SCIENTIFIC PROGRAMME

ORGANIZATION AND MANAGEMENT

Using Modified Concept Lattices for Organizational Structure Modeling and Analysis

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ABSTRACT

The organizational structure is usually defined using the best experience and there is a minimum of formal approach involved. This paper shows the possibilities of the theory of concept analysis that can help to understand organizational structure based on solid mathematical foundations. This theory is extended by the concept of knowledge sharing and diversity that enables to evaluate the organizational structure and to use it for the purposes of re-engineering.

INTRODUCTION

Business processes represent the core of the company behavior. There are many possibilities how these processes can be defined. Although usually all modeling tools are focused on various kinds of business process aspects based on what abstraction is considered as the main, there are some standards in business modeling. Most of them are focused on: *structural view*, *behavioral view* a *functional view*. For capture specification is used some formal or semiformal language e.g. UML or more sophisticated approaches based on the theory of Petri Nets (Peterson 1977).

Unfortunately, none of these views captures organization structure of roles implemented by human resources participating in processes being modeled. The next chapters will show how the theory of concepts might remove the gap between process models and organizational structure.

MOTIVATING EXAMPLE

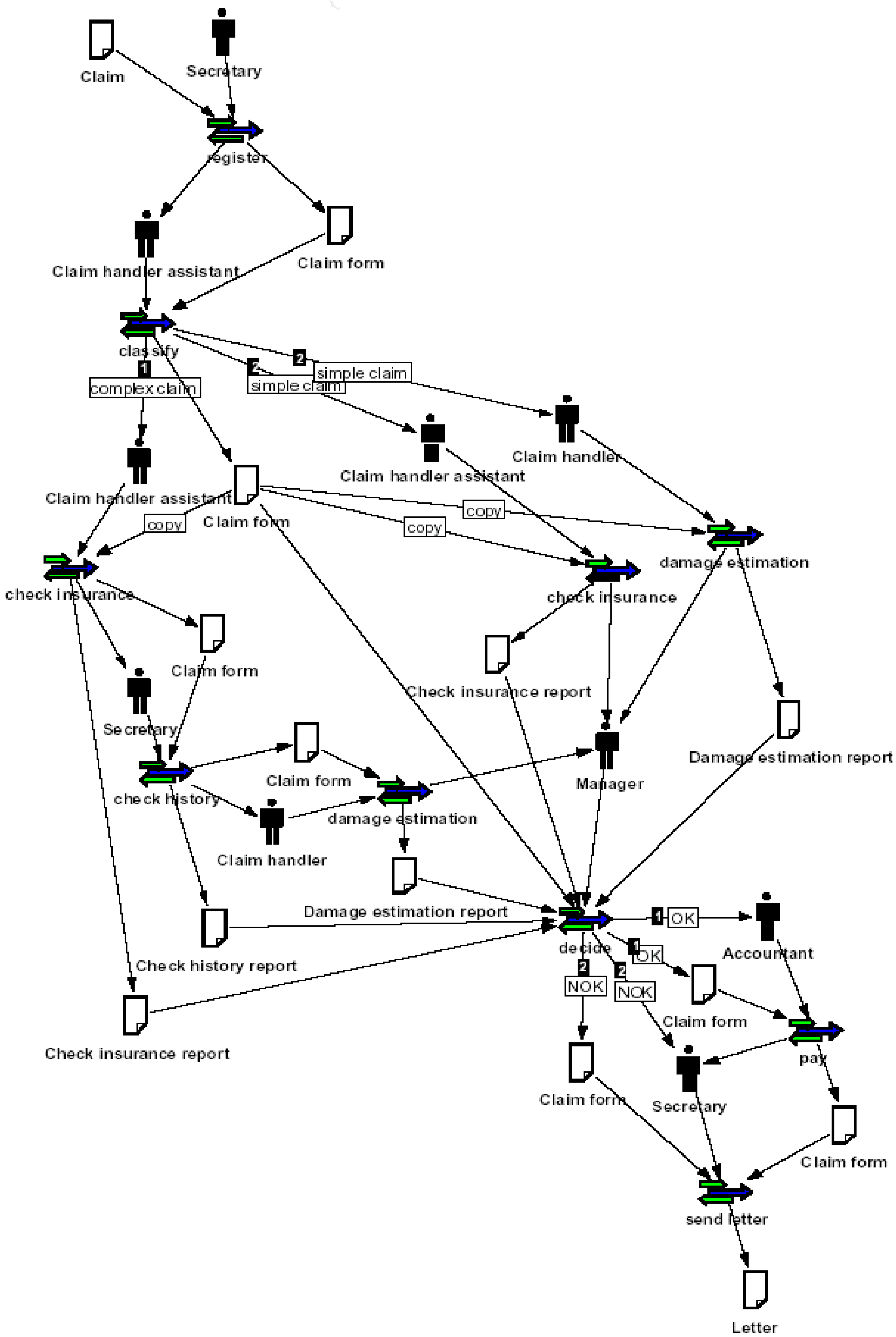
Presented example is adopted from (Aalst and Hee 2002) and represents process in some insurance company. We use this toy example to demonstrate how the business process definition serves as a source of the organizational structure specification.

