SCIENTIFIC PROGRAMME

ORGANIZATION AND MANAGEMENT

RELEASE-MANAGEMENT – THE EMERGING SUCCESS FACTOR FOR PRODUCT INNOVATIVENESS

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ABSTRACT

It bears a fundamental meaning for any company to be in the market place with competitive products. However, current trends increasingly accelerate the deterioration of mechatronic products especially when compared to more recent rival products. The actual pace of innovation in the field of mechatronics has to be understood as a mix of diverging innovation cycles. Considering the increasing number of models and derivative products to penetrate market niches, this challenge becomes even more complex. While companies understand the need to cope with today's dynamics of change and to reduce complexity-related R&D efforts while utilizing the potentials of electronics and embedded-software, a process to achieve this is not always clear.

Release-Management is a principle from software engineering which can be transferred to complex mechatronics systems. Within this paper, the focus will be on automotive engineering. This paper describes the innovative approach of Release-Management as a methodology to increase R&D effectiveness and to manage rising system-complexity. Decreased interdependencies within a product line, the impact of Release-Management on innovation frequency and the well-directed control of a product's perceived level of innovation are described as the main benefits. Subsequently, a step-by-step method of how to build Release-Units is introduced.

INTRODUCTION

The trend in today's dynamic markets is marked by increasing customer orientation and rising product variety. Thus, the balancing act between differentiation due to customized product offerings being launched at ever shorter intervals and concurrent amortization of R&D efforts becomes one of the main challenges. The obvious consequence is that the proactive management of product innovation and variety generation during the product life cycle and of associated R&D efforts is a key factor to success.

Within present R&D appendages, carefully detailed product development processes exist; but the critical decision of when and how many variants will be generated is not defined.

A Release-Management concept will incorporate the potential to establish new design potentials within R&D. The idea of a proactive, release-driven change management originates from the software industry and can be adopted for components and modules within mechatronics by R&D departments.

INNOVATION DYNAMICS WITHIN AUTOMOTIVE ENGINEERING

Innovation in today's automotive industry is characterized by progressively emerging trends that will increasingly gain significance and need to be considered within the product development process. A frequently cited statement quantifies 90% of automotive innovation today to result from electronics (for instance Roland Berger 2000 and Weinmann 2002).

Two significant trends that influence automotive innovation to an increasing degree shall be described at this point. Firstly, the product life and innovation cycle of the various types of components within an automobile diverge increasingly. The product life of the auto equals typically six- to eight-year cycles. This life cycle is not subject to radical changes at this point since the economic model of the entire industry depends on this pattern. However, the cycle of innovation in electronics and embedded software engineering is characterized by a very different framework. Product generations typically do not last longer than one to two years with the product performance often doubling from generation to generation. Improvements and updates may take place monthly and sometimes even weekly. The process of aging products and declining prices will increase rapidly. The result is a drastic acceleration in obsolescence of cars and components. Dated products will not be on a competitive basis anymore; this will supposedly influence the auto's sales volume and its price realization.

A contemporaneous trend is the increased generation of derivative products. The diversification of the model range offered in the market place is carried forward by the ongoing tendency to fill niches by launching products targeting these particular customers. Thus, an increasing share of platform vehicles will be launched. At the same time, the total number of platforms will decrease through the ongoing concentration of OEM's and suppliers. The effect of this interrelation will inevitably be an exploding number of model-related projects.

Resulting from these observations are two necessities. It will be essential to coordinate innovations across individual projects without allowing R&D efforts to explode. Also, the development and innovation cycles need to reflect the particularities of electronics and embedded software engineering. Innovation cycles of various components will differ increasingly. It will, therefore, become a necessity to harmonise these diverging patterns already during early stages of the product development process, if the full innovation potential of individual components is to be exploited.

THE ORIGIN OF RELEASE-MANAGEMENT AND ITS TRANSFER TO MECHATRONICS

Engineering in Releases is a principle from software development which supposedly can be transferred to complex machine tools or automotive products. There are two major reasons why software developers coordinate software development in Releases. They differ in their temporal domain – proactive complexity reduction over the life-cycle as well as R&D efficiency enhancement within scores of developing stages. In personal computer business, software always has to be adapted to new hardware specifications or devices. Without Release-Management, either the software would always be obsolete or none of the sophisticated hardware components could be installed.

Product releases are also built so that they are approved for various platforms and markets (Cusumano and Selby 1995). Thus, one release represents a harmonised bundle of enhancements to a product's functionality. The cycles in which releases take place are planned ahead; i.e. during the Windows 2000 development, Microsoft enforced a strict schedule for submitting revisions. Here, a release typically equals up to 250 changes (Freeman 1999).

Release-Management benefits could also be achieved within automotive mechatronics development. As the complexity, quantity and diversity of applications within electronics and embedded software engineering increases, companies experience difficulties in achieving sufficient product quality and timely delivery (Graaf et al. 2003). In order to achieve this, they will need to apply methods that are appropriate for this specific situation. The general Release Engineering approach is based on three hypotheses.

1st hypothesis: Adjust variety and control changes in a sustainable manner. An unnecessarily high level of product variety occupies a large share of management capacities and cannot be corrected by a one-time optimisation.

2nd hypothesis: R&D variant-drafts involve too much development performance. Release-Management favours sustainable, product-specific differentiation due to a proactive variant planning approach.

3rd hypothesis: New ways in product architecture and module configuration – Release-Management not only supports the idea of modularization but also offers the chance to establish new directions of innovation impact.

BENEFITS OF RELEASE-MANAGEMENT WITHIN AUTOMOTIVE INNOVATION

Applying the approach of Release-Management to automotive innovation enables various fields of benefit. They can basically be separated into effects regarding the effectiveness of the R&D process and effects regarding the exploitation of market potentials.

The R&D process becomes more effective especially when considering the application of the methodology across various products resp. derivatives. Ahead of the product life, Release-Management involves increased R&D related activities in order to build Release-Units and to plan innovation cycles ahead. However, economisation effects already take place before SOP through the bundling of changes and the resulting reduction of reactionary changes. However, the methodology of Release-Management shall lead to reduced R&D efforts seen over the entire life cycle of a product and its derivatives. Figure 1 visualizes the effect qualitatively. The dashed line illustrates the cumulative design effort under a common product management, whereas the continuous line visualizes the graph for Release-Management. As market requirements and technical specifications change over time, the cumulative design effort for the product and its derivatives increases. Major updates, usually being introduced as facelifts, cause a significant step increase. As opposed to this, Release-Management causes much more frequent but merely incremental steps. The fineness of Release-Management is the foresighted view over the whole product family and derivatives.

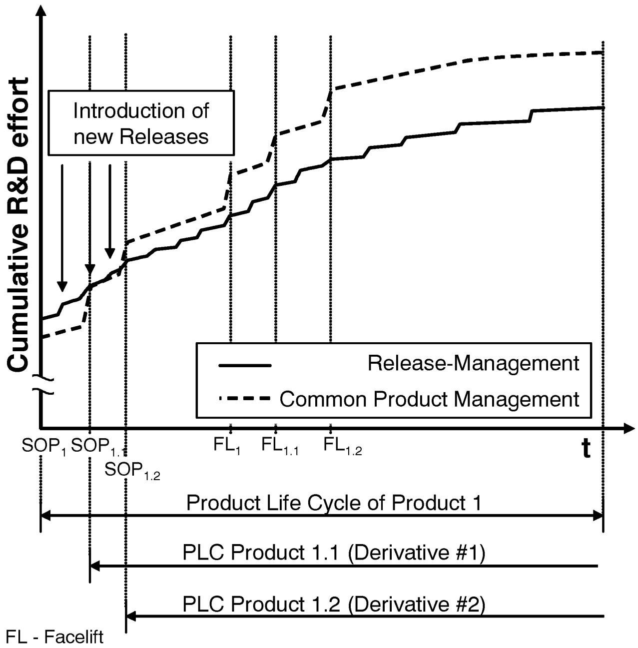

Figure 1: Schematic Illustration of the cumulative R&D-effort over product life cycle

In comparison to the common procedure, the small discontinuities indicate reduced effort e.g. when derivatives are established in the market or when facelifts take place. Also, design modifications that are carried out require less R&D related effort which is indicated by the lower steepness of the curve. How these curves actually look is certainly also subject to the number of common parts, interactions between components, physical integration, modularization etc. This illustration can,

therefore, only render the basic impact of Release-Management on the cumulative R&D effort.
Release-Management also features a decoupling of Release-Units according to their respective innovation rate. Automotive Engineering still is mostly hardware driven, meaning from a mechanical viewpoint. Release-Management also involves requirements management, i.e. it offers a way to manage the different requirements from the different sources throughout automotive development, e.g. engine, body, electronics etc. This also applies to the innovation rate or clockspeed which is very different for the individual product components in the area of mechatronics. Automobile clockspeed for instance can roughly be seen as a mix of engine, body, electronics and software clockspeed with automotive companies usually still operating at engine or body clockspeed (Fine 1998).
As a market-wise effect, features can be managed according to their contribution to the perceived innovation level of a product. Naturally, the perceived level of innovation decreases as the product ages (cf. dashed line in figure 2). A major facelift may cause a temporary amplitude in the course of this graph, but controlling this pattern beyond this effect so far still is a major challenge to product managers.

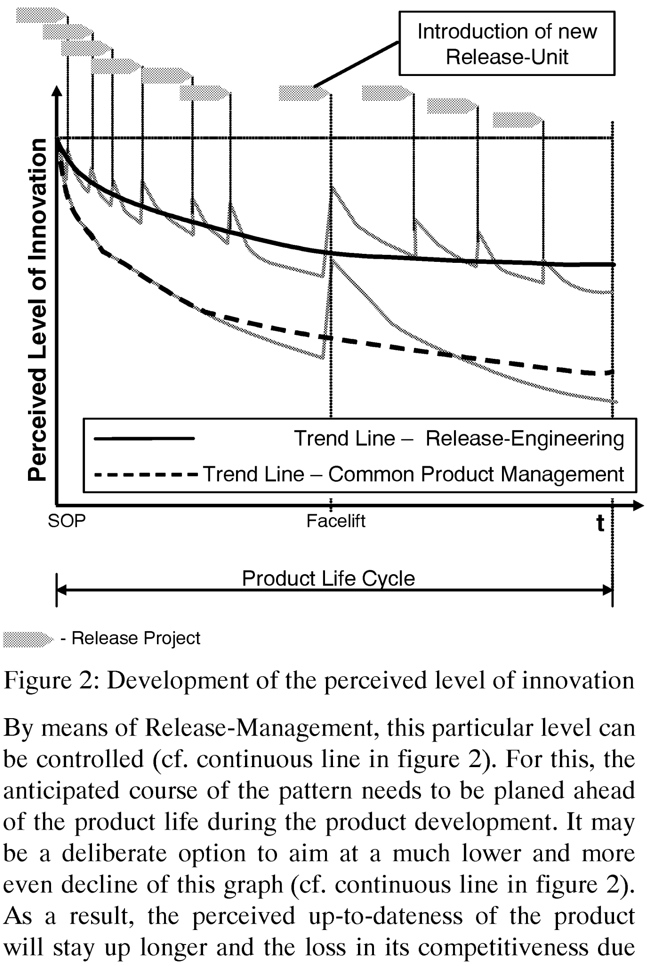

Figure 2: Development of the perceived level of innovation

By means of Release-Management, this particular level can be controlled (cf. continuous line in figure 2). For this, the anticipated course of the pattern needs to be planed ahead of the product life during the product development. It may be a deliberate option to aim at a much lower and more even decline of this graph (cf. continuous line in figure 2). As a result, the perceived up-to-dateness of the product will stay up longer and the loss in its competitiveness due to obsolescence can be delayed to a large degree. Obviously, a precise awareness of the impact of any innovation or of a bundle of innovations in the market needs to be generated for this purpose. Since a synergetic connection of product- and process-leadership aiming at a reinforcement of innovation will be increasingly decisive for succeeding in future competition (Karsten and Wolters 1999), Release-Management has the potential to become a meaningful success determinant in innovation management.

BUILDING RELEASE-UNITS

Shaping Release-Units to fulfil the potentials described above is a complex task that has to be initiated already during early stages of the product development process. It needs to be conducted in conformity with other processes of product structuring such as modularization or integration. The actual process of building Release-Units consists of five basic steps (cf. figure 3) and may be iterative depending on the degree of concretion of the product concept. First of all, the product has to be structured, the degree of decomposition being subject to the own position regarding the respective component (supplier/ OEM etc.). The aim of this step is the identification of all components available for the Release-Units. As a result, all parts that are supposed to be involved in Release-Units are identified. The next step is a key activity within Release-Management. The identified components need to be clustered according to their ideal innovation rate which will ensure Release-Units are consistent as to their development frequency.

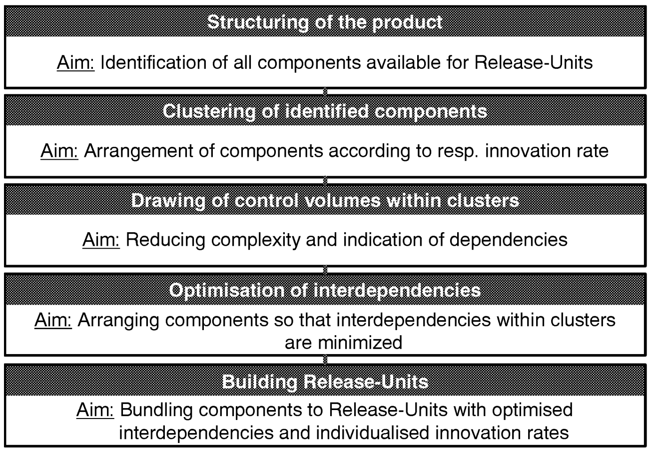

Figure 3: Steps of building Release-Units

However, a sound ration between innovation rate, redesign or change effort and aspired market effectiveness needs to be ensured at all times. Otherwise, one would run danger of counterproductively relocating R&D efforts as far as the market impact is concerned. In other words, it needs to be ensured that a Release-Unit will have amortised before its change. The conformance to this ratio can be understood in analogy to the field in figure 4.

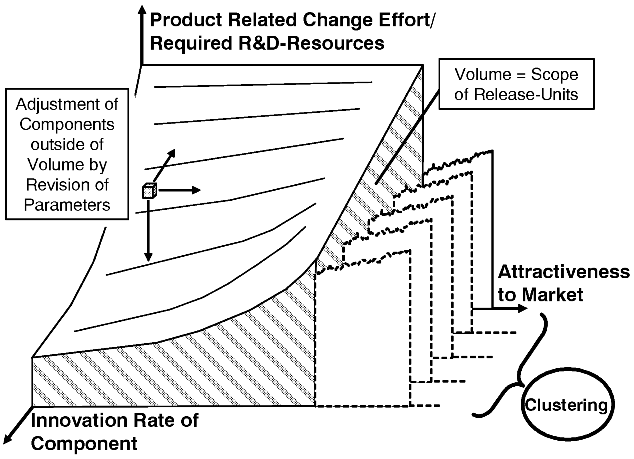

Figure 4: Clustering of product components

As described in figure 4, components that are found to be located outside of the volume require a revision of their parameters. Basically two possibilities for repositioning these components can be identified. One way is to bundle this individual component to another, functionally related component so that one or more of the three parameters in question are changed. After this step, the component bundle should be located within the volume. An alternative is to adjust the innovation rate associated with the component. This is an option if the suggested change will not cause a significant decrease in competitiveness compared to the original innovation rate. The related change effort is subject to the estimated innovation rate and can be understood as a percentage of the original design cost. Interdependencies to other parts when changing the considered component are not to be regarded at this point. A suggestion to estimate the attractiveness of a component in the market is a location within a portfolio illustrating the contribution to customer value and the sustainability of competitive leadership (cf. e.g. Karsten and Wolters 1999 or Deschamps et al. 1996). The result of this step will be a clustering of components according to their innovation rate.

Subsequently to this, control volumes are to be drawn around the components within the clusters. Control volumes are boundaries around a system reducing complexity and indicating flows into and out of that system. The control volumes enable the determination of inbound and outbound interdependencies. The composition of control volumes bases on components located within innovation rate clusters and needs to happen in a way that considers low interdependencies and similarity in-between the components of one control volume. As far as possible, the control volumes should be approximately at the same level of complexity (i.e. a single relay vs. a steering column module would represent very uneven levels of complexity). As a result, the innovation rate clusters now consist of several control volumes.

The next step is the categorisation of interdependencies between the control volumes (figure 5). This categorisation differentiates the sensitivity of an interdependency, which is measured by the figures 1 to 9. Also, two kinds (inbound versus outbound) and four classifications of interdependencies are differentiated (the four classifications are structured in dependence on Pimmler and Eppinger 1994).

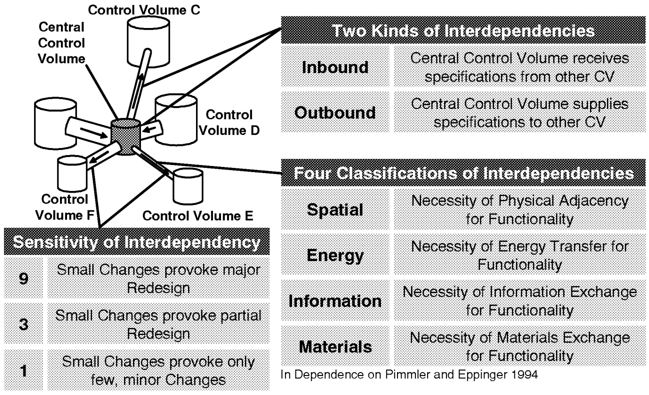

Figure 5: Categorisation of interdependencies between control volumes

In order to build Release-Units out of the control volumes with optimised interdependencies between them, a structured analysis of the interdependencies is inevitable. The matrix renders the mentioned categorisations of interdependencies. An important aspect of its composition is the grouping of the particular control volumes according to their innovation rates (cf. figure 6, muster along rows and columns). An examination of this matrix needs to consider fields with high interdependencies. If these occur within one cluster (highlighted field C/B in fig. 6), the control volumes are suggested to be consolidated within one Release-Unit.

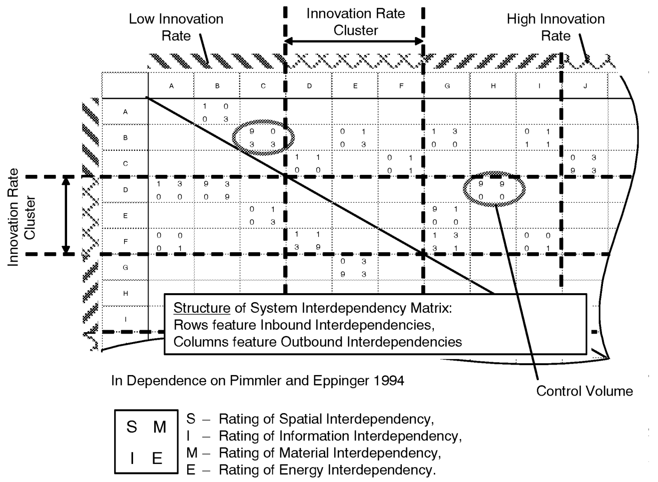

Figure 6: System Interdependency Optimisation Matrix (cut-out)

If significant interdependencies occur across clusters (highlighted field H/D in fig. 6), four approaches can be applied in a possibly iterative process. Firstly, a change of the innovation rate cluster for one of the control volumes can be considered. This solution can only be applied if this change does not lead to a relevant decrease in competitiveness of the components. The two control volumes need to be located within the same cluster after completion of this step. A second approach would be to adapt the specifications of the components involved. This can be done by rearranging the affiliation between functions and components. Another possibility is the reduction of the sensitivity of the interdependencies involved by redesigning interfaces within the components.

Yet another approach to reduce the interdependencies between control volumes across the clusters is to increase the headroom of the components. This implies designing the components so that they can absorb a larger change before requiring redesign. This can also be referred to as overdesign (see also Martin 1999). The result of this iterative process is an arrangement of control volumes that provides optimised interdependencies across innovation rate clusters.
After the Release-Units are defined, the innovation rates have to be defined. Ideally, all frequencies ought to be multiples or fractions of each other (cf. figure 7). This allows the definition of predefined freezing points.

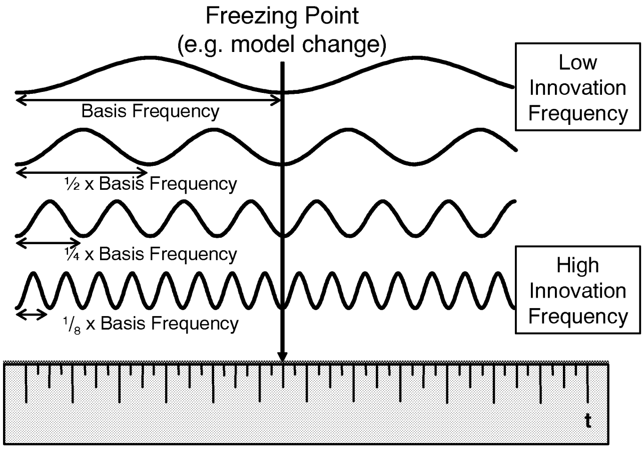

Figure 7: Freezing point implications

The definition of stringent freezing points implies the opportunity for a simultaneous change of all Release-Units within a product family.

CONCLUSION AND RESEARCH EXTENSIONS

Release-Management reduces R&D complexity and increases the competitiveness of products by adopting this development principle from software engineering and introducing it to the field of mechatronics engineering. R&D efforts can be reduced when considering the entire product life cycle and innovation rates will be adjusted on a component level. Another effect of Release-Management is the well-directed control of a product's perceived innovation level in the market place. Subsequently the process of how to build Release-Units was particularised.
The process of building Release-Units needs to be integrated with other processes of structuring a product such as modularization. Only if these approaches will intertwine to the highest degree possible, the full potential of Release-Management can be realized. From a long term perspective, Release-Management also supports the idea of marketing products only in bundles as an enabler to reduce R&D and manufacturing-related complexity as well as to better exploit profit potentials (Fuerderer et al. 1999). These factors will dominate the future work since they allow expanding the benefits of Release-Management.

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LIFE-CYCLE COSTING
IN MOLD AND DIE INDUSTRY

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ABSTRACT

As a single piece producer of high-complex products, the mold and die industry faces an increasing price-war on global markets. Rapid and accurate calculations combined with a calculation of profitability of the mold resp. die life-cycle are significant requirements for success. Within the EU-funded project IMPC (Integrated Mold and Product Calculation for injection molded parts) an integrated approach has been developed to handle these aspects. The developed activity based life-cycle costing for molds and dies permits exact and fast cost calculation and is based on a few cost drivers. The complete process chain comprising all direct and indirect sectors of the mold and die maker as well as the part producer is taken into account. A life-cycle-optimized mold resp. die concept can be identified by a knowledge based variation of specific cost drivers.

INTRODUCTION

In the recent years especially the emerging countries in Eastern Europe and Far East try to enter the mold and die industry market following the strategy "leadership in terms of costs", by making use of their low wage level. Therefore a strategy which is only focused on the sales price is no longer suitable for companies in high wage countries like Germany. In fact it is essential to differentiate from the competitors by manufacturing high-quality molds and dies, i.e. molds and dies optimally fulfilling the demands of the mold and die user such as quality, productivity, reliability and flexibility. Yet the challenge to realize "leadership in terms of quality" combined with "leadership in terms of total life-cycle costs" requires more. On the one hand companies must be highly transparent with respect to costs arising in their company in order to minimize the uncertainties in cost calculation. On the other hand they have to be able to demonstrate their leadership in terms of quality already in the offer phase. In order to emphasize the benefits of a high-quality mold resp. die the calculation of the initial costs is not sufficient; the estimation of the costs and the benefit along the complete life-cycle of the mold resp. die must be taken into account. This means a quantification of the mold quality in terms of life-cycle costs.

WZL and partners from research institutes and industry initiated the project IMPC which was funded by the European Union. The main targets of this project were the development of a method to support quotation costing and the implementation of this method into a software prototype. The method had to fulfill three central objectives: higher accuracy of the quotation costing, reduced efforts for the preparation of the quotation costing and support in optimizing the mold resp. die design with regard to effects on life-cycle costs, thus quantifying quality.

METHODOLOGY OF ACTIVITY-BASED LIFE-CYCLE COSTING FOR MOLDS AND DIES

The developed methodology is based on the theory of resource-oriented activity based costing (Figure 1) and takes all costs influenced by the quality of the mold into account.

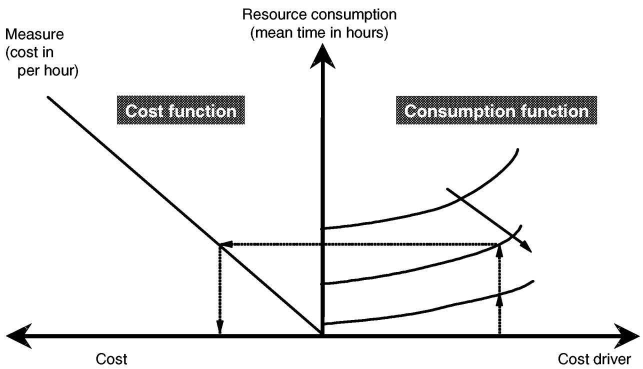

Figure 1: Resource-oriented activity based costing

As a further development of the resource-oriented activity based costing application "differentiated cost estimation" (Eversheim et. al. 1994) it widens the perspective from a production-centered to a life-cycle spanning perspective. It is focused on the most important life-cycle phases: development and production of the mold resp. die, production of the molded part and maintenance of the mold resp. die. By identifying interdependencies between the distinct elements of the life-cycle costs, especially between costs for the production of the mold and costs in the production of the molded part, the mold and die making company is able to demonstrate the advantages of its high-quality molds and dies to the potential customer thus objectifying the assessment of quality.

The configuration of the activity based life-cycle costing method is divided into three steps (Figure 2): the definition of a process model of the order processing, the identification of cost influencing factors and the quantification of the cost influence of these factors. The quantification entails the generation of cost resp. consumption functions for each process step (a) as well as the modeling of interdependencies of the costs in different phases of the life-cycle (b), thus enabling life-cycle oriented optimization.

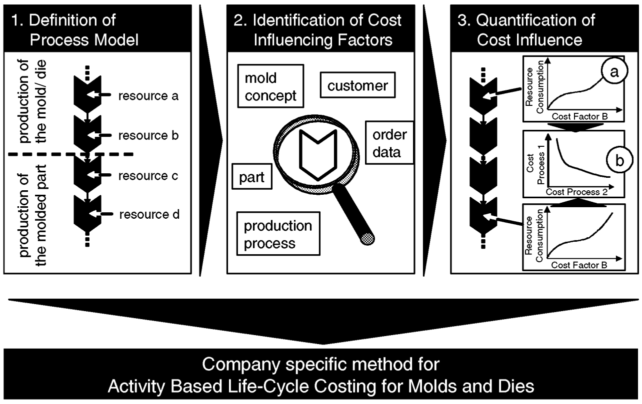

Figure 2: Steps for configuring the activity-based life cycle costing method

For the definition of the process model certain boundary conditions have to be taken into account: the process model has to include all activities in the life-cycle of a mold resp. die, which begins with the order processing by the mold and die making company, is succeeded by the production of parts and finalized with the end of the productive use of the mold resp. die. It has to contain all planning (e.g. development) and executing (e.g. milling) activities. The level of detail of the process model is determined by the resource-orientation. As soon as the resource for processing the order changes a new process step has to be defined.

After defining the process model, the cost influencing factors have to be identified. In the case of the differentiated cost estimation method, the influencing factors are limited to characteristics of the product to be calculated (here: the mold resp. die) (Eversheim et. al. 1994). In the activity-based life cycle method furthermore data are taken into consideration (Figure 3). The broad structure of input data is due to the necessity of incorporating all relevant data to maximize the accuracy of the calculation. In addition few characteristics of the mold itself are available at the time the quotation costing is prepared.

The input data are subdivided into order specific and general data. Order specific data are e.g. data relating to the mold making process (e.g. level of automation), the part to be produced with the mold (e.g. number of holes), the mold itself (e.g. number of slides) and the injection molding process (e.g. lot size in production). General data as e.g. data relating to the customer (e.g. general quality demands of the customer) can be stored into databases. This ensures quick and easy availability of these data.

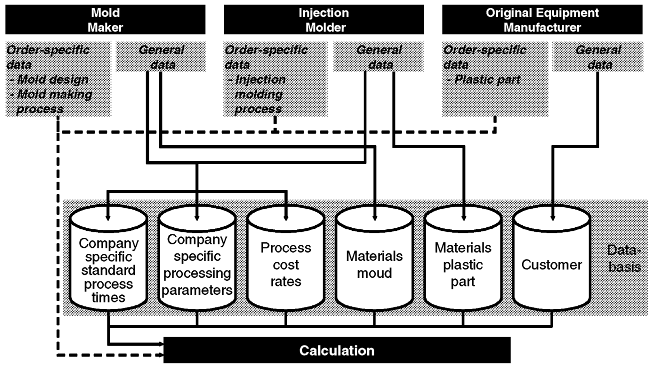

Figure 3: Structure of the input data for activity based life-cycle-costing

The last step in the configuration of the method is the quantification of the influence of the identified factors on costs. In order to define consumption functions for each process step the identified influencing factors have to be combined to mathematical functions. To ensure accuracy all basic types of mathematical functions must be taken into consideration (Figure 4).

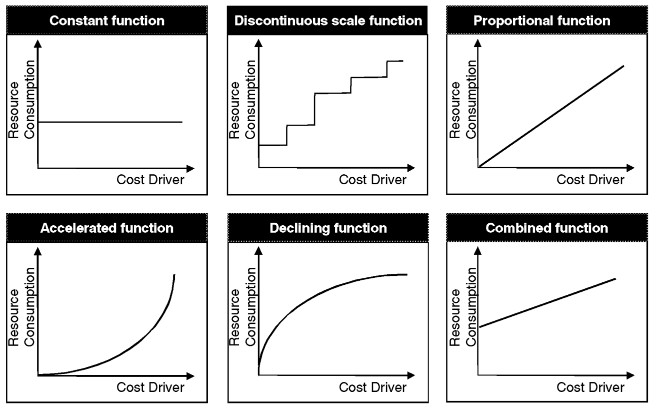

Figure 4: Basic functions used for the representing the consumption functions

The determination of the consumption functions can take place either analytically or based on interviews. In order to define cost functions for each process step an hourly rate based on full costing must be determined. A fair representation of all costs according to the input involved is important. To ensure the up-to-dateness and thus the accuracy of the calculation, the consumption and cost functions must be revised at regular intervals taking company-specific changes as well as new and widened experiences into account.

As a prerequisite for modeling the interdependencies of the costs in the different phases of the life-cycle of a mold resp. die and in order to realize an optimization of the life-cycle costs it is necessary to identify factors with influence on the life-cycle phases ´development and production of the mold` and ´productive use of the mold including maintenance`. Especially those factors which influence costs in a contrary manner during these life-cycle phases and which can be influenced by the mold and die making company are relevant for a life-cycle oriented optimization of the mold resp. die.

The quality of the mold, determined by the surface treatment and the quality of the raw material, exemplifies an influencing factor fulfilling these demands ("life-cycle spanning influence factor"). On the one hand an improvement with respect to quality requires efforts in the production of the mold, e.g. the use of special coatings. On the other hand an improved mold quality contributes to a decrease of costs during the productive use of the mold, e.g. by extending the maintenance intervals (Figure 6).

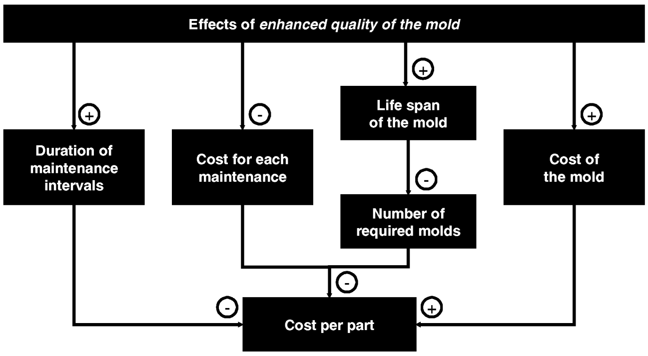

Figure 6: Effects of enhanced quality of the mold

As can be seen in the example variations of the life-cycle spanning influencing factors have both direct and indirect influence on costs. E.g. an improvement of the quality of the mold by applying a special coating has for one direct influence on the cost due to the extra costs for coating, and for another indirect influence with regard to the extension of the maintenance intervals. In order to simulate the effects of a variation of a life-cycle spanning influencing factor it is therefore important to identify and quantify all direct and indirect influences on costs.

To determine an optimal life-cycle oriented mold design, the variations of the single life-cycle spanning influencing factors have to be combined for scenario calculation. This method permits the cost estimation of different mold concept alternatives leading to variations of the life-cycle costs of the mold. This allows the mold making company and its potential customer to comprehensively survey the whole life-cycle, enhancing the analysis of effects and supporting the development of the optimal mold for specific production requirements.

Within the IMPC project the above approach was applied for the configuration of the activity based life cycle costing method for three mold and die making companies. Although the characteristics of these companies varied to a great extend, the configuration of the method lead basically to the same result. This indicates that this configuration is a generic configuration which can easily be adopted to the particular characteristics of any company in the mold and die industry. This generic model consists of 59 process steps and about 200 cost influencing factors. Due to the separation in order specific an general data as well as the mapping of interdependencies between the cost influencing factors the amount of input variables for the preparation of a specific quotation costing was reduced to less than 50.

Once the basic configuration is accomplished the application of the method allows efficient preparation of specific quotation costings. For each new quote the order specific data has to be quantified and fed into the method. Subsequently, the influencing factors with life-cycle spanning influence have to be varied and, using the scenario calculation functionality, the life-cycle optimized tool has to be configured.

SOFTWARE PROTOTYPE

The IMPC calculation method was implemented in a software prototype. The two main goals of the prototype were to prove the feasibility of such a software tool in practice and to validate the calculation procedures in practice.

The implementation of the method was realized on the platform of the database tool Microsoft FoxPro. Due to the fact that the method is based on a complex database-structure (compare Figure 3) this platforms enables fast and easy programming as well as high flexibility for supplementary add-ons or improvements and high performance in the use of the tool.

During the testing and validation of the software two key success factors for use in practice were identified: intuitive usability and compatibility with existing IT-infrastructure. To realize intuitive usability it was necessary to structure the data in a way that reflects the way of thinking of the calculator resp. his way of working when preparing an quotation costing. Furthermore the large amount of input data required a subdivision into manageable groups.

A first element of the solution is the differentiation between order specific and general data on the first level of the structure. This means on the one hand that the calculator is only working with order specific data while preparing a new order. On the other hand the calculator can work tightly focused on the general data when the software tool is initialized or the general data have to be adopted due to changes in the company.

The data structure within the general data is primarily process orientated. In order to ensure clearness the complete life-cycle was broken down into a hierarchic process model. The data input takes place within every single process step on the bottom of the process hierarchy. This means that data as e.g. standard process times, process cost rates and processing parameters are requested with direct reference to the belonging process. The evaluation with the industry partners showed that this structure reflected the way of thinking of the calculators. Furthermore the structure supports collaboration of experts, who are usually focused on single process steps.

The order specific data are structured with reference to the data origins taken into account for the calculation, e.g. part to be produced with the mold resp. die or the mold resp. die itself. The next level of the structure is subdivided according to the functional/geometrical elements of the mold (e.g. cavity or slides) resp. the part (e.g. surface, parting line).

To ensure compatibility with existing IT-infrastructure the software has to be able to be integrated properly into the system scenery of the mold and die industry. The basic requirement is the compatibility with Microsoft Windows. Obviously this requirement is fulfilled by using Microsoft-FoxPro. Further more the interfaces to all IT-systems that are working with input or output data of the quotation costing have to be analyzed. These systems are PDA (Production Data Acquisition) systems, ERP (Electronic Resource Planning) systems and CAD (Computer Aided Design) systems. With interfaces to ERP and PDA systems it is be possible to build up a feed-back control system for the order planning and processing by ensuring a continuous data stream from the earliest planning activities (order preparation) until the final costing analysis. Such a feedback-loop is the precondition for the realization of a self learning calculation.

Today ERP and PDA systems are rarely spread within the mold and die industry, especially in small and medium sized enterprises which were the target group of the IMPC project. Therefore the prototype is not yet equipped with an ERP/PDA interface but offers the possibility of an easy integration of such an interface. Anyway the interaction with ERP/PDA systems is a key element in the future research towards improved calculation methods.

In contrast to ERP and PDA 3D-CAD systems are state of the art in the mold and die industry. Many data, e.g. the dimensions of the part or the size of the parts surface, can directly be extracted from a CAD system. Therefore an interface to CAD systems will be includes in the final version of the software. A further development of the CAD interface could include algorithms for the detection of special features relevant for the calculation, e.g. slides.

During the course of the project the software tool was continuously evaluated and tested. The calculation method as whole but also the single subfunctions/ elements of the method were tested with a set of parts. These parts represented different degrees of size and complexity. The evaluation proved that the IMPC-method is well suited to improve the effectiveness and efficiency of quotation costing in the mold and die industry.

CONCLUSION

The activity based life-cycle costing for molds and dies is a method well-suited to support the quotation costing in the mold and die industry. By modeling the interdependencies of the costs resp. investments in the different phases of the life-cycle the method enables a life-cycle oriented optimization of the mold and die concept. This is an essential success factor for companies in high-wage countries having to focus on the strategy “leadership in terms of quality” and thus have to demonstrate the effect of the quality of their products to potential customers.

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COST ENGINEERING WITHIN COLLABORATING PRODUCTION NETWORKS

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ABSTRACT

Production networks are a growing concept for further improving the ability of companies to compete and become more agile. The new concept of production networks requires a corresponding innovation in cost modelling. Suggestions for requirements for innovation are supplied. A potential drawback to collaborating in networks is a relevance to cost-related data. The method of fuzzy sets is suggested with some associated network-based cost drivers. In particular, the use of managerial experience and intuition is identified as the best source of data to counteract mistrust found in forms of data collection. To support the concept of production networks cost engineering can be further aided by the use of agent technology to automate cost estimating tasks. Various types of agents are explored, for example, for data collection, in addition to the exploration of agents in seeking business opportunities.

INTRODUCTION

The notion of collaboration leads to structures such as the supply chain and varying types of production networks. Production networks discussed by Wiendahl and Lutz (2002) moves the notion of supply chain relationships forward into networks of companies sharing resources, for example manning levels, and detailed data, and communicating in an "intense" fashion. This increased co-operation includes collaboration between competitors even, on this new and closer level. Lu and Yih (2001) discuss the meaning and significance of the concept of the "Collaborative Manufacturing Environment" (CME). After finding that no formal definition exists they formally state, "it is an environment where production entities, which can be a manufacturing site, line, cell or machine, work collaboratively on a short-term basis to produce a product that cannot be produced by any individual entity within the environment". Further to this, a CME can contain entities that come from different companies, and that belong to different CMEs. In addition the CME is transient because of the short term nature of the order. It is thought by these authors that the concept will become a necessity in the prevailing manufacturing environment.

In this paper, two separate and novel concepts that can be used for cost engineering production networks are introduced, i.e. fuzzy sets and software agents.

TYPES OF COLLABORATION

Collaboration across a supply chain has occurred in several different ways:

1. Variable Production Networks (VPN) are "a dynamic co-operation system or network of companies for a specific period" (Wiendahl et al 1998).
2. Computer Supported Cooperative Work (CSCW) and telecommunication (Wiendahl 1998).
3. Workflow management systems (Wiendahl 1998).
4. "function orientated production networks (procurement, production, marketing / distribution)" (Wiendahl 1998).
5. "product-orientated networks (manufacturing of production systems)" (Wiendahl 1998).
6. "infrastructure-orientated networks (communication and information exchange)" (Wiendahl 1998).
7. Resource sharing to overcome production bottlenecks and avoid large capital outlay (Wiendahl et al 1998).
8. Buying for economies of scale described by Wiendahl et al (1998) as the "piece count effect".
9. Taking advantage of a core competence.
10. Co-operative work via "exchange of messages, exchange of data, video-conferencing, workflow, application sharing and shared information use" (Wiendahl et al 1998).
11. STEP standard to facilitate the use of different CAD systems
12. Product Data Management or Engineering Data Management Systems for parallel design.
13. Co-operative product engineering, i.e. "integration of models and methods of design, manufacture and logistics, information transfer in networks, and parallel training" (Wiendahl et al 1998).
14. Four types of variable production networks (Wiendahl et al 1998), i.e. strategic network, virtual enterprise, regional network, and operational network.
15. Virtual enterprise, supply chain management and production networks (Wiendahl and Lutz 2002).
16. Virtual enterprises that are transient, involve short life cycles and low technology (clothes and toys), and include the use of core competencies and capacity of

each autonomous partner (Wiendahl and Lutz 2002). Virtual enterprises appear to the consumer as a whole one and are characterised by their use of Information Technology.

17. Wiendahl and Lutz (2002) provide an extension to the virtual enterprise, i.e. clusters. Clusters are geographical and contain a government institute. The members of the cluster are in the same market sector (co-opetition), share IT, and have the same strategy.
18. Wiendahl and Lutz (2002) refer to production networks involving co-opetition, and lots of communication between all members of the network as an important aspect. Value-adding is shared, as well as resources. Examples of shared information provided by Wiendahl and Lutz (2002) are "actual and future load of machines, resource availability, demand and order progress". It is important to note that production networks are very much more for the long term than virtual enterprises.
19. Petrovic et al (1999) define a supply chain as "generally viewed as a network of facilities that performs the procurement of raw material, its transformation to intermediate and end products, distribution and selling of the end-products to end customers". It is stated that controlling systems of one SC member, controls others.
20. Design review enterprise portal for collocated, dispersed, and geographically dislocated collaboration. The tools of axiomatic design and fuzzy logic are used in an automated solution , called "Fuzzy STAR".
21. Engineering Collaborative Negotiation (ECN) being developed by a CIRP International Institution for Production Engineering Research) working group, where a philosophy of "Design *With* X" is employed for decision making.

