supply-chains according to the SCOR-terminology. Every single process category of Level II has to be decomposed into process elements, which are the main modelling objects of the Level III model type. These pre-defined process elements are used to describe the standardised supply-chain processes in a more detailed way.

For each modelling class are SCOR-defined performance attributes like reliability, responsiveness, flexibility, costs, assets available. These metrics are used to measure and asses the supply-chain performance in comparison to alternative configurations. Additionally ADOLog® provides for every single standard process the documentation of the Supply-Chain Coun-

cil, which consists of a detailed process description, required inputs and generated outputs as well, as management practices, that produce best-in-class performance.
To ease process oriented supply-chain modelling the whole SCOR-Model was implemented in ADOLog®. The model should serve the user as a pattern for the configuration of a specific supply-chain. Standard processes can be easily adopted to own models by copy & paste.

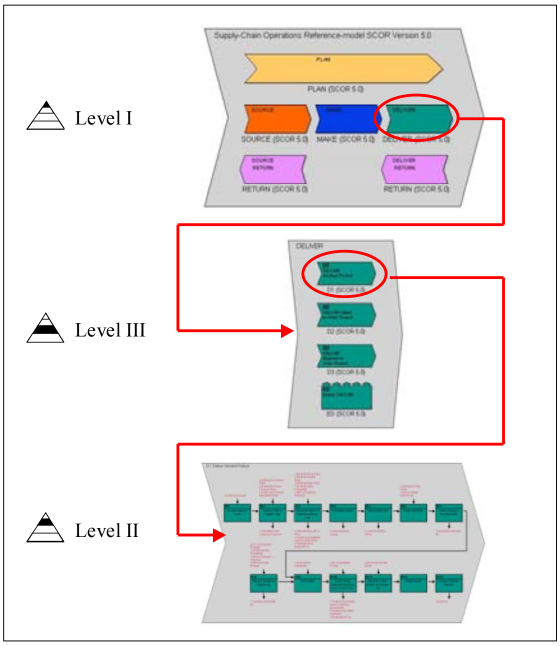

Figure 2: The Supply-Chain Operations Reference-model in ADOLog®

PROCESS ORIENTED SUPPLY-CHAIN MANAGEMENT WITH ADOLog®

In addition to the three SCOR-levels ADOLog® provides another three model types for configuring a specific supply-chain.
Every supply-chain modelling starts with a Geographic-Product-Flow (GPF)-model. The GPF-model type serves for illustration of physical locations of production facilities, distribution, and sourcing activities including material and information flows as well, as utilised transportation and resources. The main purpose of implementing the GPF-model was to simplify the transformation of illustrated supply-chains into the methodology of SCOR.

To convert the illustrated configuration into a SCOR-Level II-model, it is recommended to choose the most appropriate pre-defined SCOR-process categories, which describe the activities at each location, to build an individual product specific supply-chain according to the standard of the Supply-Chain Council. The process categories have to be decomposed into separate Level III models, that allow a closer look at the details of the single supply-chain activity.
For the implementation of the company specific courses of activities and organisational structure ADOLog® provides in Level IV two separate model types for processes and organisation. To fill the Level III standard processes with contents it is necessary to assign to every single predefined process element a Level IV process model, which contains the specific course of activities. For that purpose ADOLog® provides a whole string of modelling classes like activities, decisions, and resources. The Level IV organisation model type serves for illustration of the working environment. Activities of the process model can be assigned to groups or single persons of the company's staff. Following this procedure it is possible to calculate relevant times and costs by using different simulation algorithms. Based on the results of simulation the user is able to analyse the supply-chain configuration concerning the already mentioned performance attributes. The metrics can be examined in detail, using Level III, or aggregated at Level II. Supplementary specific key performance indicators can be defined and used for optimisation of the supply-chain layout.

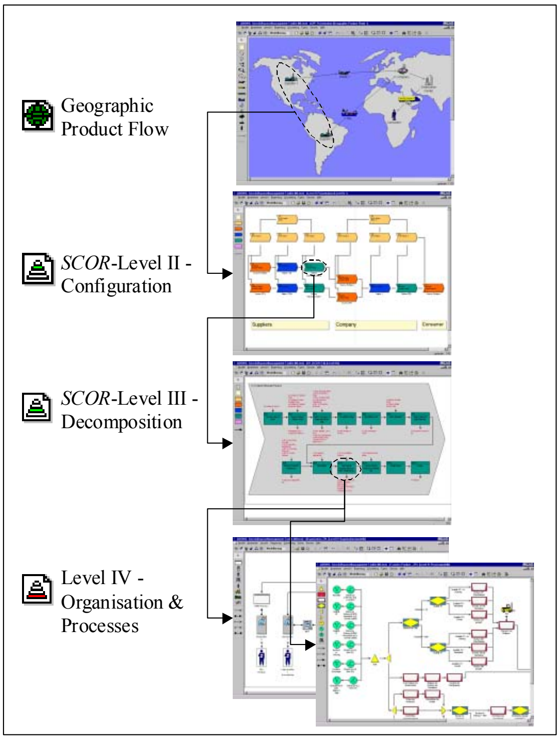

Figure 3: Process oriented supply-chain management with ADOLog®

PRACTICAL EXPERIENCE

The extensive documentation provided by the Supply-Chain Council and the clearly defined hierarchical order of the different model types enable SCOR to be a modelling language. For effective use as a supply-chain design tool it is necessary to implement it into a software solution. The exceptional ADONIS® customising capabilities and unique meta-modelling concept made it possible, to realise the ADOLog® solution rapidly.

Not defined is the Level IV implementation area, which is used to model the company specific processes. To fill this free space in a useful way, there is an extensive knowledge in business process modelling required. The ADOLog®-Level IV model types are the result of the experience of many years of successful business process management projects realised by BOC GmbH.

First practical experience applying an ADOLog® prototype was gained at TECWINGS in Austria, an Alcatel management buyout. ADOLog® was successfully utilised to build an outsourcing justification by constructing several business cases backed with reliable metrics and financials (Auer 2001).

One major problem seems to be the generation of data for all SCOR-defined performance attributes. But practical experiences pointed out, that it makes no sense to optimise the supply-chain activities according to all SCOR metrics. Actually supply-chain practitioners define only a few key performance indicators to meet the requirements of optimisation.

CONCLUSION AND FUTURE WORK

The Supply-Chain Operations Reference-model is gaining increasing importance as a standard for process oriented supply-chain management. First software solutions are available to support the implementation of integrated process chains.

Concerning ADOLog® it is required to gain more practical experience and to find industry partners with the intention of applying the SCOR standard. Currently two projects in automotive industry are in realisation, that are aiming to evaluate the SCOR-Model by applying ADOLog®.

To fix the problem of generating data for the SCOR-defined performance attributes another project was initialised. One part of it is the creation of interfaces to operative planning and execution systems to integrate strategic and operative supply-chain management. The project will also include the integration of standard software for simulation and optimisation in industry and logistic to create a supply-chain design solution with easy to use modelling and far-reaching simulation capabilities. Using the latest findings concerning interorganisational business processes the project goal is the development of an integrated supply-chain management solution, that supports the user in scope of strategic supply chain design as well, as in the area of operative management decisions.

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USING CONCEPT LATTICES FOR ORGANIZATIONAL STRUCTURE ANALYSIS

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KEYWORDS
business processes, re-engineering, organizational structure, concept analysis, concept lattices

ABSTRACT

Business process re-engineering is based on changes of the structure of business processes with the respect to obtain their higher efficiency. As a result of this business process re-engineering new organizational structure has to be defined to reflect changes in business processes. The organizational structure is usually defined using the best experience and there is a minimum of formal approach involved. This paper shows the possibilities of the theory of concept analysis that can help to understand organizational structure based on solid mathematical foundations.

INTRODUCTION

Business processes represent the core of the company behavior. There are many possibilities how these processes can be defined. Usually all modeling tools are focused on various kinds of business process aspects based on what abstraction is considered as the main. From this point of view there are three basic approaches that can be employed (Christie 1995) for the business process specification:

- Functional View. The functional view is focused on activities as well as on entities that flow into and out of these activities. This view is often expressed by Data Flow Diagrams (DeMarco 1979).
- Behavioral View. The behavioral view is focused on when and/or under what conditions activities are performed. This aspect of the process model is often based on various kinds of State Diagrams or Interaction Diagrams. More sophisticated approaches based on the theory of Petri Nets are convenient for systems that may exhibit asynchronous and concurrent activities (Peterson 1977). The behavioral view captures the control aspect of the process model. It means that the direction of the process is defined on current state of the system and event that occurs.
- Structural View. The structural view is focused on the static aspect of the process. It captures objects that are manipulated and used by a process as well as the relationships that exist among them. These models are often based on the Entity-Relation Diagrams or any of the Object Diagrams that are used by the various kinds of Object Oriented Methods.

Unfortunately, none of these views captures organization structure of roles implemented by human resources participating in processes being modeled. For example, BPM (Business Process Modeling) method (Vondrak 99) involves roles in a process specification but there is no option how the organizational structure implied by such models can be analyzed and evaluated.

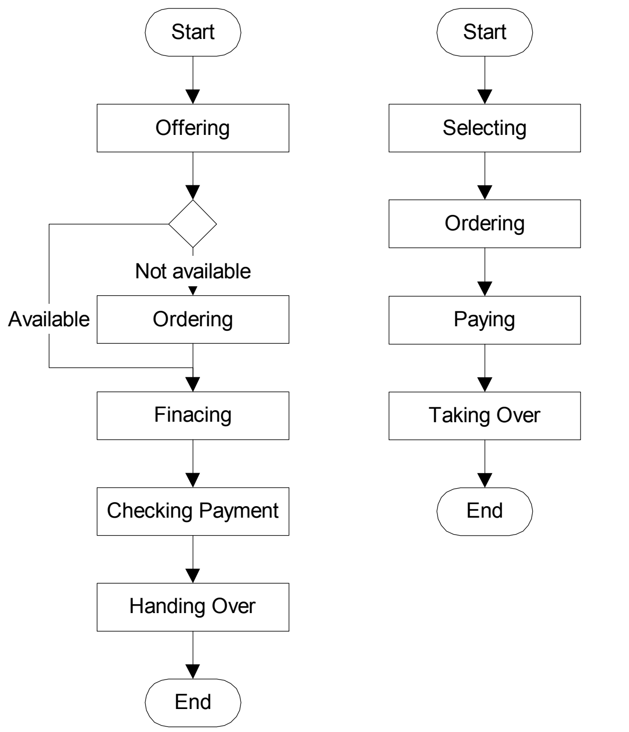
The next chapters will show how the theory of concepts might remove the gap between process models and organizational structure.

A MOTIVATING EXAMPLE

Lets start with a toy example to demonstrate how the business process models serve as a source of the organizational structure specification. Let's assume that we have a car sale company with a showroom that employs four people: *manager*, *salesman*, *technician* and *accountant*. Let's assume that we have only two business processes enacted: *car sale* and *car fleet purchase*. The first one reflects the situation when a customer wants to buy a car; the second one is performed by the showroom when a fleet of cars has to be purchased for demonstration and for immediate sale purposes.

Car sale process starts with the activity of *offering* a car to a customer. Activity of *ordering* the chosen car from a manufacturer follows if the car is not available in the showroom. Employees of the showroom try to help the customer with *financing* afterwards and finally the payment from the customer is *checked* and the car is *handed over*. *Fleet purchase* process is started with the *selection* of the appropriate fleet, and then the selected cars are *ordered*, *paid* and *taken over* by the showroom.

Simple flow chars of the following structure can model these processes as follows (Figure 1):



Car Sale Process **Fleet Purchase Process**

Figure 1: Flow Charts of Core Processes

It is obvious that the next logical step is to assign roles responsible for the specified activities. Based on that assignment it is possible to derive so called table of responsibilities that can be used for the purposes of the organization structure specification. Let's assume that in the car sale process for *offering* activity the *salesman* or *technician* is responsible. The showroom *manager* or *salesman* can realize the *ordering* activity while the *accountant* or *manager* takes care of the financial operations like help with *financing* and *checking* the payment. Finally for the activity car *hand over* the *technician* or *salesman* is responsible. The process of fleet purchase has to be assigned with its roles, too. Resulting tables of responsibilities are following (Table 1, 2):

Table 1: Role Assignment for Car Sale Process

	Offering	Ordering	Financing	Checking P.	Handing Over
Manager		X	X	X	
Salesman	X	X			X
Technician	X				X
Accountant			X	X	

Table 2: Role Assignment for Fleet Purchase Process

	Selecting	Ordering	Paying	Taking Over
Manager	X	X		
Salesman		X		
Technician	X			X
Accountant			X	

It is obvious that our showroom would have to implement some additional processes with more complex structure in a real life situation but for our purposes that are to demonstrate the potential of the theory of concepts this simplified example should be sufficient.

CONCEPT ANALYSIS

Concept analysis theory can be used for grouping of *objects* that have common *attributes* (Ganter 99). Concept analysis begins with a binary relation, or boolean table, T between a set of objects **O** and set of attributes **A**. It means that $T \subseteq \mathbf{O} \times \mathbf{A}$. For any set of objects $O \subseteq \mathbf{O}$, their set of common attributes is defined as

$$\sigma(O) = \{a \in \mathbf{A} \mid \forall o \in O : (o,a) \in T\}.$$

For any set of attributes $A \subseteq \mathbf{A}$, their set of common objects is

$$\tau(A) = \{o \in O \mid \forall a \in A : (o,a) \in T\}.$$

A pair (O, A) is called a *concept* if $A = \sigma(O)$ and in the same time $O = \tau(A)$. The very important property is that all concepts of a given table form a *partial order* via

$$(O_1, A_1) \le (O_2, A_2) \Leftrightarrow O_1 \subseteq O_2 \Leftrightarrow A_1 \supseteq A_2 .$$

It was proven that such set of concepts constitutes a complete lattice called *concept lattice* $L(T)$. For two elements (O_1, A_1) and (O_2, A_2) in the concept lattice, their *meet* $(O_1, A_1) \wedge (O_2, A_2)$ is defined as $(O_1 \cap O_2, \sigma(O_1 \cap O_2))$ and their *join* $(O_1, A_1) \vee (O_2, A_2)$ as $(O_1 \cap O_2, \sigma(O_1 \cap O_2))$. A concept $c = (O, A)$ has *extent* $e(c) = O$ and *intent* $i(c) = A$. More about concept analysis can be found in (Ganter 99, Snelting 97).

Concept lattice can be depicted by the usual as lattice diagram. It would however be too messy to label each concept by its extent and its intent. A much simpler *reduced labeling* is achieved if each object and each attribute is entered only once in the diagram. The name of object O is attached to the lower half of the corresponding object concept $c = (\tau(\sigma(O)), \sigma(O))$, while the name of attribute A is located at the upper half of the attribute concept $c = (\tau(A), \sigma(\tau((A)))$.

ORGANIZATIONAL STRUCTURE MODELING

The tables of responsibilities specified in the previous chapter correspond with boolean tables described in concept analysis where objects of the relation are substituted by roles and attributes of objects are substituted by activities that the roles are responsible for.

Before we construct the conceptual lattice describing roles and their responsibilities from our showroom example we have to join two tables of responsibilities defined for each process separately. The reason is that we want to have one organizational structure for the showroom as a whole not for each of the defined processes. The resulting table will have the following form (Table 3):

Table 3: Role Assignment for All Processes

	Off.	Ord.	Fin.	Check.	Hand.	Sel.	Pay.	Tak.
Manager		X	X	X		X		
Salesman	X	X			X			
Technician	X				X	X		X
Accountant			X	X			X	

The set of concepts that can be derived from the joined table of responsibilities consists of:

C_{MSTA} =({Man., Sal., Tech., Acc.},{})
C_{MS} =({Man., Sal.},{Ord.})
C_{MT} =({Man., Tech.},{Sel.})
C_{MA} =({Man., Acc.},{Fin., Check.})
C_{ST} =({Sal., Tech.},{Off., Hand.})
C_{M} =({Man.},{Ord., Fin., Check., Sel.})
C_{S} =({ Sal.},{Off., Ord., Hand.})
C_{T} =({Tech.},{Off., Hand., Sel., Tak.})
C_{A} =({Acc.},{Fin., Check., Pay.,})
$C_{\varnothing}$ =({},{Off.,Ord.,Fin.,Check.,Hand.,Sel.,Pay.,Tak.})

Concept lattice (Figure 2) can be constructed from the set of described concepts using following rules defining a structure of the graph:

- Graph nodes represent concepts and arcs their ordering.
- The top-most node is a concept with the biggest number of roles in its extent (cMSTA in our case).
- Concept node is labeled with an activity if it is the largest concept with this activity in its intent.
- Concept node is labeled with role if it is the smallest concept with this role in its extent (reduced labeling).

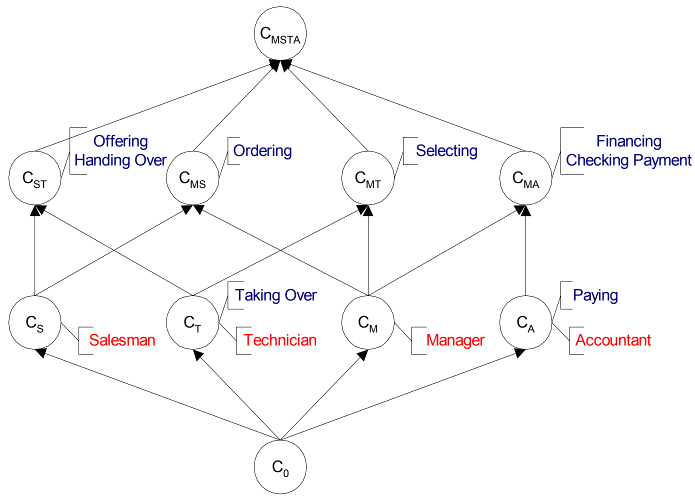


Figure 2: Concept Lattice of the Organizational Structure

Resulting graph provides alternate views on the information contained in the above-described table. In other words, the concept lattice enables to visualize the structure "hidden" in the binary relation. In our example we can see that the technician is the only one who can take over delivered cars but he/she can also select a fleet of cars as well as the manager or to offer and hand over car like the salesman. Obviously, the more complex is the table of responsibilities the more difficult is to understand who is responsible for what.

RE-ENGINEERING

Visualization of the organizational structures opens new possibilities to its re-engineering. The concept lattice described in previous chapter (Figure 2) shows that the accountant resp. the technician are responsible for paying resp. taking over activities and thus cannot be substituted by anybody else. On the other hand, the technician in case of offering a car and handing over activity can substitute the salesman as well as the manager can substitute the salesman in the ordering activity. It means that the salesman can be removed. The manager has five activities that he/she is responsible for. If we remove his/her responsibility for checking payment activity then we obtain simplified organizational structure with a new graph of the following structure (Figure 3):

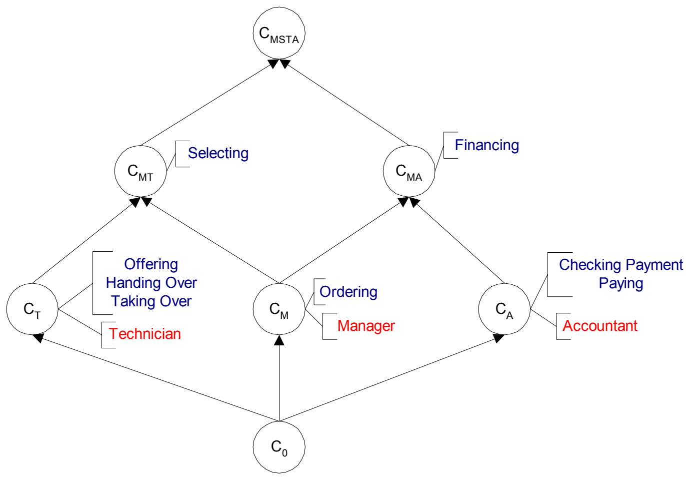


Figure 3: New Organizational Structure

It looks that such kind of organizational structure is better balanced than the previous one because all roles have responsibility only for three activities except the technician that has four of them.

Since the lattice and table can be reconstructed from each other we are able to define new version of table of responsibilities for the given organizational structure (Table 4).

Table 4: New Assignment of Roles

	Off.	Ord.	Fin.	Check.	Hand.	Sel.	Pay.	Tak.
Manager		X	X			X		
Technician	X				X	X		X
Accountant			X	X			X	

CONCLUSIONS

Presented method of concept analysis provides exact and formally well defined way how the organizational structure can be analyzed and re-designed. The example used in our paper was simplified but it demonstrated sufficiently the potential of concept lattices and the way how they can be adopted for purposes of re-engineering. The future research is focused on building appropriate software tools that will enable to deal with much larger examples than the presented one and to verify the method in real-life situations.

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IMPLEMENTATION TECHNIQUES

AN INTEGRATED SYSTEM FOR ENTERPRISE PRODUCT DEVELOPMENT

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KEYWORDS
Computer Aided Process Planning, Computer Integrated Design for Manufacture.

ABSTRACT

This paper presents a software system that implements manufacturing planning in a CAD application. A genetic algorithm is used to generate plans optimised with respect to criteria such as resource availability, product quality, product delivery and cost. A manufacturing model common to all the modules in the system facilitates integration.

INTRODUCTION

The most important decisions about product quality, cost, delivery (QCD) and other requirements are usually made during the early stages of design. For this reason a Computer Integrated Design for Manufacture (CIDFM) system should allow design decisions to be informed by actual manufacturing scenarios from these early stages, so that these often unpredictable aspects can be managed.

This paper describes a pilot system which integrates an enterprise database with CAD software, using a manufacturing model and a planning engine derived from the CAPABLE system (Bramall et al. 2001). In addition to CAPABLE's manufacturing planning system, the system can import manufacturing scenarios from a web-based middleware application, has several planning algorithms and options, and is embedded into a CAD application which also contains a 3D virtual manufacturing environment.

This paper first describes the structure of the system, then the planning engine. The planner uses a novel genetic algorithm for manufacturing planning. Finally the manufacturing model and its role in integration is described.

SYSTEM STRUCTURE

At the heart of the system is the planning engine. It is tightly embedded within the CAD application (Dassault Systèmes' CATIA V5) by using the Microsoft COM interfaces (Rogerson 1996) exposed by the application. These interfaces are also used to extend the CAD functionality to support the manufacturing model understood by the planner.

The design and planning modules do not work in isolation. These core activities need to be informed by information from the enterprise, particularly existing production timetables that the planner can use as scenarios to generate likely manufacturing plans.

A enterprise collaboration system (PTC's Windchill) is used by the planning module as a source of manufacturing scenarios and information about resource availability and existing enterprise commitments. This middleware application is built on the Java Servlet framework (Lewandowski 1998; Singhal and Nguyen 1998) and is designed to be customised through the addition of web based Java servlet components. Here it is extended with a servlet that supports the manufacturing model, so that it can communicate with the planner.

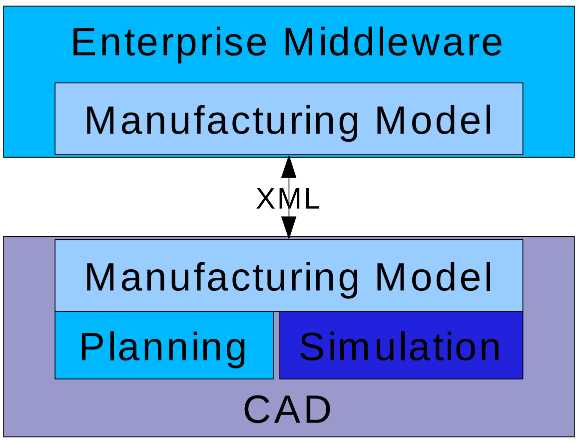

Figure 1: System Structure

When the development of the product gets to the stage where a manufacturing plan has to be evaluated in detail, a third party module in the CAD application allows plans to be realised as 3D simulations in a virtual manufacturing environment (Dassault Systèmes' DELMIA).

PLANNING ENGINE

Planning systems for combinatorial planning problems have been developed before (Váncza and Márkus 1996). CAPABLE used a simulated annealing algorithm to produce realistic manufacturing plans (Maropoulos et al. 2002). The main purpose of the algorithm is to generate a realistic process selection starting from a manufacturing scenario, given as a timetable of resource availability and process start and finish times.

Genetic Algorithm

Well defined and restricted manufacturing planning problems such as the RCPSP (Klein 2000) have been extensively studied. Our problem is more general; processes can make any change to the timetable, not just consume resources. The goal is not merely to schedule the processes to minimise makespan, but to find a good plan with respect to several criteria. Such multicriteria optimization problems are well suited to a genetic algorithm (GA) (Forrest 1996).

A simple GA is used to optimise over all possible plans for product manufacture. A candidate plan, or chromosome, is represented by a set of processes, each associated with a key value. A population of these chromosomes is present at each iteration of the algorithm. New candidates - produced by crossover and mutation - are added to this population and all candidates are scored by a multi-criteria evaluation function. The population is ranked from lowest scoring at the top, to highest scoring at the bottom. The bottom candidates are removed until the population is at its initial size.

Two point crossover (Figure 2) is implemented by partitioning two sets of processes (Figures 2a and 2c). Each set is partitioned into two about a random key value (Figures 2b and 2d). The two new chromosomes are the union of one low part with its partner's high part (Figures 2e and 2f). Mutation is implemented by simply selecting a process at random and changing its parameters or key value.

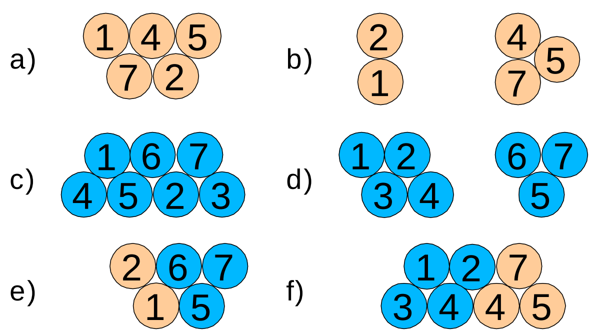

Figure 2: Two Point Crossover with Sets of Processes

Timetabling

Each candidate plan must be evaluated according to several criteria; for this to happen a timetable must be constructed. A timetable is a history of changes taking place over time in an enterprise, such as resource availability, process start and finish times and the state of products being produced.

The timetable is built by adding each process in turn to a base scenario timetable. Each process alters the timetable by consuming resources, altering a work in progress or any other change to be modelled.

There are several variations on the way processes are added; using each process's key value as its start time; starting each process as early as possible so as to incur the minimum penalty for resource starvation; or starting at the earliest time *after* its key value. Further variation is possible by changing whether the processes are added in ascending or descending key value order, or starting each process as late as possible with respect to a finish time (Klein 2000).

Each process, when added to the timetable, will attempt to find the resources it needs to proceed. If it cannot, it will note that it carries a resource starvation penalty, but it consumes what resources are available and *produces its outputs anyway*. Plans that are invalid may carry good sections that are useful to the GA optimiser, so they should not be scored too highly and eliminated.

Evaluation Function

The goal for the planner is the appearance of a finished product somewhere on the timetable, with a suitably high quality, low cost and short delivery time. It is the job of the evaluation function to score candidate plans according to the criteria given by the designer as it cooperates with the GA in the search for good plans.

The function looks for the presence on the timetable of the product that is being produced. Failing that, it looks for successfully produced sub-assemblies. It should award a score even to a plan which only partially completes the product, as the GA discovers good plans by combining plans which have some good parts.

The quality of the product is based on the process capability (Cpk) values of its features, which depend on the processes and resources that were selected to make them. Cost is derived from the timetable as a whole, by examining the additional cost burden on the enterprise as compared with the original scenario. Delivery criteria are assessed by checking how soon after the start time the product becomes available. These scores are combined with the total resource starvation score (which, if present, is always greater than any QCD score, ensuring that no valid plan is ever outranked by an invalid one) to give the score that will be used in the GA.

MANUFACTURING MODEL

The manufacturing model is based on a feature based product model derived from CAPABLE (Maropoulos et al. 2000), combined with process and resource models which reflect those in the enterprise. It is first specified in UML (Figure 3) (Kobryn 2000) because some parts are implemented in more than one area of the system. This common, formal definition is used differently in the planner, in the middleware and in the XML fragments that travel between them.

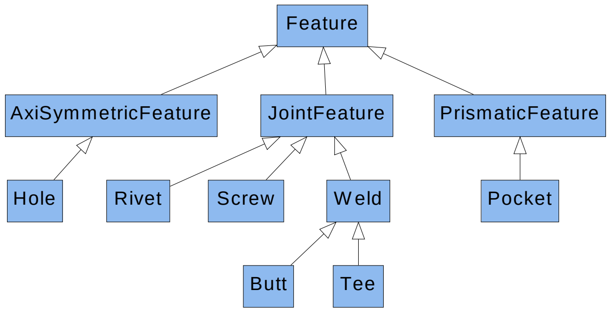

Figure 3: A Part of the UML Product Model

In the middleware context, entities are stored as records in a database with their essential parameters. When communicated to the planner they are represented as an XML fragment (Figure 1). These XML fragments are read by the planner, validated against an XML schema and the planners own rules for validity, and instantiated as C++ components.

The CAD application is a feature based parametric solid modeller. CAPABLE used a custom design by feature modeller that supported more feature types than a typical CAD system. Assembly features such as weld and joint features were better represented, and the CAD application is being extended to support these concepts.

CONCLUSION

A Computer Aided Process Planning (CAPP) system is proposed which will allow a realistic manufacturing plan to be generated in the early stages of design. Embedding a manufacturing planner - built on previous research - in a CAD application and integrating with enterprise middleware, the system will allow a designer to evaluate and control the cost, quality, delivery and other aspects of the product.

FURTHER RESEARCH

Including aspects of the product model or the resource model in the optimization will allow different kinds of analysis to be done. Design decisions, such as choosing materials, could be made automatically by making the optimiser choose the best with respect to the given criteria. A make-or-buy analysis would be possible in a similar way.

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CONCURRENT PROTOTYPING USING FPGAs FOR THE LINE TRUNK GROUP PROJECT

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KEYWORDS

ASIC, FPGA, prototyping, system development process, EWSD, Virtex-II.

ABSTRACT

The Line Trunk Group is part of the digital telephone exchange system EWSD by Siemens ICN. The project was a design-to-cost exercise for an improved version of the product. On the system boards, where hardware and software were combined, ASICs (Application Specific Integrated Circuits) were re-designed and concurrently prototyped by FPGAs (Field Programmable Gate Arrays). The existing low-level software of the system that controls the hardware would be re-used but some modifications were necessary due to the changes in the hardware platform. With the FPGA prototypes it was possible to start testing the software changes, on the target hardware, fourteen weeks earlier than would have been possible otherwise. Since it is the software development that is typically the bottle-neck, this time saving has a direct bearing on the product release date. Hardware/software co-verification on the target system had the additional benefit of testing the hardware rigorously. Since test results were available before fabrication of the ASICs would begin, as an added benefit, the risk of functional failure in the ASICs was reduced considerably. The novelty in this paper is that FPGAs were developed from the existing ASICs of the previous version, whereas the usual route of migration in prototyping, is to design a FPGA from scratch and migrate to an ASIC implementation later.

INTRODUCTION

Telecommunications equipment manufacturers are continually faced with the challenge of improving existing products. Not only as far as features and functionality are concerned, but also in terms of reducing the manufacturing cost for the same system performance. The continual shrinkage in silicon technology allows increased levels of integration on the hardware components. This makes reductions possible in the cost, size and power consumption of the equipment, for a given data throughput. For every new release of a product there is the pressure to re-design the hardware in order to achieve these design goals. However, although these factors are essentially determined by the hardware they may cause changes in the software. This applies particularly to the low-level software that is embedded in the system boards and directly controls the hardware. This is an important consideration, since due to the complexity of modern software systems, the system development schedule is chiefly determined by the software design process and normally less by the hardware development effort.

Therefore, the anticipated software development effort needs to be estimated, when planning a new hardware platform. The software is being developed concurrently to the hardware, but traditionally software debugging cannot begin until the hardware is fully designed and the system board has been received and tested. Despite extensive verification of the designed hardware devices there is always the risk of functional failure, particularly when complex control structures are implemented, as exhaustive verification is practically impossible in these cases. Such a failure can prove disastrous if the functionality of the system is significantly reduced or even disabled completely. In this event software debugging cannot commence until the hardware is re-designed, with the error corrected, and new samples have been received. Using ASICs (Application Specific Integrated Circuits) such an iteration can take two to three months as extensive verification is necessary as well as the production cycle. Therefore, it is important to consider how the system development cycle can be shortened using new tools and techniques. Essentially the system development cycle can be shortened when it becomes possible to test the software being developed on a model, before the target hardware becomes available. Two methods have been proposed which address the problem and allow concurrent hardware design and software testing. Firstly, tools exist to perform hardware-software co-verification. This allows simulation of the hardware and debugging of the software to be performed in a single environment [1]. The main disadvantage of this method is that the performance is limited by the hardware simulation and is very poor. This means that it is computationally too expensive to run all test cases of interest. Another alternative is to use emulation to model the ASIC on a hardware platform [2]. This method achieves a good performance, and typically an ASIC can be modelled with a system frequency of about 1 MHz. An additional advantage is, provided that the complete system can be run at the reduced frequency, in-circuit testing is possible, i.e. the emulator can be connected to the system board. However, the emulation platform is very expensive. This also means that having more than one testbed is unrealistic.

In this paper we present an alternative method using FPGAs (Field Programmable Gate Arrays) to prototype the ASICs while they are being developed. If the FPGA pinning can be made footprint compatible to the ASICs the target system board can be used for testing the software giving the true system environment. This is similar to the emulation approach, however at a considerably lower cost, and higher system frequency. Another advantage is that several boards can be made available which allows the software teams to test their modules in parallel.

SYSTEM OVERVIEW

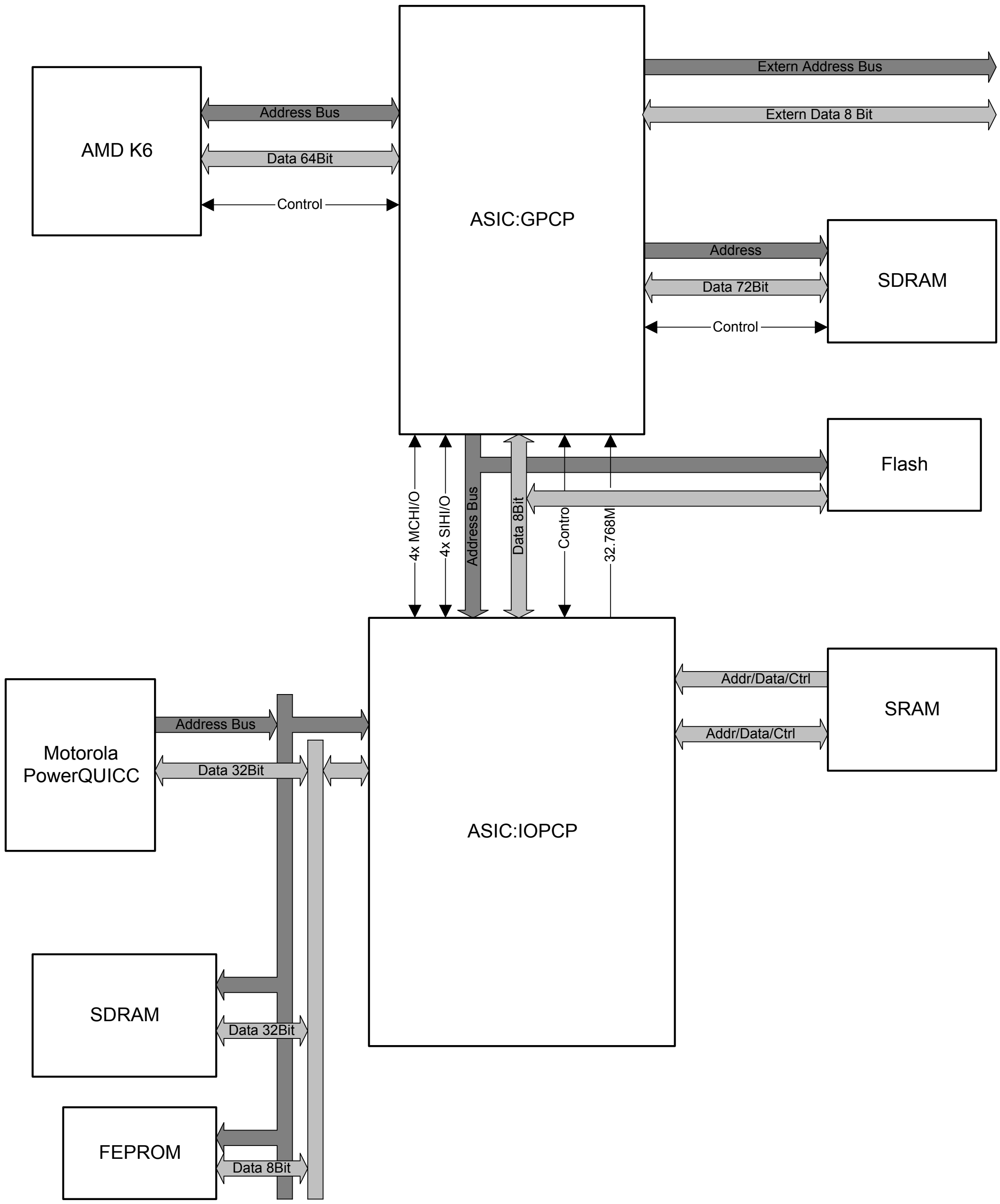

Figure 1: Block Diagram of the GPP Module

The Line Trunk Group version P (LTGP) project is part of the digital telephone exchange system EWSD by Siemens ICN. The project was essentially a design-to-cost measure. Cost reduction was achieved by combining several identical components from the previous version in a single device using a modern 0.18µm technology for the ASICs. Figure 1 shows a block diagram of one of the system boards for the new version LTGP called GPP, for which the prototypes were developed. As indicated there are two ASICs IOPCP and GPCP. The ASICs communicate with each other, and each ASIC communicates with its own microprocessor and can access off-chip flash and SDRAM modules.

The previous version O of the board GPO, consisted of the old ASICs GPCO and IOPCO, again controlled by a microprocessor each. The new ASICs GPCP and IOPCP were effectively four components of version O integrated into a single device respectively. Whereas the GPO had a throughput of 120 PCM-30 channels, the GPP had an increased throughput of 480 channels. The ASICs were not simply four instantiations of the old netlists, but complex additional control logic was required to manage access onto the new, shared system busses. Moreover, the fact that a single microprocessor controlled four functional units that were previously controlled by a single microprocessor each, caused significant changes to the software to be made. The version O software was working in the field, so that the main concern in the project was not to introduce any software bugs into the system. To allow early software testing, FPGAs were developed concurrently to the ASICs.

FPGA PROTOTYPING

When FPGAs are used for prototyping of a product, the normal route of migration is from a FPGA implementation to an ASIC implementation. This is typically applied when designing new products. The FPGA implementation reduces the time to software testing and allows features to be included at a later date without a production step being necessary. When the feature requirements are settled and volume production is about to begin the ASIC can be developed with relatively low effort as functional verification has already been performed on the prototype system. Also migration from FPGA to ASIC is relatively straightforward, as the performance of an ASIC technology is considerably better than FPGA performance.

In this project, as far as the prototyping is concerned, the route of migration was from ASIC to FPGA. The FPGAs were developed by re-using extensively from the design database of the existing ASICs GPCO and IOPCO. Concurrently the new ASICs were developed, but would be available three months after the FPGAs. The FPGAs would thus only be used for software testing until the samples of the new ASICs were available, and testing would continue with the ASICs. However, this type of migration from ASIC to FPGA causes a number of issues, which do not tend to be a problem in the usual migration from FPGA to ASIC. FPGAs have significant performance limitations in comparison to state-of-art ASIC technologies as far as clock frequency, power consumption and gate count are concerned. When the ASIC design database was created these limitations were not accounted for, and a straightforward re-use was not possible without adaptations to account for the FPGAs. However, functional changes, such as introducing re-timing stages into the design database were deemed unacceptable, as any minor change could have an effect on the low-level software controlling the ASICs. This meant the topology of the designs could not be changed to suit the FPGA technology, as the software development had clear priority. Therefore very careful analysis was required to determine whether the migration was possible without violating the performance requirements of the FPGA technology.

IMPLEMENTATION

Before the project started the feasibility of integrating a new device on an FPGA had to be investigated. The gate count of the ASICs of the previous version LTGO was known, so by assuming an increase in a factor of four an estimate was obtained for the new ASIC versions. However, using the gate count it was difficult to estimate the required FPGA master size. It was necessary to estimate the ratio of ASIC gates to logic elements in an equivalent FPGA, but this ratio tends to vary with the topology of the design. Also as the FPGA devices would be very large only a new, state-of-art, device series could be considered for which no experience was available at the time. In particular the effect of the percentage device utilisation on the placement and routing of the FPGAs was not known. The ASICs were coded in the hardware description language VHDL. In order to obtain a better estimate at the beginning of the project the VHDL codes of the old devices were used to test the feasibility of the FPGAs. By simply instantiating four of the old devices in one netlist an approximation to the new device was obtained early that could be used to estimate whether the new device would fit in an FPGA. The advantage was that the code could be used in a trial synthesis and place and route runs. Thus the targeted tools could be evaluated on a netlist with a similar topology to the new devices. The Xilinx Virtex-II series was chosen to implement the FPGAs [3]. The XC2V6000 turned out to be the smallest member of the series where the netlists would fit in.

	IOPCP	GPCP
Logic Gates	676k	400k
RAM	480 kbit	280 kbit
Core Frequency	40 MHz	66 MHz
No. Of Clockdomains	10	2
No. Of Signal IOs	410	426
Power Consumption	1 W	2 W

Table 1: Key ASIC figures

Table 1 shows the key figures for the two ASICs IOPCP and GPCP. For the GPCP device the trial synthesis, using code of the previous device version, indicated that the FPGA would be unable to achieve the required frequency of 66 MHz. Therefore a frequency reduction scheme was necessary. This was a critical point as system testing is possible only within constraints determined by the system interfaces. The GPCP core frequency was reduced by a factor of two. This required the microprocessor connected to the GPCP to be operated at reduced frequency. Some changes in the VHDL were necessary to reduce the core frequency while keeping the interfaces between GPCP and IOPCP at the original frequency. The IOPCP FPGA managed the required 40MHz frequency, so no changes were required here. With this frequency reduction scheme full functional system testing would be possible.

In the project the FPGAs were designed concurrently to the ASICs by separate teams. The project was a pure design-to-cost exercise and as far as the ASICs were concerned, no additional design features were added. Therefore, extensive re-use in the VHDL code of the ASICs from the previous product version could be done. There were functional changes necessary however, since all four old devices would now communicate with a single off-chip microprocessor. Also, changes to overhead circuitry such as test structures were necessary. The ASIC teams performed the necessary changes when integrating four devices on one new device. The FPGA teams would use the same VHDL code from the ASICs, with some modifications. In particular instantiated gates from the technology library, the IOs, and RAMs had to be replaced in the code. Minor changes were necessary to satisfy the FPGA synthesis tool.

Figure 2 shows the time schedule of the parallel FPGA and ASIC development. The FPGA project did not begin until about one month into the VHDL coding phase of the ASIC teams. At this point a first version of the code was available and could be used by the FPGA team. Until that time the FPGA teams were involved in creating a common pinning for the ASIC and FPGA device.

The FPGAs were planned to be footprint compatible with the ASICs in order that the system target board could be used for testing the FPGAs. Normally an adapter socket would be used on the board. This would allow an independent pinning for ASIC and FPGA. However, 1152 ball BGA packages were used for the FPGAs, and for the large number of balls required no adapter could be obtained. Therefore, the pinning for the ASICs and FPGAs were done early to ensure a common pinning could be found. The pinning constraints of both ASIC and FPGA had to be considered to achieve this. The ASIC and FPGA packages had different locations for power supply pins. A switch on the board had to select between FPGA and ASIC device as these locations were incompatible. Also different core voltages existed for the FPGA and ASIC technology, which also had to be selected according to whether the board was mounted with ASICs or FPGAs.

FPGA timing was verified using static timing analysis. Here a number of difficulties were encountered, as the design database of the re-used ASICs had obviously been created without the limitations of an FPGA design in mind. The circuit topology was not suitable for a FPGA implementation. The number of data re-timing stages (flip-flops) was minimized in the design in order to reduce the latency time of the data passing through the system. This meant the combinational logic paths had a large number of logic levels and correspondingly a large number of connections to be routed. The density of mapped logic is less on an FPGA compared to an ASIC which means the ratio of wire delay to gate delay is greater for the FPGA making timing closure more difficult. Also due to large data multiplexors in the design a large number of false paths existed in the design. Since FPGA design tools are not as mature as ASIC tools, the quality of FPGA tools is significantly poorer. In some cases the false path definitions used in the ASIC STA script could not be implemented in the FPGA toolset. In one case a multiplexor output had to be disabled from the timing analysis as no way existed to properly define and exclude false paths over this net. A separate timing analysis was necessary to examine the functionally valid paths over this net.

Floorplanning was absolutely essential to achieve the timing goals for both FPGAs. The timing driven place and route tool was not able to place all critical components in order to achieve timing. So, timing critical blocks needed area constraints to limit the maximum distance between cells in these blocks. Also critical paths e.g. to rams had to be limited by placing the RAMs close to the target modules. The floorplanning was a lengthy iterative procedure, in which the violating paths had to be examined after each trial, and the floorplan adapted to improve these violations accordingly. Finally a worst-case timing of 34 MHz was achieved for the GPCP FPGA and 42 MHz for the IOPCP FPGA. Due to the frequency reduction 33 MHz was required for the GPCP, so the timing requirements were just about achieved using the highest speedgrade availabe for Virtex-II at the time.

In the time schedule in figure 2 it can be seen that the first FPGA image was available at roughly the same time as the ASIC started into the final layout. The ASIC would require a layout step, verification and typically one or more engineering changes as well as the production cycle, before samples could be received from the manufacturer. During this time the FPGA was available for mounting and testing on the system board. An additional fourteen weeks of software testing time were gained compared with waiting for the ASIC production samples. As the SW is invariably the bottleneck in a large telecommunication system development, this has direct bearing on the final product release date.

Some minor problems needed to be overcome after the board was switched on for the first time. This was due to errors in the assembly of components which distinguish the boardfunction for ASIC or FPGA design as well as due to electrical effects concerning the download

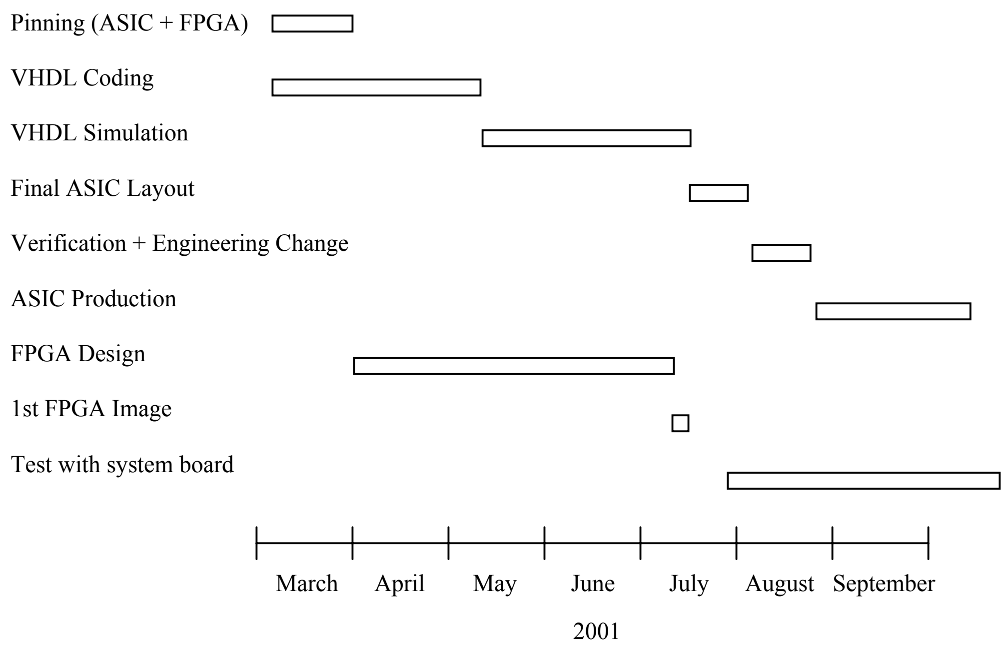

Figure 2: Time schedule of the parallel FPGA and ASIC development.

of the FPGA programming information onto the device. This is indicated in figure 2 by a two week gap between the FPGA samples being available and the start of tests on the system board. The boards were distributed to the software engineers for testing. In total testing took place in parallel on 15 boards. During the subsequent fourteen weeks the boards mounted with the prototype FPGAs were used for testing the software. After this the ASICs had arrived, and testing continued with the ASIC mounted system boards. As an important additional advantage, the hardware was also tested as part of the software tests. Any functional error that could be detected on the FPGAs before the ASIC production cycle started could still be fixed with relatively little cost. The risk of product delays due to functional failures that were not simulated by the ASIC teams was reduced considerably. Also the entire hardware of the board was tested, so when the ASICs did arrive, testing continued smoothly, as all hardware problems had already been detected and fixed using the FPGA mounted boards.

CONCLUSION

Concurrent prototyping using FPGAs was used effectively to reduce the product development cycle for the version P of the Line Trunk Group Project. Planning a concurrent FPGA in an ASIC development can save considerable time in having hardware available for system testing at an earlier time. However this only makes sense if the software is available at an early time, which is typically the case in a cost reduction measure of an existing product. Also great care must be taken to ensure the FPGA can operate at the same frequency as the ASIC, or at least a frequency reduction scheme must be used that still allows full functional system testing.

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REVERSE ENGINEERING: AN ETHICAL APPROACH FOR TECHNICAL TRANSFER TO SMALLER FIRMS

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KEYWORDS

Technical Transfer, Concurrent Engineering Teams, Ethics, Small and Medium-sized Enterprises (SME).

ABSTRACT

Reverse Engineering is rarely documented as a technique for carrying out Concurrent Engineering in small and medium-sized enterprises. In part, this is due to Reverse Engineering having negative connotations of imitating more innovative designs. However, Reverse Engineering may be carried out as legally, ethically and in quite different circumstances than previously encountered. Moreover, the benefits of using Reverse Engineering as part of an integrated approach to Concurrent Engineering design and manufacture yields distinct benefits for a smaller firms.

The paper investigates a number of novel points. For example, it highlights the interplay between firms of different size and focuses upon their different engineering strengths. Another rarely documented point is the use of small firms to design or manufacture specialist bicycles for much larger firms. The relationship may then be closer to cooperation and technical collaboration than straightforward competition. Furthermore, the changing composition of Concurrent Engineering teams to reflect a more inclusive role in modern manufacturing has benefits to both the engineer and the user.

Finally the paper concludes by noting that both the SME and much larger firms typically focus upon different engineering tasks. This is in part due to the internal resources of the firm and its technical strengths. However, they may benefit from learning from the strengths of the other. This means that technical transfer becomes a two-way process. This would be particularly beneficial if there are plans to cooperate or act as subcontractors and suppliers.

INTRODUCTION

In smaller firms Concurrent Engineering techniques for Reverse Engineering may yield particular benefits. Frequently, they are aware of new components announced by major component manufacturers from a variety of sources. These sources include trade fairs to intelligent guesswork based upon observation of new or innovative items on competition bicycles. Furthermore, there is a good deal of personal communication between suppliers and customers that remains undocumented. However, the smaller manufacturers know that they will generally wait longer for an order to be filled, especially for new components in demand, than the larger customers.

The smaller bicycle manufacturers receive less-favourable treatment from the manufacturers of components than the larger purchasers from the major bicycle-component manufacturers. Quite simply, the component manufacturers fill the largest orders first so that they can repay the costs of design, tooling and marketing quickly. The smaller firms must wait or substitute components.

This can include making-do with older designs or less-well-known brands. The difficulties encountered by the smaller manufacturers clearly encourage reverse engineering. Thus, any technique that enables the smaller firm to catch up with the major manufacturers would be extremely useful.

THE SMALL AND MEDIUM-SIZED ENTERPRISE (SME)

A recent paper (Hignett and Zobel 2001) highlighted the conditions that affect Small and Medium-sized Enterprises (SME) in the United Kingdom. For example, the term SME is legally defined in the Companies Acts of the United Kingdom. This well-established definition is the one used in the paper.

Additionally, the Companies Acts in the UK allow smaller firms to reduce the kind of information that is legally required in company reports. Moreover, the smaller firms compete in a market dominated by much larger companies with greater resources. Therefore, it is understandable how the smaller firm may be easily overlooked in such circumstances.

THE LACK OF PUBLIC INFORMATION ON SMES

There is a comparative dearth of publically available information on individual small and medium-sized enterprises (SMEs) because the Companies Acts of the UK require less financial and organisational information from the smaller firms. This has the effect of reducing the amount of information available in the public domain to both business rivals and researchers.

Table 1: A Comparison of Different Sizes of Firms

SME	Large Firm
Fast to respond	Slow to respond
Direct control	Multi-layered hierarchy
Lacks in-depth planning expertise	Planning and management expertise in-house
Mainly personal experience	Extensive organisational experience
Experience and expertise concentrated in key personnel	A formalised range of expertise and experience

Table 1 highlights the key advantages and disadvantages of different sizes of firms.
Note that the advantages do not entirely benefit a single size of firm. Furthermore, a well-organised firm can use the weaknesses of competitors in certain areas to lever an advantage.

GROUPING TOGETHER: TO BUY GROUPSETS

One novel technique so far undocumented in the bicycle industry is the practise of forming special-interest groups to influence manufacturers and suppliers of components and materials. These special-interest groups, composed of smaller firms, could then function as a single entity to secure guaranteed delivery times and quantities. Furthermore, individual smaller firms can improve the chance of obtaining high-quality parts and materials on time by winning races or a connection with a much larger firm, perhaps as a designer or specialist manufacturer.

Concurrent engineering tools such as the Japanese PASSOT on-line purchasing and specification system (Ito 2001) could be used to speed up the processes of agreeing specifications and finalising the purchase.

TOMORROW CATCH UP: THE SOURCING OF PARTS

If the smaller firm can plan for the future and not become fixated on the present then it has a number of advantages. The smaller firm can retool and turn out new models or variants from the master model very quickly. This is shown by the success many smaller firms have in competitive sports. In fact, some smaller firms may produce the very high-quality specialist frames for “famous-name” much larger companies. This is less surprising when one considers the reality. The smaller firms are specialist-designers and manufacturers used to meeting special needs. They often manufacture in batches, small production runs or even make “one-offs” or “custom-builds” for wealthy or special customers.

However, the much larger firms are very different. They are focused upon high-volume production and may, in fact, employ outside companies to design their most expensive kinds of bicycle.

COMPROMISE AND COOPERATION

The use of small firms as designers and manufacturers of limited quantities of high-quality expensive bicycles as well as special parts is a common practice, yet it is seldom documented. Typically, a large firm needs to focus upon manufacturing in large quantities. This frequently means that a large firm must have a “flagship” in its range. This is a very high-quality item that is specifically intended to attract a lot of public attention. The “flagship” is expensive and may be available only in limited quantities. All of this is intended to increase its desirability. The high-quality bicycle does attract attention to the large firm that has commissioned it. Thus the large famous firm can become a little more famous. The cheaper bicycles mass-produced on the normal production line of the large firm inherit some of the reflected glory of their more expensive counterparts because they are sold as the same brand.

Moreover, this subcontracting of specialist expertise encourages reverse engineering because firms of opposites sizes and engineering interests need to cooperate. The design of the smaller firm must resemble the ordinary production bicycles of the larger firm. Typically the smaller specialist firm incorporates or adapts some well-known feature found in the large firms more general production output. This may be a general outline or a matching of styling and colour. Firms that formerly viewed each other as competitors move closer to become different parts of an overall engineering design and manufacturing strategy. The smaller firm uses reverse engineering to quickly produce a high-quality bicycle for the larger firm.

TECHNICAL TRANSFER IS A TWO-WAY PROCESS

Traditionally, technical transfer has been thought to be a kind of "trickle-down" effect with the largest firms pioneering the technical breakthroughs that eventually are implemented in smaller firms. However, it is the case that large manufacturers of bicycles buy up small specialist firms that are well known for their design expertise. In these cases, the former owner of the small firm is retained in some way, perhaps as a consultant or a supplier of parts and accessories. Furthermore, this trend is not only found in the design and manufacture of bicycles. It may be observed in other branches of engineering. This shows that large firms are not the only sources of expertise. Furthermore, the different sizes of firms encourage specialisation in the kind of expertise require to meet their specific requirements. The smaller firm concentrates upon innovative design and the imaginative use of expensive materials to gain the lightness and strength necessary for competition use. These are also the requirements of enthusiasts.

Table 2: The Gains from Technical Transfer

Smaller Firm Gains	Large Firm Gains
Chance to learn mass production skills	Difficult to obtain racing experience
"Economies of scale" to buy in larger volumes of parts and materials	Opportunities for generalisation from specialists in high-quality materials and manufacture
Opportunity to use spare engineering capacity	Additional capacity to fill special needs and circumstances
Opportunity to learn of emerging trends and techniques	Opportunity to learn of emerging trends and techniques

Table 2 summarises the benefits of technical transfer. Note this may be viewed as a win-win situation. Each firm benefits in some way.

THE ADAPTATION OF CE DESIGNS

In the case of smaller firms the bicycles need to stay in production for a long period to recoup the cost of tooling. However, designs planned by CE techniques should be able to accommodate modifications and some change of use because these points were originally considered at a very early stage. The "Mix and Match" strategy (Hignett and Zobel 2001) is a recent example of this forward planning and has the built-in ability to handle changes in the detailed specification that arise because of shortages of material or parts. The explicit intention of the "Mix and Match" strategy is to support changes during its life cycle without disruption of production.

THE USE OF REVERSE ENGINEERING TO ADAPT OTHER CONCURRENT ENGINEERING DESIGNS FOR DIFFERENT PURPOSES

Reverse Engineering can take desirable characteristics from other CE designs and apply them in quite different areas. For example, the CE designed bicycle for senior citizens (Ito, 1998) was designed to be easy to use. It had also other characteristics that are capable of generalisation. Previously it was suggested (Hignett and Zobel 2001) that the Japanese CE designed bicycle could be generalised to benefit other physically less able people such as young children or disabled people.
However, a brief examination of the CE designed bicycle from Japan reveals characteristics also required in high quality competition bicycles. This would include the transfer of materials and parts. Moreover, it could be further generalised to utility bicycles, such as delivery bicycles, where durability and ease of maintenance is more important than speed.

Table 3: A Comparison of CE Designs for Bicycles

The CE designed bicycle for old people (Ito 1998)	Competition bicycle
Light-weight	Light-weight
Strength	Strength
Easy to balance	Easy to balance
Powerful progressive brakes	Powerful progressive brakes

Table 3 compares the CE designed bicycle for senior citizens with the requirements of competition bicycles. Note the parallels in the requirements of the two different kinds of bicycles. The riders of both kinds are from different extremes of skill and speeds. The essential characteristics are the same.

LEGAL AND ETHICAL ISSUES

These can be examined together because ethical debate is frequently part of a legal argument or the original driving force behind a change in the law. However, the real distinction is that laws are codified into a formal body of regulations and generally have penalties imposed if the laws are not obeyed.

The major legal issues relating to reverse engineering are patents, copyright, contract laws and licensing agreements as well as professional codes. Furthermore, the legal process is not a single decision. It maybe followed perhaps by appeal: a judicial-review by higher legal authorities. The legal process is characterised by an adherence to formal procedures, occurring over an extended period accompanied by a profusion of documentation. An important point relating to firms using overseas expertise, parts and materials is that different national laws, remedies and penalties may be applied in disputes.

Ethics are somewhat different in that they do not involve the imposition of specific penalties. Ethical issues are also less clear-cut because they may lack the formalised nature of law and legal definitions. Moreover, ethical questions lack the formalised procedure of establishing and documenting legal-precedents. However, there is an emerging trend for some countries to debate and document guidelines for the members of professional engineering organisations.

ETHICAL EXAMPLES OF REVERSE ENGINEERING FOR CE TEAMS

The use of Reverse Engineering is much more than simply copying the designs of competitors. It is used when firms find that plans, documents and specifications are lost. It is also the case that old techniques and information are required again. This is a situation likely to arise as firms are subject to take-overs and acquisition. Furthermore, even the largest firms may seek to reduce costs and/or development time by transferring production overseas.

THE USE OF CE TECHNIQUES

An important consideration in carrying out Reverse Engineering is that CE tools and techniques can be used that were simply not available some years ago. Moreover, the various specialists may use different tools to carry out their work. For example, in the past Engineers drafted their plans on paper but this is now largely superseded by CAD. In a similar vein, even accountants used to paper-based records and ledgers now access financial records using a spreadsheet.

THE CHANGING COMPOSITION OF CE TEAMS

CE teams were once principally engineering teams whereas today one would expect that specialists from Marketing, Finance and Public Relations would be included as well. This can actually encourage innovation: the marketing people focus upon selling the new and improved design while the Finance specialists seek to reduce costs by maximising production levels and re-using existing tooling as well as incorporating parts. For example, a smaller firm can trace-back the different sub-processes that form its design and manufacturing in order to highlight areas of particular concern.

These areas of concern can then be analysed by the various functions of the CE team and using the range of professional expertise from Purchasing, to Design and Marketing. This is done in order to seek points where one function may lever an advantage for another. For example, the use of one single kind of part throughout the entire range simplifies both purchasing and Inventory. This might be useful in convincing sceptical retailers to place orders.

However, even two firms cooperating may lack the required in-house expertise to complete a new design in time for seasonal demands.

It should be noted that at least some of the expertise might come from outside the firm. Here, the CE community has already made some very positive contributions in the form of publications, consultancy or workshops in Norway (Aasland, 1998) and the electronic component manufacturing industry of Wales (Lewis and Brown 2001).

Table 4: the modern Concurrent Engineering team

Specialist	Focus	Impact
Engineering	Quality	Re-use or novel combination
Finance	Cost	Re-use / substitution
Marketing	Novelty	Innovation or novel combination

Table 4 summarises the various inputs of different specialists within a multi-disciplinary CE team.

Note that the various roles may arrive at similar outcomes but for different reasons. Furthermore, in a small and medium-sized enterprise (SME) one person may have to perform more than one role. The changing composition of CE teams along with a trend for greater integration encourages variants of Reverse Engineering. Moreover SMEs are frequently highly individual in their methods (Lewis and Brown, 2001).

CURRENT AND FUTURE DIRECTIONS

There continue to be many unresolved issues in the application of reverse engineering. A wider acceptance of its usefulness seems to be emerging; yet this is hampered by a lack of documentation. The future publication of case studies and success stories would assist in raising the public image of reverse engineering as a legitimate and ethical tool. The ongoing research at the University of Manchester within a wider Concurrent Engineering context suggests that technical transfer occurs as a two-way process. The different sizes of firm can both cooperate and compete, according to their individual interests and expertise. Both firms benefit. Furthermore, the technical transfer can be of different kinds and at various levels because of the evolving nature of concurrent engineering teams.

CONCLUSIONS

The exact motives for small and medium-sized enterprises (SMEs) carrying out reverse engineering are difficult to establish yet it is clear that the smaller firms are at a disadvantage in obtaining high-quality parts and materials. Frequently the smaller firm must innovate, adapt or adopt in-house solutions in order to continue in production.

Furthermore, the smaller firm is typically focused upon meeting the specific very demanding requirements of a small number of knowledgeable customers. This means that the smaller firm must maintain a leading presence in racing and competitive sports.

It is this constant emphasis on excellence in design and manufacture that makes the smaller firm particularly useful as a source of high-quality bicycles and parts intended to be manufactured in small numbers. This subcontracting allows the larger firms to concentrate on manufacturing large numbers of cheaper bicycles that inherit at least some of the status of the more expensive ones. There is need for more research in the issues raised in this paper. Here in the future, external researchers and consultants may yield particular benefits to firms adopting reverse engineering as part of an overall concurrent engineering strategy. One positive step would be comparing the practice of reverse engineering in different locations and industries. A further step is the use of CE workshops for SMEs or groups of SMEs to gauge local interest.
This would assist in raising the public profile of reverse engineering and perhaps reveal it as more frequently carried out than documented. Moreover, further research into the often-complex relationships between smaller firms and their larger counterparts could result in a more realistic appreciation of the engineering strengths of firms. Bigger does not always mean better. In a similar vein, the small firm is not always the weakest. Many small firms are long established. These smaller firms develop extensive informal contacts and benefit from frequent feedback from experts. The benefits of close contact with expert customers found in some smaller firms would prove difficult to replicate in a larger firm with additional layers of management and more formalised methods of interfacing with customers.

Another interesting point is how reverse engineering is applied in different places or industries and what is the driving force behind it. For example, is the primary concern of reverse engineering cost, time or quality? This may be difficult to ascertain because even in a single firm various key personnel may be focusing on different aims. This again raises the point about the changing composition of CE teams and how some smaller firms may adopt a highly individual approach. This is important because CE is generally carried out and documented in large-well resourced firms with codified procedures and formalised management structures experienced in bringing about change. This situation may be quite different in much smaller firms.

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BIOGRAPHIES

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RICHARD ZOBEL graduated in Electrical Engineering from London University in 1963. His first experience of simulation was obtained during 1962-66 at Sperry Gyroscope whilst working on naval surface to air missiles, using mainly valve analog computers. His Ph.D., obtained in 1970 at Manchester University, concerned hybrid analog-digital computing. As Lecturer and Senior Lecturer he became involved in digital signal processing, instrumentation and design environments with special emphasis on the simulation aspects of real-time embedded systems. He is a former Chairman of the United Kingdom Simulation Society (UKSim), Former Secretary of the European Federation of Simulation Societies (EUROSIM), and is a European Director of SCSI, the Society for Computer Simulation International. His current research work concerns distributed simulation for non-military applications, model re-use, distributed simulation model databases, issues of verification and validation of re-useable simulation models and security for distributed simulation under commercial network protocols. He is now semi-retired.

PROCESS MODELING AND CONTROL

REAL-TIME MONITORING AND CONTROL UNDER RT-LINUX

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KEYWORDS

µrobotics, Embedded systems, Real-Time Operating Systems, Scheduling algorithms, Factory Floors.

ABSTRACT

Routing problems arise in several areas of distribution management and have been the object of study by mathematicians and operational researchers. In the field of automatic generation of movements in a Cartesian space, have been developed multiple representation models and path computing based on graphs theory (Assad and Golden 1995). On our paper we focus on the design, implementation and validation of a Scheduling and Guidance solution of Auto-Guided Vehicles (AGVs) based on Monte Carlo simulation, and its execution under the Real-Time Operating System (RTOS) RT-Linux verifying feasibility using Earliest Deadline First (Stankovic et al. 1998) scheduling policy.

The objective of our study is the substitution of AGVs by Mobile Robots incrementing in this way the flexibility and avoiding the outwork infrastructure. For these purposes we are simulating the environment at the laboratory previously to its real integration in the ceramic tile factory floor, working with "Intelligent" Autonomous µrobots and Profibus Fieldbus Data Link (FDL) as the fieldbus communications network (Bender 1993). The µrobots' intelligence is provided by an Embedded Real-Time Controlling application, and the whole factory is Monitored by another Real-Time application, both implemented using pthreads (POSIX threads) running under RT-Linux.

INTRODUCTION

Routing problems arise in several areas of distribution management and have been the object of study by mathematicians and operational researchers. In the field of automatic generation of movements in a Cartesian space, have been developed multiple representation models and path computing based on graphs theory (Assad and Golden 1995).

A graph is any set of elements $G = (V, E, \{c\})$ where V is a finite not empty set which elements are known as vertexes or graph nodes, E is a set of pairs (i, j) of V elements known in general as links or specifically arcs or edges depending on if it has been assigned a sense or not to them (in the case in which links have a sense the graph is known as directed graph) and $\{c\}$, that could be present or not, that represents a cost function over the arcs or edges of the graph.

Some real life applications of routing problems include post delivery, garbage collection, the inspection of distribution systems –gas pipelines, electric power distribution networks, etc.- (Assad and Golden 1995) (Eislet et al. 1995) and factory floors transport systems.

There has been an increasing interest in the industry for the development of new technologies where real-time systems could improve the quality of products and provide cost savings. Market forces and the acceptance of RT-Linux in industrial applications make it a good choice (Ramamritham and Shen 1998).

In a climate of world overproduction in ceramic tiles, quality and price are the two key factors for which European tile manufacturers are competing. So, the development of methods and tools to implement an integrated and fully automated production plant is needed (FEDER-CICYT 1997).

In our paper we focus on the industrial environment where autonomous mobile robots have a great importance. A mobile robot is defined as a self-propelled not manned machine able to freely move and under control with a specific degree of autonomy in a determined environment. Industrial mobile robots are being developed as an evolution of transport systems based on Auto-Guided Vehicles (*AGVs*) in order to provide them a greater flexibility avoiding the outwork infrastructure that their installation requires. Besides transport functions, mobile robots could perform more complex functions as machines feed, mounting, installations maintenance, etc. This type of robots requires a large degree of autonomy due to the per worker cost saving is crucial for its implantation (Tornero 1996).

MONTE CARLO METHOD

The classical way of solving the problem of the automatic generation of movements in the Cartesian space could be applied to two-dimensional or to three-dimensional Cartesian spaces. If we focus on the case of punctual vehicles moving in a Cartesian space with static polygonal obstacles, we find the *VGRAPH* method (that based on the principle of searching of the minimum path express using a graph all the existing movement possibilities)(Díaz et al. 1996).

Once obtained a representative graph of the movement possibilities, we have to solve the routing problem of that graph looking for the minimum path. In routing problems the aim is to determine a minimum cost traversal over a graph satisfying some specified constraints. Most of them are *NP*-hard problems and many different heuristic solution algorithms have been proposed. These algorithms are based on simple ideas strongly related with each problem and its possible solution (Díaz et al. 1996).

The name Monte Carlo (*MC*) applies to a set of heuristic procedures with the common feature of using random numbers to simulate a given process. *MC* approach has not been applied to real life routing problems in the Literature. The purpose of this paper is to justify that *MC* methods could be useful in implementing heuristic algorithms for routing problems (Fernández de Córdoba and Carrasco 1996) (Fernández de Córdoba et al. 1999) in real life environments such as industrial factories.

Routing Algorithm

In our paper we have developed an application of our heuristic algorithm based on *MC* simulation techniques for solving the problem of the computation of the minimum path over the graph that defines all the movement possibilities in a two-dimensional Cartesian space.

The basic idea of our algorithm consists of simulating a vehicle randomly moving over the graph. The vehicle begins in a vertex of the graph (initial node), it continues from one vertex to another of its adjacent ones choosing the destination vertex depending on a set of movement probabilities, and ends the path at the final node once all the constraints have been satisfied.

In this way it is generated a number of possible paths, and the best one (minor cost) is the solution of the problem. Obviously, the goodness of this solution depends on the number of generated paths (number of iterations) and the way in which we define the movement probabilities. Then, due to it is simulated that a vehicle randomly travels the edges of the graph depending on a set of probabilities, we could include this algorithm inside the *MC* techniques.

The general algorithm for the computation of the minimum path that any mobile robot travels on the factory floor is depicted in Figure (1).

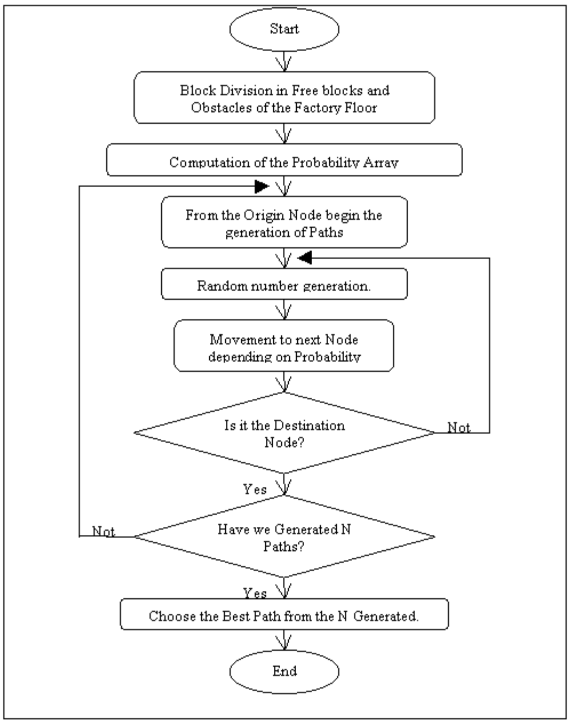

Figure 1: Flow Diagram of the MC Minimum Path computation.