Presented insurance company C *process claims* that result from traffic accident with cars where customers of C are involved in. Company employs five people: *manager, claim handler, assistant of claim handler, accountant* and *secretary.* Process starts with customer report of a claim. Every claim is *registered* and after registration is *classified.* There are two categories: simple and complex claim. For simple claims two tasks need to be executed: *check insurance* and *damage estimation*. These tasks are independent of each other. The complex claims require three tasks to be executed: *check insurance, check damage history* and *damage estimation*. These tasks need to be executed sequentially in the order specified. After executing described tasks a decision is made. The decision is made base on 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. This invokes the *payment* task. The insurance company always sends a letter to the customer who sent the claim. (Fig.1 shows process using BPstudio modeler – approach based on Petri Nets).

It is obvious that the next logical step is to assign roles responsible for the specified activities. Based on that assignment it is possible to derive so called table of competencies that can be used for the purposes of the organization structure specification. Let's assume that in the claim process for *registering* activity the *secretary* is responsible. *Claim handler* or his *assistant* can realize the *classify* activity while the *accountant* or *manager* takes care of the financial operations like *payment* is. For *damage estimation* can be responsible *claim handler* or *accountant. Checking history* activity can be processed by *assistant* or *secretary*. *Secretary* also sends letter to customer. Finally the decision is made by *manager.* Resulting table of competencies is Table 1.

Table 1: Role Assignment for Claim Handle process

	Reg.	Class.	Chck.i.	Chck.h.	Estim.	Dec.	Pay.	Send.
Manager						X	X	
Claim handler		X			X			
Accountant					X		X	
Assistant		X	X	X				
Secretary	X			X				X



Figures 1: Model of claim processes.(in BP studio)

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

CONCEPT ANALYSIS

Concept analysis theory can be used for grouping of *objects* that have common *attributes* (Ganter and Wille 1999). Concept analysis begins with a binary relation, or Boolean table, T between a set of objects **O** and set of attributes **A**. It means that $T \subseteq \mathbf{O} \times \mathbf{A}$. For any set of objects $O \subseteq \mathbf{O}$, their set of common attributes is defined as

$$\sigma(O) = \{a \in \mathbf{A} \mid \forall o \in O : (o,a) \in T\} . \tag{1}$$

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

$$\tau(A) = \{o \in \mathbf{O} \mid \forall a \in A : (o,a) \in T\} . \tag{2}$$

A pair (O, A) is called a *concept* if

$$A = \sigma(O) \wedge O = \tau(A) . \tag{3}$$

The very important property is that all concepts of a given table form a *partial order* via

$$(O_1, A_1) \leq (O_2, A_2) \underset{def}{\Leftrightarrow} O_1 \subseteq O_2 . \tag{4}$$

It was proven that such set of concepts constitutes a complete lattice called con*cept lattice* $L(T)$. For two elements (O_1, A_1) and (O_2, A_2) in the concept lattice, their *meet* $(O_1, A_1) \wedge (O_2, A_2)$ is defined as

$$(O_1 \cap O_2, \sigma(O_1 \cap O_2)) \tag{5}$$

and their *join* $(O_1, A_1) \vee (O_2, A_2)$ as

$$(\tau(A_1 \cap A_2), A_1 \cap A_2) . \tag{6}$$

A concept $c = (O, A)$ has *extent* $e(c) = O$ and *intent* $i(c) = A$. More about concept analysis can be found in (Ganter and Wille 1999), (Snelting and Tip 1997), (Wille 1982).

Concept lattice can be depicted by the usual as a lattice diagram. It would however be too messy to label each concept by its extent and its intent. A much simpler *reduced labeling* is achieved if each object and each attribute is entered only once in the diagram. The name of object O is attached to the lower half of the corresponding object concept

$$c = (\tau(\sigma(O)), \sigma(O)) ,. \tag{7}$$

while the name of attribute A is located at the upper half of the attribute concept

$$c = (\tau(A), \sigma(\tau((A)))) .. \tag{8}$$

ORGANIZATIONAL STRUCTURE MODELING

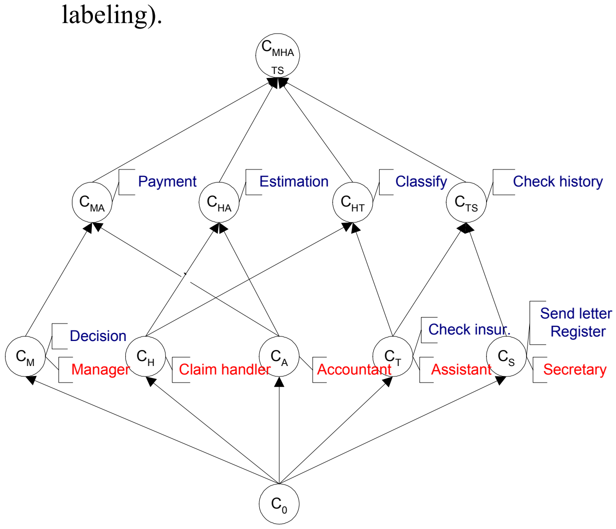
The tables of responsibilities specified in the previous chapter correspond with Boolean tables described in concept analysis where objects of the relation are substituted by roles and attributes of objects are substituted by activities that the roles are responsible for.