E-COLLABORATION

Collaboration is increasingly occurring on electronic platforms, such as that built by the University of Warwick, called the West Midlands Collaborative Commerce Marketplace. Functions enumerated by this particular platform include Requests For Quotation, Request For Information, "competence profiling", on-line work spaces, auctions, "purchasing aggregation", "clustering capability", "external links", and "catalogue capability". Electronic platforms useful for cost engineering across a network include CAD enabled web browsers (Xie and Salvendy 2003) for product visualisation by process experts.

One technical aspect of e-collaboration is that of agents. There are many aspects to collaboration that can be modelled using the concept of agents (Franklin and Grasessar 1996, Wallace 2003). Research into agents can be at first confusing, as special agent tools are expected. But it is found that agents are code, just like other programs, supported by languages such as Java, designed as to have agent like properties. Within large systems, the important advantage of using agents is being able to predict and model emergent behaviour, from complex systems of interacting simpler sub-systems. In summary agents are software components that possess the properties of:

1. autonomy and no central control,
2. social behaviour and negotiation,
3. continuous existence,
4. modelling of global behaviour via the aggregation of local behaviour,
5. pro-active,
6. mobility,
7. task orientation, and
8. intelligence.

Agents therefore, allow the software engineer to think and act in a certain way that is here used to promote the tasks of collaboration and cost engineering.

One of the main drawbacks in moving from traditional supply chains to production networks, is the reluctance of companies to share cost related data. But it is noticed that companies form collaborative partnerships anyway, as shown by the existence of systems such as the West Midlands electronic marketplace. It is apparent that companies are using some form of cost related data that is:

1. vague and imprecise quantities,
2. relies on the experience and intuition of managers.

As well as requiring new data types there are certain points noticed about innovation that is required corresponding to the notion of production networks. The new paradigm, exemplified by production networks, will correspondingly need an innovation in cost modelling. Innovative cost modelling methods should be able to:

- operate using latent information / "encoded" information to ensure company security
- model large complex networks
- accept as inputs network structures
- work in real-time, for example from "Monitoring for Networks (MoNet)" (Wiendahl et al 1998)
- reflect the structure of a variable production network
- model the effect of integration
- be understood by many users

Two concepts that can be used for cost engineering production networks are therefore fuzzy sets and software agents. Fuzzy logic can be used to model vagueness and imprecision in cost engineering (Baguley et al 2003). A list of possible cost engineering related fuzzy concepts are listed in Table 1. Agents can be used to model and automate tasks in potentially complex systems. A list of advantages of using fuzzy logic in cost engineering production networks is provided in Table 2. A list of potential agents for use in cost engineering is listed in Table 3.

Table 1: Possible Qualitative Cost Drivers of a Production Network

Cost Drivers	**Collaboration**
Interoperability	The degree to which companys' processes are seamless
Situational awareness (Xie and Salvendy 2003)	Low awareness breeds sub-optimal designs and production
Resource allocation interference (Wallace 2003)	Delays in allocating resources cause unnecessary time penalties
Time frame for which the collaboration exists	Shorter time frames cause correspondingly increase in problems
Information Technology Integration between partners	The degree of difficulty in swapping information
Multi-plant production planning effects (Shen et al 2003)	Complex logistics cause more contingency

Table 2: Fuzzy Logic Solutions to Collaborative Production Networks.

Problems for Collaborative Production Networks	**Advantages of Fuzzy Logic**
Many collaborating SMEs means data identification and data collection tasks become difficult to synchronise.	Process experts can change their opinion on the fly dependant on the state of the CME. Opinion can change by manually tweaking fuzzy models.
Collaboration is difficult because of the variety of data sources in companies.	Data sources that are qualitative are easier to communicate and share. Skilled measurements are not necessary to impart subjective opinion.
Synchronising data flow is a necessary expense of collaboration.	Overall decrease in data collection cost by the use of process experts.
The implicit speed of response in collaborative networks means knowledge structuring is a problem.	Structured method to collect knowledge and knowledge re-use.
Tools for collaboration present opportunities for novelty	Use of PDM systems to visualise products and form subjective opinion.
Changes in the collaborative network can occur frequently and unpredictably	More responsive and hence advantageous when considering the workflow for cost modelling tasks. Fuzzy sets can be easily understood when changing them. An example is changing subjective quantities such as amount, or skill.
Information sharing promotes efficiency and effectiveness.	A more transparent model to audit and understand for multiple users. Easier communication via a rule base.
Collaborative production networks can rapidly become complex.	Fuzzy logic can model complexity by using its tolerance for imprecision.

Table 3: Potential Agents For Use in Cost Engineering

Types of Agents	**Collaboration**
Scanning Agent (Collan and Liu 2003)	Are used to monitor selected data sources via the web and deliver information at the right time, in the right format.
Resource agents. (Shen et al 2003)	"Wrappers" are used to control non-agent hardware and software.
Yellow Page agents (Shen et al 2003)	Used as a lookup table for communicating with needed agents.
Server and Engineer Agents (Xie and Salvendy 2003)	The server monitors and communicates with engineer agents that aid communication, collaboration awareness, and activity scheduling. An engineer agent provides availability and schedule related information regarding designers' situational awareness.
Feature-based design agents that might hold cost related knowledge or equations (Jacquel and Salmon 2000)	A number of global rules are defined to bring forth a global view of the local interacting features, as agents, to define manufacturability of a product or collection of features.
Resource, group and actor agents (Wallace 2003)	These are used to manage the allocation of resources and groups of resources to actors where the actors are aircraft or manufacturing plants for example.
Mail-agents (Loia et al 2003)	Mobile agents, i.e. agents that can exist and move across different computers, are used to provide an interest rating of a potential E-mail to be sent, based on the information contained in the web pages of the potential receiver.

Using the concept of agents, the emergent cost of a production network, is calculated in real-time as decisions occur. The occurrence of missing or fragmentation of cost related data is circumvented using fuzzy logic and the leverage of vague managerial experience in bringing forth cost related rules concerning the cost drivers in Table 1, and implemented using Table 2 and the examples of agents in Table 3. It is noticed that rules are applied for the interaction of agents. For example Jacquel and Salmon (2000) and Wallace (2003) use a rule that resources are only free when their associated resources are also free. Associated resources are exemplified by those that can interfere with the use of the original resource. In an analogous situation the addition of a collaborator to a production network can be associated with other collaborators via distance, or competences for instance, and should be handled using special cost engineering related rules. The essential idea is that agents shall perform tasks, as put by Sommers, (1997), to "look for the needle in the information haystack", or monitor data. In short, to perform data, information or knowledge processing tasks, more efficiently and effectively, to better bring forth opportunities and estimate their cost. Importantly simple implementation is provided in java, via message passing and methods called by simple "if then rules", the kind that have always been used in computer programs.

PREVIOUS USE OF FUZZY LOGIC IN COST ENGINEERING

The use of fuzzy logic is justified by examining previous research and also the experience of the author in its application. Fuzzy logic, in addition, is a relatively easy concept to implement.

Shehab and Abdalla (2002) built a fuzzy logic module onto their intelligent knowledge-based system for product cost modelling. The reason was simply stated as a method to model uncertainty and no real indicators were given on how to use the method effectively. There are a number of possibilities for building a fuzzy logic model.

Jahan-Shahi et al (2001) use multi-valued fuzzy sets to build a fuzzy logic model to predict process time for flat plate processing. Uncertainty is due to the human factors involved in the process that previously were modelled using allowances that only use a subjective number and do not capture any imprecision in the process.

Pedrycz et al (1999) use a clustering algorithm to predict effort for software projects. Clustering was used because the data set was "spread" over the considered space. The application provides a data driven example of fuzzy logic modelling that produces a Fuzzy Inference System (FIS) as an endpoint.

Baguley et al (2003) successfully use fuzzy logic to model a number of cost examples provided by an artificial Cost Estimating Relationship. The Mamdani method, a neural network and a fuzzy clustering algorithm used to generate errors of about 50%, 15% and 5% Mean Average Percentage error respectively.

FUTURE RESEARCH

Future research will proceed by integrating the activity of process mapping via the object-oriented method or the Unified Modelling Language, and the properties of agents as attributes or methods of objects. This shall map specific requirements of agents onto a production network type and example. A useful output shall be a library of general production network objects and a library of agent-type objects that can be mapped to each other for specific solutions. Supply chain process models will be considered in this respect.

CONCLUSION

The task of cost engineering the potential collaboration of production networks can be facilitated by the use of fuzzy set theory to lever managerial opinion about key cost driver production network concepts.

Production networks are viable, and increasingly so, in the identification of new opportunities, by SMEs acting in groups apart from, and competing, with large organisations. In addition a network of SMEs competes for business with large organisations against other networks.

Fuzzy logic is a growing method for cost engineering yet has not found application in collaborative production networks. Collaborative production networks have found increasing application through the concept of agility. Agility seeks to be more competitive in fast moving markets with short lived opportunities. The sharing of value across companies is part of the strategy. A more responsive cost engineering function that is shared across the network can potentially be facilitated by the use of fuzzy logic.

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CONCURRENT ENGINEERING THE VIRTUAL ENTERPRISES: AGENTS AND THEIR STRUCTURAL ORGANISATION

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ABSTRACT

Engineering the virtual enterprises is considered as a critical task in organisation of successful business. This paper outlines key problems in concurrent engineering the virtual enterprises. We consider business process agents and their cognitive capabilities/compatibilities as underlying elements for the successful operations of virtual enterprises. It is recognised that most current virtual enterprises are based on rigid structural organisation, which defines long-standing business partnership. However modern business environments, that encompass e-business, distributed intelligent/cognitive agents, and physically distributed management, require support for the dynamical development of virtual enterprises with intermediate-term interconnected business partnerships. This paper presents a formal approach to concurrent engineering the virtual enterprises that can be used for the development of flexible and working model of virtual enterprise organisation.

INTRODUCTION

It is recognised that most contemporary approaches to modelling the virtual enterprises cannot be successfully used for practical applications due to the complexity of problems and dynamic nature of modern business processes (Eversheim et al. 1998; Kluber, 1998; Carmarinha-Matos and Afsarmanesh 1999). However, there are several benefits that can be suggested for utilising virtual enterprise modelling. The main ones are (but not limited to): facilitating reasoning and communication about the business process; analysing, studying, controlling and managing the process; determining ways in which the process may be improved. Research community attempts to provide support to operations of virtual enterprises via consideration and analysis of various critical factors, problems in virtual enterprise organisation/operation (Faisst 1997; Wijk et al. 1998; Jagers and Steenbakkers, 1998; Kluber 1998; Carmarinha-Matos and Afsarmanesh 1999). E-business, distributed intelligent/cognitive agents, and physically distributed management have been defined as underlying characteristics of modern business environments. Practitioners acknowledge that most current virtual enterprises are based on static structural organisation, which ensures long-standing business partnership. Long-term contracts can establish reliable partnership, compatible culture and styles that ensure successful operation of virtual enterprises. However, static nature of virtual enterprise organisation defines inconsistency problem in operation and management of business partners. In particular, a member of the virtual enterprise has to be flexible to reflect modern business environment, new complexity of business tasks that require new competence, new requirements, goals, perspectives, tools, and business styles. Dynamical development of virtual enterprises with intermediate-term interconnected business partnerships is considered as a solution to the successful operations of virtual enterprises. This solution determines a great need for support to distributed management that requires concurrent engineering the virtual enterprises.

Study shows that most existing process models and conventional project management approaches ignore consideration and analysis of cognitive capabilities/compatibities of business process agents, instead they over amplify the technical components (Plekhanova 1999; Wysocki and Crane, 2000). This work defines business activities as cognitively driven processes and recognises that key elements of business process are people/agents, processes and products. Concurrent engineering the virtual enterprises is considered as a critical task in organisation of successful business. In this paper, we use formal approach to concurrent engineering of a cognitive system, which consists of knowledge-interrelated business agents. This paper considers engineering the virtual enterprises via engineering cognitive capabilities of business partners that have impact on their structural organisation. It provides flexible model for development of virtual enterprises to ensure successful business operation.

This paper is organised as follows. First we outline key problem in concurrent engineering the virtual enterprises. Then we introduce basic definitions of knowledge profiles that are used for description of a cognitive agent/system. We show how profiles and their integration may be used for cognitive system modelling. Next we describe a formal approach to the cognitive structure modelling that has been used for a flexible organisation of virtual enterprise. Lastly, we conclude with discussions on the key aspects of the proposed approach to concurrent engineering the virtual enterprises.

CONCURRENT ENGINEERING THE VERTUAL ENTERPRISE: OBJECTIVES AND PROBLEMS

Concurrent engineering is largely discussed by research community as a process that supports formation of multifunctional teams, their effective coordination and communication (Winner et al. 1988; Jagannathan, et al. 1991; Dean and Unal, 1992). Basic objectives of concurrent engineering are to support the integration of methodologies, processes, tools, and human agents to ensure effective product development. Concurrent engineering is used as a systematic approach to the system development and operation that ensures integration of heterogeneous system components and related processes. We use concurrent engineering the virtual enterprises to support consistency between physically distributed cognitive agents in virtual enterprises in terms of cognitive capabilities and compatibities of business agents/partners. We recognise that distributed management requires concurrent engineering the virtual enterprises, because business agents can have concurrent problems in business process, process management, and different types of inconsistency problems. Concurrent engineering involves the interaction of distributed cognitive business agents. We use concurrent engineering to ensure consistency of capability and compatibility of business agents/partners and to support flexible structural organisation of virtual enterprise.

We consider virtual enterprise as a distributed cognitive system, which consists of knowledge-interrelated (cognitive) business agents. We recognise that a cognitive agent has to have knowledge in order to be autonomous, adaptive, reactive, etc. We study cognitive structures of distributed cognitive agents in order to define the content and formation of distributed cognitive systems.

VIRTUAL ENTERPRISE MODELLING: A PROFILE BASED APPROACH

We consider business process agents and their cognitive capabilities/compatibilities as underlying elements for the successful operations of virtual enterprises. Knowledge factors are considered as basic factors in the modelling of cognitive agents/systems, since agents must have knowledge capabilities to perform tasks. In a description of the knowledge of cognitive agents we identify the importance/priority of the factor for performance of the task, the property (e.g. level, grade, degree) and existence or non-existence of the factor.

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 *i*th profile factor is defined by indicator characteristic, property, and weight. In particular, we define a **profile** a (Plekhanova, 1999; Plekhanova 2000) as a set of factors $a_1, a_2, ..., a_n$: $a = \{ a_i,\ i = \overline{1,n} \}$, where the *i*th factor b_i is represented by a pair $a_i = (\iota_i, e_i)$ with ι_i - an identification of the *i*th factor, i.e. a name/label of the *i*th factor; n - a number of factors; $e_i = < \varepsilon_i, v_i, w_i >$ with:

- ε_i - indicator characteristic, that indicates and expresses, by factor presence in the description of a cognitive agent, the existence of certain conditions. In particular, ε_i may be defined as a time characteristic of the *i*th factor $\varepsilon_i = \varepsilon_i(t)$; ε_i may also represent a number of times of factor utilisation; ε_i may represent a binary case, e.g. Boolean variable.
- v_i - property of the *i*th 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 can be determined in the context of practical applications.

We use a notion of profile superposition (Plekhanova, 2000) for description of knowledge profiles of business agents in virtual enterprise. In (Plekhanova, 2000; Plekhanova 1999) a **profile superposition** b was defined as a set of profiles: $b = \{a^{(1)}, a^{(2)}, ..., a^{(N)}\}$ or $b = \{(u(a^{(j)}),\ <\varepsilon(a^{(j)}),\ a^{(j)}, w(a^{(j)})>),\ j = \overline{1,N}\}$, where $u(a^{(j)})$ -name or identification of the *j*th factor profile; $\varepsilon(a^{(j)})$ - profile-factor existence $\varepsilon(a^{(j)}) = 1$ or non existence $\varepsilon(a^{(j)}) = 0$; $a^{(j)}$ - the *j*th factor profile; N - number of factor profiles.

That is, each profile factor in a profile superposition is described by a profile, which represents multiple properties of this factor.

For example, suppose that virtual enterprise consists of three business partners, i.e. agents – Agent 1, Agent 2 and Agent 3. Each agent is represented by available knowledge profile $a^{(j)}$, $j = \overline{1,3}$. Thus, profile superposition can be defined as follows:

b = {(Agent 1, <1, $a^{(1)}$, 1/3)>), (Agent 2, <1, $a^{(2)}$, 1/3)>), (Agent 3, <1, $a^{(3)}$, 1/3)>)}

Thus, a virtual enterprise of N cognitive agents (i.e. business partners), can be defined as a set of knowledge profiles of individual agents presented by a profile superposition $b = \{a^{(1)}, a^{(2)}, ..., a^{(N)}\}$, where $a^{(j)} = \{ a_i^{(j)},\ i = \overline{1, n_j} \}$, $j = \overline{1,N}$ is a knowledge profile of the *j*th agent with n_j number of knowledge factors.

In order to facilitate the analysis and comparison of the multiple factors and its characteristics we need to define the *integrated* profile characteristics that introduce the quantitative descriptions of a profile and its factors. We consider profile characteristics such as profile power, factor capability, profile capability, capability index, capability indices profile as follows:

- **profile power** $Pw(b)$ as a number of the profile factors included into profile description, e.g. if a number of the profile factors is equal to n than $Pw(b) = n$;

- **factor capability** $V(b_i)$ as the *factor quality* of being susceptible to the use;

- **capability profile** Pv as a *set* of elements which are the profile factor capabilities.

A **capability profile** Pv is defined as:
$Pv = \{(\iota_i, <\varepsilon_i, V_i, w_i>), i = \overline{1,n}\}$, where V_i is a given capability value.

VIRTUAL ENTERPRISE AS A DISTRIBUTED COGNITIVE SYSTEM

Let us consider a virtual enterprise as a distributed cognitive system B with N interrelated available cognitive agents. A cognitive agent is described by knowledge profile and a cognitive system by a set of N interrelated available knowledge profiles. Profile's relationships define the cognitive structure of the cognitive system. A cognitive system is described by a profile superposition (i.e. a set of available knowledge profiles) and their cognitive structure.

In fact, structural organisation of a distributed cognitive system can be defined by K number of alternative sets of the available knowledge profiles: $\Xi = \{B_i, \quad i = \overline{1,K}\}$, where B_i is the set of M_i available knowledge profiles $B_i = \{b^{(j)}, j = \overline{1,M_i}\}$, $B_i, \subset B$, $M_i \le N$. That is, a cognitive structure of the virtual enterprise may be represented by different combinations of different available knowledge profiles that can define intermediate-term interconnected business agents. These combinations define the alternative cognitive systems.

In order to select possible combinations of the available knowledge profiles we should define how they satisfy the required knowledge profile.

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 *i*th factor capability can be determined by the following formula:

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

where v_i, ε_i are available level and time/existence, respectively; $v_i^{(0)}$, $\varepsilon_i^{(0)}$ - are required level and time/existence. Capability of cognitive system, which represents a given virtual enterprise, can be measurement by the following value: $V = \sum_{i=1}^{N} V(b_i)$.

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:

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

where n is a number of required knowledge factors for a task; $b \cap b^{(0)} \ne \varnothing$.

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: $d_p(b, b^{(0)}) \le r(b)$. For example, we can consider the following distances for profile **compatibility** measurement:

- the distance δ^j between two profiles $b^{(0)}$ and $b^{(j)}$, which provides consideration of capability and compatibility constraints, is defined by the following formula:

$$\delta^j = \sqrt{(V(b^{(j)}) - V(b^{(0)}))^2}$$

- the distance σ^j between two profiles $b^{(0)}$ and $b^{(j)}$, which ensures consideration of all required factors, is defined by the following formula:

$$\sigma^j = \sqrt{(V(b_1^{(j)}) - V(b_1^{(0)}))^2 + .. + (V(b_n^{(j)}) - V(b_n^{(0)}))^2}$$

Modelling the Virtual Enterprise Integration

We consider virtual enterprise integration as a critical problem in distributed management that can have impact on successful business organisation. Since business partners have to possess a number of key knowledge factors, the integration of which ensures better business operations, we consider integration problem as a problem of integration of available knowledge profiles of business partners that constitute the virtual enterprises. Result of knowledge integration can be represented by profile superposition. The goal of knowledge integration is to define the satisfaction of available knowledge from the cognitive system to the required knowledge.

Let us consider two cognitive agents via their knowledge profile superpositions $b^{(1)} = \{b_1^{(1)}, b_2^{(1)}, ..., b_n^{(1)}\}$ and $b^{(2)} = \{b_1^{(2)}, b_2^{(2)}, ..., b_n^{(2)}\}$.

Let us define by: $\mathrm{I}(b) = \{ \iota_i : \iota(b_i), i = \overline{1,n} \}$ a set of all names or identifications of the profile b, where ι_i - name of the *i*th factor; ι - a subset of identifications of the factors: $\iota = \{ \iota_i : \iota_i = \iota(b_i), i \in \{1,2,...,n\} \}, \iota \subset \mathrm{I}(b)$.

In (Plekhanova, 2000) the **union** U_p **of two knowledge profile** $b^{(1)}$ and $b^{(2)}$ is defined as the set of all pairs $(\iota_i, e_i(b^{(1)} \cup b^{(2)}))$, the factor identifications of which belong to $b^{(1)}$ or to $b^{(2)}$ or to both $\iota_i \in \mathrm{I}(b^{(1)}) \cup \mathrm{I}(b^{(2)})$:

$$U_p = \{ \iota \mid \iota \subset \mathrm{I}(b^{(1)}) \text{ or } \iota \subset \mathrm{I}(b^{(2)}) \}$$

The *i*th knowledge factor is defined as

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

where ε_i takes the value from a profile with $\max[v_i^{(1)}, v_i^{(2)}]$, if $v_i^{(1)} \neq v_i^{(2)}$; and v_i from a profile with $\max[\varepsilon_i^{(1)}, \varepsilon_i^{(2)}]$, if $v_i^{(1)} = v_i^{(2)}$; $w_i = \max[w_i^{(1)}, w_i^{(2)}]$.

We define the union of two knowledge profiles U_p as an *integration of available knowledge profiles* $b^{(1)}$ and $b^{(2)}$:

$$U_p = \{ (\iota_i, e_i(b^{(1)} \cup b^{(2)})) \mid \iota_i \in \mathrm{I}(b^{(1)}) \cup \mathrm{I}(b^{(2)}) \}$$

Knowledge integration models can be defined by different integration criteria, e.g. with respect to knowledge capability/compatibility and/or performance factors. Integration criteria priorities/importance of the knowledge profiles and knowledge integration goals can define underlying elements of an integration model. We may identify different requirements (e.g. integration criteria, priorities) for integration models that define a set of integration models (Plekhanova, 2002).

Structural Organisation of Virtual Enterprises: Cognitive System Structure

We consider structural organisation of virtual enterprise via formation of cognitive structure of distributed cognitive system, since a structure is an essential element in modelling, design, development and management of any system. We realise that the internal properties of knowledge factors are changed with time and they effect the cognitive system structure (Plekhanova, 2000; Plekhanova, 2002). It is recognised that 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 (Plekhanova, 2000). In turn, this influences the formation of cognitive systems. We use profile theory for system structure modelling and study the impact of the knowledge properties (knowledge capabilities and compatibilities) of cognitive agents on the formation of the cognitive system structure (Plekhanova, 1999; Plekhanova, 2002). In order to define a discretionary cognitive structure in a cognitive system we consider different combinations of the parallel and series cognitive structures of available knowledge profiles that cover the required knowledge profile, e.g. parallel-series, series-parallel.

We define the available knowledge profiles superpositions $b^{(1)}, b^{(2)}, ..., b^{(M)}$ of cognitive agents 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.

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, i.e. the required knowledge profile is covered by a union of available knowledge profiles and this union is a non-empty set: $\bigcup_{j=1}^{M} b^{(j)} \neq \varnothing$. These profiles define series cognitive structure β. That is, cognitive business agents with mutually complementary knowledge profiles form virtual enterprise with series structure.

We define the available knowledge profile superpositions $b^{(1)}, b^{(2)}, ..., b^{(M)}$ of cognitive agents 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 $b^{(1)}, b^{(2)}, ..., b^{(M)}$ of cognitive agents as **equivalent profiles** with respect to the **available knowledge factors** if they satisfy the given metric d for the required knowledge profile: $d(b^{(1)}, b^{(0)}) \leq r, ..., d(b^{(M)}, b^{(0)}) \leq r$. These profiles define parallel cognitive structure β. Thus, cognitive agents with equivalent profiles form a virtual enterprise with parallel structure.

Structure with Compatibility-weight

Superposition of profiles can be represented by a structure with corresponding compatibility-weights of profiles. Since different profile superpositions may have different values of compatibility-weights, profile structures may be compared with respect to their compatibility-weights. Let β_1 and β_2 be two structures of profile superpositions $b^{(1)}$ and $b^{(2)}$ respectively, with equal profile powers: $Pw(b^{(1)}) = Pw(b^{(2)}) = N$. We say that a set of profiles or a profile superposition forms a **structure with compatibility-weight** W:

$$W = \sum_{j=1}^{N} \prod_{i=1}^{n} \frac{V(b_i)}{V(b_i^{(0)})},$$

where

- a structure β_1 with compatibility-weight W_1 **equals** structure β_2 with compatibility-weight W_2 if $W_1 = W_2$ and β_1, β_2 are *both series or parallel* structures;
- a structure β_1 with compatibility-weight W_1 is **equivalent** to a structure β_2 with compatibility-weight W_2 if $W_1 = W_2$ and β_1, β_2 are *discretionary* structures;
- a structure β_1 with compatibility-weight W_1 **dominates** structure β_2 with compatibility-weight W_2 if $W_1 \geq W_2$;
- a structure β_1 with compatibility-weight W_1 **is dominated by** structure β_2 with compatibility-weight W_2 if $W_1 \leq W_2$;
- a structure β_1 with compatibility-weight W_1 **strictly dominates** structure β_2 with compatibility-weight W_2 if $W_1 > W_2$;
- a structure β_1 with compatibility-weight W_1 **is strictly dominated by** structure β_2 with compatibility-weight W_2 if $W_1 < W_2$.

We can define different structure combinations for the virtual enterprise organisation, compare these structures with respect to their compatibility-weights and select the most appropriate one. It is important to note that knowledge factors are considered as time variables. Therefore, we can study the dynamics of structural organisation of virtual enterprise to ensure the dynamical development of virtual enterprises with intermediate-term interconnected business partnerships. Thus, concurrent engineering is used to provide consistency of capability and compatibility of business agents/partners and to support flexible structural organisation of virtual enterprise.

CONCLUSIONS

In this paper we have considered concurrent engineering the virtual enterprises via engineering the distributed cognitive systems, i.e. engineering of system's cognitive structure and integration of agents' knowledge. We have introduced integration problem of virtual enterprise as a critical problem in distributed management via a problem of integration of available knowledge profiles of business partners that constitute the virtual enterprises. We use a formal approach to knowledge integration that is based on the application of the profile theory and apply it to concurrent engineering of cognitive systems, where the cognitive structure of distributed cognitive agents is defined by structure of their knowledge profiles and is flexible. This approach provides for the consideration and analysis of the impact of knowledge factors and their properties on the organisation of virtual enterprises via the formation of distributed cognitive systems. The proposed formal approach to concurrent engineering the virtual enterprises ensures the development of flexible and working model of virtual enterprise organisation with intermediate-term interconnected business partnerships.

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PROCESS MANAGEMENT

HDA AND RESOURCES MODELING IN BUSINESS PROCESS

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Business process modeling (BPM), Chu spaces, higher dimensional automata (HDA), model of concurrency, resource modeling

ABSTRACT

This paper deals with Higher Dimensional Automata and their use as model of Business Process. Text is concentrated on modeling of resources especially on graphical representation of resources usage. There is mention about Chu spaces that are used to represent higher dimensional automata to bring in mathematical algebra. That algebra allows formally well defined composition of two processes.

INTRODUCTION

One of most important task in Business engineering is to build right model of business process. There are few of possible models. We can use UML, but this is only graphics representation of process. It is not mathematical model so there cannot exist any formal method of verification. Another model is Petri net. Petri net is mathematical model and there exist a lot of formal methods to verify them. Unfortunately the graphical representation of Petri net is a bit difficult and some special knowledge is needed to understand them. Our task is to find representation of business process that has understandable graphical representation and can be formally analyzed. Now we are focused on Higher Dimensional Automata.

HIGHER DIMENSIONAL AUTOMATA

Classic automata model concurrency of event (activity) **A** and event **B** as automaton that performs event **A** and then event **B** or performs event **B** first and event **A** afterwards (see Fig. 1). Automaton in both cases ends in state 11. State 00 is start state. State 10 represents state where event **A** is done and **B** is not started. State 01 represents state where event **B** is done and **A** is not started. State 11 represents state where both events are done. But there is no method how distinguish *true* concurrency of events **A**, **B**.

Higher dimensional automata [Pra91] append *n*-dimensional space for *n* concurrent events. For two events **A**, **B** we append 2-dimensional space (surface) (see Fig. 2). States and events are signed by pair *ab*, where 0 indicates not started event, 1 indicates event in progress, 2 indicates finished event. This label can be substituted with three-value fuzzy logic (0, ½, 1) as well.

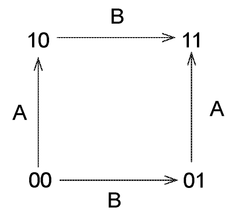

Fig. 1: Standard automata

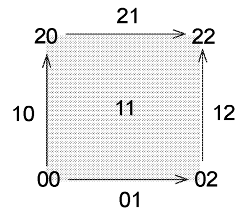

Fig. 2: Higher dimensional automata

EXAMPLE OF BUSINESS PROCESS MODEL

As example of business process we select process represented on Fig. 3. That example is model of purchase of commodity in Business Company. Let us imagine a worker (employee) requesting a new computer (commodity) for example.

Modeled process contains following activities. *Approval of request* (1) – a worker makes request to purchase commodity and manager approves this request. *Selection of supplier* (2) – worker selects suppliers from register of suppliers. *Appraisal of price of request* (3) – worker estimates price of requested commodity. Afterwards the following three scenarios can occur. If the price of requested commodity is under first limit, then first scenario occurs and worker realizes the purchase. If the price is over first limit and under second limit, then second scenario occurs and manager confirms purchase order. If the price is over second limit, then third scenario occurs and director selects best supplier. *Realization of purchase* (4) – worker purchases commodity. *Selecting of best supplier* (5) – director selects best supplier for requested commodity. *Make out purchase order* (6) – worker makes out purchase order for selected supplier. *Confirmation of purchase order* (7) – manager confirms purchase order for selected supplier. *Place copy of purchase order in files* (8) – worker places copy of purchase order in files. *Hand over of purchase order to supplier* (9) – worker hands over purchase order to selected supplier. *Deliver commodity (10)* – supplier delivers ordered commodity. *Takeover of* commodity (11) – worker takes over commodity from supplier.

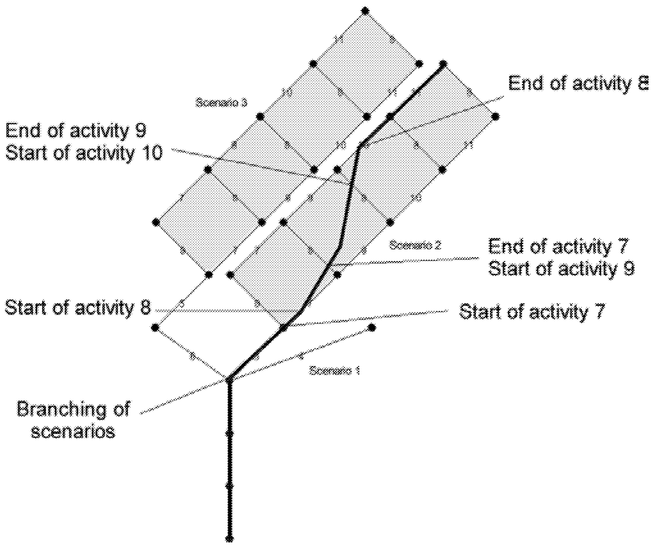

Fig. 3: Example of business process represented by Higher Dimensional Automata

We can read following information about process form Fig. 3. Process contains three scenarios. Only two activities can run concurrently. Activity 8 can run concurrently with activities 7, 9, 10, 11. Bold line shows possible path of process through the automaton.

Higher dimensional automata described above can be obtained automatically from reality and used for re-engineering of process. Method of automatic construction of model of concurrency is described in [JVS03].

RESOURCE MODELING

Higher dimensional automata described in previous section don't take into consideration resources. We describe possibility how to model resources as part of higher dimensional automaton in this section.

We consider a resource as another dimension and usage of the resource as shift in direction of this dimension. Let us have Activity **A** and resource **R**. Resource **R** is used on 75% if activity **A** is in progress. This situation is depicted on Fig. 4. Automaton defined like that is not right higher dimensional automaton, but we can use graphical rules of HDA to depict it and formal method based on Chu space can handle this representation.

Let us use process mentioned in previous section to depict bigger model of process with resources. Usage of resources is denoted in Tab. 1.

Whole process is depicted on Fig. 5. Bold lines and dark surfaces represent among of resource usage. Whole model is depicted in 3-dimensional space. Third dimension is used to model Resource 1. This figure offer global view on resource usage in whole process. All states of process are "elevate" over basic model of process. Elevation of state is given by resource usage in this particular state. This model of process and resources become more understandable if different colors are used to depict basic model of process and elevated states.

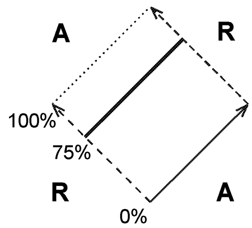

Fig. 4: Modeling of resource

Activity	**1**	**2**	**3**	**4**	**5**	**6**
Resource 1	60%	100%	25%	70%	0%	0%
Activity	**7**	**8**	**9**	**10**	**11**	
Resource 1	25%	25%	50%	0%	20%	

Table 1: Usage of resource

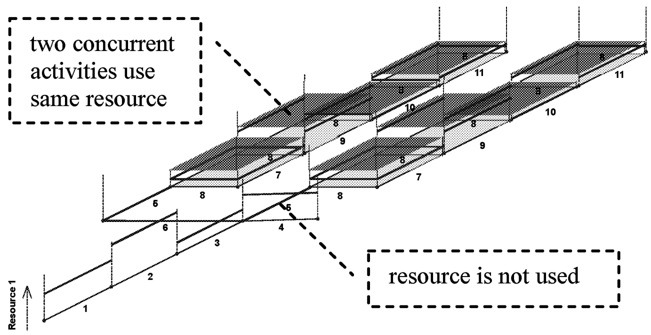

Fig. 5: Model of business process with resource

HDA AND TEMPORAL ASPECT

Reflect temporal aspect of activities is another way how make model of business process closer to reality. Higher dimensional automata naturally model all activities as states with duration. The duration is expressed by length of edges. All edges have same size and model dose not reflect different length of activities duration.

Different length of activities duration can be expressed by different length of edges which represent activities. Formally each activity is represented by one dimension of n-dimensional cube. Each dimension can be rescaling to correspond with length of duration of activity.

Model of business process mentioned in previous example which respect length of activities duration is depict on Fig. 6. Length of activities duration is denoted in Tab. 2. We can clearly see that process is almost sequential and there is not significant concurrent run. Only activity 8 can run concurrently but length this activity duration of is insignificant.

Activity	1	2	3	4	5	6
Duration (hours)	3	8	5	9	20	3
Activity	**7**	**8**	**9**	**10**	**11**	
Duration (hours)	8	0,5	8	8	8	

Table 2: Usage of resource

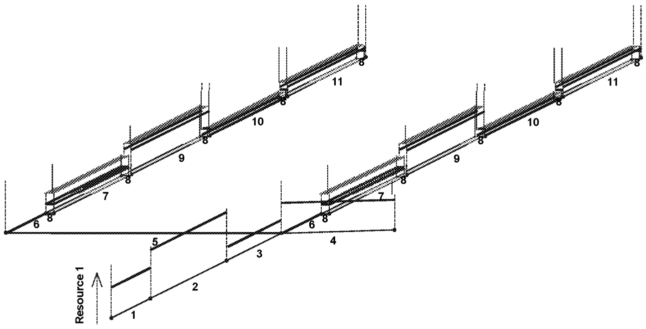

Fig. 6: HDA with temporal aspect

HDA REPRESENTED AS CHU SPACE

Chu space is mathematical structure that is formally well defined and is independent of higher dimensional automata. Chu space is a matrix over a set ∑. It is formalized in [Pra99] as follows:

Definition 1
A Chu space $\mathbf{A} = (A, r, X)$ over a set Σ, called the alphabet, consist of a set A of points constituting the carrier, a set X of states constituting cocarrier, and a function $r : A \times X \to \Sigma$ constituting the matrix.□

In our case it is matrix with rows corresponding to activities (events) and columns corresponding to states and transition of higher dimensional automaton. Chu space entries are drowning from {0, ½, 1}. Where 0 indicates activity not started, ½ indicates activity in progress and 1 indicates finished activity.

Formally, carrier *A* is set of activities, cocarrier *X* is set of process states and alphabet is ∑={0, ½, 1}.

Chu space for higher dimensional automaton from Fig. 2 is shown in Table 3.

A	0	½	1	0	½	1	0	½	1
B	0	0	0	½	½	½	1	1	1

Table 3: Chu space for HDA from Fig. 2

If we use Chu space for representation of higher dimensional automata, we obtain algebraic operations defined in [Pra99]. These operations represent different composition of two processes [Pra00].

For example **Concurrency** composition of process **A** and process **B** is represented by operation $\mathbf{A} + \mathbf{B}$ defined as follows:

Definition 2
Let $\mathbf{A} = (A, r, X)$ and $\mathbf{B} = (B, s, Y)$ be Chu spaces. Chu space $\mathbf{A} + \mathbf{B}$ is defined as $\mathbf{A} + \mathbf{B} = (A + B, t, X \times Y)$ where $t(a,(x,y)) = r(a,x), \forall a \in A$ and $t(b,(x,y)) = s(b,y), \forall b \in B$. □

CONCLUSION

Method described above uses formal model of business process and allows understandable graphical representation of process and resources. Chu spaces bring in mathematical algebra that how allows composition of processes (sequence, concurrency, choice, etc.). We tried to demonstrate the potential of that approach on a small example.

On the other hand there are issues related to an explosion of states for bigger number of activities. For n activities we get n-dimensional cube. This cube is represented by Chu space with n^3 columns. There is also a problem with displaying higher dimensional automata and calculating of layout of nodes representing states for dimension bigger than 3.

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CONCEPTUAL AND CLUSTER ANALYSIS FOR ORGANIZATIONAL STRUCTURE MODELING AND ANALYSIS

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business process, business process modeling, organize structure, formal concept analysis, cluster analysis,

ABSTRACT

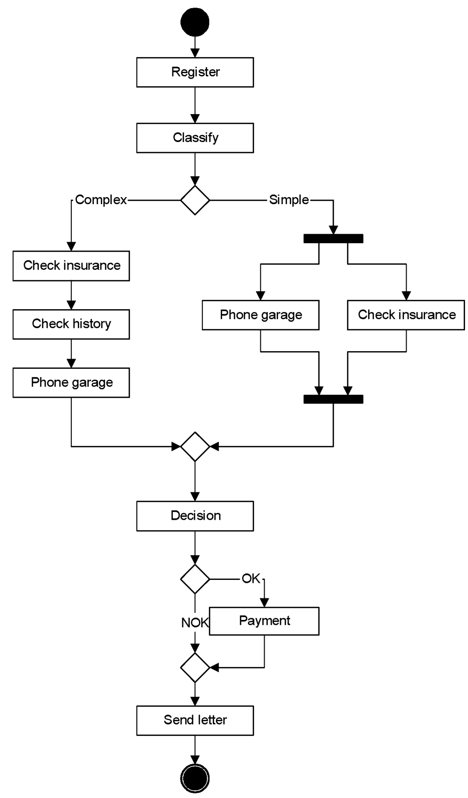
The organizational structure represents structure of roles implemented by human resources participating in business process. The organizational structure is usually defined using the best experience and there is a minimum of neither formal nor semiformal approach involved. This paper reminds the possibilities of the theory of formal concept analysis that can help to understand organizational structure based on solid and well defined mathematical foundations. Formal concept analysis provides rather suitable view to organizational structure based on the Hass diagram. Further the paper compare previous approach based on the formal concept analysis with alternative approach based on the hierarchical methods of cluster analysis.

INTRODUCTION

Business processes represent the core of the company behavior. 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.
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. Unfortunately, none of any 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 show how conceptual and cluster analysis might remove gap between process models and organizational structure.

PRESENTATION EXAMPLE

For demonstration we use small example of claim handling process. This fictive insurance company C *process claims* that result from traffic accidents where customers of C are involved in. The process starts with customer's report of a claim. Every claim is *registered* and after registration is *classified.* There are two categories: simple and complex claim. For the simple claims two tasks need to be executed: *check insurance* and *phone garage*. These two tasks are not related to each other. The complex claims require three tasks to be executed: *check insurance, check damage history* and *phone garage*. These tasks need to be executed sequentially in the specified order. After the execution of the described tasks a decision is made. The decision is made based on the result of previous tasks and has two possible outcomes: OK (positive) or NOK (negative). If the decision is positive, then the insurance company will pay the claim. This invokes the *payment* task. The insurance company always sends a letter to the customer who sent the claim. Activity diagram of this process is in Figures 1.