The algorithm begins processing the plan of our factory floor for obtaining a discrete version of it divided in blocks or squares that could be considered in two states: *free* or *obstacle*. In order to decide the size of each block we consider that it is equivalent to the size of the mobile robot that travels, that is, if we represent the mobile robot as a circle whose radius matches with the radius that our mobile robot occupies if it rotates round its axis, the size of the block matches with the smallest block able to inscribe that circle. We assign the state of *obstacle* to a square if it contains any point that corresponds to an obstacle; otherwise we assign the state of *free*.

Once done the division, we compute the probability array that assigns to each node of the discrete floor a probability of moving to each of the four adjacent nodes: left, right, up and down. The definition of these probabilities is crucial because the correct working of the algorithm depends on it. In fact, it is the true modelling process.

"Given a point (i,j) of the graph, the probability of moving to the:
right:

$$P_{rigth} = \left(\frac{1}{E_{uclidean}(i, j+1, n, m)} \right)^{\alpha}, \qquad (1)$$

left:

$$P_{left}=\left(\frac{1}{E_{uclidean}(i,j-1,n,m)}\right)^{\alpha}, \qquad (2)$$

up:

$$P_{Up}=\left(\frac{1}{E_{uclidean}(i+1,j,n,m)}\right)^{\alpha}, \qquad (3)$$

down:

$$P_{down}=\left(\frac{1}{E_{uclidean}(i-1,j,n,m)}\right)^{\alpha}, \qquad (4)$$

where, $E_{uclidean}(i,j,n,m)$ is the Euclidean Distance between the point (i,j) and the destination point (n,m):

$$E_{uclidean}(i,j,n,m)=\sqrt{\left((i-n)^2+(j-m)^2\right)}, \qquad (5)$$

The sense of α in the calculus of movement probabilities is the differentiation of the value of these probabilities when we are far from the destination point computing the minimum path.

After the computation of *N* paths from an origin node to a destination node, we choose the best one that in our case is the shortest.

INDUSTRIAL MONITORING SYSTEM

Our monitoring system for tile manufacturing industry shown in Figure (2) has been designed and programmed using standard, off-the-shelf tools obtaining several advantages over embedded SCADA tools such as: great flexibility, easy-to-handle data interface adding control of processes or systems supervision, and remote interconnection facilities (Zaera et al. 1999).

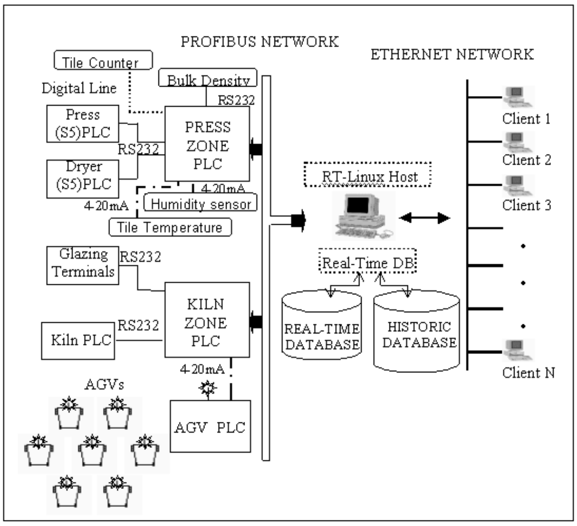

Figure 2: Layout of the industrial plant, and internetworking

Definition of the Problems to Solve

The main tasks of the *AGVs* that work on the factory floor are the tile transference from the glazing terminals to the kiln, and from the kiln to the classification zone. For doing this, they must travel over the factory floor using the shortest path (if possible) from their current origin to their destination. In order to obtain this minimum path we have to implement a Distributed Real-Time algorithm that considering the current location of the *AGV* inside the factory floor, generates its minimum path considering possible crosses between paths followed by another *AGVs* and anomalies in their working due to stops, breakdowns, etc.

On this paper we focus on the *AGVs* scheduling and guidance algorithm based on Monte Carlo Simulation, and its execution under the RT-Linux Real-Time operating system. For these purposes we are simulating the environment in the laboratory previously to its real integration on the factory floor, working with mobile robots (µrobots) instead of *AGVs* incrementing in this way the flexibility and avoiding the outwork infrastructure.

We must solve two problems: The first one related with the µrobots that consists of the computation of the minimum path by each µrobot and the design, implementation and validation of the Monitoring and Control Real-Time Embedded application that runs under RT-Linux at each µrobot ; the second one related with the Monitoring of the whole plant using a Real-Time application running at the RT-Linux Server that uses Profibus FDL as industrial communications network.

In the case of the first problem, the solution to the computation of the minimum path that we propose in this paper is based on Monte Carlo simulation and works as we have previously described. The solution to the monitoring and control of the mobile robots is solved working with several concurrent pthreads managed by an embedded RT-Linux application.

The problem of the global monitoring is also solved working with several concurrent pthreads but in this case managed by a RT-Linux Host. The host performs the data acquisition through Profibus FDL and stores these data inside a Real-Time database (in-memory database) for on-line monitoring, and inside the Historic database for off-line analysis.

µROBOTS MONITORING AND CONTROL

Each µrobot must execute a Real-Time embedded application. The solution we have chosen consists of a multithreading application that uses pthreads performing two tasks: the environment knowledge and the minimum path computation.

The first task involves the knowledge of the μrobot position using encoders (optical encoders), state of the μrobot (using bumper sensors), distance measurement (ultrasonic sensors), and tile temperature (temperature sensor). As we could see in Figure (3), the Launcher Process launches five threads: four Monitoring threads (*MT_i*) (one for each sensor) and one Control thread. The *MTs* read the current information from each sensor with a periodicity of T_s milliseconds and store that information in a memory buffer.

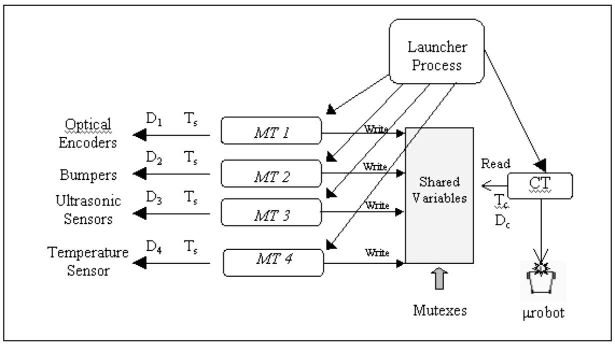

Figure 3: Multithreading Embedded Application

The second task is related with the minimum path computation using the Monte Carlo Simulation Algorithm. The Control thread reads from the memory buffer the current information with a periodicity of T_c and according with this information computes the Minimum path.

The general functioning of our scheduling and guidance scheme consists of in first place each μrobot computes its minimum path, ensuring using forbidden turns (defined in the probabilities array), that a path could be crossed by any other(s) path(s) any number of times but without overlapping. Next, each mobile robot autonomously travels over the factory floor being monitored by its *MT_i* each T_s time period and controlled by its *CT* each T_r time period.

Then, we have to types of deadlines: the first one is related with the monitoring and control of each mobile robot using the *MTs* and *CTs* and the second one is related with the arrival time of each mobile robot to its destination. In this paper we have focused on the first one where monitoring and control tasks are involved and determine the global state of the system. Several solutions could be adopted from this knowledge for achieving predictability in the behaviour of the mobile robots verifying arrival deadlines to their destinations as for example in the case of a robot break down the use of a back-up mobile robot.

We plan to integrate our real-time scheduling and guidance system inside the real-time monitoring system of Figure (2), storing the mobile robots information inside the *PLC* of the kiln zone, reading it as another set of variables of our industrial process for on line monitoring. In this way we could be aware of the state of all the mobile robots at each instant of time.

EXPERIMENTAL RESULTS

Previously to the integration of our system inside the ceramic tile production plant of Figure (2), we have simulated its working at the laboratory. We have focused our study on the Monitoring and Control of mobile robots but we need for the analysis of the results the data acquired from the AGVs PLC by the global monitoring system. The global monitoring system verifies feasibility under EDF scheduling algorithm (Zaera et al. 1999), then we have to verify feasibility of the Monitoring and Control mobile robots task.

For this purpose we present a factory distribution where we have three automated stores where Puma robots perform the storing (from the boxes carried by the mobile robots to the storing boxes), and two numeric control machines with IRB-3000 robots that perform their tasks leaving the final pieces in boxes that will be transported by mobile robots to the automated stores.

The first step of our algorithm consists of dividing the plant into cells which size is defined by the working space of the mobile robots. Once done this division, we assign the state of *free* or *obstacle* depending on if the cell contains some point that belongs to an obstacle (state equal to *obstacle*) or not (state equal to *free*). At the destination point we could consider reorientation of mobile robots to the download or upload position avoiding possible collisions with the flexible manufacturing cells.

Next, each μrobot applies the Monte Carlo method obtaining stable results with an $\alpha = 5$ for the probabilities definition and *1000* paths generation. The initial routes computed by four mobile robots are shown in Figure (4) where the circles represent the origin and destination of mobile robots.

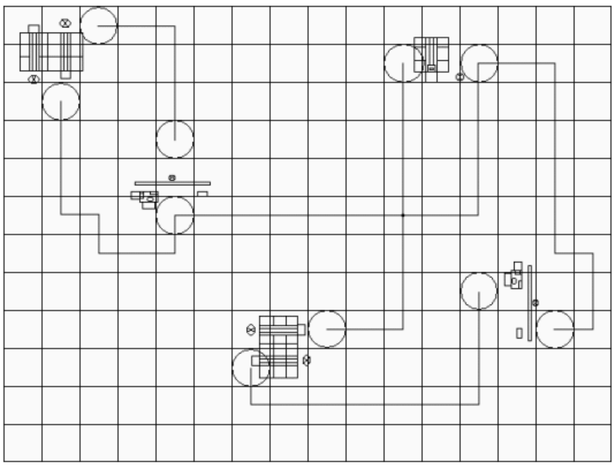

Figure 4: Computed Routes.

Each µrobot is composed by the next elements: SBC (Single Board Computer) *Advantech PCM-5864/L*, Autonomous control card *Microbótica CT6811* equipped with a *Motorola MCM68HC11* µcontroller, Power card *Microbótica CT293+*.

Each µrobot communicates with the AGVs PLC via the serial port using a spread spectrum radio-modem. The AGVs PLC uses for this communication a *CP-341* serial module. The AGVs PLC is connected to the Profibus network using a *CP-342-5* module of the *Siemens S7 PLC*. The interface card of the *Host PC* that allows the connection to the *Profibus FDL network* is the *Applicom PCI-1500-PFB* configured to *1.5 Mbps*.

The software used consists of *RT-Linux RTOS*, *Siemens Step 7 v5 under Windows NT*, gnu C compiler and Assembler *AS11*.

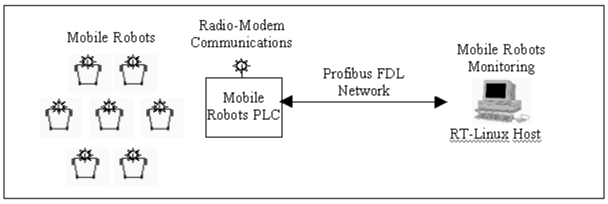

Figure 5: Simulation Scenario.

As we could see in Figure (6) we have verified feasibility obtaining an utilisation factor minor than 1 in any case using the simulation scenario of Figure (5) applying the EDF scheduling algorithm. In the first case we have two tasks: one MT and the CT; in the second case we have two MTs and the CT; in the third case we have three MTs and the CT and in the last case we have four MTs and the CT.

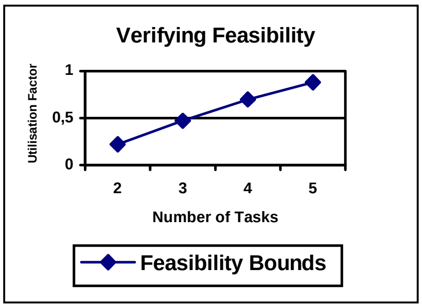

Figure 6: Feasibility Verification

CONCLUSIONS AND FURTHER WORK

Our scheduling and guidance algorithm could be easily included inside our global monitoring scheme providing an accurate state of each mobile robot. Our monitoring system is very flexible and easily scalable. It permits working with any fieldbus network (not only *Profibus* network), and it also permits the connection of any corporate network to the monitoring system.

We have empirically verified the feasibility of our scheduling and guidance algorithm through *EDF* scheduling policy ensuring in this way the predictability needed in any real-time system as our one.

The results of the above study should provide system designers with guidelines into the design of real-time scheduling and guidance applications, specially monitoring or data acquisition and routing problems, supported by the RT-Linux RTOS.

As further work, we plan to evaluate the real-time operating system *Lynx 3.1* with *RT-Linux* under the *PC* architecture, looking for solutions to the monitoring problem of industrial manufacturing comparing the advantages and drawbacks of their use.

As another future work, we plan to introduce several heuristics inside the Monte Carlo minimum path computation algorithm in order to decrement the number of CPU cycles improving in this way the schedulability of the global scheduling and guidance algorithm, and compare our method with other approaches based on minimum path computation..

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PDML – AN XML-BASED PROCESS DESCRIPTION LANGUAGE

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KEYWORDS
Microsystems, process configuration, process management, process optimization, design verification, XML, XML Schema, databases.

ABSTRACT

A new description language for describing processes in microsystem technology is developed. The Process Description Markup Language (PDML) is based on the extensible Markup Language (XML). XML provides an extensible and powerful mechanism to describe complex data. Since XML is pure text it can be read also by humans as well as computers. PDML can be used as a data format for describing process flows. PDML is the data format in the development framework PRINCE for internal and external data interchange. PRINCE provides the missing continuity in the engineering process.
Engineers in the microelectronic and microsystem industry have discovered, that there is a need to describe their manufacturing processes in a continuous way. A lot of time is wasted with "reinventing the wheel", because nobody knows that it has been done before. And even if, there are no standardized records about the different materials and parameters and their effects on the results. This paper describes a new approach for a Process Description Markup Language (PDML) using XML.

INTRODUCTION

Process management becomes a more and more important subject in industry. Meanwhile it is normal in certain areas to use tools for creating and testing processes. In the chemical industry new facilities and their process flows are modeled and tested before even the first stone is set.
But also in microelectronic and microsystem industry process management becomes a serious task. Engineers have to cope with the problem, that more and more processes have even more parameters. No one knows all the adjustments for all processes.
If we want to change that, it is necessary to describe processes, materials and resources in a standard language so that CAD tools can communicate with each other. To reach a high acceptance it is an imperative to use industry standards for description languages. XML has become this standard for data exchange. Widely spread in business and economic application it now reaches also the natural sciences.
This paper gives a brief introduction of the current problems and the requirements for a process description language. After that XML and the reasons why to use it are shortly presented. At the end of the paper an outlook of the integration of PDML in the design framework PRINCE and current and coming work is given.

CURRENT STATE OF MICROSYSTEM'S DESIGN

Nowadays development of microsystems is still a kind of pioneer's work. Unlike in microelectronics industry the process flow of many microsystems is not standardized. Commonly the design flow is dominated by "trial-and-error" methods.
Nearly each new product needs a new or adapted process flow, which has to be newly developed. To evaluate single process steps and to assess their implications on other process steps, materials etc. many experiments and test series have to be performed. Often the same experiment is made more than once by different people, because a specific process step can appear in different process flows. Those procedures require valuable resources like time and manpower. Prime reasons for this unsatisfactory status quo are the missing knowledge and accordingly the insufficient knowledge exchange also within same departments caused by the lack of adequate tools to archive the results.
CAD tools often insufficiently support the specification of new process flows since standard office tools like word processing, spread sheets, drawing software and presentation tools are in use. These tools are stand-alone solutions and not adequate to archive complex process descriptions. Most important they provide no common interface to database systems. In this sense the tools are less proper for knowledge exchange and for automatic knowledge exchange with tool support.
On the other hand the large design frameworks for microelectronics are used to layout the lithographic masks of the process steps. To design the masks layout- and design-rules have to be taken into account. Since the automatic transfer of technology data from one tool to another is not supported, these rules have to be manually extracted and transferred.
To make things even worse the design of a new product often requires many iterations of altering the process flow and the layout. The cycle model [Figure 1] - described in detail in [Hahn 1999] – brought this approach to a formal base. But up to now there is no software available to support the whole cycle. Only makeshifts are used without a standard proceeding. According to the cycle model a new language called LIDO-PDL [Hahn 1998] was developed as a unified approach for describing processes. A concept of how to describe lithography-based processes was introduced with this work.

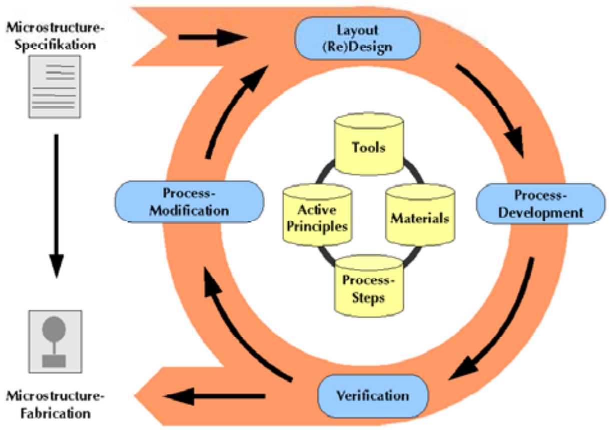

Figure 1: Cycle model (Brück/Hahn)

With the increasing interests in process design and verification in industry new requirements raise up. New cognitions have to be implemented. The need for a new and more powerful description formalism has emerged.

REQUIREMENTS TO A PROCESS DESCRIPTION LANGUAGE

For the description of the process flows a new language has to be developed. The language has to describe not only the process flow but must also reflect the impact of the specific design and layout of the microsystem. Due to the complexity of microsystems there is a need for extensibility of the language. It should be easy to adopt new features to the new language. So the architecture has to be open.
The language itself must be portable and independent from any software or computing platform. This guarantees that data can be transferred without any conversion problems and implies a very simple data format, which can be read by the most people and computers.
The structure is designed to be self describing and easy to read and write. Taking into account the data which has to be modeled an object oriented design is advised. There are many groups or classes of related process steps. For example the process steps can be grouped by application. These groups or classes are assigned by specific parameters and data. The idea is to inherit similar parameters from a kind of mother-process and to adapt and to use them in the current process. For example all deposition process steps like CVD, LPCVD, APCVD and PECVD inherit from one abstract "mother" process step. The inherited features will be adopted if necessary.
The ability to substitute is also postulated. For example a process flow requires any kind of deposition. The engineer does not need to name a specific deposition process step. He can flexibly substitute the abstract deposition by any other step from the deposition group [Wagener 2001].

XML - PDML

The postulated features of the description language listed above can be realized by using the eXtensible Markup Language (XML).

XML is a flexible and powerful markup language. It provides a simple but standard way to describe and delimit data. Since XML is "only" text it can be shared and used on any computing platform and with any programming language. XML was recommended by the World Wide Web Consortium (W3C) in 1998 and forms a real subset of SGML.

Listing 1: PDML-Example

```
<?xml version="1.0"?>
<pdml:process>
[…]
  <pdml:processStep>
    <name>oxidation</name>
    <version>1.0</version>
[…]
    <pdml:processParameter>
      <name>time</name>
      <value unit="sec">300</value>
[…]
    </pdml:processParameter>
    <pdml:processParameter>
      <name>temperature</name>
[…]
    </pdml:processParameter>
  </pdml:processStep>
</pdml:process>
```

Commonly XML is used to format and describe text in web applications for example. But it can also be utilized to qualify complex scientific relations. Some prominent representatives are the Systems Biology Markup Language (SBML) and the Chemical Markup Language (CML).
One of the reasons why XML is so popular is surely its flexibility. XML serves as a meta language and provides mechanisms to build up powerful descriptions.

Listing 2: XML-Schema Example of PDML

```
<?xml version="1.0"?>
<xsd:schema […]>
<xsd:complexType name="ProcessStepType">
 <xsd:sequence>
  <xsd:element name="name" minOccurs="1"
                            maxOccurs="1">
    <xsd:simpleType>
      <xsd:restriction base="xsd:string">
      </xsd:restriction>
    </xsd:simpleType>
  </xsd:element>
  <xsd:element name="version"
             minOccurs="1" maxOccurs="1">
    <xsd:simpleType>
      <xsd:restriction base="xsd:string">
      </xsd:restriction>
    </xsd:simpleType>
  </xsd:element>
[…]
  <xsd:element name="processParameter"
       type="pdml:ProcessParamType"
       minOccurs="1" maxOccurs="unbounded">
  </xsd:element>
[…]
 </xsd:sequence>
</xsd:complexType>
</xsd:schema>
```

XML's great advantage is its self-describing nature. The information is grouped and bordered by tags. Also people who were not familiar with XML before can read the listings very easily.
In Listing 1 there is an excerpt of a description of an oxidation process step. The structure of this listing is hierarchical. The most upper tag-border is `<pdml:processStep>`. It includes any desired tags, which can be built of an own hierarchy themselves, too.
The allowed structures in Listing 1 are constrained by XML-Schema [W3C 2001]. In Listing 2 there is a part of the corresponding Schema to Listing 1. The Schema itself is also written in XML. It defines which tags may or must appear in the XML description. It also allows defining own types, extending or restricting them.
The root structure in PDML is the process. A process consists of one ore more process steps. These process steps include all information and parameters for the design and fabrication. Since XML is extensible the Schema and consequently PDML is extensible.

FUTURE WORKS

PDML is designed to accompany the engineer during the whole engineering process. Ideally PDML is used by an engineering CAD framework. Such a framework, named PRINCE, is being developed at the University of Siegen. PRINCE (PRocess management and INformation CEnter) uses PDML for internal and external data interchange. PRINCE covers the whole engineering cycle as described in the cycle model.

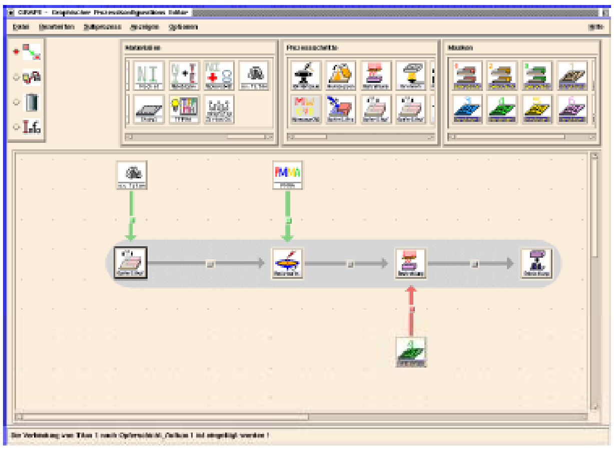

Figure 2: InterLIDO

In previous papers we described InterLIDO [Hahn 1999], a tool based on the description language LIDO-PDL. It was designed as a graphical process editor to help developers assembling the process. This will be the part of the design framework to help in "fine tuning" the processes. Additionally other editors are needed. Most of the developers do not think in "process steps". When developing new parts they think in functional layers. An Editor for drawing cross sections in combination with appropriate algorithms to particularly automate the design process will close this gap [Figure 3]. MISTIC, a CAD-System developed at the University of Michigan, provides a layer-editor and process compilation [Gogoi et. al. 1994]. Experiences with both tools, InterLIDO and MISTIC, have shown, that these detached tools support only a part of the wanted features.
Ready with the process flow masks are needed. There are well-established layout tools on the market. But they lack a function to automatically generate design and layout rules. Given the flexibility of PDML it becomes possible to extract these data from the process description for the layout tool.

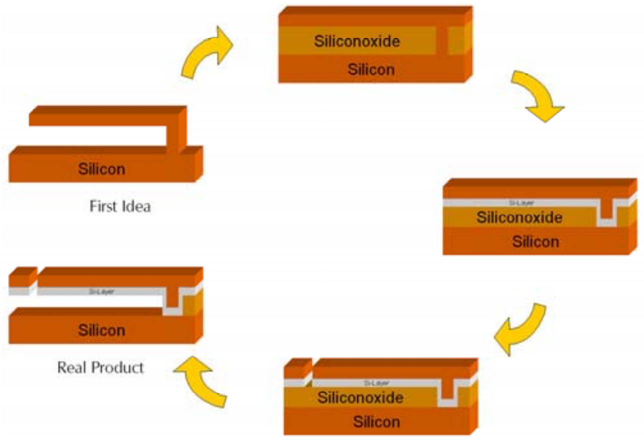

Figure 3: Product generation

In combination with a powerful data storage system (DBMS) PRINCE unites the features of InterLIDO, MISTIC and more that are not implemented in a tool yet. It can be used not only for process management but also as a knowledge base. Since all available process steps and processes are stored it provides a library. With PDML as a standard language it will become possible to exchange this knowledge with other tools.

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ENHANCING CUSTOMER SATISFACTION BY EFFICIENT INFORMATION SHARING BETWEEN OEM AND SUPPLIER

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KEYWORDS
Mass Customization, Business Processes, Product Configuration, Customer Profile

ABSTRACT

Original Equipment Manufacturers (OEM) and their suppliers are confronted with a paradigm shift from variant production to Mass Customization. Previously, market segments were identified using detailed surveys with customer reference groups. On this basis, product variants were determined anonymously before starting product development. Thus individual customer's wishes could not be considered explicitly. In contrast to variant production, mass customized products are directly configured by each customer's individual requirements and nevertheless are sold at a price comparable to standard products.

In order to economically offer such customized products, OEMs and suppliers must closely cooperate and apply appropriate solution approaches. In this article an overview of interconnected business processes between OEM and supplier is given. Starting with processes being independent from an individual customer's order, focus lies on grasping customer's requirements and profile. Consistency checks are performed by car configuration and simulation tools. The individual customer order is subsequently transferred into the OEM's and supplier's data management systems. As an example, product configuration of a Mercedes car is illustrated.

MASS CUSTOMIZATION AS NEW COMPETITION PARADIGM

The term Mass Customization combines the contrasting approaches of Mass Production and Customization. Mass Production implies cost reduction due to scale effects and gained production experience. Customization focuses on exact fulfillment of customer's requirements and results in an unique competitive position. Mass Customization therefore aims at producing products to meet individual customer's needs with mass production efficiency (Tseng, M.M., Lei, M., Su, C., 1997). Thus customized products are offered at prices comparable to standard products and continuous individual relationships are established between each customer and the manufacturer (Toffler, A., 1971, Davis, S., 1987, Pine, J.B., 1991 and 1993, Kotha, S., 1995, Oleson, J.D., 1998). The combination of cost leadership and differentiation results in a simultaneous, hybrid competitive strategy (figure 1). The competitive strategy of Mass Customization is enabled by advances in manufacturing and information technology as well as new management methods, such as Just-In-Time and Lean Production.

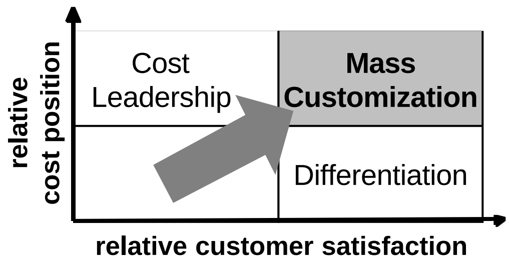

Figure 1: Competition principle of Mass Customization

INTERRELATED BUSINESS PROCESSES

In order to provide customer specific cars in a short delivery time, business processes of OEMs and suppliers must be coordinated and interrelated by intense information flows. In figure 2, an overview of main business processes including mutual interfaces is given. During research and development, suitable innovative product and production technologies are realized and new product ideas are generated. Knowledge, new product ideas and technological insights are continuously exchanged between OEM and supplier. As soon as a subsumable shared intention becomes evident, responsibility for further development is transferred from supplier's corporate development to pre-development in the corresponding supplier's division. At the car manufacturer, engineering without relation to a specific car model is initiated. During engineering – when the concept's technical feasibility is proven – the car manufacturer orders the needed components from the supplier. At this point, component specific series development starts at the supplier. Often, car specific engineering at the OEM starts shortly after. During progress of component series development and car model specific engineering, usually the initial component's configuration is detailed step by step and adapted to insights gained at the OEM's or supplier's engineering. Also,

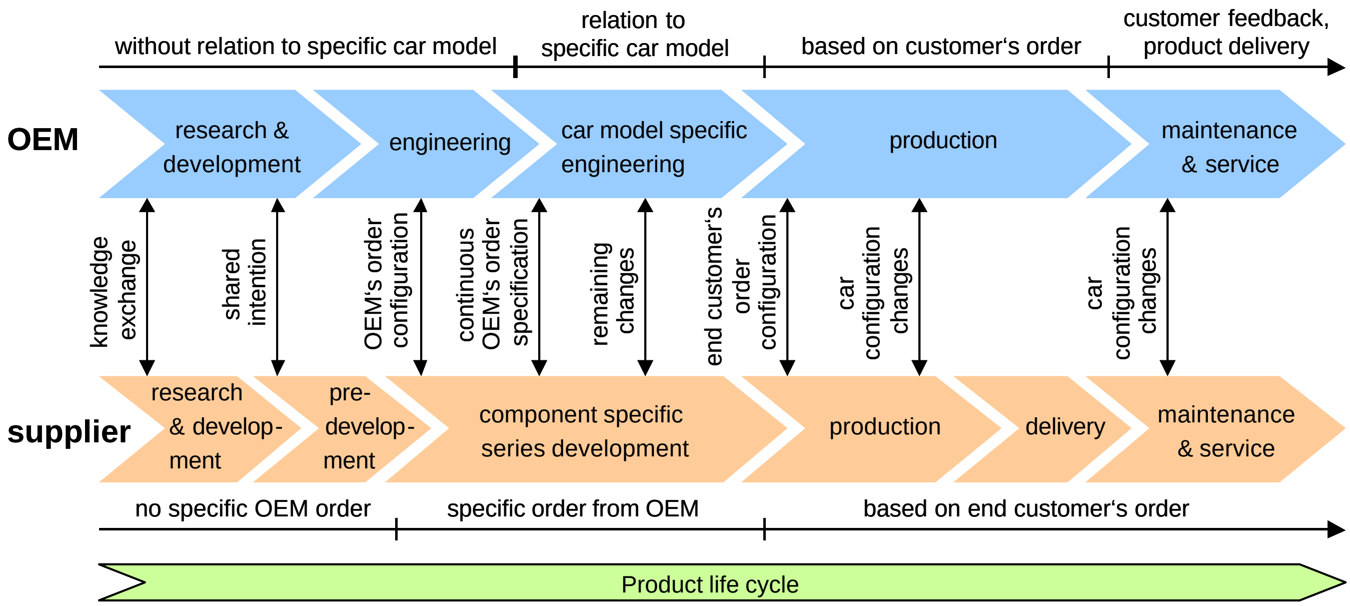

Figure 2: Business processes interrelated between OEM and supplier

remaining changes due to internal or external reasons are processed continuously. Concluding engineering, a new car model is put on the marketplace. When an end customer wants to purchase a car, his requirements are grasped and an individual car is configured by selecting suitable components and adapting components using built-in-flexibility. As far as the component provided by the supplier is concerned, the generated order configuration is transmitted from the OEM to the supplier. During car production, maintenance and service, car configuration may have to be updated due to configuration changes initiated by the end customer. Key elements of the associated business processes are car configuration and after sales services. In this contribution, car configuration process is taken up and described in detail.

CAR CONFIGURATION PROCESS

Product configuration means tailoring a product according to individual customer's wishes and needs. In order to create a customer-unique product, a close interaction with each customer is necessary. A wide-spread way of adapting a product to each customer's requirements is to let the customer select appropriate functions or components out of a group of alternatives. In addition, adaptable components are adjusted to an individual customer's specification (built-in-flexibility). First configuration contents result from technical restrictions and sales decisions determined during engineering (figure 3). In parallel to car configuration, main part of the customer's profile is generated. When the end customer's order is configured, either the whole car is determined at once (single configuration) or initial configuration is completed step by step during production, maintenance and service (configuration followed by changes). In additional cases configuration is only changed during production or during car use.

In order to enable product configuration process a knowledge data base and defined code rules are applied (figure 4). The knowledge data base contains selection alternatives within each decision step. Code rules comprise selection logic and choice restrictions. Choice restrictions result from the technical context as well as from sales department decisions. The configuration process is structured into a logical sequence of query steps. Sequence of the query dialogue can be oriented according to product structure, i.e. starting with top level and ending with bottom level of product structure (Schuh, G., Schwenk, U., 2001). In the illustrated example, exactly one choice must be taken out of the options concerning body, engine, transmission and line. In contrast, any desired number of options can be chosen out of the equipment alternatives or after sales services. Parallel to each selection decision the resulting configuration is analyzed and analysis feedback is returned to the customer. Feedback comprises e.g. technical feasibility, choice visualization, estimated price range, product description and product offer. The configuration process is brought to conclusion by generating and confirming an individual customer's order.

INPUT TOOLS

According to the wide range of possible application options, different input tools are used in order to grasp the end customer's requirements and to generate an initial customer profile. Potential customers can be inspired by car configurators offered in the internet. Following the query sequence, the car is configured interactively. After each selection step, the user receives feedback such as feasibility, choice visualization and price range. The internet tool must be easy to apply as potential customers use it on their own. The user usually stays anonymous. Therefore the generated customer profile can not be used to build up an individual customer relationship, but can be taken as a basis for

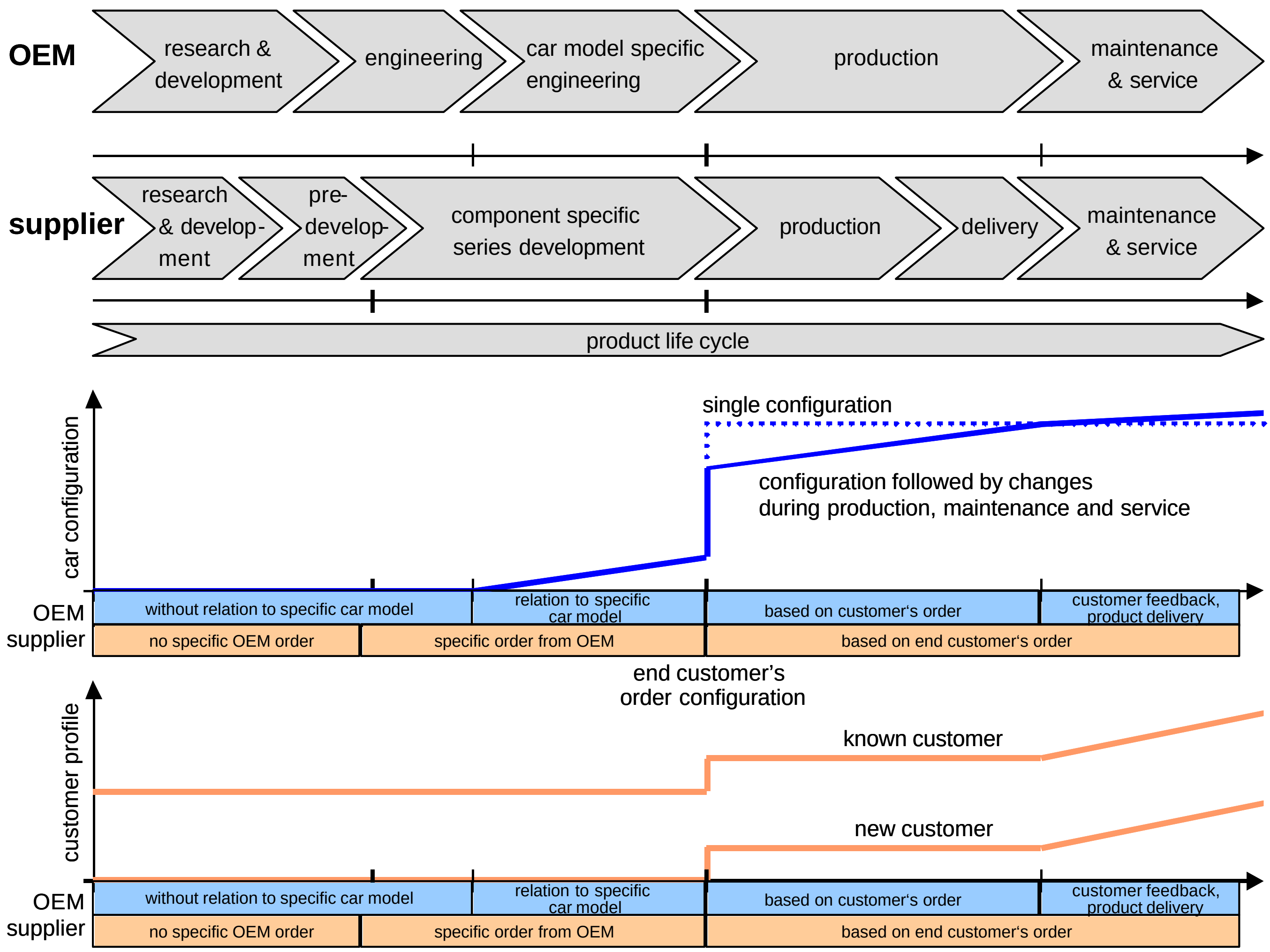

Figure 3: Information sharing between OEM and supplier

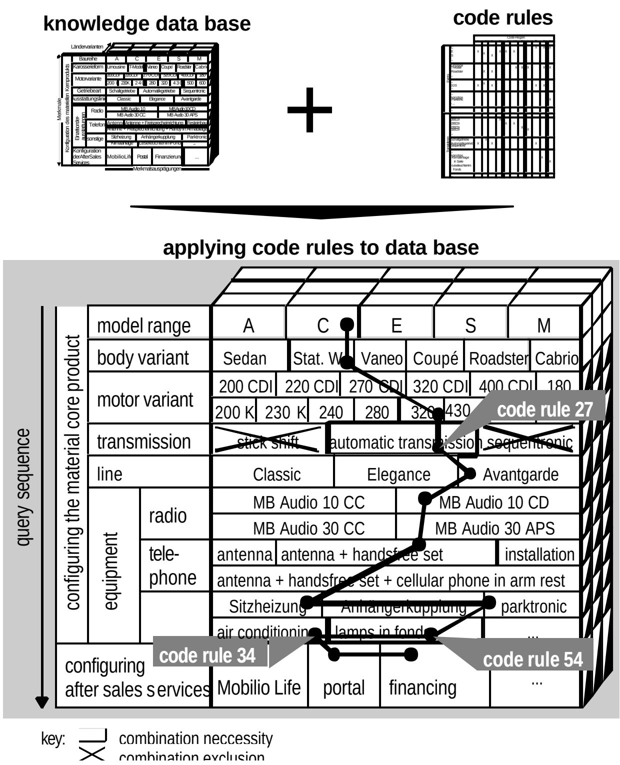

Figure 4: Configuration process of a Mercedes car

empirical market analyses. Most internet car configurators only aim at inspiring and informing potential customers. Due to legal restrictions, in most cases there are no opportunities to directly order a car via internet. Instead the customer has to order his car at a dealer. At the dealer, touch screens can be used by the customer and stationary computers are used by sales representatives. Stationary sales computers are characterized by enhanced functionality, such as online connection between showrooms and manufacturing locations and immediate calculation of car delivery date. Usually this functionality is embedded into a Computer Aided Selling System (CAS, Hildebrand, V.G., 1997).

In addition to internet and stationary input tools, mobile web pads can be used by customers as well as sales representatives within the show rooms. A web pad is a mobile display device with a touch sensitive display based on html browsers and a hand held operating system, as used in Personal Digital Assistance (PDA) devices. A potential future sales concept is illustrated in figure 5. The concept called “The vehicle that sells itself” bridges the gap between personal sales dialogue and online sales. With the help of the web pad, the customer informs himself independently about any exhibited car which he is facing. The vehicle is identified by an infrared interface and affiliated information is provided by the web pad. Using the wireless connection to the sales

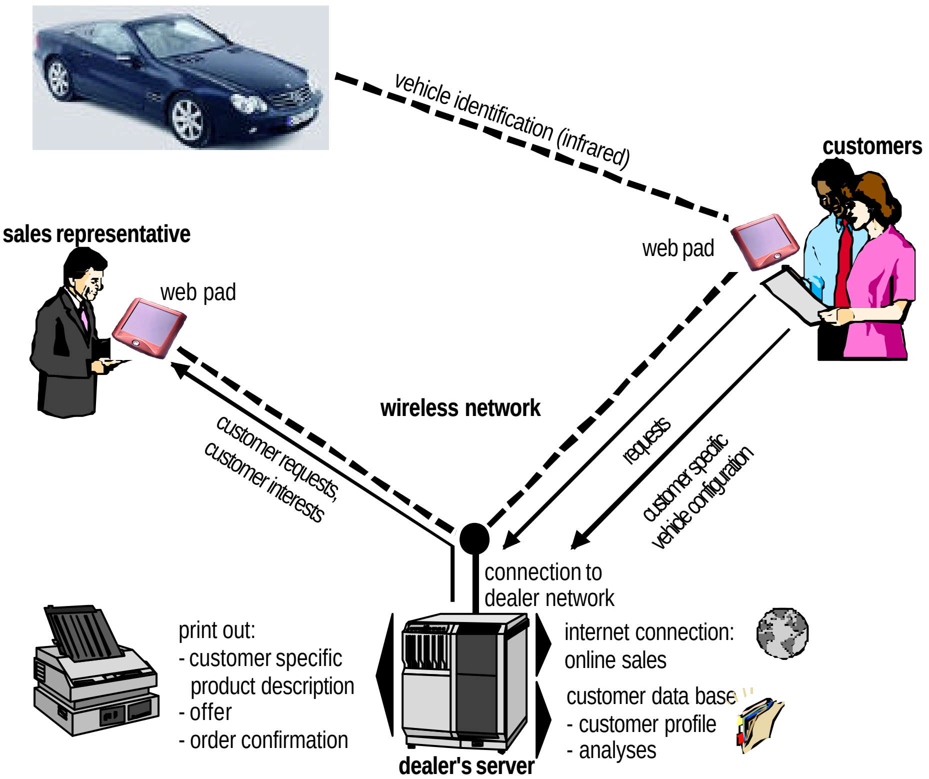

Figure 5: Potential future sales concept

server, additional information is provided and an individual vehicle can be configured by the customer. Also, the customer can call a sales representative for personal assistance. The sales representative can monitor the customer's requests and interests via web pad in order to open up the sales dialogue at the customer's points of interests. At the end of the customer's visit, the customer specific configuration including an offer is printed out. Generated customer specific data is saved for subsequent sales dialogues and analysis purposes.

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ENHANCING CUSTOMER'S LOYALTY BY PROVIDING PERSONALIZED AFTER SALES SERVICES

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KEYWORDS
Mass Customization, Customer Profile, Customer Relationship Management, After Sales Services

ABSTRACT

In addition to the previous contribution on enhancing customer satisfaction by efficient information sharing between OEM and supplier, this article focuses on personalized after sales services. Besides vehicle sales, after sales services contribute significantly to the OEM's revenue. Based on customer's profile gained in the previous order and production process, the profile is supplemented step by step during vehicle use. Providing maintenance and service processes fitting customer's unique requirements, high loyalty rates are expected. Potentials of changing software versions, e.g. of Infotainment modules as well as configuration changes, will be described. Thus affiliated business models are made accessible.

CUSTOMER RELATIONSHIP MANAGEMENT

During the first deal between end customer and car manufacturer, an initial customer's profile is generated. Applying this profile during maintenance and service develops not only a better product offering, but also a stronger relationship between customer and manufacturer (Anderson, D.M., 1998). Because long-lasting relationships with customers as well as customer's loyalty make up decisive assets of business success, a systematic Customer Relationship Management becomes a worthwhile business goal. By personalized interacting with the customer, companies can better learn the wants, needs, and preferences of each customer and can then fulfill those preferences with better tailored goods and services. This combination of Mass Customization with One-to-One-Marketing forms the basis of learning relationships which grow, deepen, and become smarter over time (Peppers, D., Rogers, M., 1993, Pine, B.J.II, Peppers, D., Rogers, M., 1995).

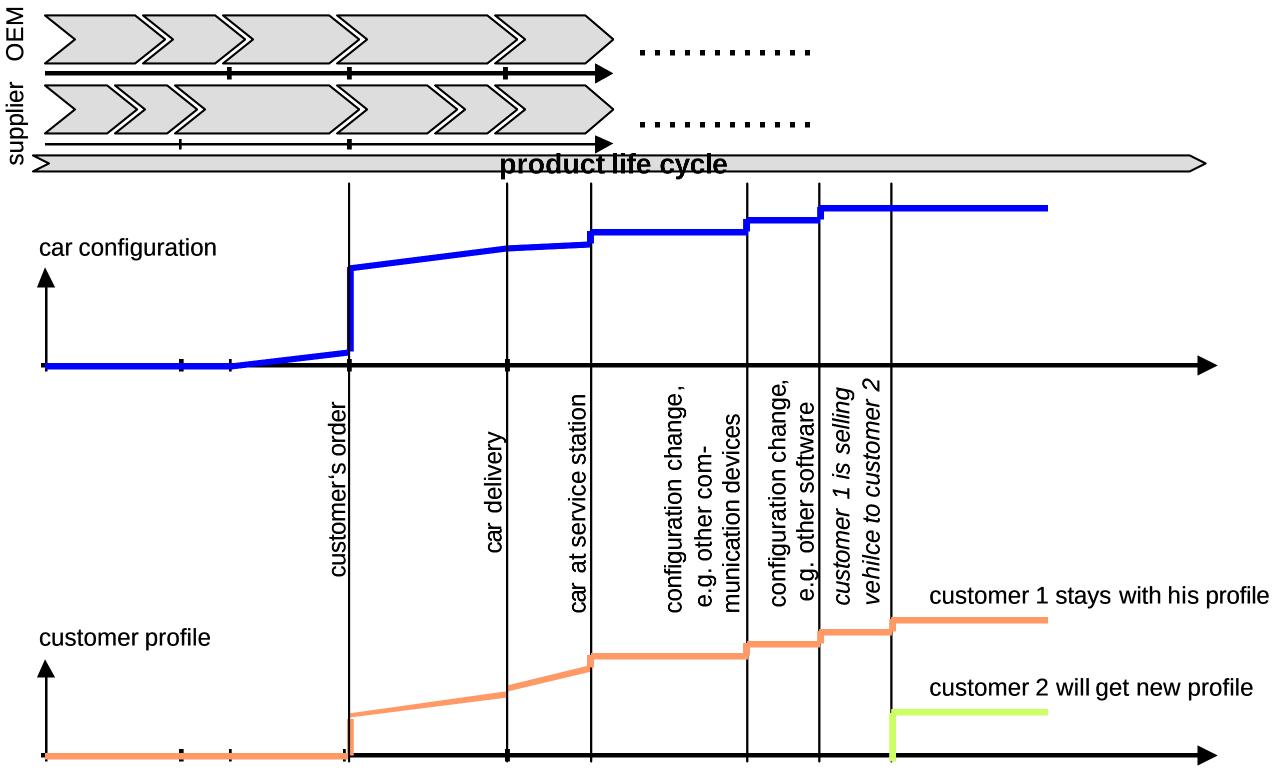

Figure 1: Applying and detailing the customer profile

AFTER SALES SERVICES

As core element of Customer Relationship Management, the customer profile is applied in each interaction between end customer and OEM and thus continuously detailed. A schematic overview of stepwise expanding the customer profile is given in figure 1.

The main initial step of creating a customer profile is taken during first order configuration. Supplementary information is gathered during car usage when the car is at the service station for maintenance and service. For example, vehicle's mileage, customer's satisfaction or customer's choice of a replacement vehicle may be included into the customer profile. Furthermore, the customer profile is expanded with each configuration change, e.g. adding a cellular phone with handsfree option into the dash board, updating Global Positioning System (GPS) or supplementing the car with a trailer coupling. When the car is sold to another end customer via dealer, data concerning car configuration is transferred to the used car customer and a new customer profile is generated for the second car customer. The first customer's profile is kept up until a new car is bought and then diversified.

The business impact of after sales services rises continuously. Therefore, the range of offered services is steadily increasing. Also, the share of non or less car specific after sales services increases. Thus, part of business success becomes independent of car sales figures. Basic types of after sales services and their relation to a specific car are shown in figure 2.

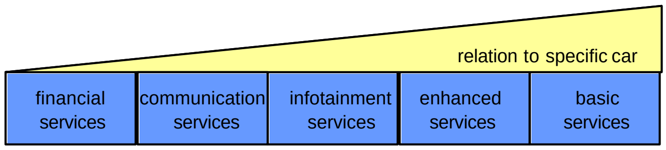

Figure 2: Types of after sales services

To provide meaningful services to the customer, the offered services must fit best to customer's specific needs and interests.

key:
X……needed input, updated and supplemented information

provided services			**customer profile**: identification data			product related data			customer's business area			customer's life style			customer's financial situation			….
			name (unique identification)	postal address	phone numbers	configuration of vehicle	product usage	customer's other vehicles	profession	branch of business	customer's main relationships	preferred hotel categories	preferred restaurant categories	vacation preferences	solvency	turnover with brand	range of salary	………
provided services	basic service	mobility services	X	X		X	X											
		warranty services	X	X		X	X											
		maintenance services	X	X		X	X									X		
	enhanced service	replacement/exchange of devices	X	X		X	X									X		
		software update	X	X		X	X									X		
		configuration change	X	X		X	X									X		
	infotainment service	news/personalized news	X	X	X		X	X		X	X	X	X	X				
		weather & road condition	X	X	X		X											
		navigation & traffic information	X	X	X		X											
	communication service	cellular phone	X	X	X				X									
		eMail & voicemail service	X	X	X													
		concierge service	X	X	X						X	X	X	X		X		
	financial service	financing	X	X		X	X	X	X	X					X	X	X	
		customer's financial transactions	X	X							X				X	X	X	
		credit card	X	X					X	X		X	X		X	X	X	
	…	………..																

Figure 3: Correlation between provided services and customer profile

In figure 3 an overview off exemplary service categories and services, matched with categories out of customer profile and corresponding single information classes is given.
Prerequisite for offering tailored services is the unique identification of the customer, first with customer's name and second with customer's postal address, possibly also with his phone numbers. Therefore the identification data are mapped with all provided services.
All the other categories of customer's profile are needed for different services. At a first step the car manufacturer, seen as service provider, is enabled to offer proper services to his customer. In the second step, customer's response is used to update and verify the existing customer profile as well as to supplement the profile.

CONCLUSIONS AND FUTURE PERSPECTIVES

In the previous contribution "Enhancing customer satisfaction by efficient information sharing between OEM and supplier" the cooperation between OEM and supplier as well as the interrelated business processes were described. In the present contribution the correlation between after sales processes and Customer Relationship Management was discussed.
It is expected that the revenue out of after sales services will increase during the next years. It is also seen that the share of services without relation to specific vehicles will increase.
To offer best fitting services to the customers and therefore to ensure a meaningful share on these upcoming business potentials, it is seen crucial to have most effective Customer Relationship Management in place and also to have highly effective interrelated business processes between OEM and supplier established, as both can serve as service provider to the customer.

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DETAILED PARAMETRIC COSTING AS AN EARLY DESIGN STAGE OPTIMIZING TOOL.

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KEYWORDS

parametric costing; CAPP; parametric modeling; cost estimating; supplier cost modeling

ABSTRACT

Cost modeling can be employed at early stages of product development, especially if one models the product parametrically. Parametric modeling allows the creation of a product structure (BOM) and process plans for each part, with a relatively small amount of parameters. The depth of detail in either the BOM or process plans is up to the user, and the more detailed, the more precise the cost model, and the more information reuse is possible is subsequent product development phases, but it costs more to build the model. After the BOM and Process Plans are built, the user can decide among several costing alternatives, for either the Manufacturing Cost or Indirect Cost, again depending on the level of depth needed. Usually, Indirect Cost modeling is used when Supplier Cost Modeling is needed, a reality that is becoming common in the industry, because of the level of transparency it allows in cost negotiations with suppliers.

INTRODUCTION

Cost of a certain product is not regarded in the early stages of development for several reasons. The design engineers shouldn't be constrained in early stages of development, some purists might say, or the lack of enough information to create a reliable cost model, others might say. Depending on how early one is at the design, both are correct. After some basic concepts about the product are laid down (does it fly or is it a car?, for instance), however, there are today computational means to evaluate cost for many products that can be expressed in terms of parameters (parametric parts).

The main problem resides then in a systematic and structured approach to build a cost model that is flexible enough to change according to design changes, and precise and integrated enough to provide the designer a reliable planned cost.

Our approach is then providing a tool that allows the designer to:

- model parametrically his product, which will result in a product structure (BOM) that has as many details as the designer views at that moment, with process plans linked to each part of that BOM, which will have the manufacturing details needed for each part.
- calculate the cost of this product (based on the product structure provided in the first step and the process plans linked to each part and on a series of cost elements used to calculate all the direct and indirect costs that the product will have)

On the following lines we will then describe in more detail what we mean by parametric modeling and by cost calculation

PARAMETRIC MODELING

Before we discuss about parametric modeling, a distinction must be made between parametric parts and parametric design. The first consists of parts that can be represented by a reasonable amount of parameters, such as the ones described through features and their attributes. Parametric design is one of several ways of creating a parametric part and consists of the creation of a product model with variational dimensions that can be connected with each other via mathematical expressions.

The term 'Parametric Modeling' is used here to mean the modeling of parametric parts, their BOM (Bill of Materials, or product structure) and the Process Plan for each part.

To better illustrate the meaning of 'Parametric Modeling', we will use a very simplified example of an hypothetical airplane, for which we will describe some parameters.

Our hypothetical plane has then two dimensional features (wingspan and body diameter) to describe its shape, and say 2 more, load capacity (in tons) and range (in kilometers) (see figure 1).

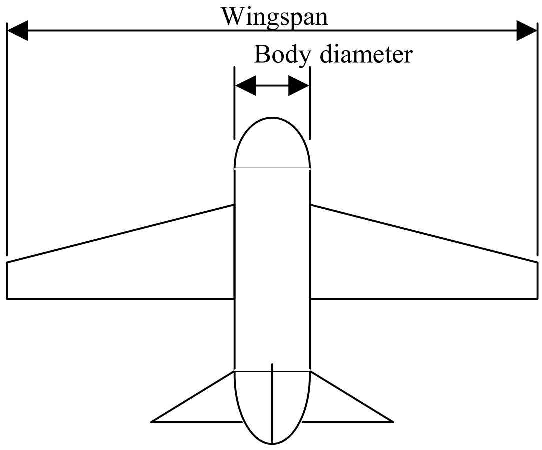

Figure 1: Simple Plane Model

Still keeping it simple, we can say that this plane's BOM (see figure 2) is made of the airplane body itself (where the cargo resides), right wing, left wing, right elevator, left elevator and rudder.

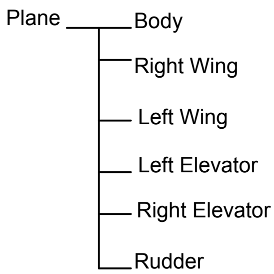

Figure 2: Simple Plane BOM

Now we can start to derive some parts and its parameters from the main product (the plane). We can calculate the wing's dimensions from sophisticated math equations, but still keeping it simple, we can say that the wing length is equal to the wingspan minus the body diameter divided by two ('wing length'= ('wingspan' – 'body diameter') /2). The Initial width and final width can be a function of several parameters, among them load capacity and range.

Inside each wing, there are a number of ribs to create rigidity (figure 3):

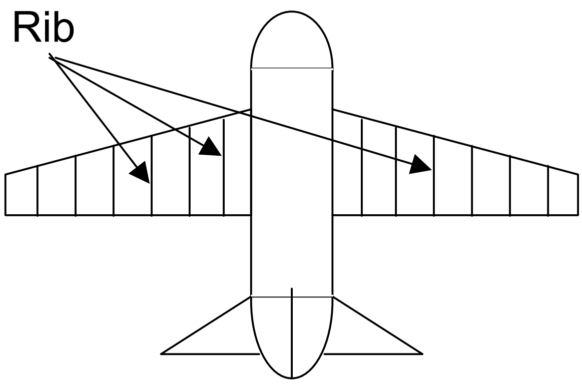

Figure 3: Ribs inside Wings

The number of ribs can now be defined as a function of the wing length, and each rib dimensions (length, width and depth) can be calculated as a function of its position in the wing and the load the wing is supposed to bear.

We can now imagine a product structure like the following (figure 4):

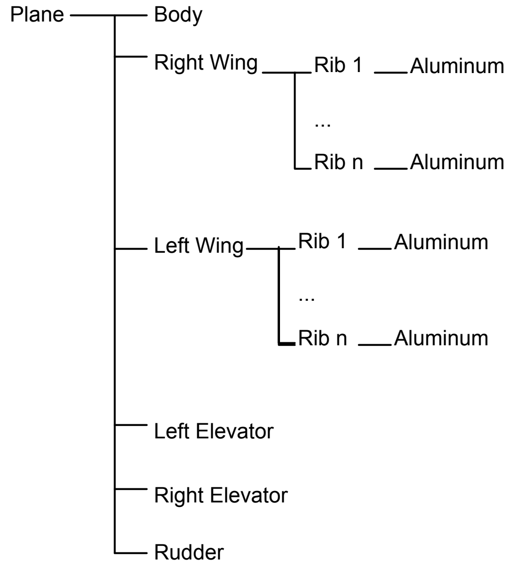

Figure 4: BOM with wing ribs

We can continue the reasoning for many plane parts, and detail as much as one wants to detail (or it is reasonable to detail at the development phase).

Parametric Process Planning

Each part can also have a process plan attached, which, through a Parametric CAPP (Computer Aided Process Planning) system, can create a process plan for the part, again based on rules the user can establish.

Rules can be created for each family of parts, so different rules will be applied to ribs and pylons, for instance.

The rule structure for this particular Parametric CAPP system allows selection of blocks of operations from a standard plan that contains all manufacturing alternatives that a family of parts has. A standard process plan for a hypothetical rib family can look like the example in figure 5 below:

Sequence	***Machine***	***Description***	***Set-up time***	***Std. Time***
10	MIL01	Mill [par1]mm x [par2]mm x [par3]mm	? min	? min
10	MIL03	Mill [par1]mm x [par2]mm x [par3]mm	? min	? min

10	MIL04	Mill [par1]mm x [par2]mm x [par3]mm	? min	? min
20	MIL05	Mill internal profile	? min	? min
20	MIL06	Mill internal profile	? min	? min
20	MIL02	Mill internal profile	? min	? min
30	LAT01	Turn external diameter [par1] x [par2], speed [par3], feed [par4]	? min	? min
30	LAT02	Turn external diameter [par1] x [par2], speed [par3], feed [par4]	? min	? min

Figure 5: Standard Process Plan for Rib Family

For each operation the user can relate a rule that decides whether the operation will be used for that part or not. The rule can be based on the following chain:

Part properties

Part Parameters

Process Plan properties

Process Plan parameters

Operation properties

Operation parameters

Besides decision rules for deciding the main operations of the process plans, rules (that follows the same chain above) can be created to calculate any operation property (standard time, set-up time, transport time, etc.) or parameter ([par1]...[par3] above are examples) (length, width, speed, feed, depth of cut, number of passes, torque, etc.).

Also, rule-based tool selection is available, based on rules to calculate tool parameters linked to a standard operation- tool family relationship. The automated process plan creation process can be seen on figure 5:

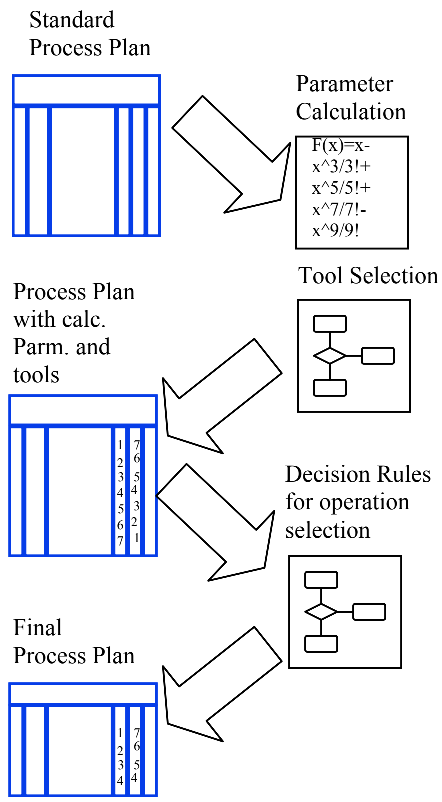

Figure 5: Automated process plan creation

Continuing on the example of figure 4, the process plan for a typical rib could be the one described in figure 6:

Sequence	***Machine***	***Description***	***Set-up time***	***Std. Time***
10	MIL01	Mill 2800mm x 90mm x 560mm	15 min	32.3 min
20	MIL02	Mill internal profile	5 min	45.8 min

Figure 6: Example of a Rib Process Plan

Of course, the length, width and depth parameters would be functions of the rib parameters, and the times can be calculated as a function of the rib material, tool used and again rib dimensions.

The quantities of each link of the product structure can be calculated as functions of part parameters (again using the rib, the material quantity can be a function of the rib's length, width and depth).

Once a parametric model is built, one can create as many variations as desired for a product, most work is reduced to changing some of the product parameters.

The level of detail shown here for the process plan is very basic, as it is usual when in the planning is in its initial phase. It can be much more detailed (and graphically rich) as the product development goes on to other phases, including tool set-up instructions, machine set-up instructions, control plan, characteristics matrix, operators instructions, etc.

COST CALCULATION

One of the basic foundations of cost calculation is knowing what the product is made of, and how it is manufactured, and this is precisely what the Parametric Model produces, once new product data is given.

Then, using a simple cost roll-up algorithm, one can calculate part of the product cost, producing a Cost Simulation (figure 7).

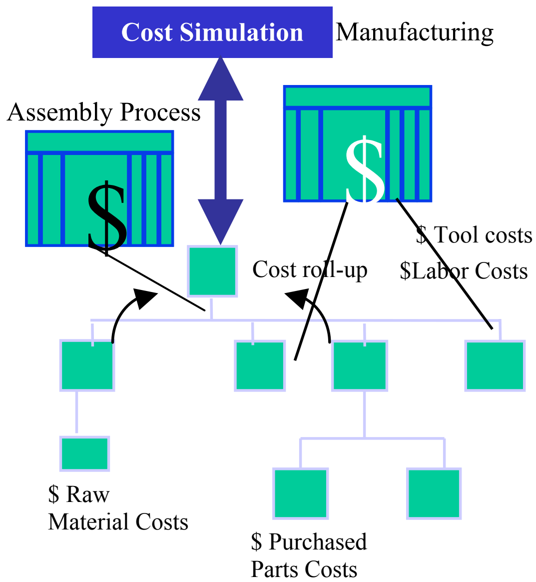

Figure 7: Cost roll-up algorithm

Costing can be much more complex than that, though. The cost modeling tool must allow the designer (in fact, the design team, that can be comprised of design experts, manufacturing experts and cost experts) to drill down to several levels of detail, depending on the cost aspects he wants to understand.

Manufacturing Cost

The design team can have several decisions to make, like make or buy ones, hence the varying degrees of depth. For some parts, cost aspects like material cost and manufacturing cost (based on set-up time and standard time plus tooling costs) are enough. For some, they are not.

Manufacturing cost is seen as in figure 8.

The Purchased Parts and Material Cost can be broken into:

- External spend
- Purchase Burden
- Cost of Money (which can be very important especially for the aerospace industry)
- Process Attrition (scrap)

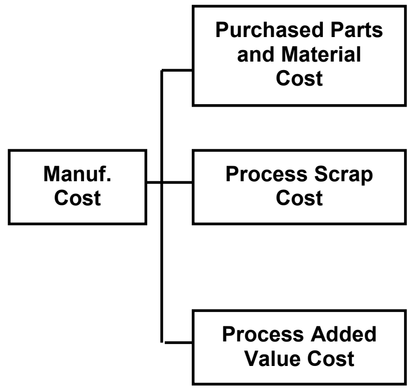

Figure 8: Manufacturing Cost Breakdown

The process scrap cost can be declared directly at the operation level.

Process value added cost can be broken into (figure 9):

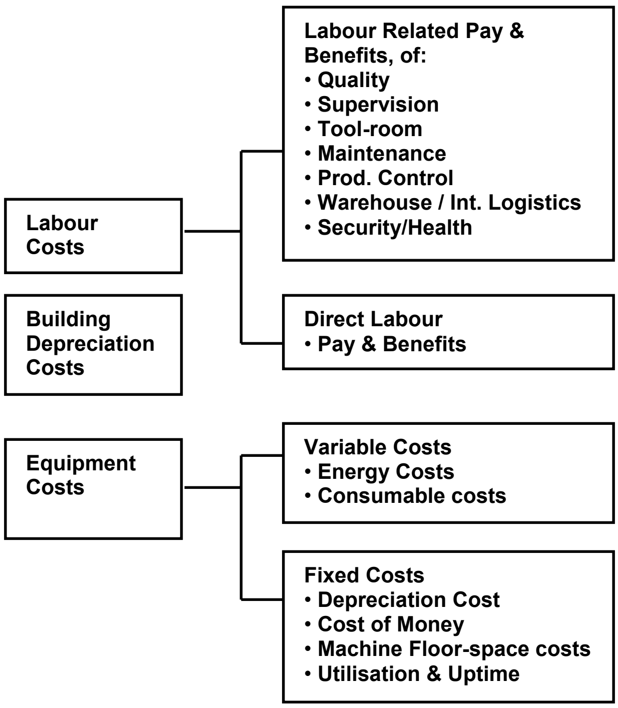

Figure 9: Process Value Added Cost Breakdown

Depending on the level of detail wanted, the user can stop at any level. For instance, for equipment costs, the user can either go detailed (input of Energy costs, Consumable (coolant, air, etc.) costs, depreciation cost, cost of money (interest rates, floor space costs, utilization and uptime factors) or simple (declare the rate for the machine in its cost center).

Indirect Cost Modeling/ Supplier Cost Modeling

Large companies are more and more outsourcing their manufacturing, focusing on essential aspects of it and on assembly. Some companies, like Volkswagen, are not even assembling some of their products (Volkswagen trucks in Resende-Brazil has all its assembly performed by a modular consortium).

Thus, a supplier cost modeling tool is also needed. This cost modeling tool allows the purchaser to better understand the supplier business and achieve better pricing agreements.

The cost model described until now lacks indirect cost modeling, which is fundamental for understanding supplier businesses, and logistics costs. Figure 10 shows a more complete model.

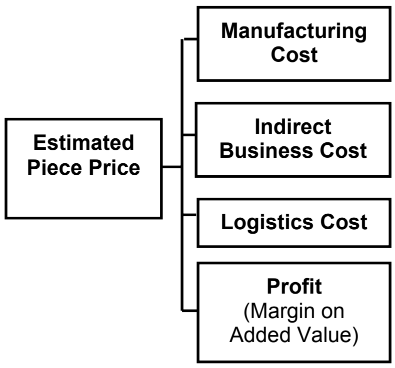

Figure 10: Estimated part price cost breakdown

Like the Manufacturing cost breakdown described above, the Indirect Business Cost model can be broken into several detail levels, which are up to the user to decide which level to use. Figure 11 gives an insight of what this breakdown is made of.

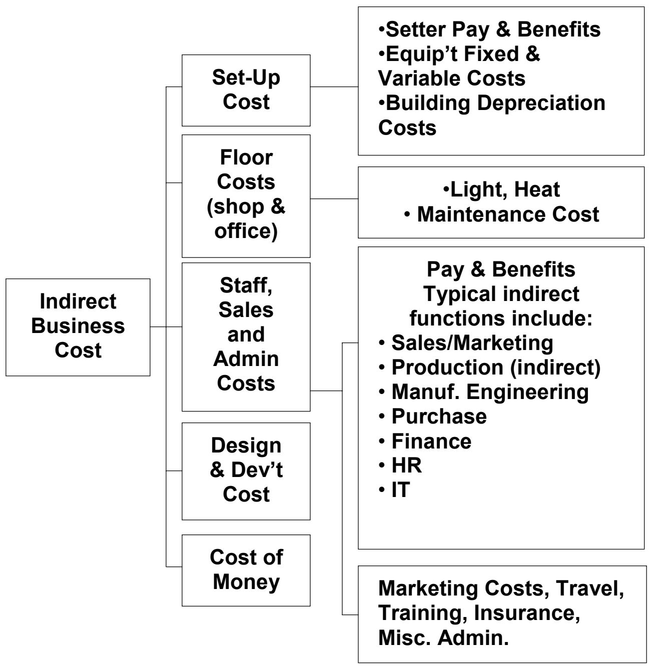

Figure 11: Indirect Cost breakdown

One of the most difficult aspects of supplier cost modeling is defining the indirect cost model structure, even more than defining profit margins. The usual workaround is to define 'virtual models' in which the supplier should fit. One can define virtual models for companies based on their size (100 employees, 200 employees, 300 employees,...) or their income (50 million, 75 million, 100 million,...), or their technology field (titanium alloy machining companies are prone to have some kind of R&D, whilst regular machining don't), or a hybrid of the above.

Another difficult aspect is agreeing on how the indirect cost should be distributed for each part supplied. This usually involves the old discussion of ABC (Activity Based Costing) costing versus TOC (Theory of Constraints) costing, and defining parameters to share costs is still very subjective. Common questions:

- how much of this director's time is taken by the business of supplying this part?;
- how much of this building floor space is taken by the business of supplying this part?
- how much design and development effort has been employed on this part?
- how much heat and lighting has been employed on this part?

There are no easy answers for the questions above, and continued application of the modeling tools will probably give the design/ cost estimation team more experience on how to answer them. There is no common agreement in the industry on how to proceed, though.

Of course, the cost of the supplier modeling increases with the depth, and there is an optimum level of detail, which is also very difficult to find. Relying on the cost estimating team experience is what is commonly found on the industry.

Also, supplier modeling is usual at the mid to end of product development, when suppliers can be developed (if they don't already exist), and is usually not a concern in the initial phases of product development.

CONCLUSIONS

The computational tools that exist nowadays allows cost estimation at early design stages, and can provide multi-functional teams invaluable decision making tools for new products. Cost estimating at this stages is also a tool that provides better background for team discussions on design decisions, enabling cost reductions not possible before.

The solution presented here cannot be applied to highly complex problems, where the number of alternatives in both BOM building and process planning is too high. Fortunately, there are many products that can be expressed in a reasonable number of parameters, that may take full advantage of the parametric cost modelling approach to create a large number of simulations and achieve cost reductions at early stages.

Supplier cost modeling is a trend that tends to be more widespread, because it allows better understanding of supplier's businesses, and more transparent negotiations on product margins.

Next steps include enhancing the rule processor interface, for easing the automated BOM and process creation, and creating more tools for comparing and analyzing the several cost simulations that are the output of the system, to give the design team more resources to make key cost decisions. Also, enhancements for the indirect cost modeling interface are expected, giving the user more automation in some tasks that are time consuming today.

BIOGRAPHY

HAROLDO KERRY was born in São Paulo, Brazil and studied mechatronic engineering (a new branch that treats the aspects of mechanical engineering interfaces with electronics, like robotics) at University of São Paulo, at their São Carlos site, and obtained his degree in 1991. His master degree was obtained in 1997, on CAPP (Computer Aided Process Planning). He worked on a small company from 1991 to 2000, developing products for the manufacturing industry, and since 2000 is head of process planning product development at T-Systems.

DECOMPOSITION OF LARGE SIMULATION SYSTEMS FOR SUPPLY CHAINS AND MANUFACTURING SYSTEMS

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Distributed Simulation, HLA, Supply Chains, Manufacturing Systems, Templates

ABSTRACT

Today, simulation systems for manufacturing are basically closed systems, which always run the complete scenario within one simulation execution machine. This brings several disadvantages, especially for the efficiency of the team work, the reusability of simulation models and the protection of the intellectual property rights (IPR). IPR are a specific issue if the system under consideration is a supply chain or a virtual enterprise, and includes several legal entities.
Based on the work within the IMS MISSION project, the authors propose mechanisms to solve these issues by structuring the simulation model into several separate federates, which run on different computers within different simulation execution machines, even from different software vendors. Specification methods and tools provide the necessary environment to model the federation on the interface level, to generate the required interface information in XML format and to start and monitor the federation at run time.
The mechanisms have been tested with a large supply chain model, which now serves as an adaptable system to configure and test supply chains very fast. Any component of this model may at any time be replaced by an application-specific detailed model. This has been proved with one application from the automotive supplier company Bosch.