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

C_{MHATS} = ({Man., Claim hand., Acc., Assist., Sec.}, {})
C_{MA} = ({Man., Acc.}, {Pay.})
C_{HA} = ({Claim hand.,Acc.}, {Est.})
C_{HT} = ({Claim hand., Assist.}, {Clas.})
C_{TS} = ({Assist., Sec.}, {Chck.h.})
C_{M} = ({Man.}, {Pay.,Dec.})
C_{H} = ({Claim hand.}, {Est.,Clas.})
C_{A} = ({Acc.}, {Est.,Pay.})
C_{T} = ({Assist.}, {Clas.,Chck.h.,Chck.i.})
C_{S} = ({Sec.}, {Chck.h.,Send.,Reg.})
$C_{\varnothing}$ =({},{Reg.,Clas.,Est.,Chck.i.,Chck.h.,Pay.,Dec.,Send.})

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

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



Figures 2: Concept lattice of the organizational structure.

Resulting graph provides alternate views on the information contained in the above-described table. In other words, the concept lattice enables to visualize the structure "hidden" in the binary relation. In our example we can see that the Manager is the only one who can make a Decision but he/she can also make a Payment as well as the Accountant. Obviously, the more complex is the table of responsibilities the more difficult is to understand who is responsible for what.

KNOWLEDGE SHARING AND DIVERSITY

The nodes in our picture of concept lattice can be considered as a potential source of how the organizational units can be defined. For example, concept node labeled as c_{TS} unifies roles responsible for administrative operations. One of them *Checking history* are common for both roles A*ssistant* and *Secretary*. On the other hand *Send letter* is the activity that only the *Secretary* can be responsible for. The question is how to evaluate identified concept from point of view if they should or should not be the source of organizational units? In other words, is it appropriate to put together these roles with the common set of activities or not? Let's assume that we would like to have in one organizational unit activities that have something in common. This "something in common" we would call *Knowledge Sharing* and we can define it formally as

$$K_{share}(a_i, a_j) = 1 \qquad \textbf{(9)}$$

for activities a_i and a_j that share the knowledge,

$$K_{share}(a_i, a_j) = 0 \qquad \textbf{(10)}$$

otherwise. It is obvious that this relation is symmetric and reflexive, i.e.

$$K_{share}(a_i, a_j) = K_{share}(a_j, a_i) \qquad \textbf{(11)}$$

and

$$K_{share}(a_i, a_j) = 1 \quad \text{for} \quad i = j \ . \qquad \textbf{(12)}$$

Based on that a Table 2 of the knowledge sharing among activities can be defined.

Table 2: Knowledge Sharing

	Reg.	Clas.	Chck.i.	Chck.h.	Estim.	Dec.	Pay.	Send.
Reg.	X							X
Clas.		X			X			
Chck.i.			X	X				
Chck.h			X	X				
Estim.		X			X		X	
Dec.						X		
Pay.					X		X	
Send.	X							X

The knowledge sharing among activities can be used to evaluate each concept from point of view how wide knowledge is required by a group of roles common to this concept (potentially organizational unit) to cover all its activities. Let's introduce the new notion of *Knowledge Diversity* that reflects the width of knowledge required by the concept (O, A) and that is formally defined as

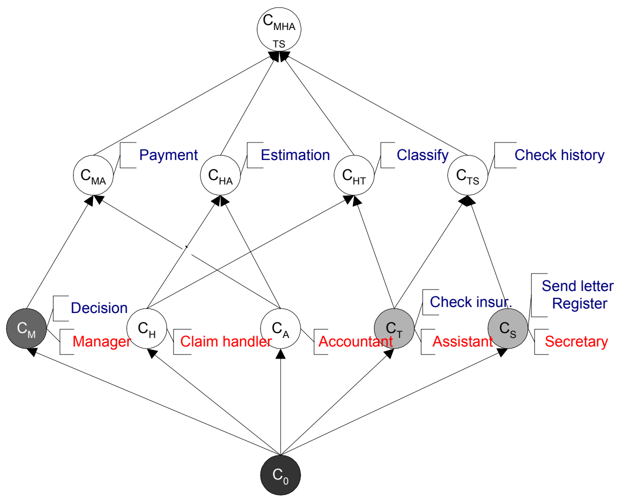
$$K_{div}(O, A) = 1 - \frac{\sum_{a \in A} K_{share}(a_i, a_j)}{|A|^2} \ , \qquad \textbf{(13)}$$

where $|A|$ is a cardinality of the set of attributes related to a given concept. The highest possible knowledge diversity has value 1 and the lowest one is equal to 0. The knowledge diversity computed for each of our concepts identified in the previous chapter has the following values:

K_{div}({Man., Acc.}, {Pay.}) = 0
K_{div}({Claim hand.,Acc.}, {Est.}) = 0
K_{div}({Claim hand., Assist.}, {Clas.}) = 0
K_{div}({Assist., Sec.}, {Chck.h.}) = 0
K_{div}({Man.}, {Pay.,Dec.}) = 0.5
K_{div}({Assist.}, {Clas.,Chck.h.,Chck.i.}) = 0.44
K_{div}({Sec.}, {Chck.h.,Send.,Reg.}) = 0.44
K_{div}({Claim hand.}, {Est.,Clas.}) = 0
K_{div}({Acc.}, {Est.,Pay.}) = 0
K_{div}({},{Reg.,Clas.,Est.,Chck.i.,Chck.h.,Pay.,Dec.,Send.})=0.75

Obviously, the highest knowledge diversity has the concept with all activities associated. In our case it is represented by the whole insurance company as the biggest organizational unit.

Values of knowledge diversity can add third dimension to our graph of organizational units represented by the darkness of each node. The higher is the knowledge diversity the darker is the node representing the concept (Fig. 3).

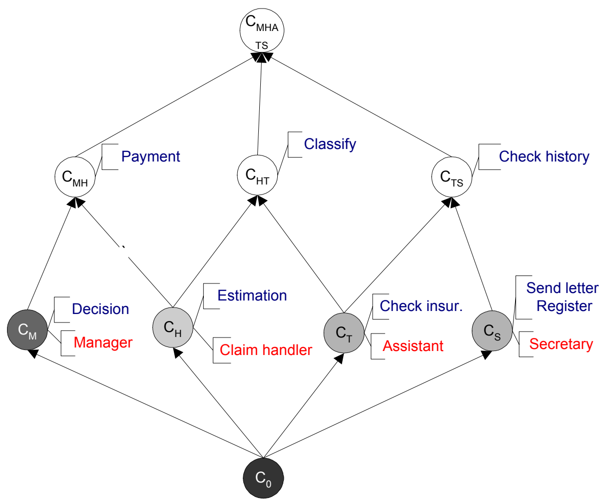


Figures 3: Concept lattice with associated knowledge diversity.

As we have mentioned knowledge diversity reflects the width of knowledge required by the given concept. After seeing Fig. 3 we can say that the knowledge requirements for concepts C_H a C_A are smaller than for concepts C_M, C_T a C_S. All of these concepts represent roles in *insurance company*. Concepts C_H and C_A represents role of Claim handler and Accountant. This view indicates that the model of business process is not ideal. The way how this problem can be solved is to unify two above mentioned roles to a new one – Claim handler. Corresponding table 3 shows new responsibilities and the result of the reorganization is visualized by concept lattice (Fig. 4). Apparently, the knowledge diversity is more balanced than before.

Table 3: New Assignment of Roles

	Reg	Class.	Chck.i.	Chck.h.	Estim.	Dec.	Pay.	Send.
Manager						X	X	
Claim handler		X			X		X	
Assistant		X	X	X				
Secretary	X			X				X



Figures 4: Concept lattice after reorganization

CONCLUSIONS

Presented method of concept analysis provides exact and formally well defined way how the organizational structure can be analyzed and evaluated. The example used in our paper was simplified but it demonstrated sufficiently the potential of concept lattices and the way how they can be adopted for potential re-engineering. The new approach based on knowledge sharing extends this algebraic theory with the option to evaluate concepts and to decide if the potential organizational units are sufficiently focused on their activities in case of functional organization or vice versa in case that the organizational structure is built around business processes. Of course, this formal approach to organizational structure modeling cannot substitute the process of re-engineering but it can help to understand the organization using presented methods of visualization.

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FORMAL MODEL OF THE NORMATIVELY REGULATED ORGANIZATIONAL ACTIVITIES

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ABSTRACT

This paper focuses on a particular aspect and modeling of the normatively regulated organizational activities. These activities are characterized by precise objective or purpose, participation of actors as role holders, and norms and rules that govern the performance of these activities. The main goals of the software systems in support of normatively regulated activities are increased efficiency and effectiveness, monitoring and control. The paper also describes aspects of the normatively regulated organizational activities and approach to make model of normatively regulated activities, which are bases for building software systems to support their performance. The formal model, which is based on the Petri nets, is illustrated by an example of claims processing in an insurance company.

INTRODUCTION

Specification of the needs and definition of information requests represent the most critical phase in the information systems development, especially in the complex uncommon organizational processes that are normatively defined. These activities are credit authorization, monitoring repayment in the bank, processing and decision making on the customer's claim request, receiving, processing and finishing cases in administration and on the court etc. There are different approaches to modeling organizational activities. One of them is classical method of the information systems analysis which use languages SADT, ISAC, DFD commonly characterized by insufficient representation of the meaning and content of one activity. Current technology for modeling of the organizational activities is workflow technology. Workflow can be considered as a method and technology that offers modeling and control of different organizational processes (Stohr 2001). Powerful analytic tool like Petri net is very useful for formal analysis of the workflow systems, e.g. their correctness and consistency. It is an excellent tool to describe and model the systems which have the following characteristics: parallelism, repetition, coordination, hierarchy and determinism (Van der Aalst 1998).