Figures 1 Claim handling process

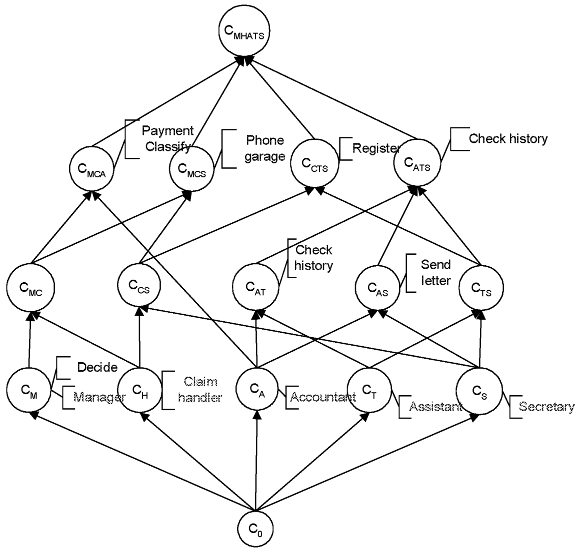
There are five roles in this process: *manager, claim handler, assistant of claim handler, accountant* and *secretary.* Ad-hoc definition of competency table follows:

	Register	Classify	Check i.	Check h.
Manager		X		
Claim handler	X	X		
Accountant		X	X	X
Assistant	X		X	X
Secretary	X			X

	Phone garage	Decision	Payment	Send letter
Manager	X	X	X	
Claim handler	X		X	
Accountant			X	X
Assistant				
Secretary	X			X

FORMAL CONCEPT ANALYSIS

Formal concept analysis (FCA) theory can be used for grouping of *objects* that have common *attributes* (Ganter 1999). The terms from these classic disciplines as context, concept etc. can be found in (Ganter 99). For the formalization a theory of ordered sets and the theory of lattices are applied.
The idea of formalization of terms of context and concept by means of theory of lattices is not quite new. Formerly isolated experiments at application so-called Galois´ lattices already existed, especially in the area of Information retrieval, but systematically built up theory did not arose until the work of Rudolf Wille in about 1980 at the Technical University Darmstadt, Germany and his group. FCA is a mathematical approach to data analysis based on the lattice theory of Garret Birkhoff 93.
Detailed conceptual analysis using for organize structure modeling can be found in (Vondrak and Kozusznik 2003). We map roles and activities participating on business process definition to objects and attributes appearing in FCA.
We purposely miss out construction of all concepts for competency table. This construction is mentioned in (Vondrak and Kozusznik 2003). We only present result Hass diagram representing concept lattice (Figures 2). This 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. Obviously, the more complex is the table of responsibilities the more difficult is to understand who is responsible for what. The nodes in our picture of concept lattice can be considered as a potential source of how the organizational units can be defined.
Based on such modification of concept lattices this theory provides exact and formally well-defined way how the organizational structure can be analyzed and re-designed.



Figures 2 Result Hass diagram

ALTERNATIVE APPROACH

Concept lattice is not the only one approach how to model and analyze organizational structures. Another possibility is to use cluster analysis for the same purposes. The method based on hierarchical aggregation seems to be the right one because its output shows clearly how the organizational structure should look.
Hierarchical aggregation is based on a similarity of objects (roles in our case). There are many options how the metrics of such similarity can be defined. We chose the association coefficients between two roles R_i and R_j defined through so called association table (Tab.1) to quantify this metrics.

Table 1 Association table

		R_j	
		1	0
R_i	1	a	b
	0	c	d

In this table *a* represents a number of positive correspondences (activities associated with both roles). Coefficient *d* represents a number of negative correspondences (activities that are not associated with none of both roles). A number of differences where an activity is associated with R_i and it is not associated with R_j reflects *b* and a number of differences where an activity is not associated with R_i and it is associated with R_j is represented by *c.* Table 2 is association table filled for claim handling process. The *association coefficient* can be computed from the following formula:

$$Assoc(R_i, R_j) = \frac{2(a+d)}{2(a+d)+b+c}.$$

The value of *Assoc* belongs to interval <0,1>: the more similar are two roles then the higher is the value of the association. For couple of roles that are identical this value is equal to 1. More practical for purpose of hierarchical clustering is to use a coefficient of *dissimilarity* defined as follows:

$$Diss(R_i, R_j) = 1 - Assoc(R_i, R_j)$$

Table 2 Association table for claim handling

	Manager		Claim handler		Accountant		Assistant		Secretary	
Manager	4	0	3	1	2	2	0	4	1	3
	0	4	1	3	3	1	3	1	3	1
Claim handler	3	1	4	0	2	2	1	3	2	2
	1	3	0	4	3	1	2	2	2	2
Accountant	2	3	2	3	5	0	2	3	2	3
	2	1	2	1	0	3	1	2	2	1
Assistant	0	3	1	2	2	1	3	0	2	1
	4	1	3	2	3	2	0	5	2	3
Secretary	1	3	2	2	2	2	2	2	4	0
	3	1	2	2	3	1	1	3	0	4

The association coefficient can be computed from Table 2 for all roles based on the above described formula. Table 3 shows resulting coefficients of dissimilarity.

Table 3 Table of dissimilarities

	Manager	Claim handler	Accountant	Assistant	Secretary
Manager	0	0.143	0.455	0.778	0.6
Claim handler	0.143	0	0.455	0.455	0.333
Accountant	0.455	0.455	0	0.333	0.455
Assistant	0.778	0.455	0.333	0	0.231
Secretary	0.6	0.333	0.455	0.231	0

Next the *hierarchical agglomerative method* (Lukasova and Šarmanová 1985) was used to build clusters of similar roles:

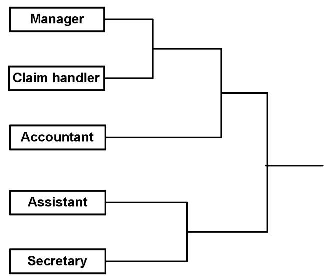
1. At the beginning there are only clusters containing just one role.
2. Then two clusters with the lowest dissimilarity are taken and they are unified into a new aggregate.
3. The step number 2 is repeated until there is only one cluster containing the whole set of roles.

Since the later built clusters contain more than one role it is necessary to define a *dissimilarity coefficient D* between such two aggregates e.g. A and B. For our purposes the coefficient called as *farthest neighbor* was chosen (Lukasova and Šarmanová 1985)

$$A \neq B \Rightarrow D(A,B) = \max_{R_i \in A, R_j \in B} \{Diss(R_i, R_j)\}$$

$$D(A,A) = 0$$

Dendogram is a graphical representation of the resulting hierarchical clustering. It shows clustering of roles based on what activities they have in common. Result *dendogram* of our examples is in **Chyba! Nenalezen zdroj odkazů.**.



Figures 3 Result dendogram

The dendogram seems to be more illustrative than above mentioned concept lattice represent by Hass Diagram but it has one important disadvantage. There is no visualized information that would give reasons for such grouping. We do see on the diagram of concept lattice what activities have group of roles in common. The dendogram shows only that they have something in common.

CONCLUSION

The method of concept analysis provides exact and formally well defined way how the organizational structure can be analyzed and re-designed. The examples used in our paper were simplified but they demonstrated sufficiently the potential of concept lattices and the way that this theory can be adopted for purposes of organizational structure analysis. The problem is how to identify organizational structure itself. For that purpose the use of hierarchical aggregation seems to be a better tool because as well as the organizational structures they both employ hierarchy as the main abstraction. On the other hand the theory of concept shows better why the roles are grouped together and thus it serves as a better tool for understanding how the knowledge is shared among roles. We consider both approaches as complementary to each other and the future research is going to be focused on how they can be integrated together.

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ENGINEERING DATA MANAGEMENT

A STANDARD ACCESS INTERFACE FOR PRODUCT DATA

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Product Data Management, Computer-aided Engineering, System Integration, PDM Federation, STEP, Distributed Applications, Virtual Reality

ABSTRACT

Integration in the area of product data management systems is still an open topic. Even though various approaches for offline (typically based on STEP) and now also for online integration have been developed, the effort and costs of integration are still too high. What we need in the context of a highly integrated environment or a collaborative virtual environment, including systems such as CAD, CAE, Virtual Reality and tele-cooperation, is an open and powerful approach for exploring and modifying product data.
This paper puts forward additional arguments for dealing with this topic in terms of motivation and afterwards presents an approach employing a standard access interface as the core concept. Using previous work from the STEP community, we also define an API which makes integration tasks in a given environment much easier. Based on the presentation of the interface, the paper illustrates usage and advantages of the approach on the basis of two application scenarios: federation of PDM systems and integration of PDM and Virtual Reality. The paper ends with a summary and an outlook on future work.

MOTIVATION

Permanent access to all current data in the product development process is an important prerequisite for efficient engineering. While the existence of digital product data is no longer a problem for most companies, the seamless and immediate access to this data across systems, disciplines, locations and organizational units still is an open issue. STEP already provides a uniform data model for product data, which is used for offline exchange of assemblies and complex product structures. However, this typically is an expensive process requiring a lot of manual support for export, transfer and integration of the structures in remote systems. Even more critically, this sometimes causes significant delays in the process.

An additional problem is the creation of a tight integration of the PDM systems with various applications (CAD, CAE, Virtual Reality etc.) to form an integrated engineering workplace. This integration is feasible today. However, due to the variety of proprietary interfaces it is a very expensive task, requiring a lot of customization and resulting in high maintenance costs. Figure 1 (below) illustrates that application integration will remain an important market over the coming years. This market has enormous potential and is driving growth within the overall software and project services market.

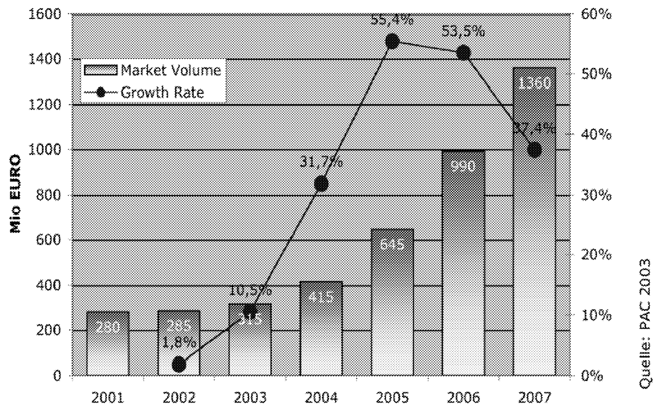

Figure 1: German market for integration solutions (products and services)

In addition to general integration projects that can be handled with off the shelf Enterprise Application Integration (EAI) toolboxes, we still find very specific and complex integration challenges. The integration of product data across company boundaries is a typical example of such a challenge which must be built on top of application-specific methods and tools.

THE WAY TO OPEN ACESS INTERFACES

Any novel approach to integration and cross-enterprise data sharing must fulfil a set of important requirements:

- Flexibility: Each concrete integration project requires a different solution. For example, the distribution and/or integration model, which specifies what data are held in which system, must be individually adaptable. By utilising modular architecture together with the disclosure of the substantial interfaces it is possible to merge further functional modules to implement more complex Use Cases.
- Scalability: The integration should not set limitations in terms of the size of the data sets and the number of integrated systems (clients and servers). Together with a suitable specification of the interface, the selection of high performing technologies and the implementation of efficient algorithms for search and traversal etc. are also crucial in this context.
- Universality: The integration approach should not be considered to be useful only with concrete PDM systems from certain manufacturers, but also for

arbitrary systems whose data model can be mapped to a neutral PDM schema. Furthermore, the binding of an existing PDM system must be possible within a justifiable expenditure.

The first substantial step for the integration of PDM systems is to define a uniform system-spreading data model. In this context, extensive work has already been done by STEP (Standard for the Exchange of Product Data) (ISO 1994) which can be made use of. For the automotive industry in particular, the specifications of STEP AP 214 (Core data for automotive mechanical design processes) are of interest.
STEP is well established for the exchange of CAD data and numerous tools for data exchange exist in the market, which are compliant to this standard. The deficiency of STEP is in the absence of a fine-granular on-line interface. The usual STEP processors only support a coarse-grained data exchange with the PDM system on a file basis.
This deficiency has been recognised and there have been different approaches made to close the gap. In the interest of an open and standardized solution, only vendor-independent concepts will be considered here.

- The Standard Data Access Interface of STEP (SDAI) was an early but fruitless attempt by the STEP community to establish an online interface to STEP data bases with bindings for C, C++ and, later on, for Java as well. Limitations in interoperability, lack of object-orientation and performance problems were the main reasons for the failure of this approach.
- A very promising approach was developed by the Object Management Group (OMG). Their "PDM Enablers" define a neutral CORBA interface for PDM systems (OMG 1994) and develop a product data model closely related to STEP. However, due to its high complexity, it did not become generally accepted by the end-users. A PDM Enablers client needs dozens of CORBA requests in order to query the meta data belonging to a product part. This is definitely the wrong granularity for a permanent online connection to a PDM system. Meanwhile, the OMG are working on a follow-up specification which will repair these deficiencies and which also abstracts from CORBA as the technology for the interface (OMG 2004).
- In the PDTnet project for the German automotive industry, a uniform web service interface was developed for PDM systems (Sachers 2001). Its foundation, once again, was formed by the STEP data model, which was now formulated as an XML Schema. By the use of XPath as a query language, PDTnet was successful in offering a highly flexible read accesses to PDM systems. The semantics of the update operations are not further specified. It stops at the level of the import functionality of STEP processors; i.e. it is not accurately specified what effect an update has on the data in the PDM system.

To cope with the challenges of distributed processes and integrated engineering environments, we need an IT approach that is based on an open interface. This interface should act as the common denominator of the various PDM systems. Thus, our approach neglects the sophisticated features of different commercial PDM systems and concentrates on managing product structures and related documents.

The following figure gives an architectural overview of our approach. It introduces the PLM Connector Interface as a "bus" to easily connect clients (browser applications, CAD systems etc.) with data sources. With this architecture we are in line with previous frameworks such as the CAD Reference model (Vaterrott 1995) and iViP (von Lukas 2001). From those projects we learned how important it is to define the interfaces in the optimal granularity and that it is crucial to build the approach on technologies that are already established in the industry.

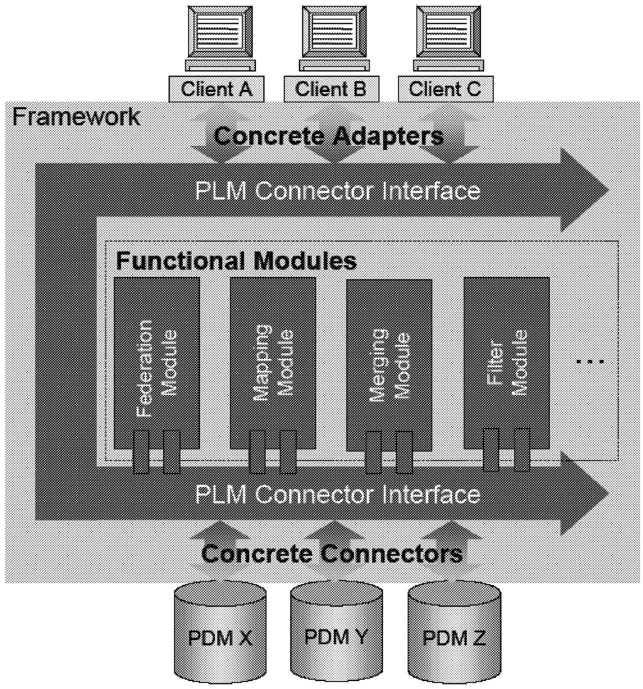

Figure 2: The architecture model of the integration

STANDARD ACCESS INTERFACE: THE PLM CONNECTOR

As illustrated in Figure 2, the PLM Connector Interface plays a prominent role in the overall design. The following section describes our standard access interface in detail. This illustrates the functionality of the API and our lightweight but powerful approach.

The PLM connector is a similar model to that defined in the J2EE Connector Architecture specification. The PLM connector uses five specific object types: `PLMResourceAdapter`, `PLMConnectionFactory`, `PLMConnection`, `PLMRecordFactory` and `PLMRecord`.

The PLMResourceAdapter Class

```
<<abstract class>>
PLMResourceAdapter
+ getInstance(in className: String):
  PLMResourceAdapter {static}
+ getConnectionFactory(in name: String, in
  properties: Properties):
  PLMConnectionFactory {abstract}
+ getConnectionFactoryNames(): List<String>
+ getRecordFactory(): PLMRecordFactory
+ getSupportedXPaths(): List<String>
+ getSupportedSchemas(): List<String>
```

A PLM connector vendor must provide an implementation of the abstract `PLMResourceAdapter` class. A client can get an instance of a specific PLM resource adapter class by the static member function `getInstance()` with the class name of the specific PLM resource adapter.

With the operation `getConnectionFactory()` the client can get a `PLMConnectionFactory` object. The value of the parameter `name` is the name of the PLM connection factory. The list of all supported values for this parameter can be obtained by the operation `getConnectionFactoryNames()`. In the parameter `properties` the client can pass specific parameters. These could be the properties "`java.naming.provider.url`" and "`java.naming.factory.initial`" if the PLM Connector implementation uses a JNDI name service.
The operation `getSupportedXPaths()` returns the xpath expressions that can be used in the `query()` and delete() operations of `PLMConnection` objects of this `PLMResourceAdapter`.
The operation `getSupportedSchemas()` returns a list of XML schemas. The `PLMConnector` objects of this `PLMResourceAdapter` support as parameters in their `update()` operation only data sets that validates in regard to one of these XML schemas.

The PLMConnectionFactory Interface

```
<<interface>>
PLMConnectionFactory
+ getConnection(in properties: Properties):
  PLMConnection
```

The interface `PLMConnectionFactory` provides the Operation `getConnection()` which returns a `PLMConnection` instance. In the parameter `properties` the client can pass specific information to the `PLMConnectionFactory`. This could be "`user`" and "`password`" properties.

The PLMRecordFactory Interface

```
<<interface>>
PLMRecordFactory
+ createDOMRecord(in value :
  org.w3c.dom.Document): PLMRecord
+ createInputStreamRecord(in value:
  java.io.InputStream): PLMRecord
```

The `PLMRecordFactory` interface provides create operations for PLMRecord instances for all data format representations.

The PLMRecord Interface

```
<<interface>>
PLMRecord
+ getDOM(): org.w3c.dom.Document
+ getInputStream(): java.io.InputStream
```

All PLM data that is passed as an input parameter to, or returned as a result from, an operation in this specification must be valid with regard to the PLM XML Schema. `PLMRecord` serves as a union for all provided formats of PLM data representations. These can be XML input streams, DOM objects, or instances of a root element interface generated by a JAXB compiler. For the Java-based Platform an Independent Model (PIM) of the PLM Services a normative JAXB customization will be defined. To avoid ambiguities

The PLMConnection Interface

```
<<interface>>
PLMConnection
+ query(in initialXPath :String, in
  recursiveXPath:String="",
  unsigned depth = 0): PLMRecord
+ update(in data: PLMRecord): Map
+ delete(in xPath: String)
+ getDownloadURL(in fileXid: String): URL
+ getDownloadURL(in fileXid: String): URL
+ close()
```

The `PLMConnection` is the central interface of this specification. It is used to grant access to the PLM system. For passing PLM data, it uses instances of the class `PLMRecord`. By the use of `PLMRecord` as a universal parameter type for all PLM data representation formats, the `PLMConnection` interface can be kept short and clean.
The **`query`** operation expects an XPath expression as an input parameter. By applying this expression to the data in a PDM system, a set of pre-selected nodes is generated. Due to the fact that JAXB marshalling and unmarshalling functions are only defined for valid XML data sets, the query operation always returns a valid data set with all selected nodes.
A schema-valid data set is expected by the **`update`** operation as an input parameter. The PDM system uses the id-attributes of the single elements in the data set to identify which elements already exist and which ones have to be created. When creating a new element in a PDM system, it is not possible in all cases to use the id-attribute from the parameter data set. For this reason, the update operation returns a data structure that defines a mapping for all changed id-attributes from the initial value to the new value.
The **`delete`** operation needs an XPath expression as an input parameter. By applying this expression to the data in a PDM system, a result set of pre-selected nodes is generated and the affected nodes – together with their descendant nodes - are deleted in the PDM system in a consistent manner.

The `getDownloadURL` operation is assigned an id-attribute of a Digital _file-Element as the only parameter. As a return value, it delivers an URL to retrieve the content of a Digital_file from the PDM-System.
The `getUploadURL` operation expects an id-attribute of a Digital_file-Element as the parameter. It returns an URL which is used to upload a new content of the Digital_file to the PDM-System.
The `close` operation shuts down a connection to a PDM system. After a successful call of the close operation, all subsequent calls to this connection will raise an exception.
Having presented the PLM Connection Interface in detail, we will now step back and give an rough overview of the surrounding framework and other components for the integration which have already been introduced in Figure 2.

FRAMEWORK AND COMPONENTS

Based on experience of the employment of the CORBA PDM Enablers and the results from PDTnet, a concept for the federation of product data was developed by the joint project PDM Collaborator (PDMC 2003). The handling of complex operations in a neutral way on the large and deeply structured product data in XML representation is only possible using sophisticated technology. Apart from the conventional XML technologies SAX, DOM and XSLT a further technology specification was adopted recently: the Java Architecture for XML Binding (JAXB) (Sun 2003). While the past technologies granted a Schema-independent generic access to the XML data, JAXB permits the transfer of the XML data into typed Java objects of Java classes derived from the XML Schema. Thus JAXB enables the full support of the type system of the Java programming language for the implementation of algorithms for Schema valid XML data. This power is used to implement a framework for handling XML-based product data.
However JAXB possesses advantages for only a part of the algorithms as opposed to SAX and DOM. For the algorithms needed for federation, both generic and typed XML technologies are needed. It is particularly problematic that the technologies are based on different data types, so that a technology change always requires a data conversion that, in turn, causes a runtime overhead. The innovation of the XML technology described in this paper is that it overcomes the problems of merging the generic and the typed approach. With our JAXB-based approach, both of these work on the same physical data objects and conversions are no longer necessary. Thus, without these performance deficiencies, the appropriate technology can be used for the implementation of each partial algorithm of the complex integration operations.
The resulting architecture is distinguished by its open, modular character with the defining characteristic of a uniform interface for PDM integration (Nowacki, von Lukas 2003). As already discussed, three groups of modules were implemented as the basis of a framework for the efficient, XML based processing of product data:
Function modules: In these modules generic functions such as federation and, also, filtering are performed. The modules work on the uniform data model and can be simply configured. These modules are all addressed via the standard access interface and are in this way combinable arbitrarily one with another in order to also work in complex integration scenarios.
Connectors: These provide the binding of existing PDM systems. The connector makes use of the proprietary programming interface of the PDM system and translates the data model and the interface into our neutral format.
Adapters: Here we also see that an adjustment of the interface is made – this time for the client side – which also makes use of the neutral interface.

PDM FEDERATION TO SUPPORT COLLABORATION

PDM-based Collaboration

In the life cycle of the product, it is during product development – with its phases of planning, construction and testing – that the substantial product characteristics, manufacturing costs, and intended uses are specified.
However these phases cannot be sharply separated any longer in the modern development processes we see today. Rather, an iterative process takes place in which all data needed for manufacturing are produced and verified in an incremental way. The virtual product is thereby the sum of all product-determining and– other, accompanying information (Spur, Krause 1997). All product data, from the initial planning of the construction up to the preproduction phase, are continuously digitally mapped and are thereby readily available at individual locations and beyond normal enterprise boundaries. As opposed to material prototypes, material testing methods and material manufacturing, computer-aided procedures exhibit numerous advantages. In particular the virtual product is not bound locally: It can be accessed immediately from anywhere in the world.. In addition, it can be used, added to and altered, in parallel, from several places simultaneously. This characteristic creates a great potential for tele co-operation.
Virtualisation is made possible by the availability of several computer-based procedures, such as computer aided design (CAD), Virtual Reality, simulation methods and, last but not least, by flexible product data management. Apart from these technological aspects, the methodical and organizational dimensions must, of course, be considered. Relevant concepts such as concurrent engineering, virtual enterprise and massive outsourcing are sufficiently well known. In the automotive industry, and increasingly in other industries too, intensive co-operation with hundreds of suppliers and service leaders is the norm. The automotive industry provides us with a good example of strong cross-linking between enterprises, wherein distributed co-operation processes can be seen running efficiently with the support of modern IT systems only (Champy 2002).
As consequence of these changes in product development, the information and communication requirements of the parties involved increase significantly. If this requirement is not provided for, then errors are recognized too late in the process and this may cause substantial direct (correction of the error) and indirect (delayed appearance at market) costs.
A further challenge is the optimal breaking-down of the total task into sets of sub-tasks and the co-ordination and/or simultaneous synchronisation of the distributed work on these subtasks. In addition to direct communication and efficient data retention, the steering of the project and/or process plays the crucial role with virtual engineering of

complex products. Virtual product creation thus forms, on the one hand, the most important reason for the supply of computer-assisted procedures for co-operation and, on the other hand, it is fundamentally dependent on such tools for the support of distributed working groups.
In the past, the unsophisticated transfer of CAD files – partly by means of the File Transfer Protocol (ftp), partly as physical data media – was sufficient in itself to transfer the results of a construction partner to the final product manufacturer. But today we have an intensive, bi-directional data exchange of product structures. The partner is under an increasing obligation to constantly bring its construction into accordance with the environment (e.g. design space) and to make its data available for Digital Mock Up (DMU) at the OEM at increasing stages of development. Thus, the boundary conditions that apply to enterprise-spreading co-operation are almost identical to those in place in an intra-corporate division of work. For the internal range, in previous years, the product data management system (PDM system) was established as a central information turntable. In PDM systems the product structure is managed, versions are maintained, variants and approvals are specified and rights of access are defined. The use and the propagation of PDM systems is thereby characterised by the following ancillary conditions:

- The OEM's and the large system suppliers of the automotive industry have tried for years to increase the ties of their suppliers to PDM technology. There are however a set of problems which lead to the fact that close integration succeeds only in exceptional cases. In the predominant majority, the solutions do not extend the scope of the FTP service in a noteworthy way.
- In particular small and middle-sized enterprises do not yet own PDM systems and thus don't possess the know-how in the use of these systems as well as in the process arrangements.
- A multitude of PDM systems established in the marketplace have identical core functionality but some important functions and concepts differ. This heterogeneity is intensified further by the fact that, because of ability to customise these systems, different installations of a PDM manufacturer can deviate strongly from each other and thus data exchange is made more difficult.
- Numerous competitive technologies exist for the integration of data holding systems (e.g. PDM systems). Due to the divergence of proprietary models and open standards, we are lacking a technology, which is supported by the majority of both system vendors and users.
- In principle, PDM based integration can be advanced a long way and thus be able to support comprehensive workflows, as for example with inter-enterprise change management. This also implies, however, very high requirements to whatever integration technology is used: it must be both scaleable – in order to be used efficiently with highly-complex data structures – and flexible enough to be adapted to the specific requirements.

Our solution: PDM Federation

The federation of PDM systems offers a comfortable and efficient approach for Use Cases in which the user must have parallel access to different PDM systems. This includes internal collaboration between various engineering teams as well as cross-company collaboration between an OEM and his suppliers. By the provision of a "virtual PDM system", unproductive work procedures for data acquisition and storage are avoided. The engineers get more time for productive and/or creative activities.
Instead replicating the product data to a central repository or database (as we have it today with frequent offline updates via STEP files) we prefer to leave all the data at the sources where it belongs. The federation level must have all the "knowledge" of how to split queries into sub-queries in different PDM systems and how to merge the sub-results.
Relying on our standard access interface we can even integrate PDM systems from different vendors and, with different data models, to a single virtual PDM system. This is accomplished by means of various functional modules. The merging module simplifies the internal structure of an assembly down to coarse-grained structures. The mapping module transforms non-uniform properties in arbitrary formats. A filter module is used to mask-out irrelevant parts of the data set, e.g. to implement a specific user view. The federation module connects two PDM systems via split and merge.
The following figure gives a simplified overview of the federation: two different clients are connected to the virtual PDM system offered by the federation via the standard access interface (dark circle). The federation module (and the mapping, merging and filter modules which are not visible here) are connected to "real" PDM systems via connectors. Any request to the federation is modified and routed to one or both PDM systems to collect the necessary partial results. Afterwards both results are combined to create the final return value for the request. This works for query, update and delete operations.

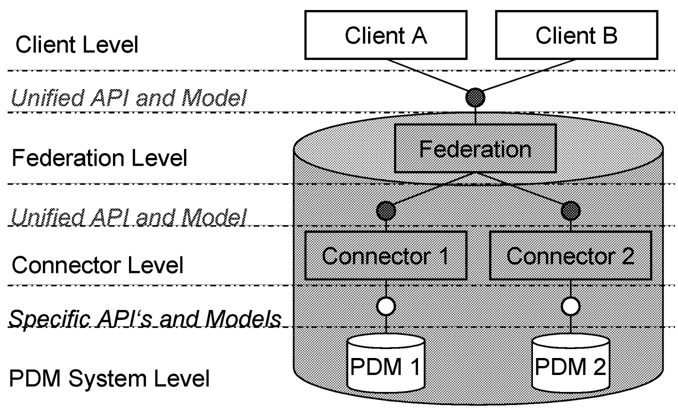

Figure 3: Concept of PDM Federation

In Figure 3 our PDM Browser is presented as an example of a typical Client application. With the Browser the user can directly connect to individual PDM systems or create federations and connect to the resulting federated system. If necessary the documents (e.g. 3D-Data) of the federated systems can be handed over to a Viewer and/or a CAD system.

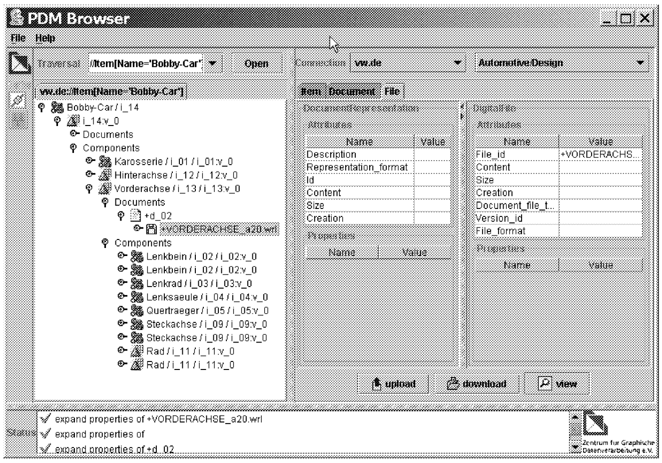

Figure 4: PDM Browser with federated product data

Field Trial

The developed modules for the federation are being evaluated by Volkswagen at present. After the successful realization of in-house co-operation scenarios, including the PDM systems, KVS (a specific Volkswagen system) and Enovia VPM, the next step will be to include suppliers, as external co-operation partners, in the federation. Early results show that, by using the federation, not only are the product development engineers relieved of work, but also the integration costs of the systems can be clearly reduced, costs which must be provided by the IT departments or external partners.
During the evaluation, a Use Case based procedure worked satisfactorily: a co-operation scenario is described accross the sum of all the applications which can be supported (e.g. "to search construction unit in federated PDM systems" or "to store changed data record as new version". From this, the technical requirements are then derived to the federation. The necessary function modules can be selected and can be extended, if necessary, by additional functions. After adjustment or implementation of the necessary connectors, and the adjustment of the distribution model by an interactive tool, the test phase can start.
If further co-operation scenarios in the same enterprise are realized by means of the federation, the advantages of the open approach can be seen: numerous modules can be reused and the concatenation, from individual use cases to complex scenarios, is possible without considerably increasing the degree of the complexity. Since the business logic is centrally administered and configured, and not distributed over various connectors and clients, such a federated system can be maintained substantially more easily.
A free trial version of the PDM federation is available on the web server of ZGDV Rostock for download (ZGDV 2003). Recently the spin-off company, PartMaster GmbH, was founded to commercialize the PDM Federation.

ACCESS TO PDM DATA IN VIRTUAL REALITY ENVIRONMENTS

The second use case focuses on immersive environments for Virtual Engineering. The state of the art there is characterized by the availability of model representations (VRML in general) derived from CAD systems. The model representation is suitable only for presentation purposes and does not offer all the information which is available for a given part or product structure.
Using the access interface presented above, we can overcome this problem. We have coupled ZGDV's VR framework *O4* (ZGDV 2004) with the PDM Federation by means of the standard access interface. This offers us a bi-directional link between both worlds. The following functionality is supported:

- Selecting structures in the tree-like interface of the PDM browser and exporting the corresponding VRML data files to the VR system. During this step, all the necessary IDs to reference product data are generated automatically.
- Clicking an object in the VR world, retrieving the available product data for this object from the (federated) PDM system and presenting this information as an annotation to the object.
- Selecting objects in the PDM browser and highlighting the corresponding part of the VR model.
- Selecting objects in the VR system and presenting the structure plus available meta data in the PDM system.

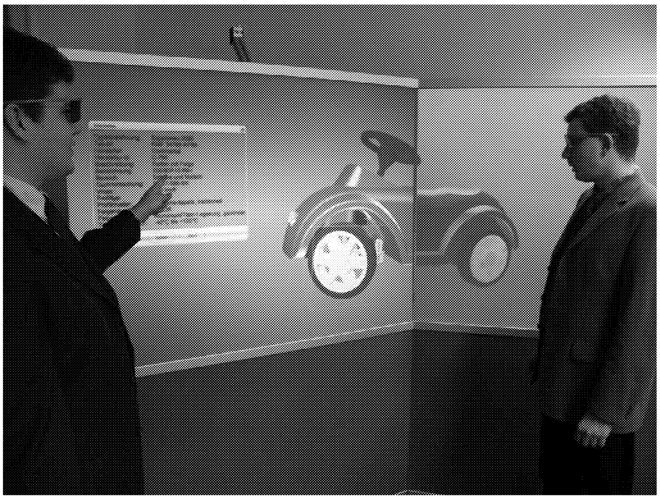

Figure 5: Presenting PDM data in an immersive environment

In Figure 5 we see an example of meta data which is retrieved from a PDM system and presented as an annotation in an immersive 3D environment. The following Figure 6 illustrates the architecture. Once again we see the PLM Connector Interface but this time, there is a functional model "VR Messenger" installed, which handles the bidirectional communication with the VR environment.

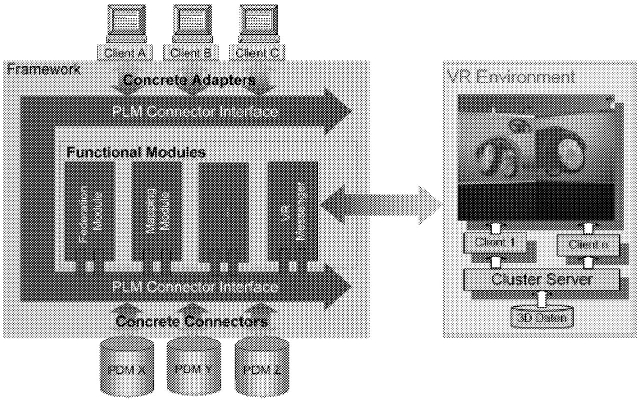

Figure 6: Architecture of the PDM VR integration

Within the German project InViS – Integrated Virtual Shipbuilding ZGDV and its' partners (Aker Ostsee Yards, Scheller Systemtechnik, Meerestechnik Engineering, Fraunhofer IPK) are developing an integration platform and developing services upon this platform. Using the virtual machinery space as a showcase, four applications are integrated: CAD, Simulation, tele-cooperation and Virtual Reality. The following figure illustrates the use of PDM data in a VR environment. The integration platform relies on the data model and access interface described above which proved to be a powerful basis for various integration scenarios.

Figure 7: Environment for the virtual machinery space

Future work in this area concentrates on seamless presentation of the meta data in the VR scene and natural interaction metaphors to explore and even modify the PDM data in immersive environments.

SUMMARY AND OUTLOOK

This paper presented our approach for a uniform access interface for product data based on the STEP data model. This vendor-neutral interface offers a lightweight approach to integrate PDM systems in heterogeneous environments and implement online data access across various systems and locations.
We have presented two use cases for the application of the access interface:

1. The PDM Federation implements the vision of a virtual, distributed PDM system. The access interface is not only the prerequisite to avoid complexity of integration of proprietary API but also the key for a modular approach, where filter, mapper and other business logic can be combined in a plug & play fashion.
2. The integration of PDM and Virtual Reality is an important step to make the immersive VR environment more useful for Virtual Engineering. The standard access interface offers all the functionality to explore data and even make changes to product structures. By avoiding proprietary API calls this approach can be applied to arbitrary PDM systems.

Our interface is now part of the PLM Services specification as a chapter entitled "Computational Viewpoint". This specification is currently in the standardization pipeline of the Object Management Group. Supported in particular by the German automotive industry, this specification has a good chance to find its way from academic to commercial use.
Further work in this area should try to apply a similar approach to CAD systems as well. In this area we also have the need for a neutral interface to avoid integration problems. However, due to the big differences in the internal architecture and design philosophy, this will be a difficult piece of work.

ACKNOWLEDGEMENTS

This work was carried out with financial support of the German Federal Ministry for Education, Science, Research and Technology in the projects *PDM Collaborator* (BMBF grant 02PL10xxx, supervised by the Project Management Agency for manufacturing technologies and quality management) and *Integrated Virtual Shipbuilding* (BMBF grant 03SX119xxx). Furthermore the authors gratefully acknowledge the fruitful discussions in the working group XPDI of the ProSTEP iViP Association.

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BIOGRAPHIES

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STEFFEN NOWACKI graduated in technical electronics from the University of Rostock. He was a researcher in the Fraunhofer Gesellschaft for five years and joined the Computer Graphics Center Rostock as a senior research assistant in 1998. Since 2003 he is co-founder and CEO of the company PartMaster GmbH in Rostock.

DATA ANALYSIS OF THE LOGISTICAL BENCHMARKING DATABASE WEBSCAN

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KEYWORDS
Benchmarking, best practice, top objective, logistics

ABSTRACT
The paper describes preliminary results derived from the logistical benchmarking database Webscan. This way we would like to stimulate the SME's to use the exposed knowledge embedded in the causal model LOGIWATCH and retrieved from previously experienced problem situations. The results of the different ranking combinations fortify current industrial management objectives. The patterns discovered and analysed manipulating and reworking the available data are indicative and aligned with the causal model LOGIWATCH.

INTRODUCTION
Best practices describe the state of the art of how to perform a business process. They are the means by which leading organizations have achieved top performance. Therefore, best practices are suggested actions for other organizations striving for excellence. The overall effectiveness of the business will only be achieved by changing the current practices of performing business processes and adapting them to best practices (Camp 1989).

Benchmarking focuses on which best practices are available and ensures an understanding of how they are performed. Several logistical benchmarking activities have been deployed up to now. One of the most notable is the bi-annual benchmarking study sponsored by the Supply Chain Council (Supply Chain Council 2002). The cost report by the Council of Logistic Management is another one. On top of that, most major consulting firms have their own benchmarking database. However, most of these databases focus large companies and are fairly expensive to use. This inspired the authors to set up a publicly available benchmarking database Webscan, aimed at SME's and accessible through a web browser on the Internet (Van Landeghem and De Vos 2003).

The proof of concept of this online benchmarking tool Webscan standed last year. We now started to analyse the benchmarking data gathered from SME's and stored in our Webscan database. This database is still a bit lean because SME's are very difficult to convince in trying out tools which are no business and which do not fetch a great deal of money right away, much less cost. All the more reason why to publish preliminary results as early as possible.

EXISTING MODELS
The link between best practices and performances has been established by (Voss 1995). The same model – called 'context-practices-performances framework' – was proposed by (Ho and Duffy 2000)) and refined for use in logistics context by (Ho and Newton 2002). In the latter publication the authors also express a need for conceptual models, clarifying the scope and dynamics of supply chain.

Throughout the years the Department of Industrial Management build up expertise in this field. (Domenech and Van Landeghem 1998, Van Landeghem and Persoons 1999) made a thesis on modelling relationships between best practices and the four main objectives (emerging from numerous literature sources): Flexibility, Reaction Time, Quality, Return on Assets, this way creating a causal model LOGIWATCH (Figure 1). This model serves both as a framework for knowledge transfer and as an analysis scheme for benchmarking i.e. as a diagnostic procedure. The extensions on the Webscan tool and the diagnostic procedure in particular are described in (Van Landeghem and De Vos 2004). The latter also notifies the acquisition of funding from the European Social Fund. This funding supports our structured long-term approach.

DATA ANALYSIS AND INTERMEDIATE RESULTS
The data stored in the Webscan database are mainly answers to the question lists from the online benchmarking tool Webscan. Most questions are of a 'yes' or 'no' type, for some questions a 5 point Likert scale has been used. So our Webscan database indicates the yes or no application of related best practices. This permits to make several ranking lists. Each ranking indicates the relative

importance of the best practice in relation to the groupîngs.

TOP20 Most frequent used Best Practices
When we rank and normalize all best practices according to their usage within the SME's, we notice a positive preference for flexibility as top objective (Figure 2).