1. REMARKS ON SOFTWARE

1.1. Efficiency

Software efficiency is not a well-defined term. Zehnder (1986) states that at least three categories must be regarded:

- Operation efficiency (for simulation, this can be measured by the execution time of the simulation program).
- Development efficiency, defining the amount of resources necessary to develop this simulation program. Resources include team members, computers, compilers, etc.
- Maintenance efficiency, defining the effort for program development tasks after the "first application" of the software.

The second and third category require a smooth communication within the development team. But, reducing the necessary communication supports the efficiency, too, as the less communication is necessary, the more effort may be spent to the remaining most important co-operation. Modules have been proved as a suitable concept to focus communication on well defined interfaces.

1.2. Modules

In computer science, there is a common understanding that large systems need to be split into parts ("modules"), which can be specified, developed, tested and maintained independently. Zehnder (1986) claims that the maximal size of the single parts should be chosen in a way that a single person can do this job within "some days". Following Zehnder, the usage of a module concept

- clearly structures the tasks,
- enables the co-operation within a team of programmers and
- supports a precise separation of program sections (much better than procedures).

In fact, the module concept is enforcing, what the procedure concept is proposing: the communication between the single parts through the specified interfaces, only. Erbs and Stolz propose to their students within their lecture book on Pascal (1982) the "society to combat global variables". This is documenting that just procedure definitions are only one step to efficient modularization.

1.3. Languages and Development Environments

For several reasons, which cannot be discussed here, a significant number of programming languages have been developed, which typically focus on different application areas. Suitability for a specific application as well as aspects of reusability have encouraged programmers to combine modules which have been developed using different languages. For major languages, the programming environments provide mechanisms to combine these modules, e.g. to call procedures from operating system modules (typically written in C or macro assemblers) from application programs.

2. THE CHALLENGE TO MANUFACTURING AND SCM APPLICATIONS

2.1. State of the Art in Decomposition

Today, all the important simulation systems for manufacturing provide several modeling levels. These levels include, typically:

- A building block level with application-oriented building blocks. Building blocks can be selected, combined and parameterized without programming skills. All commercial systems support this level.
- A formal subnet structure. Examples are functional networks (ARENA, eMPlant) or Petri nets (SIMPRO). This level is supported by some, but not all, commercial systems.
- A programming language level. The language can be proprietary (Simtalk for eMPlant, SIMAN for ARENA) or a standard language like C++.

Therefore, several decomposition mechanisms are available:

- Functional network nodes can be used to encapsulate programming code (procedures, methods). However, this requires the discipline not to use any global variables or other knowledge about the expected "outside world".
- Building blocks encapsulate programming code or substructures. However, it is still the programmers' responsibility to access outside information through a well defined interface, only.
- In very few systems there are further mechanisms to support decomposition. The tool eMPlant supports an object oriented class structuring mechanism, which improves the reusability of modules.

2.2. Major Drawbacks

Commercial simulation systems within the targeted application area only support modules to run within a single environment. Typically, there is no pre-compilation of modules. There are no efficient means to encapsulate, and there is still reason to support the above mentioned "society to combat global variables". Only few systems provide at least proprietary module mechanisms (e.g. AutoMod, which has its application focus on transport systems).

Furthermore, mostly there is no real difference between "source code" and "object code". While for regular programming, intellectual property rights (IPR) may be (at least partially) protected by providing source code, only, there is no adequate mechanism for simulation systems in the manufacturing area.

Regular programming environments combine modules with one standardized mechanism, which operates independently of the calling level and, mostly, independently of the module's source language. This is difficult, if simulation systems run all modules together, within one execution environment and specified just as one large model. New terms are needed to specify this integration, and there are no standards supporting this specification.

As a further consequence of this single execution environment, there are few methods to reuse models which have been developed using a different environment. There are some exceptions for proprietary "system families", but they support mutual communication between some tools of the same software manufacturer, only.

Summarizing, we state that for commercial simulation systems in the manufacturing application field:

- There is no efficient module concept (efficient for development and maintenance).
- There is no means for protecting IPR regarding the models or the respective real-world systems.
- There is no efficient modeling methodology to specify the complete system.
- Reusability is limited to modules of the same "system family".

2.3. Solution Approach

In the year 1998, already, the author has proposed to generate a mechanism of open simulation modules (Rabe 1998). This mechanism was further specified, showing up the requirements (Rabe 1999):

- distributing simulation models among several partial simulation systems ("federates").
- specifying partial simulation systems for re-use.
- providing an environment for federate co-operation.
- providing mechanisms and tools to specify the co-operation on application level.

From 1998 to 2001, Fraunhofer IPK headed the European module of the MISSION project ("Modelling and Simulation Environments for Design, Planning and Operation of Globally Distributed Enterprises"), which was conducted in the IMS framework as IMS 97001 together with a Japanese and a U.S. consortium. The project has developed methods and software to fulfill these requirements.

3. THE MISSION PROJECT

3.1. Introduction

The general goal of MISSION is the support of the Manufacturing System Engineering (MSE) process by integrating the tools, which could be employed in various aspects of the process. However, in order to enhance and accelerate the process, they must particularly refer to both the usage of simulation, and the integration of simulation tools with other software tools. The architecture therefore incorporates both the MSE and the distributed simulation of the manufacturing processes.

The MISSION demonstrator shows the modeling and simulation of a supply chain between different independent companies. Each company has its own simulation model. The details of these models are hidden from the other companies. The modelling and simulation is supported by:

- a manufacturing process design agent (MPDA).
- a supply chain agent (SCA).
- different commercial simulators (Arena, Taylor ED).

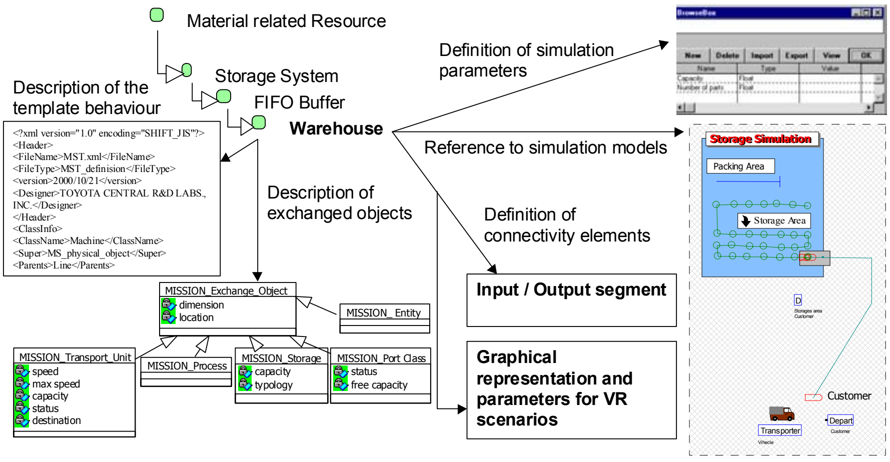

Figure 1: Elements of an Application Template

logistics system by a re-usable template, and store it within a library for later use (Mertins et al. 2000).
Additionally, manufacturing systems are often similar in various aspects with respect to the supply chains. Therefore, structuring the templates in an object oriented class structure saves modeling effort and at the same time supports additional transparency as well as some standardization.
Within the MISSION architecture, supply chains can be tested applying simulation, which requires simulation models, too. In total, six major groups of information form the MISSION templates (fig. 1):

For this paper, the focus is set to the mechanisms to specify the simulation environment. Furthermore, a focus is set to supply chains as application field.

3.2. Methods and Standards Applied

Fraunhofer IPK was among the first exploiting the High Level Architecture (HLA) for distributed simulation (Mertins et al. 1998). The HLA (Kuhl et al., 1999) satisfies many requirements for distributed simulations (Schulze et al., 1999), e.g. time synchronisation, communication between independent simulation models etc. (IEEE P1516.1/D5). Therefore, the HLA was selected as a base for the MISSION architecture.
Within military applications of the HLA, for each new model a new simulator will be programmed, typically. Therefore, a flexible interface for simulation models is not required for military applications. This is completely different within civil domains, where the total effort spent to one simulation study is extremely low, compared to defence applications. The dependency of the interface description from the specific simulation model is a critical disadvantage for regular civil applications of HLA. Within MISSION an approach has been established that allows flexible configuration of interfaces within a simulation scenario. Therefore, not the interface implementation, but the interface configuration needs to be done for each case (Rabe et al. 2001). XML is used for interchanging the configuration between the specification modules and the executing simulation tools. However, XML is still not a very comfortable means for a manufacturing engineer, and further supporting mechanisms are necessary.

3.3. Template Library

1.1.1. General Structure

When setting up a supply chain, elements of this chain have to be selected and arranged in order to achieve both an effective material flow and a smooth organization. Furthermore, the interfaces regarding material and order flow need to be specified. If enterprises or parts of them are integrated in multiple supply chains, the specification work can be significantly reduced by describing the manufacturing or

- **description of the template behaviour**
  This specification can be described in a natural language or in a formal language like XML.
- **referred simulation models**
  One or more simulation models can be referred which satisfy the template specification. The simulation model has to be created within a simulator, which has an interface to the MISSION Modelling Platform (MMP). Simulation models are not stored within the template library, but only referenced.
- **parameter descriptions**
  Each application template has a set of attributes. A subset of these attributes can be directly linked to simulation parameters. Each simulation parameter requires a link to an attribute but not each attribute does necessarily link to a simulation parameter.
- **description of exchanged objects**
  Exchanged objects are those objects which are necessary to define a communication with other templates. They describe the interface to the supply chain.
- **visualisation of the template**
  Each application template needs one or more possible representations within graphical views or animations. These representations are used for static or dynamic visualisation of the supply chain.
- **definition of connectivity elements**
  A specific type of exchanged objects describes the direct ("physical") connections between the templates. E.g., if a container of finished goods leaves a factory and enters a railway system, it is of utmost importance to know at which station this railway system is entered. Furthermore, the container might have to leave the factory at different locations depending if it will be fetched by railway or by a truck. Therefore, the suitable input and output segments need to be connected before an evaluation can be done.

The template library content is not fixed. The user can add classes and attributes at any point of time to fulfil the project requirements for a specific supply chain.

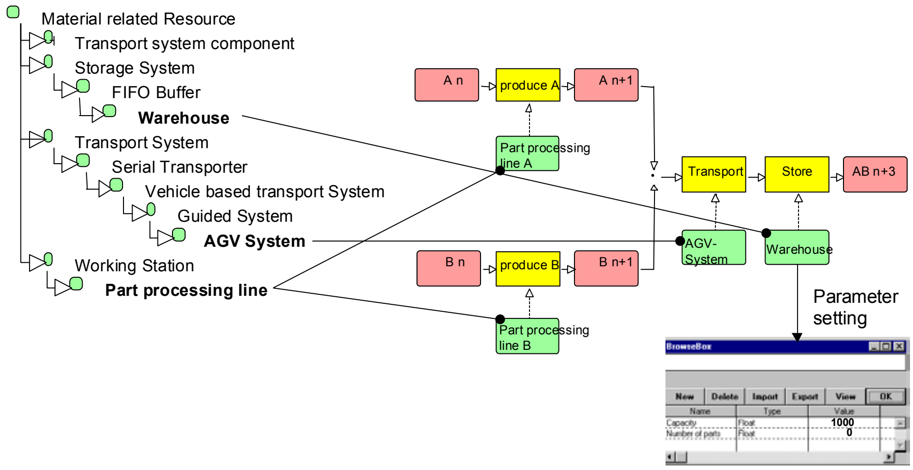

Figure 2: Process Model and Template Library

1.1.2. Exchanged Objects

For the simulation model, objects have to be specified, which are necessary for the communication within the distributed simulation environment. These objects are called Exchange Objects, and they have to be described for each template. The hierarchical class structure of the Template Library can be used to simplify this task.

Furthermore, attention to the input and output segments (connectivity elements) as well as the input and output objects is necessary. An output segment of a processing line could be the output buffer. Within a simulation scenario this output segment will be associated with an input segment of an other simulation model, e.g. a transport system. The objects which pass those segments have to be described, also.

1.1.3. Process Modelling

The manufacturing system, which is established by the supply chain, has to be planned and modeled before evaluation is possible. This is done within the Manufacturing System Engineering (MSE) process, and the result is the process model of the Manufacturing System (MS) (Rabe et al. 2001).

This MSE task is done in two steps (fig. 2). First, the process itself is modeled (produce, transport, store and connections). This process describes the necessary steps for production and logistics, but it does not define the systems implementing these steps. Then, the template library (class structure is given left in fig. 2) is searched for suitable production and logistics systems, and those resources are added to the model, connecting from the bottom to the respective process steps. In the same step, parameters are set for the single templates. For example, if a specific warehouse is selected as part of the chain, it should be specified how much space for pallets should be reserved there for this specific supply chain. This information is important, as the single systems might be part of multiple supply chains. Furthermore, these parameters are absolutely important for the evaluation of the supply chain, regarding cost as well as the dynamic behavior.

1.1.4. Dynamic Evaluation

Evaluation is done by simulation. However, there is no super-model describing the supply chain as one large simulation model. In contrary, models of the chain elements are communicating in a way, which is rather similar to their communication in reality. As a consequence, the interface descriptions generated by the MISSION process description can be directly used as specification of the supply chain interfaces.

Figure 3 shows a simple example for this type of supply chain simulation. There are three simulation models (each represented by a template in the process model), which represent the production and one representing a common transport system. These models are connected by the HLA Run Time Interface (RTI). Within the HLA terminology, the single models are called federates, and the whole system is called a federation. Further federates perform auxiliary functions, like visualization of the system in total or monitoring the results.

The MISSION consortium has developed a software package (GLUE 4D™), which includes all the necessary interfacing components as well as special sets of building blocks for specific commercial simulation

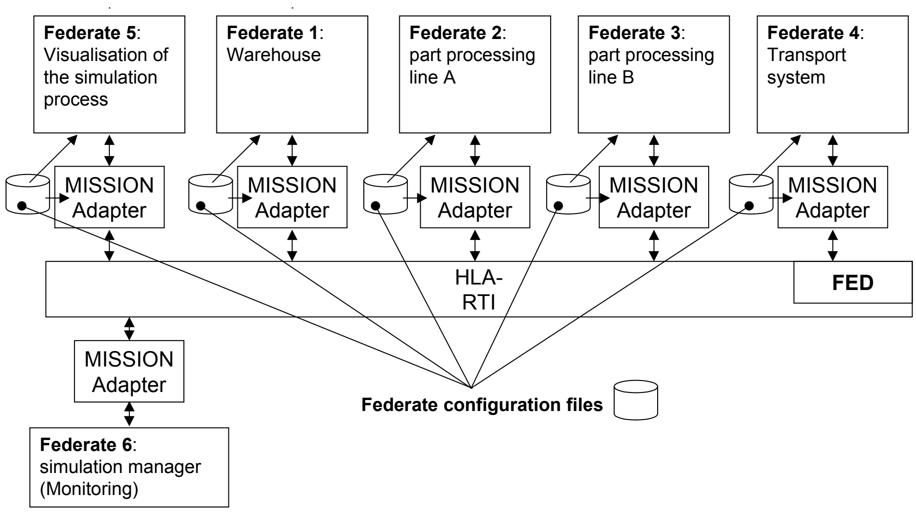

Figure 3: Execution of a Simulation Scenario

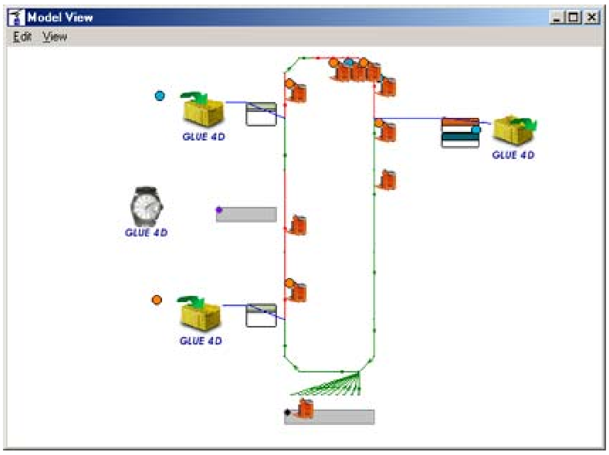

Figure 4: Taylor Model with GLUE 4D™ Interface Elements

systems (Taylor and ARENA available, will be extended). Using these building blocks, engineers can model the interface of the simulation model just in the same way they are used to model the manufacturing system itself (fig. 4).
This approach requires that the interface between the commercial simulation system and the HLA-RTI is somehow "self-configuring". This is done by separating all model-specific information from the interface code, and storing it in a separate XML file, the *Federate Configuration File*. All information which is contained in this file has already been specified by the engineer within the template library or the process model before, as described above. Therefore, it was possible to automate the generation of these files.
This automation is done by the Simulation Manager. This tools generates the Federate Execution Data (FED) file, which is required by the HLA-RTI, too. For generating the FC files, the Simulation Manager uses the process model (including the parameters of the single templates), the Template Library and the information about the input and output segments (fig. 5).

Further details about the the interface and the underlying mechanisms as well as about the FCF are reported by Rabe and Jäkel (2001). Further information about the technical implementation is given by Rabe and Gurtubai (2001).

4. SUPPLY CHAIN APPLICATION

The MISSION methods and software have been applied within a demonstration scenario, the "MISSION Enterprise" (fig. 6). This enterprise is world-wide distributed. It has a main assembly facility in which electric motors are assembled. The necessary components –housing, rotor, stator, control cards and bearings- are supplied by specialized Manufacturing Shops, placed in Spain, Germany, Japan and U.S.A. Specific focus has been set on the realistic representation of the order flow. Research conducted at the U.S. National Institute of Standards and Technology (NIST) in the framework of the IMS MISSION project (Lee and Umeda 2001) has been the used for the Exchange Objects representing the order flow in this demonstrator.
The Assembly Factory controls the production of the manufacturing shops depending on retailer demands. Therefore, any problem in any of the manufacturing shops could affect single part delivery times.
The Manufacturing Shops produce components depending on the received orders in behalf of the downstream customer (Assembly and Warehouse). After completing the production, the Manufacturing Shop ships the components to the Assembly and Warehouse simulation model.
Depending on orders from the Trading simulation model the Assembly and Warehouse produces finished goods and sends them back to the Trading model. In order to fulfill this task it generates orders for buying components from the Manufacturing Shops. The internal component and processing lists of the demonstration simulation model support up to 10 different (component) product types from up to 4 different suppliers. These components can be assembled in various variants to a maximum of 10 final product types.

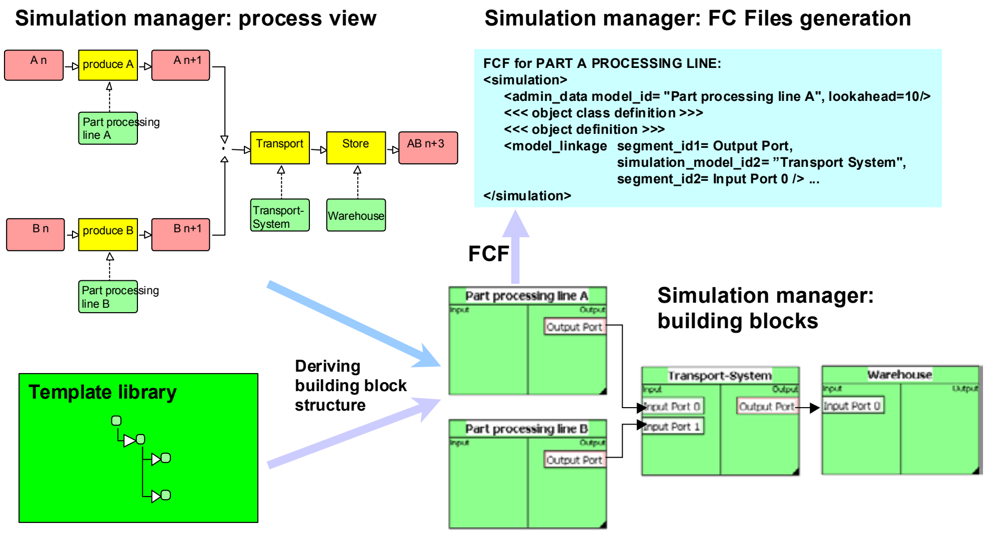

Figure 5: Generation of the Federate Configuration Files (FCF)

Figure 6: MISSION Supply Chain Example

Additionally, the Assembly and Warehouse model simulates a transportation network and a warehouse. The demonstration model supports two different distribution pathes: (1) direct distribution (the end products are sent directly to the customer) and (2) distribution via the warehouse. The kind of distribution selected depends on the kind of final products.

The Trading simulation contains different modules, too. One module simulates a distributor, another one the retailer and the third and fourth module simulate the transportation. The retailer contains a customer simulation which orders products. The retailer sells the ordered products and sends them from his internal storage to the customer. Depending on the storage level the retailer creates orders for the Distributor or for Assembly and Warehouse. The upstream supplier (and receiver of the order) depends on the distribution path. The distributor operates applying the same principles.

The statistical monitoring is an additional module within the demonstrator. This module does not simulate anything. It collects and calculates statistical data generated by the other modules. For this purpose, it uses on the one hand statistical attributes of the Exchange Object "MISSION_product" (Total_cycle_time, Total_processing_time etc.). The statistical monitoring collects and counts all incoming product entities and calculates the minimal, maximal and average values of the statistical attributes. On the other hand, simulation models can sent freely definable "MISSION-statistical-data" Exchange Objects to the statistical monitoring federate, to be avaluated there.

5. CONCLUSIONS

The approach described has proved to work with large applications, including real-world simulation models. Modeling is very efficient, and can be performed without significant additional skills compared to an engineer applying simulation today. The major advantages achieved are:

- IPR protection, as models can be run on any server with specific access rights. Only the template has to be published.
- Reusability, even when changing simulation tools, as the single federates can be implemented by any system with a suitable interface.
- No need to agree on common simulation tools within the supply chain members, for the same reason.
- Clear and structured teamwork on large simulation models, as the single parts can be developed, tested and maintained separately.
- For large models, performance improvement is achieved by distributing computer power together with the models.

The major application available now is for supply chains. However, the specification has been done for any kind of manufacturing system, and tests have been performed with a common Japanese-European example during the development work. Therefore, the mechanisms can be used for any large manufacturing simulation model, in order to improve the reliability and efficiency of the work.

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AUTHOR BIOGRAPHY

MARKUS RABE, born in 1961, studied physics at the University of Konstanz. Since 1986 he is with IPK Berlin. His main interests are factory planning, business process engineering and simulation. Actually he is head of the department Enterprise and Plant Engineering and responsible for the Berlin Demonstration Centre for Simulation in Production and Logistics. He is active in the German Simulation Society ASIM, has been member in several conference programme committees and has been chair of the ASIM conference „Simulation in Production and Logistics“ in 1998 and 2000. Markus Rabe is active member of the German Engineers’ Association VDI.

A BUSINESS PROCESS MODELLING ENVIRONMENT FOR DESCRIBING DYNAMIC PROCESSES

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KEYWORDS

Dynamic Process Modelling, Petri-nets, Case Study.

ABSTRACT

In order to survive in the competitive business environment introduced by the technological burst of the last decade, most organisations automated their business activities. The efficient automation of business activities leads to improving their performance and enabling enterprise-wide monitoring and coordination. Business process (BP) modelling is an effective tool towards analysing the behaviour of business activities and facilitating their accurate and complete representation in an information system. Four types of business processes are usually studied in the literature: production, administrative, ad-hoc and collaborative. Administrative and production BPs refer to bureaucratic procedures that include well-defined steps and can be easily described by conventional modelling tools. Ad-hoc and collaborative processes deal with unique or loosely defined conditions and are dynamic in nature. Thus, they are not easily modelled.

In this paper, we present a BP modelling environment for efficiently describing dynamic processes. BP modelling is based on extensions of the Modified Petri-Net (MPN) model and enables the description of activities in multiple levels of abstraction. The environment build to support BP modelling is based upon Lotus Domino/Notes groupware product. In order to depict MPN functionality, the experience obtained from its deployment for modelling dynamic banking activities is also presented.

1. INTRODUCTION

Business process modelling provides means for describing process-oriented systems and decomposing them into manageable parts. Business processes (BPs) are collections of activities with a common objective, such as fulfilling a business contract or satisfying a customer need. Business process definition (i.e. a description of a BP at a high conceptual level necessary for process understanding, evaluation and redesign) requires a well-defined *model*, that provides a set of concepts appropriate to describe BPs [Zelm et al, 1995]. The model should be rich enough and enable process validation (e.g. by simulation or static analysis) to decide whether the process definition accurately represents the system under study. BP modelling is a significant tool for re-engineering organisational procedures and it is usually followed by BP automation, aiming at improving business process performance and enabling organisation-wide monitoring and coordination. An automated BP is referred to as a *workflow*, while a *Workflow Management System (WMS)* is the software used for its coordination and control [Mohan et al, 2000]. WMSs also provide a set of interfaces to users and applications involved in the workflow progress. For efficient workflow development, one should start with defining and understanding business processes (BP modelling), before specifying and implementing the corresponding workflow applications (BP automation). Provision of generic and flexible modelling methods is thus required both at BP modelling and BP automation levels.

Several methods have been suggested for BP modelling, most of which are based on textual programmable languages or graphical notations, such as dataflow diagrams, state transition diagrams, petri-nets and related notations. Combination of different BP modelling methods has also been examined to give new, enhanced approaches [Abeysinghe and Phalp, 1996].

Four types of business processes are usually studied in the literature [Alonso and Mohan, 1997]. These are: production, administrative, ad-hoc and collaborative. Administrative and production BPs refer to bureaucratic procedures that include well-defined steps and are controlled by a set of well-known rules. Such processes can be easily described by conventional modelling tools and are usually automated using a WMS [Hollingsworth, 1995].

Ad-hoc (dynamic) processes are similar to administrative processes, except for the fact that they deal with unique or loosely defined conditions, which are not easily modelled. Collaborative processes are characterised by the number of participants involved and the synchronisation needed, and are handled more effectively using groupware technology.

In this paper, we present a BP modelling environment for efficiently describing dynamic processes. BP modelling is based on extensions of the Modified Petri-Net (MPN) model [Tsalgatidou et al, 1996] and enables the description of activities in multiple levels of abstraction. The software environment build to support the BP modelling is based upon Lotus Domino/Notes groupware product [Lotus Co, 2000]. Notes database is used to implement MPN repositories. In order to depict MPN functionality, the experience obtained from its deployment for modelling dynamic banking activities is also presented.

The rest of the paper is organised as follows: In section 2 an overview of BP modelling approaches is presented. Section 3 provides an analytical description of the extended MPN model and the graphical environment built to support it. In section 4, we discuss our experience using it to represented dynamic banking activities. Conclusions reside in Section 5.

2. BUSINESS PROCESS MODELLING

The BP model must fulfil the following requirements:

- Enable the accurate description of dynamic processes
- Facilitate the evaluation of BPs through simulation
- Support the direct mapping of entities into the workflow environment to minimise implementation cost (optional).

Numerous modelling methodologies, such as IDEF0 [Marca and McGowan, 1993] and RADs [Ould, 1992], provide the means to understand the behaviour of static systems [Starke, 1994]. Production and administrative activities usually fall in this category. BP modelling is also used to tackle the problem of changing or evolving systems [Phalp, 1998]. Ad-hoc processes can be viewed as an evolving system. The business model used to depict such systems should be flexible enough to facilitate accurate description of business activities. BP modelling approaches based on extending Petri-net functionality [Murata, 1989] can provide better solutions for this kind of problem [Oberweis, 1996], [Tsalgatidou et al, 1996], since they focus on depicting the relationship between activities and resources rather than the relationship between activities. A Petri-net consists of *places* and *transitions* between them. *Arcs* are used to denote relations between places and transitions. A transition is performed whenever all its input places are filled with *tokens*. When a transition is completed, output places are filled with tokens. Transitions depict processes and their components as activities and tasks, respectively, while places represent resources [Jensen, 1992]. An overview of modelling approaches based on Petri-nets is included in [Tsalgatidou, 1996]. BP models based on Petri-Nets have also the advantage that they can be easily simulated using discrete event simulation [Rajala and Savolainen, 1996]. The modelling formalism adopted is the Multi-level Modified Petri-net (MPN) [Tsalgatidou et al, 1996], which is an extension of Coloured Petri-nets [Jensen, 1992]. The formal and executable nature of MPN models enables the employment of simulation techniques for validation purposes.

3.DYNAMIC BP MODELLING APPROACH

MPN is used for modelling BPs at various levels of abstraction. Transition decomposition depicts the decomposition of a BP to its activities, sub-activities and tasks and demonstrates the control and data flows between the different organisational units involved in the BP.

MPN facilitates the representation of dynamic BPs, as each activity is not connected with others, i.e. it does not follow nor is followed by another activity, as in IDEF0, and there is no activity ordering. Activities can be initiated whenever all input places are occupied by the appropriate token, i.e. whenever the necessary resources and participants are available. Upon completion, each activity provides tokens to its output places, i.e. releases the resources needed for the activation of another activity. Thus, both static and dynamic processes are described uniformly. It also provides a clear, visual representation of activity steps executed with the collaboration of many actors, facilitating the description of cooperative processes.

MPN also facilitates the description of an organisational model. Places in the Petri-net can be inscribed with organisational entities, such as actors and roles, making the integration among organisation models and process models smooth and tightly coupled. Since places can also be inscribed with resource and control objects, a desirable integration between control flow, data flow and the organisation model is attained. All entities inscribed in Petri-net places are stored as objects within the MPN Repository. The repository needed to support the MPN model is implemented using Lotus Notes (Lotus Co, 2000). Notes serves as a groupware platform and support object-based database services. The MPN repository is implemented as a Notes database. This approach offers the advantage that the same dictionary can be used during both BP modelling and workflow implementation. In this way, workflow implementation cost is minimised, since the developer only adds code segments in the preconstructed Notes structures. The MPN model and the repository architecture are presented in the following paragraphs.

3.1 Extended MPN Model

A BP model should encapsulate information related to: (a) *activities*, (b) *resources* assigned to activities, i.e. objects necessary for the execution of activities, such as actors, documents, data, etc, (c) *control* of a BP which describes 'when' and 'which' activity is executed, (d) the *flow* of data in the process and (e) the *organisational structure* which consists of organisational units, people, roles, competence, etc [Tsalgatidou and Junginger, 1995]. These entities must be therefore mapped within MPN. The formal definition of MPN model is given in [Tsalgatidou et al, 1996]. The MPN modelling approach is based on the following principles:

The overall *MPN model* represents a specific BP and consists of different *SubMPNs* depicting the decomposition of the BP into a more detailed level.

Activities, that may either be simple tasks or further decomposed, are modelled as transitions. If the activity is further decomposed, a lower level MPN is used for its description. A *script* is related with each activity and represents the set of steps to be carried out during its execution. Scripts can be described using a high level language and are particularly useful in the case of simple tasks that are not further decomposed.

Control information, *resources* and *performers* required for the execution of activities are modelled as objects inscribing the MPN places. Control objects enable the representation of control flows within the process. Resource objects are data objects used by the process and enable the representation of data flows and data modification within the process limits. Resource objects are maintained in MPN *Repository*. Each resource is identified by properties and can be either simple or complex. Actors represent a position profile, e.g. manager or programmer, assigned to a specific employee within the organisation. More than one employee may be associated with one Actor. Roles group sets of duties and responsibilities assigned to a specific actor. Roles can be described in terms of other roles. Roles, Actors or Employees are required at the input places of a given transition, where the presence of specific operators (performers) is essential for its enactment.

In order to construct MPN models, a graphical interface was developed using Java. The GUI module, named MPN editor, communicates with *Repository* database stored within Domino Server. The same database is used to maintain activity description and activity decomposition scheme.

3.2. MPN Repository Implementation

According to Domino/Notes architecture, all entities defined within Notes platform are stored as *Notes Objects*. Different kinds of object classes can be defined using *Notes Forms. Notes Templates* are used to implement basic functionality. Based on these templates, it is possible to construct *Notes Databases* supporting the characteristics of specific applications. Both templates and databases are constructed using Notes programming tools. The authors suggest the following mapping of MPN entities within Lotus Notes, as depicted in table 1.

MPN Entity	Notes Representation
Employee	Notes User and Employee form
Actor	Actor form
Role	Role form
Organisational entity	Organisational entity form
Resource	Resource form
BP definition (new MPN model)	BP form
Activity definition	Activity form
Task definition	Supported Tasks form

Table 1: Mapping of MPN within Notes Platform

Resources defined using the Resource form are maintained in the Resource Notes Database. The corresponding form and view are automatically created for each resource defined. Forms are left black so that the developer can customise them during workflow development.Definition of BPs, BP activities and tasks (simple activities) is respectively supported using BP, Activity and Supported Tasks forms. Only the Supported Tasks form is used during workflow implementation. As an example of the structures created within CT, the formal description of the object class corresponding to “Activity” form is presented in Table 2. Activity_script is the code executed upon activation.

```
Class Activity
      {
      Name:                 String;
      Parent_Activity:      String;
      SubActivities:        Activity[];
      Activity_Script:      Script[];
      Guards:               Script[];
      Input:                String[];
      Output:               String[];
      Performer:            String[];
      }
```

Table 2: Class Definition within Notes

Guards contain the conditions for trigging the activity and are realised as an array of script sentences that calculates to a Boolean value. Input/Output contain input and output places respectively.

4. USING MPN TO MODEL DYNAMIC ACTIVITIES

The banking sector is a competitive environment, where business process re-engineering is constantly needed. Business process modelling and automation is an effective tool towards this direction, improving the performance of business activities and enabling enterprise-wide monitoring and coordination. In this section, we present a case study of modelling business processes in the Loan Monitoring Department of a medium-sized Bank. Loan monitoring is a typical banking activity, which includes business processes concerning loan approval, collection of delinquent loans and initiation of appropriate legal claims. These processes are often performed in cooperation with external business partners, such as legal firms and brokers, have collaborative properties and are considered of dynamic nature. Their efficiency strongly depends on human operator experience and subjective criteria. The loan monitoring policy employed is a significant factor for determining profits. Thus, relevant business processes should always be monitored, evaluated and refined.

In the following, we discuss the *Delinquent Loan Collection* process, since it combines both ad-hoc and collaborative properties. Delinquent loan collection may be performed by any employee working in the corresponding Department. As Actors, we have defined the positions included in it: *Department Manager, Section Manager, Group Leader* and *Collector*. *Collector* role describes the task of collecting delinquent loans. Other roles are *Administrator, Case Assignor, Supervisor* etc. Collector is a simple role obtained by all employees, while Case Assignor or Supervisor roles are only obtained by specific managers.

New delinquent loan cases and loan payments are downloaded from the account management system on a daily basis. When a loan case is assigned to a specific collector, it appears in his/her daily diary. Performing loan collection actions results in the modification of the loan status. Reminder data for the loan case are also maintained. There is a predefined set of actions initiated by collectors, some of which are:

- Client contact without success
- Client contact with success, not payment scheduling
- Client contact with success and payment scheduling
- Sending a letter to the client
- Defining an auction
- Defining a new payment settlement

The loan case is handled by LMD until delinquent loan instalments are paid. The generic MPN model depicting delinquent loan collection is depicted in figure 1.

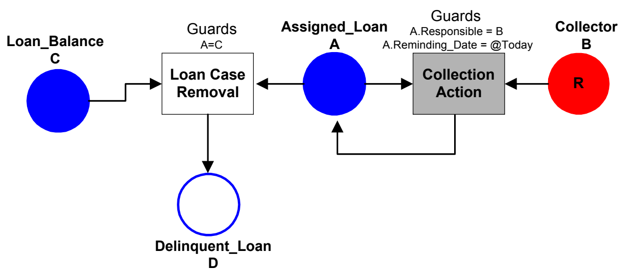

Figure 1: Delinquent Loan Collection Model (level 0)

As indicated in the figure, red places indicate performers and blue ones indicate resources. Places filled with colour indicate the existence of tokens. Grey rectangles indicate activities further decomposed by a SubMPN model. In this case, performers and input/output resources can be redefined, but not altered in the more detailed level of abstraction

Loan collection process consists of two main activities: *Collection Action* and *Loan Case Removal*. The first one is further analysed by another MNP, while the second one is a simple task. *Loan Case Removal* has no performer place as input and it is performed automatically. For *Collection Action* activity, which has such an input, the symbol "R" within the place indicates that a role has been defined as the performer, more specifically the *Collector* Role. Guards specify transition constraints. The *Collection Action* activity may be initiated when the collector responsible for the specific loan case is available (A.Responsible=B) and a reminder is set in his/her daily diary (A.Reminding_Date=@Today). Places are numbered using capital letters or numbers to simplify guard definition.

At the more detailed level, collection actions are distinguished into three categories: simple actions completed by the collector, actions requiring the approval of his/her supervisor and actions for which sending a letter is necessary. Determining the proper action is based partially on LMD policy and partially on the collector's strategy and experience, the sequence of actions, thus, is not predetermined. This is depicted in the MPN model using a control place, as indicated in figure 2. Green places indicate control. Control places represent control flow. A control place has more than one outputs, while the decision concerning which output will be activated may depend on deterministic or random rules (e.g. employee decision). Control places are particularly useful when describing semi-constructed or dynamic BPs.

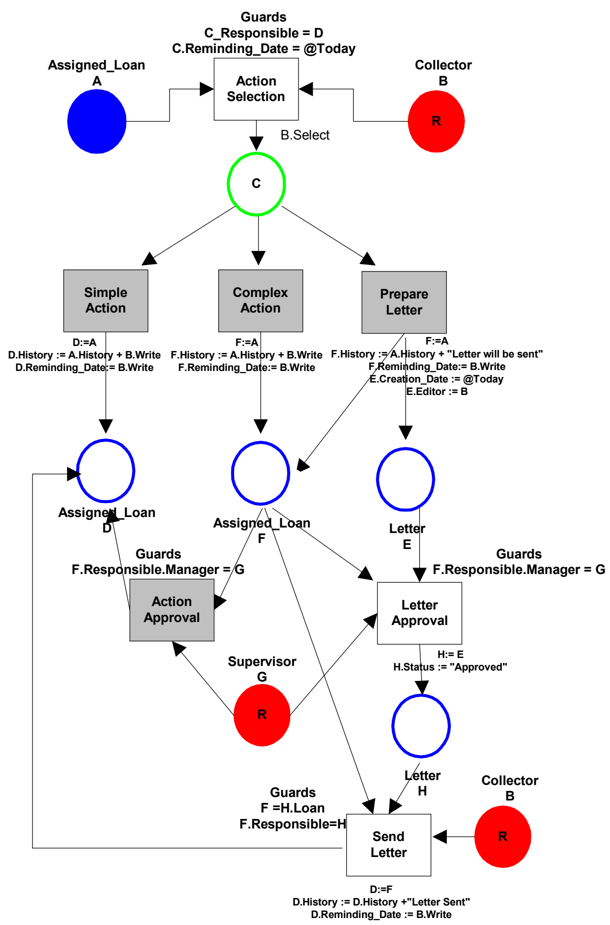

Figure 2: Collection Action Model (level 1)

The in-depth description of the *Collection Action* activity is beyond the purpose of this paper. However, one should note some points of interest. Input and output places of the MPN must be the same as the input and output places of *Collection Action* activity presented in figure 1.

Although other resources, such as *Letter*, are produced during this activity, they are not indicated as output. In the MPN model presented in figure 2, the *Supervisor* role is also depicted as a performer. This is allowed, as the *Supervisor* role also includes *Collector* role. As indicated in *Action Approval* activity, guards are not static and enable the representation of BPs with dynamic evolution. Although it is not mandatory, scripts can be defined to describe activity functionality (scripts are depicted under activities). Scripts are useful especially when describing tasks, as they are automatically transformed into code within the workflow environment.

Using the MPN model presented in figure 2, one can simulate the execution of the business processes and reach conclusions concerning the behaviour exhibited by specific collectors, as well as the effectiveness of various strategies and the indication of potential inefficiencies and bottlenecks.

The MPN enabled the formal description of all business processes related with loan monitoring. Gathering and evaluating information concerning the department operation and policies in a systematic way was one of the major contributions. Business process analysis proved to be time consuming due to the complexity encountered in gathering collectors experience. The description of all business processes within MPN and the direct mapping of BP models stored in MPN repository within Lotus Notes facilitated the accurate workflow implementation and reduced development time.

5. CONCLUSIONS

In order to efficiently automate business activities, one should first fully model their functionality. There are many methods facilitating BP modelling, such as IDEF0 and RADs, which provide standard output that can be imported within most popular workflow implementation environments. Unfortunately, they can not be used dynamic activities, since they only depict activities consisting of well-defined steps executed in a predefined sequence. Petri-net models can provide better solutions for this kind of processes.

Business process automation provides significant results only if all activities, independent of their nature, are fully described in a formal way. The extended MPN model, presented in this paper, facilitates the description of dynamic activities using multiple levels of abstraction in a concise manner. It allows the description of process by defining all activities and subactivities, their input and output and rules for their activation. The control place concept allows for the description of ad-hoc activities. Guards are used to depict the conditional invocation of activities, facilitating the provision of a general model properly initiated.

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UNIFIED ENVIRONMENT FOR BUSINESS PROCESS MODELING AND WORKFLOW ENACTMENT

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KEYWORDS
Business Process, Process Modeling, Simulation and Enactment, Object-Oriented Methods, Collaborative Networks, Petri Nets, Distributed Environment, Java Technology, Intra/Internet Application

ABSTRACT

Process modeling and workflow applications have become more an more important during last decade. The main reason for this increased interest is the need to provide computer aided system integration of the enterprise based on its business processes. This need requires a technology that enables to integrate modeling, simulation and enactment of processes into one single package. Predecessors of this paper introduced method BPM (Business Process Modeling) and its implementation in a software system BP Studio (Business Process Studio). This paper describes how this system (primarily focused on process analysis, simulation, and control) can be extended into real workflow management system. It means, how the automated aspects of business process can be controlled.

INTRODUCTION

Basic definitions as were defined by Workflow Management Coalition are introduced at the beginning of this paper to clarify what is the difference between Business Process, Process Model, Workflow, and Workflow Management System:

- *Business Process:* A set of one or more linked procedures or activities which collectively realize a business objective or policy goal, normally within the context of an organizational structure defining functional roles and relationships.
- *Business Process Model:* The representation of a business process in a form that supports automated manipulation, such as modeling, or enactment by a workflow management system. The process definition consists of a network of activities and their relationships, criteria to indicate the start and termination of the process, and information about the individual activities, such as participants, associated IT applications and data, etc.
- *Workflow:* The automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules.
- *Workflow Management System:* A system that defines, creates and manages the execution of workflows through the use of software, running on one or more workflow engines, which is able to interpret the process definition, interact with workflow participants and, where required, invoke the use of IT tools and applications.

Understanding of these notions is very important for understanding of how the original BP (Business Process) Studio was designed and how it was extended to obtain complete Workflow Management System.

BUSINESS PROCESS STUDIO

Business Process Studio is the software system that implements method for modeling called BPM (Business Process Modeling).

BPM Method

The BPM method can be characterized as follows:

- BPM is a formalized and visual modeling tool. Formalization is employed to model a process uniquely and precisely enough to use a built model for simulation and control without any change. Visual approach enables to increase modeling capabilities and clarity to make all necessary communications easier.
- BPM enables structural analysis of the process and visual simulation of the process dynamics.
- BPM uses concurrency of process activities execution as a primary focus.

BPM builds three different kinds of models for each process that is being captured (Figure 1).

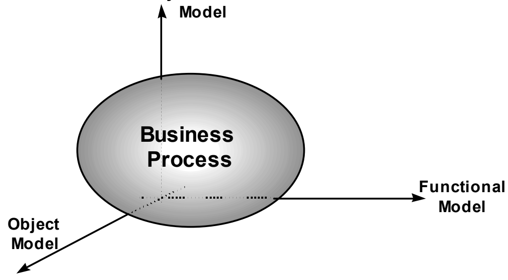

Figure 1:Three Aspects of BPM

The main aim of the *functional model* is an identification of the business process architecture, as well as the identification of process customers and products. It means to find an answer to questions what processes are employed by an organization and what is their structure.

From this point of view, the method defines two types of relationships between processes - containment and collaboration. The first one is used to identify sub-processes, while the second one shows a possibility of concurrent existence of two or more processes. The containment relationship should not be understood as a part-of or consists-of relationship. It means, that a process just launches contained process and finishes it when the required products are obtained. However, such contained process can be used by another process in the same manner and therefore, it cannot be just a part of the first one. A simple example of a *Car sale* process can be captured by a functional model of BPM as follows (Figure 2):

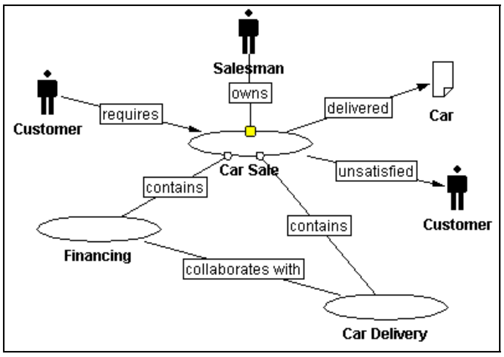

Figure 2: Functional Model of a Car Sale

Customer who *requires a car* can be either *unsatisfied* or can get a *Car* in this process (process customer and its alternative products are specified by icons and corresponding arrows). The car sale process contains two sub-processes *Financing* and *Car Delivery* that have to collaborate (car cannot be delivered until it is financed, bank needs a documentation of a car etc.). The owner of the process as a whole is the *Salesman*.

Object model identifies static structure of all entities (objects) that are essential for the enactment of the process. In other words, the answer to the question by *whom and what* the process is realized is searched. This model tries to capture all active objects responsible for an execution of activities and passive objects that can be understood as material, products or documents that are manipulated by the process. All these objects have a set of attributes associated. The notation used for this sort of models is similar to notation used by typical object-oriented method except that active and passive objects are represented by different icons to distinguish them. Object models are created for every process identified during the functional modeling. In our example of the car sale it means, that object model for sub-process of *Financing* can look as follows (Figure 3).

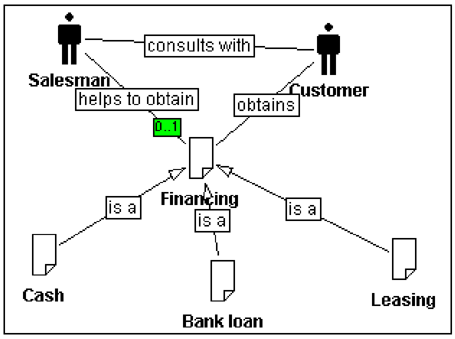

Figure 3: Object Model of Financing Sub-process

Coordination model is based on previous two models and its goal is to show *how* the process will be enacted. The coordination model specifies interactions among objects (active and/or passive) and defines the way *how* all these activities are synchronized based on principles used in Petri Net. The coordination view is the most important because it enables to define the execution order of all activities, including conditions for their potential concurrency. It means that the correct order is defined, as well as sharing of used resources. Each activity can have more than one scenario with the duration time and costs associated to provide necessary information for the analysis. Based on the architecture definition captured in a functional model, the "primitive" activities are accompanied by sub-processes icons that can be refined further into more detailed collaboration models again. Example of car sale demonstrates the above mentioned on the figure (Figure 4).

The process starts with an activity *Car Selection*. This activity requires presence of active objects *Customer* and *Salesman* as a condition for its execution. Based on applied scenario the appropriate output is selected. In this case, the first scenario represents a situation where the *Customer* found a car and together with an obtained *Order* they continue to the sub-process *Financing*. In the same time (concurrently) *Salesman* is "moved" with the *Order* toward activity *Car Ordering* (car can be in a showroom or it must be obtained from a store or manufacturer). The second scenario reflects a situation when the *Customer* does not find what she/he wants. The sub-process *Financing* is elaborated in a similar way. In a case of success, the financed *Customer* continues to the sub-process *Car delivery* where the Car is physically delivered.

INSTANTIATING PROCESS MODEL TO WORKFLOW

A process enactment is closely related to the process instance. If the process model describes how the process should look then the process instance represents real computerized process - workflow. The analogy with a class and its objects (instances of class) from object oriented world is perfectly valid here. In the implementation environment of BPM it means that the first step is to select the process model which is instantiated automatically.

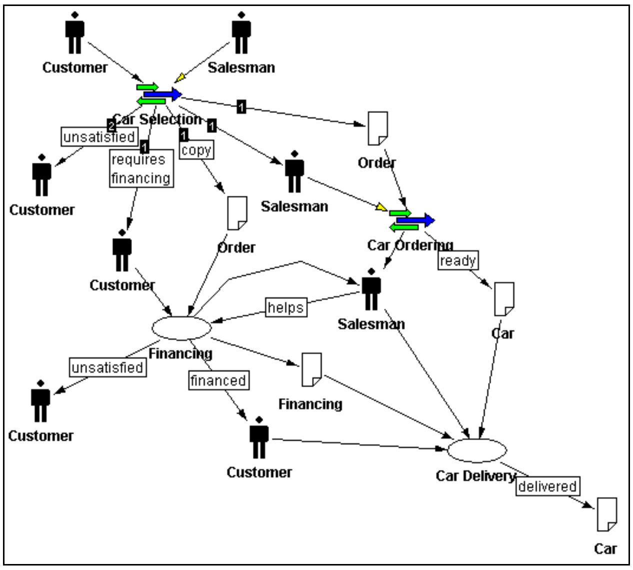

Figure 4: Coordination Model for a Car Sale Process

Resulting diagram has absolutely the same look as the coordination diagram from the modeling phase. The only remaining task for user is to define instances of active and passive objects participating in this process enactment (Figure 5).

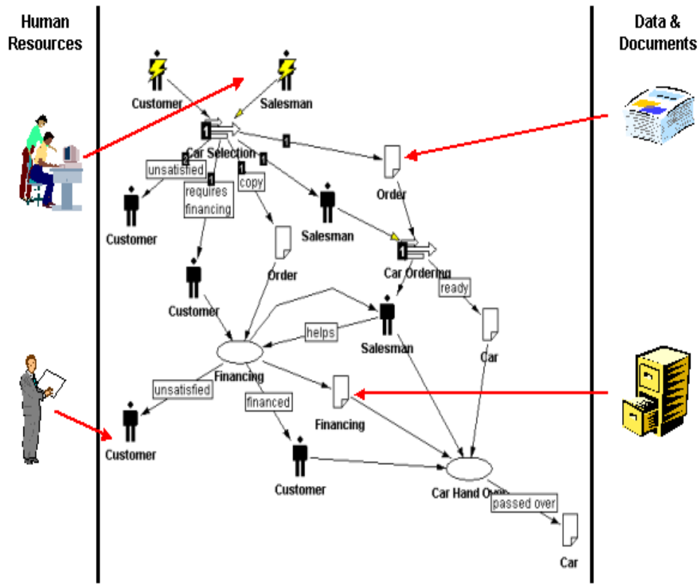

Figure 5: Process Instantiation – Mapping of instaces to real life entities

The engine responsible for the workflow execution employs the same rules that are used for the execution of Petri Nets. The only difference is that a token is represented by a real human resource or data manipulated by the process instance. The workflow engine executes code of activities designed as automatic as well as it distributes human-based activities to resources (*actors*) that are responsible for their realization. This enactment can be roughly described by the following algorithm:

1. Scan all activities
2. If there is an enabled activity (all input places are charged) schedule it for execution.
3. Automatic activities that does not require human interaction are executed in a parallel thread.
4. Human-based activities are displayed with appropriate directions in the task list of the actor. Actor registers the activity as started and finished based on how the activity is realized.
5. When the activity is finished all output places are charged with instances of a given type.
6. Go back to the first step.

From the point of view how the activities are executed we can distinguish between three kinds of activities:

- *Manual* – pure human based. No computer resources are needed. The human resource executes the activity based on directions associated with it. Instances of passive objects are available. For example, in the above mentioned activity *Car Ordering* the instance of object *Order* is available. This instances describes what car has to be order.
- *Semi-Automatic* – human activity is supported by an external application. The activity has associated not just directions but also the code that is executed by the actor. This code migrates to the actor's computer where it is executed using instances associated with the activity. For example, the activity *Car Selection* uses the application that searches in a database of car manufacturer. The list of available models is displayed to the *Salesman* and *Customer*.
- *Automatic* – pure computer based. No human resources are needed. The activity has code associated. The code uses instances and it is executed immediately. The code is executed on the same computer as the workflow engine is running.

CONCLUSIONS

The process model driven approach described in this paper shows very high potential in the area of business process and workflow management. The possibility to change process specification, verify new design and use it almost immediately in form of the workflow represents a very powerful way how to make company more flexible.

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On Enterprise Modelling Dynamics
Towards E.M. formalisation

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Keywords

Enterprise Modelling, Enterprise Models Formalisation

Abstract

Enterprise models tend to be rather static representations of (in most cases) dynamic content. Developing dynamic enterprise models requires understanding all the dynamic elements of the model as well as the elements that control these dynamics. Being able to develop real dynamic enterprise models does only help in experimenting with different structures and scenarios but it allows us to move towards formalising models at the enterprise level. The paper discusses some initial ideas towards identifying enterprise modelling dynamics and the need for expressing these dynamics formally.

Definitions

Enterprise models represent the concept of division and allocation of responsibilities to create a network of roles interacting through conversations. A Role can be considered as a composition of responsibilities which defines the boundaries of an enterprise. A conversation between roles represents the context of a single or list of transactions for the generation and interpretation of information. Resources represent domains of ownership or instruments of communication and exchange.

Spheres of control refer to the technique proposed by [Davies CT 1978] for controlling and auditing processing in a multimode multiprocessing system. We use term in its abstract form to refer to logical boundaries around a set of conversations held between roles or agencies.

Enterprise Model Dynamics

We use enterprise models to show organizational boundaries and within those boundaries abstract roles and associated responsibilities. These abstract roles and responsibilities are taken on and acted upon by entities within the organizational boundary. An activity can be considered an instance of a role or series of roles that act upon a set of responsibilities in order to maintain a state of affairs for the duration of that instance. We use the term sphere of control to define the boundary of a temporary set of roles executing responsibilities.

Within this set of definitions we identify a number of dynamic objects. Entities can implement several roles. Roles can be associated with different responsibilities. An activity represents an instance of this network of roles and associated responsibilities. A sphere of control defines the boundaries of such an activity. A sphere of control has a duration within which the participating roles have to fulfil their responsibilities. It encapsulates an action which consists of the implementation of roles but not the roles themselves. It is not a locking mechanism in technical terms but a boundary where an activity or action will be executed. Roles can be part of several spheres of control.

Within organizational boundaries many spheres can be executed at the same time. The duration as well as the roles and their associated responsibilities may vary. Entities can represent different roles within different activities and roles can act upon different responsibilities within different spheres.

Although entities are encapsulated by organizational boundaries, roles and responsibilities can be shared between different organization models.

This builds a rather complicated picture as ownership of organizational entities is implied by organizational boundaries. However spheres of control i.e. networks of roles and responsibilities can be implemented and maintained by several enterprise models that do not share a common boundary. Let us look at some enterprise models regarding a basic brokerage model.

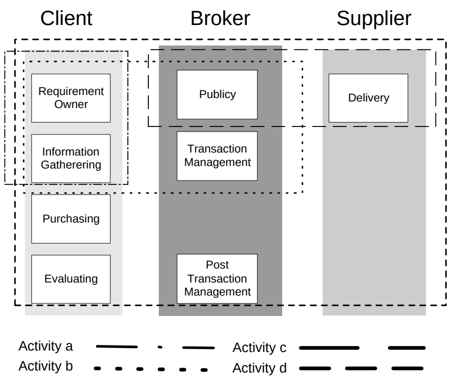
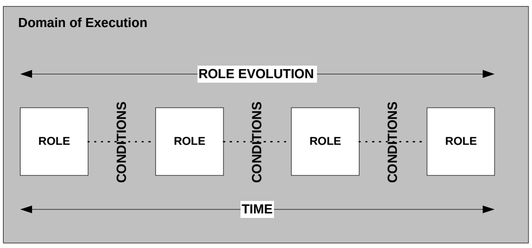


Figure1 . Activities simultaneously

The figure depicts several activities within which roles are executed. If we accept that roles and responsibilities are the dynamic concepts of an enterprise model then we also need to consider two attributes of dynamicity which are evolution and time. Indeed in the above diagram each sphere of control implements a time model which guides the evolution of the roles i.e. the execution of the responsibilities associated with each role as well as the synchronisation of the conversations.

Role Evolution

Roles are not static. They evolve according to pre and post conditions over time. This implies that roles accept new responsibilities while drop others. The evolution itself is of course conditional.



The above figure depicts the idea of role evolution which is suggested in the model. There is a domain of execution which defines a systems environment. In component based system terms this is different to the term defined by the composition as this defines only the environment of a particular service of the component system. The *time* attribute poses a constraint to the evolution. We use this attribute since we cannot imply infinite time of execution. The post and pre- conditions associated with the revolution of these roles may be esoteric to the environment or external. The execution of all roles within a scale of evolution defines an activity. The activity is initiated with the execution of a role and it terminates with the satisfaction of the post conditions of the last role in the evolutionary scale. This is easy to imagine if we consider the doctor-patient relationship. A doctor has to diagnose before he prescribes. Diagnosis and prescription have to take place within a time limit. The patient will adopt a treatment only after the prescription has been carried out. The time between prescribing and adopting a treatment is also relevant.

If we accept that pre and post conditions determine the evolution of roles over a predefined set of time constraints within which a role has to execute a set of duties then we can conclude that failure modes are in fact errors that stop or pause this evolutionary progress.

A failure can be caused by a role’s inability to execute a set of duties within a predefined set of time constraints. Since pre and post conditions determine the evolution, if post conditions are not satisfied then role evolution ceases.

Applying the concept of responsibility at this level is rather complex. Remember that the responsibility holder is the role(s) that has control over the initiation or termination of a conversation. Since this initiation of roles can be external to the systems environment, it is the obligation of the responsibility holder to deal with failure modes. Failure modes at this level may not necessarily imply exceptional circumstances where a role performs an erroneous task, or fails to perform a scheduled duty. It can also be the case of post conditions being insufficient to allow the responsibility holder to execute the duties assigned to that responsibility.

Spheres of control

So far we have been concerned with two notions namely evolution and time. In the following paragraphs we address the issue of *spheres of control* (SoC). SoC are the areas which a role controls for a specified period of time. Control is defined as the ability to initiate and terminate a conversation in order to achieve a particular task within this SoC and the pre-specified time limit. When the pre-specified time limit expires the SoC, the roles and responsibilities have to be re-considered.

Responsibility is defined as a set of duties which have to be performed by all participants in order to maintain the state of affairs. We also make the assumption here that the responsibility holder is dealing with that failure models that take place within the SoC over the specified time.

Consider the brokerage model. The broker plays a number of roles which evolve throughout the execution of the system and its interaction with the client. In order for the broker to play the role of the information provider, he has to go through the role of the information gatherer first. Similarly in order to execute the role of the seller he has to execute the role of the advertiser or information provider. Again all this has to take place in a timely fashion.

Within the hypothetical limit of thirty seconds (we assume a 30 second time out limit) the broker has to implement the duties assigned to the responsibility of the role of gathering information for the client. Within this SoC there is a number of duties which have to be implemented in order to carry out its obligation. As we showed earlier these duties can be split between roles. However the responsibility holder is dealing with the failure modes that may arise. Some of the duties may include transacting with the supplier, narrowing the request of the user etc.

By looking at the brokerage and other case studies such as a travel agent system we have so far concluded that a number of failures occur when a roles fails to execute a set of duties that form its responsibility. The remedy to this however is not to simply make sure that a role is given enough time and resources to execute those duties. Other failures involve roles failing to take on responsibilities or drop others. There are also a number of cases where execution of roles crosses organisational boundaries. This brings in a new set of problems related to the difficulty of maintaining an active conversation between roles (across organisational boundaries) whose execution semantics do not cross those boundaries.

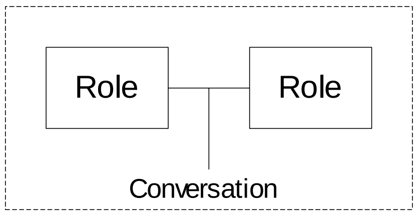
Having presented this abstract view on the dynamics of enterprise models we move on to discuss the feasibility of formalising Enterprise Models.

Towards Formalisation

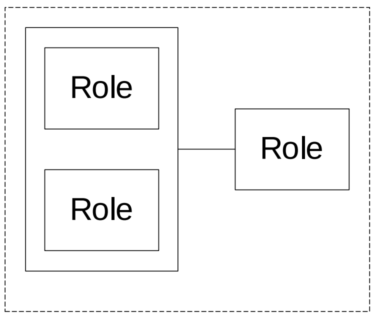
Based on the description so far about the dynamics of enterprise models, it becomes apparent that in moving towards a formal description of the above scenarios would require 3 distinct steps.

The first steps would involve description of the conversation networks between roles or agencies within the context of spheres of control. Earlier on we described the spheres of control in an abstract sense as boundaries around networks of conversations. The control element however needs to be clearly specified at this stage of modelling. Atomicity is an example of such a control element. Other control elements may include co-operative error recovery, error handling, data consistency etc.

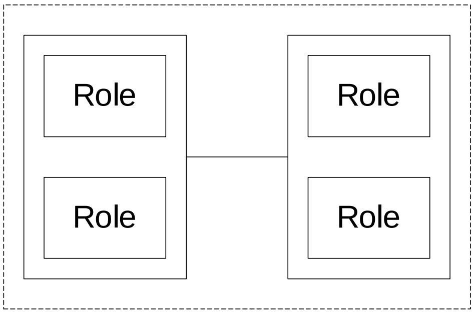
Generally speaking there are three basic types of conversation structures as depicted in the following diagrams.



The first diagram depicts a single conversation between roles. The sphere of control which may be used to address the atomicity of the conversation is providing a logical boundary of the conversation.



In this instance the conversation takes place between a composition of roles mapped onto the same enterprise and a single role. This illustrates the second type of conversation construct and the dotted line represents another sphere of control. The control element could be error recovery and exception handling.

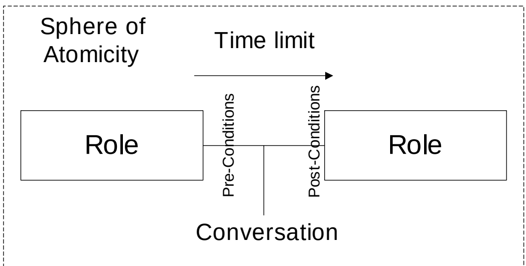


In this third instance the conversation takes place between two compositions of roles. The control element of the sphere of control could be data consistency.

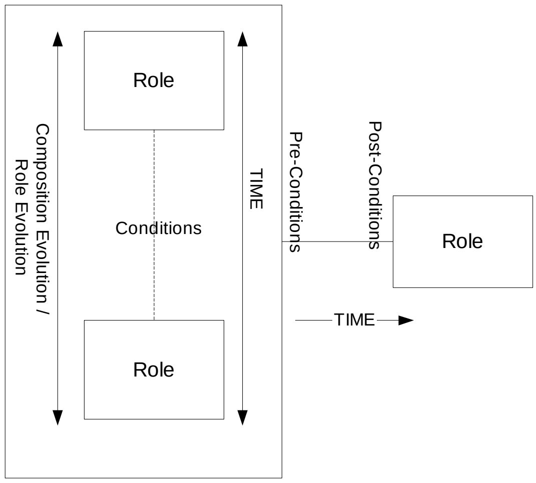
The above diagrams depict the main conversation constructs. However they do not reveal any information about the flow of the conversation. This is the second step of the process.

Conversations are controlled by several elements which can themselves be dynamic. Some of them are pre-conditions, post-conditions as well as time. They all pose constraints regarding the flow of the conversation as well as the outcome. The sphere, and subsequently the elements of control inside the sphere also pose a number of restrictions regarding the flow and outcome of a conversation.

The flow of conversation is part described in the second component. Although in the first part of the process we described the conversation structures, in the second part we described conversation flows. So what are the constraints that control the flow? Consider the single conversation diagram.



The diagram shows the some of the constraints that control the flow of the conversation. From the diagram we can conclude that within the sphere of atomicity the conversation is controlled by pre-conditions which have to be satisfied prior to commencing the conversation. The time limit poses a physical constraint; the conversation has to be completed within this limit. Furthermore the post conditions need also be satisfied. The sphere of atomicity will control the outcome of the conversation. In the case of conversations between compositions of roles additional flow constraints may apply. Consider the following diagram.



In this example there a more constraints since it is not only the conversation flow itself but the composition process and more precisely the evolution of that composition that also controls the flow. If for example we consider the above to be a simple model between a hospital and a patient (the patient represented by the single role) then the execution of the diagnosis role would proceed the execution of the prescription role, i.e. you cannot prescribe unless you know what is wrong. The evolution or composition of roles could also be guided by time and several other conditions. The actual conversation between the patient (single role) and the hospital is controlled by pre and post conditions that reflect some of the constrains we mentioned above. Time again may also be an additional constraint.

The third and final step involves expressing all the above in a formal language. Therefore we would need to select a formal language that allows us to express real time, conditions and structural constraints. We are currently working identifying the appropriate language to represent all the above.

Conclusions

The paper reports ongoing research towards a formalisation process for enterprise models. In order to describe enterprise models dynamically we need to identify all the dynamic variables that control them. Some obvious variables are evolution and time. We introduced the concept of spheres of control within which evolution takes place in a timely fashion. Future work involves identifying appropriate languages that would allow us to represent the above concepts and express them formally.

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Biography

Dr. PANAYIOTIS PERIORELLIS carried out his Ph.D. research in the area of enterprise modelling between 1997 and May 2000. Since June 2000 he has been working in the area of dependable systems with particular emphasis in the composition of systems from autonomous components. He has published a number of papers in the area of enterprise modelling and information retrieval. Further information can be found at http://ouston.ncl.ac.uk/index.htm

PROF. JOHN E. DOBSON John Dobson obtained a M.A. in mathematics and philosophy from Cambridge in 1962 and subsequently researched into mechanical translation. In 1968 he joined Rolls-Royce as computing instructor, leaving in 1971 to teach computing at Newcastle Polytechnic. From 1974 to 1980 he was employed at the University of Newcastle developing the University's computing systems and network. In 1980 he and a few colleagues set up their own R & D company, where he assumed the position of Technical Director of a company which grew to employ over 120 staff. In 1986 he returned to the University, carrying out research in computer security and in information technology and organisational change. In August 1996 he was appointed Professor of Information Management at the University of Newcastle. His current research projects are DIRC, of which he is Technical Director, a large multi-site interdisciplinary project investigating dependability of systems which involve both people and computers; AMASE, a project which is looking at systems to support the integration of public sector service delivery; and County Durham and Darlington EHR, a project which is looking at a pilot implementation of the proposed new NHS electronic health record.

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PROCESS MANAGEMENT FOCUSING INTEGRATED PRODUCT DEVELOPMENT AT AN INTERNATIONAL COMMERCIAL VEHICLE COMPANY

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KEYWORDS

Quality Gates Management
Cross-functional Engineering Standardisation

ABSTRACT

This paper presents the worldwide corporate description of quality gates management for strategic commercial vehicles development projects and some effects on the regional branch for truck and bus production at an international OEM. As a structured methodology, it provides information concerning all required activities from the planning to the follow-up of a quality gate during product development cycle. It organises compulsorily the work as a guideline for processes and responsibilities for all those involved people.

INTRODUCTION

The main target of concurrent engineering implementation is to integrate all the corporate competencies within the product development process. After the conceptual definition of a product in the strategic planning of the company, cross-functional teams are organised to work simultaneously during the several steps of the project implementation. The strategic products must ensure the existence of the company on a long-term basis. Therefore, the importance of a good planning and the accomplishment of the steps are very high.

The corporate committee for product development decisions proposed a standardised project reporting to harmonise the specific worldwide procedures, so that it would have the adequate transparency over the current description of the product creation process (PCP) [1]. The main driving forces of an optimised product development must be identified as soon as possible to improve the PCP in terms of the highest product quality by minimised use of resources and time.

The reduction of the time-to-market is the key factor of the project profitability:

- strategic advantage over the competitors
- earlier market requirements attendance
- shortened time of development, longer market appearance

There is a huge challenge for that company to collect the knowledge and experiences from their professionals and share them within a new environment where the interactivity and automation will be the masterpieces for collaborative engineering [2]. The technological improvement of the several departments, which are involved in a strategic vehicle project, is not sufficient to ensure the company's growth. The work results of each participant must be also available for the decision making by the corporate management.

At that company, the planning of the project is achieved according to the referenced methodology for commercial vehicles development, which is based on quality gates. All the pertinent activities are described within this guideline and they are grouped inside the appropriate quality gate. This methodology certifies the follow-up of the strategic objectives in proportion to the project progress.

OBJECTIVE OF THE PCP MANAGEMENT

The objective of that methodology implementation is to ensure a standardised quality gate accomplishment in the commercial vehicles development to support a common understanding of the PCP. The synchronisation of vehicles and power train systems development is also a goal to be achieved through the defined prerequisites. It has to be obligatorily applied to all strategic projects.

The main topics that influence a project development are taken into account and have their related activities described in the guideline. This way, there is a complete covering of the relevant project information:

- chronological processes from the planning to the follow-up steps
- definition of deliverables and exit criteria
- rules for assessment at the quality gate

- roles and responsibilities of those involved people
- methodological support for the overall activity accomplishment
- report structures and standardised output reports

DEFINITION OF A QUALITY GATE

PCP consists of several sub-processes that are interlinked with each other up through an input/output workflow. In PCP, the Quality Gate (QG) is a control point within the product development process, at which previously agreed exit criteria are measured and assessed by both the designated customer and the supplier, in terms of the information quality and activity completion, so that it is possible to manage the project progress.

The checkpoints work as a guidance and management tool for the managing board, because it covers the participation of all the functional areas and establishes the beginning and the end of the main steps of the product development process. As the company has the formal procedures of each involved department, a QG is based on a standard set of their required deliverables and exit criteria to be followed by the defined participants [fig.1].

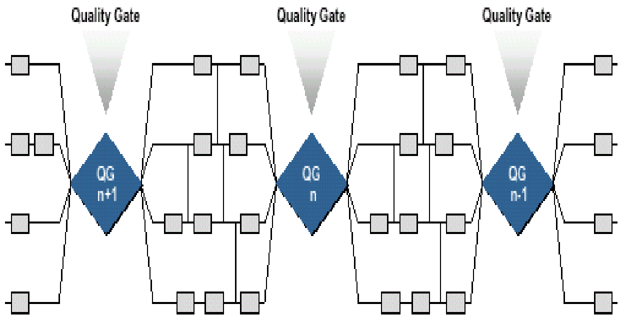

fig.1 _ Quality Gates as checkpoints

Deliverables are criteria for completion of a QG. They serve to evaluate a defined part of the product development process for every project in a standardised manner. Exit criteria describe the output of an activity, which is measurable. Its fulfilment is assessed in the QG review. The assessment of all exit criteria is the basis for assessing the deliverables.

For each exit criterion, the as-is status is measured and assessed versus the to-be definition. When necessary, action plans are also described to correct the project running. The quality gates provide the vision of the project maturity and allow the synchronisation of all activities of those involved people, who have to deliver a certain work result at a point in time.

The PCP methodology covers the whole product development through quality gate description from „10" to „0" [fig.2]. The intention is to ensure a standardised management process for all the simultaneous projects, which are in progress inside the company.