This paper presents one approach for modeling and computer support for normatively regulated activities. This model is illustrated on the example of processing claim request in an insurance company. The paper is structured as follows: Next section describes normatively regulated activities and gives short description of the claim processing in an insurance company. Third section describes basic elements of normatively regulated activities that are essential for their modeling. Fourth section presents formal and graphical model of the normatively regulated activities based on Petri nets. Fifth section gives basic model of the computer system for normatively regulated activities. In the conclusion, directions for the future development are presented.

DESCRIPTION AND EXAMPLE OF NORMATIVELY REGULATED ACTIVITIES

In this section a concept of normatively regulated activities and practical example of normatively regulated activities in an insurance company are presented.

Concept of Normatively Regulated Activities

Activities are organizational processes that consist of different actions such as decision-making, management controlling, communication, coordination among different actors, etc. In every organization general rules and norms for performing certain actions exist. There are also expected ways of performing actions. In practical situations activities are not usually performed according to strict rules and expectations. Reasons for aberration are different problems that are indicated during performing of organizational activities, as inaccurate and incomplete definitions of activities, different perception about competence and responsibilities, different interceptions of the rules and norms to perform activities etc. In this paper we are working on the class of the organizational activities that are normatively regulated. Activities that have a defined goal and task, time of realization, responsible actors and for which particular norms and rules of performing are in effect, are called normatively regulated activities - NRA. If it is proved that activities are not performed according to the norms and rules, NRA are announced as irregular and their results are cancelled. To understand meaning of one activity, it is not enough to know that it happened and that it has particular result (i.e. "Credit approved", "Claim request processed"). Content is also derived from better knowledge of the process of performing activities: did all actors perform according to their role and their authority, was the process performed in expected phases and was it finished in expected time, etc.

Example of NRA

It has been already mentioned that typical examples of NRA are the processes in the insurance companies. Only one segment of operation in the insurance company, which is full auto insurance claim processing, will be presented. This activity is very complex and we will only describe the most important part of it. Claim processing is initiated by a client report that the damage has been done on the vehicle and the client has auto insurance policy that covers all kinds of damage. Employee who is receiving documents checks validity of the policy. Client fills appropriate data about the claim and the claim is being processed. During processing the authenticity of the data that client filled in are checked. At the same time records from the police, opinion from the police court, medical report if someone is injured, and statements of the witnesses are requested. After actual cause of accident is determined, legitimate process is instituted i.e. does policy cover that type of claim. Next step is accounting the claim and notifying client about the result. If the client is not satisfied, the process is revised. During the claim process all the norms for that part of the work have to be obeyed. To finish with payment, the complete claim case has to be verified, which requests collection of different documents.

This short analysis of one NRA example shows necessity to define the following basic concepts: actions that are performed by actors who are role holders, states or phases which the action is executed through, rules for bringing about the actions i.e. transition from one state to another, etc. In the next section we will define these concepts.

BASIC ELEMENTS OF ACTIVITY MODELING

To make a model of organizational activities important elements are (Cecez-Kecmanovic 1994): actions, states, transitions, roles and actors, resources and documents.

Actions

When an actor issues a linguistic expression with an intention to produce change in the social environment, this linguistic expression is called an action. Participants that perform the actions are called actors. For each action there is a responsible actor for bringing about the action, depending on his/her role, authority and obligations.

States

Performing an activity causes successive change of state i.e. phases of activity performance. In the activity model the following states can be observed: initial state and terminate state. Initial state represents arriving into that state only by external action (it does not belong to activity). Initial state is starting activity. State is terminal if we cannot go from that state into any other state inside one activity. This state is related to the end of activity. Because activity can be finished in several different ways, there can be several terminal states. The rest of the states are called inner states.

Transitions From State to State

Transitions are the rules that define what cause the activity transition from one state to another. In general case, transition is initiated by the action and accomplishment of additional prerequisites for that transition. Transition can also be performed automatically after certain period (i.e. decision is valid after seven days).

Roles and Actors

In our model we define organizational roles, actors and employees in the organization. Role presents a set of duties and responsibilities that are assigned to specific actor. Actor presents position profile that is assigned to a particular employee in the organization. For each actor we introduce actor identification, description of the actor, and identification of the roles that are assigned to him. Actors are marked as A#n:m (n-actor, m-role)

Resources

It is necessary to make list of all resources in the system and to give a type for each resource: divisible or no divisible. After that, for each activity that has connection with some of the resources, the type of the connection is given: does activity use resource (U), does it arise in that activity (A) and does activity spend that resource (S). Resources are marked as R#n:X, where R is resource, #n is resource identification number and X can be marked as U, A or S.