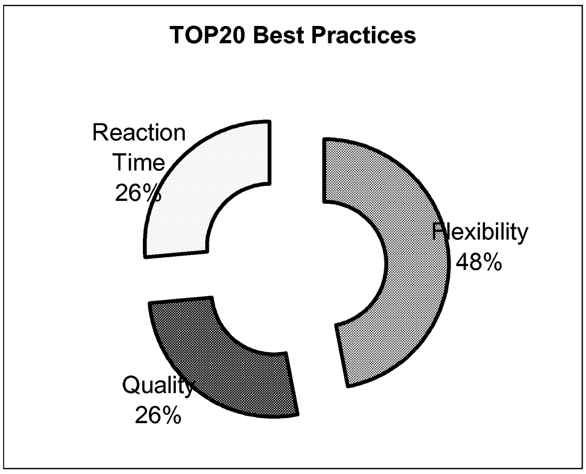

Figure 2. TOP20 Best Practices

Table 1 lists the best practices in detail for this top objective. This list relieves a sigh for total flexibility in an unstructured manner. It seems that SME's want to respond to all of their customers no matter the costs.

List TOP20 Best Practices Flexibility
Flexible capacity
Group Technology
Modularisation of the product
Virtual supplier network
Short planning time fence
Flexible organization (work force)

Table 1. List TOP20 Best practices for flexibility

Or put in another way, short and long term flexibility are contaminating each other. The cost for this sigh for total flexibility will be undoubtedly high, reducing SME's profitability. The latter performance indicator should be investigated and compared when our database grows. But still we also notice a fundamental improvement as most of our SME's are adopting '*group technology*' and '*modularization of the product'*. These best practices force a structuring of the road to attain a sustainable flexibility.

BOTTOM0 Least frequent used Best Practices
Looking at the tail of former ranking (Figure 3), we notice a relatively low figure for quality improvements, which means that most best practices within our benchmarking are adopted. Indeed quality has been top objective for many firms in the late nineteens, so most best practices related to quality should be known to our SME's. and their adoption seems to be earned. The top objective Return on Assets is not representative at the very moment and will be restructured in our benchmarking question lists.

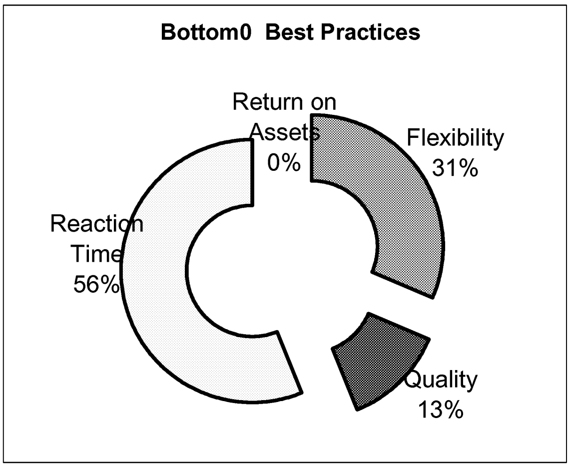

Figure 3. BOTTOM0 Best Practices

Supply Chain related best practices
We already pointed out that current management objective has changed from 'quality' to 'flexibility'. Looking more in detail at the level of best practices within TOP20, we also find evidence of a particular attention to the extended supply chain i.e. including suppliers and customers.

Best practices strengthening a closer attention **upstream** are: '*limited numbers of suppliers'* and '*virtual supplier network'*.

But best practices like '*education of suppliers'* and '*third part logistics (3PL)*' demonstrating a very close relationship with the suppliers, have a low percentile [1]ranking or are not applied at all. These poor results may be interpreted as a rather one sided attention upstream where SME's prefer to do-all-themselves or can also fortify the structure of our SME's supplying particular products to a limited number of dedicated big organizations.

Downstream we find a very high ranking for '*early customer involvement'*, '*education' of customers'* and '*customer satisfaction surveys'*. Indeed nowadays firms pay attention to their customers and customer is more than ever always right.

Deming cycle and best practices
As SME's are too often fortifying the 'doing', we want to demonstrate the importance of best

[1] Percentile ranking is a relative ranking.

practices like '*benchmarking*' , '*training and education'* and other, by placing them in the right quadrant of the Plan Do Check Act Deming Cycle (Figure 4).

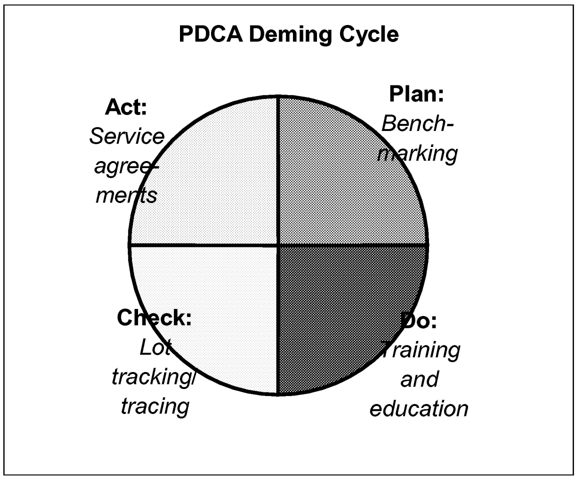

Figure 4. Deming Cycle and best practices

Deming formulated 4 steps in his decision support model also known as the Control Cycle. In the first step 'Plan', Top Management has to determine goals and targets. '*Benchmarking'* is the right tool to get focus on the missing or poor performed practices. The next step 'Do' asks for '*training and education*' before implementation of the fan of best practices. And implementation requires a 'Check' for instance with '*lot tracking and tracing*' one can evaluate oneself with former position in order to readjust where necessary the performing of the practices. And with '*service agreements*' one guarantees the right 'Act'.

Table 2 lists former best practices from the Deming cycle with their percentile ranking (Table 2).

Best Practices	Percentile Ranking
Benchmarking	61
Training and education	41
Lot tracking/tracing	23
Service agreements	44

Table 2. Best Practices with percentile ranking (lower=better).

It seems that we are a bit more than half-way which is a relative good score but with room for improvement. '*Benchmarking*' as best practice does not get any special attention from SME's: a percentile ranking of 61 which means that 61% of all best practices at study are considered to be more imported.

'*Training and education'* is another best practice (besides '*benchmarking*') demonstrating SME's goodwill to investigate time and effort in 'how' to do things rather than doing 'what'. The percentile ranking is 41.

'*Lot tracking and tracing'* shows a good score of 23. The percentile ranking of '*service and agreements'* is 44 and demonstrates that '*service and agreements*' is not yet a common practice within SME's.

Functional Classification of best practices within TOP20

Classifying the TOP20 most frequently used best practices according their function, i.e. 'Organization', 'Method', 'Technology' and 'ICT', we notice a very strong attention to organizational practices (Figure 5.). And with a relative score of 9 ICT is a slow follower. But it is worthwhile to notice that the '*Intranet*' as best pratice has a percentile ranking of 20 which means that the intranet is not yet a standard over the whole but still the technological barrier of implementing an intranet seems to be low for SME's.

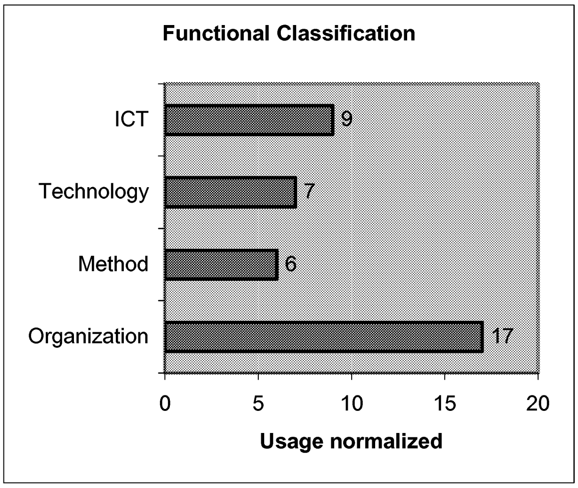

Figure 5. Functional Classification of best practices within TOP20.

So it seems that SME's prefer to solve their bottlenecks first in trying out organizational practices. Organizational practices have in comparison to ICT and Technology still a far lower relative cost. And indeed cost, scale and benefit are carefully balanced within SME's. Of course this preference also depends on the industrial sector within which the firm is operating. Some sectors require a higher manufacturing automation and thus investment than others. We therefore included an overview of the relative presence of the industrial sectors within our Webscan database (Table 3).

FURTHER RESEARCH

Our investigation also applies for further research in exposing relevant features on the links between best practices and related top objectives as well as in making longitudinal sections in order to expose similarities and differences among the industries themselves.

Parallel to these static data analyses we are doing research on classification models using machine learning techniques (De Vos and Van Landeghem 2004). Both research paths interplay with each other and are working reciprocatively. Manager's sensitivity to market needs and demands are likewise confirmed using machine inductive methods.

CONCLUSIONS

Former analyses aim to link up with former department research. The patterns discovered and analysed manipulating and reworking the available data are indicative and aligned with current causal model LOGIWATCH. The results of the different ranking combinations fortify current industrial management objectives. Gaps within analyses are only indicators that more and different data should be gathered and opens new ways for further research.

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Prof.dr.ir. Hendrik Van Landeghem holds a degree of Civil Engineer (Dipl-Ir) in Electro-Mechanics (UG) and a M.Sc. in Industrial Management (UG). He worked several years in industry as manufacturing consultant and in industrial informatics. From 1992 onwards he is Head of the Department of Industrial Management of the Ghent University (Belgium). He is Fellow of the European Academy of Industrial Management (AIM), and International Member of the Institute of Industrial Engineers (IIE).

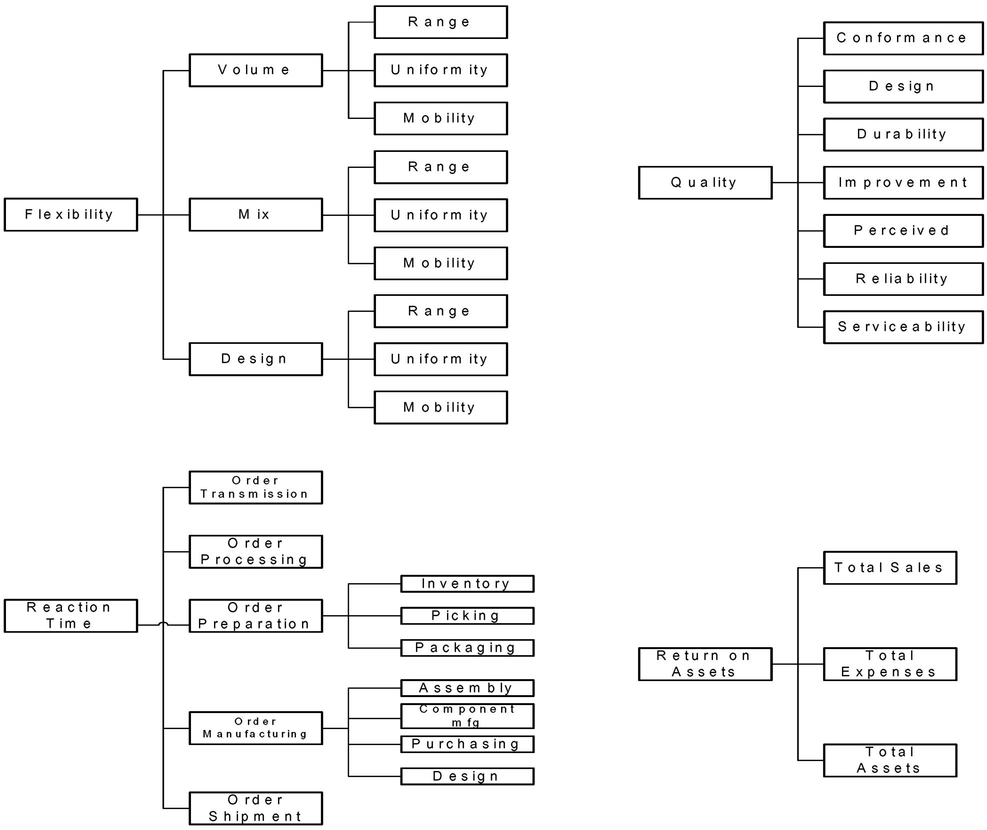

Figure 1. Structure of causal model LOGIWATCH (Van Landeghem and De Vos 2004).

NACE code	Industrial sector	Relative presence (%)
15	Manufacture of food products and beverages	13
17	Manufacture of textiles	13
18	Manufacture of wearing apparel; dressing and dyeing of fur	7
20	Manufacture of wood and of products of wood. Manufacture of articles of straw and plaiting materials	3
21	Manufacture of pulp, paper and paper products	3
22	Publishing, printing and reproduction of recorded media	3
24	Manufacture of basic chemicals	7
25	Manufacture of man-made fibres	10
28	Manufacture of fabricated metal products, except machinery and equipment	17
31	Manufacture of electrical machinery and apparatus N.E.C.	3
33	Manufacture of medical, precision and optical instruments, watches and clocks	3
34	Manufacture of motor vehicles, trailers and semi-trailers	3
45	Construction	3
51	Wholesale trade and commission trade, except of motor vehicles and motorcycles	7
62	Air Transport	3

Table 3. Relative presence of industrial sectors within Webscan database.

A Study to Investigate the Impact of Requirements Instability on Software Defects

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Abstract

Software development is a dynamic process and is characterized by change. Software projects often begin with unclear, ambiguous, and incomplete requirements which give rise to intrinsic volatility. Constant change in requirements is one of the main causes of software defects and a major issue faced by the software industry.
This paper describes the findings of our research-based study that investigates the impact of both the pre-release and post-release requirements change on overall defects by defining measures, collecting data against those measures and analyzing the collected data through statistical techniques. On the basis of the collected data and our results, we have uncovered some of the major sources of software defects. Our findings, based on industry data from 4 software projects consisting of 30 releases, all in e-commerce domain, indicate that there is a significant relationship between pre/post release change requests initiated by the client and software defects. In addition, our data analysis indicates that majority of the high severity defects are introduced due to changes in the design of the system at the later stages of software development i.e., coding, testing and after release. Also, we found that the average time spent on different SDLC phases and client communication have a significant impact on software defects.

Keywords: Requirements change, pre/post release changes, change request (CR's)[1], high/medium/low change requests, defects, severity1/severity2 defects.

1. Introduction

Requirements are the foundation of the software development process. They provide the basis for estimating costs and schedules as well as developing design and testing specifications. So the success of a software project, both functional and financial, is directly related to the quality of its requirements. Although an initial set of requirements may be well documented, requirements will change throughout the software development lifecycle. Thus, constant change (addition, deletion and modification) in requirements during the development life cycle impacts the cost, schedule, and quality of the resulting product **[4].**

However the basic problem is not with changing requirements; the problem is with inadequate approaches for dealing with them. Requirements Evolution is due to both social and technical aspects.

The *social viewpoint* is related to the stakeholders involved in the system, they range from end-users to software engineers, project managers and other business actors (e.g., standards regulators, market competitors, etc.). All stakeholders change their understanding of the ongoing system during its life cycle, hence requirements evolve. On the technical viewpoint, requirements may evolve due to production constraints, usage experience and feedback from other phases of the system life cycle (e.g., testing). Ideally, the requirements once approved by the client should stabilize with no or very few major changes.

> *According to Capers Jones, requirements change (RC) should come down to 3% in the design phase, 1% in the coding phase and ideally 0% during testing. However requirements change is always there but it can have very negative affect during the later stages of software development. For example: requirements change during the coding and testing stage can maximize the* ***defect density*** *as compared to other phase. Studies conducted by Jones have shown that the defect rates associated with the new features added during mid-development are about 50% greater than those of the artifacts associated with original requirements.* **[7].**

The requirements changes can be distinguished as: ***(1) Pre-FS (Functional Specification) Changes*** which refer to changes in the requirements during the early phases (i.e. elicitation, elaboration, analysis, modeling and negotiation) of software development before FS has been completed and signed off, ***(2) Post-FS Changes*** occur during the later phases of software development (i.e. design, coding, testing and development) after the FS has been formally signed off, ***(3) Post-release changes*** occur once the system has been deployed at the client side, after release **[20].** *(First and second type of changes fall under the category of* ***Pre-release changes****).*

In the above context, it is worth mentioning that the first type of change is constructive if correctly done, because these would help in more complete requirements. However the second and the third types of requirements can be destructive as they may affect the productivity in terms of cost overruns, schedule overruns and quality *(adding defects while incorporating a change).*

> *Malaiya* **[17]** *has examined the relationship between changing requirements and defect density at the code phase and found the requirements volatility has an impact on defect density. According to Capers Jones* **[7]**, *the maximum defects should never exceed 3.5 defects per function point (Sum of the defects found in requirements, design, code, user documents and bad fixes)*[2].

[1] Change Request (CR): Changes in requirements (addition, deletion, modification) initiated by the client through the Change Request Forms (CRFs).

[2] The data presented here is derived from top 5% of the projects in the top 30% organizations *Software Productivity Research* has analyzed out of a total of 600.

For this study we have collected data from *4 projects consisting* of *30 releases*. All these projects are from the *e-commerce domain*. However our findings would be beneficial to other companies who want to improve and stabilize their requirement engineering processes. Our research work investigates the impact of both the pre and post-release requirements changes on *overall defects* by defining measures, collecting data against those measures and analyzing the collected data through statistical techniques. Based on our results and the collected data, we have uncovered some of major sources of defects. To study the impact of changing requirements on defects, we have categorized both the pre and post-release CR's initiated by the client in three different categories[3]: high; medium; low. Similarly we have categorized the defects in two categories[4]: severity1; severity2.

This study is organized as follows: In section 2, we look at the work related to the impact of RC. Section 3 presents our hypotheses and the procedures for data collection along with brief details of the data gathered against the selected projects. In section 4, we have discussed the results based on our findings and the final section concludes our work with directions for future research.

2. Prior Literature

Recent studies have shown that both large and complex software projects experience many changes throughout the system development life cycle **[4].** Studies conducted by *Barry* **[23]** have shown that the sources of RC are manifold (changing work environment, organizational complexity, government regulations, and conflicts among stakeholders in deciding on a core set of requirements).

Lamsweerde **[24]** conducted a survey of over 8000 projects from 350 US companies and revealed that one third of the projects were never completed and one half succeeded only partially, that is, with partial functionalities, major cost overruns, and significant delays. When asked about the causes of such failures, executive managers identified *poor requirements* as the major source of problems (about half of the responses) - more specifically, the *lack of user involvement* (13%), *requirements incompleteness* (12%), *changing requirements* (11%), *unrealistic expectations* (6%), and *unclear objectives* (5%).

On the European side, a recent survey of over 3800 organizations in 17 countries similarly concluded that most of the perceived software problems are in the area of requirements specification (greater than 50%) and requirements management (50%) **[24].**

Prior studies have investigated the impact of RC *on software productivity* **[21]**, *software releases* **[16]** *and its impact on isolated software development phases* **[17].** Lane **[21]** investigated the impact of RC on effectiveness and efficiency of software development productivity and found that there was no direct impact of requirements change on these two concepts. *Lane's* findings further suggested that factors such as product size and organization size strongly influence the impact of RC on software development productivity. Another study conducted by *Didar Zowghi* **[19, 20]** provided no strong evidence to support that RC has a direct impact on software development productivity (such as code quality, quality of project management and development capability). *Hyatt et al* **[22]** reported that RC must be considered as a part of project risk assessment. *Malaiya* **[17]** has examined the relationship between RC and defect density at the code phase and found the RC has an impact on defect density. However no one has specifically examined the impact of RC on software defects throughout the SDLC and the root causes of those defects.

Our study focuses on what the previous studies fall short of coverage; that is, investigating the impact of both the pre-release and post-release requirements changes on overall defects and major sources of those defects.

3. Hypotheses and Research Site

3.1 Hypothesis-1

The purpose of this hypothesis is to test the relationship between the *pre-release* CR's initiated by the client and the defects introduced due to those changes. Here the variable 'pre-release CR's' has three categories: high=1; medium=2; low=3, and the variable 'defects' has two categories: severity1; severity2. To prove the hypothesis, we have used Cross-tabulation method and applied the Pearson's Chi-Square test.

Null Hypothesis:

$\mathbf{H_0}$: There is no relationship between defects and the *pre-release* CR's (high, medium, low severity) initiated by the client and the two variables are independent.

Alternate Hypothesis:

$\mathbf{H_1}$: There is a relationship between defects and the *pre-release* CR's (high, medium, low severity) initiated by the client and the two variables are dependent on each other.

3.2 Hypothesis-2

The purpose of this hypothesis is to test the relationship between the *post-release* CR's initiated by the client and the defects introduced due to those changes. Here the variable 'post-release CR's' has three categories: high=1; medium=2; low=3, and the variable 'defects' has two categories: severity1; severity2. To prove the hypothesis, we have used Cross-tabulation method and applied the Pearson's Chi-Square test.

Null Hypothesis:

$\mathbf{H_0}$: There is no relationship between defects and the *post-release* CR's (high, medium, low severity) initiated by the client and the two variables are independent.

Alternate Hypothesis:

$\mathbf{H_1}$: There is a relationship between defects and the *post-release* CR's (high, medium, low severity) initiated by the client and the two variables are dependent on each other.

3.3 Research Site and Data Collection

Our research site is a leading software organization that develops diverse commercial applications. Brief details of the organization and the projects under study are given in tabelow:

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[3] **High:** If a CR affects the Design, functionality or databases design of the system.
Medium: If a CR affects minor functionality or minor database changes.
Low: If a CR requires minimal GUI consistency changes.

[4] **Severity 1**: major defects, affecting the significant functionality of the system.
Severity 2: minor defects, mostly GUI related.

Organizational Details	
Organization size	140 employees (approximately)
Organization's maturity level	Tick-IT Certified; ISO Certified
Project Details	
Number of projects under study	**Four** Project A = 16 releases Project B = 10 releases Project C = 2 releases Project D = 2 releases
Domain of the projects under study	e-commerce
Average duration of each release in a project	Project A 56 days Project B 67 days Project C 38 days Project D 38 days
Average number of resources utilized in each release of a project	Project A Developers = 5 Database = 2 Quality Assurance = 3 SCM = 1 System Support = 2 Project B Developers = 17 Database = 3 Quality Assurance = 3 SCM = 1 System Support = 2 Project C Developers = 3 Database = 2 Quality Assurance = 2 SCM = 1 System Support = 2 Project D Developers = 3 Database = 2 Quality Assurance = 2 SCM = 1 System Support = 2
Technology used in the selected Projects	Project A IBM Net Commerce Project B Java/ J2EE Project C IBM Net Commerce Project D IBM Net Commerce
SDLC followed	Waterfall methodology
Communication Methodology with the onshore client	Conference calls, e-mails, meetings, telephone calls

Table-1: Data collected from organization under study

Further, for this study we have collected data against 30 releases of the four selected projects in e-Commerce domain by considering the following areas:

1. **Requirements change** *(Data collected from Functional Specification documents, Change Request Forms, Project Schedules)*
   - Pre-release and post-release CR's of high/ medium/ low severity against all releases of a project
   - Pre-release and post-release CR's of high/medium/low severity initiated in different phases (specifications, design, coding, testing, shipment) of all releases of a project
   - Requirement specifications (initial/pre-release/post-release) in all releases of a project
2. **Defects** *(Data collected from in-house Defect Repository System - Bug Base)*
   - Defects of high/medium/low severity against all releases
   - Defects of high/medium/low severity due to pre-release and post-release CR's against all releases of a project
   - Software Discrepancy Reports (SDR's)[5] of high/low severity against all releases of a project
3. **Project Duration** *(Data collected from Quality Reports[6], Project Schedules)*
   - Releases shipped on time/ with delay
   - Duration (days) for each release of a project
   - Time (days) allocated to different phases (Specifications, design, coding, testing) of a release

For our investigation, it was not possible to collect data against the other factors affected by RC such as: project cost, size and effort, since the availability of data against them was one of the constraints. Also due to intellectual property protection issues, the fully functional system was not available to us and we could not store the data in persistent media. However, we had viewing access to the project documentation through the Configuration Management System for the duration of the study, which allowed us to record the data manually.

4. Discussion of Results

In this section we will discuss our findings based on the statistical analysis of the hypotheses[7].

4.1 Hypothesis-1: Relationship between Pre-release CR's and defects

For hypothesis-1 we have combined all the releases of the four projects to determine if there is a relationship between the pre-release CR's and the defects. Our results in Table-2 indicate that *there is a significant relationship between the number of pre-release CR's and the defect since the significant value of the Chi-square test is less than 0.05.* This proves that the two variables are not independent and our null hypothesis is rejected.

5 **SDR:** It is the defect(s) in the software system that is reported by the client through formal SDR forms once the project/release has been shipped to the client.

6 **Quality Report** is developed monthly by Quality Excellence Department that contains: project shipment details, planning and tracking details, project quality and productivity details and process management details.

7 (Mathematical Description of the hypotheses is given in the Appendix)

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.526[a]	2	.003
Likelihood Ratio	8.391	2	.015
Linear-by-Linear Association	4.322	1	.038
N of Valid Cases	289		

a. 1 cells (16.7%) have expected count less than 5. The minimum expected count is 1.41.

Table-2: Chi-square results at significant level of 0.05

Figure-1 and Table-3 present the total number of defects found (categories: severity1; severity2) against the pre-release CR's (categories: low; medium; high). *It is worth mentioning that these figures explain the combined results of all the 30 releases against 4 projects. However a detailed picture of percentage pre-release defect and CR's for each project is given in the Table-5.*

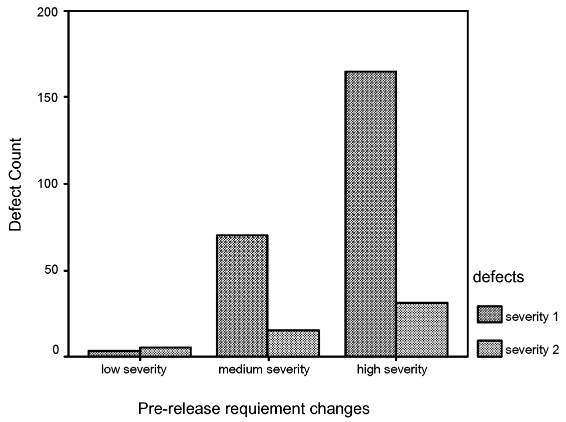

Figure-1: Defects VERSUS no. of pre-release CR's

requiement changes * defects Crosstabulation

			defects		
			severity 1	severity 2	Total
requiement changes	Pre-rel sev. low	Count	2	1	3
		Expected Count	2.5	.5	3.0
	Pre-rel sev. medium	Count	72	15	87
		Expected Count	72.7	14.3	87.0
	Pre-rel sev. high	Count	165	31	196
		Expected Count	163.8	32.2	196.0
Total		Count	239	47	286
		Expected Count	239.0	47.0	286.0

Table-3: A cross-tabulation table displaying the number of defects in each category

Results in Table-4 & Table-5 show that maximum number of severity1 defects (69%) is found due to (37%) of high severity pre-release CR's. It is important to note that although majority of pre-release CR's are of medium severity (56%) but they only caused 30% of the severity1 defects. Similarly, maximum number of severity2 defects (66%) is found due to (37%) of high severity pre-release CR's, although majority of pre-release CR's (56%) are of medium severity but they only caused 32% of the severity2 defects.

Overall Percentage of Defects of Severity 1 and Severity 2 due to Pre-Release CR's		
Pre-Release CR's	**%Severity 1 Defects**	**%Severity 2 Defects**
Low Severity	1%	2%
Medium Severity	30%	32%
High Severity	69%	66%
Total	**100%**	**100%**

Table-4: Overall percentage distribution of defects due to pre-release CR's

Percentage of Pre-Release CR's							
Projects	**High Severity CR's**	**Medium Severity CR's**	**Low Severity CR's**	**Total CR's**	**%age High Severity CR's**	**%age Medium Severity CR's**	**%age Low Severit y CR's**
Project A	9	34	3	46	20%	74%	6%
Project B	16	1	0	17	94%	6%	0%
Project C	1	5	2	8	12.5%	62.5%	25%
Project D	1	0	0	1	100%	0%	0%
Total	**27**	**40**	**5**	**72**			
Total %age	**37%**	**56%**	**7%**	**100%**			

Table-5: Project wise percentage distribution of pre-release CR's

These findings indicate that *majority of both the severity1 and severity2 defects are found due to high severity pre-release CR's.* However medium and low severity CR's also contribute towards defects but their contribution is less as compared to high severity CR's. Some reasons to this conclusion that we have found through the data analysis are given below:

1. *High severity CR's are the ones that require changes in the design of the system*, as defined for this study. Such changes require major rework and may affect all the subsequent development phases. Due to these reasons, even very minor design changes can introduce high percentage of defects if ripple effects/bad fixes are not taken under consideration and sufficient time is not spent on quality assurance.
2. Second reason to the occurrence of severity1 defects is due to the *initiation time of the CR's during the lifecycle of software development.* Our data analysis presented in Table-6 illustrates that majority of the high severity pre-release CR's are initiated late during the development of all the four projects i.e., during coding and testing.

Pre-Release CR's initiated in different SDLC phases							
	Severity of CR's	**Pre-Release CR's**					
		No. of Pre-Rel CR's	**% RS**	**% FS**	**% Design**	**% Coding**	**% Testing**
Total CR's	**High**	27	7%	4%	4%	33%	52%
	Medium	40	0%	0%	2.5%	25%	72.5%
	Low	5	0%	0%	0%	20%	80%
Avg CR's	**High**	6.75	2%	1%	1%	8%	13%
	Medium	10	0%	0%	1%	6%	18%
	Low	1.25	0%	0%	0%	5%	20%

Table-6: Pre-Release CR's initiated in different phases of the SDLC

Further Table-6 indicates that very few of CR's are initiated during the development of RS, FS and design. However most of the CR's are initiated during coding and testing phases.

Ratio between pre-release CR's initiated in Coding phase and severity 1 bugs	
Pre-Release CR's initiated in Coding phase of all projects	20
Severity 1 defects caused due to pre-release CR's	38
Ratio	20:38 = 1:2
Percentage of severity 1 defects due to pre-release CR's during coding[8]	13%
Ratio between pre-release CR's initiated in Testing phase and severity 1 bugs	
Pre-Release CR's initiated in Testing phase of all projects	46
Severity 1 defects caused due to pre-release CR's	196
Ratio	46:196 = 1:4
Percentage of severity 1 defects due to pre-release CR's during testing[9]	68%

Table-7: Percentage of CR's initiated during Coding and Testing phases

Table-7 shows that the average percentage of high severity defects introduced during coding and testing due to pre-release CR's is 13% and 68% respectively.

Further, the defects introduced late in the software development are difficult to eradicate and may cause a significant reduction in the overall *defect removal efficiency*[10] of the work product. The overall defect removal efficiency of Project A is 73% and that of Project B is 84%. Project C and Project D, however, have defect removal efficiencies of 100%. Therefore, the average defect removal efficiency of all the projects is 89%. Studies done by Capers Jones have revealed that top ranked companies such as AT&T, IBM, Motorola, Raytheon and HP achieved defect removal efficiency levels of 99%.

3. Another reason is due to the *average percentage of the time spent in different SDLC phases*. Our data analysis in Table-8 indicates that on the average only 15% of the time is spent on design of all the four projects.

Percent Average Time Planned (in days) for different SDLC Phases					
Project	**Requirement Specifications**	**Design**	**Coding**	**Testing**	**Others (Post Shipment Reviews, Shipments, Installations etc.)**
Project A	28%	12%	23%	26%	11%
Project B	32%	18%	25%	17%	8%
Project C	17%	15%	28%	20%	17%
Project D	16%	16%	33%	33%	2.5
Overall Average Duration	**23%**	**15%**	**27%**	**24%**	**10%**

Table-8: Percent Average Time Spent Planned (in days) for different SDLC Phases

4.2 Hypothesis-2: Relationship between Post-release CR's and defects

For hypothesis-II, Table-10 indicates that *there is a significant relationship between the number of post-release CR's and the defects since the significant value of the Chi-square test is less than 0.05.* This proves that the two variables are not independent and our null hypothesis is rejected.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	23.774[a]	2	.000
Likelihood Ratio	21.282	2	.000
Linear-by-Linear Association	1.009	1	.315
N of Valid Cases	1400		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 20.00.

Table-9: Chi-square results at significant level of 0.05

Figure-2 and Table-10 present the total number of defects found (categories: severity1; severity2) against the post-release CR's (categories: low; medium; high). *It is worth mentioning that these figures explain the combined results of all the 30 releases against 4 projects. However a detailed picture of percentage pre-release defects and CR's for each project is given in Table-12.*

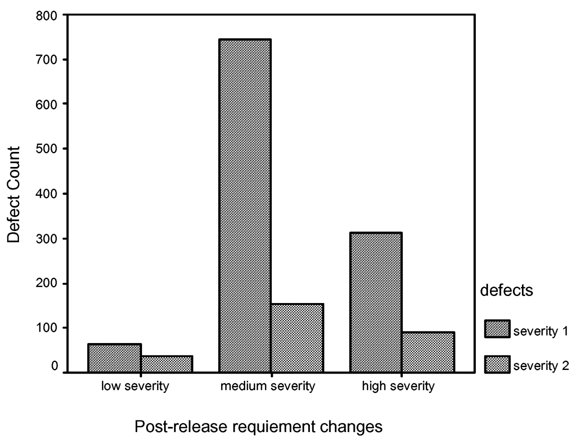

Figure-2: Defects VERSUS no. of post-release CR's

[8] (Severity 1 defects due to pre-release CR's in coding phase/Total defects due to pre-release CR's) * 100 = (38/286)* 100 = 13%

[9] (Severity 1 defects due to pre-release CR's in testing phase/Total defects due to pre-release CR's) * 100 = (196/286)*100 = 68%

[10] Defect Removal Efficiency = Total defects found during development/ (Total defects found during development + Defects reported by Customer in 1 year after deployment) * 100
To control defects, formal procedures for reviews (requirements, design, code and test cases) are the top ranked methodologies in terms of defect removal efficiency. Recent work done by *Tom Glib* support the early findings by *Michael Fagan (First introduced the inspection method at IBM)*. According to him most forms of testing are less than 30% efficient in finding defects, however the measured defect removal efficiency of both design and code inspections is more than 60% efficient which in some cases is as high as 88% **[7]**. The function point metric provides an interesting general rule for predicting the number of defect removal operations that must be conducted to achieve 95% cumulative defect removal efficiency. Using this rule raise the size of the application in function points to 0.3 power and express the results in integer. For example, an application of 100 function points would require 4 defect removal stages; 1000 function point would require 8 defect removal stages and so on.

requiement changes * defects Crosstabulation

			defects		
			severity 1	severity 2	Total
requiement changes	Post-rel sev. low	Count	63	37	100
		Expected Count	80.0	20.0	100.0
	Post-rel sev. medium	Count	744	154	898
		Expected Count	718.4	179.6	898.0
	Post-rel sev. high	Count	313	89	402
		Expected Count	321.6	80.4	402.0
Total		Count	1120	280	1400
		Expected Count	1120.0	280.0	1400.0

Table-10: A cross-tabulation table displaying the number of cases in each category

Results in Table-11 & 12 show that maximum number of severity1 defects (66%) is found due to (71%) of medium severity post-release CR's. However it is worth mentioning that only 15% of the high severity post release CR's have caused 28% of the overall severity1 defects, which is comparatively a high defect rate per CR as compared to the previous one (a high severity CR can cause two severity1 defects, whereas a medium severity CR can cause one severity1 defect). Similarly, maximum number of severity2 defects (55%) is found due to (71%) of medium severity post-release CR's but is comparatively less defect rate per CR as compared to 15% of high severity post-release CR's causing 32% of the severity2 defects (a high severity CR can cause about two severity2 defects, whereas a medium severity CR can cause one severity2 defect).

Overall Percentage of Defects of Severity 1 and Severity 2 due to Post-Release CR's		
Pre-Release CR's	**%Severity 1 Defects**	**%Severity 2 Defects**
Low Severity	6%	13%
Medium Severity	66%	55%
High Severity	28%	32%
Total	**100%**	**100%**

Table-11: Overall percentage distribution of defects due to post-release CR's

Percentage of Post-Release CR's							
Projects	**High Severity CR's**	**Medium Severity CR's**	**Low Severity CR's**	**Total CR's**	**%age High Severity CR's**	**%age Medium Severity CR's**	**%age Low Severity CR's**
Project A	21	185	33	239	9%	77%	14%
Project B	18	17	0	35	51%	49%	0%
Project C	6	12	4	32	19%	37.5%	12.5%
Project D	1	4	0	5	20%	80%	0%
Total	**46**	**218**	**37**	**311**			
Total %age	**15%**	**71%**	**12%**	**100%**			

Table-12: Project wise percentage distribution of post-release CR's

These results indicate that high severity CR's cause more severity1 and severity2 defects than medium severity CR's. However medium and low severity CR's also contribute towards defects but their contribution is less as compared to high severity CR's. There can be many reasons to this conclusion but here we have highlighted only those that we have found through data analysis:

1. Our findings indicate that average rate of requirements change[11] for the projects under study varies from 50-60%. Furthermore 83% of the CR's, for all the 30 release of four projects, are initiated once the project is shipped to the client (post-release) and only 17% of the changes are initiated before release. Furthermore, 83% of post-release CR's have caused 67% of severity1 defects and 16% of the severity2 defects. On the other hand, 17% of pre-release CR's have only caused 14% of severity1 defects and 3% of the severity2 defects. *These figures indicate that majority of the CR 's are initiated by the client once the system is released and are the major source of severity1 defects.*
2. One reason to this high percentage of post release changes is the lack of communication between the client and the development side. Either the client is not getting proper feedback at major system milestones or the client is not taking much interest till the final product is ready for deployment. Both these issues add towards the post release changes and in turn the defects. *This information was gathered through an interview with one of the project managers of the organization under study.*
3. Another reason for the initiation of such a large number of post-release CR's is that the *development side approves almost all the changes requested by the client* and does not realize the impact of those changes in the business model or the design of the system. This results in a system that has lost its original design and is patched with a broad scoped functionality.

5. Conclusion

In this paper, we have investigated the impact of both the pre-release and post-release requirements change on *overall defects* by defining measures, collecting data against those measures and analyzing the collected data through statistical techniques.

Based on the results obtained from the collected data, we have been able to uncover some of the major sources of defects. Prior studies **[17]** have examined the relationship between changing requirements and defect density at the coding phase and found that the requirements volatility has an impact on defect density. However no one has specifically examined the impact of changing requirements on defects throughout the SDLC and the root causes of those defects.

Our study is based on the industry data collected from 4 projects, all in e-commerce domain, consisting of 30 releases. It indicates that there is a *significant relationship between pre/post release change requests and overall defects.* It also indicates that

[11] Percentage rate of requirements change $= \frac{Rt - Ri}{Ri} * 100$;

Rt = The total number of requirements in a release including initial, pre-release and post-release requirements.

Ri = The total number of initial requirements in a release at the time of FS approval.

most of the overall defects are introduced due to changes in the design of the system at the later stages of software development, i.e., coding, testing and after the shipment of release. We found that the *average rate of requirements change* for the projects under study varies from 50-60% and majority of both the *severity1 and severity2 defects* originated due to *pre/post-release changes in the design of the software system.* In addition to this, average time spent on different SDLC phases has a significant impact on software defects. It was observed that only 15% of the project development time was allocated to the design of the system, which is quite less as compared to the time spent on other SDLC phases. Also, communication with the client is an important factor that contributes significantly towards the overall software defects.

Like most other researches in the context of requirements volatility, our study also has several limitations. Our analysis covers the effect of requirements change on software defects and the sources of those defects. This research needs to be further extended to study the effect of changing requirements on other factors, such as project cost, size and effort. Furthermore, our analysis is based on data collected from projects of e-commerce domain only. Future research may extend this work by considering projects from different domains and explicitly controlling other people related factors, such as programmer expertise in the particular domain and the communication methodology with the stakeholders.

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Appendix

Mathematical Description of Hypothesis-1 and 2

For hypotheses 1 and 2, both the variables have a number of categories (also called ***Categorical Variables***) and for this reason cross-tabulation procedure is used. For example: in the first case, we need to find the relationship between pre-release CR's (with categories: low; medium; high) and defects (with severity categories: severity1; severity2). In the second case, we need to find the relationship between post-release CR's (with categories: low; medium; high) and defects (with severity categories: severity1; severity2).

The basic element of a Cross-tabulation is the count of the number of cases in each cell of the table. It is based on comparing the observed count in each of the cells with the expected count. The expected count is simply the number of cases that we would expect to find in a cell if a null hypothesis is true. *In other words if the observed count is equal to the expected count then the null hypothesis is true.* Mathematically the value of the Pearson's Chi-Square test can be calculated as: **[1]**

Pearson's Chi-Square value =

$$\sum_{i=1}^{r} \sum_{i=1}^{k} \frac{(Oi - Ei)2}{Ei} \qquad \textbf{.............eq. (A)}$$

Where:

r = Number of categories in the first observation (in our case: severity1; severity2)

k = Number of categories in the second observation (in our case: high; medium; low)

Oi = Observed number of cases in the **i**th category

Ei = Expected number of cases in the **i**th category

For this study we have selected the value of ***Level of Significance (α) = 0.05.*** This is the probability of rejecting the Null hypothesis, when the Null hypothesis is true i.e. there are 5 in 100 chances that the Null hypothesis is rejected.

> *A chi-square probability of 0.05 or less is commonly interpreted by social scientists as justification for rejecting the null hypothesis that the row variable is unrelated (that is, only randomly related) to the column variable* **[2].**

PROCESS PLANNING

Improved Process Planning by a Material Flow Simulation with Multi-User-Support

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INTRODUCTION

Large simulation processes are typically organized by a team. Especially the planning of new processes requires a lot of different skills. Simulation and visualization are established methods supporting these tasks. But especially simulation models can't be build cooperatively by a team. Until today one person has to model the whole process and perform all the simulation studies.