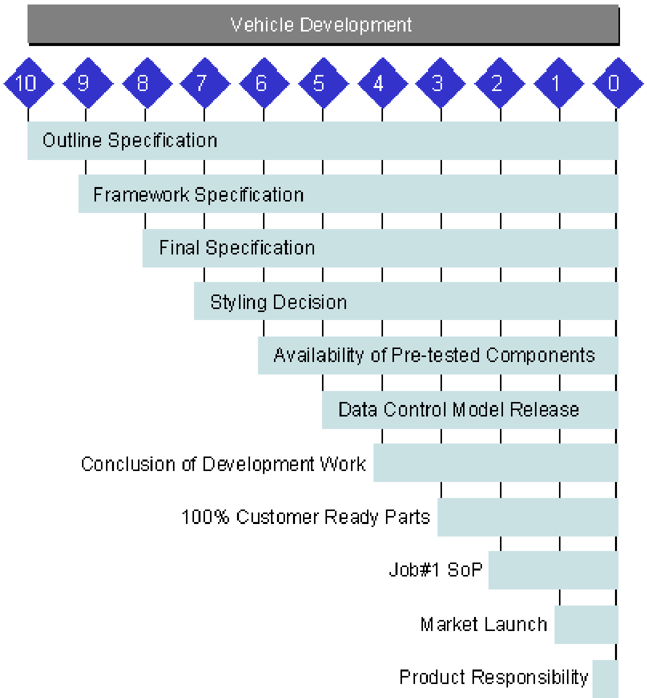

fig.2 _ Quality Gates description

QUALITY GATE SYSTEMATIC

The quality gate systematic (QGS) is described through four phases. They outline the treatment that should be given to each passage of the checkpoints.

1. Planning Phase: the requirements concerning the quality gate process co-ordination, the deliverables and exit criteria, the customer/supplier relationship and the schedule for the complete cycle are defined and agreed.

2. Preview Phase: during this phase, the deliverables defined by customers and suppliers during the planning phase are assessed, so that the project status is periodically checked. Action plans are defined in case of deviations of the planned target.

3. Review Phase: based on the fulfilment of the deliverables, a general recommendation and action plan are presented to the managing board to decide about the completion of the quality gate and the required project adjustments.

4. Follow-up Phase: the quality gate conclusion is presented to all those involved people to start the implementation of the actions agreed upon.

The description of the PCP with quality gates enables steering and synchronisation of complex product projects and the continuous implementation of optimised processes. The QGS is represented through a net of measures to control the process advance and characteristics, to co-ordinate the prerequisites, to demonstrate the path to achieve them and to synchronise all process participants.

The introduction of the harmonised QGS provides the management, steering and combination of multiple vehicle and component projects, not just parts but also the work synergy and knowledge to conduct to modular project development in a global environment.

Early experiences at that company demonstrate a specific arrangement for simultaneous product development generally based on rules for technical data exchange, almost always for component geometry. The project participants still do not have the possibility to obtain the required data with accuracy for their process, mainly the management people, who are responsible for activities scheduling . When the project management requires, the control of activity completion or even the project maturity status are obtained through exhaustive meetings.

Despite of this effort, there are no definition concerning deliverables and exit criteria, mainly because the handbook for product development does not describe them, neither basic management tools to indicate the beginning and the end of each activity. The problems have been just solved in the current systematic, instead of undertaking prevention actions to avoid them. The company has been giving special attention to this point, offering the due operational qualification through the revision of the usual methods and also the compilation of processes requirements, which belong to a matrix of integration between activities and responsibilities. Based on preparatory projects of co-design, that were implemented during the last two decades, a relevant impulse occurred with the appearance of the advanced planning implementation of product quality to allow a robust market result for the company.

The QGS implementation requires information preparation and actions for data availability to monitor the maturity degree of product development and also to have an overview of the gateway completion.

BUSINESS PROCESS MODEL

As another component of the PCP, the Business Process Model (BPM) describes the main process through logical dependency between the several activities [fig.3].

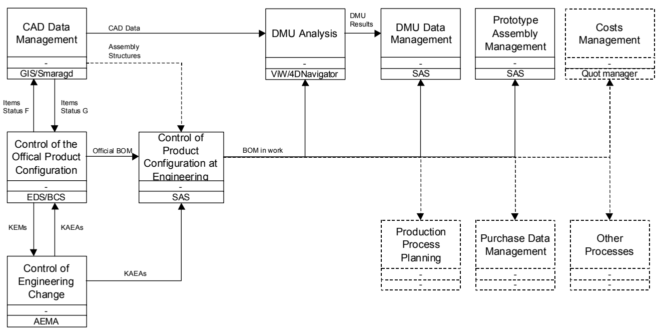

fig.3 _ Rough BPM description

In terms of a process model, the PCP allows the identification of logic breaks and contradictions in the current process, and it is the base for its improvement. It also enables the common understanding of the process flow between all participants and clarifies the deliverables of suppliers with regard to their customers. The description of the specific processes provides the recognition of potentials among process participants. It is possible to reduce interfaces and process loops through the transference of customer requirements into product features or achievement of customer-ready parts [fig.4]. The quality management of internal or even external suppliers, and the virtual product development also contribute to soften deviations of the conceptual product characteristics.

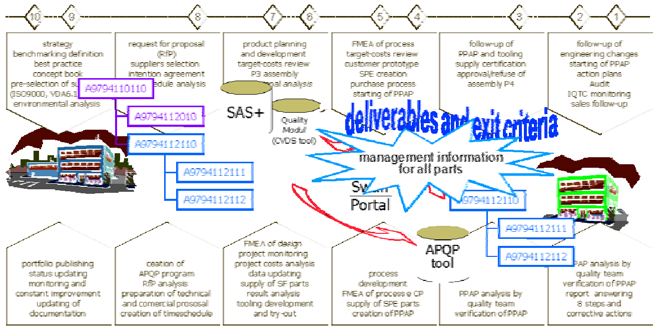

fig.4 _ Outlook for structuring and integration of processes

PCP REPORTING

A standardised reporting of the PCP progress is also required to mention the quantity and the diversity of the information from product projects to guarantee transparency and comparability for the process management.

Quality, costs and time are continuously evaluated to project progress validation through its management decision process [3]. The product project reporting has to fulfil general conditions in terms of form and procedure and must represent the most important information for the management board. The general objectives of the information handling by the management board are:

- to determine product configuration aligned with market strategies
- to inform product specifications for the project team
- to suggest strategies for pre-defined milestones of product introduction concerning economical, technical and design aspects

THE SUPPORT OF EDM PROJECT

Presently, the QGS introduction is focused on the deliverable and exit criteria description. It happens because of the lack of project management information mentioned before. That action is part of the Engineering Data Management project (EDM), which is currently in implementation phase, through the analysis of the input/output for activity execution [2].

As a specific project for integrated product development, the EDM implementation has to provide an adequate environment for fast and accurate result of the work of each required function that contributes for product engineering and production. At the same time, part of the information and data set resulting from the everyday work is used as input information for the next step. Normally, it happens with geometric data set because it is the basic language for engineering inside the company. But it is also necessary to give additional information concerning the maturity degree of the data because concurrent process requires the continuous follow up of the geometric progress.

However, the EDM project equally supports cross-functional operation. This way, most of the information, which is also used for project development and management, applies the requirements for work scheduling and ratification. That additional information controls the pace of the project progress. When a geometric data set is in the initial phase, it is not appropriate to finish the purchasing process, but to select the suppliers who are able to fulfil the project needs, for instance. That is the first aid granted by EDM to the project management: an overview of the data quality, so that is possible to start and complete all the tasks appropriately. The data quality fulfilment for each step of the development cycle allows the consistency check of each input data.

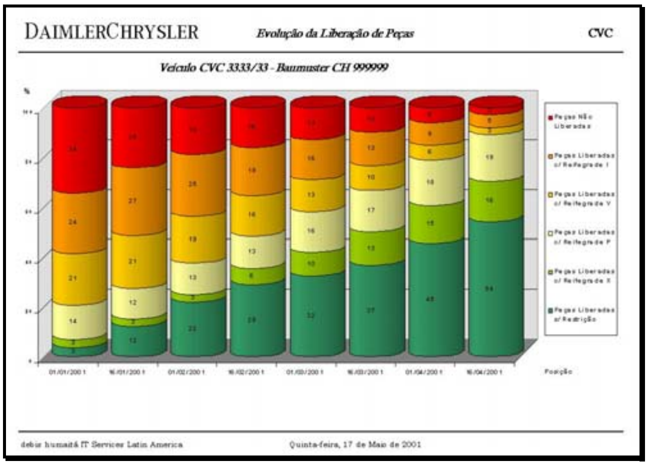

fig.5 _ Example of PCP reporting

At the beginning, the main actions of EDM introduction were focused in data quality definition and improvement. Nowadays, an another expected result of EDM project is the identification of the sub-processes interdependency, the ones that compose the whole product development cycle, to elaborate a reasonable business process model. The actions for process and roles description, the deliverables of each activity and the summary reporting put the EDM project as the platform for the company reaches the PCP requirements and the project management [fig.5]. The target to support the information raising and publishing unconditionally aligns both the EDM project and PCP implementation.
The target to support the information raising and publishing aligns unconditionally both the EDM project and PCP implementation. Through the crossing of the BPM description and the QGS, it is possible to have a comprehensive overview about the PCP status [fig.3]. The EDM project also proposed the addition of the project documentation in the product structure (BoM) to complete the fulfilment of the quality gates.

The EDM project has identified, until now, that all activities for product creation are based on single vehicle project. In future, the modular development program will put into action the integration of the upcoming projects.

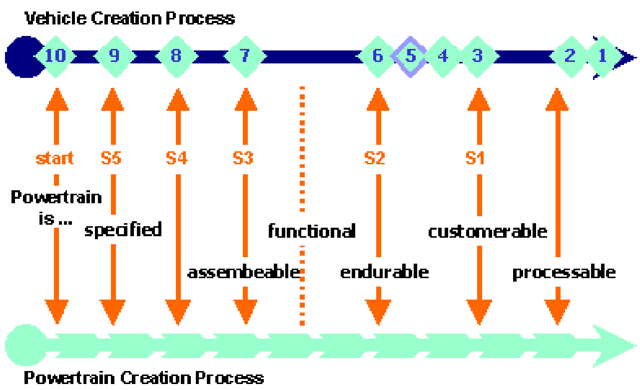

fig.6 _ Development process synchronisation

BPM allows the process synchronisation implementation between vehicle and power systems, as essential feature for overall optimisation of the complete PCP. Thus, there is the chance to lay the framework out for a standardised product project reporting through the harmonised quality gates, the process modelling and project synchronisation [fig.6]. After the global implementation of the PCP in the commercial vehicles division, the product projects will be assigned to conduct their progresses on the basis of a standardised and continuous monitoring. This includes:

- the process optimisation with regard to the presented methods for current and upcoming product projects
- the feedback of expertise and knowledge of PCP into the product projects
- the advancement of the project management methodology

The EDM project has worked to provide the comprehensive representation of the relevant PCP information. The company has experienced the usage of progress reports through project data base statistics in substitution for those ones conventionally made. There is a large amount of particular views of activity completion but the data integration is not reached yet. Obviously, this required unification has a direct dependency on the whole BPM description.

PRELIMINARY EXPERIENCES

The main partner for the PCP implementation inside the company has been the Quality Strategy Management department. It is the responsible for:

- quality planning of new products introduction
- monitoring of the corporate development process
- application monitoring of the project handbook
- evaluation of the prototypes quality
- demonstration of maturity degree of new components
- prevention of problems based on the production

Through the education process supported by that department, the migration effort towards the standardised procedures has brought significant results for the integrated development of products. It should be also mentioned that the company still keeps the conventional procedures, while this environment is not completely running.

The support to the main requirements during the project of new products has been focused on the follow-up of prototypes construction, due to the still low application of virtual product description. The evaluations of assembly of preliminary vehicles are now enclosed to the product structure (BoM), whose execution happens now through instructions of the engineering teams.

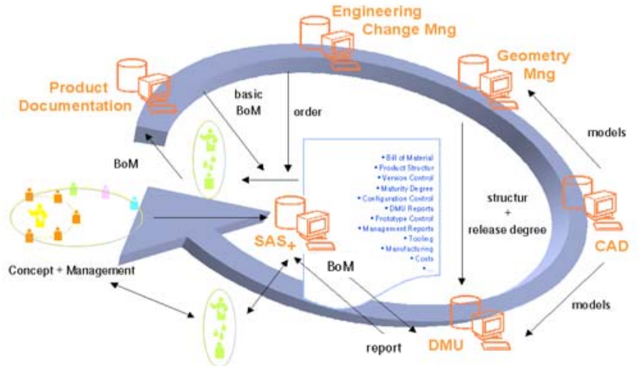

fig.7 _ Support to the current process

The processes related with the prototypes construction are no longer uncontrolled. All the members that participate in integrated process can easily access the assembly reports, mainly the responsible teams for specific vehicle components as cabin, axles, power train, etc. That follow-up allows a more effective reaction of the cross-functional teams for the reduction of development cycle. All the mistakes can still be solved when the engineering changes have an acceptable cost. Potentially, this is a point that can be develop significantly, through the complete introduction of the product virtual modelling at the company. That is also a goal of the project EDM, which is related with the accomplishment of activities through a standard procedure for the whole company.

As the whole process is still not completely transparent regarding the relevant and intermediate steps, a preliminary solution has been applied to allow a rough but correct vision concerning the main activities accomplishment [fig.7].

Thus, some key tasks can be simultaneously performed with a reasonable security level. The current status of that solution allows the project participants to handle the following information, so that they can contribute for the project target achievement:

- engineering change management
- production change management
- parts maturity degree management
- digital mock-up (DMU) analysis
- pre-documentation of product and BoM of new parts
- prototype assembly control and quality reports
- testing results control

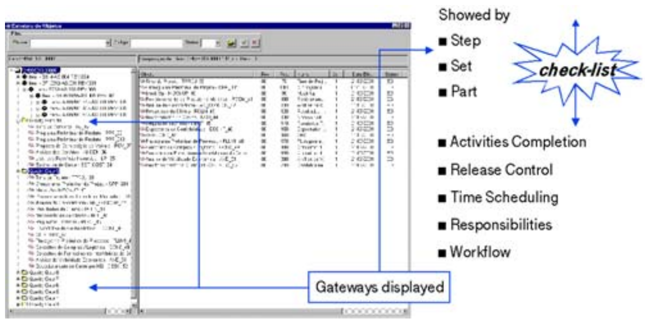

fig.8 _ Suggested IT solution

The company will apply this experience as the base to fulfil the remainder lack inside the integrated product development and to specify a robust IT solution for:

- supplier integration in the development process
- structured application of D/PFMEA
- risks management
- costs management
- manufacturing process and quality planning
- workflow management

From our point of view, it is necessary to introduce the new integrated processes combined with the required support to the information, due the dynamic change that involves simultaneous product development. We are presently working on both fields: the methodology implementation and the information tool [fig.8] that will support the product development improvement.

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ENGINEERING DATA MANAGEMENT AND INFORMATION MODELING

SMARTPDM -
DYNAMIC INFORMATION SUPPORT WITHIN DISTRIBUTED DEVELOPMENT PROCESSES

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KEYWORDS

Product Data Management, information support, early phases, product knowledge, reuse, decision support

ABSTRACT

Enterprise product data indicating e.g. previous design intentions, design histories and chosen design processes, potential useful to support distributed product development, are hidden within today's heterogeneous it-systems. On the other hand, the PDM-concept appears as the best conceptual foundation for realizing a smartPDM-vision to provide transparency. In this light, an expansion of the PDM-concept to support decision-making processes in product development is presented.

INTRODUCTION

As accelerated globalisation, dynamic marketplaces, increasing competition and customer needs have to be more specifically and dynamically addressed, industrial enterprises are forced to raise product development as the core of the value chain in efficiency (Bullinger 1999). Today, distributed product development has to cope with large product and process complexity whose management is addressed by current Product Data Management implementations. Product Data Management characterises the processing of product data in all product life cycle phases and is based on the integrated product model (Anderl and Trippner 1999). Particularly early phases of distributed product development are characterised by dynamic (by means of aligning product features to changing conditions), evolutionary (by means of gradually emerging patterns), vague (by means of loose and fuzzy product requirements), incomplete and occasionally conflicting product specifications as well as imprecise product defining data within distributed and heterogeneous system environments. As a result, the contemporary PDM-concept fails to support these early phases suitably.

CHALLENGE

As product development processes are traditionally dynamic also due to evolutionary product specification only an intuitive coupling of dynamic information demands and large sets of distributed product life cycle data is possible, at present (see Figure 1 and Figure 2). Therefore, in a typical product development scenario it can be expected that an exclusive intuitive access of large sets of distributed and potential useful product life cycle data is frequently characterised by user specific views on what sort of resources are valuable. This approach may however lead to different decisions compared to a situation where all useful product life cycle data is considered.

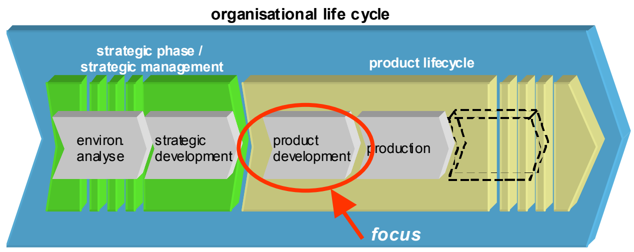

Figure 1: Focussed domain of smartPDM

In this light PDM-systems have been developed for serving as an interface between various engineering tools. However, though the PDM-concept provides a contribution to an integration of data model subsets (partial models) from various engineering systems focussing stable environments, conditions and processes of product development, a mapping/codification of dynamic workflows, design intention, design history and design experience in correlation with a specific product model is not yet addressed by current PDM data models like ISO 10303 and the PDM Enablers. ISO 10303 is an international standard for the computer-interpretable representation and exchange of product data. The objective is to provide a mechanism that is capable of describing product data throughout the life cycle of a product, independent form any particular system (ISO 10303-1). PDM Enablers are standard interfaces for the services provided by Product Data Management systems. These interfaces, made available via ORBs, will provide the standards needed to support a distributed product data management environment as well as providing standard interfaces to differing PDM systems (OMG 2000).

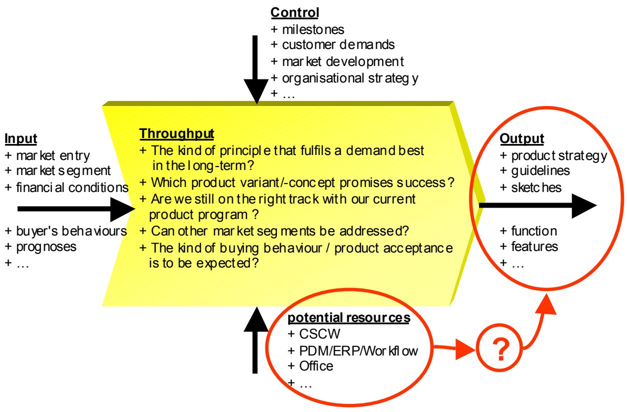

Figure 2: Characteristics of early product development phases

In detail, the following potential deficits are exposed:

- A lack of cross-organisational understanding, caused by an absence of a shared logical model, domain/partner specific application systems and processes as well as heterogeneous demands
- Partial subjective product decisions (e.g. about solution concepts) and lack of 'first time right' products due to complex product functionality dependencies and unsystematic information access and analysis possibilities of large product life cycle data sets
- Little utilisation through heterogeneous system support as well as a low level of data integration and consistency
- Limited product life cycle data reuse as a result of large documentation and classification efforts

A solution to the above deficits is seen in context to an improvement of logistical information support by means of supplying user/domain sensitive information (e.g. advantages/disadvantages/effects of current design/product approaches) by integrating dynamic information demands (e.g. product variant/feature evaluations) with dynamic product life cycle data resources (e.g. lessons learned, design history, design intention), captured within distributed databases and file directory environments as stated in the following chapters.

RELATED WORK

The main related approaches to improve information support within distributed product development environments are integration concepts such as product data management (PDM), executive information systems (EIS), middleware architectures such as the Common Object Request Broker Architecture (CORBA), Computer Supported Cooperative Work (CSCW) and research projects such as iViP, SFB374, KARE, MOKA, SEDRES and KnowWork. In this chapter, an extract of these approaches is analysed against the requirements resulting from the above deficits of today's product development.

Product data management (PDM) represents a concept on managing the entirety of product life cycle data based on an integrated product model. The integrated product model serves as a logical integration platform for the data generated by various software systems along a product life cycle (Anderl 1999). In this context the ISO 10303 (STEP), as a foundation for an integrated product model, gains relevance (Anderl and Trippner 1999). As product data within early phases is vague and evolutionary as stated above, it is problematical to map it to a more or less static data model. Furthermore, since PDM-systems, deployed in later phases of product development, represent vendor specific solutions and are commonly customised to satisfy various customer requirements, several PDM-implementations are not capable to cooperate without distinct interfaces or individual data integration layers in place. On the other hand, the integrated data model based PDM-paradigm addresses the creation of a common understanding and the gain of usability through its application-integration concepts.

The research project SFB 374 (Development and testing of innovative products – rapid prototyping) aims to support the cooperation of product development staff in a distributed environment via methods and concepts for representing and integrating active and relevant knowledge for rapid product development purposes within a knowledge database. It is based on concepts and technologies such as semantic networks, ontologies and CORBA. Thereby, the project focuses on the codification and management of current expert knowledge relevant for rapid product development. Therefore, the SFB 374 concepts present a potential basis for imaging logical dependencies within heterogeneous IT-tools and address the support of a cross-functional and cross-organizational understanding as well as an assistance to decision processes.

The EU ESPRIT project KARE (Knowledge Acquisition and sharing for Requirement Engineering) aims the support of capturing, analysing and managing customer requirements in order to raise the quality of the cooperative customer/supplier design-process. Within the project, methods are developed to formalize customer requirements as well as enterprise knowledge and to enable a mapping between them. The formalization is based on the emerging STEP Application Protocol AP 233 – systems engineering data representation. A workbench will be developed, consisting of three collaborating it-tools to implement the evolving methods. KARE is realised in close conjunction with other projects, e.g. SEDRES2 and MOKA, dealing with the standardization of STEP AP233, respectively the development of a methodology to implement knowledge based engineering applications (Urwin and Spelberg 2000).
KARE mainly focuses on the customer/supplier collaborative design process in one-of-a-kind industrial environments and increasing the quality of customer requirements. Based on a set of partial proprietary tools, it is not primarily dealing with the integration of existing heterogeneous system environments or the raising of transparency in distributed development processes. However, the results may act as a fundament for creating a common understanding and the generation of a central data model including the explicit modelling of requirements.

Subjective decisions as well as a limited reuse and analysis of product life cycle information as stated above are ascribed to a deficit on methods and tools unitising and advancing critical implicit and explicit expert know-how in a distributed product development environment systematically. The 3.1 cluster as part of the research project iViP (Integrated Virtual Product Development) aims to develop methods, concepts, software and services to support identification, acquisition, formalisation, storage, synthesis and transfer of critical implicit and explicit expert know-how for product development, based on concepts such as discussion groups and yellow pages (iViP 2001). Thereby, the 3.1 cluster focuses on know how management within an iViP specific system environment. An automated decision support based on the analysis of product life cycle data within a given heterogeneous system environment is not directly addressed.

Results

As a result to the deficits addressed before, a functionality has to be provided to assure a persistent procedure where dynamic information demands are communicated to it-resources and dynamic findings are transmitted backwards for supporting product life cycle information reuse and decision making processes. Since the PDM-technology is a de-facto-standard in today's leading engineering enterprises (though there is no common understanding of THE PDM-concept), based on the concept of an expandable integrated product model that already integrates the bulk of product data, it is postulated to be the best basis for the claimed logistical information support. However, it still lacks re- and further use of product data within dynamic processes and vague product specifications as well as a consistent methodology for product development decision support. Therefore, the extension of today's PDM-paradigm is claimed, whereas the following research approach provides contributions.

RESEARCH APPROACH

Based on the given conclusions of related work, an extension of the PDM-paradigm is aspired to address the stated deficits in distributed product development environments. In the following this vision is called smartPDM. In this context techniques for reusing and analysing large sets of product life cycle information according to dynamic user demands and incorporated by the smartPDM architecture are called smartMethods.

Figure 3 shows the conceptual overview of smartPDM and its placement within the product development process.

SmartPDM can be seen as a meta-layer and a system architecture above the conventional product development process that is based on the PDM-concept. Thereby, smartPDM serves as an interaction platform between distributed users and product life cycle relevant it-tools such as PDM- and Workflow systems. In this context, data management remains within operating it-systems. Furthermore, smartPDM is intended to provide a possibility of generating a common cross-functional understanding by developing and establishing an extended (enterprise specific) integrated product model.

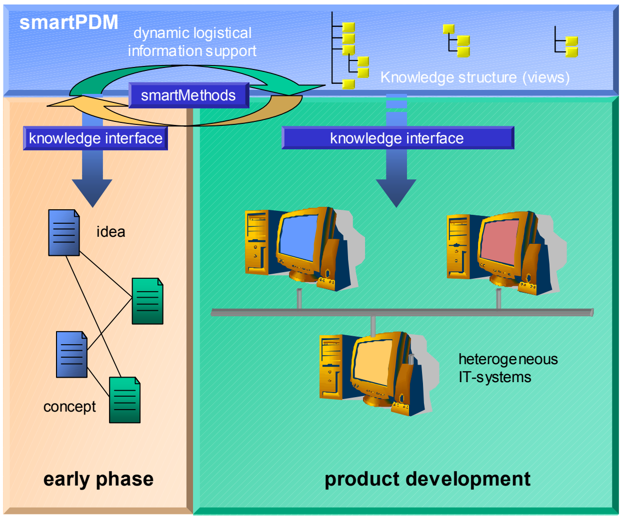

Figure 3: smartPDM conceptual overview

The overall aim of smartMethods is to support decision-making processes in distributed product development phases by enabling an ongoing process where dynamic information requests are communicated to existing product life cycle information resources incorporated within an integrated product model and dynamic results are transmitted backwards.

In this context, smartMethods correspond to the PDM-concept (that is seen as a data warehouse reference model), but on a higher abstraction level (managing product knowledge instead of product data).

In a future product development scenario user specific information demands are gradually communicated to smartPDM, and smartMethods can be used for reusing and analysing existing product life cycle information resources.

To hide data resource complexity and volume, user access to smartPDM is intended to be supported via user sensitive views on existing product life cycle information resources such as an organisational view (incorporated by a hierarchy of typical objects such as product planning, product design and quality assurance), functional/role view (incorporated by a hierarchy of typical objects such as project leader, designer and controller) knowledge view (incorporated by a hierarchy of typical objects such as implicit/expert and explicit/theoretical knowledge), and problem view (incorporated by a hierarchy of typical objects such as conceptual and methodical issues).

In this context, smartMethods correspond with the smartPDM views and are represented by concepts for identifying (e.g. agents, spiders, crawlers) abstracting (e.g. trigger procedures), synthesis (e.g. data mining, OLAP, data warehouse), reuse of data resources (e.g. case based reasoning, classification tree, requirement mapping) and functions for user monitoring. Some of these concepts are defined in the following paragraphs.

Case Based Reasoning is a methodology for solving problems by utilising previous experience. It involves retaining a memory of previous problems and their solutions (Case Base) and, by referencing these, solving new problems (Pal et al. 2001).

Agents/triggers represent automatically executed data base procedures (Lusti 1999).

Data Mining represents a concept on an automatically discovery of relations between large data sets by applying analytical algorithms (Schinzer et. al. 1999) and incorporates sub-concepts such as neuronal networks, rule based systems and OLAP (Lusti 1999).
Fuzzy Logic interprets expressions between totally true and totally false. For example, if 0 represents totally false and 1 represents totally true, values between 0 and 1 describe fuzzy states (Bulllinger 1990).
Online Analytical Processing (OLAP) describes data modelling in multi-dimensional structures for data-analysis purposes. Therefore, data can be analysed with regard to decision-making in a faster and a more significant way (Schinzer et al. 1999).
The data warehouse concept is based on the copying of operative systems-data to a separate database prepared for later data analysis (Grothe and Gentsch 2000).

One basic part of smartPDM is the extension of today's PDM-understanding by providing a smartMethod to the user for communicating product development requirements to the smartPDM system, that are mapped to the smartPDM-database.
The product/knowledge structure is synthesised of heterogeneous information both stored in various it-systems and tacit knowledge that employees develop or remember. If, in addition to conventional product data, this knowledge or solution data is accessible to the user via a component based engineering portal as a front-end (e.g. based on technologies such as EJB, .net, CORBA, etc.) to the PDM-system, the re- and further use of the product data can be warranted. In this way, the solution concept explicitly addresses the integration aspect instead of developing another system with dedicated functionality.

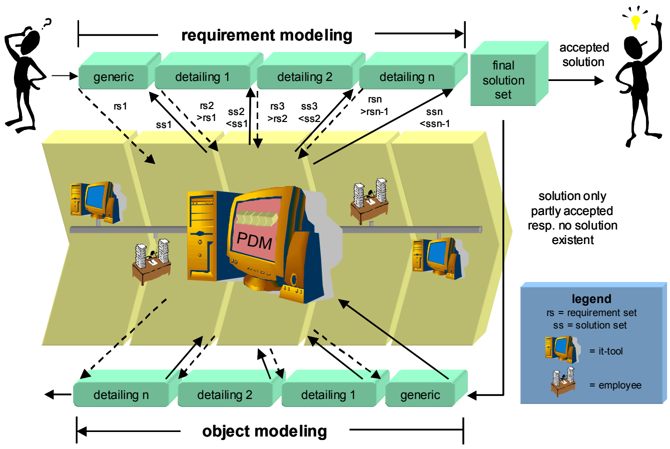

Figure 4: Reuse of product data through requirement-solution mapping within smartPDM

As shown in the above figure, the reuse and analysis of product life cycle data is based on a PDM paradigm that provides the relation of requirements and product data that fulfil these requirements. As PDM concepts like STEP and PDM Enablers are well suited to image product documentation in form of CAD-models, describing documents, specifications and so on, they lack the management of early engineering phase data (see Figure 5).

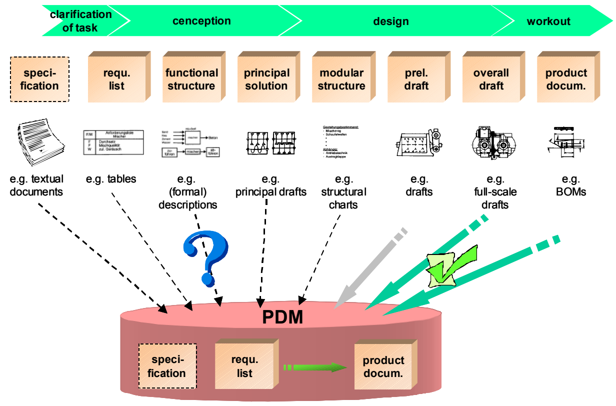

Figure 5: PDM within the engineering phase

VDI 2221, "systematic approach to the development and design of technical systems and products", divides the whole engineering process into the seven sub categories shown in Figure 5 and gives typical examples of information generated within these categories. In order to reuse existing information (products) within an enterprise and therefore to shorten the design phase - that stresses most of the development time - it is necessary to integrate a granular representation of requirements into the product model. Both STEP and PDM Enablers only support the classification of product data and in the normal case, requirements are just stored within a PDM system as black-box documents – if stored at all.
Therefore, a concept has to be defined to extend a standard data model through a requirement capable approach. As stated above, the KARE project aims at developing a requirement management process based on the emerging STEP AP 233. AP 233 was published as a Publicly Available Standard (PAS) by the SEDRES2 project in September 2001 with the title "Industrial automation systems and integration — Product data representation and exchange: Systems engineering data representation" (see Figure 6).

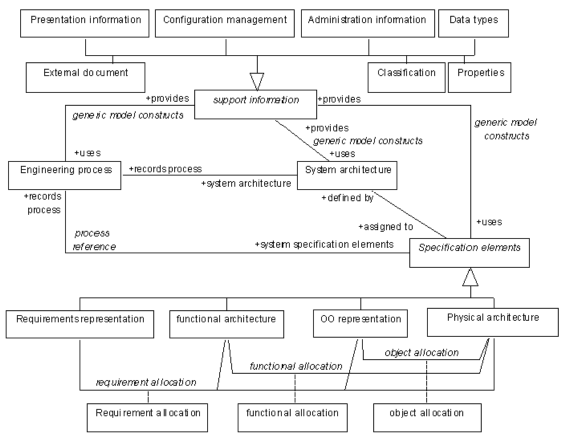

Figure 6: AP 233 overview (SEDRES 2001)

It provides a data model that covers all data generated and used within the systems engineering phase of a general systems lifecycle and especially focuses on the modelling of requirements and requirement resp. functional structures (SEDRES 2001). Although systems engineering is a horizontal discipline that relates to many other phases of the

systems lifecycle, it basically corresponds to the engineering phase describes in VDI 2221 (Figure 5).
In order to integrate these capabilities in a holistic PDM approach, the basic data model is an extension of a standard model by the AP 233 concepts. As STEP only describes a static view on product data and factors out the behaviour of these data, the CORBA based PDM Enablers standard is chosen as the foundation. Especially this standard has been evaluated by the Institute for Information Technology in Mechanical Engineering (itm) and has been supplemented to a reference model that enables an integration equitable implementation of product data management. Therefore, this reference model acts as the basis for the requirement representing extension (Wirtz 2001).
Figure 7 finally summarises the presented smartPDM functionality.

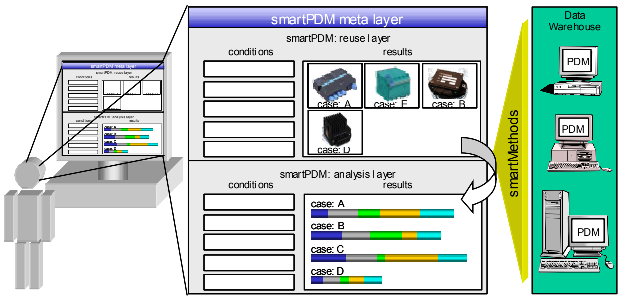

Figure 7: smartPDM functionality

CONCLUSIONS

The PDM-concept incorporated for example in PDM Enablers and STEP appears as the best conceptual foundation for realising the smartPDM vision. SmartPDM thereby represents a concept for reusing and analysing large product life cycle data sets to support decision-making processes in distributed product development environments.
Related approaches to accelerate dynamic decision support in a virtual product development environment do not primarily address an organic and cross organisational integration of relevant product life cycle data with dynamic and evolutionary product specifications and dynamic development processes. Frequently they focus on codification and management of implicit expert knowledge and categorised facts.
The extension of the smartPDM concept as well as its technical implementation is subject of further research.

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Class Query Language
and its application to ISO13584 Parts Library Standard

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KEYWORDS
CQL, PLIB, ISO13584, Set-theoretic, Product Data Interchange and Standards.

ABSTRACT

Set operations on tables are widely used by RDBMS (Relational Database Management Systems) and play a pivotal role in data representation, processing, and storage. This is because the operations and queries about data in RDBMS are performed by a standardised language known as SQL (Structured Query Language) and the basis of the language is well-founded in mathematic logic, i.e., the set-theoretic Boolean algebra. Thus the users of the RDBMS may retrieve the data and predict the resulting set based on mathematic logic, without knowing the algorithmic detail of the data-interface language. In contrast, the users of OODBMS (Object-Oriented Database Management System) must well understand the data-interface specification of the embedding language, because the data-retrieval is done procedurally and is influenced by its syntax.
The Class Query Language(CQL), presented herein, is a theoretical extension of the SQL toward the classes in mathematical logic, and is capable of performing set-theoretic Boolean operations between those classes that form an acyclic graph structure. This language is especially useful to retrieve, manipulate, and construct data in an ISO13584 Parts Library standard (PLIB) based Library Management System. However the scope of the language is not limited to PLIB but is applicable to wide-ranging object-oriented class libraries.

1. Introduction

Set operations on tables, first introduced by E.F. Codd (Codd 1970), are widely used in Relational Database Management System (RDBMS) and still play a pivotal role in data representation, processing, and storage. This is because the operations and queries about data in an Relational Database (RDB) are performed by a query language known as SQL (Structured Query Language) and the basis of the language is well-founded in mathematic logic, i.e., the set-theoretic Boolean algebra. Thus the users of the RDBMS may select the required data and formally calculate the resulting set based on mathematical set-theory, without knowing the algorithmic detail of the data-interface language; the users don't have to mind the procedural steps to retrieve the information, because the query is declarative and not procedural. In contrast, the users of Object-oriented Database Management Systems (OODBMS) must well understand the detailed specification of the embedding language, often called "language-binding", because the data-processing is performed procedurally and thus the result is totally order-dependent on the steps of procedures and is largely influenced by the syntactic specification of the data-interface of the embedding language, provided that this may optimize data processing time for certain objects and for certain purpose, if the operations on them are well standardised and well understood by the users as analogous to the operations on real world objects.

The Class Query Language (CQL, hereafter), presented in this paper, is an extension of the SQL language toward the classes of mathematical logic, and is capable of performing set-theoretic Boolean operations between classes that together form an acyclic graph structure (ACGS). In particular, this language is effective to retrieve and manipulate data stored in a Library Management System (LMS) based on ISO13584 Parts Library standard (PLIB), but the scope is not limited to PLIB but also to cover similarly structured class library systems that have a graph-like ontology representation. In such a system, each node is supposed to be represented by a class whose members are characterised by having at minimum the same set of properties, and data records are represented as instances of one of such classes. To be exact, PLIB does not define the database structure itself, but only defines the file format of data exchange between LMS's or product parts databases, but the basic data requirement of the exchange file virtually defines the underlying conceptual database model.

2. Theoretical Background

The notion of class employed in this paper, and henceforth within CQL specification, corresponds to the class notion in mathematical logic, which is roughly a "superset" of mathematical set. This notion of the class whose members are qualified by having the same set of properties can be expressed by a predefined set of logical formulae, known as Zermelo-Fraenkel classes (ZFC), but does not necessarily coincide with the class notion of Object-oriented Programming language (OOP) which merely implies such an entity be a named aggregation of data records of composite data types, that allows inheritance of member attributes to its subclasses, often accompanied by a functionality of selective data encapsulation. A class in OOP does not necessitate that every class be a member of another class, neither the collection of those classes forms an ACGS. In a marked difference to this, every class in the sense of mathematical logic is a subset of *Universal Class*, or *Universe*, thus having the same ancestor node. This class definition neither corresponds with that of semantic ontology in which the analyses of the meaning of vocabulary plays a significant role in the configuration of class hierarchy. In CQL, a subclass A' of class A can be defined strictly by the formula *(1)* in the following;

$$\boldsymbol{A' \subseteq A \leftrightarrow \forall x(x \in A' \rightarrow x \in A)} . \qquad (1)$$

Hence, the subclass ***A'*** must have all the properties that class ***A*** has and may have some more properties than class ***A***.
In almost all the cases, classes and sets are mutually replaceable, however, according to the textbooks of mathematics such as(Jech 1997) or in a classic work of mathematical logic such as (Church 1956), a set is always a class but the reverse is not always true. A well known example of such a class being not equivalent to a set is known as Russell's paradox that states a set ***S*** is a collection of elements such that they are not a member of themselves;

$$\boldsymbol{S = \{ X \mid X \notin X \}} \qquad (2).$$

A class having the above characteristic is given a special name, "*Proper Class*". Beside such special cases given in *(2)*, all the Boolean operations that apply to sets apply to classes as well;

$$\boldsymbol{A \cap B = \{X \mid X \in A \ \wedge \ X \in B \}} , \qquad (3)$$
$$\boldsymbol{A \cup B = \{X \mid X \in A \ \vee \ X \in B \}} , \qquad (4)$$
$$\boldsymbol{A - B = \{X \mid X \in A \wedge \ X \notin B \}} . \qquad (5)$$

In this paper, authors denote the *class* with the above definition ,but also connote that an assemble of those classes form an ACGS, and it must be distinguished from a simple table composed of a list of tupples, having the same set of data types. As well known, the Boolean algebra allowed in case of RDB are essentially limited within a table or between such tables that have the same set of columns.

The CQL differs from OQL(Object Query Language) proposed by ODMG（Object Data Management Group）(Cattell and Barry 1999), in that CQL allows set-theoretic Boolean operations to define a new class and to extract information, while the OQL uses methods defined in a class to do so. Thus in the OQL, the actual creation of a class depends on what properties it has, in which order the properties are defined, and how the constructor arguments are specified. In CQL, a class is defined by a set of properties but the order of definition of those properties has no relation with the class creation, nor with the data operation. In fact, each property as well as each class is identified by a unique code, named BSU (Basic Semantic Unit) whose issuing organisation is identified by a code named "Supplier BSU", whose uniqueness and integrity are guaranteed by the ICD (International Code Designator) defined in ISO6523. In addition, the collection of properties and classes is bundled together as an exchangeable meta-data, and given a special name, i.e., "dictionary " or "data dictionary".

3. CQL LANGUAGE---SCOPE AND DEFINITION

In the following, an outline of the features of CQL version 1.4. is presented first, and then a structural comparison among CQL, SQL and OQL is shown. Some of the language constructs in view of the application of the language to PLIB are illustrated in the last section.

3.1 Typical Features of CQL

The CQL has the following five distinguished features.
1) Boolean operation between classes
2) Ancestral search
3) Part-Whole Relationship
4) Property classification
5) Three level security controls based on a business model

3.1.1 Boolean operation between classes

The Boolean operation between operand classes modifies the search scope of the query in the class hierarchy. The expressions are given as below.

select * from A* AND B*; *(6)*
select * from A* + B*; *(7)*
select * from A* − B*;. *(8)*

where "*" attached to a class variable signifies all the subclasses of the class are included in the operand.
It is clear from the comparison, that the expression *(6), (7), (8)* corresponds to the mathematical expression *(3) ,(4), (5)* respectively, where ***X*** is taken to be a collection of instances belonging to a class or to one of its subclasses.

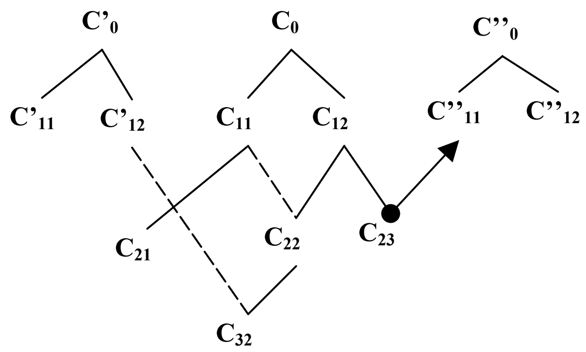


Figure 1: Sample Class Tree

For example, in a class hierarchy like the one depicted in *Figure 1*, if the ***from*** clause is written "***from*** $\boldsymbol{C_{11}}$" , the search scope is strictly limited to the class $\boldsymbol{C_{11}}$ itself. But if the ***from*** clause is "***from*** $\boldsymbol{C_{11}}$*", the search scope is the class $\mathbf{C_{11}}$ and its subclasses. Therefore, **AND** operation of the class $\mathbf{C_{11}}$* and the class $\mathbf{C_{12}}$* means that the search scope is the class $\mathbf{C_{22}}$*.Likewise,"***from*** $\boldsymbol{C_{11}}$**** and*** $\boldsymbol{C_{12}}$*" yields the scope "from $\mathbf{C_{22}}$*".
Meanwhile, subtraction operation, "***from*** $\boldsymbol{C_0}$**** -*** $\boldsymbol{C_{22}}$*" means that the class $\mathbf{C_{22}}$ and subclasses are removed from the search scope of $\mathbf{C_0}$*.

3.1.2 Ancestral search

The Ancestral search extends the scope of search from a child to parent nodes. The expressions are given as in the following;

select * from A%; *(9)*
select * from A! ;. *(10)*

The expression *(9)* extends the search scope to all the superclasses of ***A***, while the expression *(10)* limits the scope to direct ancestors of ***A***. In the example given in *Figure 1*, if the ***from*** clause after ***select*** is "***from*** $\boldsymbol{C_{22}\%}$", the search scope is extended from $\mathbf{C_{22}}$ to all the ancestors, i.e., $\mathbf{C_{11}}$, $\mathbf{C_{12}}$ and $\mathbf{C_0}$. On the other hand, if the clause is "***from*** $\boldsymbol{C_{22}!}$", the search scope is limited to only its direct ancestor s and excepts the class $\mathbf{C_{11}}$that exports properties to $\mathbf{C_{22}}$. Consequently, the search scope is $\mathbf{C_{22}}$, $\mathbf{C_{12}}$ and $\mathbf{C_0}$. In *Figure 1,* a dotted line is used to signify a secondary line of inheritance or a partial inheritance that is given a special name "*case_of*" in PLIB standard. In fact, PLIB allows single inheritance alone, but enables importation of designated properties from classes other than its superclass. In this way, it effects an *interface* for those properties, as it is in JAVA[TM] language. In the same manner, CQL can deal with multiple inheritance, though it arbitrary takes one of its superclasses as the primary superclass for ***"* from A!"*** type of operations.

3.1.3 Part-Whole Relationship

The Part-Whole relationship enables conditional reference from the whole(body) of a product to constituent parts. The Part-Whole relationship appears in the expression *(11),(12),(13)* for search, construction and updating;

select Pn from A where B.P' = 'condition'; *(11)*

insert into A(Pn) values (
B condition qid B.P' = 'condition'
); *(12)*
update A set Pn =
B condition qid B.P' = 'condition' where $\boldsymbol{P_0}$***= n;.*** *(13)*

In PLIB a specific data type named "class instance", represents this part-whole relationship. But this "class instance" differs from the conventional *part-of* in OOP in that the parts are referred not by an object-ID but by a set of reference conditions on membership.
In *Figure 1*, an arrow from $\mathbf{C_{23}}$ to $\mathbf{C''_{11}}$ represents *Part – Whole* relationship between $\mathbf{C_{23}}$ (*Whole*) and $\mathbf{C''_{11}}$(*Part*).
The example in *Figure 2* shows the image of this reference relationship from an instance in the *Whole* to a set of instances in a *Part*. Q1,Q2,Q3 are conditions for extracting a set of suitable member instances. In *Figure 2*, the expression *(14)* retrieves the set of members from the *Part* class $\mathbf{C''_{11}}$ **.**

select $\boldsymbol{P_2}$ ***from*** $\boldsymbol{C_{23}}$ ***where*** $\boldsymbol{C''_{11}.P'_1 = v_{11}}$***;*** *(14)*

To refer to a set of instances in *Part* class from an instance in *Whole* class, it is necessary to set up a condition in the "class instance" type property. The following expression (15),(16),(17) sets the condition.

insert into $\boldsymbol{C_{23}(P_0, P_1, P_2)}$ *values (*
v_{01}, v_{11}, $\boldsymbol{C''_{11}}$ *condition* Q_1 $\boldsymbol{C''_{11}.P'_1} = v_{11}$
); *(15)*

The expression *(16)* allows setting the value range as the condition.
insert into $\boldsymbol{C_{23}(P_0, P_1, P_2)}$ *values (*
v_{02}, v_{12}, $\boldsymbol{C''_{11}}$ *condition* Q_2
$\boldsymbol{C''_{11}.P'_1} > v'_{22}$ *and* $\boldsymbol{C''_{11}.P'_1} < v'_{24}$
); *(16)*

The expression *(17)* sets a condition by using a variable instead of a value.
insert into $\boldsymbol{C_{23}(P_0, P_1, P_2)}$ *values (*
v_{02}, v_{13}, $\boldsymbol{C''_{11}}$ *condition* Q_3 $\boldsymbol{C''_{11}.P'_1 = C_{23}.P_1}$
); *(17)*

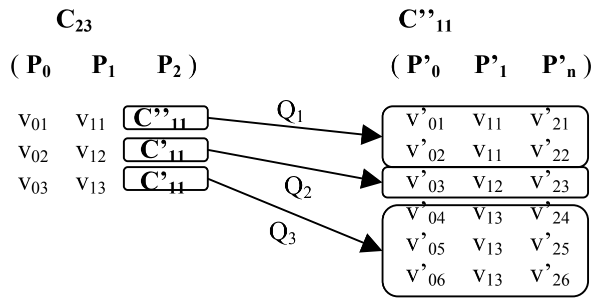


Figure 2: Class Instance

3.1.4 Property classification

The fourth feature, "Property classification", groups the properties by a label named ***classification***, that is currently a number. The expression is *(18)*.

create extension on A (
$\boldsymbol{P_1}$***,***
….
$\boldsymbol{P_i}$ ***constraint cid classification -100,***
….
$\boldsymbol{P_n}$
);, *(18)*
where A is a class and $\boldsymbol{P_1}$, $\boldsymbol{P_i}$ and $\boldsymbol{P_n}$ are properties.

The system may perform different process according to the *classification* of the properties. It depends on the implementation what kind of process is actually assigned to it, but the original intent of this feature is to control the visibility of properties depending upon the user groups.

3.1.5 Layered Security Controls

The last feature, "*Layered Security Controls*", exerts security control at the three levels, class, property, and instance.

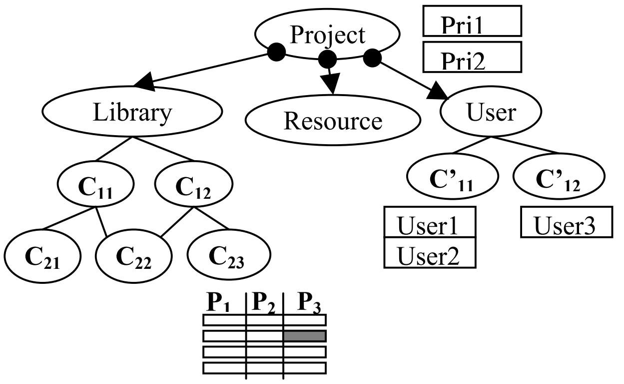


Figure 3: Special reserved classes for administration

In addition, CQL provides the following four special-purpose classes to administer the LMS.

1) ***Project***
2) ***Library***
3) ***Resource***
4) ***User***

The ***Project*** is the basic unit of data management. If a user wants to address a product data through CQL, he needs to be enrolled in at least one of the ***project instance*** as depicted in *Figure 3* that has one or several libraries of products. This concept does not derive from PLIB, since PLIB presumes the use of a textual file for data exchange; however, it is necessary for the CQL-based LMS to manage projects that utlise resources, because several people are engaged in several projects to exploit limited resources. The ***Project*** is the *whole* class for the three *Part* classes, ***Library, Resource***, and ***User***.
The **Library** is the root class of ordinary class hierarchies modelled in a project. From time to time, several libraries may be found in a projects. A library (in plain letter) here means a class hierarchy(ies) with product instance data. The ***Resource*** is the class which stores a physical file such as image files related to the project. The ***User*** is the class which stores information about the users of the project.
The ***User*** class may have subclasses, and each such a class has individual users as its instances.
Now, if a system grants a privilege to a class under ***User*** to do a specific operation to specific data, the expressions are as follows. To give access right to the classes under ***A*** to a User class,

grant select on A* to User_class; . *(19)*

If the privilege should be revoked,

revoke select on A* from User_class; . *(20)*

CQL grants privileges to a class under ***User*** instead of an individual user. Thus all the users, belonging to a class under ***User***, have same privileges. By appropriately organizing classes under **User,** based on a business model, user access may be controlled for each class of people.
The example in *Figure 3* shows a project's structure.
The following expression grants "select" operation on class $\mathbf{C_{12}}$ and its subclasses to the **User** class $\mathbf{C'_{11}}$.

grant select on C_{12}**** to*** C'_{11}***;*** . *(21)*

Other operations could be also permitted instead of "select". Secondly, CQL can exert access control over a property. The class $\mathbf{C_{12}}$ is assumed to have properties, $\mathbf{P_1}$, $\mathbf{P_2}$, $\mathbf{P_3}$. In this case the following expression revokes "select" operation on the property $\mathbf{P_1}$ from the ***User*** class $\mathbf{C'_{11}}$.

revoke select on P_1 ***from*** C'_{11}***;*** . (22)

At third, it can exert access control about an instance. The following expression revokes "select" operation on the class $\mathbf{C_{12}}$ and subclasses with the ***where*** clause meets the condition specified by "P_3 ***!= 'painting'*** " from the (users in) class $\mathbf{C'_{11}}$.

revoke select on C_{12}*******
where P_3 ***!= 'painting' from C';*** . (23)

"Property classification" that has been mentioned before, may also be used as security level classifier for properties.

3.2 Structural comparison of CQL, SQL, and OQL

In application of a database language to PLIB, we must first consider that PLIB has rich reservoir of data constructs to represent product data. In particular, it has an ability to describe a product that is composed of several components or parts. In addition, PLIB is extensively used in many leading industrial projects such as MERCI (Wilkes and Broking 2000) ,in Japan and in Europe to replace old-fashioned product database systems. Thus the language to describe product library system must reflect the PLIB model that requires the following four layers for representation.

1) Meta-schema for housing ontology
2) Ontology data as a class hierarchy or dictionary
3) Product database Schema
4) Database content data (product instance data)

Class library such as PLIB must provide competence to model those layers at least from the second to the fourth, and the first layer might be necessary if an LMS (Library Management System) is in consideration for the incorporation of various product libraries over time. SQL could define the data structure of a table and its attributes, but it doesn't take care of the ontological structure among tables. SQL-99 allows inheritance of data elements, however it only takes care about simple inheritance from another table. Thus, it is difficult to represent product ontology by SQL.
On the other hand, OQL uses methods to define a class and store data. Because of the data encapsulation, indeed, an OQL user has to comprehend the intent of the class-designer to effectively manipulate data, for the views of the world are different among designers of the objects and there is no "objective view" about this. Note that CQL uses Boolean operations between classes and the specification of class properties in where clause to retrieve the requested data. Thus the order of the property specifications is irrelevant to the resulting set.

CQL provides three types of definition language, the first is Class Modeling Language (CML), the second is Data Representation Language (DRL), and the third is Library Manipulation Language (LML). In addition, if CQL processor is available, a record of CQL commands stored in a file addressed the necessity for the first layer. Thus, the CML manages the product ontology and also a meta-schema for ontology, the DRL manages a database schema and the LML manages content data. *Table1* shows the comparison among CQL, SQL, and OQL in each PLIB layer.

Table 1: Comparison of Query Languages

	CQL	SQL	OQL
Product Ontology	CML (create class alter class i.e.)	-------------	Method
Database Schema	DRL (create alter i.e.)	DDL (create alter)	Method
Content Data	LML (insert, update i.e.)	DML (insert , update i.e.)	Method

3.3 Application of CQL Language to PLIB

3.3.1 Basic notation of property and class.

The fundamental concept of CQL about object identification is that it identifies an object by a code not by a name of the object. In addition, in application of the CQL to PLIB, some additional functionalities are provided. Firstly, the name space resolving functionality that converts a name of a given object in a known context into a full BSU notation. This does not imply that any automated semantic analysis of terms was brought into CQL like the one in Semantic WEB project in W3C. Unlike the semantic approach, CQL only enables a kind of shortcut notation at the level of user-interface, that translates an input class name into a full fledged BSU notation since a property of a class is noted as,

suplier_BSU. class_BSU. property_BSU . *(24)*

The name space resolver only adds a supplier_BSU code to the class_BSU, linked by a dot when a supplier_BSU code is defined a priori as the default value.
Secondly, following the description of updating rules defined in Part42 (Pierra 1997) and Part24 (Pierra 2001) of ISO13584, the version and revision controls are added to the BSU notation of CQL. Thirdly, the dictionary is assigned an identifier with a version and a revision; when two systems employ exactly the same set of classes and properties, the two must have the same dictionaries with the same version and the same revision. This will facilitates the parts library exchange between two systems, since the export of data from one system to another is only possible if the target system has an identical or a newer version of the dictionary .

3.3.2 Usage examples of CQL

The example in *Figure 4* shows a simple class tree of vehicle and each class has properties as illustrated in *Figure5*. The class tree and the properties are simplified just for the ease of explanation. For simplification, hereafter, supplier_BSU's are omitted for the notation.

- *Creation of Class and Property, and its container*

The class and properties are defined by CML.
The following expression creates a class named "Electric Vehicle" as in Figure 4. The class_BSU code is assumed to be "Electric" for the ease of understanding, although in PLIB this is an unrecommended practice.

create class Electric (
super_class Ecological,
preferred_name 'Electric Vehicle',
short_name 'EV',
definition 'The Vehicle equipped with
the electric motor as a motor.'
) *(25)*

where "super_class", "preferred_name", "short_name", "definition" .. i.e., are reserved words in PLIB.
Next, the following expression creates a property named "motor_max_power" within the class "Electric Vehicle".

create property motor_max_power (
preferred_name 'motor maximum power',
name_scope Electric,
data_type real_measure_type,
unit 'kW',
definition 'The maximum power of motor which
can be exploited within the limit of
the number of rotation.'
); *(26)*

Likewise "**case of**" class, is constructed as follows;

create class Hybrid (
super_class Electric,
preferred_name 'Hybrid Vehicle',
short_name 'Hybrid car'
definition '',
is_case_of (Sedan)
imported_properties (displacement, engine_type)
); *(27)*

After the creation of classes and properties, a container for storing instances is required. It is defined by DRL. The following gives the container of the class "Electric Vehicle".

create extension on Electric(
pid, name, maker, weight, max_speed,
motor_max_power, motor_type
); *(28)*

Similarly the container for the "Hybrid Vehicle" can be built.

Now, it is ready to insert an instance into each container. LML manipulates an instance into a container. In the following manner, instances are inserted into respective containers:

```
insert into Electric(pid, name, maker. weight, max_speed,
motor_max_power, motor_type)
values ('2', 'EV1', 'GM', ,129, 102, 'Transverse-
mounted, front-wheel drive' );                    (29)
```

```
insert into Hybrid(pid, name, maker, weight, max_speed,
motor_max_power, motor_type, displacement,
engine_type)
 values ('4', 'prius' ,'toyota', 1220, , 33, '2CM', 1496,
DOHC);                                            (30)
```

```
insert into Sedan(pid, name, maker, weight, max_speed,
displacement, engine_type)
values('5', 'E CLASS', 'BENZ', 1690, , 4265, 'SOHC')
                                                  (31)
```

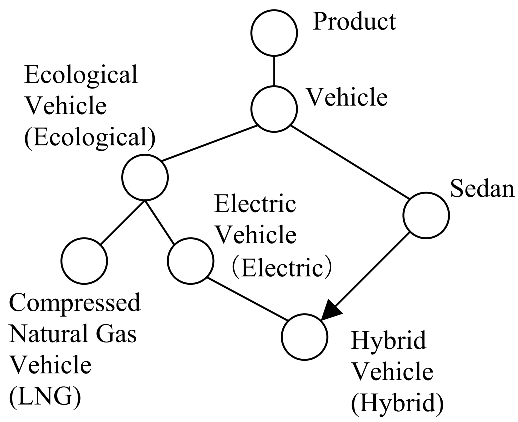


Figure 4: Sample tree for vehicle

Product(pid, name, maker, price)
Vehicle(weight, max_speed)
Sedan(displacement, engine_type)
Electric Vehicle (motor_max_power, motor_type)

Figure 5 : Sample: Class (Properties)

- *Querying the data*

The formal syntax of CQL for ***select*** operation is as follows:

```
SELECT * | [suplier_BSU.class_BSU.] property_BSU
        { , [suplier_BSU. class_BSU.] property_BSU }
FROM [suplier_BSU.] class_BSU[*] { [ AND | - | ,
        [suplier_BSU.] class_BSU[*]  }
[WHERE [suplier_BSU.class_BSU.] property_BSU
         OPERATOR VALUE
        { [AND | OR]
         [suplier_BSU.class_BSU.] property_BSU
        OPERATOR VALUE }
        [ INSTANCENUM
        COMPARISON_OPERATOR NUMBER ]
]
[ORDER BY[ suplier_BSU.class_BSU.] property_BSU
         [ASC] | [DESC]
        { ,[suplier_BSU.class_BSU.] property_BSU
         [ASC] | [DESC] } ;
                                                  (32)
```

OPERATOR may be either **<, >, =, <=, >=, <>, *LIKE*** .
VALUE may be a literal value or a sequence of ***suplier_BSU.class_BSU. property_BSU*** .
COMPARISON_OPERATOR may be either **<, <=** .
NUMBER must be a number value.

In the example given in *Figure 4*, the subclasses inherit their superclass's properties. The class "Electric Vehicle" is a superclass of the "Hybrid Vehicle" class, and the "Sedan" class exports its own properties to the "castoff" class "Hybrid Vehicle".
If the user would like to search instances whose maker is 'toyota', without caring about detailed classification, the following query expression is helpful.

```
select * from Vehicle* where maker = 'toyota';  . (33)
```

The result gives instances found not only in the class "Vehicle" but also in the subclasses, "Sedan", "LNG", and "Hybrid Vehicle". *Figure 6* gives the summary of this.

pid	name	maker	weight	max_speed
2	EV_1	GM		129
4	prius	toyota	1220	
5	E class	BENZ	1690	

Figure 6: The result example

If the user would like to search the ecological vehicles with the characteristics of Sedan, the Boolean operation like the following expression is useful.

```
select * from Ecological* AND Sedan*;      (34)
```

The result of this query might be the instances in "Hybrid Vehicle".

pid	name	maker	weight	max_speed
4	prius	toyota	1220	

Figure 7: The result example for the Boolean operation

Like an Electric Vehicle, according to the development of new technology, it might be necessary to create a new subtype of vehicle class. For this, the class classification needs to evolve. In this situation, the instances built with conventional technologies would remain in some ancestral classes, while the new instances would be stored in a derived class. The following expression provides the ancestral search for those conventional instances.

```
select * from Hybrid% where motor_max_power > 30
                                                  (35)
```

This query searches not only "Hybrid Vehicle" but also the ancestor classes having the property "motor_max_power". Thus the search scope extends to "Hybrid Vehicle" and

"Electric Vehicle". Consequently ,and the result of this query is summarised as in the following.

pid	name	maker	weight	max_speed	motor_max_power
2	EV1	GM		129	102
4	prius	toyota	1220		33

Figure 8: The result example for the ancestor search

If the search scope is required to except the class with "case of" relationship, "!" is used instead of "%".

3.3.3 Class instance and the conditional reference

Tires are considered to be parts of a product, named car. Since class instance make reference from products to parts, we add the tire property whose data_type is class_instance, to the Vehicle class. This property refers to the tire class.

create property tire(
preferred_name 'tire information',
name_scope Vehicle,
data_type class_instance tire
); (36)

And then, we create the tire_size property and the container for contents.

create property tire_size(
preferred_name 'tire size',
name_scope Vehicle,
data_type string_type
) ; (37)

create extension on Sedan(
pid constraint spk1 key,
name constraint spk2 key,
maker constraint spk3 key,
weight,
max_speed,
displacement,
engine_type
tire_size,
tire
) ; (38)

The reference condition is set by the following expression. It means this product refers to tires whose size is specified as '175/70R13 82S'.

insert into Sedan(pid, name, maker, tire_size, tire)
values('7', 'familia', 'mazda', '175/70R13 82S',
tire condition q1 tire.size = '175/70R13 82S');
(39)

In conditions, variables are also available. The following expression uses Sedan's property "tire_size" as a variable instead of the string value.

insert into Sedan(pid, name, maker, tire_size, tire)
values('7', 'familia', 'mazda', '175/70R13 82S',
tire condition q1 tire.size = Sedan.tire_size);
(40)

maker	name	size	outline_size
Brigdgestone	GR-7000	175/70R13 82H	578
Brigdgestone	GRID-II	175/70R13 82H	576
Brigdgestone	B-Road SF-270	175/70R13 82S	576
FALKEN	SINCERA	175/70R13 82S	576
TOYO TIRE	TRANPAT	175/70R13 82S	576

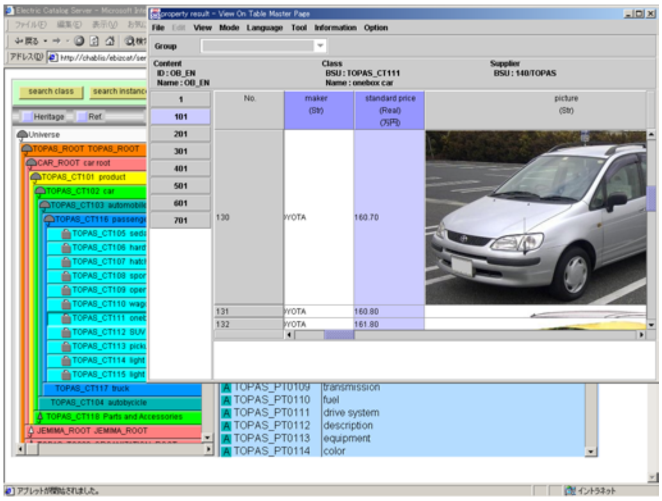
Figure 9: The sample of tire instances

If the tire class is assumed to have instances in Figure 9. The applicable tires for this car would be the instances given in *Figure10*.

maker	name	tire_size	outline_size
Brigdgestone	B-Road SF-270	175/70R13 82S	576
FALKEN	SINCERA	175/70R13 82S	576
TOYO TIRE	TRANPAT	175/70R13 82S	576

Figure 10: The applicable tires

In this way, the car makers and tire makers can concentrate on building their own catalogues without incorporating the data of the other into the body of their catalogue description. Also, this helps making the process of the engineering more concurrent.



Figures 11 OmniPhase Screen Image

4. Conclusion and Future Prospect

In this paper, a new database language short named "CQL" is presented. This language has an advantage over SQL in that it can model class hierarchy. It also has an advantage over OQL in that it employs Boolean operation for data operation. This gives ease to end-users and eliminates the necessity to know about the detail of the class definition or the specification of embedding language. Lastly some examples of CQL operation to build a simple class library for automobiles are presented.
With the implementation of CQL in our laboratory, construction of an extended PLIB-LMS code named "OmniPhase" is under way. *Figures11* gives a glimpse of

the image of the software. In the system, the CQL is exploited for two objectives; one is to facilitate the communication between database server and its client programs. This was actually programmed in JAVA™ language, and the server employs servlet technology and most of the clients are realised with applets including swing libraries. In one client program, the Java Scripts and DHTML are used to give ease to the integration with external application programs. The other objective is to give user interface to external users or programs. This interface is currently programmed in C++ language and it renders service to a CGI program that is also programmed in C++ by another company. This interface allows a connection to a client program with an execClassQuery statement, like the one available in JDBC (Java Database connection). More detailed specification is given in one of our PLIB sites specified by the following URL:

http://www.toplib.com/en/cql.html

5. *Acknowledgement*

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A CAPABILITY ANALYSIS METHOD FOR THE TECHNICAL ASSESSMENT OF QUALITATIVE DESIGN AND PROCESS PLANNING KNOWLEDGE

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KEYWORDS
Enterprise Knowledge Management, Process Planning, Capability.

NOMENCLATURE

s_r	Required capability score
s_z	Worst capability score
s_{rz}	Bandwidth
I	Improvement potential
s_{oz}	Total bandwidth
PCS	Priority confidence score
s	Current score
F_w	Factor weighting

ABSTRACT

Recent developments in the area of emergent synthesis problems (Ueda et al. 01) mean that it is possible to explore the effects of manufacturing process and resource selection during the earliest phases of design. To do this effectively requires new approaches to the modelling, management and representation of enterprise knowledge. This paper describes a Knowledge-Enriched Aggregate Process Planning (KEAPP) framework for supporting early design and enterprise-wide process planning with a new method for capturing and managing quantitative and qualitative forms of enterprise knowledge which are represented as 'knowledge statements'. During knowledge-enriched planning, knowledge statements (relating to important improvement areas, or *factors*) are processed to determine their relative performance. Thus areas of low capability can be identified, and targeted for improvement, within a large process plan hierarchy.

INTRODUCTION

During the earliest stages of design, choices made regarding the selection of manufacturing processes and resources have a major bearing on the final cost of a product. However, such decisions are often executed without reference to past experience and are characterised by imprecise or uncertain knowledge on the part of the designer. For complex assemblies, such as those commonly found in the space industry, these decisions are often complicated by the vast amount of information which is involved in constructing a process plan. The link between effectively managing knowledge, throughout the whole enterprise, and business performance has long been recognised (Roberts 01). Eighty five percent of companies surveyed for the Cranfield/Information Strategy Knowledge Survey (Cranfield 98) recognised that the knowledge that their employees possess was an exploitable asset. The survey concluded that, in order to obtain real business benefits from enterprise knowledge, new integrated approaches to its product and process knowledge management will be required.

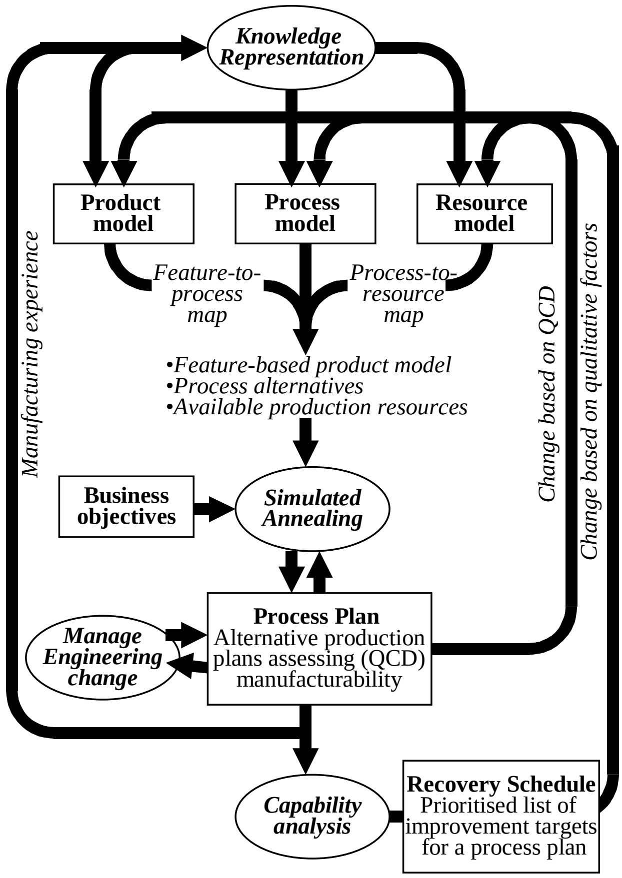

Figure 1: CAPABLE/space Functionality

CAPABLE/SPACE: THE FOUNDATION

The underpinning technology for KEAPP is an Aggregate Process Planning methodology for translating product designs into process and resource requirements. This methodology has been implemented in CAPABLE/space, a

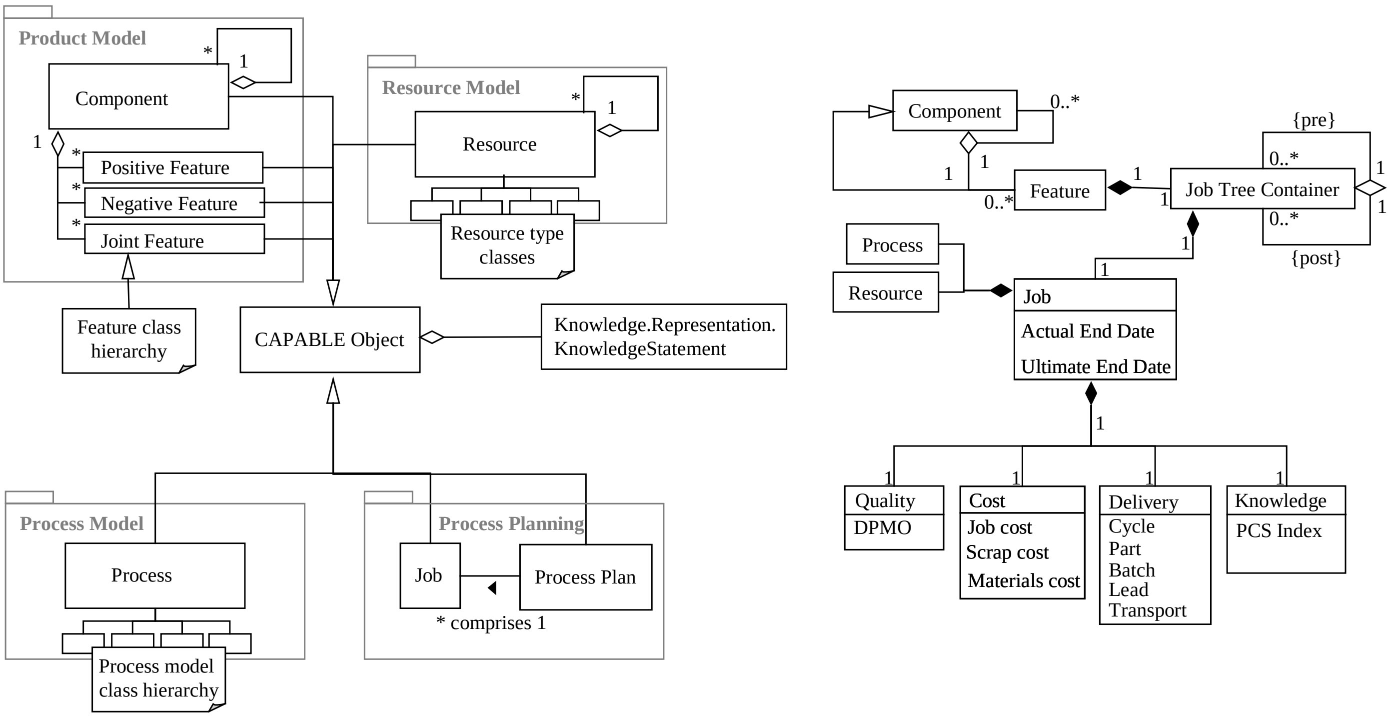

Figure 2: The Enterprise Models in CAPABLE/space

Java based prototype planning system for satellite structures (Figure 1). The key features of CAPABLE/space are:

- Distributed modelling of products and resources for the enterprise
- Optimising the selection of processes and resources
- Representation of knowledge related to products, processes and resources
- Management of knowledge via Capability Analysis

For the purposes of Aggregate Process Planning an enterprise model is constructed, at an appropriate level of detail, from three libraries of object-oriented classes. Figure 2 shows the implementation of the three models, note that, three super-classes, Component, Resource and Process all have the ability to be associated with multiple Knowledge Statement classes.