Documents

By describing the activity we also introduced a concept of "document", which contains important elements of routing case and its regular execution. Content of the document consists of information, obligations, responsibility i.e. normative content and time clauses. Documents and information are requested and used inside the activities and that is way they are produced inside the activity. Document is marked with symbol 🗎identification_document.

During the execution of the event, it is important to respect temporal constraints. Temporal constraints are different rules that regulate the time component of business process (Marjanovic 1999).

Particular activity that is performed according to the given model is called instance of NRA. Number of instances can be performed under one model. For example, new instance of the activity model "claim processing" is run every time for new client who submits claim request.

FORMAL MODEL OF THE SIMPLE TYPE OF ACTIVITY

Case study described above can be formalized by model using higher-level Petri nets. Basic elements of the theoretical model: actions, states and transitions, described in previous section, can be mapped into Petri nets. Beside mapped concepts recognized by analysis of business processes, in Petri nets also exists concept that cannot be directly mapped with existing syntax and to which we want to give special meaning. These elements are actors, resource and documents, and we introduce marking for them. Mapping of the elements is shown in table 1.

Table 1: Relation Between Described Model Elements and Petri Nets

Described elements	**Petri net**
Actions/transitions	Transitions, triggering of the transitions
State	Place
Active state	Mark in place
Flow control with all elements of syntax	Flow of the relation which is mathematically formalized with construction of routing
Case attributes	Colored marks, local variables
External event	Envelope
Temporal event	Clock
Enabling task	Down arrow
Roles and actors	A#n:m on the transition
Resources	R#n:X and mapping by symbol in place and on the transition
Document	🗎identification_documument on the transition

Syntax of Petri nets supports all construction of routing that we introduced during analysis of our activity (sequential performing, parallelism, selection, iteration) and gives formal correspondence with workflow constructors (Van der Aalst 1998). With this construction flow control is mathematically formalized.

COMPUTER SYSTEMS FOR ACTIVITY SUPPORT

After entire formal model of the activity "Processing claim" is defined, it becomes possible to monitor and control each particular activity i.e. instance according to this model. This practically means that all actors during performance of activity can, checking the model, identify their obligations at that moment, further actions that are mandatory or choose between two or more actions, conditions for their execution and transition to the new state, etc. Formal model and its graphical representation with Petri nets are just a way to represent rules of performing activities that are usually described in normative act, decree, law, etc. Difference is that formal model of NRA is exact and does not leave a possibility of arbitrarily interpretation. Using formal model to define a type of activity and monitoring instances based on that model, higher regularity and legality and also consistency of some instances are accomplished as well. The main issue here is how to apply formal model and at the same time make easier performance of the activities for all actors. For that purpose it is proposed to develop software system that will allow assignment of different types of the activity in the form of the formal model and in the way that is most suitable for human natural way of presentation (the most of all graphically). Link between performing activity in reality, activity model and following activity with support to agents presents basic elements of the software system for support of normatively regulated activities, which is presented on the figure 1.

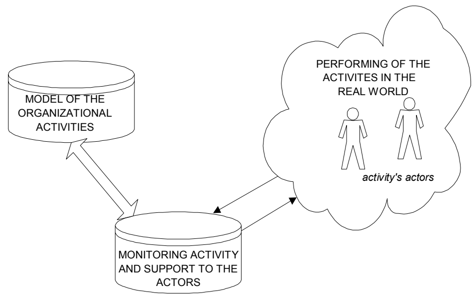

Figure 1: Segments of the Software Model for the Activity Support

CONCLUSIONS

In this paper the concept of the normatively regulated activities and formal model based on Petri nets to describe these activities are presented. We introduced additional symbols in Petri nets that are discovered during the case study. Formal model of NRA is illustrated on the actual case of processing claims in insurance company. Formal illustration of NRA is the basis for design of the software system for their support. Namely, based on formal model of NRA, software system for representing type of activity model and instances of given type of activity can be developed. Moreover, elements of the formal model can be built into reengineering of the traditional applications.

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DEVELOPMENT OF AN INTEGRATED COST MODEL FOR NUCLEAR PLANT DECOMMISSIONING

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Nuclear decommissioning, nuclear waste management, nuclear engineering, estimating tool, nuclear cost estimating.

ABSTRACT

A need for an integrated cost estimating tool for nuclear decommissioning and associated waste processing and storage facilities for Intermediate Level Waste (ILW) was defined during the authors recent MSc studies. In order to close the defined gap a prototype tool was developed using logically derived CER's and cost driver variables. The challenge in developing this was to be able to produce a model that could produce realistic cost estimates from the limited levels of historic cost data that was available for analysis. The model is an excel based tool supported by 3 point risk estimating output and is suitable for producing estimates for strategic or optioneering cost estimates (+/- 30%) early in the conceptual stage of a decommissioning project. The model was validated using minimal numbers of case studies supported by expert opinion discussion. The model provides an enhanced approach for integrated decommissioning estimates which will be produced concurrently with strategic options analysis on a nuclear site

1.0 INTRODUCTION

Decommissioning & Waste Management: The focus of this research has been to define Cost Estimating Relationships (CER's) between the volume of a plant for decommissioning and the decommissioning cost and the cubic meters of ILW for processing and storage and the cost of the relevant plants required for these functions. Before going into further detail it may be helpful to define exactly what decommissioning in a nuclear facilities context means;

"All the administrative and technical operations allowing the withdrawal of a facility from a list of licensed facilities. The administrative operations concern particularly the preparation of decommissioning plans and the obtaining of authorisation and free release certificates for the facilities and the site; the technical operations include among others the decontamination, the dismantling and the waste management. The decommissioning does not aim at destroying the buildings, but it liberates them from all obligations and controls to the class they belong to, it is the final objective to achieve" (Grove 2001).