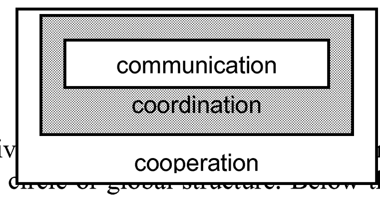
This paper analyses the interaction techniques, which are required to build and execute a material flow simulation model. Based on these techniques potential conflicts, aroused by parallel action of different users on one model, will be analysed. A locking, versioning and cloning based method set will be introduced and discussed to solve these problems. Finally the architecture, on which these methods work will be presented.

STATE OF THE ART

Methods of cooperation

Cooperation serves the acquisition of potentials to generate higher benefit. Enterprises with a huge amount of divisions need to coordinate the different points of view. In order to improve efficiency, methods of cooperation have to be realised. Characteristic for cooperation is the harmonization or the collective gratification of operational tasks by several independent departments.

Putting cooperation in a more global context, it must be connected closely to the terms of communication and coordination. Collaborative work is the summation of task based activities, which are done by group members to achieve goal oriented tasks and therefore gain group targets. Therefore group processes need to be initialised as communication, coordination and cooperation, which can be organised as shown in Figure 1. While communication is the understanding of multiple persons among each other, coordination is communication, which is necessary to adjust task based activities performed within the scope of collaborative work (Teufel et al. 1995).



Weidner div[...]ructures as the star, chain, circle or global structure. Below they are briefly shown (cp. Figure 2). So coordination adjusts local actions and decisions to fulfil global targets. For this reason coordination enables exact resource-input and efficient teamwork.

Figure 1 Group processes in collaborative work

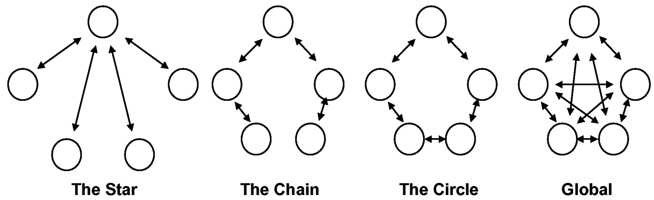


Figure 2 Communication systems (Weidner 1998)

Cooperation must also be illuminated from the perspective of computer supported collaborative work (CSCW). Collaborative work includes two essential aspects: Space and Time. Spatial viewed, collaborative work can be arranged face-to-face or in a distributed group. Temporally focused it can be arranged synchronously or asynchronously. This leads to a contemplation of collaborative work by building a space-time matrix (cp. Figure 3).

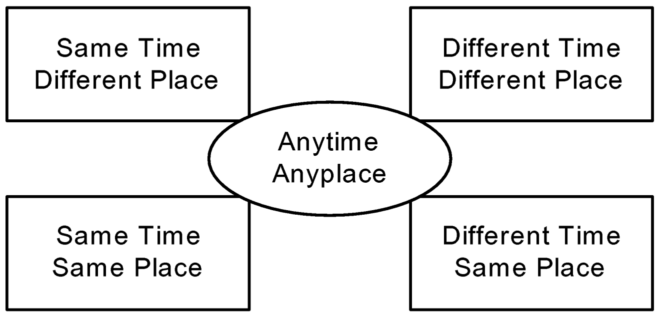


Figure 3 Anytime-Anyplace matrix (cp. Johansen 1991)

The realisation of cooperation at any time and any place can be supported by two mechanisms of communication: direct and indirect communication. While direct communication deals with propagation and management of message streams between the involved co-workers, concerning services as creation, transfer, synchronisation and filtering of message streams, indirect communication is based on a central or distributed workspace to work on shared artefacts (Schlichter et al. 1998). This is accomplished by group editors which allow a simultaneous editing and a synchronous observing of changes. Features of such group editors are part of the functionality of a single-user editor and in addition collaborative awareness, concurrency control, replication management, versioning and locking mechanisms (Prakash 1999).

Collaborative awareness yields an understanding of the activity of others to provide a context for own activities. This is one essential assumption to work on shared artefacts.

Concurrency control is needed to ensure consistency of shared and edited data. It is cut into an pessimistic and optimistic approach. The pessimistic approach makes high demand on consistency realised by central or peripheral control. The optimistic approach does not assure consistency and in turn allows inconsistent access on shared data which is in some cases even beneficial (Davidson 1984).

Fundamentally, replication management can increase availability. Here the disadvantages of replication have to be mentioned, if co-workers have different rights to work on shared data. Access then has to be separated into writing and reading access. Regarding the writing access, the power of a distributed CSCW-system might be reduced, because the constancy of the extrapolation of logical data raises with the amount of its physical copies.

To reduce the impact of extrapolation interdependencies concerning messages have to be regarded. Both, few messages with big volume and many messages with little volume have influence on power. To decrease this access entities of a defined size will be embodied as data blocs. If modifications are made within the data blocs the system needs access algorithms to transfer the replicated data blocs to a corporate consistent state. Meanwhile, it is not permitted to successfully have access to inconsistent data.

Versioning assigns a distinct number to a replicated data bloc, in order to compare the actuality of similar data blocs in different files.

Locking mechanisms are adopted on the data bloc level and define, whether a co-worker is qualified to modify or just to read a data bloc. A lock can prevent a concurrent access on the same data bloc within the same file and in turn still admit parallel access on different data bloc within the same file.

The entire data structure of a shared artefact can be illustrated as shown in figure 4.

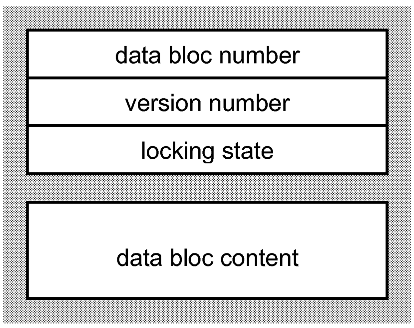


Figure 4 Structure of a data bloc (Borghoff 1998)

Cooperation in Material flow simulations

Today integrated packages like eM-Plant or Taylor ED are used for material flow simulations (Mueck and Dittmann 2003 or Klingstam and Gullander 1999). With these tools the user is able to model and execute models of production processes in one simulation environment. The whole process of modelling, execution, analysis and modification takes place on the computer of one person. If more than one user wants to edit a model, this can be done only sequential (Dangelmaier and Mueck 2003). Only one user can work at one model at the same time.

An established approach is to operate with several sub-models, where the whole model consists of sub-divisions. Each disjoined sub-model can be modelled by another team member. To calculate the whole model, one has to integrate all sub-models into a large aggregated model. In this approach all dependencies between the sub-models must be recognised by the integrating user. If changes are required, the integrated model can't be modified by more than one user at the same time. Due to the lack of versioning, it's difficult to reconstruct the changes of other team members during the modelling process. After the integration in a entire model, it is difficult to separate the sub-models again in their building blocks, for example, if one sub-model has to be replaced by a newer version. To solve this problems of interaction, the modelling process of a material flow simulation has to be regarded closer.

MATERIALFLOW-SIMULATIONS

Models

Material flow simulation models typically consists of blocks representing the modelled process entities and marks representing factors of production (e.g. parts). If two blocks interact, they are linked by connections. During the analysis phase the marks follow these connections.

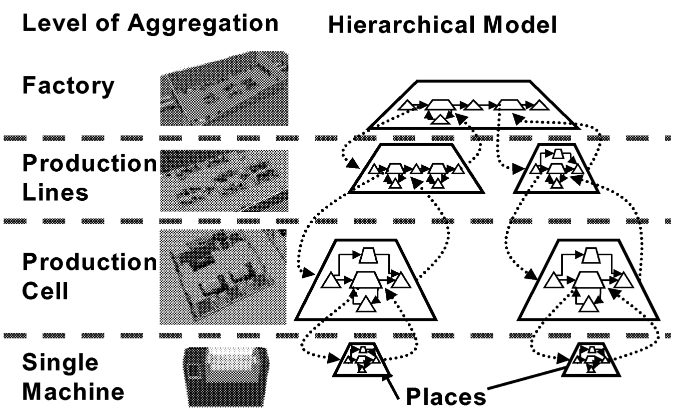


Figure 5 Hierarchical models for material flow simulation

In order to handle large models they are organized hierarchically. Several machines can be aggregated to one production cell represented as one place or block. Connected blocks can be aggregated to lines and lines can be aggregated to production stages. Links exist only within a sub-model. To interact on a more aggregated level the blocks have special connectors. The user can work with the whole aggregated building block at once. Large models become manageable (cp. Figure 5).

The Modelling Process

To Manage models and their sub-parts, several interaction techniques are required. It is necessary to allocate behaviour types to the used objects. This parameterisation defines, how objects can be placed, resp. integrated in the modelling environment in any way. Major types are: create, delete, select, move or connect objects. These types are considered closer during the next paragraph.

1. Creating objects is the fundamental step in modelling a simulation scenery. In most cases the objects are archived in component libraries. By drag & drop objects can be placed in the scenery.

2. Selecting objects is the precondition to apply other types of interaction. Selection is required before any movement on a focused object can be generated. The user needs a visual respond on the object to see, if the selection was successful. An example is given below in figure 6 (a frame which is placed around the selected object).

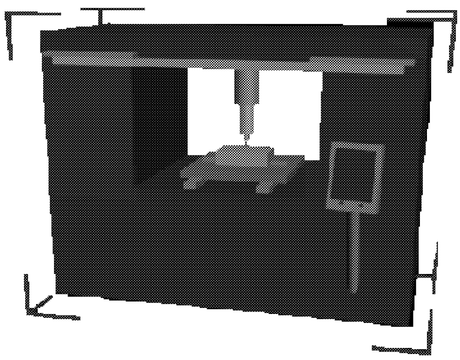


Figure 6 Selection frame around the object

3. Deleting objects is essential to make work flexible. It allows to recreate the scenery at any place and any time. Therewith exists the possibility to repair errors. It is not necessary to show the action since it is deleted anyway.

4. Referring to the layout, the movement of an object is required to organise the scenery. By moving objects a way to arrange them is given. After the selection the user can move the object within the scenery. By the use of moving features it is possible to clarify the activity structure or the hierarchical order. At best, a combination between the simulation an the 3D-factory planning is generated by placing the representatives of the simulated blocks in a most realistic environment.

5. Finally, connecting objects describes the relations between the items, e.g. how the child responses to its parents. These connections also determine the directional flow of the marks.

For every object special parameters can be adjusted, which influence its behaviour. By changing calibrations the material flow within the objects changes. Therefore a block must be selected, so that the operator has access to all specific parameters. Another aspect is the modification of the mark running through the object. Through the transformation within a block or object, it can change its condition. Modifications may be the dimension or a new shape.

As long as the working environment is limited to one user at the same time, all these types can be handled easily, but through the possibility of a multi-user interface, several conflicts may be generated by the application of several types at the same time.

The Simulation Process

After the modelling phase the execution of the simulation analysis takes place. It includes the simulation parameters, the execution itself and the analysis of the result. In contrast to the general parameters in the modelling phase, these input parameters determine the simulation flow and contain, how flexible the execution of the simulation flow can be configured and of what complexity the information about the simulation flow can be collected. During the execution the user-friendliness takes centre stage, e.g. how easy control commands can be entered (Mueck and Dittmann 2003). Several interaction techniques have to be implemented to change input data online during the execution of a simulation experiment. The analysis comprises, if there is a valid examination or an error statistic and how results can be illustrated appropriately.

Similar to the modelling phase the interaction of more than one user has influence on the execution. The next paragraph elaborates possible conflicts which might occur in a multi-user simulation environment.

CONFLICTS

The system follows the ideal of a multi-user system to model and simulate parallel in any situation. Upcoming conflicts can be separated in three cases. First, two users want to change the simulation model at the same time. Secondly, two users would like to run their simulation experiments at the same time, based on the same model. Thirdly, a user wants to change the model while another one runs a simulation experiment on the same model.

The first aspect includes the requirement for time parallel modelling since two or more persons have significant ideas or defaults to be directly integrated in the model. Possible conflicts are, for example, the access on the same object or the delete of an object, that is necessary for another.

Referring the second category of conflicts, the same simulation model is used for two or even more simulation experiments at the same time. Solving this conflict leads to another additional feature of simulation experiments. If it's possible to simulate different parameterisations on the same model, one user can deposit several adjustments, which can be simulated at the same time on different machines.

The third aspect bases on the conclusions of the first and second one. While the simulation is running an adjusted experiment, a change in the origin model would adulterate the experiment result, because it could possibly lead to variances of the material flow concerning the modified elements running throughout the system.

Concerning all three dimensions, the next paragraph will point out the most important methods to solve the conflicts.

APPROACH

In order to handle all the described conflicts three methods have been adopted: Locking, Cloning and Versioning.

One possible way to work parallel on a subject is cloning, the multi-instantiation of a basis model. At the beginning of the working progress a clone of the actual model is created for every request. The difficulty is the integration of the different clones at the end of every process. Versioning helps to solve these conflicts, as long as it is possible to generate former versions of the actual model and compare them to the actual changes. Mechanisms have been identified , which handle those change conflicts.

During the modelling phase another method is more encouraging. By the use of lock mechanisms, several users can work on the same model. As long as they work in different parts of the model, no conflicts are generated. If two users want to access the same object, it is locked by the first user and stays locked until he finished his adjustment. Of course, a locked object has to be visualised. With available communication possibilities, the users can arrange themselves in the virtual environment.

Remembering that the model bases on different levels of hierarchies, the implementation of the locking method is more difficult. The lock of a specified object is deeply connected to the lower (more detailed) levels of the simulation model. Furthermore the upper elements connected to the locked object have to be marked, so that they also can not be changed. Figure 7 shows an example of the locking mechanism. Despite that the system allows users to work parallel on the model on each level whenever two objects are not connected in their hierarchical order. Conflicts can only occur when two different users work in the same branch. The users will directly resp. indirectly take influence on sub- or superior objects by editing sub-models of a locked node from a higher level.

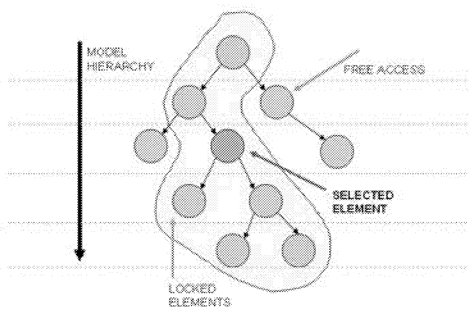


Figure 7 Locked elements in the model hierarchy

While saving the different changes of the model, several possibilities for the change management are imaginable. Beside the creation of a new version number, sub-versions are as allowed as the backup under a complete new model name. If a new (sub-)version number is given, the changes always have to be recorded, so that former versions can be computed. Every object of the basic model has its own timeline to reproduce the changes over the different versions.

Cloning is still the most easiest way, if the user wants to adjust a special simulation experiment. Through the versioning it is possible to generate older versions from the new ones, and therefore it is only necessary to save the actual version number, if a experiment is configured. The clone itself exists just over the simulation time. Afterwards the adjusted parameters and, of course, the simulation output as a compressed result resource has to be stored in the database. There is no need to archive the hole model.

The next paragraph will introduce the working architecture, in which the described mechanisms are realised.

ARCHITECTURE

The development of a entire simulation architecture for the process planning in virtual environments leads inevitably to the question, how multi-user requests to the database model are handled.

The module-based simulation environment for virtual process planning and control, which is developed at the chair of business computing, esp. CIM at the University of Paderborn, bases on a central data management of standardized objects and a controlled access to the necessary data fields. By the use of authentification and authorization the access to the data models can be limited and all applications have a restricted access to the necessary data areas. While all simulation data is held in a central storage, mechanisms of multiple access to the data areas had to be developed. Figure 8 shows the general architectural layout of the entire simulation environment.

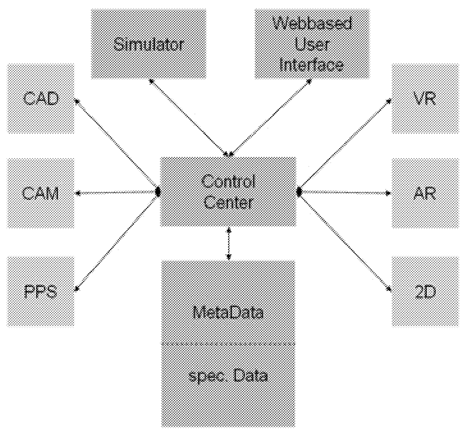


Figure 8 Architecture "digital plant"

The information flow is always attached to the central control center, where all accesses and filter methods are implemented. While every user (or application) access is bounded to the contol center, the described mechanisms for multi-user access are here integrated. The different versions are handled and administrated, and the generation of clones is initiated and controlled.

With the use of a single data area and a centralized access several modules can be established on the same data environment. Through the multi-user capabilities a parallel work on the data basis keeps possible.

CONCLUSION

Though large simulation projects can only be handled by teams, today's simulation applications don't support any multi-user capabilities.

Enabling team work in virtual environments, communication methods must be supported as well as the coordination of the collective work through coordination methods. According to the planning and control of manufacturing processes especially the development of simulation models and the parameterisation of simulation experiments must be coordinated.

With the present approach the multi-user capability of the module-based simulation environment is supported through the use of three methods: Locking, Versioning and Cloning. Whereas locking and versioning allow parallel development work on the same model, the combination of versioning and cloning leads to multiple simulation experiments based on an actual process model. The cloned model itself has not to be stored separately after the termination of the simulation process, because every version of a simulation model can be computed. The simulation input and output data are saved separately in the database system.

The system architecture of the module-based environment supports the usage of this regulating methods by the use of a central control center, which is bounded to every application relating on the consistent data area.

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BIBLIOGRAPHIE

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SYSTEMS ENGINEERING BASED APPROACH FOR PRODUCT AND PROCESS CONCURRENT DESIGN

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KEYWORDS

Systems engineering, concurrent design, product upstream design, manufacturing process upstream design, requirement modelling.

ABSTRACT

This paper deals with the concurrent design of a new product and the process to obtain it. The presented approach is based on the use of the principles defined by the Systems engineering community. The attention is called on a point of peculiar interest: the upstream design step, where are shown the necessary relations established between the product upstream design and the process upstream design. The electrochemical oxygen microsensor example is used to illustrate this design step of a new product.

I. INTRODUCTION

The goal of this paper is to suggest a formalisation based on Systems Engineering methods for product and manufacturing process concurrent design. The use of these techniques can be a valuable aid to point up the interactions between product design and process design. These interactions are particularly significant since the product is an innovative technology product like micro or nanosystems.

Let us consider two points: on the one hand, it's obvious that system complexity is increasing, and quite difficult to take into account all the system with all its details. On the other hand, in order to reduce the costs and the time to market of new products, as micro/nano-systems, it is now necessary to know how to carry out the concurrent design of the « Product » and the « Process ».

These two points are intensively taken into account by Concurrent Engineering which suggests the development of new product using a global approach [Prasad 95]. All the tasks of the project are performed in parallel reducing the time-costly sequential operations, among others, for very large project, or less (cf. the research project ENHANCE of the European Aeronautic product development, or the contribution of [Eversheim et al. 02]).

An other way to hit cost and time to market reductions for an innovative product is obtained when applying the principles of the Systems Engineering [Buede 99]: « *an interdisciplinary approach and means to enable the realisation of successful systems* » as defined by INCOSE[1]. Systems Engineering is based on several processes such as « V-life cycle » and « Requirement Modelling ».

It could be recalled in few words that the V-life cycle is defined to separate the problem area from the solution area, using an iterative cycle based on four steps. The Specification step defines in a detailed and rigorous way all the requirements the system needs to respect. The Design step consists in designing the technical tree structure to obtain the lower level components by an iterative decomposition. The Integration step is assigned to build the system by its components composition. Finally, the Validation step is needed, for each requirement, to check the conformity of the integrated system with all the defined specifications.

Because of the difficulty to separate the product from the manufacturing process [Abadi et al. 03] [Leibrandt et al. 98], it seems useful to work with the same basic process in both cases.

For this, the second quoted process, « Requirement Modelling », helps to solve this difficulty. This is one of the different processes used by Systems engineering approach. It is a helping tool for the control of the system development and for the control of its evolution during all its life. The way in which the steps of this general process follow on from each other is shown on figure 1. The first step concerns the users needs capture. The objective of this step is to explore, collect and understand the need of the system. This task is performed simultaneously with the analysis of users and stakeholder needs and expectations. The second step is the requirements analysis: the activity of this process consists in the translation of the stakeholder needs into system technical requirements, and to do the technical analysis of them. The third step includes the verification and validation step of the technical system requirements. Verification addresses whether the system, its elements, its interfaces, satisfy their requirements. Validation confirms that the system will satisfy the user's needs. This process analyses the quality of each requirement and the coherence of the set of them. Finally, the fourth step has a modification activity. A corrective action may be necessary, consequently to the activities of the different processes performed during the global cycle of requirement treatment.

[1] International Council on Systems Engineering

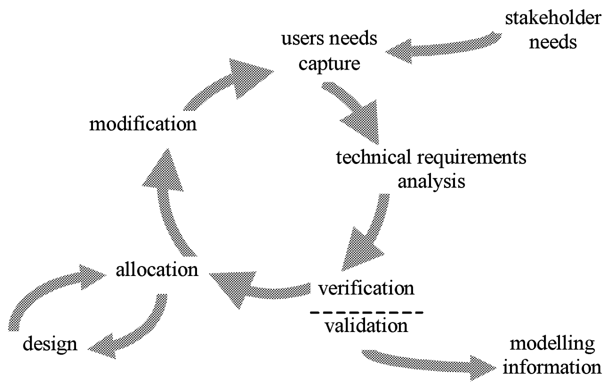

Figure 1. Requirement Modelling

This introduction was necessary to explain the two basic processes used by our approach. The second section of the paper shows the main aspects of our approach for the « product » and « process » concurrent design. The third section details an example selected to illustrate the use of the approach and to point up the interactions between the two processes. Finally, the fourth section concludes the paper.

II. APPROACH

In aim to reduce the costs and time to market of new system products, it is essential to run in parallel the product design and the process design processes [Cohen et al. 96] [Duhovnik et al. 01].

Our approach is primarily Top-down, and it associates in parallel (figure 2): Product design, Process design, Project management.

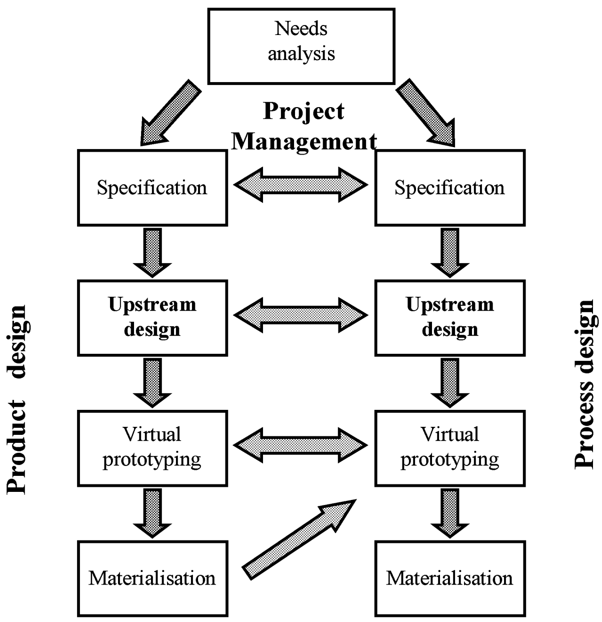

Figure 2. New product design methodology

Generally, a project begins with a phase from upstream study which determines the feasibility of the project and defines its high level objectives. This phase of needs analysis consists in exploring with all concerned parts the various aspects of the problem field.

II.1. Specification level

The specification phase consists in defining in a detailed and rigorous way the requirements needed to be respected by the system [Meinadier 02]. This phase is placed in the field of the problem to solve, independently of the chosen solutions. The requirements to define can be selected from two classes [Meinadier 98]: functional requirements or non-functional requirements.

The finality of the requirements definition step consists in deriving from the exploration of the problem field, all the requirements to which the solution will have to conform. These requirements are translated into technical requirements from system or subsystem needs.

The following step is the Requirements verification and validation step. The verification of the requirements modelling consists in making sure formally that the transformation process of the stakeholder needs into technical requirements is correctly applied. The validation of the requirements is made up of evaluation activities, with the objective to make sure that the technical requirements are the best translation of the problem. During this validation process, some mistakes can be pointed out to the designer, like the lapse of memory or the fact that some stakeholder needs are not taken into consideration. These deductions imply a new iteration on the requirements analysis process [Meinadier 98].

The processes of the specification level for product design and process design will not be more detailed in this paper, we will focus on upstream design. However, it is necessary to indicate which is the information needed by the design level. This information will be associated to the requirements of the product upstream design and the process upstream design processes.

Thus, in the case of the product specification, this information is gathered in a "product specification file", including technical data and information on costs and time to market expected values. Information resulting from the process specification relates to the production cost, production rate, and time to market, among others.

Now, we will consider the upstream design level detailed on figure 3. The next three parts will explain the chosen approach to obtain the reference frame of requirements.

II.2. Product upstream design

The product upstream design process is based on the requirement modelling process. The specification file constitutes the starting base for the design process (figure 3, left part).

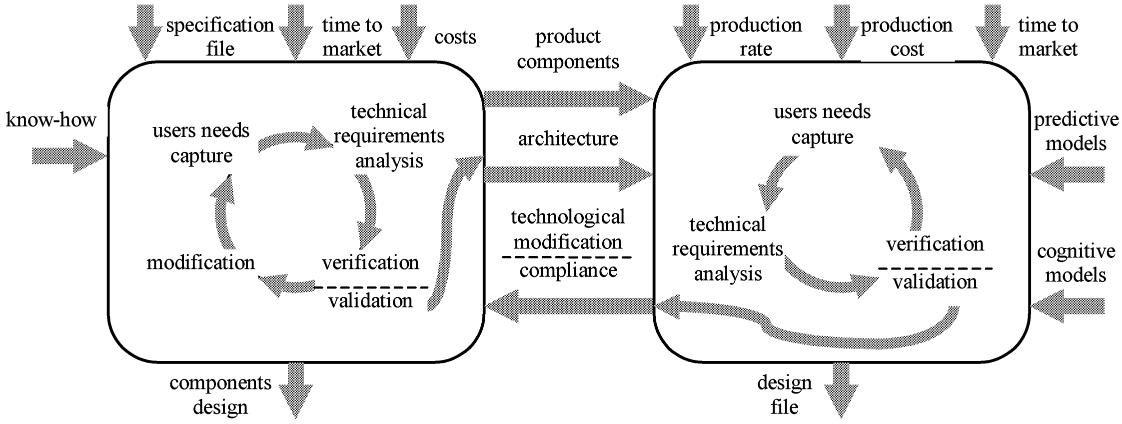

Figure 3. Product (on left) and (on right) Process upstream co-design

The first step of the process relates to the users needs capture. It is an important step because there are a lot of technical information, from the functional class (e.g. “dimensioning of the product”) and non-functional class (e.g. “the cost”). Moreover, the know-how of project manager is useful to be ensured of the realism of these needs, and to refine them if necessary.

The second step of the process consists in translating stakeholder needs into system technical requirements. The most important result of this step is the initial creation of a design file containing the characteristics of the product: its architecture, the needed components and their characteristics, etc.
The third step is verification/validation of the technical requirements. On the one hand, the verification consists in evaluating each technical requirement to ensure that it would have the quality representation of the users need from which it is the translation. On the other hand, it would be checked that there is no contradiction among the expressed requirements. Validation is based on the stakeholder needs, which led to requirements description. The question here is to ensure that each stakeholder need would be taken into consideration.

The technical requirements verification/validation failing involves to return on the requirements analysis step. At the end of this step, the product design process is achieved and the product design file is transmitted to the manufacturing process upstream design, which will analyse it. This process answers either by a continuation development acceptation or by a modification request. The second situation is associated to a technology modification request or to a non-conformity problem. This implies a new capture of the users needs.

II.3. Process upstream design

This design process is based on the requirement modelling process (figure 3, right part).

As the product design process, the starting step of the process is the stakeholder needs capture. However, in addition to the stakeholder needs, this step has to take into account the information transmitted by the product system design process, by way of the product design file. This set of needs is analysed and refined and is presented to the next step.

The requirements analysis step is developed to ensure of the feasibility of the needs. For this, the activity is based on the experience feedback, realised by predictive and cognitive models and constituting the know-how for project manager. A set of system technical requirements is then available.

The verification/validation step can lead to conclude that some technical requirements don't respect the initial needs: a new iteration is carried out within the design process, as an « internal feedback ». When these iterations are ended, the result of this step is transmitted to the product design process in various terms: either the product associated to the design file proposed is feasible, or it is feasible with some compromise of realisation, or it is not feasible. The product design process will react consequently to these « external feedback ».

When the product is realisable, it is then possible to continue the development of the process design. The virtual prototyping level can be started with all the information defined above: the objective is to obtain the best knowledge of the manufacturing process, before its effective realisation.

II.4. Product and process co-design

The concurrent design consists in binding the two design processes as suggested in figure 3.

The product design process is a “major” of the design movement and provides a design file expressing a set of technical requirements that the process design task would have to take into consideration.

The process design task considers:
1) the product design file proposed is the description of a feasible product: it is then possible to pass to the following level,
2) the product detailed in the design file is not feasible: the upstream design processes will have to be reactivated for the elaboration of new technical requirements,
3) the product is feasible if some compromises are respected. The product design process checks the acceptability of them for the stakeholder needs it must honour, and gives a new product design file with more precise design information. This induces a new iteration between the two design processes.

When no more iteration of this development level is necessary, it is possible to refine the two branches of design, while evolving the level of virtual prototyping.

III. EXAMPLE

The presented approach will be illustrated by the following example: an electrochemical oxygen microsensor [Dilhan et al. 95]. The sensor is an essential component for measurement and regulation: it converts the observed phenomenon in an electric signal. LAAS-CNRS interest in these problems is to consider that microsensors constitute an economic challenge for the ten next years. It was decided to open a prospective thought of electrochemical microsystems for production, an other domain interested by concurrent engineering [Ohtomi et al. 02]

III.1. Analyse of the users needs

This first step is based on an interview of the users to know their needs. The designed microsensor has to be able to measure the oxygen rate dissolved in water and that according to an electrochemical principle and the smallest size as possible. These users needs can be translated into terms of cost, quality and functionality.

III.2. Specification level

In this level, we can distinguish the product specification and the process specification.

- product specification
From the data provided by the analysis step of the users needs, we deduced non-functional information (time to market, cost) and functional information (dimension of the microsensor, measurement range, temperature of use) collected in a specification file.

- process specification
Based on the previous specification file, among others, this step gives some information concerning the process, as the annual rate of production, the production cost, the increase in the production rate, and the satisfaction of the customers.

III.3 Product upstream design

- users needs capture
This step collects the stakeholder needs and the product specification file. The main information are time to market, selling price, life span, and the functional information collected in the specification file.

- requirements analysis
The translation of the stakeholder needs into system technical requirements for the dissolved oxygen microsensor is mainly based on the knowledge and the know-how of the design team. Previous works, usage of paste-ups or simulations lead the design engineer to define the structure of the sensor (figure 4) and to dimension its elements such as the two electrodes and the volume of the electrolyte.

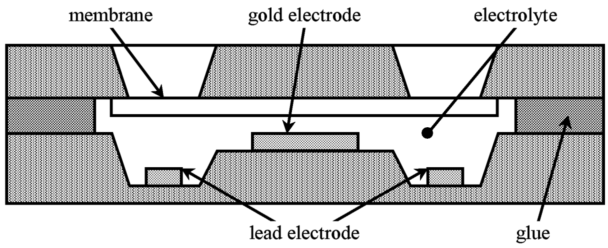

Figure 4. Electrochemical oxygen microsensor

The components of the system are: first electrode, second electrode, electrolyte, porous membrane. The electrodes are immersed in the electrolyte, and a permeable membrane with oxygen separates these elements from the solution to measure. The oxygen contained in the solution diffuses through the membrane towards the electrolyte, and the two electrodes are consumed by chemical reactions. These chemical reactions induce the creation of an electric current between the electrodes, which value is in proportion with the number of oxygen molecules of the solution.

- technical requirements verification
Each technical requirement is analysed, to verify its conformity with the user need. For instance, a functional user need is the reduction of the dimension of the sensor: the technical requirement is to realise a microsensor no much greater than a few cm^3.

- technical requirements validation
Is there any contradiction between several technical requirements ? For instance, is the compatibility of the silicon parts and the porous membrane sufficient for insuring of the best quality ? When all the answers are positive, the product design file is closed and is available for the process design task.

III.4. Process upstream design

- users needs capture
For this step, the information is coming from two origins:
- users needs coming from the specification level: production cost, production rate are some of them,

- the product design file provided by the product upstream design.

- requirements analysis
The translation of the users needs into system technical requirements may lead to various possibilities in terms of choice of components, implementation or assembly techniques. There are two techniques of implementation of the microsensor, called « dry engraving » and « wet engraving ». When the first is expensive, precise and with a relatively short time of realisation, the second is not expensive, less precise, and has a realisation time greater than the other. In the same way, different assembly modes are available, and the fastest and most judicious technique must be adopted.

- technical requirements verification/validation
The conclusion of the verification/validation step is the execution of different feedback loops.

- ***Internal feedback*:**
necessary to choose the assembly mode of the microsensor, because several alternatives are possible: serial assembly and parallel assembly. The chosen technique will be based on parallel assembly, because the production will be faster, even if this implies some synchronisation in the production technique.
However, the second technique lends itself better to a faster production because the two parts can be carried out in parallel before to be stuck sets.

- ***External feedback (between processes): modification***
for the oxygen microsensor a problem is detected concerning the precious metal electrode, because the initial technical requirement is to made it from silver. Working techniques for this metal are relatively expensive. Then a proposition is made to the product design process to reformulate the need, i.e. to propose to work with another metal, if possible. This proposition is evaluated by the other process, which defines new modelling requirements and proposes the use of gold.

- ***External feedback (between processes): choice***
because of the two techniques of implementation, it is necessary to propose to the product design process to choose between « dry engraving » and « wet engraving ». This information is sent with the entire characteristics dimension, to define the use of the most suitable technique. New technical requirements will be defined for the product design, taking into account the dimensions suggested by the process design.

When the requirements verification/validation step is ended, both product and process are designed. It is possible to start the next level of development called « virtual prototyping » which will allow the design teams to know with a lot of detail the manufacturing process before its effective realisation.

IV. CONCLUSION

This paper shows a Systems Engineering based approach for a new product design and the concurrent design of the process to obtain it. The Systems Engineering approach and more particularly the "requirement modelling" process permits to clarify the interactions between product design and process design which are necessary in the case of new technology product like micro/nanosystems.

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COLLABORATIVE CE-ENVIRONMENTS

AN APPROACH OF WHITEBOARD-BASED INTERFACE FOR COLLABORATIVE ENVIRONMENT

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KEYWORDS
Video conference, whiteboard interface, collaboration tool, teleoperation application.

ABSTRACT

As the increasing demand on video conference/meeting for business or technical meetings, a number of commercial or free systems are available, and a user can easily setup an environment for video meeting/conference. However, the main objective of these system is to provide an environment for audio/video communication for participants and is not suitable to share a common virtual space where participants can work furthermore collaboratively just like a face-to-face meeting. What we are pursuing in this study is to develop a collaborative environment where participants can share a common virtual space for collaborative work. Just like typical meetings, what we only need is a typical whiteboard to setup this environment so that participants should have the same feeling just like attending a typical meeting. However, what the participants can do is not only to write down some memo on a whiteboard, but also to control computers to hold a video conference, and even to manipulate teleoperation in the same environment. To set up this environment, we have developed CALAVIS system as the main video conference module, BOCOLLA system for whiteboard interface, and a sample teleoperation model to be used in our experiments. This paper describes the overview of these subsystems and model, explains what we can do in this environments to show the approach in this study, and presents the direction towards which the study is going.

INTRODUCTION

Demands on collaboration environment for distance and/or global participants have been expanding in various areas, including product design and development, regular or special meetings, routine communications, and so on. Video conference system, for example, provides very advantageous environment, which allows participants to join the meeting globally even across the world. Several kinds of commercial or free video conference systems are available today to enjoy the benefits of video conference environment. Web conference pro by Valu-Tel, NetMeeting by Microsoft, ViaVideo or PictureTel by Polycom, Flash Communication Server by Macromedia, CuSeeMe by First Pro, etc. Some of these systems requires specific hardware, whereas others do only require general web-camera with headsets. In either case, it is becoming quite easy to set up an environment to start a video conference.

Although video conference is one of the application systems running on PC environment, it is basically used independently from other application software. Even if the participants are supposed to discuss, for example some data on CAD application, or to discuss some developing application over the video conference, participants cannot share them over the video conference. Therefore, much integrated environment in video conference is strongly required to support more collaborative work.

For a single participant who communicates with the counterpart participants, PC monitor provides ideal interface, because the participant can join the video conference as well as work on general PC applications. However, for multiple participants who communicate with other party comprising multiple participants, a large display or a large screen with projection would be better to support suitable communication. In that case, the display or the screen is prepared as a specific environment especially for the video conference, which is separated from general PC applications.

For meetings or lectures in general, it is very common and effective to use a whiteboard to describe or to show something which might be very difficult to explain in spoken words, but could be easier to explain in written words, memos, figures, equations, sketches, and so on. In video conference, participants can communicate each other face to face even located physically in different places. In this sense, participants do not have to worry about the location where other participants currently are. However, video conference participants cannot use whiteboard-based communication, which is primitive but an effective tool in meetings.

This study adopts whiteboard as communication media which should contains all of the information to be shared in virtual spaces for video conference, and is implementing a whiteboard-based interface system for integrated environment to support collaborative activities, which could overcome the difficulty in communication over popular video conference systems. The whiteboard interface works not only as an interface for video conference, but also for computer which controls teleoperation devices as well as application software to be shared in the virtual space.

This paper presents an overview of the prototype system to implement the idea mentioned above, describes two of the key component subsystems, which are called CELAVIS and BOCOLLA, and shows how the video conference can be carried out through the whiteboard interface. In addition to this basic features, teleoperation for remote device can also be embedded to the prototype system. Describing a miniature crane, which we have developed for this objective, the paper shows how the participants for a video conference can include teleoperation under the whiteboard interface. Finally, the paper summarizes what we have done and found in the research, and discusses the feasibility of our idea.

PROTOTYPE SYSTEM OVERVIEW AND ITS EVALUATION

To evaluate the idea of whiteboard-based interface for collaborative environment which this study is proposing, we have implemented a prototype system, of which basic component is a custom-made video conference system module called CELAVIS (Collaborative Engineering LAb VIdeo conference System). Participants can join a CELAVIS video conference using a standard PC via an IP based network connection. Another key component of the system is a whiteboard-based interface called BOCOLLA (BOard-based COLLAboration interface), with which participant can join the video conference through a conventional whiteboard, and also manipulate local or remote computers during the conference.

Video conference interface (CELAVIS SYSTEM)

To set up the prototype system environment, we have developed CALAVIS system as the main video conference module. Figure 1 shows an internal process of CELAVIS system, when video conference is being carried out between client 1 user and client 2 user through celavis server in the middle of the figure.

The main control system of CELAVIS is based on Flash communication server which runs on a Linux server machine. Our original client software which is required on each client PC to access CELAVIS system, is portable and very compact software written in Flash programming, can be easily accessible through a portal web site which is provided by our laboratory to support video conference.

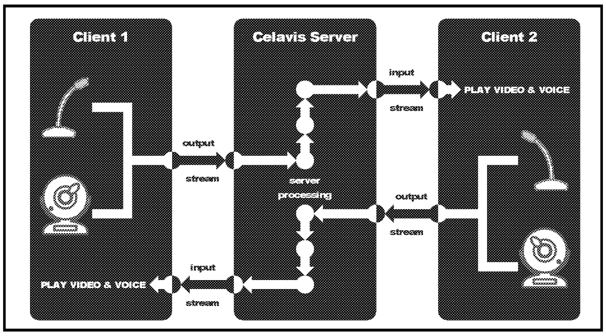

Figure 1: Overview of data transmission in CELAVIS

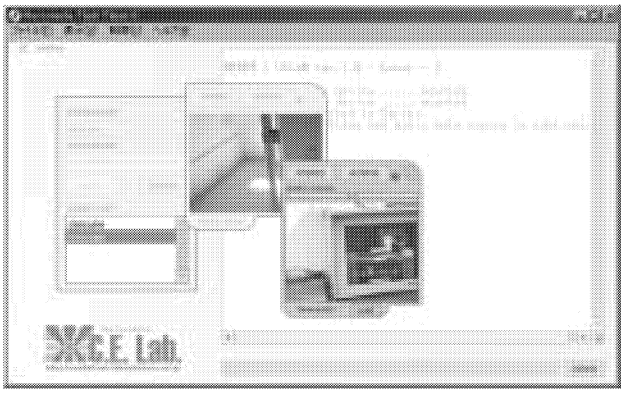

Figure 2: Snapshot of CELAVIS interaction

Figure 2 show a snapshot of the main window of CELAVIS interface. In this example, 2 users are participating in video conference. The left-most small window shows the user list, and the other two small windows monitors each site. The large text area on the back shows chat area as well as the status of video conference, and a text box at the bottom is an input area for a text message. PC monitor is convenient for a personal use to have video meeting with somebody, but a projection monitoring on a large screen is preferable for a group use so that participants can work together on the large screen.

CELAVIS system provides video conference environment for participants who just needs typical microphone-headsets. Some of the typical video conference system requires special hardware but CELAVIS does only require typical microphone-headsets for a peer-to-peer conference with a single participant in each site. However, we use a hands-free speaker phone system, which is available from a commercial market, for group communication to avoid echo-back problems. Because of our site license reason, the number of participating site in our experiments are basically two, but we have already confirmed that participation from multiple sites can be available in CELAVIS.