Product Model

The Product Model is a hierarchy of components and features, which serve to represent various products. The features are taken from a library of classes, modelling manufacturing features. Features are further classified into positive, negative and joint features. The digital representation of a product utilises these classes in a parent-to-child hierarchy and is constructed within a feature based design environment. The aggregate product model allows the effective representation of early product configurations including:

- Bill-of-Materials-like assembly structure
- Key feature geometry
- Un-related tolerances
- Material information

Resource Model

A factory model is also generated, for each potential supplier, which describes their manufacturing capability through the use of resource objects. A resource object describes the manufacturing capability of a machine or person by capturing process data and a reduced set of operating parameters relevant to its class. The parameters captured by the Aggregate Resource Model include:

- Process compatibility map
- Critical operating parameters
- Historical process capability data
- ABC cost data
- Machine availability
- Physical location of resources

Process Model

A taxonomy of process classes for discrete part manufacture (machining and ancillary processes) and assembly operations (part handling and fastening) exists to model manufacturing operations. Central to the aggregate process model classes are algorithms, derived from the simplification of detailed process models, which estimate Quality, Cost and Delivery (QCD) performance based upon the feature characteristics of the product model and operating parameters from the resource. Each Aggregate Process Model contains the following:

- Feature compatibility map
- Simplified physical or empirical process model
- Pre- and post- process requirements
- Technological process constraints

AUTOMATIC EXPLORATION OF THE SEARCH SPACE

The CAPABLE/space system uses a custom Simulated Annealing (SA) algorithm to intelligently explore the search space generated as a result of the many possible process and resource configurations. The result of aggregate planning is a routing, consisting of a hierarchical tree of jobs (a job is defined as one feature, one process and one resource) which mirror the product model structure and represent the sequence of required operations. The SA functions by random selection, substitution and evaluation of the processes and resources assigned to jobs within the plan, and is evaluated via an energy function (Equation 1) based upon quality, cost, delivery (QCD) and knowledge criteria to represent the manufacturability of the current solution.

$$\text{Energy}_{SA} = f\left(Q_L, (C_J + C_M), D_L, K_L\right) \qquad (1)$$

where;

D_L	Cost associated with exceeding the delivery target
Q_L	Quality loss based on probable yield multiplied by scrap or rework cost as appropriate.
C_J	Processing cost, as process delivery multiplied by cost rate
C_M	Cost of raw materials
K_L	Knowledge loss - penalty due to capability deficiencies of a job

The SA requires that each process model maintain algorithms capable of generating sufficiently accurate estimates for the quantitative manufacturing performance metrics of QCD. QCD are important guides to process plan performance because they are directly visible to the end-user, however, they are of limited use for internal performance improvement strategies. The challenge facing manufacturing research is the development of robust methods for the progression of traditional knowledge management techniques to cope with the incomplete environment specifications and to deal with the differing information needs of various users during design. More specifically, the requirement for aggregate planning is for the addition of new tools for capturing and making use of distributed design and process knowledge to ensure synergy between the product design and the production system that will make it.

KNOWLEDGE-ENRICHED PLANNING

The enhancement of the planning function with quantitative and qualitative knowledge has two key functions: representation and management via capability analysis.

Definition of Capability Analysis Terms

'Knowledge statements' are defined as statements and opinions resulting from enterprise knowledge, which are expressed either verbally or written by experts, that can be collated using traditional knowledge elicitation methods and attached to process plan classes and/or objects collected using existing methods (Thurston 91) (Sriram and Garcia 97).

Capability is defined as the extent to which an enterprise is achieving required performance with respect to factor-specific business objectives. To measure capability three concepts are defined:

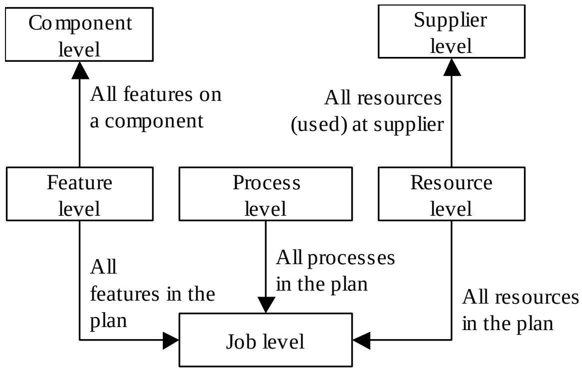

Figure 3: Capability Level for Analysis of Process Plans

A *capability factor* is an unambiguous and measurable indicator of some aspect of manufacturing performance against which knowledge statements can be evaluated.

A *capability level* is a group of capability factors which address a given aspect of the process plan; in this case levels correspond to jobs, components, features, processes, suppliers and resources (see Figure 3). Note that the capability scores assigned at feature level can be used to calculate summarised scores at the higher component level.

A *capability score* is the measured value, either calculated or user-defined, of a capability factor for a given object. The premise of CA methods is that all the capability scores for a factor should be similar.

Knowledge Representation

Capturing design knowledge is a complex issue and presents many difficult problems (Bailey et al. 00), thus, for the CAPABLE/space technology demonstrator, a stand alone performance measurement system was developed to capture the manufacturing performance implications of expert knowledge related to key business objectives. When an expert attaches a qualitative Knowledge Statement to one of the enterprise model objects he/she is required to provide the following information which permits a capability score to be generated after process planning has taken place.

- **Conditionality**. Often, knowledge statements will be conditional on the presence of a particular combination of feature, process and resource. The default case is to have knowledge valid for all objects, but experts can alternatively restrict the knowledge to be applicable when a job contains certain objects only.
- **Probability**. Qualitative enterprise knowledge is a stochastic element, that is, events represented by knowledge statements may or may not take place in the future. This is accounted for by assigning a probability to the score referred to by the statement and calculating an expected score based on the factor value.

- **Factor Value**. A factor-specific value is assigned to a knowledge statement to express an expert's preference for including an object in the plan as a result of his or her experience. All scores allocated to each factor must be ranked on the same scale. For qualitative knowledge scores an arbitrary scale from 0 to 100, where 0 means strongly desirable and 100 represents strongly undesirable, was selected. Alternatively, as in the case of quantitative knowledge factors, the directly calculated values (including units) can be used directly as long as they remain consistent within the factor.

The authors are aware of important issues such as data lifespan, duplication and of confidence in user input that are not addressed in the current prototype system. It is planned that these issues will be addressed as part of an ongoing effort to link these technologies with a PDM system.

Knowledge Management

Capability Analysis is the method for determining the relative priorities of factor scores from knowledge statements from the large number which could be associated with the objects in the process plan. Priority Confidence Scores are the primary units for measuring capability. These represent the potential for improvement of a collated group of reliability scores, determined by measuring a score's capability deficiency from the best-in-class performance. Critically, priority confidence scores (PCS) are dimensionless, and hence PCSs for different factors can be directly compared and ranked according to their potential for improvement. The outcome is that weaknesses in the process plan are flagged for detailed analysis.

Capability Analysis Walkthrough

Enterprise Model Object	Statement	Expected Score	c_m	PCS
Factory 1	98% on time	2.00	0.09	0.08
Factory 2	99% on time	1.00	0.04	0.04
Supplier A	95% on time	5.00	0.22	0.21
Supplier B	94% on time	10.00	0.43	0.42
Supplier C	76% on time	24.00	1.04	1.00

Table 1: Capability Analysis Data for 'supplier_delivery'

With reference to the data provided in Table 1, showing capability scores relating to the 'supplier_delivery' factor at the supplier level, the priority confidence scores for the collated group of scores are formulated as follows:

1. In practice, capability scores which are assigned to a factor all vary, thus each collated group will have a worst score and a best score. The optimum capability score represents the ideal case, where all capability scores are zero. For simplicity, the analyses described assume that the required score will be equal to the best score in the group. A collated group of scores can be visualised as shown in the figure. Bandwidth is defined as the difference between the required and the worst capability scores:

$$s_{rz} = s_z - s_r \tag{2}$$

2. To facilitate the comparison of dissimilar indicators of manufacturing performance, marginal capability is defined to express the capability score as a percentage of the required capability of the collated group.

$$c_m = \frac{c}{s_{rz}} \tag{3}$$

3. The improvement potential of the collated group of scores is used to indicate the improvement possible though moving the required capability score nearer to the optimum. Thus:

$$I = \frac{s_{rz}}{s_{oz}} \tag{4}$$

   The improvement potential of the collated factor, 'supplier_delivery', is therefore, s_{rz}/s_{oz} = 0.96. An interesting characteristic of the improvement potential is that it can be used to provide a quick assessment of how much further a design or process can be improved. By simply ranking the improvement potentials of all the groups in the analysis, the design team can observe the slackness in capability for each key factor, quickly forming an opinion as to questions such as "can we make this 20% cheaper/faster, or should be thinking about re-design/new suppliers?".

4. To measure the extent that each individual score is a target for improvement a priority confidence score (PCS) is calculated. As already mentioned, PCSs are dimensionless and can thus be directly compared with one another, even where the source data is not comparable. A factor weighting is used to model the importance of each capability factor in the current analysis. For simplicity, the factor weighting is taken from a user-defined value which is applied at the domain level (calculated using a normalised weighting procedure).

$$PCS = F_w.I.c_m\% \tag{5}$$

   Assuming a factor weighting of 1, the calculated PCSs for the group are shown in Table 1.

The ability to investigate information in detail and to provide representations of any summarised information is achieved through the use of a recovery schedule. A recovery schedule is created for each capability level and ranks the PCS vales of all the scores belonging to factors at the current level. Thus, the scores with the greatest PCS are identified and hence brought to the attention of the designer. The recovery schedule aids product redesign and factory configuration during subsequent design phases. Recovery schedules can be re-generated at each level and sub-level in order to discover the root causes of high capability deficiencies at the higher level. For example, the designer may first carry out a factory level analysis of a process plan. This might highlight a supplier with a particular quality problem, and a subsequent lower level analysis of all the machines in the factory could pinpoint the problem to a specific machine.

CONCLUSION

A Knowledge-Enriched Aggregate Process Planning system has been developed in which a generic Capability Analysis method has been integrated with an Aggregate Process Planning system to provide a powerful toolset for the technical assessment of early product designs using multiple criteria. In particular, this research has shown that the fusion of qualitative and quantitative knowledge factors with the traditional planning metrics of QCD is possible, giving designers access to knowledge and expertise that they do not normally possess. The benefits of the system to industrial users are:

- (i) Combined optimisation of product structure and resource allocation.
- (ii) Detailed product design and factory reconfiguration are more efficient because the feedback of prioritised improvement targets in the recovery schedule triggers the application of target areas, where detailed modelling would be most beneficial.
- (iii) Gain competitive advantage by quantifying, analysing and acting upon enterprise knowledge.

Clearly, a key requirement for the future adoption of these new methods is that they should be compatible with existing and future enterprise management software, and indeed, such additional functionality is already being developed.

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BIOGRAPHY

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COLLABORATIVE CE ENVIRONMENTS AND VIRTUAL TEAMS

THE SELECTION OF APPROPRIATE CE TOOLS FOR SMALL AND MEDIUM- SIZED ENTERPRISES

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KEYWORDS
Concurrent Engineering tools, Scalability issues, Small and medium-sized enterprise (SME), Organisational learning

ABSTRACT

The paper deals with scalability and compatibility issues in Small and Medium-sized Enterprises. Novel issues examined include the choice of CE tools for servicing contracts between manufacturing firms of different sizes as well as the interplay between the firms as both competitors and technical-collaborators. The firms investigated are UK bicycle manufacturers competing against a global trend to larger manufacturers located in the Far East. However, the relationship between smaller firms and much larger ones is far from straightforward and influences the decision-making process. Furthermore, the choice of CE tools is more than simply an engineering decision made by engineers in isolation. The widening of participation to include specialists from other disciplines makes the present-day composition of CE teams different than in the past. The paper makes suggestions for using an integrated approach to the selection of CE tools for smaller firms in the light of these findings.

SMES ARE SPECIAL: THE REASONS WHY

SMEs constitute special instances of corporate resources and may provide imaginative and innovative approaches difficult to replicate in larger, more structured firms. However, there are frequently shortages of materials, manpower and machinery. This may be compounded by a lack of money to invest in new production facilities. Therefore, it is essential to "get it right" first time and it is here that CE techniques may yet yield the greatest benefits.

SCALABILITY ISSUES

This is using tools that are much too powerful for the task in hand, like using a sledgehammer to crack a nut. Interestingly, scalability is usually documented in dealing with larger tasks. The scaling-down of CE tools is frequently ignored. It is inappropriate to suggest that what suits large well-resourced multi-national firms will work equally well in much smaller firms. This is because the smaller firms have a much smaller pool of time and talent to draw from. Moreover, the smaller firm requires a greater working-life from CE tools to recoup the initial cost of acquisition because of the smaller production runs.

PARALLELS WITH LARGE FIRMS

Even in the largest and best-resourced firms there will still be room for improvement. The documenting and honest admission of shortcomings, however minor, is a very positive characteristic in Concurrent Engineering. It reveals a very high level of professionalism and a willingness to share with others. It also shows an extremely positive insistence on ever-higher standards. A recent case study (Baake et al. 1999) noted some very promising possibilities for improvements to an extremely useful system of producing and storing a virtual specification.

Table 1: Using an Electronic Specification -A Case Study from CE Literature

ADVANTAGES	DISADVANTAGES
Reduces reliance on paper	Difficult to obtain correct data and process history
Can be sent electronically	Difficult to obtain correct data and process history
Stable	Lacking safe file
In-house development	Sometimes lacking a follow-up
Enables technology transfer to other locations e.g. new factories	To save or not- at the engineers discretion

Table 1 outlines the advantages and advantages of an innovative and interesting system to store an electronic specification. Note that the difficulties can be viewed as management problems rather than technical.

In other large-scale projects there are issues outside the purely technical arena. A recent paper (Schwarz and Vilsmeier 1998) dealing with the European Aircraft Industry (EAI) notes that aspects of human resource management are becoming more important for achieving co-operation between two equal partners.

Table 2: The Implications of using simpler Software Tools in smaller Firms

DISADVANTAGES	ADVANTAGES
Software firms less interested	Easy to use
Less-versatile	Stable
May require more frequent upgrading	Easy to maintain – few features
Employees may feel “short-changed”	Can run on older, slower hardware
Fuels a feeling a that “bigger is better”	Simple to transfer to other industries

The above table outlines the benefits and drawbacks of simpler software for smaller firms. Moreover, smaller firms may lack expertise in the acquisition, implementation and maintenance of new CE tools. All of this may represent an undesirable additional burden upon hard-pressed small firms.

THE IMPLICATIONS FOR SMALL FIRMS

Smaller firms cannot hope to deal with the many features and changes of the systems in larger firms. Rather, the smaller firm must focus on doing what it does best and satisfying its customer base. This suggests a simpler system than used by larger firms. However, the simpler system should have a number of advantages for firms with scarce resources.
Furthermore, an integrated approach to dealing with suppliers or prospective suppliers would represent a step forward. There are already leading North-American large-scale manufacturers that insist on all suppliers or prospective suppliers undertake the administration of orders on-line. The use of on-line resources for managing engineering specifications is an extension of this.

THE NEED FOR A METHODOLOGY

The difficulties noted in a high-quality study (Baake et al.1999) point toward the need for a clear and consistent methodology. This is necessary in order to obtain up to date process histories and data that are transparent as well as accurate.

THE NEED FOR AN ORGANISATIONAL MEMORY

This may seem superfluous in a small firm. After all, the total number of workers is small and there is a great deal of informal interaction. However, it is these two points-common features of smaller firms-that makes it important to document information that could be used in the future. The documentation of CE information needs to be clear and unambiguous so that workers may access relevant and accurate information.

The very nature of small firms means that if one key worker leaves then much of that knowledge is also lost. Moreover, the informal nature of many smaller firms means that much of the existing knowledge is “Caught not taught”: - it is passed from one worker to another in an unstructured way (Hebst and Manhart 1998).

DECISION-SUPPORT TOOLS

There are many possible decision support tools available at present. However, some of the tools are rather difficult to use. Moreover, it is problematic to integrate a full range of tools to make comprehensive CE toolkit for smaller firms.

ASEASYAS Tool

This decision-support tool assists manufacturers in a number of key areas. However, it does not actually provide an answer to the most basic questions that are pivotal. These basic questions range from the “buy or build” question to the most basic question: “Is this activity necessary?”

Table 3: The “ASEASYAS” tool

ADVANTAGES	DISADVANTAGES
Can estimate run-times	Accepts nonsense units and quantities
Can predict costs of storage	Treats non-hazardous and hazardous materials as the same for predicting costs
Can predict optimal quantities for manufacture	Possibly viewed as rather old-fashioned
Can predict costs of finishing	Results not very simple to understand
Well-documented	Needs manual input of data

Table 3 summarises the advantages and disadvantages of the ASEASYAS decision-support tool.

When used with care the ASEASYAS tool can provide insight into the costs and quantities required for the efficient use of materials, manpower and machines.

The PASSOT system for open tenders

The PASSOT system for tendering and supply (Ito 2001) is a very useful tool. It provides clear and unambiguous information regarding quality, quantity and cost. However, it is suggested that PASSOT could be further refined by the addition of greater degree of interactivity. This could assist both supplier and purchaser in reaching an agreement.

Thus, the on-line communication would mirror the highly interactive process of striking a bargain and may result in arriving at orders that will be filled on time. The PASSOT system may well be more appropriate for smaller companies because it is exactly these smaller firms that have difficulties in obtaining parts.

Moreover, the smaller firms do not have large amounts of money to advertise their needs in trade journals so web-based communication should be more cost-effective in reaching distant suppliers.

At a bare minimum, the use of the PASSOT decision-support system assists manufacturers in the clarification of submitting bids and tenders. This is because it requires the explicit expression of information regarding cost, warranty, performance and relations.

THE SIMULATION OF ALTERNATIVE PARTS, MATERIALS AND SUPPLIES

This could include the upgrading or production of cheaper economy ("clipper") variants or to simply allow for continuing production when suppliers fail to deliver on time. The difficulties in obtaining parts and materials are known to be recurring problem areas (Hignett and Zobel 2001), particularly in SMEs.

THE CHANGES IN SCHEDULING

A research engineer (Arenas 2000) working on a real-world project for a bus factory in Hungary found that the reorganisation of scheduling could deliver a two-fold increase in production as well as other benefits.

The following table summarises the example of the Hungarian bus-factory. Note that the disadvantages are really management problems and not engineering or technical difficulties.

Table 4: A Case-study - The Advantages and Disadvantages of Re-engineering Scheduling

ADVANTAGES	DISADVANTAGES
Doubling of production	Less slack in the system
Painting shop-simpler and less stressful	Requires more organisation
The load on production stations is less	Requires better co-ordination between different sections
Overtime was reduced	Production staff may become disaffected
Lead-time reduced-one week per bus	Spares inventory may become depleted
Work-in progress reduced	Marketing may be problematic
New system is more reliable	
Uses existing production site	
Linked to Excel spreadsheet	Professional spreadsheets need audit-trails and trace-backs of changes

OTHER TOOLS AND TECHNIQUES FOR SCHEDULING

In the case of smaller firms there may not be sufficient manpower available to try more than a few of the various tools and techniques for scheduling. Therefore, it is suggested that a "short-list" be made to identify the main advantages and disadvantages of each tool. This would help simplify and speed up the process of selection as well as produce a more accurate specification. The balancing of positive against negative features also helps keep the decision-making more objective and less personal. Additionally, the use of process modelling could help in dealing with difficult areas like places or processes where production is held up ("bottlenecks"). This could point to the use of "buffers" where parts can be stored for a short time until required. The use of "buffers" at suitable places could even serve the firm if the stored parts were also in demand as consumable spares.

Thus, the production of spares as well as complete bicycles could then be integrated. At present, the production of spares is sometimes an afterthought and this can harm the reputation of the firm. However, this goes against current practice for holding minimum stocks. The cost of holding unsold stocks is a well-recognised cause of firms ceasing manufacture.

Moreover, there are significant environmental concerns. Firms producing more parts than necessary for immediate needs are consuming energy and raw materials as well as using manpower and machine-time in a less-than frugal way. The modern firm should be lean, mean as well as green and this is a delicate balance.

COMPATIBILITY ISSUES

When smaller firms seek to act as suppliers, designers or sub-contractors for much larger firms there may be compatibility requirements imposed on smaller firms by larger customers. The larger firms can specify the suppliers must comply with certain interfaces in order to fulfil the terms of a contract. The different sizes of firm can then interact although they clearly differ in terms of size, structure and specialisation
Additionally, this may introduce other issues such as Human-Computer Interaction (HCI).

The smaller firm may then be viewed as a subset of the larger CE system.

NETWORK MAINTENANCE ISSUES

The smaller firm may find itself in a strange position after it has won a sizeable contract with a much larger organisation. The first point is that the smaller firm starts to incur costs in order to service the new contract. The second is that the small firm loses independence over how it must service the terms of the contract. One point that may encompass both organisational independence and costs concerns the support of networked services. The smaller firm maybe required to acquire new or improved hardware, software and maintenance. Additionally, there maybe new software licences to obtain.

COMPATABILITY ISSUES WITH DIFFERENT – SIZED ORGANISATIONS

The various partners supplying goods and services to a much larger organisation may find themselves locked into systems that they would not have otherwise chosen. The largest firm takes the decision. The situation may be further complicated because a large organisation may source from a number of different suppliers. This means that any technological lead enabled by CE tools and techniques may be negated. They are all available to all.

CONCURRENT ENGINEERING TOOLS FOR ENABLING TECHNOLOGICAL COMPLEXITY

The largest firm must place its Engineering requirements first. After all, typically large firms compete on a supra-national basis. The compatibility issues may also exist within the different functions and national branches of a single large corporation. This becomes further complicated when dealing with a number of smaller suppliers that may be overseas.

THE MATCHING OF TASK TO THE FIRM

The difficulties in matching CE tools to different sizes of firms may be summarised as:
Heterogeneity
Interfaces
Legacy Systems
Lack of Standards
All of these represent a technical challenge that adds to the burden upon the smaller firm.

SOFTWARE SUPPORTING SMALLER FIRMS

In the case of imposed systems the question that should be asked is:
"Who is supporting whom?"
This is because smaller firm may have no need for new or different systems-its organisation is already flat and closely related.

CONCLUSIONS

Recent studies from industry by leading engineers (Haussman and Baake1998) showed how a large well-resourced company could realistically represent a modern commercial vehicle by storing the specification in a computer. Their study found that it was possible to reduce the number of physical models and analysis in the hardware. However, smaller firms lack similar facilities and have neither the methodology nor the appropriate IT tools to carry out this virtual product description.

As a parallel to the larger firms, CE techniques are used to shorten the development time. However, the ability to anticipate difficulties and plan for them is of considerable utility to firms that experience problems from suppliers. Furthermore, the support of a range of variants from a single generic master is an advantage in filling niche markets as well as extending the useful production life of some of the variants.

The matching of methodologies and tools to the task is important. In this area there remains considerable scope for further work.

At present, the leaders in CE are the largest firms. They have the greatest resources and need to compete on a global-scale. However, much smaller firms could gain at least a foothold in the increasing use of CE technology. This occurs by two processes. The first and most obvious is a kind of "trickle-down technology." Here the smaller firms follow the larger ones. The other way is for smaller firms to develop the tools that meet their own requirements.

Furthermore, the sheer scale of corporate resources invested by large "blue-chip" companies in simulation and CE applications points to their utility and potential for real-world industrial environments in a wide variety of countries. The benefits are open to both generalisation and replication.

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BIOGRAPHIES

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RICHARD ZOBEL graduated in Electrical Engineering from London University in 1963. His first experience of simulation was obtained during 1962-66 at Sperry Gyroscope whilst working on naval surface to air missiles, using mainly valve analog computers. His Ph.D., obtained in 1970 at Manchester University, concerned hybrid analog-digital computing. As Lecturer and Senior Lecturer he became involved in digital signal processing, instrumentation and design environments with special emphasis on the simulation aspects of real-time embedded systems. He is a former Chairman of the United Kingdom Simulation Society (UKSim), Former Secretary of the European Federation of Simulation Societies (EUROSIM), and is a European Director of SCSI, the Society for Computer Simulation International. His current research work concerns distributed simulation for non-military applications, model re-use, distributed simulation model databases, issues of verification and validation of re-useable simulation models and security for distributed simulation under commercial network protocols. He is now semi-retired.

AN EVENT DRIVEN SESSION MANAGEMENT SYSTEM FOR COLLABORATIVE DISTRIBUTED SYSTEMS ENGINEERING

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KEYWORDS
Computer-supported cooperative work, Distributed System Engineering, session management, event driven architecture.

ABSTRACT

The work presented in this paper is part of the Distributed Systems Engineering project, a European research IST project aiming to build-up a multi-layer architecture to support engineering activities, enabling collaborative design, simulation, verification and review in large space domain programs. The developed architecture involves horizontal layers whose components are coordinated through different other components grouped in a vertical layer. The Session Management Service component is a coordination component that enables collaborative multi-type sessions supporting a distributed group of engineers during the design and the review a common system. This paper presents an event-based implementation of the Session Management Model specified in UML in a earlier version of this work.

INTRODUCTION

Distributed engineering is likely to be the most important and challenging activity for the next decade. Different engineering domains are concerned and different enabling technologies are involved in the design of collaboration systems that support these activities. Activities include different domains varying from collaborative software engineering (Krasner et al. 1991) enforcing efficient components reuse and integration, and hardware engineering using CAD tools for mechanics and electrical components design and integration in a distributed way enforcing rapid and efficient interactions during the whole product life cycle. Distributed System Engineering is an emerging activity that needs collaborative technologies both software and hardware components design and integration. Different tools have to be used in a distributed way by different users making Session Management Services play a major role in starting, stopping, joining, leaving, and browsing collaborative scenarios in the distributed applications (Patterson et al. 1990).

Distributed System Engineering is the experimented activity in the work developed with the DSE project (Drira et al. 2001). The objectives are to design and to develop an efficient integration architecture for the large scale application of Collaborative Engineering Platforms within the European Industry, supporting the whole system engineering life cycle (Martelli and Todino 2000). The engineering activities that were distributed put special emphasis on design and verification activities in large, international projects, involving a complex and multi-level customer-supplier network.

To correctly and efficiently integrate the different applications involved during the different steps of the systems engineering life cycle and used by the distributed participants, the DSE environment introduces a multi-layer architecture, with a generic and open infrastructure (for communications and GroupWare) and a users community specific layer, enabling data and application sharing among heterogeneous tools in use during the systems engineering life cycle.

Within the global architecture, the Session Management System (SMS) is a centerpiece that guarantees the efficient coordination between the different participants and the different applications during the different steps of the collaborative work scenario. The coordination functions involve the correct handling of GroupWare tools and domain specific applications. GroupWare includes audio-video conferencing server (MeetingPoint MCU) and standard clients (NetMeeting and CuSeeMe). Domain Specific applications interact in a distributed way through the middleware layer and are coordinated through a common shared data space whose structure may be managed directly by session administrator or in an automated way based on session events generated by the SMS components. The collaboration scenarios planned for the validation of the DSE environment include a predefined set of communication and coordination rules including roles of participants, scheduling of events, and defining dependencies and constraints between the different shared engineering data and documents on the one hand and between the engineering tools on the other hand. These rules are introduced and checked by the Responsibility Management Component which is part of the system. The rules are then enacted by the SMS component which ensures the correct generation and propagation and consumption of events in a correct order as specified by the collaboration scenario.

The main objective of this paper is to present the Session Management System, implementation using an event-driven architecture.
The implemented system shares common characteristics with the most representative session management systems found in today's literature, and has specific features that are not provided by the existing systems. A SMS collaborative session can be seen, similarity to Habanero approach (Chanbert et al 1998), as a meeting where participants join together with the intention of collaborate by using a common set of tools. Tango (in its first version) approach (Beca et al 1997) does not allow granting the master role among users. The session ends if the *creator-master* participant leaves. The SMS approach enables the creator-master participant (the initial chairman) to leave the session, by granting its role to any other participant among those initially planned for this privilege. Systems based on replicated architecture, like JCT (Kvande 1996), do not support latecomers connections; in the SMS a hybrid (partially centralized and distributed) architecture overcomes this challenge.

The paper is organized as follows: first, we will present the main service characteristics of the session management system. Then, we will discuss the hybrid architecture which underlies its implementation. A detailed presentation of the events and their related producer/consumer relationships are then provided. Finally, we will discuss the current status of the system implementation and provide further development ideas in the conclusion.

THE MAIN PROVIDED SERVICE FUNCTIONS

The SMS sessions are defined around collections of participants connecting from different locations to work together on shared information (engineering data and documents) using distributed or shared engineering tools. Session participants may access the shared information through different views according to their skills and roles and as stated by the responsibility specifications. The service functions provided to these participants are of three families:

- Sessions browsing and group membership class allowing any participant to find, to join and to leave a collaboration session,
- Session Status Management functions allowing the specified session originator to create a session, to invite planned participants, to open a created session, to close an opened session and finally to delete a closed session.
- Awareness functions class providing coordination functions including : session-related and participant-related notifications for individual and group status allowing any participant to be informed about the status of his requests and the session context including visualization of group composition and shared data management and instant messaging for activity coordination and collaboration information exchange.
- Control functions allowing authorized participants to control the behavior of running applications and services including distributed simulation tools and GroupWare tools.

SMS is capable of managing multi-type sessions, which involve different families of applications, running on different hosts and interoperating by the frequent exchange of data through the networked components. This is a requirement of the engineering processes specified by the collaboration scenarios of the DSE users communities.

SMS ARCHITECTURE OVERVIEW

The SMS is supported by hybrid architecture as depicted by Figure 1. On the one hand, we use a central node to save the session context. This is the so-called SMS server created for each collaboration session. On the other hand, and for each successfully connected participant, the context is retrieved from the session server and then replicated on the participant's site. Maintaining replicated contexts consistent and up to date is driven by events publishing. This allows in particular affording latecomer participants while providing them valid collaboration context.

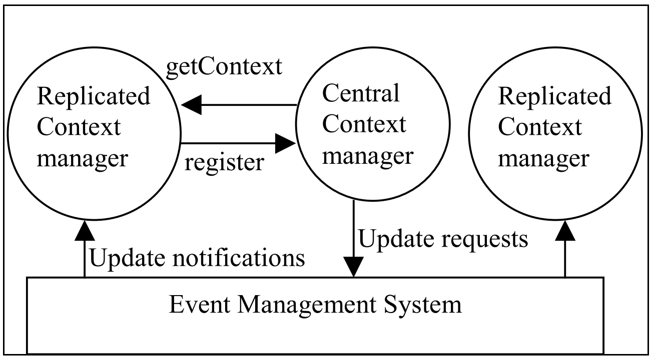

Figure 1: SMS Components and Updating Protocol Primitives

Session events play an essential role in this type of architecture. The events guarantee the mode WYSIWIS (What You See Is What I See) for all session participants. These generated events are of different families and my serve for session context update and for other collaboration component coordination within the global DSE environment and for updating the shared data among the distributed applications.

EVENTS FRAMEWORK

Generic Events

Definition.
The term "event" is widely used within the IT software community and it is sensible to consider the characteristics of events in the context of the DSE project. Events are employed in the DSE general architecture as the way of intercommunication among the several systems. This approach gives us the following advantages:

- Clients and servers can be started independently.

- Several clients and servers can be implied in the same type of event.
- Clients are connected to servers by means of a publish/subscribe system, so clients do not need to know in advance the machine address identity of the server.
- Communication can be initiated by client or by servers.

Structure.
Events are defined as a pair composed of: a trigger –or cause, and an action –or response. The trigger is the recognition of some predefined set of circumstances associated with the operation of the system that causes a particular action to be taken. The action is the pre-defined system response following a trigger condition.

Classification.
Every component of the global collaboration environement has been associated with a domain event and every domain may contain one or more type of events. Events structure has been modeled using the XML language. We have selected XML since it enables us to represent structured information in a generic form that can be mapped to a particular form for transmission and visualization, allowing dynamic adaptation to heterogeneous environments. Every domain has a Document Type Definition (DTD) which defines the specific attributes for every event type.

Architecture.
The generic event architecture is defined by three kinds of components:

- The *suppliers* are the systems which generate events.
- The *consumers* are the systems which utilize the events.
- The *event channel*, which is responsible of managing the events and it is the medium of communication between suppliers and consumers.

Components can act simultaneously as supplier and consumer. The way of interaction between suppliers and consumers is defined by a announcer structure. In this structures, suppliers start the communication by pushing events in the event channel. The event channel, in its turn, pushes the events to the consumer systems.

Session Specific Events

Definition.
A Session Event is the occurrence of a particular situation or condition, which has significance to session handling. The instances may be: to create or delete a session instance, to join or to leave any participant in the session, to open or to close a session, to grant the chairman role among the participants.

We have defined three types of session events that we will define in the following subsections: the state-related events, the participant-related events and the messaging events.

State-Related Events.
The state-related events connect triggers and actions associated to the management of the session. This kind of events are defined following the DTD depicted by Figure 2, where the session events are composed by the ID of the session and the type (name) of the event. The attribute *%NotifDateTime* makes reference to the notification date and time defined in an external generic event DTD. This attribute represents the creation date and time of the event. The *Conference* structure, which is also defined in an external generic event DTD, contains relevant data of the associated conference (ID, name, start date and time).

```
<?xml version='1.0' encoding='ISO-8859-1'?>

<!-- DSE State Related Event definition -->
<!ELEMENT Session_Event (Conference*)>
<!ATTLIST Session_Event
          Session_ID CDATA #REQUIRED
          %NotifDateTime;
          evName  (OPEN|CLOSE|CREATE|DELETE|INVITE)
#REQUIRED>
```

Figure 2: DTD for State-Related Events

The triggers and actions defined for these events are:

1. Create. This event is triggered to initialize the instance that represents a collaboration session. This event is consumed by the domain specific applications manager to create a folder to contain the documents that will be used during the session. Also, the GroupWare system reacts to this event by sending configuration commands via telnet to the videoconference server in order to setup the conference parameters (bandwidth, quality service, maximal number of participants, welcome message, reject message, start date and time, duration, etc.).
2. Delete. This events is employed to delete a session instance.
3. Open. This operation is triggered when the collaborative session is opened. This event marks the start of the collaborative phase of the session (applications and tools are started). This event is consumed by the GroupWare manager which sends a remote command to the videoconference server in order to enable the conference associated with the session.
4. Close. This event occurs when the collaborative session is closed. This step is characterized by closing the tools. This event is employed by the GroupWare system to send a command to the videoconference server with the intention of disable the conference related to the session.
5. Invite. This type of event is used to announce the scheduling of the session to participants.

Participant-Related Events.
Participant-related events consist of triggers and responses concerning participant activities. Participant-related events are defined according to the DTD depicted by Figure 3. Participants events are built up of three attributes: the session ID which sends the event, the sending date and time, and the type of the event. *User* attribute is defined in an external

generic event DTD and contains the full name of the user, his/her IP address, and his/her email address.

```
<?xml version='1.0' encoding='ISO-8859-1'?>

<!-- DSE Participant Related Event definition  -->
<!ELEMENT Participant_Event (User, Conference*)>
<!ATTLIST Participant_Event
            Session_ID    CDATA #REQUIRED
            %NotifDateTime;
            evName  (JOIN|LEAVE) #REQUIRED>
```

Figure 3: DTD for Participant-Related Events

Participant-related events are described by the following triggers and actions:

1. Join. Participants trigger this event when they join the collaboration session. The SMS located in each participant's site is concerned by this kind of event. It is used to update the list of on-line participants in every site.
2. Leave. This event is triggered when participants abandon the session. This event is used to update the on-line participants list in every participant's site.

Messaging Events.
Instant messaging are used to send text messages and warnings to groups and individuals. This type of messages are formatted according the DTD defined in Figure 4, where the messaging event is composed of the session ID, and the event type attributes. The identity of the user who sends messages is described by the Originator structure. This later is defined in an external generic event DTD.

```
<?xml version='1.0' encoding='ISO-8859-1'?>

<!-- DSE Instant Message Event declaration -->
<!ELEMENT Info_Ses_Event (Originator)>
<!ATTLIST Info_Ses_Event
   Session_ID CDATA #IMPLIED
            evName (MESSAGE | WARNING) #REQUIRED>
```

Figure 4: DTD for Messaging Events

This kind of events is defined by the following triggers and actions:

1. Message. This type of event is triggered by participants to send a text message to other participants. This kind of events is displayed in the awareness console.
2. Warning. This event is sent among participants to warn possible errors during the session. This event is displayed by the awareness tool, and it is very useful in trouble conditions like, erroneous starting tools, communication problems, high latency, etc.

Architecture.
The SMS system acts basically as an event supplier in the whole DSE architecture. The relations between the SMS system and the other systems in terms of supplier and consumer roles are depicted by Figure 5. State-related events are consumed by the database service contained in the domain specific applications and by the videoconference server, in our application we have employed the MeetingPoint Server. Participant-related events are consumed by the SMS service. Messaging events are consumed by the awareness service, which display in its GUI console messages and warnings.

IMPLEMENTATION

Status

The system is implemented in the Java language. The SMS events are implemented in the CORBA and the Java Shared Data Toolkit (JSDT) standards. CORBA is used to send events to integrate SMS with the rest of the systems. JSDT is used to send events that are consumed by the same SMS system. In order to implement the full system functionality, we have also employed the following Java libraries: Java Mail, RMI, JCE, JNLP, and Web Start. The total system is approximately 9,000 lines of code.

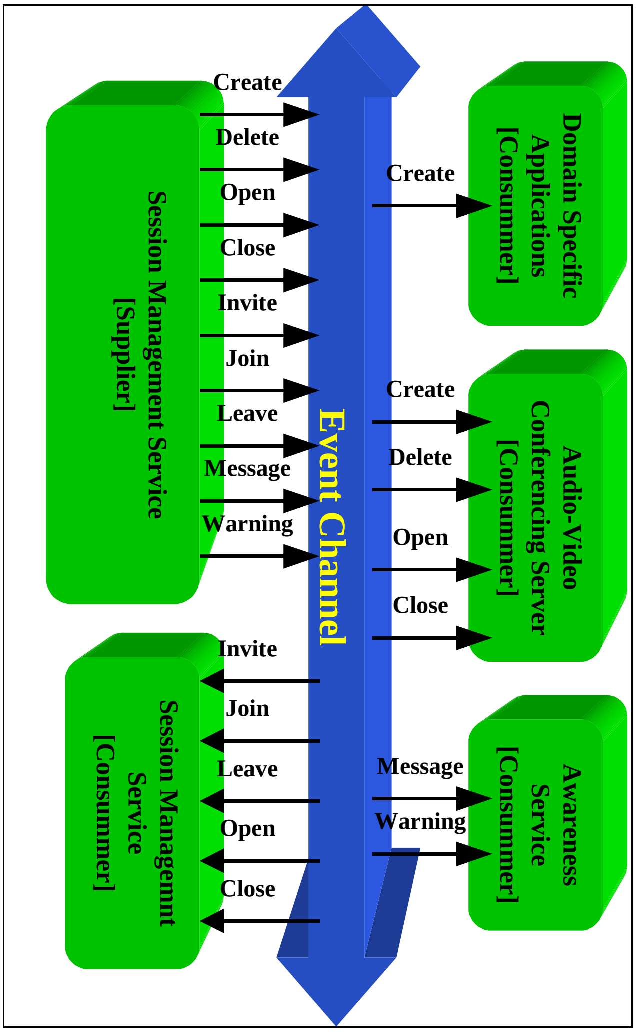

Figure 5: Supplier/Consumer Relations among Systems

SMS Validation

The SMS is currently implemented in the version 2 of the DSE project. The system was validated successfully during the second review of the project. The scenario employed was the Preliminary Design Review process applied to the Automated Transfer Vehicle (ATV) program, this process is described in (Avino et al. 2001). The SMS has been enhanced with respect to preliminary version (Molina et al. 2001) specially in ergonomics aspects. Ergonomic quality was identified as an important factor of DSE acceptance by users and the following features has been improved :

- The tight graphical integration of the responsibility management system and the SMS has decreased the number of windows; all windows are contained in a unique window for the both systems and each window can be iconized inside that main window,
- Session chairman and participants of a distributed session have a better view of presence of their colleagues in the session. This is done through a concept of "Meeting room" which permits to visually manage presence,
- Session chairman can get the number of participants who have accepted the invitation to join the session.

CONCLUSIONS

We have presented an event-driven session management system. The correct definition and ordering of events allow us to achieve two principal service functions. On the one hand, we maintain a synchronous up-to-date awareness space within the distributed collaboration team. On the other hand, we guarantee correct integration of different collaboration tools within a unique coordination space.

Our work is now focusing on a number of directions. First, A virtual meeting room is being developed to enhance GUI ergonomics. For coordination issues, we are implementing hierarchical coordination spaces allowing easy while efficient collaboration sub-groups definition and visual management. Generic interoperability with external applications is being developed based on the integration of an LDAP connector. Finally the implementation over a causally-coherent distributed event service is being planned in collaboration with other researchers of our research group.

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MIXING MANUAL AND COMPUTER-SUPPORTED INITIATIVE FOR SCHEDULING AND NEGOTIATION ACROSS DISTRIBUTED ORGANIZATIONS

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KEYWORDS
Negotiation, Scheduling, Business-To-Business Electronic Commerce, Collaborative Environments, Decision-Making.

ABSTRACT

Several user studies have shown that in many cases electronic planning and scheduling tools are perceived by the users as disruptive with respect to their actual work practices often based on physical tools. This can result in rejecting such electronic tools without fully appreciating the long-term benefits of their adoption. As a part of a larger effort for providing support along scheduling and negotiation processes across distributed organizations, we have designed a solution to allow manual and computer-supported mixed initiative that aims at letting the users continue working according to their work practices leveraging the benefit of an automated support.
In this paper, we describe our solution also motivating the design choises we made. We show how our solution allows users interact with a manual editing facility to schedule and manage their work activities and, when appropriate, to select and publish scheduling information for triggering negotiations on services with other, possibly remote, users. We illustrate our approach in the context of a business-to-business scenario where users are decision-makers in print centers scheduling and negotiating print jobs.

INTRODUCTION

Users for several reasons may reject planning and scheduling tools. In many cases the main reason is that the tool is not adapted to the actual work practices or, even worse, the users perceive it as totally disruptive, even if they are very interested in the functionality the tool provides them with.
Let’s take as an example a workplace where people managing tasks schedule are used to work on a paper support. They may be reluctant to change this practice for adopting a fully computer-supported scheduler, even if the scheduler is very flexible and powerful. They would feel forced to make a choice between the two approaches. On one side there is a consolidated work practice that they know and that is more or less satisfactory. On the other side, there is a new work environment, that they do not know and that after a given time period would (probably) prove to be more effective.
Several field studies and surveys have shown that a number of people prefer to work on physical supports more than with on-line tools (Whittaker and Schwartz 1995). This seems to be due to a general lack of confidence in non-physical objects and also the greater commitment a physical interface imposes. However, without providing electronic information, users loose the benefit of an automated support.
For many years, research has been undertaken on how to bridge the gap between the physical and the electronic worlds. For instance, in the case of a paper-based physical world, existing approaches to this problem can be classified into two groups as described in (Karsenty et al. 2000). The first group includes systems linking the paper to the electronic world; a typical example of this category are barcodes. The second group includes paper-based applications, namely systems that take a specific existing paper object, e.g. a print coversheet or a flyer, and extend its capabilities. See (Karsenty et al. 2000) for examples of systems belonging to one of the two groups.
In this paper we propose a solution, consisting of an architecture and a protocol, enabling a mixed human and computer-supported initiative along distributed scheduling and negotiation processes. We assume a distributed setting with autonomous workplaces offering similar and/or complementary competencies and abilities. Each workplace collaborates, but also competes, with other workplaces to improve its own ability to accomplish customer requests. Moreover, each workplace is very much or completely responsible for managing its schedule.
Users work on a manual editing facility. Our solution encapsulates methods allowing: (1) Users to express scheduling decisions by manually selecting and moving scheduling information slots; (2) Translation of scheduling information to negotiation information; (3) Activation of task negotiation across distributed sites; and (4) Translation of negotiation information back to scheduling information.
In order to show our approach we use a scenario where workplaces are print centers (called printshops in the sequel) and users are printshops decision-makers scheduling and negotiating print jobs. However, the kind of interactions we consider is very generic and can be applied to other contexts involving scheduling activities.
The paper is organized as follows. We first show the design choices for the solution we propose and the printshops scenario. Then, we describe the architecture and the protocol of our solution and a paper-based instance of it, called PaperSchedule. Finally, we discuss related work.

OBSERVING THE SCHEDULING ACTIVITY

Several case studies have been conducted to observe the impact of the introduction of electronic schedule tools and to

compare them with practices based on physical artifacts. We have based our design choices on two of such studies: the first one comparing the usage of electronic tools with large visible planning board in the context of project activities, the second one studying the more specific setting of factory production printing.
The authors of the first study (Whittaker and Schwartz 1995) have observed two groups of approximately twenty people in size, one using a commercial scheduling tool, the other one using pen-and-paper manual procedures on large wall boards. The results coming from the qualitative observation has provided us with insights regarding the different phases of the scheduling activity, that have informed the design of our system:

- *Initial planning.* A key feature of the initial planning is to be accurate and credible, because it impacts heavily all the starting decisions. What has been observed is that the **physical manipulation** required by the paper artifacts resulted in a higher degree of engagement. Moreover, the **public** nature of schedule encouraged a collaborative effort in creating it and awareness of the decisions.
- *Updating.* The activity of keeping the planning accurate and reflecting the current situation that other people can rely on to take appropriate decisions. Therefore easiness in updating is a key feature to achieve collaboration. The **public** nature of the schedule provides a way to acknowledge individual contributions (or lack of those), is therefore an incentive. However, they observed as well the drawback that the updates are more costly on a physical artifacts and this can have a counter effect decreasing accuracy of updates.
- *Replanning.* Replanning is a typical frequent activity on schedules and of course all the advantages of the planning phase are present in this one. Additionally the physical artifact has been proved to provide more **flexibility**, by allowing the allocation of a neutral area where to keep tasks not yet allocated.

We agree with the authors of this study that electronic shared scheduling tools have to be designed taking into account the above-observed benefits. In particular they should "be public, to promote commitment and conversation; material in affording engagement and reflective use of the tools; and they need to simulate the dimensions of size and visibility in supporting ready access to complex information" (Whittaker et al.1995).
The second case study is about the observation of how the order of production printing activity is carried on in one of the major UK factory. This case study provided us not only the observation of the usage of physical artifacts, but also a more complex setting, because the possibility for the factory to work as part of a network of autonomous printshops. We were interested here in the nature of the physical artifacts used in that organization and the perceived affordances they presented. Several paper-based artifacts have been observed to store information about the incoming requests, their current schedule and the resulting current activities. Among those the artifact specifically supporting the scheduling activities is the "forward-loading-board". The forward-loading-board is a scheduling artifact used to work up the daily array of jobs into a rational production order, such that the administrative manager can perform calculation and take decisions for example about accepting an incoming order or a negotiation with another manager for a given print job. In this setting, as a previous one, a key feature of these artifacts has been observed: they were visible "at-a-glance", because they were publicly available and on public display. In this setting this aspect was observed as to be a crucial one to see which jobs have to be shifted and which delays in production can be detected. Additionally, because of the willingness to work in a network of printshops, being therefore able not only to manage locally the schedule, but to exploit resources of other printshops if possible, this observation suggested that an ideal solution would be a system being able to keep all the benefits provided by existing physical artifacts, while being able to publish to the network information on the current status for negotiation purposes.
Building upon these case studies (Button and Sharrock 1997, Pycock et al. 1998, Whittaker and Schwartz 1995) and the description of a variety of print work processes (Eliezer and Zwang 1997), we have defined a model describing printshop activities (Andreoli et al. 2000) as illustrated in next section.

SCENARIO

We assume a distributed setting with autonomous printshops offering similar and/or complementary competencies and abilities. Each printshop collaborates, but also competes, with other printshops to improve its own ability to accomplish customer requests. Moreover, a printshop is very much or completely responsible for managing its schedule. In a printshop, users use manual supports (e.g. paper sheets) to manage their planning/scheduling activities.
The planning/scheduling can be represented in several ways. For example, a representation of the schedule on a paper sheet could be a Gantt chart with print machines along one dimension and the time units along the other dimension. Users allocate jobs trying to optimize the workload of the machines and respecting the time constraints. Jobs may be represented as rectangles whose length is proportional to the estimated duration of the job on a given printer machine. Additionally, unallocated jobs can be listed outside the Gantt chart. Figure 1 shows a simplified example of a schedule, with several jobs allocated to machines on the vertical axis.

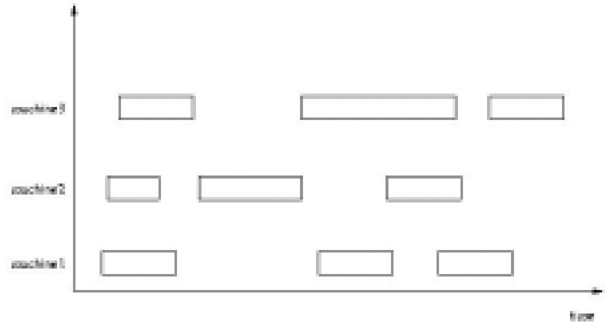

Figure 1: A Sample Schedule

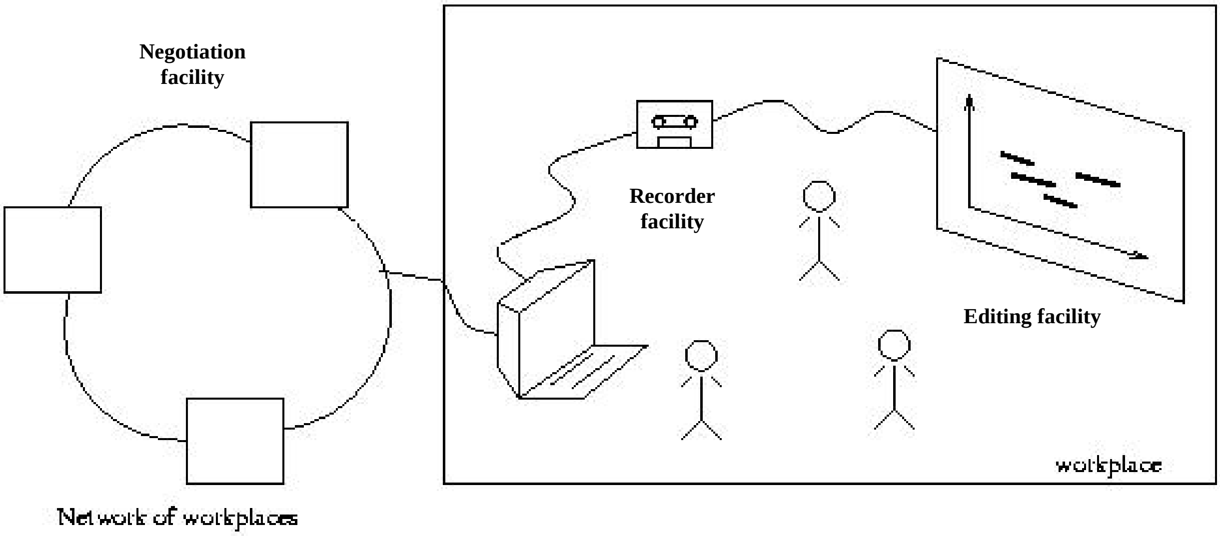

Figure 2: The architecture including an editing facility, a recorder facility and a negotiation facility

From time to time the printshop decision-maker may make the decision to "***insource"*** a print job from another printshop, using a free time slot on a given machine, or to "***outsource"*** a given print job (part of the Gantt chart or of the unallocated jobs list) to another printshop. She will make those decisions basing upon information on the current job schedule and the printshop's technical capabilities, leveraging her knowledge of the customers. She may then start to negotiate with the decision-makers of other printshops for example to outsource a print job trying to find a satisfactory solution in terms of time and price.
This model attempts to capture significant kinds of behaviors even if it can be further enriched. Moreover, the kind of activities and interactions we consider here are quite general. Then, our approach could apply to other kind of organizations, wherever scheduling activities occur to manage work activities.
Next section describes the design of our solution for supporting this scenario, with a more detailed description of the user interactions with the scheduling and negotiation facilities.

OUR SOLUTION

Our solution comprises three facilities: a manual **editing facility**, a **recorder facility**, and a **negotiation facility**. Figure 2 shows in a simplified way the architecture including the three facilities.
Users use a manual editing facility to manage their planning/scheduling activities in a workplace, e.g. a printshop. When the user(s) (e.g. the decision-maker) make(s) decisions (e.g. *outsourcing* a print job), the editing facility will allow to manually express those decisions. A recorder facility (e.g. a camera) will recognize the scheduling decisions and translate them into negotiation information. The negotiation information will be used by a negotiation facility to manage negotiations with other workplaces. Finally, the negotiation facility will provide the results of the negotiations, if any, that will be presented to the users.

The architecture is such that several user interfaces can be adopted. It only requires the capture of selected scheduling information at a site and at specific points in time. The manual editing facility can range from being totally non-electronic (e.g. a whiteboard) through to totally electronic (e.g. a large screen display). The planning/scheduling can be represented in several ways.
Let's see more in details the interactions among the users and the three components of our architecture, in the context of our printshop example.
Users use an editing facility to manage their planning/scheduling activities allocating jobs trying to optimize the workload of the machines and respecting the time constraints. Decision-makers will express their decisions as interactions with the editing facility. When the decision-maker makes the decision to try to insource a job from another printshop, using a free time slot, she will delimitate it with an *insource shape*, e.g. a rectangle, and put an *insource mark*, e.g. a checker on it. When the decision-maker makes the decision to try to outsource a job, denoted by an *identifier*, to another printshop, she will put on it an *outsource mark*, e.g. an asterisk.
The recorder facility will capture these decisions from the editing facility capturing the marks and recording other information. Information captured by the recorder facility will be propagated to a negotiation facility thus triggering the appropriate negotiations with other printshops.
For the interactions among the user, the editing facility and the recorder facility there are at least three modalities. In the first modality, the recorder facility is active all the time; it records the information displayed by the editing facility and reacts immediately to the actions of the decision-maker. In the second modality, the recorder facility becomes active upon a decision-maker request.
The editing facility would contain a **control region** enabling the decision-maker to trigger the actions of the recorder facility. When the decision-maker puts an *activation sign* into the control region, the recorder facility collects the information and sends them to the negotiation facility. When the decision-maker puts a *stop sign* into the control region,

the recorder facility stops recording. In a third modality, the recorder facility records information displayed by the editing facility and sends this information, from time to time, to the negotiation facility as an “exploratory” information. In the first two modalities, when the recorder facility is triggered, it collects a number of time and technical information. For example if the decision-maker has selected a free time slot with an *insource mark*, the left end and the right end of the rectangle corresponding to the slot will provide respectively the earliest possible start time and the latest possible end time for it. This time information combined with the description of the machine technical capabilities will be the negotiation information sent to the negotiation facility. On the other side, if the decision-maker has selected a job (with a given identifier *id*) by marking it with an *outsource sign*, then the left end and the right end of the rectangle corresponding to the *id* job will provide the earliest possible start time and the latest possible end time for it to be performed. This time information combined with the description of the job technical requirements (which is entered in the electronic system when the job is accepted) will be the negotiation information sent to the negotiation facility. In the third modality, the recorder facility will collect information about empty spaces and tasks that will be sent to the negotiation facility for exploratory purposes.

When the negotiation facility receives the negotiation information, it starts the appropriate negotiations with the other workplaces. A number of negotiations schemes can be adopted. When the negotiation facility receives exploratory information, it will use it to search for matching requests from other printshops. For each negotiation, the negotiation facility will collect answers and possibly select solutions, if any, and provide them back to the recorder facility or to the wall editing facility. The recorder facility or the editing facility will show the negotiation results. One possibility, among others, for showing the negotiation results is to list the solution(s) found in a menu, when the user selects the item associated to the negotiation. Moreover, the negotiation facility will provide the results of its explorations, if the exploration mode is allowed.

Also, the decision-maker may want to stop some of the ongoing negotiations because in the meanwhile she has found a solution for the allocation of some of the jobs and the time slots. In that case she could mark the jobs and the time slots for which she wants the negotiation to be stopped with an *end mark* and then put an *end sign* into the control region.

IMPLEMENTATION

As a negotiation facility for implementing our solution we have adopted AllianceNet (Andreoli et al. 2000), a framework allowing users, belonging to organizations grouped into an alliance, to flexibly negotiate items or services. When negotiation succeeds, results are shown back to the user and consequent actions are performed, where appropriate. For example, if the negotiation is about a job outsourcing and the negotiation succeeds, the physical job is automatically transferred to the appropriate printshop. For the editing and the recorder facilities we have considered three possibilities.

One possibility was to use a whiteboard as the editing facility and the ZombieBoard as a recorder system (Moran et al. 1999), given the the techniques for image processing offered by the ZombieBoard (segmentation and grouping rules, symbol recognition, text recognition). Users could draw schedules and control marks with a pen and/or by using magnets. The control region could be a square delimited region at the left-hand corner of the whiteboard. The ZombieBoard allows the user to identify a specific region to be selected. This feature would allow the elaboration of specific areas of the schedule starting/stopping negotiations corresponding to jobs and time slots in those specific areas and letting the decision-maker continue working on the rest of the schedule. The negotiation facility may provide the results of the negotiations (if any) to users on the whiteboard. A projector may project different colored lights on the work items for which negotiations succeeded or explorations succeeded (if the exploration mode is allowed).

Another possibility was to use a large screen display as an editing facility. The Tivoli application (Moran et al. 1998) simulates whiteboard functionality on large screen displays. It provides basic pen-based scribbling and editing with pen-based gesturing and wiping techniques and a scripting language to tailor “domain objects” to specific applications. This layer allows the bi-directional exchange of data between the whiteboard-like display and the actual application behind it. Tivoli provides the ability to script special domain objects (imported/exported from external databases) that users can interact with on the board. In this case the domain objects would be jobs and machines and users could draw their schedules manipulating these objects through a graphical editor. The control region could be a square delimited region at the left-hand corner of the large screen display. The negotiation facility may show the negotiations results to the users on the large screen display. For example, the screen could display colored rectangles in correspondence of the work items for which negotiations have succeeded or explorations have succeeded (if the exploration mode is allowed). Multiple negotiation results could be displayed in a menu when selecting the item associated to the negotiation.

Finally, there was also the possibility to use paper for editing and a scanner device as a recorder system. We created an instance of our solution adopting this option where jobs are represented and identified on “planning sheets” and users schedule and negotiate jobs interacting with the paper. Ideally, the user will be able to walk around the printshop with the paper sheet, making decisions on the fly observing the situation and then scanning the schedule when decisions are mature. Next section shows into details this paper-based instance of our solution, called PaperSchedule.

A PAPER-BASED PROTOTYPE

Before describing PaperSchedule, we recall the principles that have driven our design:

- Physical artifact to support a bigger degree of engagement in the decision
- Public nature of the artifact to support collaborative activities.

- Public nature to support peripheral awareness of the current state of the schedule.
- Support to transient state (i.e. activities existing, but not yet allocated.)
- Possibility to publish to a network selected information about the current state of the schedule.

Jobs Representation and Recognition

Jobs are represented using cardboards with a unique identifier, associating to them DataGlyph™. DataGlyphs (or glyphs for short) are a 2-D data encoding technology, similar to bar codes (Hecht 1994), see Figure 3.

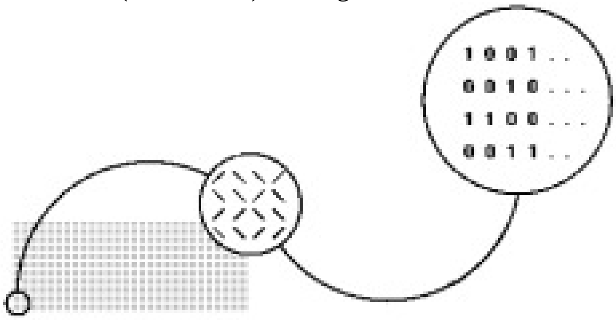

Figure 3: Xerox DataGlyphs

A DataGlyph contains an array of \'s and /'s, and within this array, any data can be coded on paper documents scanned at a resolution of 300 dpi. Figure 4 shows an example of a job glyph (close to real size) like used in our solution. It includes a 16*16 glyph encoding 12 bytes. Below the glyph, information associated to the job is displayed to allow the user recognizing the job: the name of the customer (e.g. **`client1`**) and the name of the job (e.g. **`job3`**). That information is recorded when entering the job into the system (as described later). The user attaches glyph stickers to cardboards for uniquely representing the corresponding jobs. Cardboards are one inch high, and they are precut so that they can be cut appropriately to represent jobs.

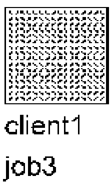

Figure 4: An Example of a Job Glyph

Analogously, free time slots where the user wants to insource a job are represented with specially tagged cardboards delimiting the time region to insource.

Planning Sheets

Users create and manage their schedules on "planning sheets", by placing cardboards on them. Figure 5 shows an example of a planning sheet.

Planning sheets are instances of interactive paper containing scheduling information in a format that can be captured when scanning them. The interpreter of the scanned images has been built on top of the FlowPort™ toolkit (Hecht 1994). FlowPort is a server application that processes scanned images and provides to our application two main set of services: location of the DataGlyphs areas (and their decoding) and image segmentation to locate the jobs and their length. Planning sheets are now described in details.

In the top left corner, there is a 16*23 glyph that identifies the sheet, including information about the layout of the week. The two black squares printed at the bottom of the page are called the registration marks and make it easier to identify the location of rectangles by using relative position to the marks. The registration marks are used for determining the corresponding time span and to which machine each of the jobs is scheduled. They are also used for determining the orientation of the image. This means that even if the image is scanned upside-down or with a 90, the program will interpret it correctly.

To identify himself as the "owner" of the schedule when scanning the schedule in, the user will use a FlowPort™ Cover Sheet as shown in Figure 6. Next section describes in details the interaction possible with the planning sheets.

Scheduling and Negotiation

The main actions the user can perform interacting with a planning sheet are to:

- Allocate a job to a machine local to a printshop.
- Ask for outsourcing a job.
- Mark an area as suitable for insourcing
- Change job schedule.
- Withdraw outsource or insource requests.
- See negotiation results, if any.
- Fixing some constraints as definitive.

The user can allocate a job to a machine local to the printshop by placing the cardboard on the position corresponding to the machine in the planning sheet. If the user wants to outsource a job, she will put it on the "outsource area" below the chart on the planning sheet (see Figure 5). If there is any free time slot where the user wants to insource a job, she puts there a cardboard with an insourcing sticker.

The extension to FlowPort™ handling specific PaperSchedule needs is the "Interpreter" servlet. When the user scans the schedule in, the interpreter observers it and recognizes the information based on position, size and identifiers. In particular, it detects the differences between the new version of the schedule and the current one, if any. It captures then the changes performed by the user on the schedule, e.g. a change in the start time of a job allocated to a given machine or the withdrawal of an insourcing request. The interpreter translates, if necessary, the captured decisions into negotiations requests. Negotiation requests are URL encoded method calls to the representant of the printshop in AllianceNet. Those requests are then propagated to the other printshops. Figure 7 describes the architecture of the PaperSchedule solution.

A job or a region can also be simply drawn directly on the planning sheet, but inaccuracy in drawing the rectangles may prevent a good interpretation.

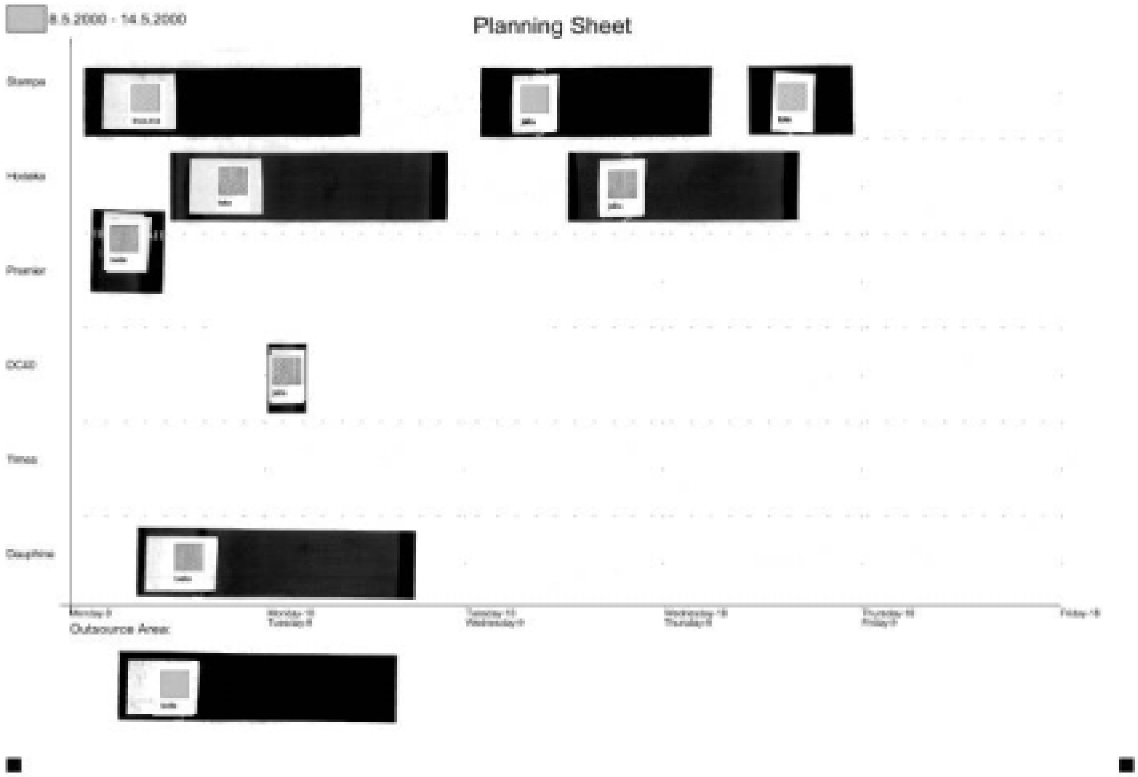

Figure 5: A Planning Sheet

Figure 6: A FlowPort™ Cover Sheet

In the current version of the prototype, feedback is presented to the user partly through a paper and partly through a web interface. Next section will describe more in details the web interface. If a job has been found for being allocated to a given insource area, only screen feedback is provided. However, if there is a job that has been outsourced, a new schedule with a name generated as a function of the date is created. On this schedule the job that was outsourced will have a blurred appearance. For example, Figure 8 shows the sample schedule after the negotiation for the job in the outsource area in Figure 5 has succeeded. The user can then continue working on the current planning sheet or print out the new version with the negotiation results and using it as the new basis.

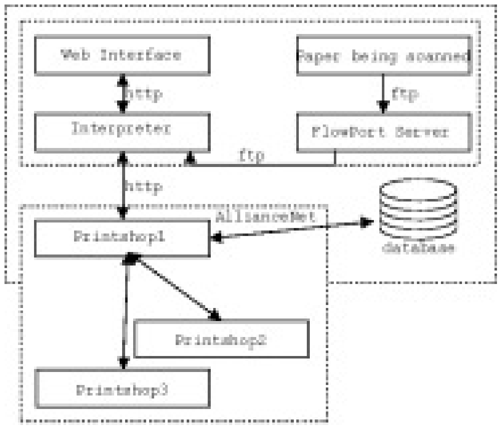

Figure 7: The Architecture of the Prototype

In the latter case, he will have to report the cardboards on the new planning sheet, except the ones he wants to fix. More precisely, if the user wants to definitively allocate a job to a machine he will not report the corresponding cardboard and then this allocation will never be changed in the future.

Browsing Jobs and Planning Sheets

As already mentioned, in the current prototype a part of the feedback is provided by a web interface. Also, this interface allows the user to: enter new jobs, browse the list of the existing jobs and the current and older versions of the planning sheets; print planning sheets; print insource stickers; check changes in the status of a job. The user can create a new job specifying its name, the estimated workload, resources needed, deadline, name of the customer, etc.

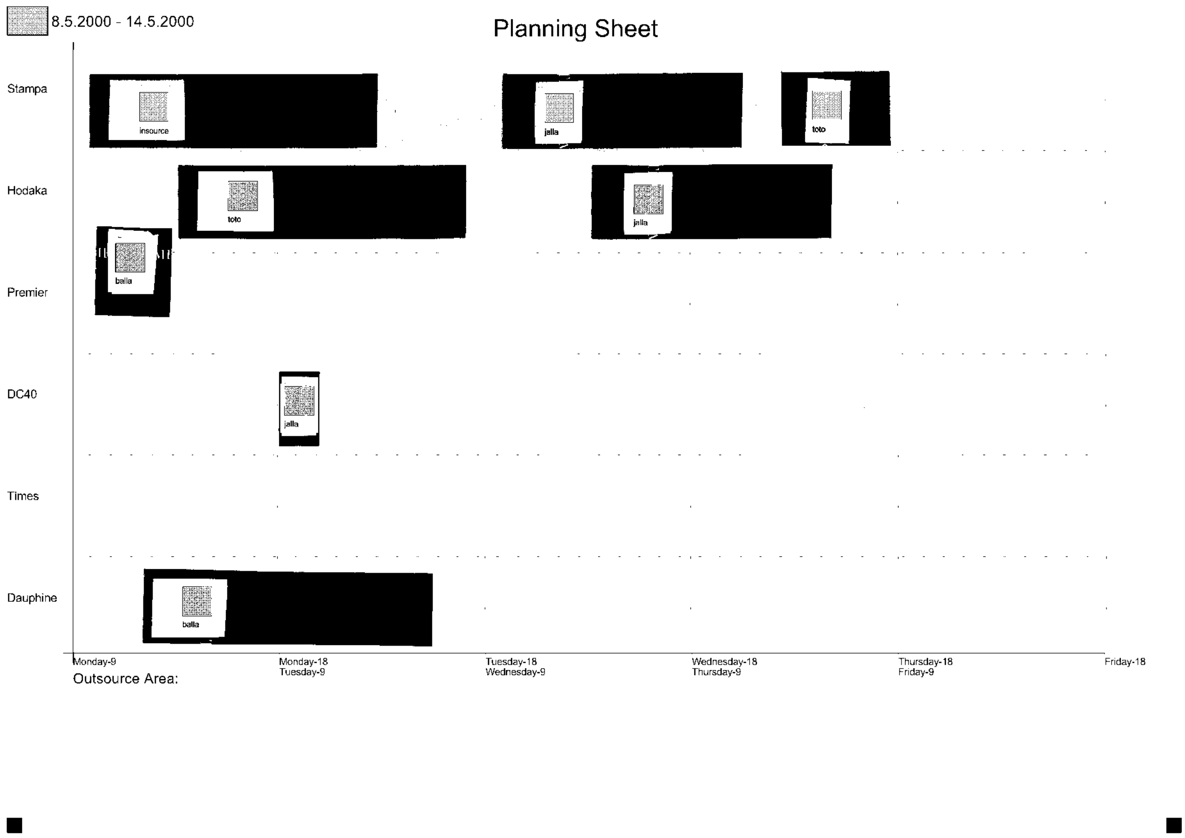

Figure 8: The Planning Sheet after negotiation succeeded

When the user is ready to schedule the jobs, he prints the planning sheet.
The user can see the list of the current jobs (see Figure 9 for an example) and print the glyphs stickers for the jobs cardboards ("PrintAllStickers").