Therefore it can be seen that decommissioning not only encompasses technical issues, a heavy emphasis is placed on project management and the satisfaction of regulatory requirements (Taylor 2001) specific to the country where the facility is located. It is also important to note that the handling, processing and final (or interim) storage (Dyck 2001) of radiological waste must be considered (Woolam 2000; Francis 2001). This emphasises the need for an integrated cost estimating approach for all aspects of decommissioning.

Pricing & Forecasting Group (PFG)-Who are PFG? PFG is a service provider to the UK MoD (specifically the Defence Procurement Agency & Defence Logistics Organisation). Its main function is to provide a cost estimating service to aid the pricing of non-competitive government contracts. PFG as an organisation has offices throughout the UK (with headquarters in Bristol) and operates as teams of engineers and accountants with specific contractor responsibility.

Experience within PFG has shown that any project within the constraints of the relevant regulatory body will tend to be structured to meet prescribed requirements. This will tend to focus the decommissioning and supporting tasks into areas or elements that will address the main requirements; this is summarised in table 1 (Francis 2001).

Table 1:Simple decommissioning WBS

Preparatory works
Final Shutdown
Removal of radioactive sources
Decontamination, dismantling and cleanout
Demolition of structure and buildings
Waste Management
Surveillance & maintenance

The simple breakdown at table 1 defines the main areas as addressed previously (Taylor 2001)and is reflected both within the ASME document (ASME 2002) and the WBS developed by the NEA in Europe (Lazo 1991). The research requirement stemmed from a requirement to formalise approaches to cost estimating for nuclear decommissioning and waste management projects within PFG.

2.0 CURRENT INDUSTRY PRACTICES, COMMERCIAL & PFG

Estimating Background-Within the working environment of PFG there is approximately 12 years of experience in the decommissioning and waste management aspects associated mainly with the BNFL & UKAEA facilities at Sellafield in Cumbria. This experience has been gained primarily in dealing with facilities where the MoD has a historic liability on specific plants. British Nuclear Fuels Ltd (BNFL) control the decommissioning of these plants but the MoD contributes to funding of the projects. As part of an audit function the MoD tasks PFG to produce parallel cost estimates (aligning with the BNFL WBS) against specific projects where MoD has a high cost liability (this is carried out for both cross checking purposes and to confirm basis of costs prior to any formal pricing arrangements). These estimates are currently produced from a "bottom up" approach and are enhanced by producing 3 point estimates for use in a proprietary Risk modelling package. Wherever possible information and data from similar projects is utilised to enhance accuracy and reduce man effort in estimate production, however, this tends to be carried out on an ad hoc basis with no consistent background approach to production of a common database of historic cost information. All of the data available on historic projects is held on paper files which remain in office for approximately 5 years, after this they are transferred to an archive repository for final storage. The main problem with this procedure is that the information held on "completed" files is held "as is"; i.e. there is currently minimal effort made to consolidate the information within the files into a consistent database. It is therefore often difficult and time consuming whenever there is a requirement to obtain historic cost information for use on other projects. It will often require information from the original engineer who compiled the relevant cost estimates before accurate data can be derived. Therefore, at present on nuclear decommissioning type projects, PFG does not utilise any estimating methodologies other than bottom up and factored (Smith 1996) (Fenton 1995) techniques.

The research was therefore based around potential methodologies to improve the consistency of PFG estimating techniques in the decommissioning area using latest available tools and information. Within the Nuclear Industry there are various software tools available which can be used to calculate the decommissioning costs from various databases using parametric techniques. However, these tools tend to focus on estimating costs for very specific decommissioning activities, there is little evidence of any tools available for determining the cost of the associated waste processing and storage plants for the actual ILW produced during the decommissioning process.

Thematic Network (Decommissioning tools and cost)-In relation to this research there are specific activities being carried out within the global environment associated with the collation and analysis of decommissioning data. The Thematic Network (TND 2001) is a European wide organisation which has the aim of exchanging experiences in all aspects of nuclear decommissioning and to enhance the expertise in this area within Europe, the UK MoD has a presence on this network with representatives from HMS Sultan providing a contribution. As part of the Thematic network steering group

HMS Sultan personnel are in the process of compiling a database associated with decommissioning tools, techniques and procedures plus a database relating to decommissioning costs. This database is yet in its infancy and is not available even in draft format

Nuclear Energy Agency-The Nuclear Energy Agency (NEA) is currently analysing cost outturn data associated with decommissioning nuclear reactors across various European countries. The NEA propose to collate cost data against a standard work breakdown structure for direct analytical comparison, the outcome of this work should be available at the end of 2003. Output from both of the above would make a useful source database for a cost estimating model in the nuclear decommissioning environment and should be assessed for future research possibilities.