Whiteboard interface (BOCOLLA SYSTEM)

BOCOLLA system is another key component of the prototype system, which provides whiteboard based interface for video conference with a marker pen as an alternative of pointing device to control computer. By attaching a special receiving device on the corner of whiteboard, any whiteboard or wall could be an input tablet. By pushing action on the head of marker-pen, ultrasonic signal is dynamically sent to the receiver, which then knows the co-ordinates position of the pen in a dynamic manner. The receiver is connected to PC by USB or Bluetooth, which means that the signals obtained from the marker-pen can be transferred to the PC as an input signal, which controls the PC. A similar kind of interface has already been implemented and their feasibility has already been reported. Hardware devices we use in BOCOLLA system is similar but the software we use is what we have written ourselves in Java and C# to implement BOCOLLA to make it easier to modify and integrate with other modules in this research.

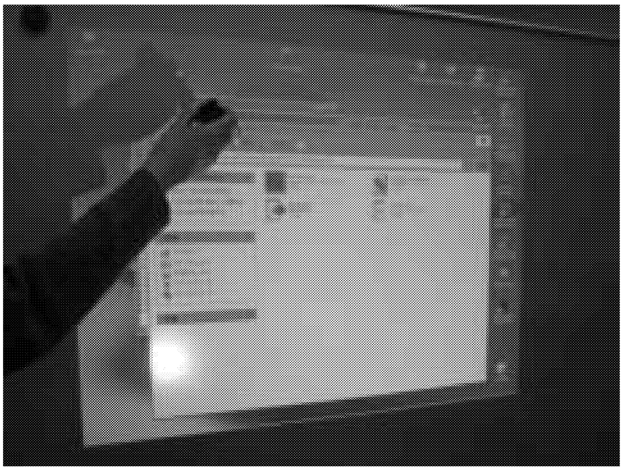

Figure 3: Snapshot of BOCOLLA interaction

Figure 3 shows a snapshot of interaction using BOCOLLA system. A typical computer monitor screen is projected on a whiteboard, which is only equipped with a receiver on the top right corner of the board. A user is using a marker pen as a pointing device in stead of mouse, and manipulate a typical computer operation just like users normally do on their PC windows. Although a rear-projection style might be better to avoid shadow interruption, we use a front-projection style so that any whiteboard should be used in our approach. Figure 4 is a view of BOCOLLA interaction for computer operation.

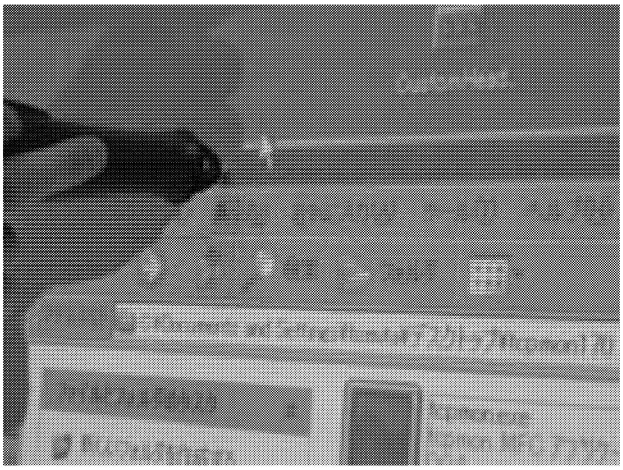

Figure 4: Controlling computer in BOCOLLA system

When the CELAVIS interface as shown in Figure 1 is projected to a whiteboard, video conference can be held through the whiteboard. Participant can see each other on the whiteboard which is located on each site. The marker pen in BOCOLLA works as a pointing device to control computer as mentioned above, but it also performs its fundamental function, or to write something on the whiteboard. Furthermore, tracking of the pen movement is detected and recorded by BOCOLLA, which means what a user writes on the whiteboard can automatically transferred to the computer, and be processed to CELAVIS, so that participants should share them in the virtual space which is provided by CELAVIS through the whiteboard.

Prototype system evaluation and discussion

Since we confirmed that we can use CELAVIS for video conference on local sites, we have conducted several evaluation video conferences between one site at California in US and our site at Tokushima in Japan to see if we can use CELAVIS for a global video conference in actual situations. As a result, we did not find any significant difference in terms of quality of communication during the evaluation video conferences comparing from routine video conferences which we regularly have for our local meetings in our local site. From those experiments, we have concluded that CELAVIS system is appropriate to use as a basic framework of collaboration test environment.

As for BOCOLLA system for local use to manipulate local computer is quite acceptable. However, visibility is interrupted by the shadow of manipulating person, introduction of rear-projection system is now under consideration. Although it would be possible to setup an environment, with an erasable plate on the surface of projection screen to use a marker pen just like a whiteboard, it means that a typical whiteboard itself cannot be used anymore. With further trade-off consideration, we would like to decide which direction and how we should go.

Another unique feature of BOCOLLA system is a kind of flying mouse pointer, moves back and forth among multiple computers. The idea is derived from interactive workspace project at Stanford, where a user can manipulate multiple computers from his/her own laptop as if he/she is using a single computer.

In BOCOLLA system, we have adopted a server-client approach in JAVA programming to implement this idea. Here we call BC_SV for server machine and BC_CL for client machine in BOCOLLA, although each machine can be both in actual use. When BOCOLLA process is started, BC_SV is waiting for a signal from BC_CL. After BC_CL is started, it sends a packet with user ID code and establishes connection to BC_SV. Once the connection is established, a target machine to control is determined by tracking the coordinates of mouse cursor on the screen.

Currently we only have one set of BOCOLLA system, which means that only one site can use and evaluate BOCOLLA system. We are planning to prepare another set of BOCOLLA system so that evaluation from both sites can be conducted to have much discussion to improve the usability of the system. However, the prototype system presented in this paper provides more collaborative function in addition to the typical function of video conference system.

APPLICATION TO TELEOPERATION

Feasibility of the prototype system was recognized in the several video conference tests as described in the previous section. Differing from typical video conference system, the prototype system provides more interactive features for participants. Participants can share a virtual space where they can provide/obtain data, information, idea, etc., all of which can be used in video conference. We would also like to control a physical device which could be accessible via IP network connection and could be manipulated by telamatic operation, so that participants can also share them in video conference. For example, when participants are having discussion on operation procedures, sometimes they actually perform some operation to make sure how the operation should work appropriately or not. Interaction with remote machines or devices can be available during discussion over the video conference, as a result, they can continue the discussion without interruption of putting off the conference until the result of teleoperation should be obtained later.

Teleoperation device and its controller

To set up an evaluation environment for application towards teleoperation, we have, as a test case, prepared a very simple miniature crane, which can be controlled by a dial controller. Figure 5 shows the exterior image of the crane which is to be connected to a computer, and Figure 6 shows its internal view. As you can see from these figures, only some basic functions are available in this crane, such as lifting up/down of the boom, or rolling up/down of the wire.

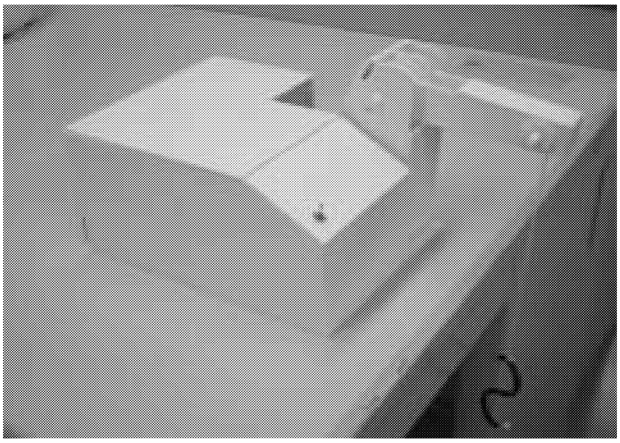

Figure 5: Outside view of miniature crane

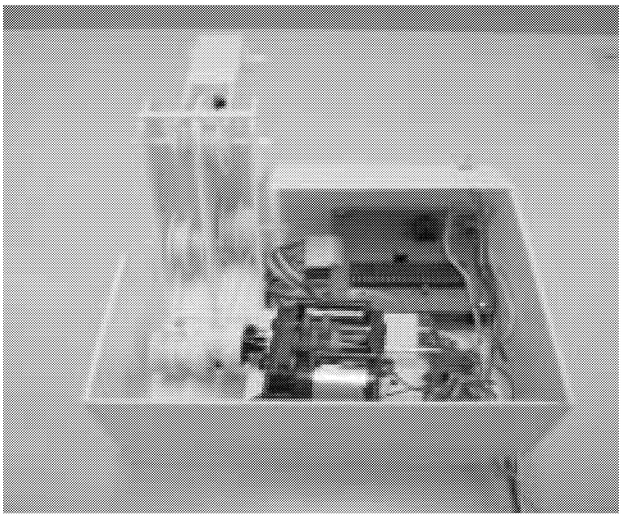

Figure 6: Inside view of miniature crane

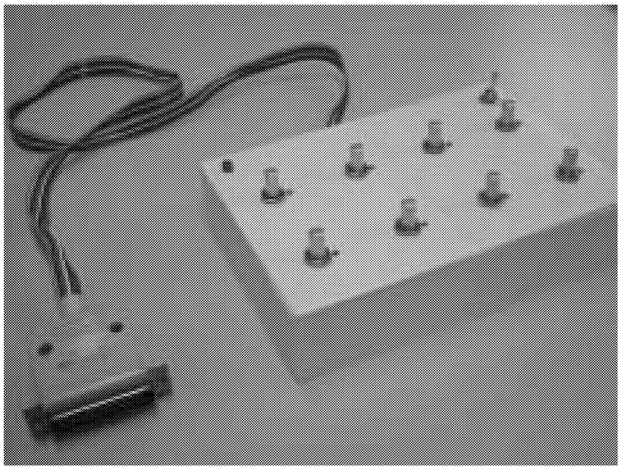

Figure 7: Dial controller

Figure 7 shows a controller box, which is also connected to a computer to manipulate the crane. Although we can use some typical controlling device such as a joy-stick to manipulate the crane, but we have created our own controller aiming at the extension of the idea towards force feedback operation using our own device. We have also prepared a control menu window software so that a user can manipulate the crane with mouse or other pointing device, in that case the user does not need this dial controller.

Two kinds of basic operation are available with the controller. One operation is up-down of the boom, and the other operation is rolling up-down of the wire. Although the operation which we have prepared seems to be simple, but the objective of this miniature crane is to see if we can include teleoperation by the use of a marker pen which we use during a video conference on a whiteboard. For this reason, this crane is suitable for our needs in this research.

Teleoperation using BOCOLLA system with CELAVIS video conference

During video conference session, what participants would like to share is not only the information regarding the topics which they discuss during the conference, but also, hopefully, digital data, software, and/or devices which they might also need to control during the conference. Since we are proposing a whiteboard based interface for collaborative environment, where participants can share a virtual space, we would also like to combine the teleoperation into this virtual space without any additional interface or devices, which means that participants can conduct teleoperation only by the use of a marker pen just like they use it to write down something on the whiteboard. To setup an environment for our idea, we have integrated BOCOLLA interface system with CELAVIS video conference system, and also integrated the miniature crane system. Computer screen is projected to a whiteboard or to a large screen, which shows the participants and/or miniature crane in each local site as well as remote site so that participants can understand what is going on during the conference, and also during teleoperation on the crane over the network..

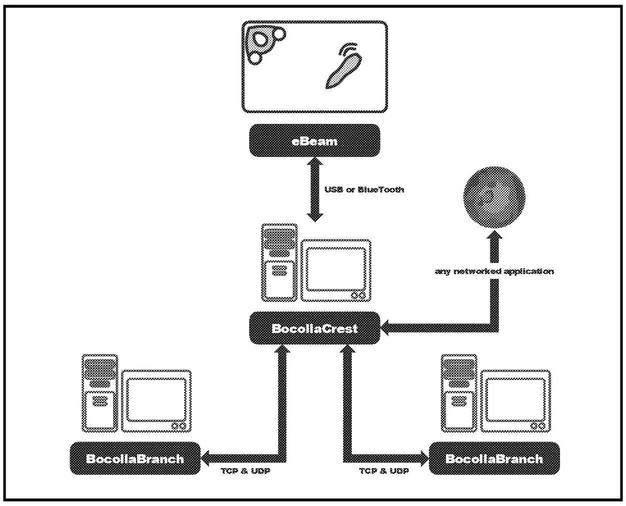

Figure 8: IT connection in collaborative teleoperation

Figure 8 shows the overall image of network connection through the whiteboard interface. A marker pen on the whiteboard can control not only local computers, but also remote computers, which can also open a door to the remote world, where teleoperation machines and devices are working. To setup a test environment, the minituare crane described in the previous section was connected to a serial port on one of the computers used for a video conference. The crane is directly controllable from the computer either by a dial controller or a control tool window with mouse operation. With BOCOLLA system, a marker pen is equivalent to mouse, which means the crane is also controllable by the marker pen on a whiteboard.

CONCLUDING REMARKS

As the increasing demand on video conference for business or technical meetings, a number of commercial or free systems are available. However, the main objective of this system is to provide an environment for audio/video communication for participants. If we have a phone conversation with visual images on the counterparts, then it surely works fine. We have developed CALAVIS system as we described in this paper, and we confirmed that our small group meeting which we held a couple of times between Japan and US sites works quite fine. In this sense, we have highly evaluated the performance and usability of CELAVIS.

During our video meeting experiments, we also have found that when we have a face-to-face meeting, what we would like to share is not only the information which is discussed in the conference but also the data, software, or physical devices on which the agenda of meeting might be much related. Currently available system including CALAVIS does not provide such an environment where participants can share those items. Under these circumstances, what we are pursuing in this study is to provide an environment where participants can share a virtual workspace where they can not only hold video conference, but also they can work more collaborate and naturally with the common sharing of those items.

What we have employed in our test environment was a teleoperation as an example of collaborative work during video conference. To do so, we have prepared a toy crane and controller, both of which can be connected to PC either locally or remotely, so that an operator can control it during video conference. This is a test environment which simulates a collaborative work over a video conference. At this time, we have prepared a single-operation mode, but we can expand it to multi-operation mode, so that participants can control the crane from each participating site. Current version of CELAVIS basically provides video monitor and chat windows just like common video conference systems do, but we are working on embedding the control module into CELAVIS so that participants can work more effectively on collaborative task with the use of teleoperation.

BOCOLLA interface presented in this paper is also a new approach to support collaborative work over video conference. When we have a meeting, we often use a whiteboard-like panel to write down words, phrases, figures, marks, etc., which surely support understanding each other with reducing difficulty and mistakes caused by miscommunication, and with increasing easiness and mutual understanding supported by visual aides. Some researches uses an interactive rear-projection display to avoid interruption of visibility, which proved to be an effective way of presentation for video conference, but we currently use a front-projection style so that we can setup the environment without any special device except for installation of a portable ultrasonic receiver which was explained in the session of BOCOLLA system in this paper. With only a marker pen, participants can not only control computers located locally or remotely, but also even manipulate teleoperation to control a remote machine located on a remote site. Although what we did in this study was limited to a simple operation on a miniature crane, but we are actually able to manipulate various kinds of devices, including remote computers, mechanical machines, electrical devices, home appliances, etc. only if we can make it available to control them via IT network, which can be available in a variety of ways.

What we have presented in this paper may seem to be a very old fashioned style of approach for collaborative work in some sense, but we are pursuing a new approach to setup a collaborative environment using a video conference.

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PROVIDING SUPPORT FOR ENGINEERING COLLABORATION

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KEYWORDS
Supplier, Supplier integration, engineering collaboration, ITIL, Hotline, Business process, partner management, motivation, problem management.

ABSTRACT

Product development and related processes are featured by high complexity as well as shorter running times. The necessity of working together with other companies for these processes is proven every day. In order to organize the distributed collaboration efficiently, it is important to establish a support center, which can handle occurring problems fast and competently. If problems are solved promptly, the users are more content and efficient collaborative engineering can be ensured.

This paper describes the role of a support center as single point of contact (SPOC) under consideration of current trends of supplier integration. As first level contact for all parties involved in the engineering collaboration process (suppliers and OEM associates), the SPOC plays a major role for the communication between different companies. The longtime experience in operating hotlines for the collaboration in product development at a German automotive manufacturer will be described in the end.

CURRENT TRENDS

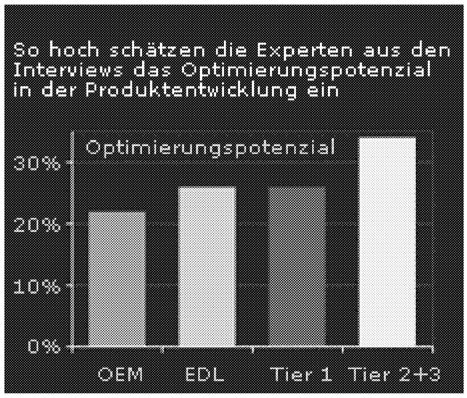
Supplier integration within the Automotive Industry

If you take into account various results of current market research on the topic of supplier integration, the following trends can be summarized:

- Increase of external processing
- Specialization of the suppliers
- Necessity of an efficiently distributed project management

"C-Commerce is a means of leveraging technologies to enable a set of complex business processes across distinct operation entities, allowing participants along the entire value chain to share decision-making, workflow and capabilities" [DEL02]

For the subjects "project management, development processes, cooperation" a 30% increase potential for automotive manufacturing is anticipated. [VDI03]



Figures 1: Estimated optimization potential for product development [www01]

"The survey calls a spade a spade: There are problems in project management; projects are often started too late, development partners are not involved soon enough, stipulations are left out or overlooked. The consequences: Operation at a hectic pace and deficiencies in project management." [www01]

Consequential, on the side of the suppliers, there is the desire for a "dependable cooperation strategy", "fair distribution of opportunities and risks", "definite rules for cooperation". [VDI03]

Another point of issue: Who takes on the project management? The OEM assigns more and more mega modules or whole derivatives. Engineering suppliers offer their services and request for the cooperation of the system suppliers. [www02]

The VDA survey [VDA03] provides further impulses:

- Because of the upcoming cost and innovation pressure, the OEM gets into the "efficiency screw"
- In the year 2015 the development depth of the suppliers has increased to 60% (assembling and integration of parts/components for complete system solutions; complete deliveries)
- The suppliers experience that their share of the value added in the automotive manufacturing industry is clearly increasing (with all assets and drawbacks)
- Great integration achievements in combination with further transfer of value added to the OEM bring forward the development of great "Tier-0.5 suppliers"

In the future suppliers will set many technology trends, since there is such a concentration of specialist knowledge

- In order to ensure effective cooperation, the suppliers need to be integrated into the development process as fast and intensive as possible. Supplier assessments and long-run contracts perfect the collaboration
- The next step is to group suppliers into so called "supplier competence profiles" (suggestion for a classification: *Integrator* [module, system, purchasing and logistic efficiency], *Innovator* [electronic and integration efficiency], *Specialist* [operative excellence and cost efficiency])

Considering the trends mentioned, the importance of supplier integration becomes clear, since the influence and the importance of the supplier in the distributed product development in the automotive industry will increase continuously.

PROVIDING SUPPORT FOR ENGINEERING COLLABORATION

The supplier often has too many different contact partners (professional/technical contact, hotline etc.) and needs too much time for the organization of the collaboration.
An idealized aim would be the trouble free collaboration without any disturbances. In fact there are a lot of different conflicts

- Unclear technical and contractual conditions
- Application for relevant permissions
- Lack of information transparency
- Non ergonomic software
- User errors
- System / network errors
- etc....

The perception of provided and received support to solve conflicts between OEM and the supplier can differ considerably: only one third of the suppliers feel adequately supported by OEM if it comes to "on-site problem solving" [CEL02].
In order to ensure successful and efficient collaboration it is important to establish a contact for the suppliers, which takes care of all their concerns. This contact should be provided in addition to the still remaining technical contact at OEM.
If you go by ITIL [www03] the reference offers a detailed description in the field of "service-support" about how this SPOC (Single Point of Contact) should function as main contact point.
ITIL (IT Infrastructure Library) is a collection of best practice references for the IT service management. The formation dates back to 1989, when the CCTA (Central Computer and Telecommunication Agency; today OGC: Office of Government Commerce) of the British government published the first elements. ITIL is structured in different processes (incident, problem, configuration, change, release) and concentrates on two main fields: "service-support" and "service delivery".
Of course there are differences between the diverse hotlines. Operating PC workstations, support of a complex administrational program, hotline for supplier integration – all of these will make different demands on the hotline associates.

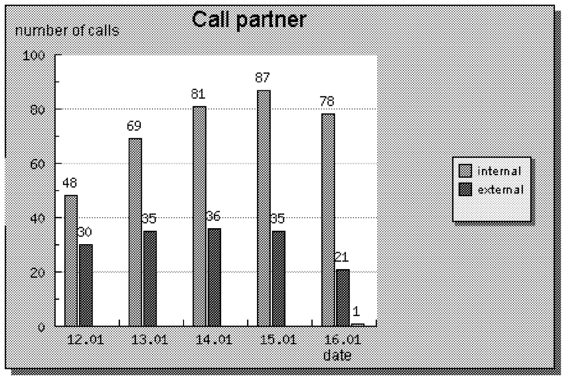
Next a longtime experience in operating hotlines for the collaboration in product development at a German automotive manufacturer is described.

DATA EXCHANGE / SUPPLIER HOTLINE

For large OEMs the supplier hotline establishes the contact between the engineers of both sides. In this way the hotline provides the essential interfaces for a good collaboration in the field of concurrent engineering.

Functions of the Supplier Hotline

The supplier hotline acts as contact for internal as well as external users. The distribution of calls is shown in the following figure:



Figures 2: Ratio internal to external calls

Thus, over a long term, the number of calls of external and internal development partners is approximately equal.
The calls usually refer to problems regarding data exchange or data format of the respective partners. The main support of the supplier hotline covers a data management system and a portal for internal and external users. At the hotline all questions and problems related to the exchange of information between the supplier and the OEM engineer will be processed.

Organization from 1998 to 2000

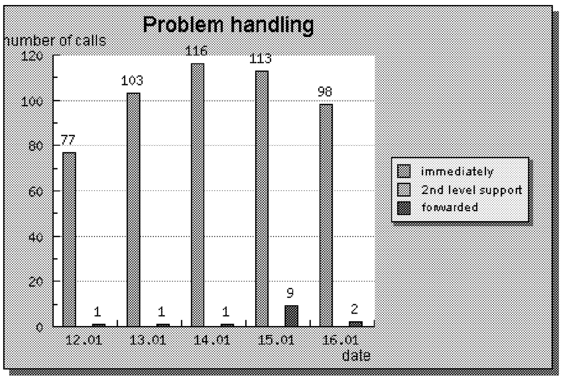
Right from the beginning there was the demand for immediate processing of questions and problems by the supplier hotline. At the beginning this could be achieved as the experts were answering the phone directly. In this way requests could be processed immediately and the satisfaction of users was high. The disadvantages of this procedure were the high costs for qualified staff and after some time the dissatisfaction of the specialists in this hotline position. Furthermore it turned out that real specialists didn't necessarily have a general knowledge of the whole system. This resulted in referring the user from one expert to the other. Besides, many engineers are not exactly skilled, regarding friendliness and helpfulness on the phone.

Rearranging the Hotline

As a result of these experiences as well as the findings of the ITIL recommendations, in 2002 it was decided that the hotline should be rearranged. However, it was essential to retain the ambition to process requests immediately.
In contrast to the standard SPOC (Single Point of Contact) solutions for us it was very important to make sure that even the first level support should be higher qualified than usual. The idea was that at least 80% of the questions could be processed by the first level support. In order to achieve this aim, intensive training programs were organized. In addition to these programs, hotline members receive are permanently education.

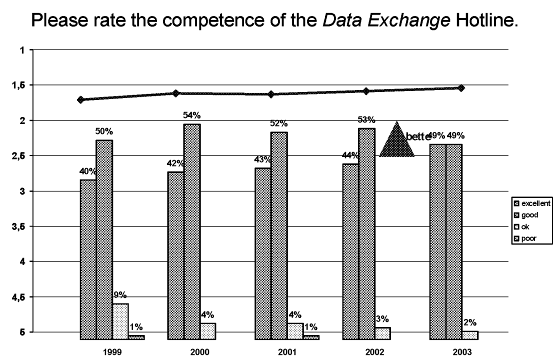
Current Model, Results

The rearrangement of the hotline was finished in 2003. The model has approved in many ways. First the satisfaction of the hotline members rose notably. In this way the continuity of staff could be clearly increased. A usual first level associate is obviously enhanced because of these extensive qualifications. As shown in the following graph, the problem handling could be maintained.



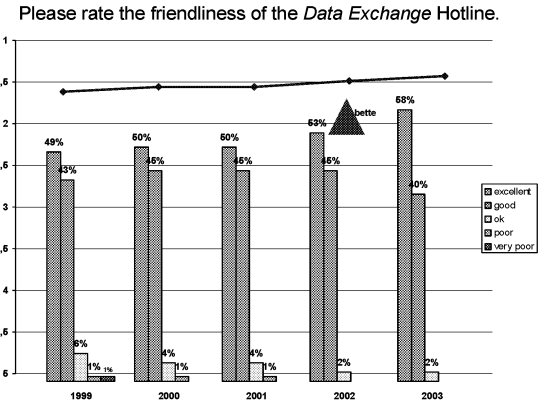
Figures 3: Problem handling

The results of a user survey showed that the users were even more content than before.



Figures 4: Competence of Data Exchange Hotline

And the friendliness was also rated noticeably better than before:



Figures 5: Friendliness of Data Exchange Hotline

In this way the quality of the hotline was improved and at the same time personnel costs could be reduced.
The higher training costs for the hotline associates paid off very fast if you consider the increased quality and the reduction of personnel costs, since the experts can concentrate on other tasks now. Insofar the SPOC model has turned to account in more than one way.

SUMMARY

The statements of the diverse studies mentioned before (see: Current Trends: Supplier integration within the Automotive Industry), presuppose that there will be an increase of external processing in car production. Considering these statements and the assumption that fast and efficient problem solving with Collaborative Engineering will increase the motivation of the users, the necessity of a Single Point of Contact for the suppliers becomes obvious. It is important that there is one contact that can take care of all relevant questions.
In order to satisfy the users one needs fast and efficient problem solving, availability, competence and - last but not least – cordiality and service orientation.

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Figure 2-5 © SSC-Services GmbH 2004

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PERSPECTIVE ALLOCATION IN THE PERFORMANCE DESIGN AND IMPROVEMENT OF COLLABORATIVE ENGINEERING SYSTEMS

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KEYWORDS
Collaborative engineering system, performance evaluation, performance improvement, Qualitative Reasoning.

ABSTRACT

Single and parallel structure servers, although powerful mathematical models in queueing theory, do not address a wide range of real-life systems. In this paper we propose a composite-server model and make use of the knowledge of the intrinsic composition of its service providing units (personnel or equipment) to arrive at Qualitative Rules needed to evaluate its performance. The composite server model has wider scope in its applications and can be used to represent a variety of system classes. We use this novel concept in the performance design and improvement of collaborative engineering systems. A frequent source of bottleneck in collaborative systems is the lack or surplus of service-providing units, known as "Perspectives" in the Multi-Context Map (MCM) modelling terminology. Bottlenecks due to inappropriate Perspective allocation are resolved by the Qualitative Reasoning approach.

INTRODUCTION

Real-life collaborative engineering systems are too complex and too messy to allow a neat mathematical formulation. As an alternative strategy, we adopt a rather descriptive modelling technique and pursue the ensuing performance evaluation and performance improvement by the application of Qualitative Reasoning (QR). QR has been applied to diverse problems (Bobrow 1985, Kuipers 1994). We employ QR to circumvent the mathematical complexity in solving simultaneous equations involving queueing network variables. The Multi-Context Map (MCM) technique presents an elaborate model of the collaborative engineering system, capturing the workflow and the allocation of personal in collaboration. The basic entity in MCM is the context (fig. 3). At a given context the requestor ("Left-hand Perspective") requests the service providing unit or the performer ("Right-hand Perspective") to perform the collaboration activity. There exists an interface between the two through which *Token*, *Material* and *Information* (TMI) pass. An aggregate of contexts related to each other through the exchange of TMI flow give rise to the MCM (Hasegawa et al. 200). The constituents of MCM network are amenable to queueing theory analysis. We have analyzed the emergence of bottlenecks due to the non-uniformity in the flow of TMI and have proposed a Qualitative Reasoning (QR) approach in resolving the bottlenecks (Gonsalves et al. 2003). In this short paper we propose a similar QR approach in resolving the bottlenecks that appear in the MCM queueing network due to the improper allocation of personnel.

While most of the contexts in MCM can be represented by the single and multiple service channels of the queueing theory, some of them have to be treated differently. This is because they possess a composite service time; i.e., service-time which is a complex overlap of individual service-times of the collaborators. To model these kinds of servers, we introduce the concept of composite servers. We then incorporate the composite server model into MCM and use it in system simulation, performance evaluation and improvement.

COMPOSITE SERVERS

In the case of the single-structure and parallel-structure servers, no knowledge of their internal structure is necessary to evaluate the performance of the servers. For composite-structure servers, on the other hand, their internal workings determine their performance. The knowledge of the structure and behaviour of the service providing units (SPU) that constitute the server is essential to evaluate the performance of the server. In this section we define the concept of compositeness in servers, illustrate their internal structure and the nature of their service times.

Schematic representation of composite servers

SPU1 is the main contributor to service and does not move from the server at any point of time. Its service-time is represented by the circle in the centre. SPU2 and SPU3 provide auxiliary service at each of the servers and keep shifting among the servers. Their service-times, represented by semicircles, overlap with the service-time of the main contributor.

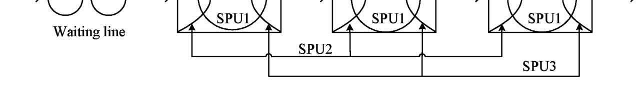


Fig. 1 Composite Service Model

Composite service time

When service time is composite, each of the SPUs or Perspectives contributes towards the service time depending on its level of profession. P1 offers first degree of contribution and is indispensable for service; P2 and P3 offer second and third degrees of contribution, respectively, and are auxiliary in terms of service. The composite service time for each of these Perspectives is illustrated by the following diagram.

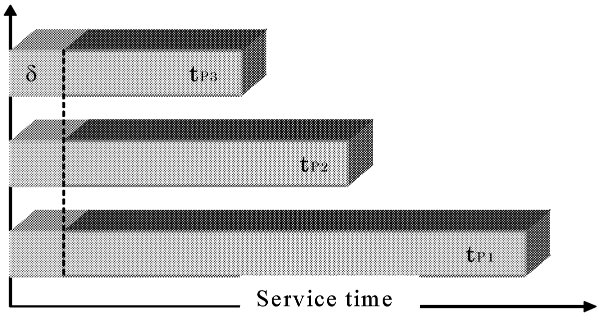


Fig. 2 Fractional delay in service times

Let Ci, Cj, Ck be the contexts in proximity in the given MCM. (We consider only three contexts to keep the analysis simple). We arrange the contexts in the descending order of the magnitude of service time ($ts_i \geq ts_j \geq ts_k$). Perspective P1 at each of the contexts is immobile. He/She/It represents a professional without whom/which the server cannot offer service. P2 and P3 are available for service at all three contexts. P2 offers service at Ci for part of Ci's total time and then spends the surplus time at Cj and Ck. Similarly P3 offers service at Ci for part of Ci's total time and then spends the surplus time at Cj and Ck.

When P3 is free to render auxiliary service at Cj and Ck, it may, however, spend more time at these contexts than what is available at Ci. This would imply that P1 and P2 have to wait for the return of P3 to offer their "composite service". In other words, the over-generosity of P3 introduces a fractional delay, α in the total service time of Ci. Similarly, P2 spends its surplus time at Cj and Ck and if it overshoots the extra available time, it introduces fractional delay, γ. The effective delay introduced in the context service time is, $\delta = \max(\alpha,\gamma)$. The fractional delays caused by P3 and P2 are shown in figure 2.

Perspective Allocation in MCM

Fig. 3 is a part of general medical system MCM. (for the fuller version see Hasegawa et al. 200). Each rectangle in the model is a service-providing context. Diagnosis, Medical tests and Prescription are grouped together as three contexts that are proximate in function.

Doctor, medical technician and pharmacist are respectively the first degree contributors (P1) in each of these contexts. Senior nurses (P2) and junior nurses (P3) are second degree and third degree contributors, respectively. They keep shifting among the three contexts as and when need arises.

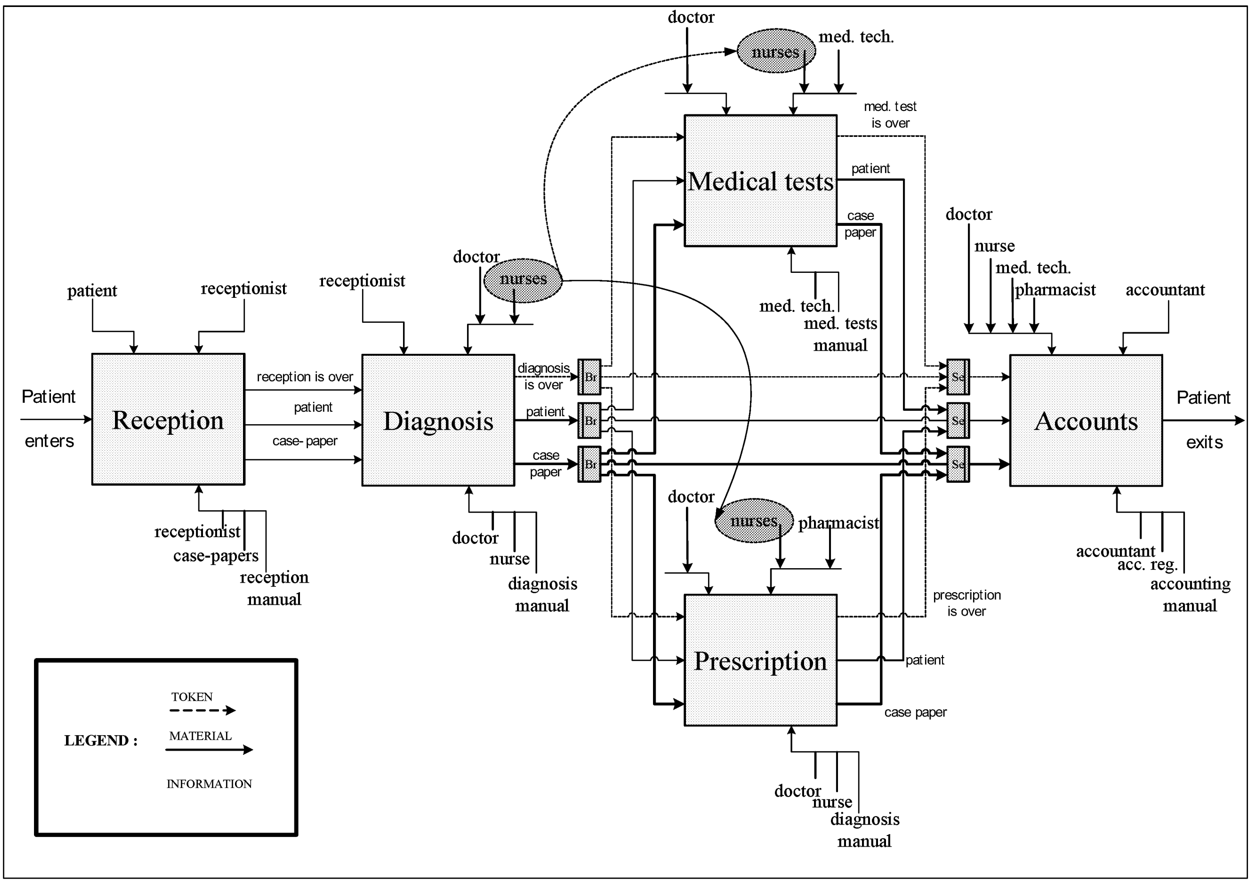


Fig. 3 Perspective allocation in MCM of general clinic

Performance Improvement

We do not have complete knowledge of the system, but have the expert's heuristics. For a discussion of heuristics in the improvement of bottlenecks in queueing networks, refer to Itoh et al. and Sawamura et al. These heuristics that we have developed for improvement in Perspective allocation in MCM are framed in the form of Qualitative Rules in table 1. The rules are qualitative in the sense that they indicate whether a causal parameter has to be increased or decreased so as to resolve the bottleneck. The rules in table 1 are referred to when one out of the three contexts engaged in Perspective allocation become a bottleneck.

We proposed composite server model to represent the overlapping service times of the different collaborators offering service at multiple contexts in proximity in the MCM model of a collaborative engineering system. We applied the Qualitative Reasoning method to solve the bottlenecks arising due to improper allocation of the Perspectives at the proximate contexts and fine-tuned the system performance. Performance evaluation by simulating a real-life example of collaborative engineering system and enhancing its performance gave satisfactory results with our method.

Conclusion

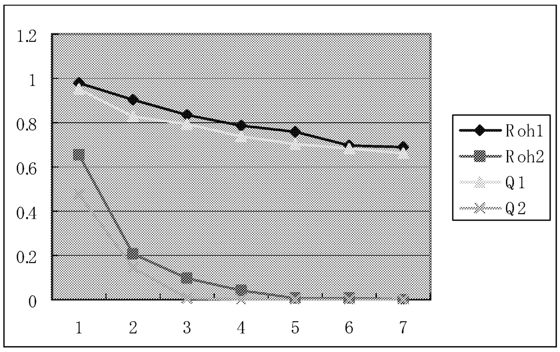
Table 1 Qualitative rules for performance improvement

symptom			solution														
C_i	C_j	C_k	C_i					C_j					C_k				
			external		internal			external		internal			external		internal		
						lend	lend				borrow	lend				borrow	borrow
ρ_i	ρ_j	ρ_k	t_{ai}	t_{si}	t_{P2i}	t_{P2ij}	t_{P2ik}	t_{aj}	t_{sj}	t_{P2j}	t_{P2ij}	t_{P2jk}	t_{ak}	t_{sk}	t_{P2k}	t_{P2ik}	t_{P2jk}
H	M	M	↑	↓	↓	▼	▼	○	○	↓	↓	○	○	○	↓	↓	○
H	M	L	↑	↓	↓	▼	▼	○	○	↓	↓	↓	↑	↓	↓	↓	↓
H	L	M	↑	↓	↓	▼	▼	↓	↑	○	↓	○	○	○	○	↓	○
L	H	M	↓	↑	↑	↑	↑	↑	↓	↓	▲	▼	○	○	↓	↑	↓
L	M	H	↓	↑	↑	↑	↑	○	○	↓	↑	↑	↑	↓	↓	▲	▲
L	M	M	↓	↑	↑	▲	▲	○	○	↑	↑	○	○	○	↑	↑	○
L	L	L	↓	↑	↑	○	○	↓	↑	↑	○	○	↓	↑	↑	○	○
M	H	M	○	○	↓	↑	○	↑	↓	↓	▲	▼	○	○	↓	○	↓
M	M	H	○	○	○	↑	↑	○	○	↓	○	↑	↑	↓	↓	▲	▲
M	M	M	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
M	M	L	○	○	↑	○	↓	○	○	↑	○	↓	↓	↑	↑	▼	▼
M	L		↑	○	↑	↓	○	↓	↑	↑	▼	▲	○	○	↑	○	↑
M	H	L	○	○	↓	↑	↓	↑	↓	↓	▲	▼	↓	↑	↑	↓	↓
M	L	H	○	○	↓	↓	↑	↓	↑	↑	↑	↑	↑	↓	↓	▲	▲
M	L	L	○	○	↑	↓	↓	↓	↑	↑	▼	▲	↓	↑	↑	▼	▼

H: High; M: Medium; L: Low; ↑: Increase parameter; ↓: Decrease parameter;
▲▼: Parameter increases/decreases as a result of the changes made.

Results

The expert system is a Qualitative rule-based expert system. It diagnoses the bottlenecks in the performance of the system and advices the user to change the value of different given parameters to resolve the bottlenecks. The graph below shows the improvement in SPU2 and SPU3 utilization and queue-length in case of the three proximate contexts engaged in Perspective allocation, in the hospital MCM.



Graph 1. Improvement in utilization and queue-length

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DATA WAREHOUSING

COLLECTING ACTIVITY-TRAVEL DIARY DATA BY MEANS OF A NEW COMPUTER-ASSISTED DATA COLLECTION TOOL

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KEYWORDS

Data collection, activity diary data, VIRGIL, computer-assisted data collection.

ABSTRACT

Activity-based transportation models have set the standard for modelling travel demand for the last decade. It seems common practice nowadays to collect the data to estimate these activity-based transportation models by means of activity diaries. This paper has explored potential advantages and disadvantages that may occur in the collection of this type of data by means of a new developed computer-assisted data collection tool.

1. INTRODUCTION

The demand for transport services is expected to grow considerably as incomes rise, the trend toward urbanization continues and as the process of globalisation moves forward with expected increases in world trade and personal travel (United Nations, Economic and Social Council 2001). In order to meet this rising demand and because governments cannot afford to allow transport constraints to have a negative impact on the future competitiveness of their products, considerable future long-term investments are indispensable. In order to better guide and substantiate the decisions of transportation planners, the use of traffic and transportation models has been advocated by governments and by research communities. In some cases (especially in the United States) the use of transportation models is even required by law. However, given the significant political consequences that transportation plans may have, transportation models are often used, even without this legal imposition.