Figure 9: A List of Current Jobs

The user can check changes in the status of the jobs. If there are changes, a new image of the schedule is created, and it is given a name reflecting the time it was created. There will also be feedback on the screen.
The user may also see and print out the latest planning sheet that was generated. Also, he will be able to browse previous versions of the schedules.

RELATED WORK

As already mentioned, several field studies and surveys have observed the affordances of physical supports with respect to on-line scheduling tools, for example (Whittaker and Schwarz 1995) provides an interesting summary of benefits of using physical artifacts to collaborate around scheduling activities. On the base of observations like such, the area of work has recently addressed the design of systems connecting and bridging the physical with the electronic world. In particular other examples of paper-based applications can be found in (Karsenty et al. 2000).
Tagging technologies are widely used. Without talking about bar codes, largely used in our everyday life, we can give a couple of examples of projects that use DataGlyphs: Campiello (Karsenty et al. 2000) and Collaborage (Moran et al. 1998). Campiello supports tourist and local community sharing. In the Campiello Paper User Interface, DataGlyphs are used to identify tourists and flyers. The Collaborage system consists of a board with a collage of tagged items. In Collaborage, DataGlyphs are used to identify items on the board. The content of the board is continuously monitored and the information on it exported and interpreted in correspondence of specific tags being put on the board.

The Collaborage project has designed and implemented an architecture (using and extending the ZombieBoard functions) for physically representing information on a board and connecting it with electronic information. The connection is achieved by tracking the board and applying image analysis techniques on it. Collaborage has also proposed three applications: “In/Out and Away”, “Project Task Wall” and “Whiteboard”.

The “Project Task Wall” allows to describe tasks on a “wall” representation. However the way the users interact with the board and the architecture behind are different. In particular in the “Project Task Wall” all the tasks are retrieved to produce their electronic representation, while the proposed protocol allows to “retrieve decisions” made by the users. Moreover the “Project Task Wall” doesn’t provide an architecture to support distributed negotiation of schedules.

The other application, “Whiteboard”, provides features for whiteboard writing and selective command specification on parts of the board. “Whiteboard” would be a possible user interface to be used to implement our solution for mixed human and automated distributed scheduling.

CONCLUSIONS

In this work we have addressed the design of tools to support distributed scheduling and negotiation activities, and in doing so we have first analyzed user studies drawing from them design principles arguing for a mixed reality support system. We have presented a general architecture where several editing facilities could be used and we have then described in detail one of such possibility, that have been prototyped: PaperSchedule. We have illustrated our approach in the context of a business-to-business scenario where users are decision-makers in print centers scheduling and negotiating print jobs. We have shown how PaperSchedule is a possible mixed reality implementation that complies to the design principles we have drawn from the user studies.

On the other side we are aware of some limitations of the current implementation and current and future work includes enriching the degree of interaction both between the user and the paper and between the paper and the negotiation system. In particular we are aware that the current implementations can be cumbersome from the point of view of the required effort to create tasks (cutting cardboards and gluing them). While the physical manipulation has been proved to stimulate more engagement in taking appropriate decisions, we believe that lighter interaction ways could be provided. For example the cardboards could be cut from a continuous semi-adhesive tape similar to PostIts. Similarly, the unique identifiers coded in the DataGlyphs could be provided in preprinted adhesive sheets alleviating the users from the task of producing them.

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WORKING SITUATIONS IN PRODUCT DEVELOPMENT: LINKING TECHNOLOGY, CONTEXTUAL FACTORS AND DESIGN TASKS

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ABSTRACT

This paper describes a framework for understanding working situations and how technology, contextual factors and design tasks can be linked in order for the product development process to become more efficient. The proposed way of achieving this is to ensure a better alignment between design goals, the underlying design process, design methods, and the surrounding contextual configuration, including technology. Engineering designers utilize and depend on design methods, design processes, other people, their physical surroundings, and different technology-based generic and engineering-specific tools, in order to be effective. Hence, they "orchestrate" the design process using the wide array of methods, tools and contextual factors that are available at their disposal. Designing the working situation in which they engage in problem setting and problem solving, can be viewed a means to improve design performance in concurrent engineering. This can be done by actively manipulating contextual factors ensuring proper alignment between goals, design methods, overall design process and contextual factors.

INTRODUCTION

The process of design can be seen as "changing existing situations into preferred ones" (Simon and Schön 1982). This definition is usually utilized when designing artifacts, but it can also be used when designing the *working situation*, where the design of artifacts takes place. Product development theory describes product development as a sequence of distinct activities. What are often described, is *what* to do, and sometimes also a rationale explaining *why* this approach is necessary or suitable. However, a detailed description of *how* to perform a design task is often omitted. While problem solving can be described as a selection from available means, the one best suited to established ends, the broader concept of *problem setting*, where the decision to be made, the ends to be achieved, and the means which may be chosen, is often ignored (Schön 1982). Similarly, the activity of formulating and debating a design problem, where knowledge is represented as an open, multi-faceted problematic, is essential in product development (Engeström 1997). In this paper the context of the problem is considered a part of this problematic. Hence, how to solve an ill-defined problem does not only depend on the character of the problem, but also on the situation in which the problem presents itself. Configuration of contextual factors in different working situations thus can be handled as a means to enhance the problem solving capabilities. This can be describes as building contextual support for different processes that occur in product development.

Designers often find themselves in situations that do not fully support the processes they are engaged in. Often there are discrepancies between the requirements of the problem and the solutions the current situation has to offer, which can reduce the efficiency of the design process. These discrepancies can be described as misalignments between goals, design methods, overall design process and contextual factors. These should all be adjusted in such a way that they are compatible with the overall goal. In these instances, it may become necessary to change the configuration of the working situation.

An example of such a discrepancy can be two designers discussing a design problem on a set of paper printouts. Without knowing it, they may be "captives" of the working situation they find themselves in. While trying to look for solutions in what they perceive as the real problem, they may neglect the contextual aspects of the problematic, as lack of larger visualization aids, atmosphere creating aids et cetera. Thus, solving a contextual problem or addressing the contextual aspects of a larger problematic by changing the working situation may reveal a more elegant solution to the a problematic than working out the perceived problem in the normal manner, or "the hard way."

OBJECTIVES AND GOALS

A design process is a very complex set of activities that are in some way related to the contextual factors of these activities. This paper describes a framework for understanding the product development process by defining the set of different working situations in which the designer finds him or herself as the basis for evaluating constraints and possibilities in the overall design process, in addition to design activities and methods. Working situations that in some way or the other support product development and concurrent engineering in virtual teams are of special interest.

This approach will offer a foundation for a product development methodology that allows the problem solving process to become more adapted to the core design problems, better adjusted to contextual factors of the design process, and less controlled by external and internal constraints and requirements. A way of achieving this is to better understand the role of working situations, which consist of different configurations of design methods, design processes, people and technology in a physical context.

EXISTING THEORIES AND WORK

During a typical engineering designer's working day, they find themselves busy doing individual design activities on their workstation, searching for information using the web and other resources, receiving and making several phone calls, sending and receiving a number of emails, meeting with visitors in their office landscape, and interacting informally with peers and customers in project meetings. In addition, they make informal sketches on a whiteboard or a piece of paper to clarify certain design aspects, perhaps as they meet colleagues by the coffee maker. They also make presentations and collaborate with others using chat, data conferences, and then save their work in virtual workspaces in order to make their latest updates available to others that are working on the same projects. As described above, the design process is indeed very complex, and it is often difficult to categorize the different sub processes that are taking place in the overall product development process.

According to Ulrich and Eppinger, the product development process can be described as *"the sequence or steps that an enterprise employs to conceive, design and commercialize a product"* (Ulrich and Eppinger 1995). The traditional, sequential, problem-oriented approach prescribes a logical cause and effect relationship between current design problems and how to solve the problem. The essential relation is between the problem and the standard problem solving method for that particular problem or group of problems. Lerdahl has described these context free methods as follows: *"The user context is then viewed as one of many rational criteria in the specification phase. Furthermore these methods try to be independent of the context in which the product is supposed to fit"* (Lerdahl 2001). Hence, traditionally, external factors in product development have not been considered to be important. However, the product development is a very complex activity where the designer typically changes environment several times per day. The availability of tools and people, in addition to differences in the surroundings, change as the designer move from one working situation to another. Contextual factors should be treated as a mediating element in working situations. The framework discussed here suggests that the problem solving process should be a configuration of the best available problem solving methods that are properly aligned with a supportive combination of contextual factors.

CONTEXTUAL FACTORS IN PRODUCT DEVELOPMENT

Contextual factors in product development can be described as surroundings, people and technology. Different surroundings define the physical context of any design process. Different configurations of people within certain surroundings influence the way and how often we communicate with each other. Technology influences the way we perform tasks related to any design process by introducing new opportunities and new ways of communicating, exchanging and sharing information, and the way we conduct other tasks. In addition, technology enhances the functionality and adds flexibility by making it possible to perform design activities independently of time and location. It is considered necessary to gain a better understanding of the relations between the tools designers use when designing, communicating and collaborating while they are using both a main virtual workspace and various remote technologies of a supportive character.

The physical domain is strong in terms of supporting a feeling of presence and real time collaboration, and for communicating through effective, large-scale visualization and the use of body language, which can trigger many senses simultaneously. One of the most prevalent advantages of interactive surfaces in the physical domain is that the input and output surfaces are the same, and this is well adapted to the favorable process that takes place during engineering design, where the designer actively reflects on his or her own design process (Schön 1982). On the other hand, the use of virtual communication tools such as virtual workspaces and data conferencing tools increase steadily. As much of the designers' interaction with others happen through these channels, it is becoming increasingly important to position these technologies as a natural part of the physical context. This two-step process is described below:

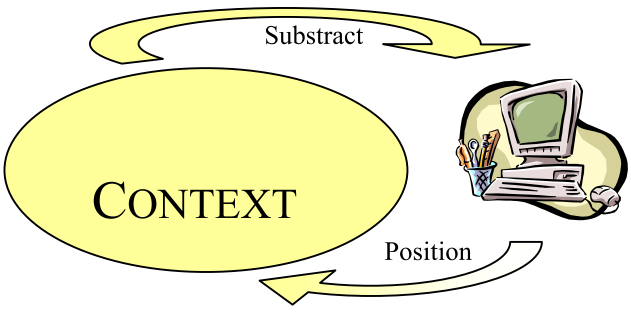

Figure 1: Linking Technology and Other Contextual Factors

1) Subtract important characteristics from the physical environment in order to create adequate functionality in the virtual workspace, and increasing the usability of these workspaces by using familiar terms and expressions known from traditional physical context, such as room metaphors et cetera. This process can be described as giving virtual

workspaces physical characteristics, and this process has been in progress for quite some time, as recent virtual workspaces usually come bundled with a wide variety of different tools.

2) Effectively position the virtual workspaces in the right context, and understanding the relations between the virtual workspaces and the environment they are operating in, or the designer interaction space. In particular, this can be accomplished by making use of technologies with combined characteristics, such as digital whiteboards that combine excellent visualization characteristics with virtual characteristics, such as the ability to share information effectively over distance, et cetera.

The physical domain is defined by the surroundings and other aspects of the physical context that encompass engineering designers. These are placed in the physical domain because of their distinct physical characteristics, by representing physical artifacts. Interactive surfaces in the *physical interaction space*, such as drawing surfaces (blackboards, whiteboards, paper, etc.) are of special interest, since these represent the points where engineering designers interact with their surroundings using pre-described, accepted methods.

Acknowledging the importance of understanding the designer interaction space is a key factor enabling the transition from physically co-located design work to effective design as performed by teams organized virtually. Improved design effectiveness and efficiency is the outcome of understanding and learning to master the opportunities prevalent in the interaction space of the designer, and understanding the role of virtual, collaborative workspaces in the context of the interaction space. The designer interaction space thus describes the system of physical context and virtual communication and collaboration components the designer interacts with, either by interaction through physical presence or through various virtual means of communication and collaboration.

WORKING SITUATIONS

Working situations describes the configuration of design methods and activities, design process, and contextual factors. These are all interrelated. Working situations occur within the framework of the designer's interaction space. Different working processes typically have different key configuration characteristics, based on external constraints and requirements and individual problem solving preferences, in addition to those introduced by the contextual factors people, technology and surroundings, which define the context of any given task-oriented working process.

The Complexity of Working Situations

Working situations are very complex of nature. The complexity of working situations is indicated in Table 1. In this table a small excerpt of the configuration variables surroundings, people, technology, process, and activities, is shown. Any configuration of these that is internally consistent defines a unique working situation. Hence, any changes in any of the configuration variables will inherently lead to a new working situation.

Table 1: The Complexity of Working Situations

Design Context: Surroundings	Office	Design studio	Meeting room	Informal zones	Travel	Home
Design Context: People	Team of One	Co-located (small to medium)	Co-located (medium to large)	Co-located with remote member	Mix of co-located & distributed	Fully distributed team
Design Context: Technology	CAD, CAE	Digital whiteboard	Telephone (mobile)	Virtual workspace	Data conferencing	Mail & messaging
Design Process	Detailed modeling	Concept generation	Analysis and evaluation	Information sharing	Decision making	Transfer of experience
Design Methods / Activities	QFD	TRIZ	Synectics	Brainstorming	Morphological Box	Value Analysis

Efficient Use of Working Situations

A new approach is proposed that is based on the use of working situations as the main perspective where surroundings, people, technology and design tasks are considered a part of the same, holistic framework, and where the significance of contextual factors are acknowledged and emphasized. Important aspects of this approach include gaining an understanding of how to make effective use of the visualization potential in active and passive spaces, how to act in accordance with people and their presence, and how to create atmospheres that support creativity and decision-making through motivation. This leads to a new perspective proposing a situation-based design where the designer actively reflects upon the different design situations he or she is exposed to.

Identifying and Configuring Working Situations

A working situation is here described as an outcome of a configuration process, where the goal is the input and the configuration process a means to achieve a favorable working situation. This is adapted to the goals, by providing appropriate design methods and a suitable design process, backed up by a supportive context consisting of a well balanced configuration of people, surroundings and technology.

When configuring working situations, the point of entry for the designer should be the goal, or what he or she wants to accomplish. This provides guidance to the design methods, the overall design process, and contextual factors. The type of process the designer is facing, whether this is concept generation, evaluation, structural analysis, decision making or any other kind, is related to both contextual factors, the overall goal, and the specific activities he or she engages in.

The designer should then move on to identify possible configurations of surroundings, people and technology he or she could choose from that would provide adequate support for the process he or she is about to engage in, and then select the most appropriate configuration. The configuration variables of working situations are shown in Figure 2.

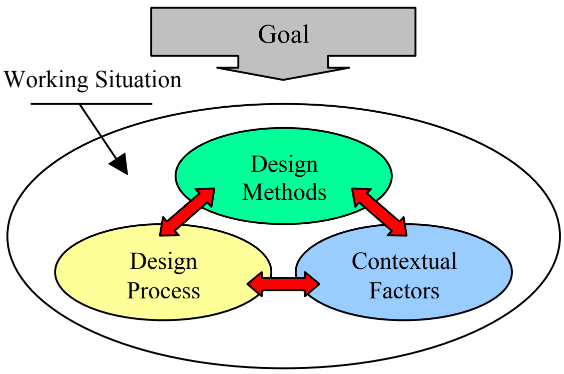

Figure 2: Working Situations, Conceptual Framework

CASE STUDY

A series of case studies in graduate course SIO2043 Machine Design and Mechatronics at Department of Machine Design and Materials Technology at NTNU (Fyhn et. al. 2001, Hildre et. al. 2000), showed that there were differences in how product development activities were carried out, depending on the working situation. Special attention was paid to contextual factors in concurrent engineering. In one of the case studies, half of the student groups were physically co-located, and the others were organized virtually, communicating through the use of data conferencing (using MS NetMeeting) and email. All the different stages in the overall product development process were observed, but special attention was paid to the creative processes, concept generation in particular. Concept generation is a very creative activity that depends on the concept of flow (Fyhn et. al. 2001). This process requires a working situation that supports this kind of activity.

Co-located Groups

In the co-located groups, the students developed concepts using PAD-techniques (Ottoson 1998), while using body language to explain and discuss ideas. The contextual configuration supported a strong feeling of presence and close collaboration. Furthermore, being co-located created an atmosphere, which supported flow. In addition, the tools in use were perceived as being transparent for the students, there were few obstacles, using them did not obstruct the flow in the creative processes. Finally, the paper-based sketches were perceived as being personal, with a strong ownership. The students in general neither drew nor wrote on each other's sketches. Instead, they made new sketches incorporating combined ideas from the group. All work had to be scanned in order to make it available to anyone, anytime.

Virtual Groups

In the virtual groups, the lack of body language, lower feel of presence and other aspects of altered contextual configuration changed the design methods in use as well as the design process. The design methods changed as the distributed team configuration required use of different tools to contribute to the product development process by communicating, or by making sketches or comments. The case study indicated that the virtual team configuration to some extent was inferior to the co-located team setting in terms of creating an atmosphere for close collaboration. In addition, the technology used by the students was not perceived as being transparent due to many technical problems. The students could often feel that the tools in use obstructed the flow in the creative processes. However, other interesting aspects were observed as well. The virtual medium used for collaboration over distance was to a much greater extent than the paper-based media perceived as being a shared medium where the students could build on each other's drawings and ideas.

There was a tendency that the working situations were adapted to fit the goals over time. At first, the teams were confused by the new, imposed working situation where they had to collaborate over distance, but they gradually learned how to master this situation. Although slow at first, the ability to make necessary adjustments in the working situations eventually improved the efficiency of the design process, as the students discovered ways to make these adjustments.

FINDINGS

In these case studies, there were strong indications that contextual factors and the way these were configured had a significant impact on both the overall design process, the design methods, and the activities the student were engaged in. The team configuration influenced the tools in use, which in turn affected both the overall design process and the different design activities.

Among the criteria that were observed, achieving a feeling of presence and close collaboration were important for the students. A team of designers needs a framework in which they can express opinions and excitement. Hence, the use of body language is important. For this process, adapting the working situation so that the contextual configuration supports the various activities taking place in the process is very important. To ensure a smooth process, it is important to make the technology as transparent as possible so that the creative process is not hampered. The surroundings, or physical environment, should be equipped with technology with required functionality. To some extent one can say that the virtual groups lacked contextual support. Hence there is a need to establish strong links between the technology in use and the context in which the technology is in use, as described earlier, in Figure 1.

It seems like the most common basis for choosing setting is habitual practice, one chooses between a set of "standard solutions" where one feels experienced. These standard solutions often represent only a fraction of the available contextual configurations. Hence, designers often get "stuck" in the wrong working situation, or there is often a lag between the change of process and the necessary adjustments in the working situation. However, over time the standard solutions are slowly adapted to fit the problems better, in particular in terms of providing better contextual support for the design process.

CONCLUSIONS

Describing the design process through a set of working situations describes an approach for designing based on an notion that designers are present in a physical context, and that different configurations of surroundings, people and technologies can be adapted to different design methods and activities, besides providing contextual support for different design processes. These configurations each define a distinct working situation that is unique and has its own characteristics in terms of modes of communication and collaboration. The great selection of possible configurations should be used as a means to ensure better contextual support for design processes, methods and activities, which will allow the problem solving process to be better aligned with the problem setting, by taking contextual factors into consideration.

A series of case studies has shown that there are clear indications that an increased awareness of the role of working situations in product development will improve the utilization of the principles of concurrent engineering. This is particularly important for working situations dominated by real time collaboration.

In order to make use of configuration of working situation as a design tool, there is a need to make contextual factors tangible and for reaching a deeper understanding of how contextual factors relate to the design process and the design problem itself. Once this is established, the reflective designer can become capable of monitoring his or her own design activities in such a way that a feed forward approach is made feasible. This can be described as “The best working situation is always the next”, where the designer actively navigates through different working situations instead of drifting between them, which is the logical outcome of not taking contextual factors into consideration.

FURTHER RESEARCH

Suggestions for further research include defining a framework where the contextual factors are made tangible. There is also a need to establish a set of criteria, which can serve as guidelines for configuring working situations. Combined, it is then possible to make tools and methods for configuring suitable working situations as a function of goals and available activities, processes, and contextual configurations.

Furthermore the dynamics of working situations should be explored, in order to understand the transition mechanisms between different working situations and how to avoid the lag or delay between the point where the working situation does not provide sufficient contextual support, and the point where the designer discovers this, and decides to make the necessary adjustments by configuring a new working situation.

It would also be useful to explore tools, methods and technologies that can assist the transitions between different working situations, making it easier to move a product development process from one working situation to another, without losing momentum.

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BIOGRAPHY

KJETIL KRISTENSEN was born in Bærum, Norway. He received his graduate degree (sivilingeniør) from the Faculty of Mechanical Engineering at the Norwegian University of Science and Technology in March 2000, specializing in product development and distributed collaboration. He is currently pursuing a dr.ing. degree at the Department of Machine Design and Materials Technology at NTNU. He is also a co-founder of Boost Communications, a company offering SMS-based marketing tools and communication solutions for businesses and organizations.

TUTORING ACTIVITIES SUPPORTED BY ARTIFICIAL TUTORS

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KEYWORDS

Agent-Based Computing, Artificial Tutors, Distributed Systems, Knowledge Engineering, Concurrent Engineering, Java Technology, Jini, and Jess.

ABSTRACT

Siesta is a distributed multi-agent system specially conceived to support e-learning activities in a conventional university environment. The system operates in a private intranet domain, providing on-line facilities for student evaluation and tutoring in multi-disciplinary domains, through conventional web browsers. Tutoring activities are supported by a specialized group of expert agents, the system tutors. These artificial tutors have the ability to follow students as they progress in the execution of a particular set of tasks, monitoring them or generating explanations about terms, concepts or other kind of requests necessary to the correct execution of an exam, a homework, or a laboratory test. This paper presents the design and implementation of the Siesta system, focusing on its functional architecture, agents, and interface platforms functionalities.

INTRODUCTION

Nowadays, it is not an unusual situation to find in a typical university environment teachers being solicited all the time to provide students with complementary information related to the scientific and technical areas that they usually study and learn inside classes. Additionally, they use also to require to teachers past exams, new or more advanced exercises, or simply some minutes more to discuss a particular case study. Some of them also expect to find teachers every time they need help in the execution of a particular task. Usually, teachers do not have the time they wish to satisfy all students' requests. They are frequently involved with management tasks, invited talks, or special tutoring activities, which systematically consume all the available time they have. Trying to attenuate this lack of attendance, teachers use to define special attendance periods exclusively dedicated to receive students and provide some additional tutorial support. But, in specific disciplines, with a large number of students, these periods are clearly insufficient to surpass such kind of problems. Cases like these, specially the ones concerning with the availability of teachers to attend students and in the definition of additional studying plans and tutoring proposals, demand and justify the existence of special tools and structures to help teachers on such activities. The main goal of this work was to define and build a specific subject-oriented tutoring system with the ability to support students in scientific and technologic fields where they develop study activities and projects.

The *Intelligent Tutoring Systems* (ITS) field (Murray 1999) (Chappell and Mitchell 1997) provides us the abilities to develop sophisticated software systems oriented to support and giving help in specific knowledge domain learning processes. Usually, an ITS presents means that students could use in the development of their own studying and knowledge acquisition models. Furthermore, an ITS also has the ability to follow students as they progress in the execution of a particular set of tasks, monitoring and correct them when necessary, or generate explanations about terms, concepts or other kind of requests during the study sessions. We believe that the integration of an ITS inside an university environment, accessed and used through an intranet infra-structure, will allows the improvement of student assistance, and attenuates in fact the effect of teachers' unavailability. An ITS can act as a private (artificial) tutor, with a high level of availability to attend students. Potentially, with the right operational conditions, students can use it 24 hours a day. Many are the examples of ITS projects and applications that we could easily found in scientific repositories, in the Internet, or in specialized literature (Pamela et al. 2001) (Viryou and Moundridou 2000) (Angehrn et al. 2001). Artificial tutors will be very important and useful tools, acting as complementary means to teachers' expertise and knowledge, since they have the ability to follow the evolution of the students in tutoring sessions, providing exams, quiz sessions, or simple exercise texts.

In this paper we present a general overview of the implementation of an agent-based computer-aided tutoring system - the Siesta system -, approaching essentially all the aspects concerning its functional architecture, agents' classes and interaction models, user-system facilities, and system's data repositories.

THE SIESTA SYSTEM

General Overview

SIESTA is a distributed multi-agent system specially conceived to support e-learning activities in a conventional university environment. The system operates in a private intranet domain, providing on-line facilities for student evaluation and tutoring in multi-disciplinary domains through conventional web browsers. It provides specialized means to access and use remotely distinct repositories of evaluation and tutoring packages through conventional Internet browsers. System's tutoring activities are supported by a specialized group of expert agents, the system tutors. Searching, comparing, learning, and collaborating are typical tasks that agents can do on behalf of students, teachers and system's administrators. Spontaneously, they promote the division of tasks, according to their own expertise and knowledge, taking advantage of their abilities to cooperate and, consequently, conciliate all their independent efforts (Jennings and Wooldridge 2001) (Kinny and Georgeff 1997).

The system does not intend to substitute a teacher or a human tutor, but it is a good complementary mean to follow and support students in specific areas of knowledge. It is a first attempt to reduce the effort of evaluation and teaching of large communities of students. Additionally, in case of an evaluation process the system is impartial and the results are more accurate that the ones obtained in a traditional way. In order to allow teachers and question makers to adjust future evaluation or studying sessions' parameters, the system stores all the data concerning topics, answers, questions, and explanations posed or required by students in specific decision support structures.

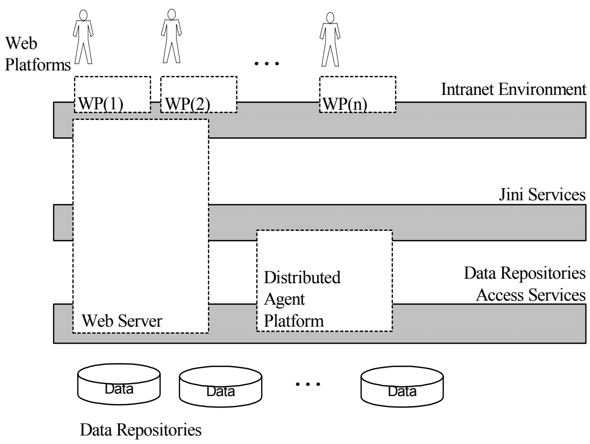

Figure 1: Siesta's Functional Architecture

System's Architecture

The system's main functional architecture (Figure 1) is organized into four distinct layers, namely:

- Web Platforms, which represents the computational platforms that support conventional browsers, providing access and granting services to system's users inside an intranet environment.
- Web Server, which is responsible to ensure and support the communication channels between the system's users and agents. It is built upon three main components: *Communication*, that ensures the dialogue between the web browsers and the system; *Web Services*, a set of plugins integrated into the web server in order to make it parameterised and extensible - the extensions are typically Java Servlets; and the *Data access*, which is in charge to manage the connections between the Web Services component and the system's data repositories.
- Distributed Agent Platform, which provides the means and structures to receive and support the system's expert agents, whose main responsability is to decide what kind of questions and tutoring strategies should be selected.
- Data and Knowledge Repositories, which is responsible to provide data and decision support structures to tutoring and evaluation activities.

The distributed agent platform is the main system's component, due to its primer positioning in tutoring and evaluation activities. However, the servlet server, which attends requests and delivers them to the corresponding servlets, assume as well a major role in the global system functioning, since it maintains all the interaction processes between the system and the users. There are many advantages in using a component like this. It facilitates significantly the process of adding a new component or service to the system, or even to personalize any of the system's interface platforms. The servlets communicate with the system's expert agents through a private communication medium - the distributed agent platform - using interface agents as communication service gateways. The communication medium is supported by Jini (Sun Microsystems 2001). System's agents use this medium to exchange messages among them and share data structures.

The Agents

Basically, the system integrates two classes of agents: interface and tutors. The former class is responsible to ensure a subject oriented communication platform between the web server and the tutors, providing facilities to present and evaluate the answers of the students during an exam, or during a presentation of a specific lesson. They also have the possibility to show the entire interaction history between users and the system, explain a particular inference path, or giving some help in the initial selection of an artificial tutor. They act as specialized gateways, granting the connection between the system's web services layer and the community of expert agents located in the distributed agent platform. The expert agents community constitutes the second class of agents - the tutors. As intelligent agents, with expertise and knowledge in specific domains, they have abilities to follow the students as they progress in the execution of a particular set of tasks, monitoring them or generating explanations about terms, concepts or other kind of requests necessary to the correct execution of the task - an exam, a homework, a laboratory test, or a simple studying session. An expert agent has the ability to supervise the students' working sessions accordingly to their system profiles and select the evaluation packages, deciding what kind of tutoring strategy it will apply in order to follow or evaluate the student's knowledge acquisition process. The expert agents are capable of interacting with each other, delivering control messages, status messages or data.

During the system sessions, tutors supervise the activities performed by students accordingly to their profile and the selected evaluation or studying package, deciding, in real time, the "best" plan to apply the studying strategies improving student's knowledge and expertise. The content details of a question or a teaching action are determined by the strategies stored in the tutor's knowledge base, which also stores a particular set of decision structures that allows the tutor to determine the appropriate teaching strategy. If a student select a session involving more than one tutor - a multidisciplinary session integrating several knowledge domains -, the tutors are able to promote cooperation among them, evaluating together the student session, exchanging data or results accordingly to the evaluation process requirements. Lessons and evaluation tests are presented in a conventional web browser using hypertext structures.

Globally, two independent data repositories are responsible to provide data and decision support structures to maintain tutoring and evaluation activities performed by system's agents. They are: the online transaction processing unit, which is responsible to manage and store the necessary information to support all the evaluation and tutoring processes - questions and inter-related data (images, texts and others), and tutoring sessions information; and a tutoring and evaluation subject-oriented data warehouse, which keeps basically the information related to past processes, maintaining historical data that will be used later in the (re)definition of the student's profile.

The Users

The system allows the definition of three different user profiles: system administrators, knowledge domain administrators, and students. The former profile is exclusively used by system's administrators to perform conventional maintenance tasks. The second one is the teachers' profile, which provides them access to the system and supports all the services used to configure and set up the evaluation and tutoring activities. Finally, the student's profile provides the means that students can use to access the system, in order to apply for a tutoring or evaluation session.

Implementation Issues

All system's components were developed in JAVA. The distributed agent environment was implemented in Jini and the expert agents' reasoning mechanisms in Jess.

CONCLUSIONS AND FUTURE WORK

The many applications that we find today in ITS fields show clearly the benefits that we can reach when using them in the support of tutoring and evaluation tasks. The integration of agent-based technology in this kind of systems it is not a new approach, having been used in several research and application efforts in the last years (Rickel and Johnson 2000) (Roda 2000). We believe that Siesta opens new perspectives in the support of tutoring and evaluation activities, namely in areas where it is required expertise and knowledge to deal with multidisciplinary problems. Additionally, it provides very flexible interface platforms, allowing system expansion to new student operational requirements without being necessary to develop special user interfaces or adapt the structures and functionalities of the system's agents. The current version of the system must be improved, in order to increase its efficiency and performance towards a more robust and efficient system. The coordination and cooperation models implemented must be refined and extended to receive new forms of inter-agent communication and information sharing. We also intend to create new forms of system interfacing based on mobile devices, such as PDAs or Web-PADs, providing to students the means to take with them a set of tutoring sessions, that will be latter appreciated by the corresponding expert agents.

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ENGINEERING A DMU-RESULTMANAGEMENT SYSTEM

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KEYWORDS

System Development Process, Specification Languages, Workflow Management in CE, Practical Solutions, Case Studies, Pilot Projects and Experiments

ABSTRACT

Rapid technological progress is responsible for continously changing IT-infrastuctures. This makes the introduction of new long term IT-solutions a difficult task. To handle software requirements for a new IT-tool we chose use cases, a software engineering technique for requirements documentation, and adopted it to our specific needs. Use cases have a number of well known weaknesses like feature interactions and early focus on human-machine interaction. We varied this technique by extracting commonalities and giving additional context information. Further, we kept requirements descriptions abstract with respect to the concrete software environments used by different development projects. Our experiences were positive. The only disadvantage of our approach was the effort needed to create structured lists of requirements for management reports.

INTRODUCTION

One of the main goals of the ECoS (Engineering of Cooperative Information Systems) group of DaimlerChrysler corporate research is the development of software engineering methods for cooperative information systems (De Michelis et al., 1997). In a close cooperation with various business units of DaimlerChrysler these methods are applied in a practical context, evaluated and improved. In this paper we describe the application and evaluation of a use case based requirements analysis and system evaluation for a DMU-resultmanagement system together with our partner from the Mercedes-Benz passenger car division.

As the automotive industry is muving from a manual DMU (digital mock-up) process for collision and distance violation checks to an automatic process, new IT-tools are required. Automatic collision and distance violation checks produce a huge number of results on a regular timely basis. These results need to be inspected, evaluated, classified and if necessary communicated to the engineers of the conflicting parts. As there is usually only a small percentage of changing results from one such check to the next succeeding check, not all of the produced results need to be inspected. Hence, there is a need for an intelligent management of those computation results to avoid unnecessary re-inspection, -evaluation or -description.

To optimize costs a unique strategic solution for result-management that satisfies the needs of all car development projects should be developed to replace the local systems. What made this effort difficult is the rapid technological progress. As a consequence, different car projects, which of course have completely different target dates for the start of production, use slightly different IT-infrastructures not only within the DMU-process. Hence, a software development method for such a long term solution must deal with this continous change appropriately. This article describes experiences of applying our software engineering method to find, document and negotiate the requirements for such a resultmanagement system and to identify a strategic solution for the DMU-process.

HANDLING SOFTWARE REQUIREMENTS

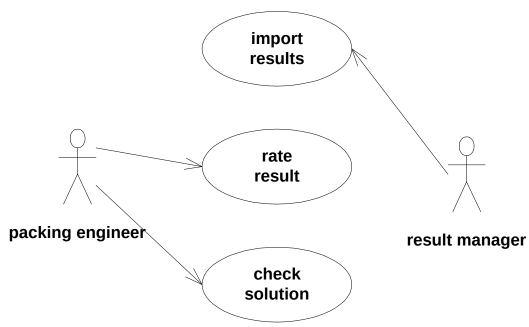

Figure 1: Use case diagram

To handle software requirements we chose use cases (Cockburn, 2001; Jacobson et al., 1994; Larman, 1997; RUP Development Team, 1999). Use Cases are a software engineering technique to elicit, document and validate software requirements. They describe the tasks to be supported by the software from a user's point of view. In general, two types of documents are supported: a use case diagram, describing the set of tasks under consideration, and use case descriptions, a text document, that provides the detailed information how each task will be executed with the support of the future software system. A use case description is structured into a short description, a precondition, a flow of events and a postcondition.

Figure 1 shows an example: A use case diagram, here given in UML notation (OMG, 2001), consists of actors ('packaging engineer', 'result manager'), use cases ('import results', 'rate results' and 'check solution') and relations indicating what actor initiates what use case. An actor represents a role that interacts with the software system under consideration. There are several extensions to this simple notation. We refer the interested reader for further information to the literature given at the beginning of this section.

A use case description for 'rate result' may look like given in Figure 2.

> *Use Case 'rate result:'*
> A specific result that has to be rated manually is searched and rated.
>
> *Precondition:*
> Most recent results imported.
>
> *Flow of events:*
> – Result manager logs on.
> – The system provides the current list of results to be rated manually.
> – Result manager chooses one of those.
> – He gets all attributes displayed.
> – He sets the rate based on this information.
> – The system stores this rate permanently.
>
> *Postcondition:*
> The desired result has been rated.

Figure 2: Use case description

The flow of events is a detailed documentation of the interactions between the actor and the system they will go through in order to solve the task.

Known Problems

Use cases have experienced wide acceptance in the software engineering community. They are easy to understand by the future system's user and provide good context information where the requirements come from since the requirements are usually directly embedded into the flow of events, that is, in the user's work sequence (Kulak and Guiney, 2000). But also a number of difficulties with their applications have been reported.

It is up to the software engineer to choose a *level of abstraction appropriate* for such a description. Writing good use cases and including the right information without describing too much detail is mainly based on personal experience (Cockburn, 2001) and dependent on the application context. So, this technique can misguide the software engineer by drawing his attention too early on human-machnine interaction before understanding requirements. But, in the software development process, interaction design is considered to be a step after requirements understanding (Jackson, 1998; Kovitz, 1998).

The above mentioned advantage that a use case description gives a context for a requirement has also a downside. The drawback of this documentation technique is, that a *single* requirement, for instance 'the resultmanagement system provides a standard query for all results to be rated manually', can appear in *many* use cases. Changing this requirement at one place makes a complete review of all the other use case descriptions necessary in order to keep the documentation consistent. This phenomena is also known as *feature interaction* (Jackson, 1998; Kovitz, 1998).

The resultmanagement system has to be integrated into an existing DMU process and an existing IT-infrastructure. A use case is a single user single task view. Hence, there's *no possibility to express* this *embedding* of the resultmanagement system. A common way of (partially) solving this problem is modeling surrounding components by actors. But we also need descriptions of such components themselves. For instance, there is the need to describe the expected input format from the clash computing system. Based on this information, requirements for the import of this data into the resultmanagement software can be de£ned. Further, the problem of describing the integration into the process remains.

Our Approach

To address these problems, we varied use cases to better fulfill our specific needs.

We kept requirements descriptions abstract by chosing a description level that is unspecific to the concrete software environment used by the different development projects. For instance, instead of talking about a specific clash computing software and describing technical file formats of one or several such systems, that usually needs to be included in a requirements specification, we were only talking about general aspects like necessary attributes of result lists.

Commonalites among different use cases were extracted and documented in seperate sections. The flow of events only contained references. Many use cases needed standard filters like 'results sorted by part' or 'all parts that are involved in a conflict' etc. Such filters were documented in a seperate section and use case flow of events descriptions used references to the filters needed. The same technique were applied for more detailed documentation of objects like 'result' and their attributes.

Finally, we gave an additional overview diagram to outline the resultmanagement systems integration into the current infrastructure and process. Infrastructure descriptions contain information about the IT components that feed the resultmanagement system with data (like the clash computing) and components that use the output for futher processing (like further handling of conflicting parts). This is an equivalent idea to the well known Structured Analysis context diagram (Yourdon, 1991). In addition, the DMU process steps that are supported by the resultmanagement software are directly attached to this context diagram. An example is given in Figure 3.

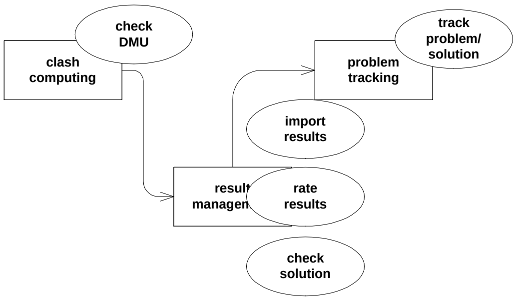

Figure 3: IT-infrastructure and DMU-process context

The resultmanagement imports data (a result list) from the clash computing software and exports a subset of those results to the problem tracking where a result is routed to the responsible engineers. Beside the use cases of the diagram given in Figure 1 we list the DMU-process steps before and after the resultmanagement and attach them to the software components that support their execution.

APPLICATION RESULTS

Our experiences with the selected software engineering method were positive. The level of abstraction chosen for the description of requirements enabled us to achieve an agreement about the requirements very quickly. Comparable projects required considerably more time for this task. It turned out that one of the main challenges of effective requirements documentation and negotiation is finding a level of abstraction that provides enough detail to talk about requirements in a concrete way but leaving out enough in order to avoid an early commitment to a specific software solution. Those desicions should be postponed until software implementation assignment. Furthermore, the use case based requirements description made the evaluation of requirements with the domain experts and the evaluation of the software alternatives with the software providers very easy. The only disadvantage of the use case based approach was the effort needed to create a structured list of requirements or an overview of the evaluation results of different software alternatives. Further improvement can be done in the modeling and description of IT-infrastructure and DMU process context information. This becomes more important when taking more than just resultmanagement into account. Possible extensions may be based on Jackson's work on problem frames (Jackson, 2001).

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EXTENDING CIM.OSA MODELLING FRAMEWORK TO e-ENTERPRISES

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ABSTRACT,
The paper is an attempt to introduce a modelling framework for e-Enterprise new concept. Taking into account the high-level research to rafinate the CIM.OSA standard for enterprise integration, an extended 7x7x7 cube is proposed.Finally, the universitary pilot within University POLITEHNICA of Bucharest is in progress as a validation test. The common research work developed by the Concurrent Enterprising Network of Excellence (IST project no. 1999 – 29107) was a usefull informational groupware experience used for the present research.

Keywords: Virtual Enterprise, Fabricator, eEnterprise, CIM.OSA

1. INTRODUCTION

The various sintagmas used for different views of the new manufacturing paradigm are describing the global research effort focusing on the digital era challenge. Th**e** ***NGMS*** (Next Generation Manufacturing Systems) (Kosanke 1998), the ***ADMS*** (Advance Manufacturing Systems), (Fabian 1998), the ***DEE***- Dynamic Extended Enterprise, (Browne 1998), the ***IMS*** - Intelligent Manufacturing Systems, (Brussel 1999) or the ***CE-*** Concurrent Enterprise, (Pallot 2000) are based on the new key-words: agile (Kidd 1994), holonic (Arai 1999), fractal (Bischoff 1998), bionic (Hatono 1999), virtual (Camarinha-Matos 2000). The new type of enterprises will have some new characteristic proprieties: autonomy, co-operation, virtual multidisciplinary team work, integrated approach for product-process-system design, re-thinking of humans position and role, they will be agile as organisation and virtual as geographic distribution and alliance. An important requirement for all post-CIM manufacturing systems is the ability to capture knowledge from multiple disciplines and store it in a form that facilitates re-use, sharing, and extensibility. The manufacturing environment is typically seen as a large, complex, man-made system of heterogeneous, interrelated activities. Designers, planners, operators, schedulers are organisationally integrated within the collaborative ICT-based system. The convergence of disciplines involves real time control, embedded control, networking control (Metakides 2001), mobile communication (Antoniac 2001), multi-modelling and simulation driven design for complex socio technical systems.

The important contribution brought into scientifically community attention by University Nova de Lisbon is concerned with an ICT support platform for Virtual Enterprise (VE). Considering a VE as a temporary and dynamic (i.e. with variable ”geometry”) organisation that appears in response to a business opportunity and disbanded on the completion of this business process (Camarinha 2000) a number of both base and auxiliary facilities&service can be identified. Potential partners' selection and negotiations agreements could be supported by the contract-net approach of the Distributed Information Management System. One of the important issues here is the identification of “who will perform this function” in this “democratic” value chain (Katzy 2000).

During operation of a VE, by Web interconnection among partners from e-commerce to points of sales and crossing all intermediate nodes: manufacturers and distribution centres, there are some important goals to be achieved: the efficiency of orders flow, follow-up of orders evolution, management and exchange of order information among partners, distributed and dynamic scheduling, quality information even distance learning.

It is the aim of the present paper to look beyond the virtual enterprise modelling framework. An attempt was planned for the debate during conference: “e-Enterprise is a powerful enough concept in comparison with VE?”. The author’s answer involves a general modelling framework : extended CIM.OSA cube.

2. FROM VIRTUAL ENTERPRISE TOWARDS e-ENTERPRISE

Now-a days the "Virtual Enterprise" is for sure a hot research domain within Information Society horizon of hope.
The closest "rival" term to VE is Extended Enterprise (EE) applied to "an organisation in which a dominant enterprise extends “boundaries” to all or some of its suppliers, where the VE can be seen as a more general concept including other types of organisations, namely a more democratic structure in which cooperation is peer to peer." [Camarinha,1999]
One could stress on the idea that geographically distributed networked enterprises have a limited life cycle due to specific business duration. Each node has to perform a dedicated set of tasks, based on their core competence (Katzy 2000). This new type of organisation, VE, is faster reactive for facing the business process finite horizon opportunity better than well-known traditional organisations. The Virtual Enterprise involves:

- **A business integrator**, allowing both the vertical and horizontally integration of SMEs, large companies (Santoro 1997);
- A web community (concerning **user friendly** e- business approach for developing activity on electronic market place);
- A multi-agent based internal **co-ordinator**, implementing Production Planning and Control (PP&C) within wide-area-network of heterogeneous platforms;
- An extended concurrent engineering oriented **designer** for product/ process / production system facilities .

There is no unique definition of VE, but a mosaik of definitions will permit us to underline some basic features, as follows
Definition 1: The Virtual Enterprise is a temporary alliance of enterprises that came together to share skills and resources in order to attend a business opportunity and whose co-operation is supported by computer networks and adequate IT (Information Technology) tools and protocols .
Definition 2: A Virtual Enterprise (VE) is a co-operative alliance often between entities with individually distinct legal identities which come together to exploit a particular business opportunity. Harnessing the power of working group technologies, the VE provides participants with a framework through which they can share the risks and returns, involved in bringing new products and services to market.
[The Alive Project/ http://www.vive-ig.net/projects/alive.html]
Advanced Legal Issues in Virtual Enterprise.
Definition 3: The Virtual Enterprise is an open meta-system in a business universe where acts a set of Fabricators utilising multi-model representations of products/processes and co-operating in the framework of temporary alliances for achieving a set of goals (Curaj 1998):

VE = (U, F, Mv, G), where:

- **U** is an universe of discrete business processes

Note: The CIM-OSA methodology was the first to formalize business as a specific type of processes triggered by market requirements.

- **F** is the set of Fabricators (Stanescu 1997)

The Fabricator is an autonomous agent having a set of core competence (*i.e.* a set of functions that it is able to accomplish). A Fabricator could co-operate with other Fabricators with similar/ different core competencies by communicating goals and data. By modifying its own performance evaluation measures according to a global goal and optimality criterion, a Fabricator defines itself as a fast-reactive component of a meta-system.

- **Mv** is the set of representations of products/ processes/facilities depending on the type of Fabricators utilising them i.e. the set of multi-model representations (Stanescu 1997)
- **G** is a structure of goal-type that is decomposable into a tree of objectives for every Fabricator implied in the VE meta-structure

As definitions underline, the main features of a VE are:

- the capacity of innovation;
- the capacity of co-operation;
- the capacity of internal reconfiguration;
- fast-reactivity;
- open system architecture compliant with well - known standards (STEP, COBRA, EDI-FACT)

Despite this high-quality research work, a lot of traditional businessmen and industrial managers are facing circumspectiously the new “type” of enterprise. Keeping in author’s mind the various discussions about this concept, an attempt could be made to broaden the power of circulation by introducing a new concept: e-Enterprise.

We are basically trying to “re-couple” the concepts of Virtual Enterprise and Real Enterprise.

e-Enterprise is a socio-technical metasystem consisting of:

- A set of product and/or services provider along of business life cycle (product life cycle) namely real Fabricators (*r*F)
- A set of functional entities involved in a role distributions to accomplish a business scenario (*v*E)
- An intelligent communication systems including enterprise collaboration system & others e-transport global platforms
- An e-business based web community created according legal issues negotiation among autonomous partners/organisational units.

Note: This e-E metasystem is fast reactive dispersed geographically organization acting on global market (aiming to be socked within an e-marketplace). The main category of disturbances is due to turbulence of higher dynamic global market.

The web community of an eE uses a mosaic of the ICT to support multidisciplinary virtual teams activities like:

- Face to face meetings (team building tools, electronic decision tools, electronic copy boards)
- Cross distance meetings (audio video conference, screen sharing)
- On going coordination (electronic mail, voice over IP, group editing, virtual project management/ scheduling)

The e-Transport platform is based on a well-balanced solution Intranet/Extranet //Internet, which must support collaboration software, knows as “GROUPWARE”. The recommended modelling framework extended CIMOSA cube, where the meta – language is XML/XSP.

The formal definition is the following quintuple:

e-E :{*r*F, (*r*P, *r*S), vE, webdt,*C*,*G*}.

In 1985, the ESPRIT Consortium AMICE started to work on the definition and specification of a Computer Integrated Manufacturing (CIM) architecture for enterprise integration.

- As a result the CIM.OSA is an ESPRIT supported pre-normative development which provides a framework based on the system life cycle concept together with a modelling language and definitions of a methodology and supporting technology

Taking into account this richness of expertise for enterprise modeling the authors do believe that the most appropriate virtual enterprise modeling framework has to be the extended CIM.OSA cube.

However, some specific modification must be operated.

The CIM.OSA three orthogonal dimension could be preserved but they will receive different purposes.

(X) Instantiation of Building Blocks

(Y) Generation of Views (structural approach)

(Z) Derivation of Layers (architectural approach)

In comparison with the CIM.OSA modeling framework , the e-CIM.OSA 7x7x7 hypercube involves the following significance:

Z

7) e-business	e-management
e-commerce	
6) e-services	Supply Chain Management
mobile communications	
5) e-knowledge	
e-learning	Customer Relationship Management
4) e-management	
suply chain / customer relationship	
3) e-design	Production Planning & Control
2) e-logistic	
1) e-manufacturing	
Transport layer (CSCW /ICS)	Platform

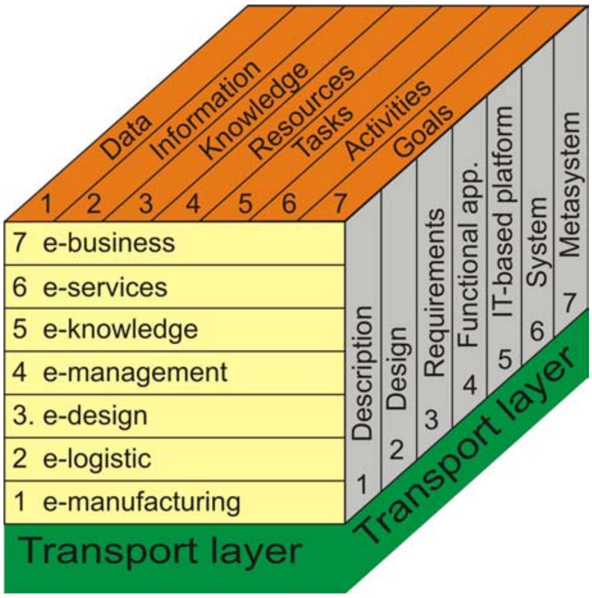
Y

7) metasystem	Transaction Processing System
V.E. / E.E. / e-E	Enterprise Collaboration System
6) Systems	Process Control System
5) IT-based CAx DFx platform	Management Information System
4) Functional Applications (APIs)	Decision Support System
3) Requirements modelling	Executive Information System
2) Design specificiation model	• Workflow Management System
1)Description of Implementation	• Product Data Management
Transport layer	• Process Planning System
	Platform

X

7) Goals / / benefic (business plan)	
6) Activities (IDEF 1,2,3,..)	
5) Tasks (project management)	
4) Resources(human, financial,capital, SW, HW)	
3) Knowledge knowledge base	
2) Information(structured data Data bases (relational, OO)	
1) Data (objects, entities)	
Transport layer	Platform

As a first validation test , a metasystem eE has been developed during last three years within the University “POLITEHNICA”of Bucharest



Based on Communication System which is described in [Cristea, Florea, Stanescu, 2000]; our universitary pilot consist of the following organizational actors: 3 Flexible Manufacturing Cells, 3km dispersed within the PUB campus, one of them Internet enabled cell (QNX – operating system) – providers ; 6 design laboratories (CATIA V4/V5 net) ;1 outsourcing DFMA ; 2 outsourcing Service Providers for modeling and optimization of manufacturing system (SIMAN-Arena and Enterprise Dynamics Taylor) ; 1 FMEA – (Failure Made and Effect Analyses) ; 1 ERP System laboratory (SAP-R/3) ; PDM system laboratory (Enovia) ; BPMS system (business process management ADONIS – BOC Gmbh) ; Executive Information System (SAS) ; Quality Function Deployment (SAS-QC) laboratory ; Process Planning System Laboratory

- A platform joining WfM. System & PDM system is planned to be supplemented this summer.

3 .CONCLUSIONS

The paper has an attempt to introduce an extended modelling framework e-CIM.OSA for promoting the e-Enterprise concept. Some recent results for Virtual Enterprise conceptual design are also proposed for debate during conference.

Finally, the collaborative e-Enterprise pilot within University POLITEHNICA of

Bucharest is described briefly. A special focus is developed to cluster research projects FABRICATOR & CoLaborator. This cluster is based on the idea that human resources, knowledge and creativity are the driving forces of the new generation of networked organisations (enterprises, laboratories, universities).

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DESIGN OF AN INTEGRATED PRODUCT DEVELOPMENT – AN ACTIVITY AND INFORMATION-BASED APPROACH –

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KEYWORDS
Integrated Product Development, Product and Process Model, Methods Database

ABSTRACT

Within this article an integrated approach to organize development processes on basis of activities and information flows will be presented. To support integrated product and process development several aspects have to be taken into account simultaneously: data and information management, process structuring and supporting methods. Within the Collaborative Research Centre 361 "Models and Methods for an Integrated Design of Products and Processes" an integrated approach has been developed to handle these aspects. For the management of data and information a generic integrated product and process model (IPPM) has been developed. Using this generic process model enterprise specific reference processes can be instantiated. Supporting methods and tools are associated in a methods database and linked with corresponding process steps. Within a case study of industrial applications the potential of the presented approach will be demonstrated.

INTRODUCTION

The development of innovative products which are in line with customer requirements and technological changes is one precondition for sustainable competitiveness. In this context, an efficient product and process development is one of the most important key factors. Therefore the Laboratory for Machine Tools and Production Engineering (WZL) developed an integrated approach to organize development processes on basis of activities and information flow. The approach is one result of the Collaborative Research Centre 361 "Models and Methods for an Integrated Design of Products and Processes" (sponsored by Deutsche Forschungsgemeinschaft) at the RWTH Aachen (SFB 361). This Collaborative Research Centre is an interdisciplinary research project of 13 institutes and chairs from the engineering as well as business administration faculty. The objective of this collaboration is the development of models, methods and tools which allow a market and customer focused parallel and integrated design of products, processes and services. The development process has to be supported methodologically from the first product idea till the layout of necessary production means.
To support these complex overall tasks both, a continuous process and product data model as well as supporting methods are necessary.

MODELS FOR THE INTEGRATED PRODUCT AND PROCESS DESIGN

An integrated product and process model (IPPM) has been developed to ensure the representation, integration and distribution of data and information for an integrated design of products and processes. The IPPM is an object oriented generic model. To ensure extensibility and transparency the IPPM is build modularly. It consists of 34 schemata. The formal representation has been realized in the data modelling language EXPRESS and its graphical subset EXPRESS-G. The IPPM encompasses data and information of all product life cycle phases, whereas the provision of data and information focuses on product and process development. With its contents and functionality the IPPM is the basis of conceptual and IT integration inside the Collaborative Research Centre 361 (Collaborative Research Centre 361 2002).
Core of the IPPM is the product model and the process model. They are connected by the meta information model. Further components are the resource model, the life cycle model and the assessment model. The resource model represents data about resources like staff, organization, materials and production facilities. Information about life cycle, i.e. life cycle phase, is stored in the life cycle schema. Information that is necessary for assessment of activities, status of activities and components are stored in the assessment model. Project example of the Collaborative Research Centre 361 is the development of a wind turbine. The generic schemata of the IPPM are instantiated i.e. with the project structure elements, processes, resources and methods of this specific project. The general structure of the IPPM is displayed in Figure 1.
In the following the instantiation will be demonstrated by the example of the process scheme. The process scheme supports modelling process structures and process networks (Eversheim, Westekemper 2001). It allows also the representation of uncertain processes. Core of the process scheme is the activity element (Figure 2). An activity is an activity group, a generic activity, a specific activity or an individual activity, where an activity group consists of one

or more generic activities. Activities reference on resources, time, objectives, organization, components, and characteristics. The data is stored in referenced schemes. Activities might have preceding and following activities.

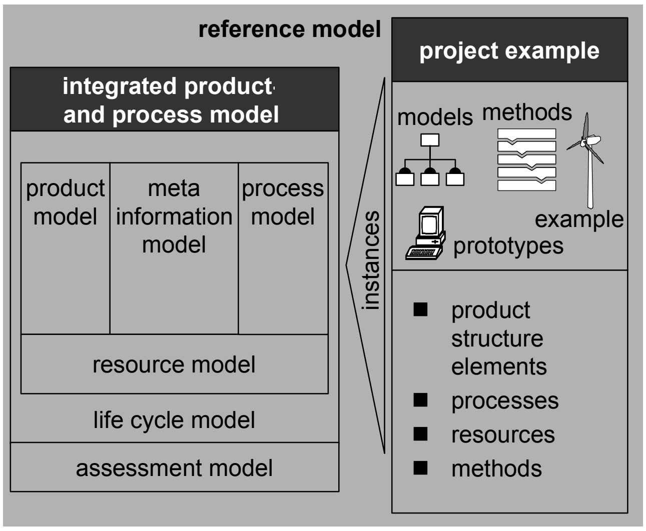

Figure 1: Structure of the IPPM

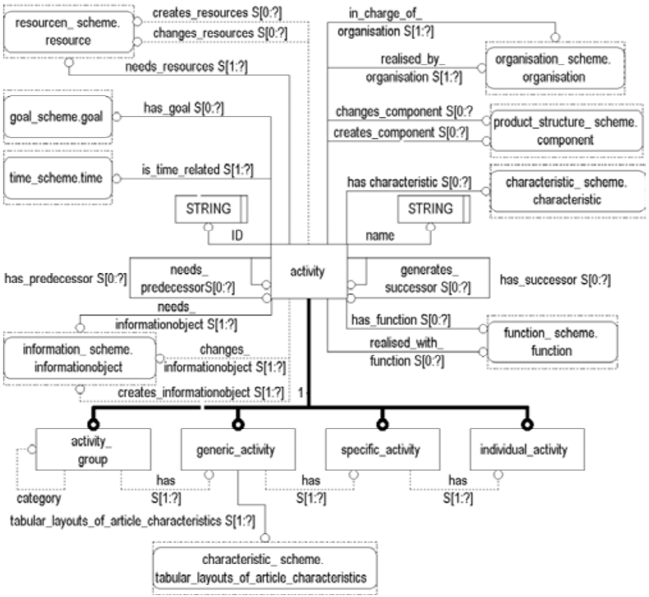

Figure 2: Process scheme

In Figure 3 two views on the instantiated process model are displayed. The project plan shows the activity group technology planning as well as the activities brainstorming for alternative product concepts and checking the technical feasibility. The activities are related to components of the product structure. The concrete product structure is shown in the upper part of Figure 3. The user interface is realised as an Engineering Data Management System.

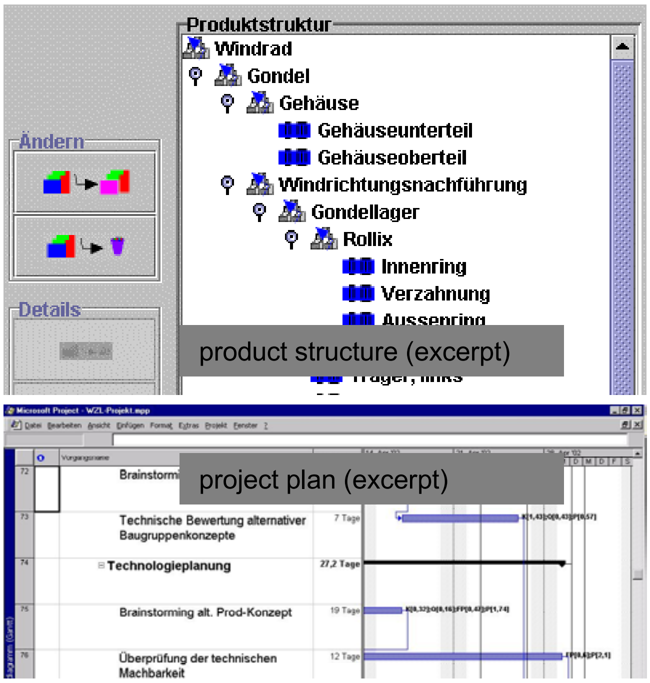

Figure 3: IPPM instances

METHODS FOR THE INTEGRATED PRODUCT AND PROCESS DESIGN

Within the Collaborative Research Centre (SFB) 361 more than 80 methods and tools to support integrated design of products and processes have been developed. These methods cover the whole product development process from systematic monitoring of customer and market demands, internal and external project management, and technology management to production planning. To manage and integrate the multitude of methods - internally as well as externally - in an efficient way, a method data base has been implemented.

The methods database needs to meet the requirements of two different user groups. For the researcher of the Collaborative Research Centre 361 it is most important to place and find all relevant information concerning the method development. Otherwise, potential industrial users are mostly interested being supported in method application. Taken into account these requirements a WWW-based methods database has been developed and implemented.

All methods developed in the SFB 361 are stored in the methods data base. The data base contains a short and an extended description for every method. Further information is provided through hyperlinks on decentral Internet-pages (Figure 4).

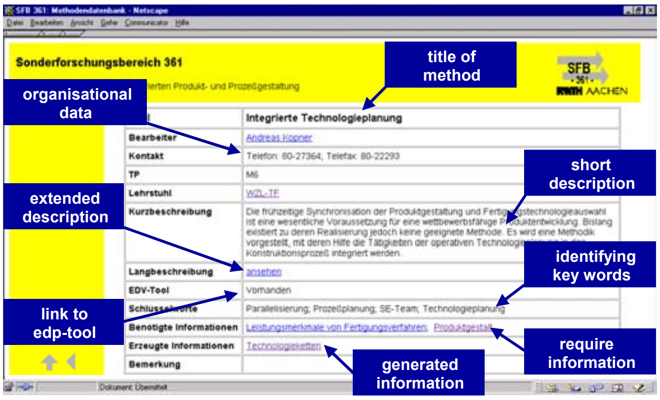

Figure 4: Methods Database - layout and functionalities

To visualize the interdependency of the methods the black-box-principle has been used (Figure 5). The methods are considered as information processing black-boxes with needed input and generated output information. Within the database every input and output information is linked via hyperlink to the generating (prior) respectively using (successive) methods. Thus, the integration and networking of the methods can be visualized by navigating through the methods landscape.

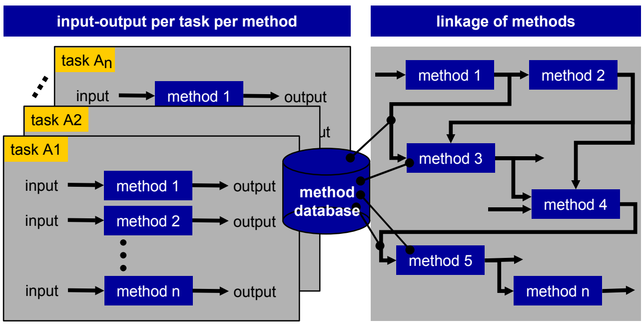

Figure 5: Black-box-approach

To identify problem specific methods to support a certain process step or task different search functionalities have been implemented: full string search, key word list and input-output-search. The input-output-information search supports identifying methods which use certain information as input or generate certain information as output.

The input and output interfaces to place and present the methods are predefined to a certain level. This ensures a consistent appearance and therefore a higher level of user acceptance. Leaving the methods database by hyperlinks to detailed method descriptions on decentral servers every author (= user who has placed a method into the database) is free in the style of presenting these comprehensive information.

The methods database is realized on a SQL-Server, connected via ColdFusion Middleware with a WWW-Interface (Figure 6). Therefore, potential users can work with database with standard WWW-Browser nearly independently of the used data operating system. All functionalities of the methods database are protected with a firewall and user-individual passwords.

Currently, the methods data base is extended by existing standard product development methods. Additionally, the application of multimedia techniques for the targeted, user friendly support of method application will be realized.

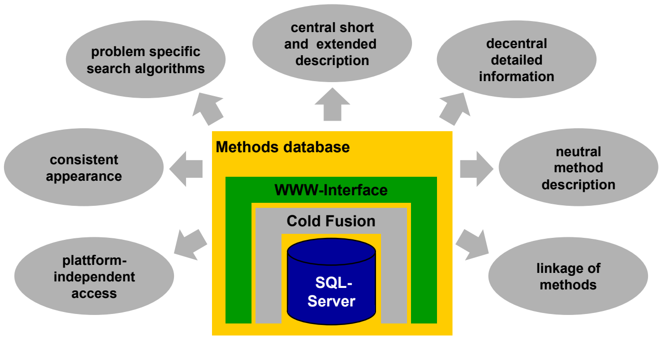

Figure 6: Methods Database – structure and characteristics

ENTERPRISE-SPECIFIC SOLUTIONS ON BASIS OF ACTIVITIES AND INFORMATION FLOWS

To transfer the presented research results to industrial application several steps have to be passed through: First of all, using the generic process model branch or enterprise specific reference processes have to be instantiated. Activities of development processes are analyzed concerning their input and output information as well as the information flow. Additionally, weak points are identified and removed by reorganizing the process.
Afterwards, every single process step has to be associated with supporting methods and tools. Therefore, in the IPPM predefined process – method links can be used. Additionally, a trade or enterprise specific product model has to be instantiated (Eversheim 2001a, Eversheim 2001b).

In the following the intranet based software tool "e-FESTOS", connecting both, the reference process model with the methods database, will be presented.

CASE STUDY: SOFTWARE TOOL "e-FESTOS"

Combining standard internet technologies e-FESTOS offers the opportunity to provide product developers with all the enterprise-specific information needed for an efficient and successful design process. Build as a server application e-FESTOS can be accessed with every standard WWW-Browser so that no special client software is necessary.

Four different perspectives on the design process are implemented in e-FESTOS. On the one hand the user needs to be informed about all mandatory tasks that have to be passed through during the design process, where it is of vital importance to provide a view on all preceding, parallel and following process steps. Thus interfaces to parallel task can be identified and an opportunity to optimize the collaboration between different resorts is provided. For that reason e-FESTOS displays a browseable and graphical depiction of all process steps, always showing all preceding and following process steps. Secondly, e-FESTOS also offers an organization chart, where all employees are hierarchically stored. Responsibilities and participations are assigned to every process step via hyperlink so that a list of all tasks for a certain employee can be generated. This general assignment creates clarity and also helps optimizing a necessary collaboration. Furthermore, methods and tools can be assigned to every process step. By that way it is ensured that always a concrete selection of applicable methods is delivered. Finally, templates needed in a specific process step can be deposited. Passing a process step the developer can download all necessary templates, e.g. for reports, documentations etc.

On the basis of a corporate project of Nordex and the WZL the principal approach for the implementation of e-FESTOS is demonstrated. The Nordex Group is one of the world's leading suppliers of wind turbines, with a focus on units with a high capacity. With the N80/2500 kW Nordex offers the largest serial produced wind turbine in the world (N.N. 2002). The core competencies of Nordex are the overall technical design, the development of rotor blades with a length of up to 45 meters and in the integrated electrical and control technology for wind turbines. The Nordex Group with its three 100 per cent subsidiaries Nordex Energy GmbH, Südwind Energy GmbH and NPV Planung & Vertrieb GmbH employs a workforce of about 750 - continuously growing - achieving revenues of about 350 million euros a year.

Starting with an analysis of existing processes a process re-engineering is carried out. Based on the experiences gathered in the Collaborative Research Centre (SFB) 361 the reference process is instantiated and optimized concerning a high degree of parallelization and a general information flow. Clear responsibilities and participating departments are identified and assigned to the process steps. All methods from the methods database are filtered so that a maximum of suitable methods can be provided for every single process step. Finally, the documentation templates are prepared.

Due to the fact that the e-FESTOS tool is equipped with a so called "content-management-system" the knowledge of HTML-programming or similar for the administrator of the tool is obsolete. User-friendly all information can be stored via a graphical user interface. Even the graphical depiction of the process is generated in this way. Later changes to the contents are also implemented as described, so all information can be easily kept up to date. After storing all information the system is immediately ready for use.

ACKNOWLEDGEMENTS

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CONCLUSION

The results of the Collaborative Research Centre 361 represent the platform for a reengineering of development organizations. The approach on basis of activities and information flows ensures an efficient design of development processes as well as IT-tools and method application. Transparency of processes is guarantied by implementation of processes and documents in the intranet-based tool e-FESTOS.

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NETWORKING AND DISTRIBUTION IN CE

USING MPEG-4 IN THE ENGINEERING DOMAIN

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KEYWORDS

MPEG-4, CAD, Streaming, ASP, CSCW, Internet

ABSTRACT

This article describes the current status of the m4CAD project. The project deals with application areas of the MPEG-4 standard in the engineering domain. Following a brief overview of the standard, different scenarios are presented, including CAD conferencing, Application Service Providing and multimedia product catalogues.

1 INTRODUCTION TO MPEG-4

Virtual Engineering scenarios frequently rely on internet technology, such as transmitting visual representations of 3D models over the network [Sen01]. Importing remote assemblies into a local DMU or discussing changes of a part in a virtual design conference are two examples in this context that can make use of MPEG-4 [BCL99] as a standard and technology for coding audio-visual objects.
The MPEG-4 standard is specified by ISO/IEC 14496 [ISO00] and builds on three application areas: digital television, interactive graphics applications and interactive multimedia. Its aim is to establish a universal, efficient coding of different forms of audio-visual objects, within which objects can be natural - as in MPEG-1 and MPEG-2 - or synthetic.

The standard itself is divided into six different Parts:

- Part 1 Systems
  This part defines the MPEG-4 terminal architecture. The decoder, synchronization, and buffer model is specified here. Additionally the BIFS scene and object description syntax and semantic is also defined in this part of the standard.
- Part 2 Visual
  In this part of the standard the decoding of visual object is defined. Various tools and profiles for different applications are specified.
- Part 3 Audio
  Audio decoding is defined in this part of the standard. As in the visual part various tools and profiles for different application scenarios are specified.
- Part 4 Conformance Testing
  In the fourth part of the standard sample bitstreams are provided to test MPEG-4 terminals.
- Part 5 Reference Software
  In this part a sample implementation of the standard is provided including source code.
- Part 6 DMIF – Delivery Multimedia Information Framework
  This part defines the interface to use MPEG-4 with application specific transport mechanisms. It specifies an Interface for application programmers to implement storage or transport protocols for MPEG-4 delivery.

The important description of the MPEG-4 scene is defined by the BIFS (Binary Format for Scenes) language, which is based on the VRML graphics description language. BIFS differs from VRML in two major aspects.

1. The scene is described in binary[1].
2. MPEG-4 Multimedia and Interaction functionality is added in special graph nodes.

Two interaction mechanisms are built into BIFS. Firstly, there is the VRML event system, which enables client-side interaction. Event sources are connected to event targets via a “ROUTE”. A possible application of this is the pushing of the button that sends an event. The event is then routed to a switch node, which changes the subgraph it displays accordingly.
Another interaction scenario is introduced with amendment 1 to the systems part of standard [2]. Here, an event is passed to the server by means of server-side interaction, and the server then has to react to the event with, for example, a change of scene.
A BIFS scene is not static. It may be added, deleted or modified. It is also possibile to add Java script to enable more advanced dynamic behaviour.

The most attractive features of MPEG-4 include:

- Scene-based and object-oriented representation
- New powerful Codec support and existing contents integration
- Script and language support for high interaction.
- Transparent network interface
- Streaming file format

[1] A textual format based on XML is defined in Amendment 1 to the Systems Part of the Standard. This can be used for exchange with the X3D Web format, for example.
[2] ISO/IEC 14496 Part 1 Amd. 1

MPEG-4 thus provides a sophisticated approach for streaming multimedia content in a very efficient manner. In covering 3D data, still images and video/audio, the standard supports all essential media in the development of diverse Internet solutions in the mechanical engineering domain.
The following chapters present initial concepts of how to use this new standard in the field of Computer Supported Cooperative Work, Application Service Providing and multimedia product catalogues.

2 Cooperative CAD with MPEG-4

Cooperative CAD uses methods of computer supported cooperative work (CSCW) to enable a group of users to work jointly on a constructive model. The problem with existing conference systems is the use of heterogeneous protocols for communication [Luk01]. Systems made by different manufacturers cannot work together, which means that users have to rely on the developer of the CSCW CAD system used.

MPEG-4 could be applied to overcome this obstacle. The goal is to create an MPEG-4 based collaboration system for CAD. Such a system would enable any MPEG-4 Terminal to be used as a front-end to a CSCW CAD system. Users could utilise a wide variety of devices to access a CAD conference, i.e. 3G cell phones as well as MPEG-4 SetTop boxes, etc.

As published in [Dob01], a rudimentary MPEG-4 collaborative CAD system was implemented based on the MPEG-4 reference software implementation. An MPEG-4 based collaboration system can be implemented by using an existing proprietary collaborative CAD system with open interfaces. This system can be extended so as to also enable it to bind with MPEG-4 terminals. This binding is achieved by a software component (MPEG-4 Transfer), which translates events and data of the CSCW CAD system to MPEG-4 and, in turn, translates events and data from the MPEG-4 terminals to events understood by the CSCW CAD system. For the CSCW CAD system, this software component is another front-end like any proprietary front-end. For the MPEG-4 terminals, the component is an ordinary MPEG-4 server, which communicates with the terminal via MPEG-4.

The advantage of this approach is that MPEG-4 terminals and proprietary front-ends of the CSCW CAD system can be used synchronously in a conference. This makes it possible to combine the advantages of both solutions. To make CAD functionality available to the MPEG-4 user, a BIFS scene is modelled to realise the user interface of a CAD application in an MPEG-4 terminal. This comprises the following items:

- The geometric model can be converted to MPEG-4 using 3D BIFS nodes or 3DMesh objects.
- The user interface, including interaction elements and status displays, can be realised using 2D BIFS nodes. A visual feedback can be provided to the user of the terminal by using ClientSide interaction.
- Interaction with the CSCW CAD application can be realised through ServerSide interaction.

Apart from CAD functionality, CSCW tools can be provided to support the joint work of the conference participants. This includes the following items:

- With the telepointer tool, a conference participant can watch the mouse pointer movements of other members of the working group. The mouse pointers of remote users can be displayed in the MPEG-4 terminal by modelling the pointer with 2D BIFS. The position of the telepointer on the terminal window is updated continuously.
- The history tool records communication during a CAD conference. When a new user logs into the conference, the recorded information is played by the history tool to bring the newly connected front-end up to date.
- With the WYSIWIS (What You See Is What I See) tool, all users observe the geometric model in the same way. Apart from the viewing transformation, this also includes the rendering attributes.
- This tool uses the abilities of MPEG-4 to code audio and video data to create an audiovisual conference. This conference can support the CAD conference by enhancing communication between the conference members.
- Digital Rights Management enables the different participants of a CAD conference to ensure that their rights on parts of the geometric model are adhered to. This makes inter-company collaboration possible.

3 Application Service Providing

Application Service Providing (ASP) is a novel and promising approach to the distribution of software [LSW00, Luk02]. By changing the philosophy from software as a material good (e.g. CD-ROM) to software as a service, a number of benefits can result for the software vendor (reducing time to customer, development of new markets, etc.) and the end-user (concentrating on usage rather than installation and maintenance, pay per use, reducing total cost of ownership, etc.). In the engineering domain, on the other hand, we find several ancillary conditions that inhibit an ASP boom, as found in other areas such as customer relationship management. The tight integration of various applications (CAD, CAE, PDM) in the design process as well as the importance of high-end graphical presentation and interaction are just two of the important requirements that must be taken into account in this regard.

Most of today's solutions use display redirection to transfer the user interface from the host computer to the desktop (ref. fig. 1). However, this approach is not suitable for applications with advanced graphical interaction. The use of display redirection includes the necessity to transfer huge amounts of data over the network, which requires a broadband Internet connection. This is why interaction is especially slow, in graphical applications.

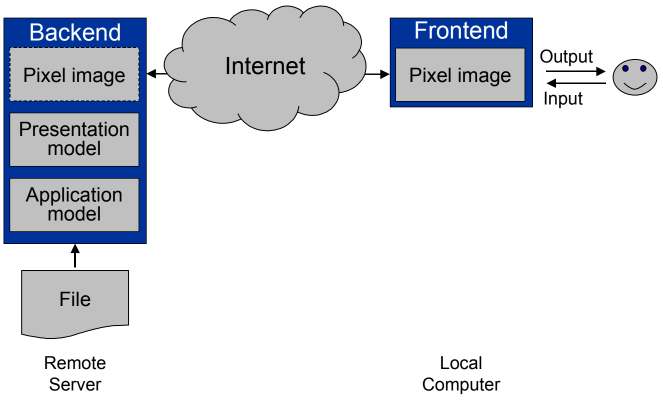

Figure 1 - Display redirection for ASP

MPEG-4 can improve this situation. One possible solution for ASP via MPEG-4 utilises the tools defined in the MPEG-4 standard for delivering the application to the user, to protect intellectual property rights (proprietary extended by accounting and billing) and to represent 3D or 2D models. Compared with the technique of display redirection, the advantage of this approach is that representations of the model are locally available on the ASP customer side (ref. fig. 2). Interactions like changing the viewing parameters can therefore be executed locally without the ASP server. This together with the ability to code the representation of the model in MPEG-4 means that only a small bandwidth is needed in this scenario.

While MPEG-4 is an official ISO standard aimed at multiple display devices, all MPEG-4 compatible terminals can be used by the ASP customer, e.g. ASP software could be used on MPEG-4 set-top boxes connected to a television screen or on 3G mobile devices.

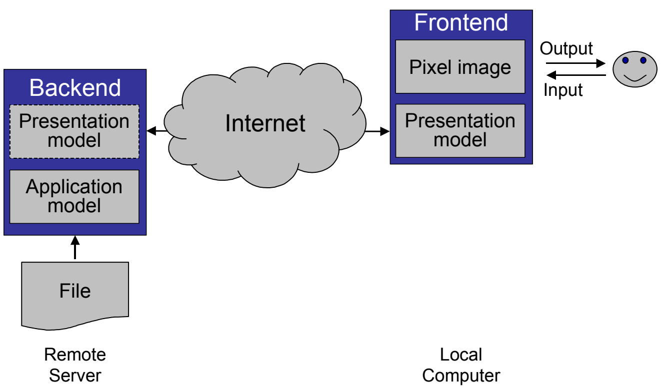

Figure 2 - MPEG-4 based application delivery

The MPEG-4 data stream is generated by an MPEG-4 server at the ASP, where 2D or 3D models are encoded in MPEG-4 BIFS and streamed to the terminal. Interaction is possible solely on the terminal side or with the involvement of the server. In this case, these interaction events are received and processed by the server.

The application of MPEG-4 for ASP is not very different to collaboration with MPEG-4, which means that solutions acquired with collaboration can be applied to ASP. It is even conceivable for the ASP costumer to be enabled to collaborate with other costumers.

4 MULTIMEDIA PRODUCT CATALOGUES

Another attractive scenario for MPEG-4 in the engineering domain is the publication of multimedia product catalogues. A 2D or 3D representation of a model is encoded in MPEG-4 and enriched with metadata, which describe the properties of the model and gives purchasing information.

The MPEG-4 representation of the model can be generated by a software module using the output of the CAD system (online or offline) as the data source. The metadata can be edited by a user derived from the CAD data or extracted from the CAD system. MPEG-4 enables interaction techniques products in the to be linked to an e-shopping system.

The catalogue can use a rich set of tools to enhance the layout of the representation. The improvements to the presentation layout can be carried out in a post-processing step. Additional media can be embedded in addition to the design of the presentation. This includes the use of natural audio and video clips and synthetic MPEG-4 media.

As a result, a file is generated in the MP4 file format, which can be given to potential customers on portable storage media (CD-ROM, DVD, etc.) or streamed over the Internet. Costumers can view the catalogue on any MPEG-4 compliant terminal device.

In contrast to the many proprietary approaches available on the market, a standardised format, such as MPEG-4, offers various advantages:

- Models of different sources can be merged without additional conversion.
- The user only needs an MPEG-4 terminal - no additional software (plugin etc.) is necessary.
- The rich support for multimedia allows for additional audio and video in the product presentation.
- A variety of MPEG-4 authoring tools and converters are expected to come onto the market in 2002.

5 PROTOTYPE

Our prototype demonstrates two of the scenarios refrerred to above: remote access to a CAD system as required within the context of ASP and a CAD conference where two or more users share a common model.

The current implementation is based on the Reference Implementation available from ISO. The so-called Terminal Player3D has been extended to meet basic requirements for use in an MPEG-4 based CSCW-CAD scenario. This includes the implementation of missing node semantics as well as the implementation of the Amendment 1 syntax. A back-channel has been added to enable ServerSide interaction.

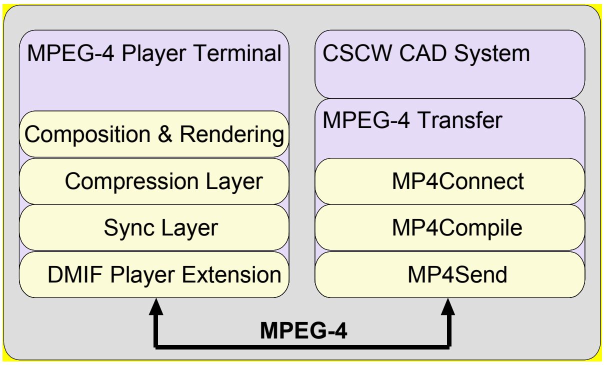

Figure 3 - Architecture of the collaboration scenario

The Terminal has also been extended with a DMIF module to enable streaming of MPEG-4 data. The implementation uses the well-known HTTP to send MPEG-4 elementary streams.

The implementation of the server is therefore realised in the form of an extension of the Microsoft WebServer IIS. The Internet Service API (ISAPI) is used to implement the MPEG-4 server DMIF. A different software component is used to encode the MPEG-4 data. The encoding process uses parts of the reference software to create an MPEG-4 representation. This component is used by another component, which translates MPEG-4 and proprietary events as well as data representations.

The implementation uses the CORBA-based TOBACO CSCW CAD system [Luk97], which provides basic CAD and CSCW functionality. By changing the actual CORBA interface to the standardised CAD Services API of the Object Management Group, any CAD system that implements this interface could be used as a back-end system in the context of ASP. The CSCW features integrated in TOBACO are unique and are not part of today's commercial CAD systems.

The biggest problem regarding implementation is the terminal. The Player3D does not represent a complete implementation of the standard. Not all CSCW tools can be demonstrated (e.g. DRM and AV-Teleconference) and the interaction possibilities are limited. Furthermore, the stability of the software is not very satisfactory.

Figure 4 shows the MPEG-4 user interface displayed by the reference software terminal during a conference. The left area of the scene is occupied by a 2D elemt, where the buttons for creation and modification of solids can be triggered. The lower area is also 2D and is used for collaboration functionality (floor control, list of users etc.). The rest of the scene is 3D and presents the model from three different viewpoints. A telepointer is implemented as an 2D overlay that represents the local pointer of the remote partner.

6 Future Work

Due to the problems with the terminal implementation, the most urgent future development will be to shift to a different terminal. An optimum solution would include an MPEG-4 server with real-time BIFS-encoding capabilities. This solution would enable the developer of an MPEG-4 based CSCW CAD system to focus on the coupling of the CSCW CAD system.

Other future issues concern the enhancement of interaction and the possibility of an orthogonal viewing transformation. Both can be achieved by extending BIFS with new nodes.

The audiovisual teleconference can be implemented. The possibilities of MPEG-J in the context of collaborative CAD must be evaluated.

Other issues include the use of Digital Rights Management and the effect of Quality of Service attributes of the communication to the conference.

In the long-term, the research conducted in this project may also contribute to an MPEG-4 based solution for application service providing (ASP).

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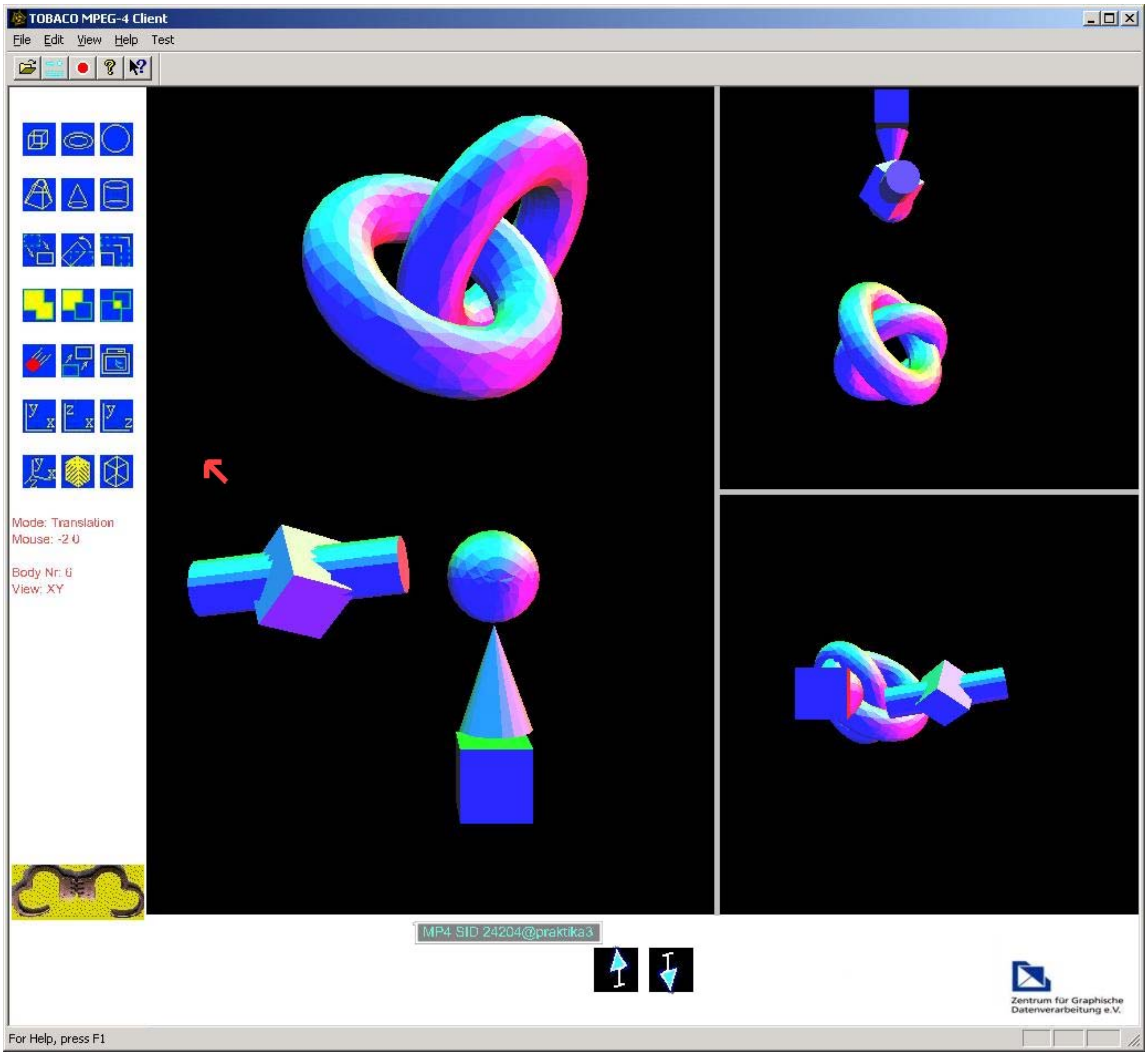

Figure 4 - MPEG-4 terminal during conference

BIOGRAPHIES

Falk Dobermann graduated in computer science from the University of Rostock in 2001. During his studies he worked as a student researcher for the Computer Graphics Center Rostock. He conducted his diploma thesis at this institute about synchronous collaboration in the field of CAD using MPEG-4. From November 2001 until January 2002 he worked for the Computer Graphics Center as a research assistant.

Uwe von Lukas graduated in computer science from Darmstadt University of Technology. He became a research assistant at Fraunhofer Institute for Computer Graphics in 1994 and, subsequently, a member of the scientific staff of the Computer Graphics Center Rostock. Since April 1999, he has been the head of the research department CAD & Teleservices. His current research interests are in the area of distributed applications, Computer Supported Co-operative Work, and infrastructures for virtual product creation.

MANUFACTURING NETWORK MANAGEMENT: ONLY 20 DAYS TO "GO LIVE"!

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KEYWORDS

E-Business Applications, Supply Chain Management, Workflow Management in CE, Information & Application Sharing, Practical Solutions.

ABSTRACT

The IPRODOC project concerns the deployment, testing and validation of a methodology able to support the rationalization of SMEs supply processes in the mechanical sector. In order to achieve an high integration of process and knowledge within the supply chain, a new business model will be developed. In the first project phase the Italian supply chain network is already "go live" adopting an ASP tool named "MANEM" and the ROI sounds very interesting.

INTRODUCTION

The IPRODOC project (IPS-2000-0029 Integration of design and PROduction activities in mechanical supply chains through e-procurement and web based DOCument management applications) concerns the deployment, testing and validation of a methodology able to support the rationalization of SMEs supply processes in the mechanical sector. In order to achieve an high integration of process and knowledge within inter-companies relationship, a new ultra flexible business model will be developed. Parallel technology scouting will be carried out and proper ICT tools will be identified. The soundness of the methodology at technological and organizational level will be proved through its implementation within 2 industrial pilot clusters (the Italian one and the Spanish one).

The European exploitation and dissemination of project outcomes will be addressed to SMEs, entrepreneurial associations and technology transfer organizations. The project is carried out by a consortium of 15 partners spread in 4 EU countries, involving 10 manufacturing companies (9 of which are SMEs) and 5 technology transfer and research organizations.

IPRODOC PROJECT

Non technical issues addressed

The IPRODOC project is addressed to supply-chain reengineering through the development and application of innovative methodologies and advanced ICT based tools. It impacts not only the economic competitiveness and technological improvements of the company interested, but it also introduces relevant implications from a social point of view, especially in terms of organization management, new working methods, relation models and individual working conditions strictly related to co-operation and inter-operation opportunities and constraints introduced by the new system structure.
Enabling factor of the Supply Chain Reengineering is the flexibility and adaptability of human staff and the capability of creating collaborative working teams composed by individuals belonging to different companies.
The IPRODOC project will take into great consideration emerging new professional roles for the optimization of the whole Supply Chain performances.
On the other hand the introduction of advanced ICTs in manufacturing SMEs requires specific knowledge and skills in order to fully exploit its potential, therefore the project will investigate the necessity of adequate training, having in mind the new employment opportunities that should be opened in a soon future in this area.

Short term objectives

The Iprodoc short term objectives are:
- the development of a comprehensive methodology targeted to achieve a high integration within inter-company relationships across the supply chain of the mechanical sector;
- the contribution to competitiveness, through the definition of indicators and guidelines enabling to measure the efficiency in the data interchange processes within the supply chain;
- a technological state of art assessment related to the users requirements concerning supply chain integration;
- a real experiment of high integration within different environments from both social and operational point of view,
- a better comprehension of organizational and societal requirements for an effective supply chain re-engineering;
- the identification of requested employee skills and new job profiles for a proper management of new tasks and relationships in ultra flexible supply chains.

Long term objectives

The overall and long term objectives of the Iprodoc project are to support and to accelerate the modernization and the rationalization of the SMEs supply process through the adoption of innovative ICT methodologies and tools in the supply-chain relationship by:
1. the creation of a suitable context where innovation can growth and SMEs creativity can be stimulated, thanks to a

better and easier collaboration among individuals from different firms;
2. the diffusion of new technologies with particular reference to web-based applications, using common standard and codified knowledge enabling faster and safe exchange of information;
3. the intensification of networking activities and co-operation between SMEs and large firms, through the adoption of new business models fostering their mutual economic development.

Community benefit

IPRODOC project is compliant with the guidelines of the Council of the European Union concerning 'Competitiveness and entrepreneurial policy of the European Union' (Brussels, 9th November 1999), as it is aimed mainly to support and accelerate the 'adaptability and rapid structural changes that are essential for the competitiveness of European industry, in particular for SMEs'.
IPRODOC project goal is to turn the fragmentation of the European mechanical engineering supply chains from a weak point to a strength one, empowering flexibility in spite of complexity. Actually the pressure of globalization on IPRODOC users-like company is becoming every day higher, forcing heavy reengineering of manufacturing and organizational processes. Usually traditional design and production processes management tools fail when the requested degree of integration is extremely high, when the distributed knowledge management becomes a must and finally when the involved companies are of medium, small or even micro size and they are distributed over the regional or even national boundaries.
The IPRODOC users represent a wide number of companies clusters, and the IPRODOC results will be completely business driven, therefore it is expected a successful and wide exploitation of project results involving a large number of potential users.
The IPRODOC project is targeted to increase the penetration of new methods and tools of purchasing and outsourcing in the enterprises belonging to the mechanical engineering sector. IPRODOC innovation content and objective is to make available a 'technology-independent', replicable methodology aimed to identify and assess the best process and knowledge integration in clusters mostly composed of SMEs, in order to foster and speed up the transformation from the traditional purchasing and outsourcing methods to the new ultra flexible systems.

BASIC ASSUMPTIONS

Mechanical engineering SMEs and main contractor / supplier relationships

New flexible schemes are based on a networked production organized in virtual enterprise. The basic idea is that the production of a certain product is organized in networks and facilities and these facilities form temporary and timely limited collaborative entities: Virtual enterprises.
Mechanical engineering sector in EU consisted of some 142.000 firms of which about 85% percent had less than 20 employees. Twenty employees is considered the lower limit for conducting industrial manufacturing of complex engineering products. Only 0,5% of the companies had more than 800 employees. This is due to the fact that few economics of scale are present in machine manufacturing.
The networked production organized in virtual enterprise and the adoption of flexible schemes should be viewed as an attained goal for the mechanical manufacturing companies.
A realistic and effective methodological approach should take into consideration the actual organizational and operational SMEs' state of the art and the evolution path and try to find key factors that can support and accelerate the process.

Operational and organizational requirements of the new flexible paradigm

In the specific context the project focuses on some operational and organizational requirements of the main contractor – supplier relationships:
Operational requirements:
- Information exchange between customer and supplier
- Product characteristics
- Quality (quality requirements and transmission of the check outputs)
- Volumes forecast
- Manufacturing lead time

Organizational requirements:
- Formalization degree of selection and evaluation tools for the supplier
- Knowledge of suppliers
- Formalized procedures for the selection and evaluation through new supply model definition and the development of appropriate organizational interface units.

Namely, team based operations is the enabling factor for the balancing between organizational decentralization and manufacturing integration needs (i.e. team buying created by responsible for supply, design, manufacturing planning, process and quality engineering, accountancy and finance).

METHODOLOGICAL APPROACH

Project management approach

The IPRODOC project is based mainly on the identification of users requirements and on the realization of an organizational model of interaction between the end users, that is to say the business partners within the supply chain.
A bottom-up approach insures the best correspondence between results and user requirements and expectations. That means that the methodology will be context-based. In other words it will be designed and deployed not merely in reference to theoretical models but being able to start from carefully considering different specific situations.

Assessment approach

Two complementary and closely related aspects would have to be assessed: economical and organizational. The basic criteria will be the measurement and comparison of the supply chain performances at the beginning and at the end of the project. Wherever possible a quantitative comparison will be performed while qualitative assessment will be made in the other cases.

Economical assessment:

1. the purchase price of the application and the necessary expense for its installation and start up (personnel training, integration, final testing)
2. the economic results obtained through the application use. In terms of immediate measurableness, they mainly come from the time and resources saving.

On the other hand, the positive effects coming from the process integration use will be considered. They are of different types:

- people time saving;
- elapsed time reduction, that is a shorter time between the beginning and the end of the process;
- better information quality: greater completeness, reliability and consistency.

In order to assess the economic impact, the pay back period will be considered. The actual economic benefit begins when the sum of annual revenues equals total costs of the system start up and software maintenance costs. The knowledge transfer and increase in the customer and supply relationships will be enabled selecting suitable evolution methodologies. In other words, pay back answers to the question "How long is the expected period in which the economic benefit of the investment will start arising?"

Organizational assessment:

1. process simplification: it refers both to the number and the content of the tasks performed in order to accomplish the process. This aspect is relevant both from the quality control and assurance point of view (i.e. process reliability and controllability) and the work load of the involved personnel.
2. time compression: it is a strategic goal in the current market situation more and more requiring short time to market. From the production point of view, this means prompt reaction to the customer demand and reduced lead time in compliance with the "Just in time" methodology strongly based on compressed and reliable manufacturing time. This factor depends on:
   - process organization;
   - process simplification (see point 1 above);
   - tasks closely connected to the data transfer: data transmission, checking information and data input in the information system.
3. People saving: to free human resources increases or creates some strategically relevant opportunities for improving the competitiveness:
   - increasing Research and Development activity for both processes and products in a perspective of Total Quality Management;
   - monitoring the market trend aimed to products innovation;
   - professional training.
4. Professional skill improvement: this is an extremely important aspect not only to keep the service quality level as high as possible, but also to fight against unemployment. In fact, in each case, a worker having a competitive professional profile will be able to find job alternatives more easily.
5. Knowledge creation, integration, transfer and management: technology infrastructure is apparently necessary but not sufficient. Creating an organizational infrastructure (roles and skills for managing knowledge) seems essential and harder to do in today's organization. A modicum of process orientation, structure and results is desirable. A benchmark of assessment methodologies concerning particular indicators of intellectual capital development and value creation will be carried out, taking into consideration already performed studies (see APQC International benchmarking Clearinghouse)

ITALIAN SUPPLY CHAIN

Consortium

The IPRODOC proposal is presented by a consortium composed of 15 partners, spread in 4 European countries, namely Italy, Spain, France and Sweden. In particular the Italian Supply chain is composed by 4 partners:

Table 1 – Italian Cluster

Name	Employees	Activity
ROSSI M.	450	Motorgears manufacturer
OMV	21	Mechanical operation
VL	22	Assembly of mechanical systems
ZVL	30	Distribution of mechanical components

ROSSI MOTORIDUTTORI is a manufacturing company that produces high customer oriented gearmotors, gearreducers and motor variators for various industries. Established in 1953, it counts about 450 employees.

Rossi has a world-class ERP system, including MRP. Due to the frequent planning changes (small lot size, high number of urgent requests) the supplier management is a very time consuming activities. It is currently done manual, with an intensive use of phone, fax and meetings.

Rossi is currently extremely under competitors pressure, especially from prices point of view.. The answer to that pressure foresees several aspects, and one of the most important one is supply chain integration with the high number of heterogeneous suppliers (almost all of the SMEs).

The Company OMV of Zaccarini Erio & C. Snc was founded in 1988 by merging two companies: Sarmec and Mptz. Presently it has 5 partners and 21 employees.

The activity on behalf of a third party consists of a precision mechanical working process in final and in half products. The workshop deals with processes as turning, milling, drilling, adjustment, (fitting), welding and grinding. The Company makes use of highly qualified freelance specialists for carrying out thermal treatment, superficial treatment and painting.

VL IDRODINAMICA SRL was founded in 1983, and the company activities foresee hydraulic, mechanical and electrical assembly and testing. They are specialists in particular for motorgears, electrical motors end electrical pumps.

Presently it has 3 shareholders and 22 employees.

ZVL ITALIA, a private company which deals with import and distribution of bearings of the ZVL-ZKL trademark. The internal structure is composted of commercials and accounting unites besides of Center of Data Processing and warehouse. ZVL ITALIA Spa employs 30 people; it is equipped with updated information tools and it pays a particular attention on the necessity of the development of this division in order to elevate the quality standards.

MaNeM

MaNeM (Manufacturing Network Manager) is a software for the supply chain management developed by Joinet and available in ASP modality. MaNeM is available on server of Joinet propriety and the users can access to the functions using a browser, like Internet Explorer or Netscape Navigator.
A prime contractor, in our case Rossi Motoriduttori, can manage the whole life cycle of the order through the Web. With this software, Rossi is able to submit the order, to negotiate possible modification after the emission and finally to confirm it. Moreover MaNeM allows manage the monitoring of the order (production phases, delivery, acceptance, closure).

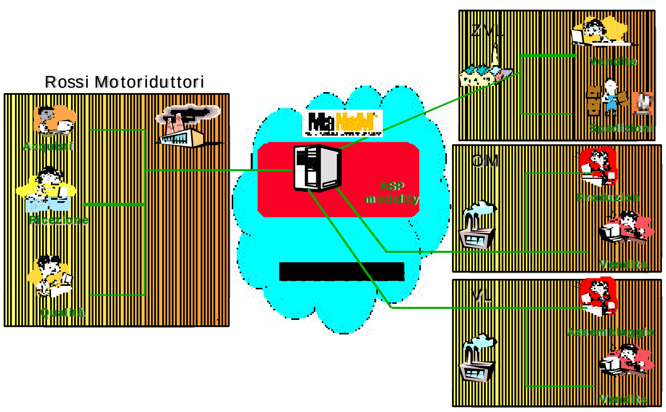

Figure 1 – MaNeM schema

Order state diagram

To illustrate the procedural flow and the information flow engaged in the supply of materials, we introduce the orders diagram.

The first state diagram (see Figure 2) represents a purchase order concerning a third party working (like OMV manufacturing process).

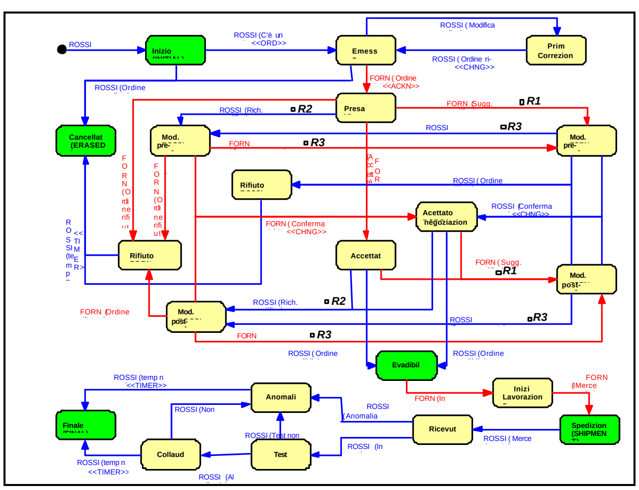

Figure 2 – Order type LE

The second state diagram (see Figure 3) represents a purchase order concerning a standard good (like ZVL's bearings).

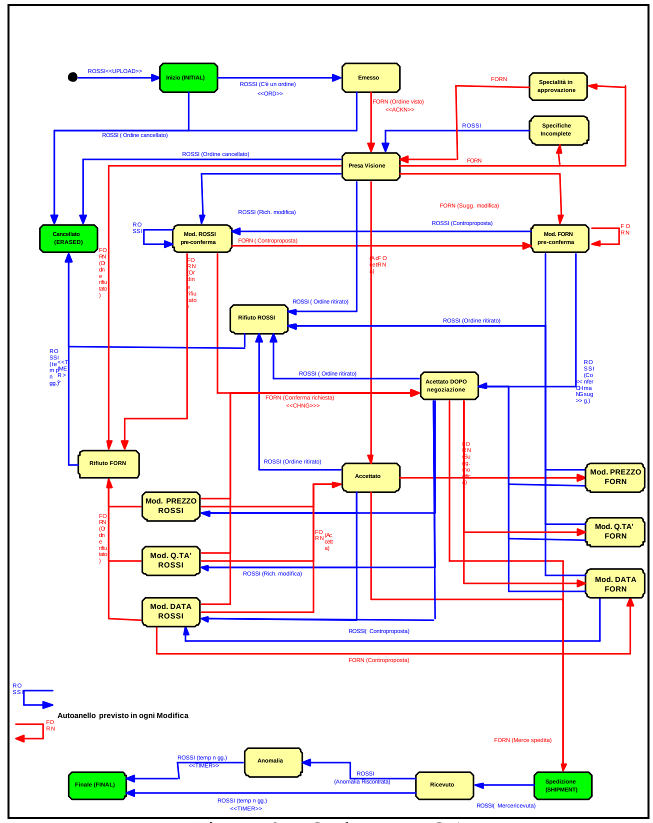

Figure 3 – Order type OA

The third diagram (see Figure 4) represents a purchase order concerning an assembly activity (like VL's activities).

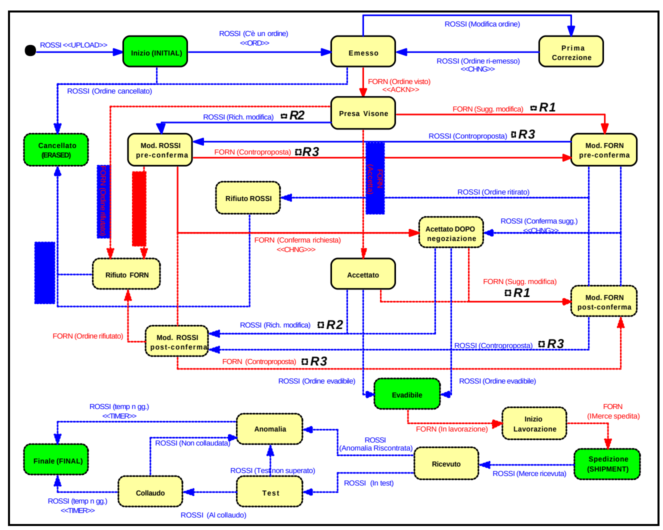

Figure 4 – Order type ME

ROSSI MOTORIDUTTORI "RETURN OF INVESTMENT"

Cost Reduction

Simplifying and organizing orders management inside the supply chain improves the information sharing and reduce the costs. As an example, the following table shows an analysis carried out by the Rossi Motoriduttori management board.

Table 2 – Costs reduction

	Number of operation in a year without MaNeM	Minutes for operations without MaNeM	Minutes of connection for operation without MaNeM	Number of operation in one year with MaNeM	Minutes for operation with MaNeM	Minutes of connection for operation with MaNeM	Men hour saved in one year	Connection hour saved in one year
To send orders	10000	3	2	10000	0,1	0,1	**483**	**317**
Reminder	2000	15	5	400	15	5	**400**	**133**
To prepare technical documentation to adduce	3000	15	0	3000	5	3	**500**	**-150**
To manage the modification of orders rows after emission	2500	20	2	2500	5	0,1	**625**	**79**
To introduce bill in the managing system	10000	10	0	2500	1	0,1	**1500**	**-17**
Mistaken bill to manage	250	30	10	25	30	0,1	**113**	**-0,04**
Total							**3621**	**362**

Market opportunities

At the same time the Rossi Motoriduttori management board has also put in evidence the growth of market opportunities thanks to the adoption of the MaNeM tool inside the supply chain.

Table 3 – New market opportunities

Results	HOW	Possible measure
Proceeds increasing	Transferring to the market an imagine of punctual, reliable, flexible and careful Company to the SERVICE to the customer	Hypothesis of % increase of the volumes of sale
	Reducing the times of delivery offers	Offering not become orders cause too much long times of delivery
	Improving the punctuality of delivery	Orders cancelled from the customer cause delay in the delivery
	Increasing the list of sale	Possibility to apply % increases of price for fast deliveries

Results	HOW	Possible measure
Cost reduction	Reducing the times of crossing is obtained by a better use of the employed resources (vital, immovable, men and means)	Hypothesis of % reduction of the immobilization costs
	Improving planning and reliability of the supply chain techniques of just-in-Time supplying can be applied	Hypothesis of reduction of the immobilized stocks like supply of emergency
	Reducing hitch, times of wait, cost for corrective actions to forehead of unreliable data	It is necessary to control
	Reducing inefficiencies and it wastes had NOT to the Quality	RNC caused by the use of designs, detailed lists, not modernized norms of assembly

CONCLUSIONS

In this paper we tried to communicate that for an high integration of process and knowledge within the supply chain is not necessary a long time to "go live".

Moreover the use of ICT tools able to create a channel for the exchange of information along the supply chain permits to speed up the management of the orders and to reduce the costs, the times of wait, the inefficiencies, the times of managing of the modification of the orders and so on.

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PRACTICAL APPLICATIONS AND EXPERIENCES

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ABSTRACT

This paper illustrates by means of two case studies how user interface design can be integrated into the development process. The case studies are both drawn from the authors' experience in the development of telecommunications products at Philips. The principles of user interface design as practiced at Philips are also described.

INTRODUCTION

George W. Bush, president of the United States, has stated the ambition, "By the time I leave office, I want every single American to be able to set the clock on his VCR." His father had similar troubles with VCRs when he was president, complaining, "I can't operate my goddam VCR". It is not only in the Bush family that the VCR is vilified as unusable, and while being the butt of many jokes, the VCR is far from being the only unusable product. As our technology develops, there is a great danger that the users will be left behind.

However, this need not be the case. The power and sophistication of today's technology should enable sufficient flexibility to be truly "user friendly". However, this can only be achieved if attention is paid to the user during the development process. Paying attention to the user during development is the cornerstone of "user-centred design".

It is sometimes argued that designing for users is simply common sense. However, if this were the case, there would not be so many poorly designed products. Numerous examples of poor design are given by Donald Norman (1998) in his book "The Psychology of Everyday Things."

An illustration of this point is provided by the Herald of Free Enterprise tragedy. The Herald of Free Enterprise, a cross channel ferry, sank just after leaving Zeebrugge harbour at about 18:00 on 6 March 1987. 189 of the 459 people on board were killed. The ferry had sailed with her bow doors open and as she increased speed, water entered the lower car deck, which destabilised her and caused her to capsize. She sank in two minutes, coming to rest on a sandbank.

The accident was blamed on "human error". Indeed, the Sheen Report (1987) shows that significant human errors were made. However, the Sheen report also points out a fundamental design flaw, which would have made all of these errors irrelevant. There was no information display - not even a single warning light - to tell the captain if the bow doors were open. This omission had previously been pointed out to the owners who had dismissed the idea of adding such an indicator. One must wonder at the 'common sense' of this decision. One must also wonder at the 'common sense' of the original designers of the vessel, who could readily have taken into account this basic requirement of the ship's bridge officers to know whether or not the bow doors were open. This could have been done for a minute fraction of the cost of the ship. The sad truth is that common sense is not as common as many of us would like to believe, and in this case lack of common sense led to multiple loss of life.

Of course, not all design flaws have the life and death consequences illustrated by the Herald of Free Enterprise tragedy. Nevertheless, an organisation which ignores such flaws can be harmed in other ways, not least of which, financially.

A significant cost for a large manufacturing organisation such as Philips is when customers return faulty products. For this reason the causes for product returns are monitored, and steps are taken to eliminate them. A major reason for product returns is the so called "no fault found", that is, there is no technical failure and the product operates "the way it should". The reason why customers return products without faults is that in their perception they really do not work; in other words, the method of operating the product is alien to them. Taking the users into account during product development can significantly reduce the incidence of such product returns.

In the Philips Fax call center in Vienna every customer-triggered event leading to an activity of a call center agent is recorded in a database. On a typical working day there are up to 30 agents on duty dealing with customers from nearly all European countries in their native languages. A typical call center agent handles between about 50 and 100 events daily.

The database's problem classification system assigns every customer problem to a problem classification code. It derives from the standard repair code system which had to be modified, however, because it originally did not contain any usability-related problem causes. It is defined like a tree structure starting at the top level with "customer problem call" as opposed to "call-back", "customer fax" and other types of events.

At the next level of the tree the branch "customer problem call" is split into "usability problem call" and "technical problem call", "marketing call" and "shipment-related call". The definition of a usability problem is that it can be solved by giving advice, while technical problems can only be solved by hardware exchange, repair, software reset, or software update. In this case the product has always performed according to specification. At the following tree levels the issues are specified in more and more detail.

Based on these data, reports are generated stating the rate of usability-related calls for each problem area. The usability call rate is a figure indicating the number of customer calls divided by the average number of sold products (appliances or service packages) in the same time frame. Because of the sales pipeline time it only becomes valid six months after market introduction of a new product.

With the help of these reports usability people give feedback to the rest of the company and help improving specific parts of the product which have shown to be responsible for a major number of customer calls. Thereby customer satisfaction and call center costs are influenced positively.

The influence of poor design on a company's performance is not restricted to whether or not products are returned. It can also damage a company's reputation, with the result that sales will drop. This is shown by the triangle of values (Figure 1). If a company has a good image, the prospective customer might consider the offer that company makes. If the offer is attractive, the prospective customer might consider making a purchase. If the purchased item is satisfactory, the customer will reinforce the positive image of the company. On the other hand, if the product is not satisfactory, the image of the company will be damaged in the eyes of that customer, as well as of anyone else he or she tells about the negative experience, and that person is then less likely to consider future offers the company makes, and is therefore unlikely to make a repeat purchase.

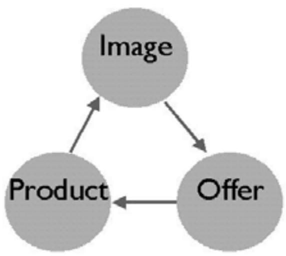

Figure 1: The Triangle of Values

A major factor influencing the perception of product quality is whether the customer is able to operate it with ease. User-centred design can therefore make a major contribution to a company's reputation and therefore sales, even if the product attributes addressed are not necessarily those which attract the customer's attention at the point of sale.

The following section describes some principles of user-centred design. They highlight the need to integrate user-centred design fully in the development process. These are illustrated in the subsequent sections with two case studies of the development of telecommunications products.

USER-CENTRED DESIGN

Type in capitals, beginning flush with left-hand margin. Use a bold font. Skip half a line space, then begin.

User-Centred Design is not a new concept. There are a number of text books available which give detailed advice concerning how to involve the users' point of view in the design process, for example Nielsen (1993), Schneiderman (1987), Salvendy (1987), and Baumann & Thomas (2001), as well as numerous web sites, for example Bruce Tognazzini's 'Ask Tog' site (http://www.asktog.com/).

At Philips Design, the user is the focus of the High Design Process. This is described by Marzano (1998) as "an integrated process incorporating all the skills on which design has historically based itself plus all the new design-related skills we need to be able to respond to the complexity and challenges of the present and anticipate those of the future". The purpose of High Design is to create solutions that humanise technology. In order to achieve its purpose, High Design combines expertise in human sciences, technology, aesthetic disciplines and communication sciences in the creative process. High design is a philosophy, but also a design process which is fully integrated in the Business Creation Process of Philips Design's clients. More information about Philips Design and the High Design Process can be found on the Philips Design web site: http://www.design.philips.com/.

The overriding principle of user-centred design is to focus on user benefits and user goals. It is better to concentrate on what users wants and need and to develop technologies to support that, rather to focus on what technology can provide and to try to convince sceptical users of its value.

In the user interface design community, the concept of usability has been introduced as a tool to support the development process. An introduction to usability has been written by Jordan (1998). Usability is defined by ISO 9241 part 11 as, "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." A particular benefit of this definition is that it expresses usability in terms which can be measured (see Thomas, 2001). This means that levels of usability can be specified, and the usability of products can be compared. This provides a means whereby the quality of a product can be evaluated from the user's point of view during the development process. An organisation does not have to wait for customer complaints before finding out if something is wrong.

According to Rakers (2001), the key element of successful user-centred design is a truly multi-disciplinary approach. This means that it is important to involve many disciplines in the design and development process from the beginning. Conversely, it is also important that user-interface design is integrated into the engineering process. Only in this way can it be ensured that usability issues are addressed when they arise, and can be resolved in a manner which is beneficial to the user.

FAX MACHINES

When specifying and developing the 2001 Philips Fax product line the following user interface improvements were implemented based on customer feedback from the call center.

The fax switch (the part decides whether a call is a phone call or a fax) was redesigned. The previous two setting methods for novice and expert users were replaced by a single one. It follows a very simple setting style by asking for input of the ring count. Several terms used in the interface and in the user manual were simplified or modified, e.g. "toll-free rings" (indicating the number of ringing signals that occur before the fax machine takes the line) was replaced by the term "fax rings". The ring count combinations named "normal", "quick" etc. were eliminated from the user interface because they were not easy to explain. These relatively small changes approached the user interface of the fax switch to the mental model generated by the users when they are facing a fax switch for the first time.

Another important change was to switch off in the default factory setting a few features that were not used by the majority of customers, for example the feature "silent fax reception" and the "timer" feature switching automatically between two fax reception settings for day and night mode.

Features like this are valuable for sales reasons and for winning comparative tests in a magazine. However, in a true "plug-and-play" product they should stay in the background until the customer actively looks for them and switches them on.

Furthermore the operation panel was enhanced by a button that switches the answering machine on or off. The fact that this function needed to be done by several key-presses in a menu before was also a major reason for customer calls.

In the 2001 product line the feature "email and internet access" was introduced. It made it necessary to have an alphabetic keyboard on the fax machine. Unlike other manufacturers who show the keyboard on the device front, Philips decided to hide the keyboard under a flap that carried a few other keys operating the answering machine. This reduced the visible number of keys by around 50%.

The keys of the alphabetic keyboard, however, are only as big as the keys of a mobile phone. This is often perceived as too small for the relatively big appliance but it was a compromise with both financial and technical requirements.

At the same time all keys of the operation panel were grouped to functional blocks. There are key blocks for the answering machine, for the fax functions, for the telephone, and for the display and menu selection related keys. This improved the perceived expliciteness of the product and gave it a well-balanced simple appearance.

Finally the acoustic signals were redesigned. New signals were introduced, like a "switch on" and a "switch off" sound (raising respectively falling tone sequence). They give appropriate feedback when a key is pressed that switches something on and off.

For the new "detachable scanner" feature some acoustic signals had to be created, indicating the start and the end of a page, normal operation, memory warning and overflow condition. As a positive side-effect ten new ringer tones ranging from conservative to video-game style were composed and implemented by a musician working with Philips Design.

Figure 2: Operation Panel of the Philips *i-jet vox* Fax Machine

Figure 2 shows a picture of the improved fax machine. In the center there is a flap which covers the alphabetic keyboard used for the input of email and internet addresses. On top of this flap there are the keys operating the answering machine. This appliance is for sale only in European countries.

Figure 3 shows the financial improvement potential of single improvement actions. The highest positive values correspond to around 30 cents.

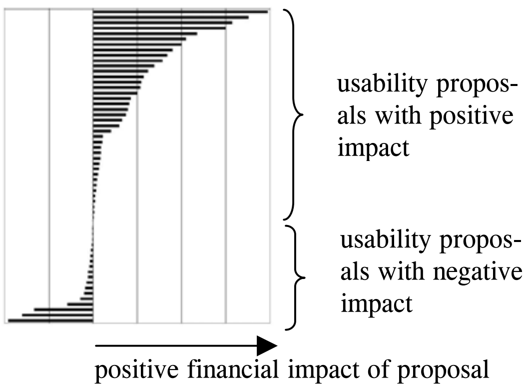

Figure 3: Estimated Financial Impact of Usability Proposals on a Single Product. (The values and the names of the proposals are not shown for confidentiality reasons.)

For cost reasons it is desirable not to have big differences in the country versions of fax machines. Like the manufacturers of cars, Philips tries to eliminate country-specific products. The aim is to create a fax machine which can be sold in all over Europe in the same version. This is not easy because of the technical diversity of the telephone systems and the user diversity.

The remaining country-specific parts of a product are: cables and connectors, the ROM carrying the software, the user manual and other printed information packed with the product. Many of the changes mentioned made it easier to simplify the user manual. In total the user manual was shortened by 50% which is an important cost factor in itself.

The help pages that the fax machine can print out were transformed to a two-column layout. This was a major challenge having an impact on the translation, the UI specification, and the implementation in software. Instead of two pages there are now seven pages of help information text permanently stored in memory.

Also we invested a lot of time in a careful redesign of the menu options and the feedback texts displayed by the software program. This was done in every one of the 10 language versions in which the appliance is available.

We are convinced that it is best to have a single well-tested product version which offers easy-to-use basic functionality, a lot of well-structured but non-prominent additional features and a good description in country-specific user manuals and help functions. The basic functionality of this product should take into account all country-specific issues and thereby avoid most problems. This is much better than to generate many country versions and thereby making compromises in time, cost and - most important - quality.

MOBILE PHONES

The Fizz™ GSM telephone (Fig. 4) was introduced on the market in 1996, and has been praised in the independent press because of its "unprecedented usability" (Mobilele Telecommunicatie, 1996). The Spark™ (Fig. 5) was introduced in the same year and received even greater acclaim, winning the Media Totaal Mobile Phone of the Year award primarily on the basis of the interface design. The Genie™ (Fig. 6) and the Diga™ (Fig. 7) followed in 1997, both incorporating the design features developed for the Fizz and the Spark. The full integration of user interface design with other disciplines was a key to the success, as well as a continued focus on the potential users through repeated usability testing.

Figure 4: Fizz Figure 5: Spark

Figure 6: Genie Figure 7: Diga

In the development of these products, product management, hardware developers, software developers, interaction designers, human factors specialists and product management worked closely together with a user focus. These projects illustrate the process and the co-operation between different disciplines in the product creation process. The techniques used during the development of these interfaces are an extension of those already described for the development of business phones (Thomas & de Vries, 1995) and communications control terminals (Thomas & McClelland, 1996). The development of these products has been described in detail elsewhere (van Leeuwen & Thomas, 1997; Thomas & van Leeuwen, 1999). A summary of the main points relating to user centred design is presented here.

The Fizz GSM phone was the first hand-held GSM phone completely developed by Philips. Because it was a completely new product the whole development team needed to build up competence in the area of hand-held GSM phones. The design of the user interface took place over a two year period. The first ideas to launch the first hand-held Philips GSM phone for the consumer market were expressed in April 1994. The low cost product was originally meant for consumers concerned with safety and convenience. Philips Design was involved from the start of the project with several disciplines.

At the time the Fizz was developed, cellular phones were used only by a small fraction of the population, primarily in a professional context. The Fizz was to be developed for a newly emerging consumer market. Unfamiliarity with cellular telephones was identified as a potential problem which a successful user interface would have to overcome. It was therefore decided to focus on achieving simplicity for the primary functions of making and receiving calls, as well as giving easy access to other functions, particularly the directory. A constraint placed on the design was that in order to achieve low costs, both the display size and the number of keys should be kept as low as possible.

Based on the preliminary product descriptions from product management and the cost constraints mentioned above, two alternative interaction design concepts were developed with quick iterations. During this process, paper, pen and flow charts were used to explain the interaction concepts to the team members. Some initial simulations were made on a PC to get a feel for the proposed interfaces. The simulations were used for internal discussions and resulted in further iterations.

Two interaction concepts emerged from this highly intense process. The first was a single line concept making use of a dedicated OK key for selection and activation. The second was a two line concept using soft keys. Usability tests of the two concepts were carried out in the Netherlands and France. There were no clear preferences for either alternative, and the soft key concept was developed further because of its overall flexibility. The test results indicated that in general users would learn how to operate the interface. After intense discussions with development and product management a number of changes were made.

A further prototype was made and another usability test was carried out in the Netherlands. The results showed that the design had been improved and successfully simplified. The test participants felt confident using the interface and their comments were generally positive, although some improvements relating to particular details were still required.

At this stage in the development a more global approach was adopted. The management team focussed on another target group and changed the constraints. The most obvious change was drastically to increase the display size and further to reduce the key count. In order to develop a user interface based on these constraints within a very limited time frame it was decided to use the existing design as much as possible. The product started to look like the final version. Hereafter the complete interface details were specified on paper and a simulation was made in parallel by the development team. The simulation was used for further testing in the Netherlands, Germany and the UK. The test participants found the interface easy to use and were able quickly to learn how to operate it. There were still some outstanding issues, but in the time available it was not possible to implement all the recommendations from the test. Nevertheless they were carried forward into the development of the Spark.

The design of the Spark took place over a much shorter period than the Fizz. The decision to develop the product was taken in October 1995, that is before the Fizz was on the market, and the product was launched in August 1996. As with the Fizz, user interface design was involved from the very beginning of the project, and was considered by product management to be one of the central issues for the development.

The intended users of the Spark were to be mobile professional people. A familiarity with mobile phones was anticipated. On this basis, the main design objectives were to highlight quality, reliability and leading technology. The user interface was to build on the experience from developing the Fizz, and should demonstrate innovation in a manner which supported the navigation structure already established.

The Spark introduced a large full graphic display capable of showing up to five lines of text as well as icons. Further, the full graphic display enabled the use of animation which was used to support navigation through the interface structure. Animations were introduced both for aesthetic and functional reasons. Gimmicks were avoided, so there were few cartoon like animations. Animations were primarily used to explain the structure of the menu.

The idea of using animations created several types of response within the development team. Some reacted very enthusiastically while others questioned immediately the feasibility of the proposals and together with that questioned the usefulness of it. Fortunately, the key decision makers believed in the concept and made it all possible. Nevertheless, many experiments and discussions were needed to find the appropriate animations. Together with the screen graphic designer a large number of experiments were conducted to find the right balance between too much and too little information.

The menu structure and use of soft keys built on the global interface and required improvements noted in the final Fizz test. A second version of the Spark introduced speech recognition for name dialling. This module was developed together with Philips Research Laboratories in Aachen.

The user interface for the Spark was simulated by the engineers and a usability test was carried out in the UK. The test participants were drawn from a population of mobile executives, both with and without experience of using mobile phones. This test again showed that the concept was readily understood and that most of the remaining issues from the last Fizz test had been satisfactorily resolved.

The Fizz and the Spark established a generally applicable user interface structure for Philips mobile phones. This meant that for the development of the Genie, the user interface design of the Spark could be re-used entirely, with only minor modifications for new functions. This possibility for re-use of a proven concept enabled rapid development. The Genie was the smallest and lightest mobile phone when it was launched in 1997.

The two line concept for the Fizz was re-used for the Diga, which was intended for the low cost segment of the market. Again, re-use of an existing concept greatly facilitated the cost and time of development.

Of course, the global concept could not be used indefinitely. New developments and the greater familiarity of users with mobile telephony have meant that newer and more exciting interface paradigms, as implemented in the Philips Xenium™ have replaced the original concepts. But that is a different development story.

CONCLUSIONS

To ensure that a development process is user-centred, a usability specialist should be involved at all stages. This person needs enough power and time to test solutions, and to question or re-think solutions which may not be usable.

User centred design achieved substantial benefits in the profile of telecommunications products within Philips, resulting in the achievement of the Media Totaal Mobile Phone of the Year award for the Spark. Equally important, a concept was developed which could be re-used over several generations, so the initial investment in understanding the user requirements paid off in shorter development times for the later products.

The case studies presented provide a glimpse of usability engineering in action. They demonstrate:

- the use of several methods in parallel in order to gather user requirements,
- user requirements as one of the starting points for the design and development of a solution
- the selection of relevant requirements
- the convergence into a sensible specification document, co-developed and agreed by the engineering team
- continuous feedback from the user on the solutions created
- iterative usability improvement of the solutions.

In particular, the case studies demonstrate rapid responses to changing requirements are sometimes required. This can only be achieved without compromising usability if the necessary engineering changes are made in full consultation with or under the direction of the user interface designer. On the other hand, the development of a scalable and re-usable user-interface concept can only be achieved in consultation with the development engineers. Both requirements are best fulfilled if the user interface designer is fully integrated into the development team.

The case studies also showed that where innovative solutions were implemented, especially with regard to the animations on the Spark user interface, there was a need for extensive experimentation and discussion between the designers and the developers. Without close cooperation, it would not have been possible to work rapidly towards a technically feasible solution which was also aesthetically pleasing and communicative to the users.

Continuous iterative usability testing and development can be time-consuming. It can also be frustrating for engineers to modify solutions as new test results become available. However, these activities are necessary to achieve a satisfactory result for the user. The case studies presented here show that the negative impacts of user involvement can be greatly reduced by developing a re-usable design. Thus, while the original development may be highly iterative and extended, subsequent developments based on the same design can be greatly accelerated, even where different markets and targets are addressed.

The full integration of the development team necessitates close working. This was achieved in the two case studies with the physical presence of the user interface designers at the development location. This was readily achieved for Fax with the designers and developers being co-located at the same site in Austria. In the case of the mobile phones the designers were based in the Netherlands, while the engineers were based in France. For the duration of the development of the Fizz and the Spark, the designers travelled frequently and for long periods to France to work with the development team. On the basis of this successful co-operation, a full time placement was created for a user-interface designer at the French development site. Thus, the development of the Genie, Diga and subsequent products was further facilitated.

It is easy to dismiss usability issues by highlighting the flexibility of users and their ability to cope with poorly designed products. If users are sufficiently motivated, they will indeed learn to use even the worst of systems. However, this approach is hardly likely to engender satisfaction with the products or systems operated, and users confronted with such systems are likely to make mistakes. Such mistakes in safety critical systems are often termed 'Human Error'. As can be seen from tragedies such as the Herald of Free Enterprise, 'Human Error' should more correctly be termed 'Design Error'. Only by adopting such an attitude is it possible to identify and correct the design faults which lead to tragedy. Although consumer products such as fax machines and mobile phones may be far removed from such circumstances, the same attitudes towards the user's role during development will eliminate much of the frustration associated with using modern products. We have attempted to show that this positive attitude can be fostered within an organisation through the full integration of user-interface and usability expertise in the development process, with beneficial results for the development team, the company and, not least, for the users.

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COLLABORATIVE WORKING WITHIN THE AERONAUTICAL SUPPLY CHAIN

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ABSTRACT

This paper presents the CASH project and its first results. CASH is a Growth project co-funded by European Commission which deals with collaborative working as a vector of promoting and spread Concurrent Engineering processes within the European aeronautical supply chain. The project has the objective to identify and package collaborative working means suited for aeronautical small and medium enterprises (SMEs) according to three axes: processes, methods and tools. This project is presented and its first results are described.

INDUSTRIAL AND ECONOMICAL CONTEXT

A global competition between large consortia and enterprises from Europe and USA mainly characterises the aeronautical industry in the last decade. In this context, European Aeronautics Industry has won these last years some strategic contracts due to the efficiency of their products in term of technical and commercial aspects but competitiveness is still at stake and improvements are still needed (Hertrich, R. and al., 01). In order to accurate this high level of manufacturing, the major players from every aeronautical sectors have set up ENHANCE, a large, single and fully consistent R&D project co-funded with the European Community - AS n°565.0425/98 - (Braudel an al., 01). This project aims at improving the aeronautical industry competitiveness by developing Concurrent Engineering (CE) standards.

Concurrent Engineering is characterised by the definition of a new common way of working in Europe : this should be achieved by the definition and standardisation of methods and tools, mostly computer and new information technology oriented. The main expected impacts in aeronautics are 30% reduction of aircraft development costs and development lifecycle.

Each segment, from product specification to final industrialisation, is to be considered, hence every contractor and sub-contractor – from major aircraft companies, through airlines, to small and medium enterprises (SMEs) –are concerned. Structure, propulsion, systems, maintenance, certification, communications, management etc… every technical issue is at stake.

The purpose of CE is to achieve a huge horizontal, inter-connected, European “Extended Enterprise” gathering together every industrialist, contractor or sub-contractor, each one becoming from now onwards a complete part of a “virtual” company (Pardessus, 01).

Following automotive industry example and boosted by competition, Airbus partners have decided to design and implement efficient Information Technology. Based on equity of the shareholders, the Airbus Concurrent Engineering initiative (ACE) has been launched in 1995 by Aerospatiale, DASA, British Aerospace and CASA and is going on (Pardessus, 01).

ENHANCE extends the Airbus designed target up to 49 companies with 38.2 millions of euro budget, and a three-year duration. This European project, started in the first quarter of 1999, considers main companies involved into Airbus construction, and takes their needs into account.

Because of the fact that half of the workload is sub-contracted in a multi-level chain, main companies need to spread this action through the whole supply chain. The 30% costs reduction will be achieved only if CE methods and tools are spread all over the aeronautical supply chain.

The need for additional dedicated SMEs research to the one undertaken by large industrialists is an outcome of the Scratch, DGXII Aeronautics, accompanying measure awareness and needs expression campaign undertaken visiting and auditing SMEs involved in the aeronautical supply chain.

The situation, as seen by SMEs, is characterised by a lack of coherence between the multileveled inspection of software tools and a certain gap between the earth reality and the existing potentialities of the information system. The experts agree with the idea that aeronautical SMEs competitiveness will be mainly related to the capacity of each company to manage the information by the effect of different ways: re-using the know-how, reducing innovation delay, reducing production cycle, mastering the complexity, increasing training performance...

The situation is also characterised, particularly in Aeronautics, by the necessity to improve the efficiency of collaborative work between major and small companies by jumping over the difficulties in the interconnection and the specific working habits of each.

The Supply chain needs to learn how to manage collaborative working in order to be able to participate efficiently to the future aeronautical products with some chances to reach the large industrialists cost reduction goals.

The best training with the aim of learning is at the level of adapting, designing, implementing and experimenting the Concurrent Engineering standards set up by large industrialists. The supply chain will contribute strongly to the European aeronautical community attempt in cost reduction. Most of the cost reduction effort goal is to be accomplished by the today subcontractors (SMEs in the supply chain) which expect to become tomorrow risk sharing partners in the future industrial projects.

On the other hand, Computer Supported Collaborative Working (CSCW) is the subject of numerous scientific and technical works and efforts inside enterprises, SMEs included.
These efforts have common goals, now part of the state of the art :

- a reduced time delay in driving project : turn to product, turn to market, ...
- a better competition in logistics, manufacturing, and marketing.
- a better communication between team members, teams and organisations (taking account the issues related to individuals, organisations and markets in the emerging digital economy).

Common goals suppose to solve with SMEs the following different points:

- Corporate knowledge management taking into account distributed product data management services;
- The organised access to the external sources related to technical, economical and commercial data (access to remote databases);
- Integration infrastructure that enables heterogeneous tools and databases to inter-operate transparently across platforms, creating a shared project environment (data flow management);
- The global integration of the tools used for solving the different problems in dynamic forms including the probable evolution in time (road mapping) of each data.

PROJECT DESCRIPTION

CASH Project main goal is to bring SMEs into the world of Concurrent Engineering standards which results from European Commission funded Projects in Aeronautics. This goal is to situate downstream from EC projects dissemination and to complement the Concurrent Engineering effort by undertaking research to adapt and package fully compatible methods, means, best practices to the intention of SMEs with the aim of SMEs implementation and validation.

CASH has placed its ambition at the level of working together according to the principles of the extended enterprise. The target is to assemble a maximum of pertinent methods and tools for getting at the SME level the best decision taken in a collaborative manner in compliance with ENHANCE standards. The project objectives are :

- to extend the CE research effort in aeronautics to the specificity of SMEs operating in the supply chain in a full compatibility with the ENHANCE methodology and standards;
- to validate in real size and real time CE, new technologies, inside the supply chain;
- to contribute to, within SMEs, the accessibility of the general CE economical goals in aeronautics (30% reduction in time to product);
- to disseminate, to transfer CE technologies from SME to SME in aeronautics.

In the following sections, we present the adopted approach for achieving these goals, then we describe the CSCW means used before introducing their validation through test bench cases. The forseen industrial validation is finally introduced.

ADOPTED APPROACH

In order to achieve the different goals of the CASH project, the work breakdown proposed has started by studying the CSCW state of art, analysing the status of the appropriation of the common collaborative processes, methods and tools in aeronautical SMEs and studying the needs of the SMEs in compliance with the results of ENHANCE.
These needs have then allowed to specify SME-oriented processes adapt collaborative processes, methods to the context of aeronautical SMEs and studying the integration and adaptation of market tools or those provided by ENHANCE.
This SME-oriented customisation is under experimentation through test bench cases in different phases of the aircraft life cycle. Transversal phases like remote access to data and network reliability are designed and/or experimented first and other specific phases are tested taking account the requirements and specific means of aeronautic SMEs.
A great effort will be done regarding to the packaging of the different solutions resulting from the CASH project. These results will be disseminated through European countries using European Community dissemination platforms (AECMA for example) and some European Projects in the area of collaborative working and Concurrent Engineering (Cepra, 99). Within the context of CASH project, a SME user group status and program will be defined in order to accurate the project results experimentation and dissemination.
Time has come to go deeply into an integration with and within SMEs of the different tools available and/or standardised by ENHANCE for collaborative working in these different areas (requirements management, product design, project management, product data management, enterprise resources management, document management. Beyond the integration objective, innovative contributions will be sought in :

- sharing understanding data/information;
- accessing to data through Internet network (remote databases);
- communication and collaboration (real time conferencing, application sharing over the Internet, …).

The final challenge of CASH is to validate the package on real situations fixed by the end user participating in the project. Validation is restricted to an illustration of implementing best practices with a first rough estimate of operational efficiency.

The first results of the project are the identification of the SMEs needs and requirements in term of collaborative working. In response to these requirements, we have defined a CASH model composed of four levels:

- Domain functions
- Collaborative sessions
- Data exchange and sharing
- Information and Communication Technology Infrastructures.

The domain functions level is characterised by the collaborative functions dedicated to a given domain (project management, design, calculations, …). This level is under experimentation through different test bench cases.
The three other levels constitute what we call "**collaborative working means**" and are described in the following sections.

COLLABORATIVE WORKING MEANS

The ENHANCE collaborative work usable solutions are limited to the Engineering tasks and the lack of the aeronautical supply chain is oriented to data exchange from engineering to manufacturing that must be improved significantly in order to reduce time and costs (due to translation and/or regeneration of transmitted data). The data flow from aeronautical large companies to theirs subcontractors (i.e. SMEs) have been analysed in order to study shared applications (CSCW tools). These applications are the basis of realising physical Extended Enterprise. Emerging solutions based on Web technologies are already in use or experimentation in other sectors like car industry. Aeronautical sector has to gain from these technologies that might need adaptation.
We have defined generic resources that are necessary for experimenting collaborative working processes. These resources are needed for setting an "Extended Enterprise" environment which includes aeronautical SMEs. Three levels have been identified and are described below.

Collaborative sessions

This level aims at designing infrastructures for SMEs access to distributed and remote information systems. The state of art realised early in the project has allowed to identify different kinds of tools used for communication (for communicating inside and outside a project team). Two types of communication have been considered:

- **Vertical communication**: One of the main problems encountered by users is information availability. Information exists but it is either too disperse in many different applications, thus becoming untraceable, or it simply isn't made available for users. The vertical aspect of communication within the CASH system allow to make each company's stored information more easily available for users. This type of communication can be seen as an inside, machine made, automatic communication. It is implemented by making use of data warehousing technology.
- **Horizontal communication**: Between each production team, there is the need to interchange information in order to improve production processes and to share critical information, i.e., improve and implement group work. Information must flow from team to team and from each team member to another team member. Each team member has access to the company information which is made available by the vertical aspect of CASH communication. GroupWare technology that includes e-mail, electronic meeting systems, desktop video conferencing, internet or intranet technologies and other more classic means such as telephone are used to implement horizontal communication.

In solving their information technology problems, many organisations find that now, their infrastructure consists of a puzzling collection of packaged applications, so they face a growing problem of connecting these different environments for a consistent view. Enterprise application integration is seen as a solution for integrating supply chain systems through common internet portals.

Data exchange and sharing

This level aims at designing processes and tools for accessing to remote information systems for collaborative working activities in the aeronautical supply chain. Most of the CSCW tools need remote access infrastructures and functionality and sharing application means also sharing data stored in a distributed environment. We have analysed and proposed solutions for SMEs that want to integrate into an Extended Enterprise (because of dispersion of their team and quarters or because of access to their clients' information systems).
Different kinds of data (technical data, resource planning data, supply chain management data, after-sales services, …) can be accessed through an internet network, allowing different teams to work together without being in a same geographic area. This functionality need support and some tools are useful to SMEs but also the large aeronautical companies working with SMEs.

Information Technology infrastructures

Communication is not only the heart of Collaborative Working but the heart of business and the Internet has become the star of communication as the new medium for communicating with customers as well as business partners. The public nature of the Internet exacerbates the security concerns that exist to some extent on any Wide Area Network. The risks associated with user authentication and unauthorised "eavesdropping" on sensitive data have been recognised for years. Collaborative Working business requires a mobile workforce and virtual teams which members scattered throughout partners need to exchange at any time, to co-ordinate their work, to quickly attack a particular problem before being disbanded. By moving to the Internet, the extended enterprise network is not only reachable all over the globe but the logistical issues of adding new connections are eased. A Virtual Private Network (VPN) typically uses the Internet as the transport backbone to establish secure links with business partners, extend communications to regional and isolated offices, and significantly decrease the cost of communications for an

increasingly mobile workforce. Prior to the advent of VPNs, the only other options for creating this type of communication were expensive leased lines or frame relay circuits. Internet access is generally local and much less expensive than dedicated Remote Access Server connections.
Creating secure, private corporate networks using the shared infrastructure of the Internet is the new promising technology called Internet-based virtual private networking. By offering not only typical data services but even real-time voice and video applications, Internet has entered the typical target market of ATM at service level. Furthermore, the Internet Society is keeping their policy of shared resources and "free" usage with the Diffserv suite while one thought they drastically loosed this policy introducing resource reservation and charging support in the Internet to provide better support for multimedia applications and service providers. Significant benefits can be gained by organisations deploying a network capable of supporting policy networking. Business objectives can be met in a reliable and predictable manner thanks to a centralised end-to-end policy management. The larger the network, the greater the benefit of policy networking. The extended enterprise policy networking provides scalability. With a global and unified directory service, users obtain the same configuration, regardless of whether they connect to the network locally or remotely.

TEST BENCHES AREAS

This part of the project aims at defining different specific stages oriented test benches covering different stages of the aircraft life cycle. For each test bench, selected methods and/or software tools are experimented.
The experimentation through such test benches allows to evaluate the common methods developed in the context of CASH. The approach used in these experimentation is characterised by analyzing the current situation and the desired evolution, performing the experimentation and analyzing the experimentation results with respect to the current baseline and to measure improvements. The different test bench cases are the following:

- **Interactive simulation** (CAD design): The design of prototype is an essential stage of any development of project in lot of industrial activities, such as aeronautics, space, automobile or architecture. The scientists and the engineers ask for prototyping to confirm and validate visually their ideas. The use of numerical prototypes is not a new idea since the applications of CAD are widespread. The results in 3D interaction and real time 3D visualisation lead to collaborative and really interactive system development for virtual prototyping. The decisions taken during the phase of design are often most sensitive, because of their effect on the results and the costs. The use of mocks-ups is usual but virtual prototyping makes it possible to the designers to examine and improve their design as by using the physical models, but better, earlier and with distant collaborations. The possibilities of the current tools of CAD are too much limited to make possible the interactive inspection and the handling of models. Moreover, the lack of support for co-operative work makes difficult the sharing of information between the geographically distant people. This is why great projects were often accompanied by the development of virtual tools for prototyping, which shows the need for generic solutions of collaborative virtual prototyping. The demonstrator used by Rolls-Royce to evaluate the facility of assembling and maintaining an engine or the visualisation system used by Boeing during the conception of 777 are good examples of this tendency. Some recent additions to the CAD products of PTC, IBM and Dassault Systèmes, Matra Datavision, Prosolvia Clarus, Unigraphics go in the same direction: to provide new possibilities of real time visualisation for the design. The products of Division, EAI, or Centrics Software are among the few products making it possible to originators to work on a shared prototype, taking advantage of concepts from CAD, distributed simulation, virtual reality, collaborative engineering. However, their model of 3D interaction does not allow fast and precise operations and their co-operative devices are often limited to the review session managed in network, which illustrates the lack in 3D interaction or in the possibilities of collaboration. There are a lot of tools and technologies used for concurrent engineering responding to the different needs from the extended enterprise (several sites, projects, suppliers, countries, …) all over the supply chain. The expected services are: CAD/CAM data exchange, remote access to digital mock-up, remote access to project management database, remote access to product/process data management database, virtual conferencing, quality analysis of CAD/CAM models, advanced mail and workflow for data management, synchronous data sharing.
- **Collaborative project management**: This test bench case is conceived to experiment with advanced tools (including the underlying methodologies and techniques) and to adapt them to the specific requirements for collaborative working of European aeronautic SMEs. Part of the experimentation will be also be dedicated at defining a preferred advanced planning system architecture w.r.t. collaborative working of European aeronautic SMEs. The remainder of the task will then be dedicated to implement the experimental advanced planning system based on the resulting selected architecture, and then to test its suitability against specific theoretical case planning needs.To achieve on e of the main goals of collaborative engineering, i.e. reducing overall aircraft development life cycle time by approximately 30%, a sophisticated planning system is needed. As a whole aircraft life cycle comprises not only the product definition, product design, manufacturing, product exploitation, but also the interdependency of different sub-product and sub-system taken on by different distributed entities at different times, all performed in a collaborative approach, it will be essential to identify, analyse, select and experiment with the appropriate tools. Prime features of these kind of tools are real time updating taking account random events (such as failures, human resources, etc.) but also the implicit

repercussions on suppliers' planning. In the context of new methods of work, new tools are available on the market and customising them for the aeronautical area is a challenge that this task will undertake. Planning is the translation process from requirements (here associated with collaborative engineering based aeronautics system development by European aeronautical SMEs) into a schedule of aircraft development life cycle related activities. Planning will ensure the end-to-end coherency of activities/operations with respect to constraints: logical conditions, temporal constraints and resource conditions (e.g. power limitations). This is converted into detailed timelines of actions and instructions for e.g. controlling sub-system production, etc, commonly referred to as (activities) scheduling. Scheduling will ensure the time-lining of these activities/operations in a sequential way.