Since 1950, due to the rapid increase in car ownership and car use in the US and in Western Europe; several models of transport mode, route choice and destination were used by transportation planners. These models were necessary to predict travel demand on the long run and to support investment decisions in new road infrastructure which originated from this increased level of car use. In these days, travel was assumed to be the result of four subsequent decisions which were modelled separately. Those models are also referred to within transportation literature as four-step models (Ruiter and Ben-Akiva 1978). More recently, especially in the eighties and early nineties, it was claimed by several researchers that very limited insight was offered into the relationship between travel and non-travel aspects in the widely used four-step models. Indeed, travel has an isolated existence in these models and the question why people undertake trips is completely neglected. This is where activity-based transportation models came into play. The major idea behind activity-based models is that travel demand is derived from the activities that individuals and households need or wish to perform. The main difference however between traditional (i.e. four-step) transportation forecasting methodologies and activity-based transportation models is the attempt of the latter to predict interdependencies between several facets of activity profiles. These facets are often identified as *which* activities are conducted *where*, *when* and for how *long*, with *whom*, and with which *transport* modes. Obviously, data is needed for all these facets in order to be used in an activity-based transportation model. This paper focuses on a virtual reality and GIS-based Logging system (VIRGIL) which has been developed in order to collect data for all these facets and which has been extensively tested during recent years. The paper contributes to the line of research which has explored the use of computer-assisted geographical information systems for geocoding the location of activities, such as Chase (Doherty and Miller 2000), Chase-GIS (Kreitz and Doherty 2002) and REACT (Lee and McNally 2001). The aim of the study reported in this paper is to explain the potential advantages and disadvantages of the VIRGIL software and to validate the activity-travel diaries collected by means of VIRGIL.

The remainder of this paper is organized as follows. Section two gives a brief introduction towards the different ways in which data can be collected by means of activity diaries. The VIRGIL software and some of the measures that were implemented for data quality control are explained into detail in section three. Next, the empirical outcome of a data collection effort that was undertaken by means of VIRGIL is described. Finally, the paper concludes and defines some topics for future research.

2. DATA COLLECTION: ACTIVITY DIARY DATA

As outlined in the previous section, activity-based transportation models have set the standard for modelling travel demand. It seems common practice nowadays to collect activity diary data to estimate activity-based transportation models. This section will discuss the potential advantages of diaries as opposed to traditional questionnaires, as well as other specific operational decisions regarding the format of these activity diaries.

The questionnaire, asking people for their average behaviour during some time period, has long been the dominant form of data collection in transportation research. It has been argued, however, that there is significant accumulated evidence that travel surveys especially under-report off-peak, non-home based trips of short duration (Robinson 1985; Dijst 1993). Based on these findings, Stopher (1992) argued that a diary outperforms a travel survey in this respect. This seems to be consistent with the findings of other authors (Clarke et al. 1981), who have reported that the diary resulted in a 13-16 percent higher level op trip making than the travel survey. Similar differences in degree of reporting have also been used in time use studies (Niemi 1993). The available literature therefore seems to suggest that the diary is likely to outperform the questionnaire in terms of the validity of the data collected.

Diaries mainly differentiate by means of the type of information which is collected. The leading question in a trip diary obviously is related to the trips (out-of-home activities) that are made, while the activity diary mainly focuses on all the activities (in-home and out-of-home activities) the respondent says to be engaged in. Since an activity diary can provide us with a richer source of information that allows additional and more detailed kind of analyses and since a fully operational transportation model should be able to take the interrelationship between in-home and out-of-home activities into account, it is argued that despite the fact that only out-of-home activities generate traffic, in-home activities can provide useful information and should be collected as well.

However, collecting data by means of activity diaries is more demanding for respondents. Therefore, one should be aware for three potential sources of bias: (i) respondents who are very busy and make a lot of travel activities cannot afford the time to fill out the diary, (ii) respondents with a relatively low level of out-of-home activities may decide not to participate because they feel their case is not relevant, and (iii) respondents may not always understand the need to collect in-home activities as well and may drop out. All three concerns may potentially result in flawed diaries with non-response biases.

It is difficult to evaluate what the influence of computer-assisted information systems is on these concerns. Some researchers have argued that data collection is facilitated, while others state that it is experienced as an additional burden. It remains undoubted however that electronic data collection yields information of higher quality. This was evidenced by Verweij et al. (1987) and by Kalfs and Saris (1997). Obviously, computer-assisted data collection tools have the advantage of data quality control. Indeed, a computer system can easily check for anomalies and prompt the respondent for additional information. Errors that report activities where the beginning hour of an activity is later than the ending hour, activity locations that do not seem to exist and many others can be easily checked by a computer-assisted instrument. Another important factor which favours the use of a computer-assisted data collection tool is cost-related. Both the data entry cost and the cost of pre- and post-processing the data, bear a significant share of the total data collection cost. Fortunately, both can be reduced to a minimum with computer-assisted forms of data collection. Based on these reasons, we believe that the advantages outweigh the disadvantages in the use of a computer-assisted tool for collecting activity diary data. Therefore, the development of such a new computer-assisted tool (VIRGIL), detailed in the next section, is warranted.

3. VIRGIL: SOFTWARE DESCRIPTION AND MEASURES FOR DATA QUALITY CONTROL

The VIRGIL software tool which has been developed mainly consists of two modules.

The first module concerns the detailed questioning of various individual and household characteristics. In particular, information can be collected with respect to the year of birth, gender, household size, number of persons in the household younger than six years, position in the household, possession of a driver's license, marital status, level of education, possession of transport modes, frequency of use for different transport modes, employment status and annual household income. Depending on the employment status, additional questions are asked with respect to the frequency of use of the different transport modes for the work-activity. Although this information is not explicitly activity- or travel-related, it provides us with additional background information. This information seems to be of key importance when carrying out detailed analyses of the collected data (for instance for the use of building different homogeneous clusters). Measures for ensuring the quality of the collected data were also implemented in this module. For instance, all the questions (except for the annual household income question) require an answer before one can move on to the next module. Almost all questions have a closed format (only the employment status question had an open format), which means that respondents can pick an answer from a pre-defined list. This probably will favour both the ease of use of the program and the post-processing of the collected data and it is also likely to have a positive impact on the willingness of respondents for co-operating in the

study. Obviously, the first module only has to be filled out once for each respondent in the household. To ensure this, VIRGIL opens with a login-screen, in which the respondent has to identify him/her with a nickname and dependent on the existence of the user in the system either the first or the second module is started.
As explained before, activity-based transportation models require data about *which* activities are conducted *where*, *when*, for *how long*, *with whom* and the *transport mode* involved. The second module explicitly collects all these facets of activity and travel-related information.

First of all, one needs data about activities. For the reasons mentioned in the previous section, other than out-home activities that generate travel, in-home activities were also collected. In order to ensure data consistency and to minimize the data post-processing efforts, a predefined list of in-home and out-of-home activities was used. In particular, respondents may select an in-home activity from the following list: eat-, sleep-, household-, personal health-, work-, study-, leisure-, and "other"-activity. Out-of-home activities are categorized as: work, study, cultural visit, restaurant visit, shopping, medical visit, doing sports, service activities (e.g. library visit), bring or get persons, bring or get goods, other out-of-home activities (related with leisure time), other out-of-home activities (non-leisure time related). Obviously, the most important facet that activity based transportation systems seek to model is the transportation activity. For this reason, VIRGIL explicitly asks the respondent whether he/she wants to enter a travel (transportation) activity or any other activity.

In case a transportation activity is added, it is obvious that additional information is required with respect to the transport mode that is used. Activity-based models do not involve any other requirements than conventional models in terms of transport mode. For this reason, the usual categorization into car (as driver and as passenger), various means of public transport, bicycling, and walking was adopted in VIRGIL.

In case a transportation activity is performed, the VIRGIL software also pops up a window which prompts the question whether other persons are participating in the transportation activity. If data is collected about persons which do not belong to the household, some problems may arise since the information collected should also be used in the modelling effort itself. In case the travel party concerns friends, business partners, co-workers, etc. it is unlikely that activity diaries of these people are available as well. In these specific cases, the collection of this data may not provide a lot of advantages for model building, except from the information to predict vehicle occupancy rates and traffic volume. For these reasons, we decided to use a rather broad definition of the travel party. The categories that were used for non-household members are "colleague", "family member" and "other".

With respect to the "when"- and "for how long"-facets (timing), respondents are first asked what activity they performed at 3 AM. This implies that one day of data collection is defined as a 24-hours period that starts and ends at 3 AM. This start time decision is consistent with previous data collection efforts in transportation (Arentze and Timmermans 2000). The idea behind this decision, is that researchers look for data that consist of activities that form an entity and "belong to each other". Obviously, when the start time is set at 3 AM this is more likely to be the case than when the start time was set at 12PM (people may often read a book till 12.05PM for example). Another important design decision for the time facet is the accuracy with which that start and end times are recorded. In VIRGIL, respondents where requested to mention the start and end time (and hence duration) of their activities up till 5 minutes accurate. This interval was considered to be short enough and therefore it will not result in the under-reporting of short trips, which may have been the case if longer time-intervals were permitted.

The spatial dimension or the "where"-facet is the most difficult to collect in traditional paper-and-pencil diaries. People often do not precisely recall the exact location or the street name where a particular activity was carried out. For this reason, traditional diaries are often restricted by limitations about the detail of information which is collected. Often, only data about the spatial dimension as represented by a set of zones is available. Obviously, computer-assisted data collection tools can make a significant contribution here. In VIRGIL, a toggling switch was implemented which enables the user to either pinpoint a location on a map or to manually enter a location. The first option uses several distinct points located at the map that are geocoded. When the user points towards one of these points, the system automatically enters this location. The geocoded points do not enable the user to provide as much as detail as specific information like for instance the exact street name. Despite this, it is believed that respondents still can more easily provide more detailed information when compared with traditional paper-and-pencil data collection efforts. The maps can be zoomed in and out in order to ensure ease of use. Figure 1 shows a (Dutch) screenshot of VIRGIL for the city of Eindhoven by means of example.

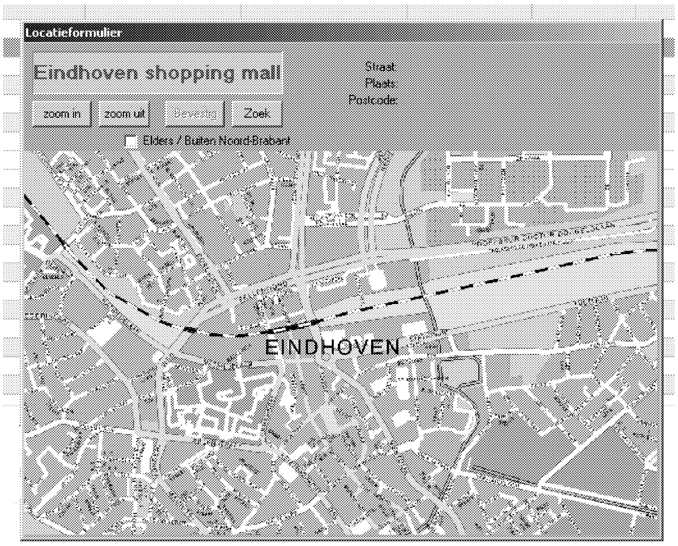

Figure 1: Storing Improved Geocoded Spatial Data

The second option (manually entering a location) also contains additional programming efforts to increase the likelihood for obtaining good quality spatial information. For instance, when a location is only partially entered, the system will recognize the particular street name and will - based on this entry- report other alternative locations which the respondent may have had in mind. In addition to this, once a location was entered, the respondent can link the location with a name of its own choice. This implies that the full detail location information only needs to be entered once and future data entries (for instance by other members of the household), are facilitated by the information which was entered previously. In the near future, this system will also be improved by entering the detailed location information about "well known and often visited places" in advance, like for instance stores or public service facilities in the study area.

All the different activity facets described until now, come together in the diary grid, for which a (Dutch) screenshot is provided in figure 2. This grid allows the user to have an overview of the in-home, out-of-home and transportation activities that were entered in the diary. The data grid also has additional functionalities that ensure an enhanced data quality. For instance, if the user wants to report a subsequence of two different activities at a different location, without first reporting a transportation activity, the particular row in the diary will colour red (see also figure 2). Accordingly, the user will notice that an error was entered in the diary and subsequently he/she has the opportunity to modify the entry. The grid also ensures the chronology of the activities that were entered. For instance, when an activity is entered which has a start time that is later than the last activity entered in the diary, VIRGIL will reposition the activity. Subsequently, the activity will be inserted at the correct position, at least, if the time slot that was entered by the user is still available in the diary.

When all the data is entered, the user either has the possibility to have the information immediately e-mailed to the researcher or to store the data on a 3 ½" disk.

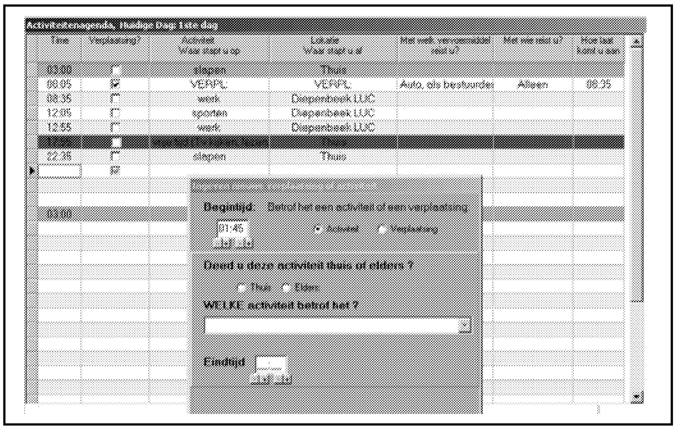

Figure 2: The Diary Grid in VIRGIL

4. EMPIRICAL RESULTS: PUTTING VIRGIL INTO PRACTICE

The aim of this section is to report the empirical outcomes of a data collection effort that was undertaken by means of VIRGIL in the spring of 2003.

In the study, respondents were provided with a setup-cd of VIRGIL which had to be installed on their computer. Accordingly, respondents were asked for two consecutive days to report their activities and travel information. The concept of frequency in collecting data has been the subject of extensive debate in the past. Some researchers argue that respondent demands are so high that reliable results can only be obtained for one or two-day periods, while other scholars (e.g. Lawton and Pas 1995) maintain that this period is too short to capture multi-day cycles and interrelationships in activity patterns. From a practical point of view however, the authors felt that it was difficult to induce people to record their activities with due precision for a prolonged period of time. In addition to this, the decision to collect data for two consecutive days was both inspired by limited resources and by the fact that a 48-hours frequency period seems to be common practice in other research projects as well (Arentze and Timmermans 2000). Besides this frequency aspect, respondents could be asked to complete their diary for specific days (i.e. designated day diaries) or for the day that is most convenient for them (i.e. convenient day diaries). Since there does not seem to be a correlation between the propensity to respond and the designated day of the week in previous research efforts, the decision was taken to use the latter option. Unfortunately, post-analyses of the collected data seems to suggest that the use of convenient day diaries may have resulted in a bias in the sense that respondents often have taken two days for which their activity and travel participation was rather limited.

In total, 553 people (older than 6 years) (i.e. an average response rate of 47%) participated in the study, which was carried out in the region of Hasselt (Belgium). The response rate is quite satisfactory especially in comparison with other, more traditional ways of data collection (Keeter et al. 2000). However, it is difficult to state that this good result is solely attributed to the computer-aided data collection technique since it is difficult to assess whether the ceteris paribus assumption was always consistently checked in previous work.

The quality of the data that was collected by means of VIRGIL was satisfactory. It is fair to say that the enhanced data quality control measures have contributed to this. However, it is also noteworthy that the number of reported activities and the number of reported transportation activities were significantly lower the second day than the first. This seems to be consistent with previous research efforts (Zwerts and Nuyts 2003) and this bias is therefore unlikely to be correlated with the computer-assisted way of collecting data.

Besides the collection of data, respondents were also asked to report their most important findings in the use of the VIRGIL software. To this extent, an additional survey came along with the software. The analyses of these results showed that most people experienced few problems and therefore reported an overall satisfaction level of "*satisfied*". The additional data quality control measures did not result in the reporting of an additional burden, except perhaps for the first module which always needed to be filled out completely. People also typically find that the overall layout of the program was clear and practically oriented. Some respondents did have some security concerns with respect to install and execute the software on their computer. Other minor complaints that were quite often reported during the use of the software were that (i) it would be better to let the program make an automatic switch from the first to the second day, (ii) in some cases context-sensitive help would be convenient for additional support and (iii) in some cases it would be better to increase the letter size of the typeface that was used, and this especially for elderly people.

5. CONCLUSION

Due to the richer set of concepts which are involved in activity based transportation models, data needs and data quality requirements are considerably higher. Given this, the use of computer-assisted geographical information systems has recently emerged in this research field. These data collection tools cannot only offer important cost-saving contributions especially in data pre-and post-processing but they can also incorporate important advantages for geo-coding and for acquiring information about the location of activities. The initial empirical outcomes in the paper seem to suggest that the VIRGIL software is a suited instrument for this. The most important topics for future research are (i) to incorporate additional geo-coded maps for other cities than Hasselt and Eindhoven and (ii) to examine the opportunity of providing the software via the internet through the use of ASP (application service provider) technology in order to deal with the security-related concerns of some respondents.

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DAVY JANSSENS was born in Diest, Belgium. He went to the university of Limburg, Belgium, where he started the studies of commercial engineer in business administration and where he obtained his degree in 2001. Ever since he has been working as a Ph.D. student at the university of Limburg. His main research interests are activity-based transportation modelling, travel survey research and machine learning methodologies.

A JAVA IMPLEMENTATION OF CART

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ABSTRACT

A data mining tool (an implementation of CART: Classification and Regression Trees) has been designed and coded. All essential tree growing and pruning related algorithms stem from the book of Breiman [1984]. The program itself is written in Java. It has all the benefits that that language provides (cross-platform, integration in larger modules, …). The program itself doesn't give new scientific insights, but it is a valuable open source alternative for constructing classification and regression trees. Some benchmarks have been applied and our implementation has been verified with an existing commercial one.

INTRODUCTION

The CART methodology has been implemented in various commercial packages (Salford systems, SAS enterprise miner, …), but using that software comes at a significant cost.
As the algorithms have been described in the book of Breiman [1984] it is possible to make new non-commercial version starting from that book. Both authors have participated in a EC project called eurosignal (www.eurosignal.org) where the aim in the data mining work package was to write an open software version of the CART methodology. This program is written in java and has a rudimentary GUI. Benchmarks have been run to compare the performance of this program with a commercial package. This paper gives a short overview of the program, its limitations and differences with the commercial version.

INITIALIZATION OF A TREE

The very first step is to set up the model, i.e., indicate to the program where the relevant data sets are and determine some initial parameter settings. The latter is done in a "Model Parameters Window" (Figure 2). It displays all the information and all the current settings from which the tree can be build. The information and the settings can be changed by addressing the menus and their items. All relevant parameters will be stored with the output in XML, so one can recall exactly how a tree was built.

In the model parameters tab (item (1) in Figure 2), most parameters can be set that influence the tree construction. The default parameter settings will work in most of the cases, but better results may be obtained by changing some of them depending on the specific problem.

By selecting the Model-menu (see (2) in Figure 2), the user can determine the input files to be used during the construction of the tree. The file format for the data to be read in is a text file where the columns are separated by tabs or comas (csv file is the general term, see Figure 1). The tab or comma delimiter is chosen in the "Model Parameters Window". Note that the first row contains the variables names and the last column contains the output variable.

	independent vars				dependent var
	var 1	var 2	var 3	…	output
obs 1					
obs 2					
…					

Figure 1 : Input format for data to be read in

There are three well-known ways of using a test dataset, (item(3) in Figure 2:

1. either by selecting an independent test file. If a separate test set is read in, the corresponding radio button is selected, i.e., radiobutton "File".
2. by sampling a proportion of the training data (part of the sample proportion will be used as test data and not as training data). This choice is shown by the radiobutton "Sample", for which the default is 1/3
3. by cross-validation, radiobutton "CV", for which the default is 10. This allows the user to set several "folds" to cross validate (test) the constructed tree with all the data. This is used when there is not much data available. The tree is constructed with all the data and the error is estimated by constructing 10 other trees (default value) and leaving for each of them one 10th of the data to estimate the error. With the 10 errors obtained the final error is estimated as the average.

From now on, we assume the files are chosen and we concentrate on the specific parameter settings.

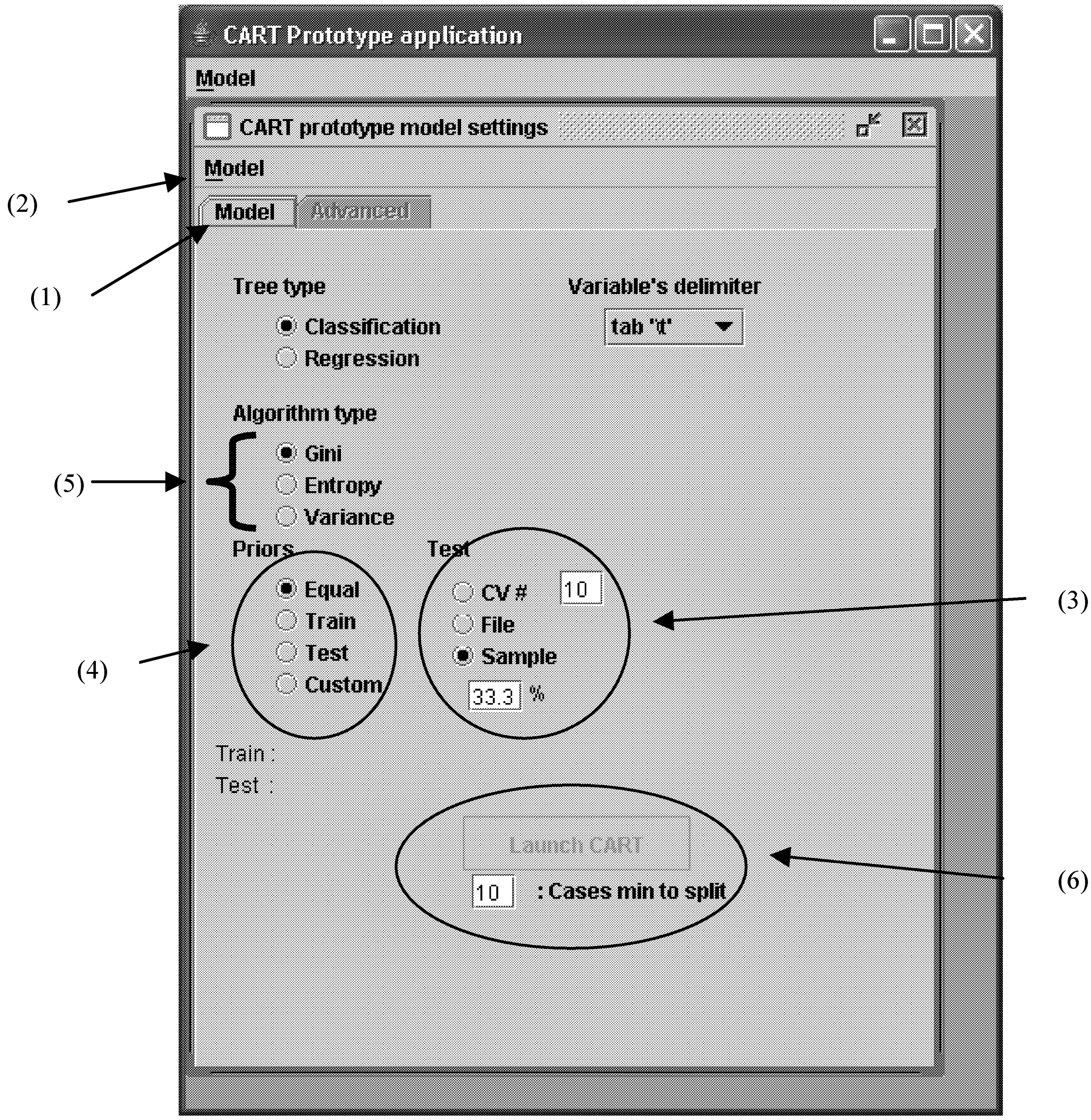

Figure 2 : Model Parameters Window

Once a training- and test set is created, one can set additional parameters that depend on the data: the misclassification costs and the priors.
Depending on the priors (the class distribution in the training set) and the misclassification costs (see further), a certain class may be picked for each (impure) node: this is cost-based classification. The estimated expected misclassification for a case classified as class *i* is given by

$$\sum_{j=1}^{J} C(i|j)p(j|t)$$

here is

- $C(i|j)$: cost of classifying class *j* as *i*,
- $p(j|t)$ the conditional probability estimated by the class proportions for a node *t*.

For the root node, one often takes as prior probabilities (priors), denoted by $\pi(j)$, the proportions N_j/N (frequency approach), where N_j is the number of cases in class *j* and *N* is the total number of cases., i.e., $\pi(j) = \dfrac{N_j}{N}$

A predicted class, which can be assigned to each node, depends on three factors:

(1) the assumed prior probability of each class within datasets;
(2) the decision loss or cost matrix;
(3) the fractions of subjects with each outcome in the learning dataset that end up in each node.

The function of node class assignment ensures that the tree has a minimal expected average decision cost for future datasets similar to the learning dataset in which the probability of each outcome is equal to the assumed prior probabilities.

More specifically, the node is assigned class i if (remark the influence of priors and misclassification costs) :

$$\frac{C(j\mid i)\pi(i)N_i(t)}{C(i\mid j)\pi(j)N_j(t)} > \frac{N_i}{N_j} \quad \text{(assignment rule)}$$

with $N_i(t)$ the number of cases from class i in note t.
Assuming equal misclassification costs, this boils down to $p(i\mid t) > p(j\mid t)$.

The program has the possibility to set the priors and the cost matrix in a separate window. Default cost settings assign a cost of zero for correct and a cost of 1 for incorrect classifications (applicable to classification only).

The class priors, item (4) in Figure 2, represent the prior probability of each class. It can be viewed as the real percentage of cases in the population (if they are different from the sample).The user can specify the prior class probabilities for classification trees. The option is ignored and disabled for regression trees. Setting the priors can be advisable if the data set is very unbalanced between classes. The priors can be used to adjust the individual class misclassification rates in any desired direction. For example, taking equal priors tends to equalize the misclassification rates. Putting a larger prior on a class will tend to decrease its misclassification rate, and vice versa, because it becomes more important.

GROWING THE TREE

The purpose of splitting a node is to generate offspring that are more preferred than the root node in some sense. Desirable splits are the ones for which the distributions of the outcome in the child nodes are more homogeneous (purer) than in the root node. It can be formalised by an impurity function. The impurity in a node t is formally denoted by $i(t)$.

Starting at the root node, each node is split with the help of a splitting criterion. For a given splitting criterion, one could try to find directly the smallest decision tree consistent with a training set. This problem is, however, NP-complete. Consequently, most tree induction methods use greedy algorithms and, hence, do not backtrack.

The goodness of a split s in a node t is defined to be a weighted decrease in impurity, i.e.,

$$\Delta i(s,t) = i(t) - \sum_{descendants} p_{descendant|s} \cdot i(descendant|s)$$

where $p_{descendant|s}$ is the proportion of cases that go into the corresponding descendant node for a given split s.
At each node t, all candidate splits s are explored. The split s^* that gives the largest decrease in impurity is then applied, i.e.,

$$\Delta i(s^*,t) = \max_{s\in S} \Delta i(s,t)$$

where S is the set of all possible splits at node t.

A good choice for impurity is the **Gini-index**, which is defined as

$$i(t) = \sum_{i=1}^{J} \sum_{\substack{j=1 \\ j\neq i}}^{J} p(j\mid t)p(i\mid t) = 1 - \sum_{j=1}^{J} p^2(j\mid t)$$

The Gini-index can be interpreted as an estimated probability of misclassification under random assignment, or as a variance for dichotomous classification.

Another good choice for impurity measure relies on the utilisation of the **Shannon entropy**. It is given by

$$i(t) = -\sum_{j=1}^{J} p(j\mid t)\log_2 p(j\mid t)$$

Impurity (in a node t) is often associated with the average amount of information needed to identify the class of a case in a given set cases (in the node t).
Many other rules can be devised, see [Breiman et al. 1984; Mingers 1989], but the 2 most popular rules (Gini and Shannon rule) are implemented (item (5) in Figure 2).

Note: In the splitting of numerical values we have a small difference because our implementation takes all splits while the commercial package bins them in the case of numerical variables.

PRUNING THE TREE

Too much splitting would yield a generally too large tree to be useful (overfitting) and this not only with regard to the comprehensibility, but also with regard to classification errors on new cases. A pruning strategy has to be designed to prevent overfitting because a tree classifier is important, not because it summarises what is known (the training set), but because it hopefully classifies new cases correctly.

There are essentially two pruning techniques available: forward pruning and backward pruning.
The CART methodology and its implementations rely on backward pruning. In this case, one may first split further and further until one arrives at single-class subsets, even if all or most of them contain a single training case. This is prohibited for it would model the idiosyncrasies of the training set. Hence, a significant number of cases at each leaf must be retained. This is an option in the implementation where one can set the “Minimum Parent Node Size” (item (6) in Figure 2). It represents the minimum size below which a node will not be split. This value is set to 10 by default. Increasing allowable parent node sizes enables the user to control tree growth and to potentially fit larger problems into a finite work space.

The window in Figure 3 shows a typical result of a tree construction with the program.

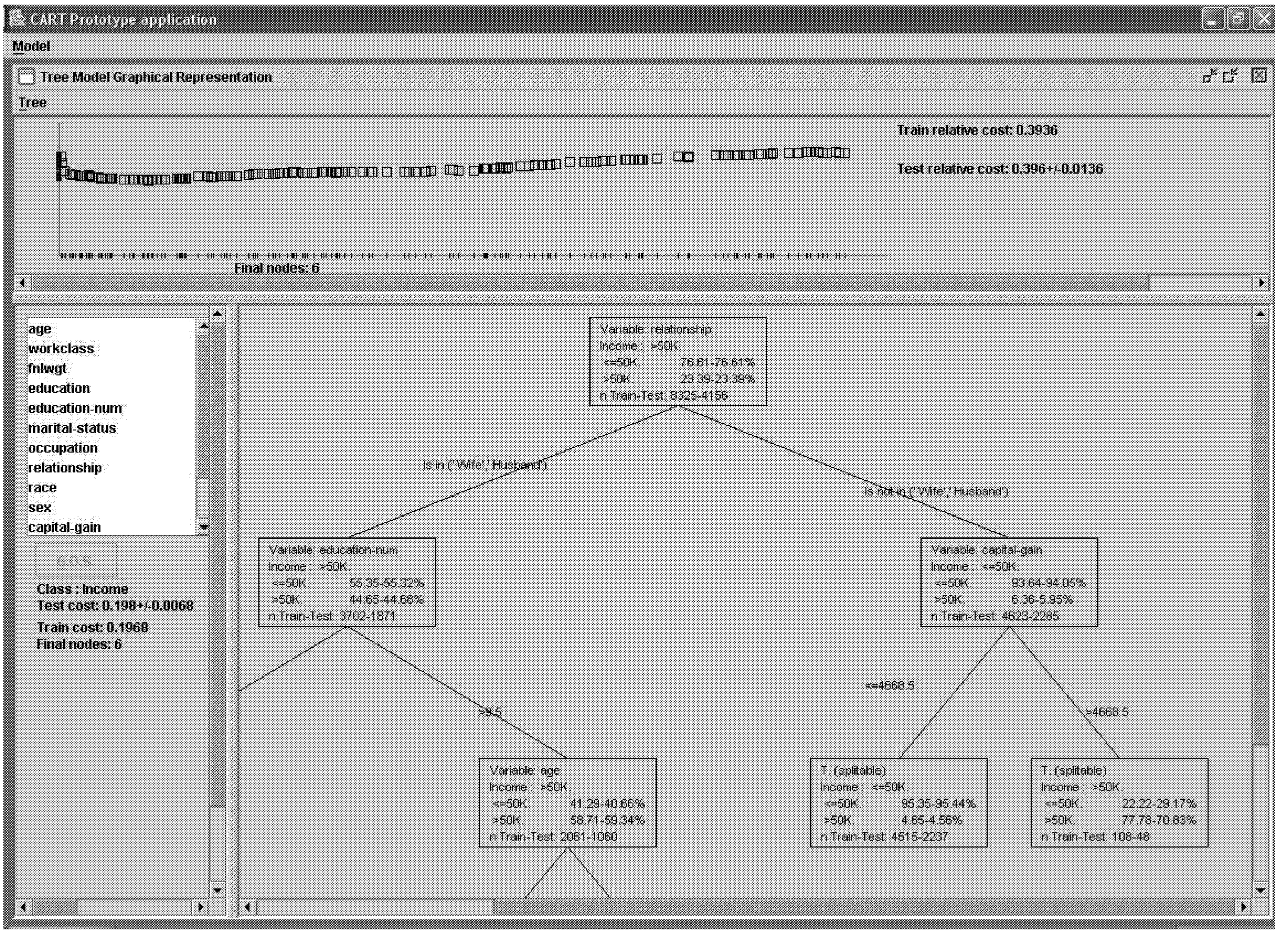

Figure 3 : The results window

The results window displays all the results of the constructed tree model generated from the model parameters set in the Model Parameters Window. The results window is divided into 3 parts:

1. Tree Panel (lower right corner): this panel displays all the information related to one particular tree in a graphical way (root node is on top).
2. Info Panel (lower left corner): this panel displays all the information related to the segmentation variables and the selected tree (ranking of important variables).
3. Pruning Sequence Panel (upper side): this panel displays the pruning sequence that was generated from the model parameters which were set in the Model Parameters Window.

The information in the tree panel nodes is :

- the variable used to split the node
- the classification of this node
- percentages of the cases for each of the classes (first in train data, then in test data)
- the amount of samples classified in this node (train test)

To be able to see the ranking of the power of the variables to split a node, one selects a node by double clicking on it, and then you press the buttons GOS goodness of split) in the info panel left.

Then you see a list of variables that can be used to split that node (if NA is written after the variable, this variable is not applicable anymore). After the variable you can see a value that is an indication of how good it is to use that variable to split the node: the higher the better.

In the tree panel select the menu Tree → Save Model and this will save the model in XML. Write a name that ends with XML so that it can be interpreted by XML browsers and click on the button save model to save the model in XML (PMML) format. This model format is the standard way of specifying models in the PMML (Predictive Modeling Markup Language) language which is an XML language to specify predictive models such as regression, association rules, decision trees, neural networks and more.
The file below gives some partial extract of the saved text for a certain grown tree.

```
- <PMML version="2.0">
   + <Header copyright="Copyright information">
   + <DataDictionary numberOfFields="5">
          <Interval closure="closedClosed"
              leftMargin="0.1" righMargin="2.5" />
       </DataField>
   - <TreeModel modelName="CART tree model"
         functionName="classification"
         algorithmName="Cart"
         splitCharacteristic="binarySplit">
      + <Extension extender="Extender name"
            name="ConstructionParameters">
      + <MiningSchema>
      - <Node score="1" recordCount="99">
           <True />
           <ScoreDistribution value="1"
               recordCount="33" />
           ...
         + <Node score="1" recordCount="33">
         - <Node score="2" recordCount="66">
              <SimplePredicate field="PETALLEN"
                  operator="greaterThan"
                  value="2.449999988079071" />
              <ScoreDistribution value="1"
                  recordCount="0" />
             ...
           </Node>
       </Node>
    </TreeModel>
 </PMML>
```

The complete specification and examples can be found at www.dmg.org, more specific in http://www.dmg.org/v2-0/GeneralStructure.html. Once the tree model is saved it can be viewed by any XML browser such as Mozilla or internet explorer. Even by a normal text editor since the model is saved in an XML file which is a text file.

REGRESSION (DEPENDENT VARIABLE IS CONTINUOUS)

If the output (response) variable Y is continuous, regression trees can be used. They can be though of as a histogram estimate of a regression surface. Many procedures, such as variable combinations, surrogate splits, missing value handling, and variable importance for tree classifiers just carry over without any modification. Regression trees are simpler because the same impurity criterion is used to grow and prune the tree, and each case has the same weight in 'misclassification'.
An example is given in the book of Breiman et al. [1984] and shown in Figure 4.

A number within each node is the average of the response. The numbers in the middle of the arcs show the cases that go left or right, and the numbers below the leaves are their standard deviations of the corresponding response. The test at each internal node, which is denoted by a circle, is written just below it. The example showed that only 4 of the 13 predictors were retained for splits. Surrogates (not discussed here) can be determined to assess the importance of each variable.

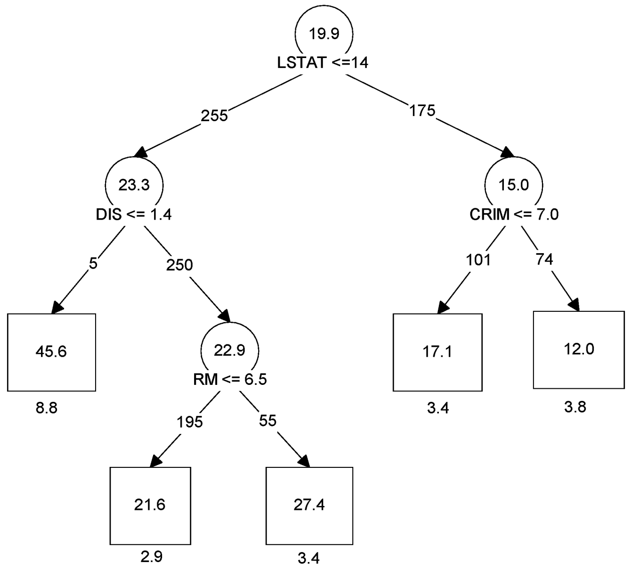

Figure 4 : Regression tree example (part from figure in [Breiman et al. 1984 p 219])

USING THE TREE ON NEW DATA

In the tree window, select the menu Tree → Evaluate and the data file to be evaluated with the given tree and press the button evaluate. This scores the data and generate a file with the classification (or prediction). The data file to score has to have the same variables as the ones used in the tree. The format has to be the same as the one from the file used to construct the model. It uses the name of the file to evaluate and adds the extension eva (from evaluated).

CONCLUSION

The Java implementation of CART performs well and gives the same results as the commercial package. Only in the splitting of numerical values there is a small difference. Times for training are in the same order as for the commercial package. Only there are less options in our implementation and the GUI is not as flashy as in the commercial version.
Work for the near future may be the addition of more splitting criteria, pruning control and a better GUI.

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A DATA WAREHOUSE SYSTEM IN BUSINESS PERFORMANCE MANAGEMENT IN SME'S

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KEYWORDS

Data warehouse; Management reporting tools; Dimensional modeling; Business performance management;

ABSTRACT

In this paper we will explain the PRESTA system.
This is one of the information systems used in a methodology that leads the company to the use of performance management. PRESTA is used for the creation of the specific KSF-PI model of the enterprise, for the generation of a specific data warehouse, for the input of company data and norm values and last but not least for the generation of the BSC en its evolution scheme.

1. BUSINESS PERFORMANCE MANAGEMENT

Organizations are seeking new, integrated systems that enable rapid changes in direction through early identification of opportunities and problems, tracking of progress against plans, flexible allocation of resources to achieve goals, and consistent execution. Traditional systems, including ERP and business intelligence software, are not sufficient by themselves to meet this demand. Out of these requirements has emerged a new category of enterprise automation technology: Performance Management.
The term Business Performance Management (BPM) is used to represent a new category of systems and processes and it pinpoints the need to integrate strategy and key indicators of performance into management processes, and to exploit technology to improve monitoring, reporting, and decision making.

Additionally, they all rest on assumptions that organizations must focus on critical success factors and ensure that the business processes of planning, budgeting, forecasting, and reporting are aligned to achieve strategic goals. This involves integrating all organizational activities "from top to bottom" around strategy.
The best known model based on the basic idea of performance management, is the Balanced Scorecard of Kaplan and Norton.
Performance Management is aimed to collect and process in a consistent way the large amounts of data available in a company into management information.

A methodology has been built that leads the company through the use of five basic steps to the implementation of performance management.
After an intake conversation, a scan of the company will be taken.
In line with the mission, the objectives and the strategies of the company, the CSF (Critical Success Factors) can be identified. The PI's (performance indicators) linked with them, modeled using PI variables, can be measured. The comparison with the selected norm values results in a BSC (balanced scorecard) report

2. DATA WAREHOUSE (DWH)

In data warehousing key operational data from around the company is integrated in a form that is consistent, reliable, and easily available for reporting.
A data warehouse is a database, with tools, that stores current and historical data of potential interest to managers throughout the company. The data originate in many core operational systems and external sources and are copied into the data warehouse database as often as needed-hourly, daily, weekly, monthly.

2.1 DWH ARCHITECTURE

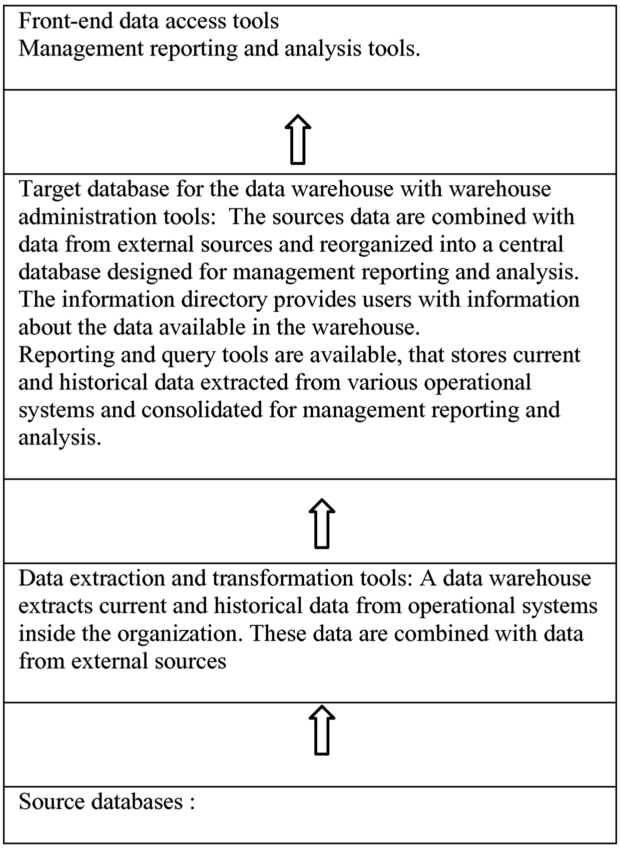

Fig 1: DWH architecture

2.2. MANAGEMENT REPORTING AND ANALYSIS TOOLS.

- Front end data access tools

- Standard C/S tools (PowerBuilder, Visual Basic, Delphi..)
  These tools are recommended for the development of customized data applications
  End -user query tool (Forest & Trees, Business Objects,..)
  These tools support flexible query and reporting features, allowing users to access to relational data without requiring intervention of database administrator. Such tools are appropriate if simple query are running intermittently against target database

- EIS/DSS tools (Pilot Desktop/Designer and Comshare) These tools are more complex for high-end multidimensional analysis. They differ from standard query and reporting tools in additional data processing (making multidimensional data reorganization, data aggregation, data consolidation). Additional data processing supports sophisticated data access (above the SQL limits) and on -fly analysis rules support. These tools brings to the data warehouse concept advanced analytical possibilities required in the financial reporting and consolidation, line of business profit reporting, marketing analysis and management reporting.

- Data mining tools (Pilot Discovery Server) Data mining products are characterized as exploratory because they seek to identify information without presuming an initial question or hypothesis. Data mining products analyze data and report back any meaningful information.

3. DIMENSIONAL DATA STRUCTURE AND MODELLING IN PERFORMANCE MANAGEMENT SYSTEM.

To become a multi-dimensional view of the data, data has to be organised following a multidimensional data modelling method. Data has to be organised in facts and dimension tables. The facts tables correspond to the processes and the dimension tables to the description of the processes. Based on the management information requirements, processes and attributes have to be selected. In our Performance management application, we have to start from the PI's, their measurement model and the underlying PI measuring variables.
To become a generic system that can become customised for a range of business situations, we define the generic data model corresponding a generic list of CSF's and PI's.

We developed the generic list of CSF's and PI's, structured in 6 domains related with the business functions, the employees, procurement and suppliers, market and customer, finance, process and product and business environment.

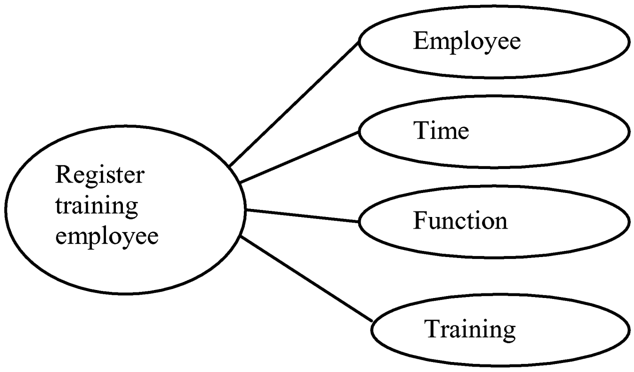

Fig.2: Example of a process and its characteristics.

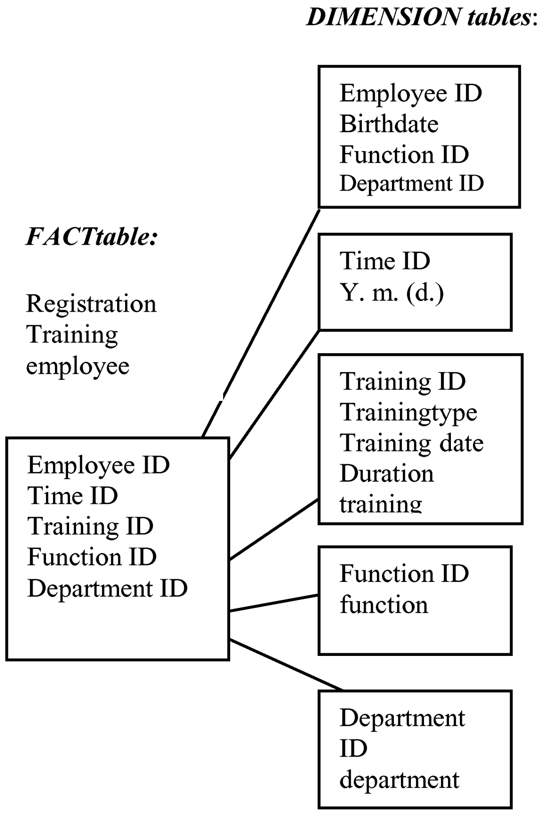

Fig.3: Example of fact and dimension tables

4. MANAGEMENT REPORTING AND ANALYSIS TOOL IN PERFORMANCE MANAGEMENT AS PART OF THE DWH SYSTEM.

In our Performance management application, we have to start from the PI's, their measurement model and the underlying PI measuring variables.
The PI measuring variables are organised in facts and dimension tables.
In the management analysis and reporting system the PI measurement models have to be implemented and the balanced score card (BSC) report has to deliver the management report on point of PI measures and the selected norm values. This BSC report will be very helpful in determining business problems.

BSC		
TIME ID: 001	DOMAIN: Employee	CSF: educated personnel
	Value of PI measure	Norm value
Average training intensity per employee	25%	10%
Proportion of trained personnel	20%	15%

BSC		
TIME ID: 002	DOMAIN: Employee	CSF: educated personnel
	Value of PI measure	Norm value
Average training intensity per employee	20%	10%
Proportion of trained personnel	50%	15%

Time ID value	Average training intensity per employee	Proportion of trained personnel
001	50/(20*10)=25%	2/10= 20%
002	42/(21*10)=20%	5/10= 50%

Time ID value	Average Number of working days	Total number of training days	Number of emplo-yees	Number of employees with training
001	20	50	10	2
002	21	42	10	5

Fig 4: Example management reporting based on input of data for PI measurement variables

5. PRESTA: DWH SYSTEM OF PERFORMANCE MANAGEMENT

The PRESTA system is planned to be a generic DWH based on a management performance system. Based on the input of specific CSF's and PI's of an enterprise, it generates a DWH dimensional data structure. The input of the data is done automatically from the operational databases.
A specific BSC report is being created

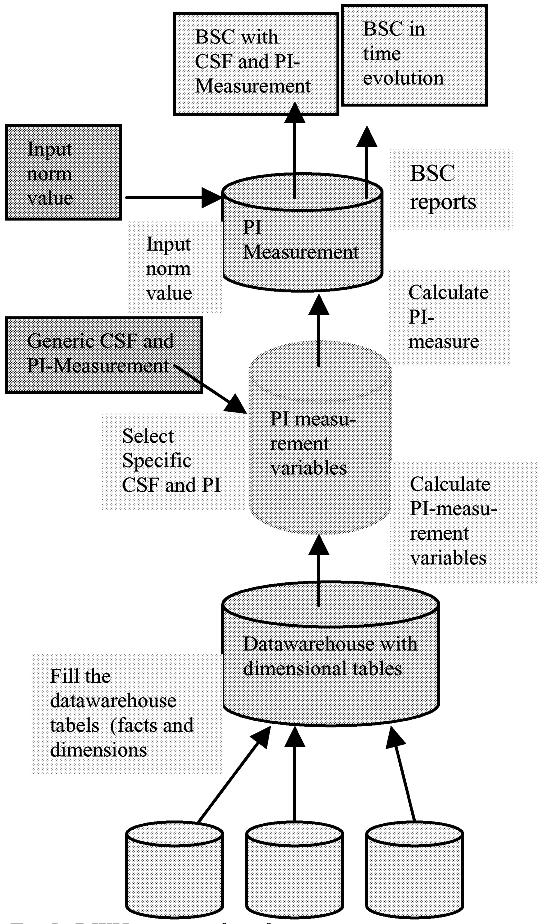

Fig 5: DWH system of performance management

6. DATAWAREHOUSE MODEL ADOPTED TO THE LIMITED SME 'S ICT INFRASTRUCTURE

6.1. THE SYSTEM

Considering the fact that within SME's, the operational database structure is far from complete, we are forced to build the system in such a way that the input of the warehouse tables can be done manually.
(We keep the data structure and we can build the database warehouse system for that company that is ready for it.)
The system is structured as follows:

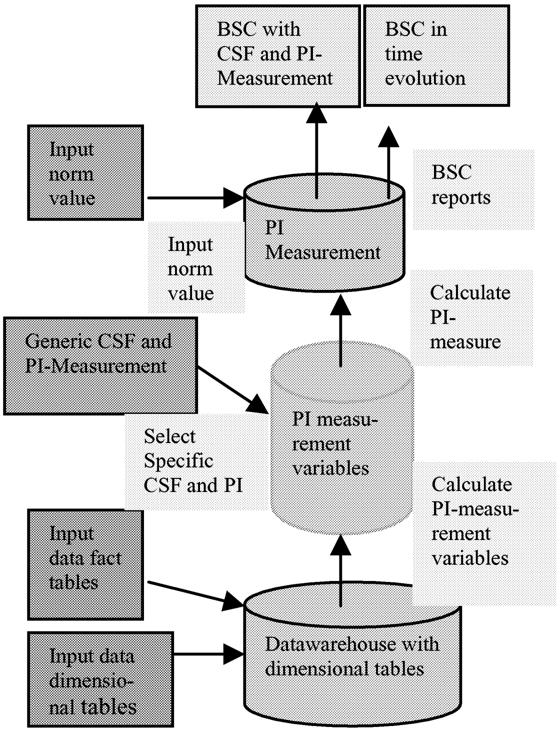

Fig 6: DWH system adopted to the limited SME's ICT infrastructure

6.2. RESTRICT THE MANUALLY INPUT BY IMPORTING ON PI-MEASUREMENT VARIABLES LEVEL

6.2.1. Data structure based on the unity of a company instead of on the level of the unit employee

Because the manual input of basic data is a lot of work and it also leads to double input of the same data, there is agreed to do the input on PI-measurement variables level. By doing this the measurements are kept at company level and one loses detailed data. These detailed data appeared not to be relevant for the BSC.
I want to point out for a moment the difference between importing and structuring on employee level against on company level (possible division level)

For example
CSF: educated personnel
PI: training intensity
PI-measurement: number of training days compared with number of working days.
(PI-measurement variables: number of training days, number of working days)

- On employee level:

input by training: once a month all trainings
this is done with an entry screen : specify month, specify employee, specify division, specify duration of training, specify training type,...
The number of rows is now equal to the number of trainings in a data tableThe program calculates the PI-measurement variables and the PI-measurement and it creates a BSC with the CSF and PI-measurements in it.

- As on business level:

The company calculates how many employees, trainings, the average number of training days by employee.
This is giving in by month and by division
This is done with an entry screen: specify month, specify employee, import the number of employees by division in that month, input the number of trainings in that division, input the average duration of the trainings.
The number of rows is now equal to the number of divisions in a table of PI-measurement variables
The program calculates the PI-measurement and creates a BSC with the CSF and PI-measurements

As you can see, the content of input changes. In the first case it deals with making a number of simple indications and one input and this for all trainings and all divisions.
In the second case the company calculates a number of data in advance and imports all this data. This happens for all the divisions
This approach of database construction is not according to the theory of DWH management.
Considering the fact that in a SME the basis is however not present, we were forced not to import this necessary data automatically in the data warehouse but deliver the input manually. Tis seems to be a great effort for a SME. The alternative is that the SME carries out a number of calculations manually and imports these results by month. This is the solution that is offered now. If the PI's can be calculated in advance, this solution is acceptable

6.2.2. The operational PRESTA system

The system is reduced to the following structure.
We put to keep the total structure and we can import for companies which have a good database structure and can and wish to build out a data warehouse.

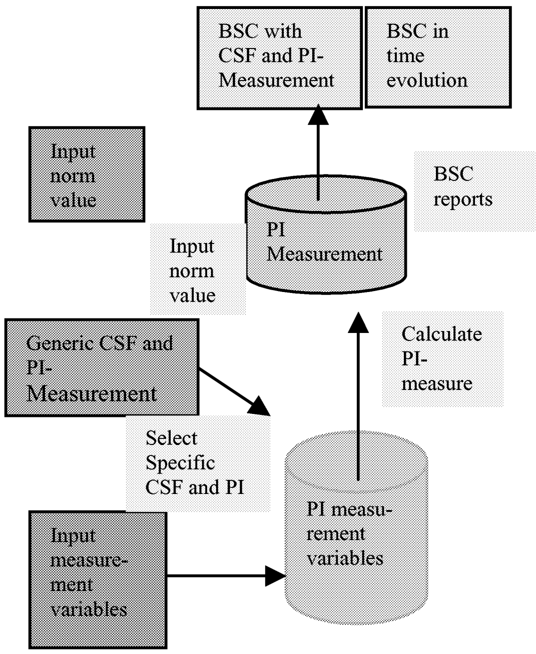

Fig 7: Operational PRESTA system

7. SYSTEM CONFIGURATION OF PRESTA SYSTEM

The overall architecture of the PRESTA IS is designed to be adaptable to the needs on point of access availability of consultants and enterprises, being located spread over our geographical region of the Province of Limburg.

In the start up phase, the system and the data warehouse are installed and will be hosted on a central LUC-LEARNING server. The consultants and the enterprises analysts have the possibility of remote access internet browser access).

Technically this infrastructure includes a web-server, a database server as application services facilities for the PRESTA system.

The web-based PRESTA system is developed in ASP. The decision on which web development tool to use has been taken, taking into account the in house available knowledge of the ASP language. Another decision element was the wide spread use of windows server in case a change of server will be needed.

We have chosen for the database system MySQL. The advantages of using an open source solution are well known. As a consequence the implementation of front-end data access tools and of commercial management reporting and analysis tools is guaranteed. Based on data from our data warehouse, our PRESTA system is generating the BSC management report, But the DWH can also be used for other management reporting, resulting from other DSS tools.

After full deployment and testing of the solution in this phase, the system will be extended to become a full data warehouse based PRESTA system. In that phase, the PRESTA system will get the data direct from the PRESTA data warehouse. A data warehouse system has to be implemented, getting its data from the corporate database. Some companies will opt for a local data warehouse system. The PRESTA system on the central server has to be integrated with the local data warehouse system.

8. CONCLUSION

Performance management is the measurement of performance in an organization which makes it possible for the management to control the company (better) on these performances. Performance management should be on the agenda of every company. A methodology has been built that leads the company through the use of five basic steps to the implementation of performance management.
One of the information systems used for the realization of this process is the PRESTA system. PRESTA is used for the creation of the specific KSF-PI model of the enterprise, for the generation of a specific data warehouse, for the input of company data and norm values and last but not least for the generation of the BSC en its evolution scheme.

In data warehousing, key operational data from around the company is integrated in a form that is consistent, reliable, and easily available for reporting. To become a multi-dimensional view of the data, data has to be organised following a multidimensional data modelling method. Data has to be organised in facts and dimension tables. The facts tables correspond to the processes and the dimension tables to the description of the processes.
In our Performance management application, we start from the PI's, their measurement model and the underlying PI measuring variables. The PI measuring variables are organised in facts and dimension tables.

The PRESTA system is planned to be a generic DWH based on a management performance system. Based on the input of specific CSF's and PI's of an enterprise, it generates a DWH dimensional data structure. The input of the data is done automatically from the operational databases.

Considering the fact that within SME's, the operational database structure is far from complete, we are forced to build the system in such a way that the input of the warehouse tables can be done manually.
Because the manual input of basic data is a lot of work and it also leads to double input of the same data, there is agreed to do the input on PI-measurement variables level.

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E-LEARNING PROCESS AND CONTENT MANAGEMENT

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KEYWORDS

Learning process, Learning Objects, Learning Management System, Learning Object Management System, e-Learning.

ABSTRACT

We will explain how the organization of the learning process is supported, how the included learning content has been defined as learning objects, how the management of the learning content is independent of the learning process itself and how the creation and the storage of and the access to learning objects in the LOMS has been organized.

1. INTRODUCTION

The LMS and the LOMS of LUC is a complete learning process support system. All functions on point of management of the learning materials, the modeling of the e-learning content modules and that of the e-learning process, ... are available in the system.
All system functions have been implemented in the courses of J.Schreurs in LUC. The students highly appreciate the approach, especially those of the “life long learning” study programs. The development of the systems was based on personal research of J.Schreurs. The development was partly funded by the Flemish Government in the frame of an innovation program.
Research and development is ongoing now in an internal project by the team of J.Schreurs in the unit LEARNING of the research group DAM.
The organization of the learning process is supported by our learning management system LMS. The learning content has been defined as learning objects. The management of the learning objects is organized in the LOMS ,independent of the learning process itself. Our LOMS is managing the creation, the storage and the access to learning objects. LOMS extensions will be in the domain of automatic modeling of e-learning modules.

2. ORGANIZATION OF LEARNING: LEARNING PROCESS

The learning process can be organized as:
- A full e-learning self-paced process for the individual learner
- As an e-blended learning process, being a mix of traditional (ICT supported) classroom activities and e-learning activities (including limited e-learning self-paced activities).

The process being a sequence of a number of activities is defined/structured in the LMS.
The learning content, as managed in the LOMS can be linked with the learning process.

3. LEARNING CONTENT AND LEARNING OBJECTS (LO)

As learning content we have the following types of information documents: E-learning course modules or learning objects (LO) about the content topics, additional supporting information documents, tutoring and/or instructional documents and student documents.

1. E-learning course modules or learning objects (LO) about the content topics.
   Most of the today generation LO’s are e-learning course modules with built in animation and interactivity elements. Those course modules have been composed of base content components, the atomic objects, being text, audio, presentations, …
   Several file formats can be applied.
   - learning content text based information.
   - Animation elements (figures, video fragments, audio, mouse over text, short questions and hidden answers, ….and interactivity elements (assignment, self test, …) are integrated with the content text. (fig 4)
   - Presentation based information;
   - Animation elements (figures, video fragments, audio, mouse over text, short questions and hidden answers, ….and interactivity elements (assignment, self test, …) are integrated with the content text.
   - Spreadsheet based information;
   - Animation elements (figures, video fragments, audio, mouse over text, short questions and hidden answers, ….and interactivity elements (assignment, self test, …) are integrated with the content text.
   - Video based information;
   - Animation elements (figures, video fragments, audio, mouse over text, short questions and hidden answers, ….and interactivity elements (assignment, self test, …) are integrated with the content text.

2. Additional supporting information documents, to support the basics or the fundaments of the learning content with extensions, explanations, case/examples, ….
   All types of file formats can be applied;

3. Tutoring and/or instructional documents
   In some cases tutorials or tutoring documents do exist,

already developed or available as freeware. If the course is organized as a virtual classroom course or as the individual learner is supported by a tutor, some instructions/explanations have been given via instructional documents.

4. Student documents: documents on the topic prepared by students/student teams to share knowledge with all students from the learners team. (fig 5)

4. LOMS

LOMS is managing the input of, the storage of and the access to the learning content in the permanent warehouse or in the temporary warehouse.
The e-learning course modules or learning objects are stored in the permanent warehouse
The documents organization follows the topics-classification system UDC (used in libraries). The metadata can be stored in a data table (all ODBC DBMS can be used).
All other information documents as we have the additional supporting information documents, the tutoring or instructional documents and the student documents are stored in the temporary warehouse.

Which LMS can be used in combination with our LOMS?

As a LMS the user can opt for a commercial LMS.

A basic requirement posed to it is the SCORM standard, especially the independency between the learning process and the content management.
A good alternative is our available standard student/instructor learning portal. It can be implemented and customized for the customer.

Which database system can be used in the LOMS?

All ODBC DBMS can be used.

5. THE LEARNING CONTENT MODULES OF THE LEARNING PROCESS ARE IMPLEMENTED IN THE LMS

Functions of LMS:

Via the instructor portal the instructor can model the learning process for the student team participating in the virtual classroom, by planning the sequence of activities and by composing the learning content by selecting course modules from the warehouse of the LOMS and link them to the learning activities.
Via the student portal the individual learner can select some learning modules fitting best his/her characteristics or priorities

fig 1: student portal

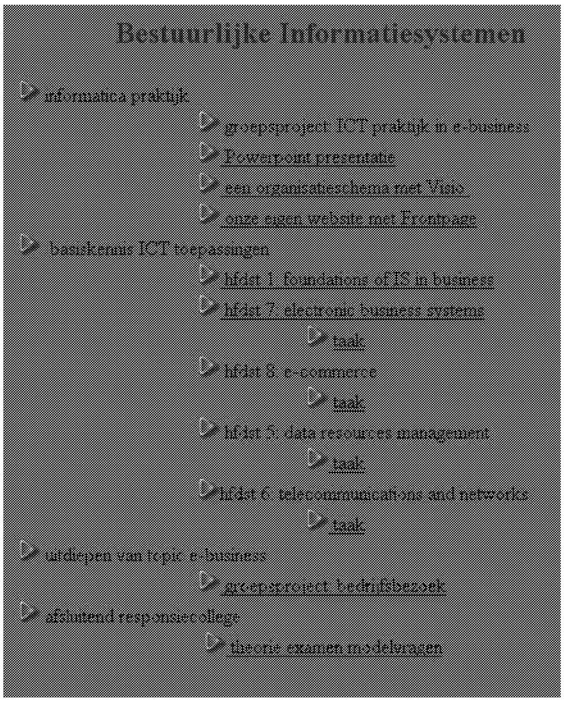

fig 2: student portal

Via a student/ instructors portal the student/ instructor can enter into the learning process and all its activities and can have access to the content. The systems underlying the activities, a.o. a (a-synchronic and synchronic) discussion forum and a self testing facility can be started from within the portal. A search facility is available to search in the warehouse of learning content.
Via the student portal the student can submit student prepared information documents into the temporary warehouse of the LOMS, and can share the documents with student team members.
User administration is part of the LMS.

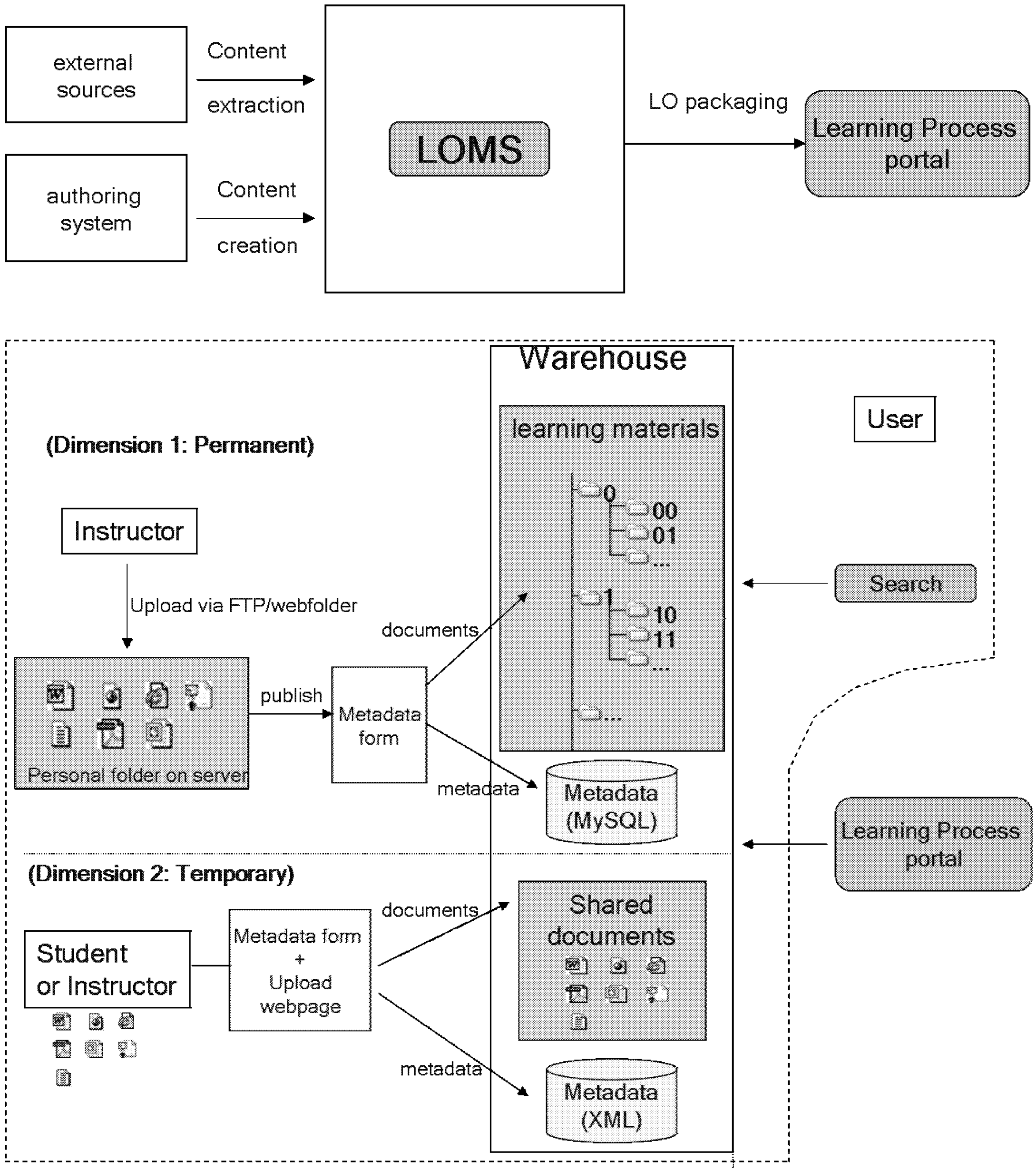

Fig 3: LMS and LOMS

6. ATOMIC OR ELEMENTARY LEARNING OBJECTS AND MASS CUSTOMIZATION IN PRODUCTION OF LO'S

Elementary components of a LO are: content delivery elements, animation elements and interactivity elements. Those elements are the basic atoms or the atomic or elementary learning objects. Structuring of those LO as independent objects is set forward. Those atomic objects will be managed and stored in the warehouse of the LOMS. So re-usability is guaranteed. The same objects can be re-used as part of more e-learning course modules. The maintenance of the atomic objects is part of the functions of the LOMS.
From the other side, the creation of an e-learning course module or LO by selecting the relevant atomic objects and packaging them, hasn't to result in a physical available e-learning course module or LO. Virtual LO's can be created to be used in ad hoc or on demand learning situations.

Modelling of the e-learning course modules or learning objects, is done by composing some atomic learning objects corresponding to all animation and interactivity elements, as mentioned earlier.
Those atomic learning objects are: base text objects, basic audio objects, figures/pictures objects, video fragments objects, audio objects, mouse over text objects, short questions and hidden answers objects, assignment objects, testing objects, …
The modeling function can be applied by the instructor, modeling the virtual classroom course for a student group. It can also be used by the individual learner composing its learning module fitting to his/her priority.

The FUTURE is to mass customization. From one side is the mass production of the atomic objects and from the other side is the customization and the personalization of the learning process, guaranteed thanks to the on demand modeling of the e-learning course module of LO. Those virtual e-learning course modules or LO's function as flexible on demand solutions and will be made available in the LMS or learning portal of the learner.

7. AN EXTENDED LOMS WILL MANAGE THE LEARNING CONTENT

LOMS will manage the learning content, being:

- the e-learning course modules or learning objects (LO) about all topic
- the atomic learning objects
- additional supporting information documents
- tutoring or instructional documents
- students documents

Most of the users have already many information documents available that can be implemented as learning content. Some e-learning modules with built-in animation and interactivity are already developed. And commercial courses can be find in the commercial learning software sector.
Presentations, video fragments and other scientific, general and professional information documents are also available.

All learning content will be organized in the warehouse of the LOMS.
All atomic objects will be structured and managed. Object classes and their repository will be defined and built.
Some e-learning course modules or standard LO's will be built to become a library of standard solutions, being a minimum supply of e-learning course modules.
The learning objects are based upon a completely XML-modelled publishing process. Base is a "problem-based-learning" Document Type Definition, so the resulting components in the central CMS are already strongly pedagogically structured (learning sequences, pre-knowledge, advance organizer, etc.). Re-configuration of "larger", didactically "allowed" content on base of user and usage specific meta data is the core element and functionality of our central editorial processes based upon our XML content management system.

8. MODELLING OF PEDAGOGICALLY STRUCTURED E-LEARNING MODULES OR LEARNING OBJECTS

The future learning objects will be based upon a completely XML-modelled publishing process. The resulting components in the central LOMS will be strongly pedagogically structured (learning sequences, pre-knowledge, advance organizer, etc.). Re-configuration of "larger", didactically "allowed" content on base of user and usage specific meta data will be the core element and functionality of our central editorial and modelling process.

A web based planner, a web based search facility and a web based learning process modeling facility will be available in the LMS or the learning portal. The instructor will use them to

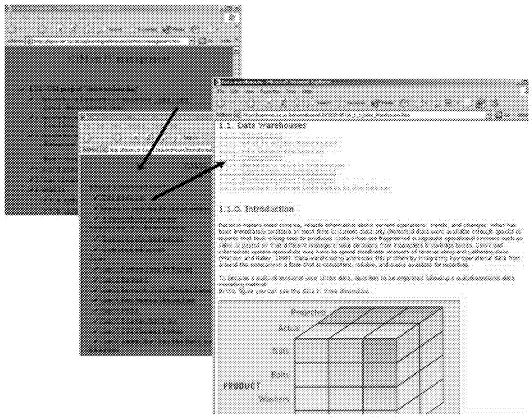

fig 4: link to LO with built in animation and interactivity

plan the learning process as a sequence of activities, to compose the learning content by selecting e-learning course modules from the warehouse of the LOMS and link them to the learning process.

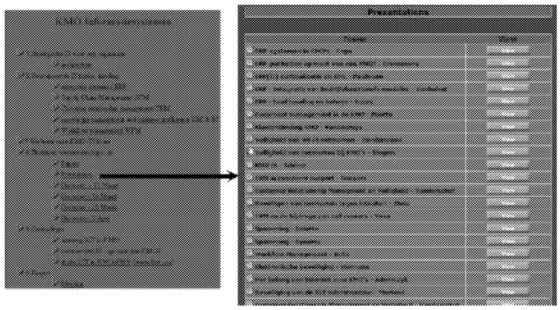

fig 5: student documents. Overview generated by the system

The instructor can create new virtual learning objects on demand. First the instructional design has to be made. Afterwards, some atomic learning objects have to be selected (using built in characteristics) from the warehouse and have to become packaged into new virtual learning objects using the e-learning module modeler
In case of more interactivity and tutoring by the instructor/tutor supporting the course, tutoring documents and instructional documents are linked with the learning process. If students have a role in knowledge sharing between the team members, the submission of student prepared information/knowledge documents is organized in the portal.

9. COMPOSING OF PERSONAL E-LEARNING COURSE MODULE BY THE INDIVIDUAL LEARNER.

On the same way as the instructor can compose an e-learning module, by packaging atomic learning objects, an individual learner can do.

10. FUTURE AUTOMATIC MODELING OF LEARNING OBJECTS OR E-LEARNING COURSE MODULES AND NEW GENERATION OF LEARNING OBJECTS.

The creation of a LO or an e-learning course module can be done at time of use. This real-time automatic modeling can be done thanks to the built in characteristics of the atomic learning objects and thanks to the defined linkages between different classes of objects.
The development of this extension of our LOMS is ongoing now.

But still we need a lot of time to convince the users of the added value of this new generation of LO's. The dynamic way of LO creation and the reusability of the atomic learning objects is the solution of the future.

11. CONCLUSIONS

This paper will convince the reader of being presenting here the best solution available, fitting the requirements of the users of e-learning systems.

The LMS and the LOMS of LUC is a complete learning support system. All functions on point of management of the learning materials, the modeling of the e-learning modules and that of the e-learning process,… are available in the system.

In the LMS, via the instructor portal, the instructor can model the learning process for the student team participating in the virtual classroom, by planning the sequence of activities and by composing the learning content by selecting course modules from the warehouse of the LOMS and link them to the learning activities.

LOMS is the kernel part of the LMS. LOMS manages the learning content.
LOMS has the modeling function to model the e-learning course modules or learning objects, as composed of some atomic learning objects corresponding to all animation and interactivity elements.

The instructor can create new virtual learning objects on demand. First the instructional design has to be made. Afterwards, some atomic learning objects have to be selected (using built in characteristics) from the warehouse and have to become packaged into new virtual learning objects using the e-learning module modeler
On the same way as the instructor can compose an e-learning module, by packaging atomic learning objects, an individual learner can do.

The ongoing research is promising the best for the near future when the user applications will evolve to more advanced and flexible solutions, thanks to automatic modeling of learning objects or e-learning course modules and the new generation of learning objects.

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THE IMPACT OF VIRTUAL MOBILITY ON TRAVEL BEHAVIOUR: AN OVERVIEW

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KEYWORDS

Internet use, mobility, travel behaviour, modal shift.

ABSTRACT

The access to and use of the Internet has increased enormously over the last years, hence providing more and more people virtual access to goods, people, services and opportunities. People perform a lot of activities in this virtual world, thus creating virtual mobility.
Transport planners studied the impact of Internet use on travel behaviour for at least the same time. Most of these researches focus on commuter and shopping trips. This paper describes an overview of research results in order to get a clear view on the relation between Internet use and travel behaviour, and on the possibilities of the Internet to change travel behaviour.

THE INTERNET AND TRAVEL BEHAVIOUR: THEORETICAL BACKGROUND

Internet access and use in Western countries has increased enormously in a short space of time. Telecommunications and the Internet in particular offer a wide range of possibilities for people to conduct activities virtually, without travelling to the activity places.

The effect of technology and more specifically ICT on travel behaviour has been examined in different studies. Most of these works draw their conclusions upon the historic relation between telecommunications and travel, not upon empirical data (Lyons and Kenyon 2003). While the first studies suggested that ICT developments will make cities obsolete, or that telecommunications might eliminate all travel (Douma et al. 2003), the discussions nowadays have been broadened.

Salomon (Salomon 1986) identified four hypothetical possible effects of ICT on activities associated with trip-making.

- *Substitution*: one part of the travel demand is replaced by ICT. Physical trips to conduct activities are no longer necessary, given the use of ICT to perform these activities. The best example here is telecommuting, where the commuter trip itself is skipped.
- *Modification*: travel demand changes by using ICT. Travel is altered either by a shift in timing, routing, linking and trip chaining or travel mode. In the case of telecommuting people can shift the starting point of their trips to of-peak hours.
- *Generation*: ICT increases the travel demand, the use of telecommunications stimulates travel. The Internet makes it easier to conduct long distance virtual activities, thus enhancing the need to perform these activities in physical space too.
- *Neutrality*: refers to those instances in which ICT has no foreseeable effect on household travel behaviour.

Most of the research focuses on telecommuting, few studies investigate e-shopping. The literature on non-work commute or leisure impacts is rare and mostly hypothetical and theoretical (Douma et al. 2003; Farag et al. 2003). For this reason this paper will be limited to telecommuting and e-shopping.

Comparing the results of different surveys is difficult as their characteristics and methodologies differ too. If the research questions are similar, differences can still occur in sample size, sample strategy, content of the survey instrument. We will not give a detailed overview of each survey design, but we will highlight some of the results.

ICT-USE AND TRAVEL BEHAVIOUR

In 2003 the first wave of a German panel survey on ICT-use and travel behaviour was carried out (Nobis and Lenz 2003). A descriptive analysis of two extreme groups was one of the first results. The ‘heavy ICT users’ i.e. people who use cell phones and computers with Internet access present in their homes multiple times per week, were compared with the group of non-ICT users. The latter group includes all people whose household owns neither a cell phone nor a computer with Internet access and therefore cannot use any of these devices at home. Heavy users and non-users showed clear differences in socio-demographic features, but also with respect to their mobility.

Non-ICT users travel fewer kilometres per year. In a disproportionately high number of cases, they drive only up to 5,000 km per year, or indicate that they do not drive at all. The car availability of households with heavy ICT use correlates with their higher driving frequency. Heavy ICT users are more likely to live in households with two or more cars. Non-users live most often in households with no or one car. With regard to their attitudes heavy ICT users have a much greater affinity for cars (Nobis and Lenz).

Table 1: Information on Mobility

		Heavy ICT users	Non - ICT users
Distance driven per year	Up to 5,000 km	49.8%	50.2%
	5,001-10,000 km	71.7%	28.3%
	10,001-15,000 km	84.8%	15.2%
	15,001-20,000 km	95.8%	4.2%
	20,001-30,000 km	96.2%	3.8%
	Over 30,000 km	97.4%	2.6%
	I don't drive	44.1%	55.9%
Numbers of cars in the household	No car	19.6%	80.4%
	One car	61.4%	38.6%
	Two cars	90.0%	9.1%
	Three or more cars	94.0%	6.0%
Item: I need a car in order to be flexible	Top Two: correct	77.7%	22.3%
	Partially	53.7%	46.3%
	Bottom Two: incorrect	33.2%	66.8%
Item: By using a car, I can save a lot of time	Top Two: correct	77.4%	22.6%
	Partially	63.7%	36.3%
	Bottom Two: incorrect	27.6%	72.4%
Item: I cannot imagine life without a car	Top Two: correct	77.1%	22.9%
	Partially	68.8%	31.2%
	Bottom Two: incorrect	51.4%	48.6%

(Nobis and Lenz 2003)

The authors conclude that high ICT users show above-average mobility. A more detailed analysis of data and new waves of the panel survey may produce results that differentiate more and reveal causalities as well (Nobis and Lenz 2003).

In an American study by Douma (Douma et al. 2003) the type of Internet connection was taken into account during analysis. The diary participants with a broadband connection (cable, DSL) made significantly fewer trips than those with dial-up or no connection. However, other factors, such as trip distance or number of shopping trips did not vary significantly.

TELECOMMUTING

Mokhtarian (Douma et al. 2003) has attempted to assemble the substantive findings to date by examining current knowledge in forecasting the demand for telecommuting and the resulting transportation impacts. From the result it was clear that telecommuting does affect trips, it also showed that these effects are not uniform and in some cases the results have been contradictory. Some studies have found that telecommuters reduce their number of travels on telecommute days, on non-telecommute days or on net travel, while others put forward evidence of travel stimulation or generation, sometimes only on non-telecommute days, or for non-work trips (Douma et al. 2003; AVV 2003).

The research of Douma (Douma et al. 2003) focuses on both telecommuting and e-shopping. In the case of telecommuting they found that e-workers take the advantage of ICT to modify their commutes, without impacting their workday. The use of telecommuting as a direct substitute for the work commute was rare in their sample.

E-SHOPPING

Handy and Yantis (Handy and Yantis 1997; Douma et al. 2003) conducted a household survey to examine in detail the potential substitutability of three different types of activities: movie watching, non-grocery shopping and banking. They found that the travel implications of home shopping were not straightforward and concluded that home shopping has not reduced shopping travel to any significant degree, since certain qualities of the physical trip were not duplicable by the ICT facilitated in-home version.

Casa and colleagues (Douma et al. 2003; Farag et al. 2002 ; Farag et al. 2003) compared in their study the travel behaviour of e-shoppers with non-e-shoppers. After controlling for socio-demographics, the results showed that Internet shoppers made more trips in general, as well as more shopping trips in particular. The authors concluded that on-line shopping has not substituted for store shopping trips, and that e-shopping is used as an additional shopping method which does not change trip making behaviour, but does change shopping behaviour.

The survey conducted in the Twin Cities Metropolitan Area agrees with this conclusion (Douma et al 2003). E-shopping broadens the range of shopping activities from home. Direct substitution appears less frequent and seems to have little impact in this sample. People use the Internet to modify their shopping behaviour, by either browsing for products before leaving home, or by using the Internet to make their trip more efficient. Here again, the type of Internet connection makes a difference: broadband users were more likely to use the Internet to generate a trip than dial up users (Douma et al 2003).

A comparative research between US data and Dutch data adds some more variables that influence travel behaviour (Farag et al. 2003). In the Dutch case it was found that online buyers have less travel time to shop for non-daily goods than non-online buyers, while in the US case no difference was found. The authors search the explanation in the difference in lifestyle between urban and suburban residents. Another finding was the fact that people who like to shop in-store are more inclined to like online shopping. This indicates that people who like e-shopping will probably continue to visit stores and therefore it seems unlikely that substitution in-store shopping will occur. Shopping via the Internet is mainly a complementary mode for in-store shopping (Farag et al. 2003).

For daily shopping as well as for non-daily shopping they found that the number of shopping trips increases if people buy frequently online. Further research to investigate the causality between in-store and online shopping is difficult since there are no data available about in-store shopping prior to e-shopping (Farag et al. 2003).

Srinivasan and Reddy (Srinivasan and Reddy 2003) modelled the relationship between Internet communication and travel activities. Their main conclusion is that the relationship is multi-directional and multi-dimensional in nature. Internet use is correlated positively with larger trip frequency, but also with shorter travel durations.

Also Choo and Mokhtarian (Choo and Mokhtarian 2003) come to the conclusion that travel demand increases as telecommunications demand increases, but the largest portion of the effects in each direction are indirect rather than direct.

WHAT WILL THE FUTURE BRING?

It may be clear that the relationship between travel behaviour and ICT or Internet use is a complex one. The further research goes into detail, the more variables are added to explain this relation. Measuring travel behaviour is already difficult and so is Internet use. A study of the combination of the two is not obvious.

The more the view on mobility is rather narrow: the focus has been set on commuter and shopping trips, which just count for 39% of the total amount of trips in the Flanders region (Zwerts and Nuyts 2002). A lot of further research is necessary to measure the effects of Internet use on other kinds of trips.

Technology is going fast. The explosion of ICT in just a few years may be repeated with other devices as well. Longitudinal research offers here the opportunity to get more detailed information on both sides of the relation.

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