- **Collaborative integrated logistics support**: « ILS » is a global approach which consists of putting together different means, engineering activities and relevant services in order to guarantee the availability of the system by optimising its life cycle costing. This approach is applied in the USA to aeronautical systems and aircraft using a structured analysis method based on the MIL STD 1388 standards. The different means, engineering tasks and services necessary for ILS approach found a set of logistics support elements which are mainly: Transportation, Handling, Storage, Packing, Technical documentation, Training, Spare parts, Maintenance plan, Staff and technical assistance, Test equipment and supporting services, Infrastructure, Computer systems and network, etc…

INDUSTRIAL VALIDATION

This task will allow also the CASH consortium to broadcast through this SMEs network SMEs-oriented collaborative working processes, methods and tools from the project by setting up dissemination materials by web and by electronic means. Besides, CASH project will have his own web site that will allow to reach the previously described objectives. It will constitute an important way of dissemination, information and electronic data exchanges.

For large dissemination, participation to events like conferences, workshops congresses, papers, … will be initiated during the CASH project.

Early in the project, a dissemination strategy will be defined by CASH consortium in close connection with ENHANCE dissemination management board.

CONCLUSION

The technical innovations of this project lie in:

- The link between Concurrent Engineering and Collaborative Working;
- The improvement of SME information system by integrating to it collaborative working means;
- The data exchange between aeronautical major enterprises and/or SMEs using collaborative working means (sharing information through collaborative working tools).

The CASH project originality is situated in the ambition to bind aeronautical major enterprises information systems and SMEs ones using Internet as network support. This is the current scientific and technical stake of the industrial areas due to the exchange world-wide and CASH aims at turning this stake in reality in aeronautical area.

Due to information and communication new technologies expansion, new needs are coming out in the integration of different enterprise information systems, like Product Data Management, Enterprise Resource Planning, Configuration Management, Supply Chain Management and Customer Relationship Management systems.

These information systems will be integrated for extended enterprise needs. Some solutions are pointing out on the market but a real customised solution for the aeronautical does not exist. ENHANCE project has defined the whole context for the realisation of such system and CASH proposes to put in reality this kind of solution which is a technological jump that could be used in other areas like space.

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THE AUTOMOTIVE DESIGN PROCESS
- ADVANCED CONCURRENT ENGINEERING

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ABSTRACT

The trend is to modularize and outsource manufacturing and design - in some extreme cases the OEM (Original Equipment Manufacturer) is undertaking only the core tasks of designing, engineering and marketing vehicles – becoming in essence a VBO (Vehicle Brand Owner).
Concurrent engineering (CE) is improving the design process – making it possible for product development members to virtually design and test parts and subsystems. Global manufacturing rouses the need for global collaboration and collaborative CE tools are making the development process quicker and more efficient.
Due to these CE tools the possibility arises to not only improve the development process, but also to change the very way cars are constructed. The Mercedes Benz CL is an example of a multi-material car – an engineering achievement unimaginable without advanced CE tools.

THE CHANGING AUTOMOTIVE INDUSTRY

A complex product development situation

The traditional way of developing an automobile was done in a series of functional steps; each step being initiated only after the previous one was fully completed. Needless to say, product development time was slow. Mercedes-Benz, e.g., followed a 12 year model cycle. Times have changed and OEMs are now using concurrent engineered methods, carrying out development steps parallel by diverse teams, shortening development time down to 2-4 year.
OEMs have in the last decades' outsourced parts and part-systems to suppliers, which manufacture to order and just in time (JIT). Some of the main drivers have been cost reduction, concentration on core-competency, risk-sharing and general complexity reduction.

Modularization is when automobile systems, e.g. the cockpit or 'inner door', are sub-assembled and brought as a whole into the final assembly. It was much hyped a few years ago as the next transformative innovation for the auto industry, as the same module could theoretically be used for different types of cars and so saving on engineering and design time as well as gaining economies of scale. Results up until now have been marked by difficulties in leaving the dominant integral product architecture and lack of standardization – auto parts present little cross-product / cross –firm

Case study: the multi-material car

Let us look at three automobiles: the Lotus Elise, Audi A2 and Mercedes-Benz CL. All of these cars took approximately two years to develop from concept study until start of production. The Lotus was launched in 1996, the Audi in 1999 and the Mercedes-Benz in 2001.

Figure 1: The chassis of the Lotus Elise

All of the teams used virtual design tools and were organized in a cross-function manner. There was however a significant difference in the way they were built – the timing of decision making regarding choice of material, material process (cast, sheet, profile, etc.) and on the choice of joining method, varied. In the case of the Lotus Elise (figure 1), all these decisions were decided at the very beginning of the design process. For the Audi A2, the (continued on next page)

standardization (MacDuffie and Moavenzadeh 2001).
In recent years suppliers have increasingly started overtaking specific design functions. Mainly the automotive parts involved are non-visible to the customer, e.g. suspension systems and engine cradles. Outsourcing design in these cases has proven to be very favorable. The suppliers, eager to be chosen, are highly motivated and better suited to innovative as they often sell to multiple OEMs, thus having economies of scale to justify intensive research and development

Design and manufacturing strategies

In the traditional markets, mass customization has replaced mass production. The niche market has become mainstream. An OEM now has modularized platforms to base a number of different cars upon. The Volkswagen group (VW, Seat, Audi and Skoda) gives a good example of this, where they use the same chassis platform for 8 types of automobiles within 4 different brands. OEMs are now building smaller, more flexible factories which can swiftly change production model and so be able to mass-customize more efficiently.
In emerging markets OEMs are setting up factories, thus being closer to market, tapping in on local expertise, utilizing lower labor costs and profiting from more favorable customs and tax laws. Suppliers set up manufacturing facilities close to the OEM assembly plant, providing outsourced modules and parts which are transported in sequence and just in time to the main assembly. In extreme cases the traditional OEMs have limited themselves to core design work, quality control and project management, giving the suppliers full responsibility for logistics, assembly and specific design. Theoretically traditional OEMs might disappear and in their place will come vehicle brand owners (VBOs), undertaking only the core tasks of designing, engineering and marketing vehicles.
Some OEMs have experimented on “World-Car” concepts where the same basic car is customized for local conditions and the preferences of customers living in countries characterized by diverse structural and social conditions (Camuffo 2001).
An interesting trend has also started within the low volume / high price segment, where we see contractors overtaking complete manufacturing, logistics and quality control responsibilities. As an example the Porsche Boxter is assembled by Valmet, an engineering firm in Finland and as of 1998 the Audi Cabriolet has been completely contracted out to Karmann.

Light weight automobiles

Governments are setting tougher regulations regarding exhaust emission levels. Non-compatible international standards add yet to the number of varying models.
In addition to optimization of combustion engines and research of alternative energy sources, OEMs are looking at weight reduction as a potential way to bring down fuel usage. For every 100 kilograms saved on the vehicle's weight, we can save roughly 0.2 to 0.4 liters of fuel per 100 kilometers-depending on the type of engine. By the year 2010, it is conceivable that we'll save up to 1.6 liters of fuel through a roughly 30 percent reduction in vehicle weight (Pollmann 2000). Here the focus is on materials selection (light metals, ceramics and carbon-reinforced plastics), construction method (e.g. profiles, plates, cast, rivets, glue) and design.

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decision of material was taken in the start of the development process, while joining methods were taken later. Finally in the case of the Mercedes-Benz CL, material usage and joining methods were taken during the whole process.

Figure 2: The Audi A2 spaceframe

Obviously the Lotus engineers had an advantage, as they knew from the beginning of the development process what material and joining methods to use – saving time and cost (not to mention frustration!). They did not have to wait for information from parallel running design activities (or develop numerous alternative solutions to fit whatever choice).
Engineers of the Mercedes-Benz CL had a

(continued on next page)

Designing multiple material cars introduces a new problem as engineers have to account for different physical characteristics, e.g. strength, toughness, heat resistance and flexibility. The Mercedes-Benz CL (figure 3) is an example of a multi-material car.

Moving further

It is clear that with market forces demanding mass-customized vehicles, increased design-outsourcing to suppliers, collaborative “world-car” projects, shorter development time, and tougher emission regulations, the necessity for advanced concurrent engineering tools is enormous.

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much tougher job, having to undertake a significantly more advanced concurrent engineering process – as material choice, material process technique and joining method decisions were not fixed from the start. The effort paid off: the new CL weighs 340 kilograms less than the predecessor model.
We can hypothesize that one of the more important factors contributing to Mercedes-Benz's decision to use a multi-material bauweise, while Lotus and Audi chose not to, was due to technological advances in the relatively short period between the developments of the three cars – the advances in concurrent engineering tools was the enabling factor.

ADVANCED CONCURRENT ENGINEERING

Concurrent Engineering (CE), alias integrated- and simultaneous engineering with added attention to 'soft' organizational factors, is one of the OEMs key success factors. With the high variety of automotive models entering the market it is difficult to place bets on all. It is therefore vital that an OEM is able to quickly catch up with a competitors successfully launched vehicle before the hype is over.
The technology trends in the past decades have shifted from being focused on individual design assistance, to replicating the drafting board, and finally to replicating the whole product life cycle (Figure 4). Today engineers are able to develop a product in some cases without physical prototypes.
As this happens issues began to shift from performance to interactive ability – i.e. being able to collaborate with the rest of the world.
In this paper, we categorize two different types of CE tools, the first kind enable users to virtually construct and test components and the second type of tools facilitate design-focused communication with a network of product development members.

Virtual design tools

The traditional automotive development process required costly and time consuming physical prototype iterations.
Traditional CAD/CAM/CAE software focused on design, development and manufacturing of parts. CAD (Computer Aided Design) allowed for rapid part design and visualization of form. CAE (Computer Aided Engineering) tools automated the once tedious (and often nearly impossible) finite element calculations, thus make it feasible to do complex meshing and analysis of structural-, thermal- and vibration effects, i.e. test functionality. Finally CAM (Computer Aided Manufacturing)

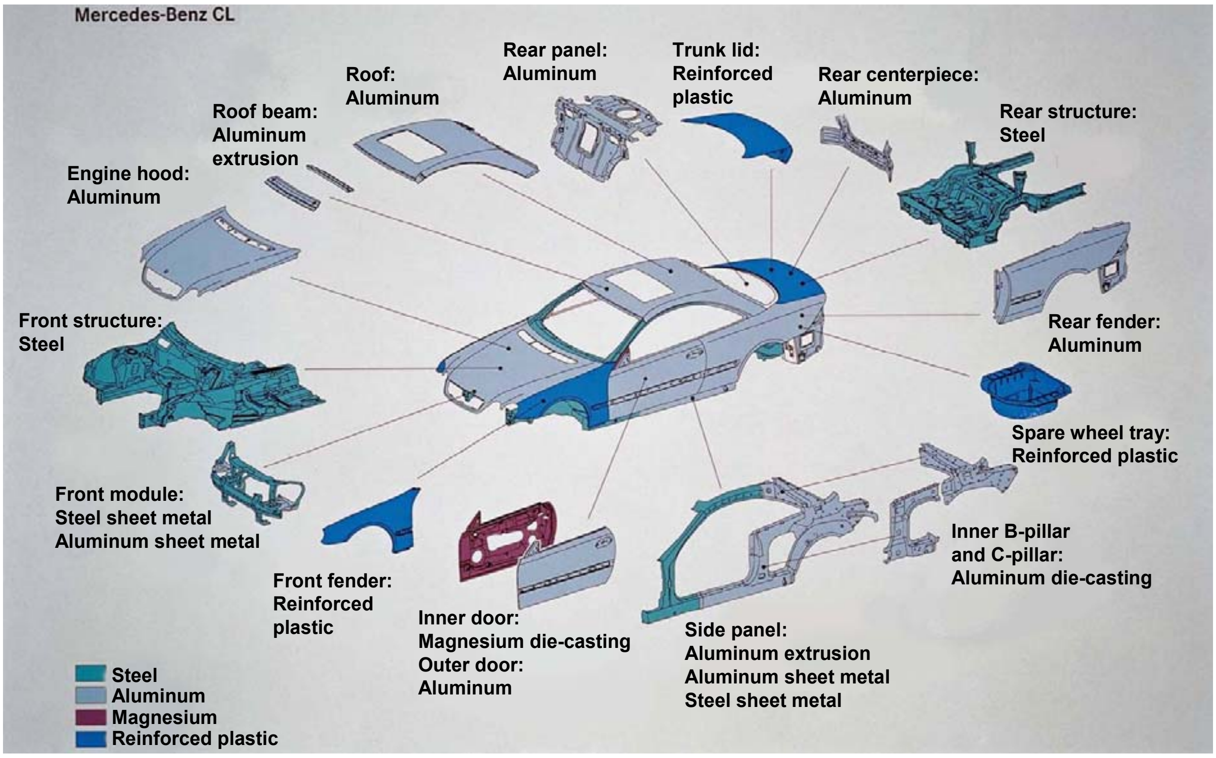

Figure 3: Hybrid Bauweise – Aluminum, Magnesium, reinforced plastics and steel in combination

tools assisted with the actual manufacturing process, providing better control of e.g. machine tools, robots, mold-, stamping- and forging procedures. These tools improved greatly the quality of parts (Ryan 1999).

	<1990	90's	>2001
CAD	• 2D/Wireframe • Drafting	• 3D Solid • Design	• Virtual Models • Product Development
Network	• Propriatary • Homogeneous Workgroups	• Open • Enterprise	• Distributed • Extended Enterprise
Issue	• Performance	• Interoperability	• Collaboration/ Integration

Figure 4: Technology Trends. (Source: Ray, C., Microsoft)

Many powerful CAD/CAE/CAM software packages exist on the market today, e.g. CATIA, Pro/Engineer, Unigraphics and I-DEAS(r).

DaimlerChrysler is increasingly working with their suppliers via e-business – making change management much quicker and the supply chain faster. According to Hans-Joachim Schöpf (Senior Vice-President, Mercedes-Benz Passenger Car Development, and a member of the executive committee, Mercedes-Benz and smart) it is all about more speed and less change. One of the prerequisites is the CATIA pipeline – nearly all their designers and engineers use it. It brings down development time and costs and brings up quality at a very early stage (Automotive Engineering 2002).

As computing power has grown more economical, systems have emerged offering a combination of CAD, CAM and CAE. More importantly it is now possible to put together a system of parts and so explore the interrelated effects of motion on the complete product or subsystem – not just the individual parts. A user models parts and connects them with joints and constraints to produce a fully functional computer model of the full-system assembly. The user then applies forces and motions and runs the model through a series of physically realistic 3D motion tests.

ADAMS and FEDEM are examples of virtual prototyping software. Today virtual prototyping software can refine and prove out the designs of suspensions, tires, shift linkages, window mechanisms, door latches, windshield-wiper systems – anything with moving parts. The car companies "test-drive" entire vehicles in the computer, running them through a full range of maneuvers, under various driving conditions. They even use the computer to realistically simulate human driver response.

Collaboration Tools

To a greater extent companies are looking at the soft side of concurrent engineering – collaboration.

What product development teams are aiming at is being able to improve manufacturability and product quality, lower the cost of designs, shorten time to market, generate a greater buy-in (avoid the not-invented-here dilemma) and reduce late costly change orders, by sharing technical information in an advanced way with all relevant members in real time. It helps incorporating ideas into design early on in the process and so gets the product right the first time and on time to market.

Collaboration tools have to be flexible, easy to deploy, secure and manage data (CAD as well as non-CAD data). They should facilitate communication, store and manage project data, manage workflows, procedures and tasks, manage project plans, dates and milestones and support CAD visualizations and annotations.

Companies have to employ technologies which enable collaborative creation, which:

1) brings people easily into the process (not only design engineers but also all people who are or should be engaged in the product design process)
2) motivates (once people are in this environment, they have to be motivated to innovate, explore ideas, bring new ideas in, decide quickly at the end and move on – they need a "sandbox" where they can all bring in their ideas and modify) and
3) preserves intellectual capital (today we only capture how we design a product and how we manufacture it, we don't capture the way we chose a certain design and which other alternatives we looked at and why we discarded those. These factors become clear when people try to explain which alternative they want to pick. This clear reasoning behind the design is really a key intellectual asset for a company.

Further development of such systems must address how to make a virtual environment more realistic and natural – so that users feel as if they were in the same room. In addition they have to become more user-friendly and convenient. This is important as the best innovations and the best creations come from small teams working together.

A CHANGING AUTOMOTIVE BAUWEISE

The term 'bauweise' is used as it refers both to the process of constructing an automobile, as well as an automobiles basic architecture.

Concurrent engineering is not only improving the product development process but assisting to explore new ways of constructing automobiles – multi material vehicles, modular structures, space frame technology, etc.

Changing the product – not just the process

We have seen how advances in concurrent engineering tools can change the way automobiles are constructed.
DaimlerChrysler offers a good example of this – demonstrating how a new breed of automobiles can be designed with the help of CE tools. They are convinced that there will not be a 100% aluminum-bodied car from Mercedes built in "high numbers," mainly because of costs and manufacturing complexity (Automotive Engineering Online 2002). Instead they are betting on utilizing each of the many available materials wherever it offers the greatest benefits, and where it best suits the component's functions. This approach has given rise to a new type of hybrid design bauweise in which individual parts of the same component (e.g. of the body) consist of different materials. Here DaimlerChrysler takes advantage of CE tools, taking into account safety, comfort, quality-at an affordable price, and environment. For its ecological balance sheet e.g., DaimlerChrysler considers, among other things, the energy consumed in manufacture, the vehicle's service life, recyclability and resource consumption. An auto body of pure aluminum, for example, must be driven as far as 500,000 kilometers before the energy used in producing this metal is offset Pollmann 2001).
The side-effects of multi-material bauweise should not be underestimated, e.g. using the right material at the right place might enable a fundamental change in design, change the structure of the supply base and trigger increased research in alternative materials.
Along the horizon we can foresee a scenario where provocative questions regarding the fundamental way we design and build cars come into view.
Bauweise changes will not only appear due to advances in design tools, but rather as an interaction of advances within the fields of material science, design tools, information technology, and others.

FURTHER RESEARCH

Looking at automotive design we see that there is a heavy focus on the optimization of current methods. Most often OEMs and suppliers are not ready for fundamental changes. Factors such as know-how, infrastructure, patents, current products, current usage of materials and production processes, and general resistance to change make it difficult for most companies to explore alternative ideas. In other words companies are very good at doing things right but not very good at asking whether they are doing the right things.
This opens for intriguing questions regarding how the design process can be organized to encourage ‘thinking out of the box’.

The NUTS Automotive Design Factory is the name of a recently established project at NTNU/SINTEF. This centre will integrate research, education and learning together with an international network of partners.
The aim is to become an internationally leading competence centre for light metal-based automotive product and process development – focusing on lean high volume manufacturing of light metal products.
We believe the way to do this is to holistically research all factors regarding the creation process – from the forging of the material to the design of the component and development for mass production friendly manufacturing and assembly. Our key research areas are Transportation Design, Product Modeling and Manufacturing.

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ASPECTS OF KNOWLEDGE SHARING IN DISTRIBUTED DESIGN BUILD TEAMS

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KEYWORDS
Distributed Teams, Knowledge Management, Barriers, Culture, Communities of Practice, E-Bok, E-engineering.

ABSTRACT

Global competition, short innovation cycles and mergers drive companies in the high-technology areas towards efficient information management and optimal usage of modern information technologies.

The development processes of an airplane in all phases are supported by information technology: ranging from the initial market studies and conceptions through the rough (high-level) and detailed (low-level) designing, computation and analysis, maintenance of modifications till the visualization and production-oriented processing of data.

This paper gives an overview of E-engineering at Airbus and its distributed design build team environment. Information Technology is used widely for knowledge sharing and transfer in this culturally diverse and geographically distributed organization, to enhance productivity and innovation. The knowledge management practices and techniques used are briefly described, issues and constraints faced are discussed and solutions presented.

DISTRIBUTED ENGINEERING AT AIRBUS

EADS Airbus is the civil aircraft division of EADS (European Aeronautic Defense and Space Company, a multi-national merger of DaimlerChrysler Aerospace (Germany), Aerospatiale Matra (France) and CASA (Spain). BEA Systems holds a 20% share of Airbus.

The current Airbus products range from short range (A318) to long range (A340). A318, 319, 320 and 321 are single aisle aircraft; the A300 and A340 both are twin aisle aircraft. The development of the A3xx, known as Megaliner, an aircraft with a capacity of up to 600 seats will be a big challenge for the future.

The development process at *Airbus Integrated Company (AIC)* is distributed integrating the work of teams in Germany, France, UK and Spain; however, final assembly takes place in Hamburg and Toulouse (Fig. 1). Due to the physical distance and distribution of the development teams the quality, availability and accessibility of information needs to be high.

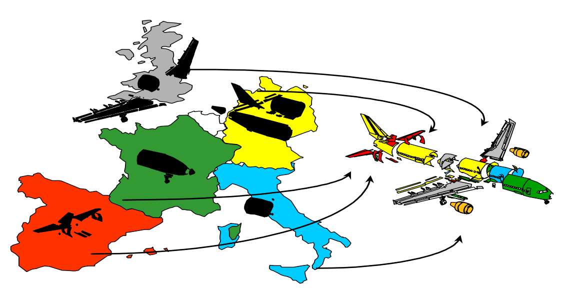

Fig 1: Distribution of tasks to the partners and main suppliers of AIC

KNOWLEDGE MANAGEMENT AND KNOWLEDGE BASED ENGINEERING

Increasing specialization, product complexity and increasing pressure of competition are handled by high-tech companies, like those in the areas of aviation and astronautics with the aid of consistent application of methods of Knowledge management and integration of this process in the business processes.

The term Knowledge Management includes a number of methods, processes and tools, which range from information technology to aspects of social science. Basically two types of knowledge are distinguished here: *explicit* knowledge and *implicit* knowledge. Explicit knowledge includes knowledge that is already commonly accessible in the form of reports, protocols, specifications etc. Implicit knowledge, on the other hand, describes the knowledge that is in the brains of employees, their experiences, and their "Intuition".

In the airplane development, Knowledge management is applicable primarily in the process of product development and in the interface between development and production. Important aspects, which are to be covered here, are:

- Competence management,
- The recording and (re-) use of implicit and explicit knowledge in the form of Lessons Learned and Best Practices, Reports, Documents, Design Rationale etc.,
- Knowledge-based Developing.

Competence management records and documents the knowledge profiles of employees. In this way, the experts of a firm can establish contacts more easily and specifically among each other. *Lessons Learned* are experiences that have been gained while solving problems and can be applied to other use cases; Best Practices describe generally accepted, optimal solutions for an engineering problem. Design Rationales record the argumentation chains, which have led to a design decision. Knowledge-based developing finally aims at automatic knowledge processing for supporting repetitive job requirements.

Designing activities are often iterative to a great degree and can often be defined mathematically also. They can be recorded by means of Expert systems and methods of Artificial Intelligence (AI). This enables a partial automation of workflows which brings with it savings in time and costs. Design Rationales reflect the decision-steps in designing and illustrate the Argumentation chains, on which a decision is based. They throw light on advantages and disadvantages, boundary conditions and alternatives and thus allow the reuse and adaptation of already existing designs.

The use of these techniques was considerably restricted in the past to designing and configuration activities. However in future, there will be interesting opportunities for using them in the areas of modeling, computation and simulation.

An example is the numeric flow simulation. The simulation process is very complex and requires the consideration of several physical, mathematical and numeric boundary conditions and initial conditions and other influencing factors. With the help of design rationale, the implicit knowledge of the computation engineer can be recorded. Thus the first conceptual approach to a problem, which forms the basis for a detailed working, can be simplified. The mathematical-physical definition of the problem and the application of the assumptions/results to similar cases are enabled or accelerated.

ISSUES FACED BY DISTRIBUTED TEAMS

Concurrent and distributed engineering may be viewed as the integration and management of engineering processes and the information they create across an engineering enterprise, its customers and suppliers. Processes for implicit knowledge exchange, transfer and capture become vitally important to organizational performance and growth. In addition, distributed teams have to overcome certain inherent barriers, which may be described as follows:

Individual level/Group level barriers include acceptance of need to share, Individual self-responsibility towards learning and sharing, acceptance of need for collaboration, low trust relationships and fear that sharing would lead to loss of power. This is especially true of distributed teams as there is little or no 'face to face ' contact.

Structural Barriers include lack of incentive for sharing knowledge with other departments as the focus is on ones own section. If a company structure values unique ideas rather than sharing information, employees will not want to use others ideas as their culture does not encourage it. This can be overcome by incentivising knowledge re-use. For example, the organization may give away an award for the person who reuses ideas to save most costs and time. The lack of a common language between departments may be a hindrance to sharing or re-using best practices.

Excessive focus on explicit knowledge may cause the organization to loose out on really valuable tacit knowledge. Informal discussion forums are a means of capturing such information and technological tools may be used for storage and retrieval.

Boundary Barriers could include Perceived and real boundaries between departments, teams, etc., and their information systems. Perceptions of the importance given to position and hierarchy may also restrict knowledge sharing; some cultures advocate top-down communication and the lack of clearly demarcated roles and boundaries in distributed teams can hinder knowledge sharing.

Management Support Barriers include perceptions of absence of top management support towards the effort, and the perceptions of the importance of knowledge sharing and management to the ROI. In distributed teams, this is further emphasized as each individual works on a very specific task and seldom comprehends the whole.

Technology Barriers include absence of a facilitative technology, training and awareness of its uses and benefits to organizational goals, lack of alignment between technology and strategy, which can result in stand alone solutions that do little to enhance performance.

Cultural Barriers an organizations culture must support knowledge sharing and provide an incentive to use the process. Culture is a barrier, which may be turned into an enabler. A good starting point is to access the current culture in terms of how well the company supports sharing. A diagnostic test may be developed and used for this purpose (such as in Table 1).

On the basis of the checklist systems and process can be designed to facilitate knowledge sharing. Distributed teams also face challenges of different national cultures and need to integrate the cultures into one common work culture. This would mean developing common stories, heroes and processes. Cross boundary communities of practice can help achieve this end.

Does Your Current Culture Support Sharing

Yes If:	**No If:**
• People learn by sharing and through teaching. • Past lessons and story telling are used by everyone to facilitate community understanding. • Ideas are constantly shared as new experiences create new knowledge. • The firm has groups of people with common interest who collaborate with each other. • The firm is willing to share issues and problems to learn as a group from them. • Relationships exist between and across section boundaries.	• Incentive system does not encourage sharing or creates a barrier to sharing. • No time is provided or no mechanism is in place to capture lessons learned. • "Assumptions about projects or activities are not challenged". • Promotions and hiring of new employees is "based on technical expertise". • Past failures are buried because no one wants to talk about them. • Each department has their own vision and culture that creates a barrier to sharing with other sections.

Table 1: Checklist for understanding Cultural Barriers within the organization

SOCIAL AND PSYCHOLOGICAL ISSUES FACED BY DISTRIBUTED TEAMS

The distributed nature of the teams leads to certain socio-psychological problems, which need to be considered while designing knowledge sharing practices. Virtuality can lead to de-indeviduation and cause negative behaviors. Lack of direct personal contact creates a sense of anonymity and often results in low trust, responsibility, sharing and commitment. Tacit knowledge is often shared within a team through informal mentoring or co-working. It would become important to build these factors into the working of distributed teams. Developing a knowledge sharing culture is one means to overcome this issue. Information technology tools such as E-Bok have clearly defined recognition mechanisms, which help overcome the problem of 'social loafing' among team members. Social loafing is a phenomenon exhibited in teams, where in the work of few members is measured for team success and the others do not make any contribution. This results in perceptions of inequity and lower knowledge sharing. Recognition and rewards act as positive reinforces to knowledge sharing.

The most important motivator is "the opportunities to learn". Organizations can ensure knowledge sharing and value adding behaviors by providing forums for knowledge exchange and learning.

Another Challenge faced by distributed teams is in the area of communication. Body language, eye contact, intonation, etc, make for more effective and culture specific communication. In the case of distributed teams there is the disadvantage of relying only on verbal or electronic communication, which might cause 'noise'. Thus hampering collaboration.

In the next section we present examples of Knowledge Management practices in the Airbus Consortium.

THE COMPOSITE MATERIALS EXPERT CLUB – AN EXAMPLE OF KNOWLEDGE SHARING

The barriers presented above may be overcome through creating awareness of the importance of knowledge sharing, developing and encouraging communities of practice, improving knowledge access, benchmarking best practices, developing stronger intra organizational relationships encouraging and recognizing learning and sharing behaviors and finally measuring the return on knowledge.

The Composite Materials Community of Practice (short: Composite CoP) at Airbus faces the following business challenge: the quality of the material must be improved and errors in handling composite materials must be reduced.

In particular, this requires close communication and efficient information exchange between Manufacturing, Engineering, Quality and Services. Manufacturing, Engineering and Services are located in different cities (e.g., Stade, Bremen and Hamburg), which further complicates communication.

In addition, competencies have to be managed, for example, in the form of „Yellow Pages" that list experts, their respective area of expertise and contact information.

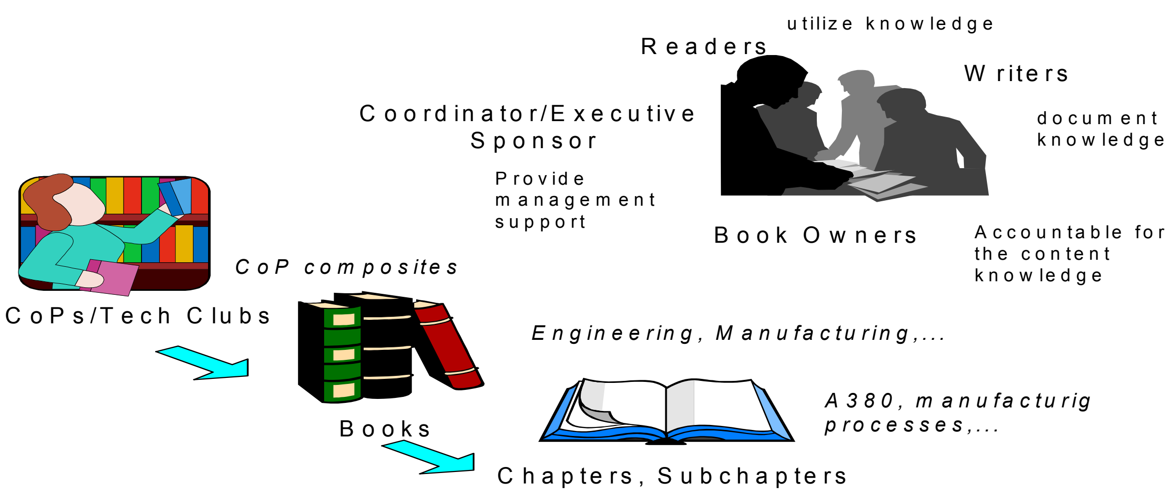

Fig 2: Knowledge-sharing and functional roles within a CoP

The *Composite Community of Practice* eventually will link all people within Airbus who work on composite materials driven by a strong management support.

The Electronic Books of Knowledge (EBOKs) of this knowledge sharing community mirror its communication needs: one each for Manufacturing, Engineering and Service. The different chapters of these books typically discuss different technologies, aircraft programs, standardization practices and so forth. The Learned and Best Practices are entered by means of a web-enabled application that is easily accessible throughout the plants and engineering offices.

Any member of the CoP (Reader status) can freely access all the documents, however, no changes can be made. Writers take a more active role as they write down Best Practices and Lessons Learned. The Book Owners (i.e. Composite Manufacturing, Engineering, Services) are responsible for the Book's overall validity, the specific focus and the approval of content. For the latter they rely on a peer review process, i.e. members of the CoP crosscheck all information and approve it.

Lets look at a simple example how this works.
Sometime ago Quality, Services and Engineering noticed some problems with tightness of composite materials that had been produced. For small components there is a simple, non-destructive solution to quickly check the tightness. This was written down as a Best Practice in the following form:

Tightness of sandwich parts shall be checked after manufacturing by dipping parts in warm water. Increased porosity of CFRP sandwich parts may cause water ingression in service. Sandwich parts may suffer defects after manufacturing. Before delivery water tightness shall be checked. This test can be done by dipping this parts in warm water; air bubbles will show possible defects. This test can easily be combined with NDT (Non destructive testing) done in final inspection. If water soak is not possible, x-ray is an option to detect water after NDT. The message quickly spread. Soon after publishing the Best Practice in the Engineering Book the method was routinely applied within Manufacturing.

CONCLUSION

Distributed teams present special challenges for Knowledge Management. Organizations need to design processes and technologies in the context of distributed teams. E-engineering and Knowledge Management can prove effective, when they are built into organizational strategy and designed with a view to overcome structural, cultural and boundary barriers. The point of focus should be the common organizational goals, thus overcoming the barriers of culture, time and self.

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LATE PAPERS

MANAGING CE PROCESSES FOR ONE-OF-A-KIND PROJECTS THROUGH WEB BASED APPLICATION

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KEYWORDS

CE processess managing, Virtual Enterprise, One-of-a-kind projects, Concurrent Enterprising

ABSTRACT

European Industry is called to increase its competitiveness by successfully answering to the requirements of the evolving global market and business (Pallot 1998):

- managing multinational customers, suppliers and corporate sites, through multi-company and company-wide integration of design and manufacturing processes;
- establishing profitable consortia to cope with requirements and features of global market.

That is important in particular for the industrial sector of large one-of-a-kind industry projects (e.g. industrial plant engineering), characterised by huge investments and by several problems like complexity of scope (in terms of time and resources employed, and variety of activities needed), distributed organisation (spanning several companies), one-of-a-kind design, geographic distribution of project activities, strict time constraints, contingency risks and revenue-loss risks.
Rarely such projects are carried out within the scope of a single organisation. More often the prime contractor, typically a large company with adequate know-how, references and financial resources to sustain the project, outsources specific components and services to smaller firms through several forms of sub-contracting.
CE approach has demonstrated its capability to improve industrial competitiveness, based on reduction of project cost and duration, and on increase of product quality, enhancing cooperation among departments of a company which are geographically distributed (Cleetus 1992). Therefore the new challenge is to implement CE processes in the one-of-a-kind product deployment realized by actors belonging to distributed, temporary alliance of independent, co-operating companies.
In order to support these companies to achieve this objective integrating the distributing companies in a Virtual Enterprise, the European research project IST 12538 named "Web-linking Heterogeneous Applications for Large-scale Engineering and Services" (WHALES), in which the authors are involved, proposes a very innovative tool.
The research project objective is to buid a web-based application allowing the design of a distributed architecture, that provides an integrated data and process infrastructure for different companies and actors participating in large projects planning and execution, at the same time safeguarding each node's autonomy as regards local operations management and information system.
This work shows an approach to manage through a web-based application the CE processes integrated into a Virtual Enterprise for designing, manufacturing and erectioning of one-of-a-kind products.

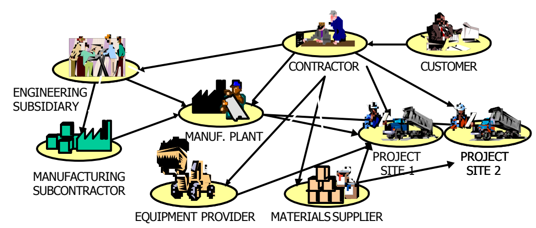

Figure 1: Virtual Enterprise for large scale one-of-a-kind project

THE VIRTUAL ENTERPRISE STRUCTURE

The structure of the virtual enterprise based on web network considered for this work is inspirited to structure proposed in the WHALES project. It is composed of three different levels (Paganelli et al. 2001):

- The Work Network Structure (WNS) is the bottom layer of the infrastructure, crossing horizontally function at companies co-operating on large scale projects. At this level physical nodes are identified corresponding to autonomous organisation units, and links are defined allowing integration of data and co-operation between nodes. The WNS gives visibility on the project network as a portfolio of assets that can be uniquely configured for each project;
- The Work Accountability Structure (WAS) is the intermediate layer of the infrastructure, representing the temporary, multi-site and multi-company organisation created to carry out one or more projects. The WAS groups and links nodes and individuals accessible through the WNS, to create a project-oriented structure specifically designed for the work to be carried out;
- The Work Breakdown Structure (WBS) corresponds to the topmost layer of the infrastructure, and represents a network-wise enhancement of WBS implementations supported by traditional Project Planning tools.

To support the outlined organisation model it is necessary a web-based application which can:

- Allow easy access by local users at network nodes (intranet access) and by remote users operating at decentralised project sites (internet or extranet access);
- Provide uniform access to data and functionalities from heterogeneous applications, both network system components and local management and planning tools at any network node;
- Allow data distribution and decentralised management, providing a unique entry point to information owned and maintained by different nodes in the real-world network structure;
- Allow process-based interaction between the responsible actors at the involved nodes, according to roles, responsibilities and workflow model specified in WAS;
- Notifies relevant events and exceptions to the appropriate actors in the project network, depending on the event type and the action required.

Moreover, the organisation model requires a common data infrastructure provided by the Network Data Model (NDM), a distributed and decentralised database which:

- maintains an updated and consistent representation of the project network from each node point of view, i.e., including all the other nodes visible to and interacting with the current one;
- aggregates and normalises information from nodes' local applications to realise the WNS model, allowing for both detail and synthesis views on physical nodes, their resources and activities status;
- allows consistent manipulation of WNS data into higher level WAS and WBS models, supporting both centralised and decentralised data management schemes;
- provides a common data model to unify the product definition in multiple perspectives.

Alignment between web application and internal node activities will be provided by Local Applications Interfaces. The ability to carry out the transactions mentioned above between remote actors, their engineering tools and the common data base represents a progress toward a truly integrated CE environment. But it is not only the fact that such transactions can be performed, but the ease with which a virtual network organisation can develop the inter-operation between engineering tools and web-based application, and the simplicity with which engineering user can employ them, that is a measure of the integration.

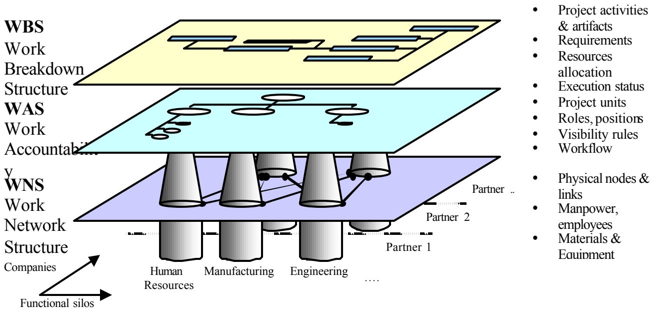

Figure 2: Virtual enterprise structure based on web network

MANAGING CE PROCESSES FOR LARGE ONE-OF-A-KIND INDUSTRY PROJECTS

For large scale one-of-a-kind-projects Concurrent Engineering (CE) is a systematic approach to the integrated, concurrent design of product items and their related processes, including manufacturing and erectioning, in terms of technical specifications, cost and schedule. Concurrent engineering processes involve, during all the project life cycle from conception through disposal, different organisations of the virtual enterprise which are connected by the web network.

For an effective use of CE transactions and then to reach a shared view of the goal for each virtual organization node involved in project engineering as a team, project manager must provide a global coordination among different actors.

First of all he must define their role into project engineering and setup the network. Moreover he must carry out entire suites of coordinated processes among multiple perspectives, from the subdivision of the work to the implementation of needed corrective actions, through negotiation between the involved actors.

Without the benefit of face-to-face meetings and often without previous collaboration experiences a formal description of these processes is needed to assure that there are shared and correctly implemented. Then it is necessary to deploy a network process model which describes the project management processes which involve interactions, workflow or information visibility among different project units. Moreover, because these processes happen through web-based network, their results and related data must be identified and standardised to be enclosed in the Network Data Model.

Project management processes needed to describe and to organise a large one-of-a-kind industry projects can be organised (PMI, 1996) into four main groups:

- Initiating processes (recognising of the project start);
- Planning processes
- Executing and controlling processes
- Closing processes (formalising acceptance of the project and bringing it to an orderly end).

Process groups are linked by the result they produce, and for large-scale project often the links can be iterated.

In addition, project management process groups are not discrete, one-time events. They are overlapping activities which occur at varying levels of intensity throughout the project life.

Following we will show what are the management processeses which allow to follow the CE approach in large scale engineering project and how these processes can be supported to the web application mentioned above.

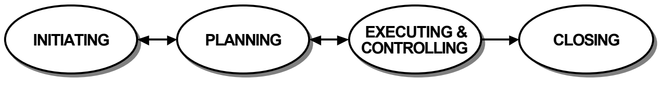

Figure 3: Links among process groups

MANAGEMENT PROCESSES AND CE PROCESSES

Among all planning processes (PMI 1996), we select the following as the most important from the CE approach point of view:

- Organisational Planning – identifying, documenting and assigning project roles, responsibilities and reporting relationships;
- Communications Planning – determining the information and communications needs of the stakeholders;
- Task Planning – subdividing the major project deliverables into smaller, more manageable components and then identifying the specific tasks that must be performed to produce the various project deliverables;
- Cost Estimating – developing an approximation (estimate) of the costs of the resources needed to complete project tasks and allocating the overall cost estimate to individual work items;
- Schedule Development – identifying and analysing task sequences and task durations to create project schedule.

First two planning processes are needed to define the concurrent engineering network. The objective of these processes is to create the structure for implementing virtual team and managing needed information exchange.

Remaining planning processes represent CE process planning because the objective of these processes is the definition of the tasks which are needed for one-of-a-kind product deployment from the design to the erection and then the conjunction definition of project cost and duration.

Among all executing and controlling processes, we select the following as the most important from the CE approach point of view:

- Performance Reporting – collecting and disseminating performance information. This include status reporting, progress measurement and local forecasting;
- Performance Control – analysing local performance information, comparing them with planned performance and individuating corrective action and project change if necessary;
- Overall Change Control – evaluating how a project change can affect planning result (Project Schedule, Cost Baseline, Resource Assignment, Requirement) in order to approve the change and provide the input for a project plan update.

As we will better show after, these executing and controlling processes represent CE processes implementing because the objective of these processes is to support the planned designing, manufacturing and erectioning tasks performed by different actors of the network realising the basic CE process.

Figure 4 shows the relationships among the processes which are included in each group and also the iterative link between planning and implementing processes realised through Overall Change Control process, which can require a modify to previous planning result. All these processes may be subjet to frequent iterations during the project life.

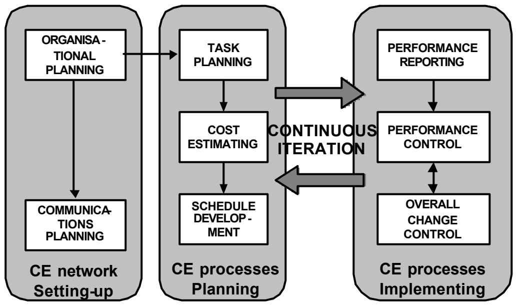

Figure 4: Relationship among project planning processes

CE Network Setting-up

In the Organisational and Communications Planning, analysing project needs (by first draft WBS and product description) and various stakeholders needs Project Manager assigns roles and responsibilities and then identifies reporting relationships.

The results of these processes are the Organisation Structure that configures the network Work Accountability Structure, the Communications Structure that configures the Network Structure and a Communications Management Plan including a project filing structure, documentation standards, production schedules showing when each type of document will be produced, methods for accessing information.

CE processes Planning

The first objective of these processes is to activate the work of the virtual team on the network, assigning specific tasks to perform for each actor.

To subdivide engineering work to be executed by the networked participants is a very critical process because it has influence on the possibility to assure effective workflow inside virtual team.

Prime contractor subdivides the project scope into smaller and more manageable components, which are referred to contract items and milestones.

Some of these items can be directly subcontracted to a company with adequate know-how, references and financial resources to sustain items project.

Rarely prime contractor accomplishes remaining items, rather he defines low detailed technical specifications and then he outsources detailed item description and his design to a designing provider. If item requires one-of-a-kind components, prime contractor could outsource their production to a manufacturing provider.

Moreover, the erectioning phases usually is outsourced to a company which resides near project site.

Sometimes prime contractor branch can deploy one of more of the outlined roles (usually designing) becoming a node of the concurrent engineering network.

Project manager, which usually represents prime contractor, must coordinate and manage concurrent engineering processes which happen on the network through a web-based application. Managing subcontractors' CE local networks is not a task assigned to project manager, he can only verify that defined project milestones are reached on time to assure coordination with the other network nodes.

So the set of CE services offered by the web application must provide the team-working glue for their tools (CAD/CAE/CAM, Design-for-X Tools, but also decision support tools single-perspective-centered like design assessment tools, quality function deployment, ecc.). Mainly they serve to elevate solo designers employing single user tools in a private workspace, to the level of team designers using remotely communicating tools on a network and sharing information in a common data base accessible to the entire team, like figure 5 shows.

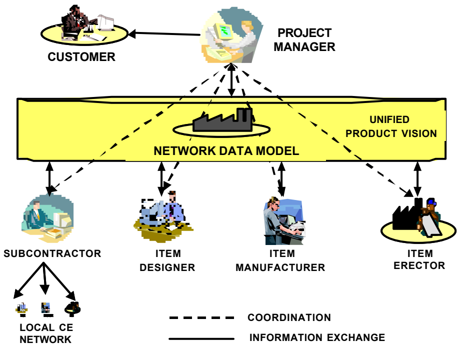

Figure 5: Concurrent Engineering Network

The planning processes are iterated with an increasing level of detail during the planning phases. Generally, first iteration can be useful in order to provide a low detailed Project Plan to the bidding process, while second iteration is necessary after the negotiation in order to complete the planning process. Further iteration can be useful if Project Plan change are necessary.
Here it is showed how we have standardised these processes to implement them in the web application.

Task Planning
In the Task Planning process:

- Project Manager uses product description, project deliverables, quantifiable project objectives, Constraints and Historical Information to subdivide the major project deliverables into smaller, more manageable components until the deliverables are defined in sufficient detail to assign each component to a Project Job Responsible. The result of this activity is a low detailed Work Breakdown Structure (WBS) and an updated Organization Structure for the network Work Accountability Structure;
- Project Job Responsible details the WBS until the deliverables are defined in sufficient detail to support future project activities (scheduling, budgeting, etc.);
- Project Job Responsible identifies which activities are needed to perform the various project deliverables and then describes each activity to ensure that the project team will understand how the work is to be done. The result of this activity is a Task List.
- Project Manager receives WBS Update Data through Network Data Model, which are verified, approved and arranged in a global WBS.
- Project Manager receives, verifies and approves the Task List.

Schedule Development
In the Schedule Development process:

- Project Job Responsible identifies interactivity sequences and estimates the number of work periods likely to be needed to complete each identified activity.
- Project Job Responsible analyses this data, resource requirements, contract constraints, calendars, leads and lags to plan start and expected finish dates for each detail activity and then to create a Job Schedule by local project management tools;
- Project Manager receives Job Schedule Data through the WHALES Data Model, which are verified, approved and then arranged in a Project Schedule.

The result of this process is a Project Schedule created by Local Project Management Tools and recorded in the Network Data Model.

Cost Estimating
In the Cost Estimating process:

- Project Manager uses WBS, Task List, Task duration estimates, Resource Assignment, Project Schedule, Bill of materials and Historical Information to estimate the costs of the resources required to complete each project job which are included in the WBS. The result of this activity is an overall cost estimate;
- Project Job Responsible allocates the overall cost estimate to individual activities (by the Project Schedule is possible to associate costs to the time period when the cost will be incurred). The result of this activity is a local time-phased expenses budget;
- Project Manager receives local time-phased budgets data through Network Data Model, which are verified, approved and arranged in a project Cost Baseline.

The result of this process is a Cost Baseline recorded in the Network Data Model.

CE Processes Implementing

As soon as a first iteration of planning processes has completed the product development process starts. It is based on CE approach, so it differs from the classical sequential process chiefly in the replacement of fewer long find-and-fix cycles, from the beginning of the process, by more frequent but shorter cycles between synchronization points. The product development process progresses in stages. Each stage comprises the activities shown schematically in figure 6. On the left it is shown the basic CE process (Cleetus 1992).
The steps indicated in the clear blocks are product oriented processes, so they depend on the industry sector of the virtual enterprise. For a large scale engineering projects normally these processes are designing, manufacturing and erectioning tasks. They start and end at the same time but their relative importance moving during project life from the design tasks to the erectioning tasks. These processes are performed by network actors by own local tools (CAD/CAE/CAM, Design-for-X Tools, ecc.) without using the CE services.
The steps indicated in the shaded blocks are project management processes, in fact they are used from Project Manager to force the team to render consistency to their decisions from time to time, and thus achieve consensus so that parallel working does not result in a permanent and irreconcilable divergence of viewpoints. Because these processes do not depend on the industry sector of the virtual enterprise, they have been standardised to perform them directly on the network using web application services.

The result of the Performance Reporting process is a Performance report for update the Products, Resources and Jobs Status on Network Data Model or a Change request to notify problems and/or to require project change.
Communications Network Structure allows a rapid propagation of Performance report, Change request and decisions across team members electronically on the base of visibility accorded by Organization Structure.
Project manager and direct stakeholders can remotely analyse Performance Reports and Change requests from different project task and then they can decide if and what corrective action are needed.
If a corrective action is needed the Overall Change Control process starts. Project Manager evaluates how a project change can affect planning result in order to approve the change and to update the project plan. He can quickly constitute or reconstitute a virtual team to implement the corrective action. This team can involve all the needed function independently their geographical collocation, included the Responsible of the job which requires corrective action that can be involved directly from job site.
In order to implement the corrective action virtual team will repeat all the needed planning and executing processes mentioned above.

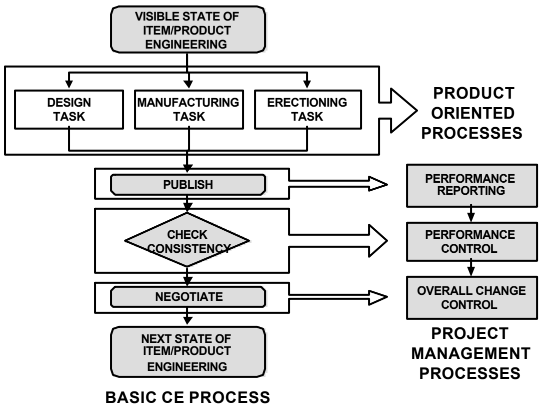

Figure 6: Basic Concurrent Engineering Process

CONCLUSIONS

This paper shows how through a web-based application, implementing visibility, workflows and shared decision making, it is possible to use Concurrent Engineering approach for an effective one-of-a-kind product deployment by network of distributed enterprises which cooperate temporarily to realise a large scale engineering project.
This integration, also called Concurrent Enterprising, allows not only to add concurrent engineering advantages to the enhanced competitiveness guaranteed by consortium of company geographically distributed, moreover it allows a reciprocal enhancement of the advantages of these solutions when they are adopted one at time.
In fact, Concurrent Engineering provides a systematical approach to effectively manage the deployment of a complex one-of-a-kind product by a team very qualified but extremely heterogenous like a virtual enterprise team.
On the other hand a web network managed by an efficient web-based application is an ideal infrastructure to an effective deployment of concurrent engineering approach.
The proposed solution has been deployed in the WHALES research project and actually it is testing from four different kind of enterprises which realise large scale engineering projects (industrial plants engineering, fire-fighting vehicles manufacturing, ships repair and conversion, information technology). Some main potential advantages which are expected are the following:

- Great flexibility (no limitation in location or composition) in constituting and reconstituting the team as the needs of the project change over time;
- Great efficienty thanks to role clarity across disciplines assured by the network accountability structure and to rapid but also controlled propagation of information and decisions across all team members electronically;
- Few changes late in the development cycle through global visibility of the evolving design and rapid and efficient negotiation with the rest of the group;
- Ability to respond quickly to customers' requests for proposals and requests for changes by means of a communication infrastructure that circulates decisions and events between appropriate actors, crossing companies and organisational units;
- Planning and budgeting improvement by means of a coordinate identification of price and deadlines of the project and technical specifications of the product.

Through these potential advantages virtual organizations can obtain cost reduction, time reduction, and quality improvement of products created which are needed to increase its competitiveness and to successfully answer to requirements of the evolving global market and business.

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MODELLING CE PROCESSES FOR ONE OF A KIND PROJECTS THROUGH UML

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KEYWORDS

UML, CE process modelling, Unified Process, Workflow, Virtual Enterprise

ABSTRACT

Process of product development is continuously changing. In these last ten years, there has been an increasing need to design and produce more complex products at lower costs and in less time for the evolving global market.
An effective solution in order to increase competitiveness is to establish profitable consortia to cope with requirements and features of global market (Pallot and Sandoval 1998).
This is specially important for the industrial sector of large one-of-a-kind industry projects, characterised by huge investments and by concurrent but disparate activities.
In order to answer to the always increasing competition, industrial organisation must be able to manage efficiently multinational customers, suppliers and corporate sites, through the multi-company and company-wide integration of design, manufacturing and erectioning processes.
A solution for this problem is the Concurrent Engineering (CE) approach. So the challenge is to implement CE processes in the one-of-a-kind product deployment realized by actors belonging to distributed, temporary alliance of independent, co-operating companies.
In order to support these companies to achieve this objective integrating the distributing companies in a virtual enterprise, the European research project IST 12538 named "Web-linking Heterogeneous Applications for Large-scale Engineering and Services" (WHALES), in which the authors are involved, proposes a very innovative tool. Research project objective is to build a web-based application allowing the design of a distributed architecture, that provides an integrated data and process infrastructure for different companies and actors participating in large projects, at the same time safeguarding each node's autonomy as regards local operations and information system.
To realise a software application of this kind is necessary to identify all its elements and then to model them in precise and unambiguous way, which can be understood from future users that take part in the application design.
Among elements which must be described Concurrent engineering processes assume special importance. They are the ones that most of all involve interactions, workflow or information visibility among different project units allowed on the network through web-based application. So these processes represent focal point for an effective description of the virtual organisation behaviour and then of system requirement.
The paper suggests a methodology to model CE processes in a way that is both precise and user-friendly using Unified Modelling Language (UML), the generally accepted notational standard in the software community.
Moreover, the paper shows how the proposed methodology has been used to model Concurrent Engineering processes for a virtual enterprise supported by web based application.
The purpose of the paper is to show how UML can be used on a general level, which is intuitive for the users of workflow systems, in order to enhance communication between domain experts, workflow specialists, software designers and other professionals with different backgrounds.

INTRODUCTION TO CASE STUDY

The case study focuses on modelling of Concurrent engineering processes which involve, during all the one-of-a-kind project life cycle from conception through disposal, actors belonging to different organisations connected in a network by a web based application.
Generally, prime contractor subdivides the one-of-a-kind project scope into smaller and more manageable components, which are referred to contract items and milestones.
Some of these items can be directly subcontracted to a company with adequate know-how, references and financial resources to sustain items project.
Rarely prime contractor accomplishes remaining items, rather he defines low detailed technical specifications and then he outsources detailed item description and his design to a designing provider. If item requires one-of-a-kind components, prime contractor could outsource their production to a manufacturing provider.
Moreover, the erectioning phases usually is outsourced to a company which resides near project site.
Sometimes prime contractor branch can deploy one of more of the outlined roles (usually designing) becoming a node of the concurrent engineering network.
Project manager, which usually represents prime contractor, must coordinate and manage concurrent engineering

processes which happen on the network through a web-based application.

This application, which is the objective of the WHALES research project is able to allow:

- easy definition of network structure in terms of role and access rules;
- easy access by local and remote users at network nodes;
- data distribution and decentralised management;
- process-based interaction between the responsible actors at the involved nodes;
- notifies relevant events and exceptions to the appropriate actors in the project network.

The web-application is based on a common data infrastructure provided by a Network Data Model (NDM), a distributed and decentralised database which aggregates and normalises information from nodes' local applications, allowing for both detail and synthesis views on physical nodes, their resources and activities status.

Alignment between web application and internal node activities will be provided by a set of Local Applications Interfaces.

So the set of CE services offered by the web application must provide the team-working glue for their tools (CAD/CAE/CAM, Design-for-X Tools, but also decision support tools single-perspective-centered like design assessment tools, quality function deployment, etc.). Mainly they serve to elevate solo designers employing single user tools in a private workspace, to the level of team designers using remotely communicating tools on a network and sharing information in a common data base accessible to the entire team, like figure 1 shows.

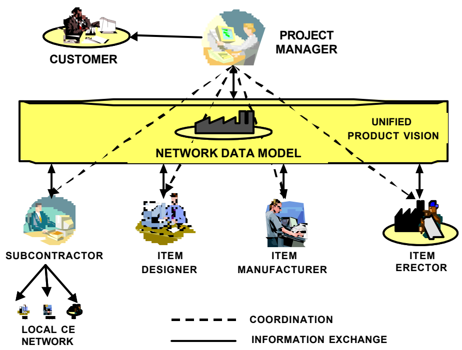

Figure 1: Concurrent Engineering Network

WHY UNIFIED MODELLING LANGUAGE?

The challenge is to model CE processes in a way that is both precise and user-friendly. Each symbol describing a CE process should be intuitive for the user and have defined semantics, so that the developers can use the description as a general, but precise specification of the software system.

In particular to allow the designing of the application which is the object of this paper, CE processes description must be able to define different automation level, from a mainly operative or decision-making deployment by people belonging to different organisation to a totally automatic deployment.

An effective means to solve the outlined problem is the Unified Modelling Language (UML). It is a consistent language for specifying, visualizing, constructing, and documenting the artifacts (model, model elements, or documents) of software systems, as well as for business modelling. A business system comprises several different, but related, models. The models are characterized by being exterior or interior to the business system they represent. UML approach to business modelling establishes that exterior models are use case models and interior models are object models.

A Use Case Model is a model that describes the business processes of a business and their interactions with external parties such as customers and partners.

An Object Model is a model in which the top-level package is an object system. These models describe the things interior to the business system itself. An Object System is the top-level subsystem in an object model. An object system contains organization units, classes (workers, work units, and entities), and relationships.

UML identifies and describes stereotypes that can be used to tailor the use of UML for business modelling. It can be used to model different kinds of systems (software systems, hardware systems, and real-world organizations).

Moreover, UML has another fundamental advantage which make it suitable for representing workflow management systems to be implemented in a software application, it is the generally accepted notational standard in the software community.

Unfortunately the UML notation is perhaps too rich to be intuitive and user-friendly, so we have deployed a methodology to use it on a general level, where implementation details are suppressed.

The suggested methodology is inspired to Unified Process, deployed from Rational in 1998, which is the Software Engineering iterative Process.

This process is the tools chosen in the WHALES research project to realise a software application based on UML design. In fact, this process ensures the production of high-quality software that meets the needs of its end users, within a predictable schedule and budget.

The main features of the Unified Processes are:

- supports object-oriented techniques. Several of the models are object-oriented models, based on the concepts of objects, classes, and associations between them.
- supports component-based software development. Components are nontrivial modules, subsystems that fulfill a clear function, and that can be assembled in a well-defined architecture, either ad hoc, or some component infrastructure such as the Internet, CORBA, COM/DCOM, for which an industry of reusable components is emerging.
- is a configurable process which is founded on a simple and clear process architecture that provides commonality across a family of processes, and yet can be varied to accommodate different situations.

Development activities of the Rational Unified Process are driven by use cases. The notion of use cases, and scenarios drive the process flow from business modelling and requirements through testing, and provides coherent and

traceable threads through both the development and the delivered system.
Starting from Unified Process the methodology described in the paper focuses only on the Business Modelling. The step by step methodology description is followed to result obtained from its application to case study mentioned above.

METHODOLOGY DESCRIPTION

The paper provides general guidelines on how CE processes workflow can be mapped through UML, the details are easy to derive from UML semantic and notation rules (OMG, 1999).
The methodology can be divided into six main steps.
For each of this step here are shown goals and descriptions of how implement them effectively. Moreover, for each step we have shown how the methodology has been applied for the outlined case study focusing on CE processes management.

Step 1: find Business Actors
An Actor is someone (individual, group, organisation, etc.) or something that must interact with the system. He can be a worker involved in the business processes or a stakeholder who uses the System directly.
Each Actor is characterised by a name which denotes his role in the system and a brief description that includes his responsability and why he interacts with the System.
For the large scale engineering project, focusing on CE processes we have found the following main Actors:
- Project Manager: subdivides project work among the team, monitors and coordinates the team to render consistency to their decisions from time to time, and thus achieve consensus so that parallel working does not result in a permanent and irreconcilable divergence of viewpoints;
- Designing Provider: designing task responsible for one or more component;
- Manufacturing Provider: manufacturing task responsible for one or more component;
- Erectioning Provider: erectioning task responsible for one or more component.

Step 2: find Business Use Cases
A Use Case is a pattern of behavior the System exhibits. It is composed by a sequence of related transaction performed by the Actors and the System in a dialogue which produces a valuable result to a particular business Actor.
A Use Case is characterised by a name which should express what happens when an istance of the Use Case is performed and a brief description that includes the result provided to the Actors.
Actors are the real key to find appropriate Use Cases to describe the business system, each relevant observable value provided by the System to Actors should come from a Use Case execution. Moreover, Use Cases should be neither too small nor too big. Remembering that each Use Case should give a result of observable value, that is, both perceived and measurable, help to find a complete flow, and avoid Use Cases that are too small.
However, often it is useful to introduce more than a single level of Use cases decomponing Use Cases of each level in more detailed Use Cases.
In the Case study we have identified three main Use Cases (Cesarotti, Introna, 2002) which has been decomposed in further Use Case of second level. The final structure is the following, between the parenthesis we have written the use case observable result:
- CE network setting-up (network);
  - Organisational planning (organisation structure initialisation);
  - Communications planning (communication structure initialisation);
- CE processes planning (project plan);
  - Task planning (task initialisation and assignment);
  - Cost Estimating (task cost estimating);
  - Schedule Development (task time assignment);
- CE processes implementing (monitoring and updating);
  - Performance Reporting (performance report);
  - Performance Control (corrective action identification);
  - Overall Change Control (replanning process activation).

Step 3: show relationship among Actors and Use Cases
UML provides Use Case diagrams to visualise the relationships among Actors and Use cases, and among Use Cases. The use case diagram presents an outside view of the system, it may contain any of the following:
- A business actor and all the business use cases with which he interacts.
- Business use cases that interact with the same business actors.
- Business use cases that are usually performed in a sequence.

There are no strict rules about what to illustrate in use-case diagrams. Relationship has showed with arrows which may be labelled to show the type of interactions represented. All the relationships which are considered important must be showed in the model. It is recommended to include each Actor, Use case and Relationship in at least one of the diagrams. If it makes the use-case model clearer, they can be part of several diagrams and you can show them several times in the same diagram.
To fully understand the role of a Actor, you must know in which processes the actor is involved. This is showed with the Communicates relationship.
Every Use Case should have a Communicates relationship to or from a business Actor.
If there is a substantial part of the behavior that is conditional or optional it is better to describe it a separate Use Case connected to the main Use Case by an Extends relationship like UML establishes.
If there is a substantial part of the behavior that is common to one or more Use Cases it is better to describe it a separate Use Case connected to all the related Use Cases by an Uses relationship like UML establishes.
The Use Case Diagram cannot easily represent the order of Use Cases instances. When it is needed to clear the sequence in which the Use Cases are employed it is possible to use a textual description.

In the case study, first of all we have described the most important business Use Cases which is shown in figure 2. This diagram can function as a summary of the complete business Use-Case model for CE processes. It shows that all the Actors mentioned above are involved in all the Use Cases of first level playing different roles. Morevover, it shows a sequence between Setting-Up CE Network and CE Processes Planning Use Cases. Instead, between CE Process Planning e CE Process Implementing may be one or more iterations when the Overall Change Control Use Case produces a corrective action which requires CE Process replanning.

Then we have described all the Use Cases of first level which compare in the general Use Case Diagram. I.e. figure 3 shows the Use Case diagram for CE Processes Implementing Use Case.

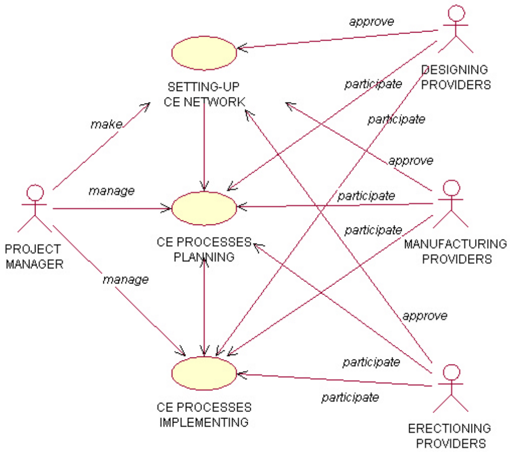

Figure 2: General Use Case Diagram

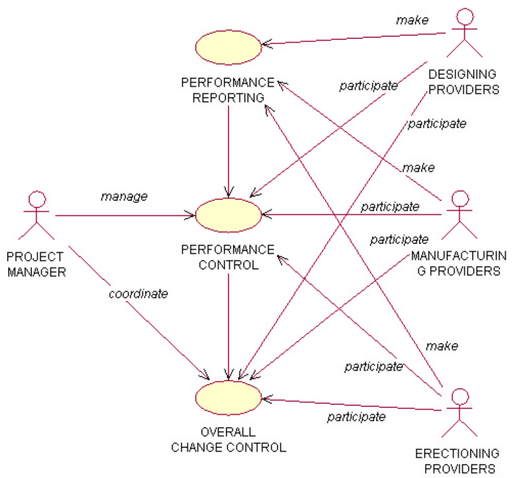

Figure 3: CE Process Implementing Use Case Diagram

Step 4: find Business Entity

Business entities represent object handled or used by the business workers as they execute a business Use Case. A business entity often represents something of value to several Use Cases or Use-Case instances, so the business entity object is rather long-lived. In general, it is good if the business entity holds no information about how and by whom it is used.

Typically, a business entity represents a document or an essential part of a product.

UML allows to describe Business Entity in term of its attributes and its operations.

An attribute of a class represents a piece of information about an object of the class that is kept with the object.

An operation defines the tool with which a business entity is manipulated.

We use to model as business entities only those phenomena that other classes (Actors in our example) in the business model must refer to. Other "things" may be modeled as attributes of the relevant classes, or just described textually in these classes

In the Case Studied one of the most important objects identified for CE processes modelling is the Task. It comes from project decomposition and it is assigned from the Project Manager to a responsible belonging to contractor or subcontractor. A Task is characterised from many attributes (i.e. planned start and end date, estimating cost, final start and end date, etc.) which are defined and updated by a set of operations (initialise, plan, start, etc.).

Step 5: show interactions between Business Entities and Actors

A Sequence Diagram describes what the partecipating business workers do, and how the Business Entities are manipulated, in terms of activations, and how they communicate sending messages one another.

An object is shown as a vertical dashed line called the "lifeline". The lifeline represents the existence of the object at a particular time. Normally an actor instance is represented by the first (left-most) lifeline in the sequence diagram, as the invoker of the interaction.

A message is a communication between objects that conveys information with the expectation that activity will ensue. It is shown as a horizontal solid arrow from the lifeline of one object to the lifeline of another object. In the case of a message from an object to itself, the arrow may start and finish on the same lifeline. The arrow is labeled with the name of the message. The arrow may also be labeled with a sequence number to show the sequence of the message in the overall interaction.

We use one or more Sequence Diagrams for each Use Case of second level. A typical organisation is to have one Sequence Diagram for the main flow of events and one Sequence Diagram for each independent sub-flow of the use-case.

Figure 4 e 5 show Sequence Diagrams for Performance Reporting and Performance Control Use Cases. The first shows how the Actors perform their engineering tasks at the same time but locally. The CE basic process (Cleetus 1992) is implemented by high frequency performance reporting which activates negotiation between Actors from different point of view concluded with a decision of the Project Manager as the Sequence Diagram in Figure 5 shows. This sequence is iterated step by step until all the concurrent tasks are completed.

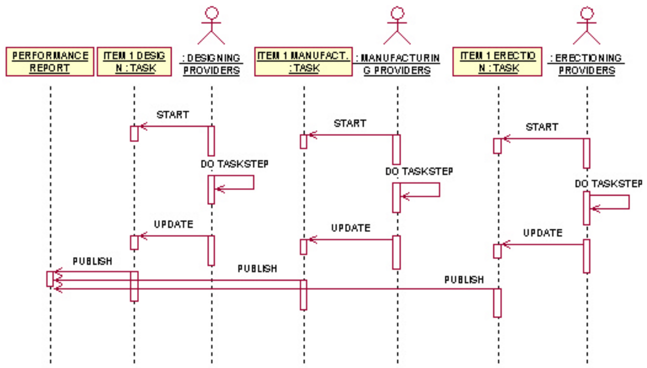

Figure 4: Performance Reporting Sequence Diagram

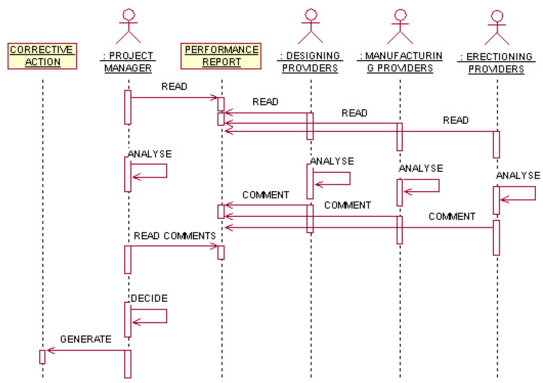

Figure 5: Performance Control Sequence Diagram

Step 6: show Business Entity states during its life

A state diagram shows the sequences of states than an object goes through during its life in response to events, togheter with its responses and actions.

The states are represented by rectangles with rounded corners and the transitions are represented by arrows connecting the state symbols.

Figure 6 shows State Diagram for Task Object. A Task is initialised decomposing one-of-a-kind object, then it is planned negotiating start date, end date and cost between Project Manager and Task Responsible. Subsequently it is started and it is performed step by step, as it is shown in figure 4, until it is completed. While it is in progress it may be suspended if an unforeseen event occurs and then it may be restarted with or without a replanning phase. Moreover, a task may be cancelled by the Project Manager for a project replanning.

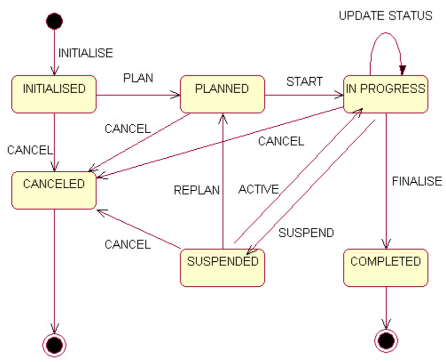

Figure 6: Task State Diagram

CONCLUSIONS

The paper proposes a methodology to use UML as a powerful tool to depict CE processes in a business system. This work in particular shows how depict CE processes implemented by a planning and management infrastructure for complex distributed organisations working as network on large scale engineering projects.

Through Use Case Diagram CE processes implemented by virtual organization are described both from an external viewpoint that focuses on what value is delivered to the Contractor, and from an internal viewpoint that focuses on roles, deliverables, and their relations in the business.

Moreover, Sequence diagrams depict the details of the interaction among subcontractors which are involved in the project, and how the objects of the web application are accessed, during the performance of a Use Case.

Finally State diagrams allow to explain the evolution of these objects during the project lifecycle.

Using the outlined methodology for the WHALES research project, the Consortium has described CE processes required to the web application in a way that is very similar to those that domain experts are already using intuitively.

This has allowed to enhance communication between domain experts, workflow specialists, software designers and other professionals with different backgrounds.

Moreover, UML symbols also have defined semantics, which means that has been possible to use the visual workflow description as a software specification. The same diagrams adorned with implementation details has been used for software design purposes.

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