Challenges-The challenge was to develop an integrated cost estimating model to aid in estimating costs for the decommissioning of a facility and the construction costs of new build facilities which are associated with the processing and storage of resultant ILW. The main challenge was to produce a working model from historic cost data held on existing PFG project files. This proved to be difficult as source data is not allied to any common WBS and there are a limited number of projects available for analysis, future work would be to define further projects on a worldwide basis. Validation of the model with suitable case studies and expert opinion was another area requiring significant effort.

3.0 COST MODEL DEVELOPMENT

The initial methodology was to identify and obtain initial high level quantitative data from within PFG and contractors and draw conclusions from this data for modeling requirements, then it was necessary to progress towards evaluation and validation in order to define further improvements to the prototype model. This was achieved by using case studies and interviews with relevant specialists. Several iterations were required before the prototype model was frozen. When moving into new areas of research it is necessary to draw information from existing data, one method available for collecting this information is to interview personnel who have specific experience. This was further enhanced by using structured questionnaires in order to apply some degree of objectivity in the responses, this allowed definition of the main cost drivers. The data was analysed for identification of usable information, sorted into some form of common WBS and significant cost drivers identified and CER's established as applicable. It must be anticipated that the data collated may not be usable in its initial state, there may be inconsistencies and contradictions which will have to be normalised before conclusions can be made. Once data was formatted into common WBS elements for analytical requirements it was possible to define relevant CER's, enhancement and clarification in this area was made through further questionnaires and interviews with key personnel. The last stage in the analysis was determining the associations between the inputs and outputs. Once conclusions were drawn from the data the next stage was the actual modeling process. There are numerous formats available but as the data being processed in this case is mainly numerical, and ease of use across various computer platforms is desirable, the excel spreadsheet format has been used plus the proprietary @Risk software package. It was important that the model had an inherent flexibility to allow further development in future research environments in both its basic concept and further modification and enhancement of the main database elements. The basic model development process is shown below:

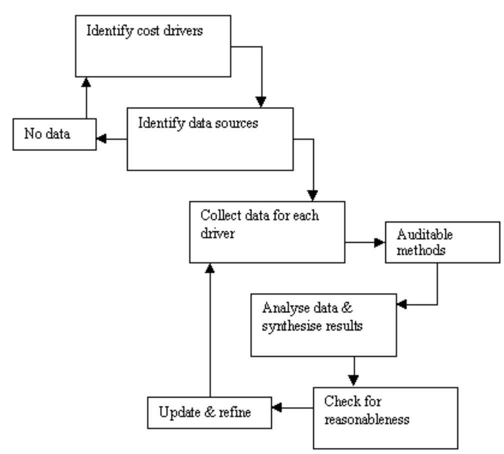

Figure 1: cost model process

Identification of Cost Drivers & Risk - Structured questionnaires and interviews were used to identify these elements. Although the analysis is based on a small number of responses

(10 personnel) there are common themes occurring across the various issues, the personnel questioned were all specialists in what can be considered a fairly specialist field; this is not a service/manufacturing type environment with a large base of companies or organisations in competition, this results in a small set of datasources. The majority were familiar with decommissioning, WBS requirements and associated cost risk and were aware that outside factors can have an influence on various aspects of a decommissioning project. They are all utilising various types of databases for capturing information for analysis and use on future projects. Cost driver and cost risk elements were defined and commented on, these are summarised below into qualitative and quantitative (Stewart 1995; Francis 2001; ASME accessed 9/3/02; CER's accessed 9/3/02; NASA accessed 9/3/02) elements:

Quantitative cost drivers: Radiological contamination (once level and type are defined) e.g. contaminated structures (m2), pipework with active liquors (m), vessels containing liquors and sludges (m3). Also, developmental requirements where trialling of new processes, equipment and techniques is required.

Qualitative cost drivers: These tend to cover more complex issues; regulatory requirements (NII) (Taylor 2001) NII requirements can result in safety case rejection (reiteration required), additional infrastructure for safety enhancement, reduced timescales enforced against safety driven milestones (additional effort/equipment required to achieve requirement), or extended timescales (authority to proceed refused until safety issues are resolved). Other elements such as radiological waste (Eisenberg, Norman et al. 1999)with no predetermined processing or disposal route is dependent on the type and condition of waste, this would require specialist handling, processing and storage equipment and facilities in support of the decommissioning activities. These are further summarised in table 2.

Table 2: Cost driver definition

Quantitative	**Qualitative**
Radiological contamination	Regulatory requirements (safety cases)
Developmental requirements	Additional infrastructure
Site conditions for construction	Reduced timescales for project (regulator/safety driven)
Types of ILW for storage	Waste routes (ILW)

The quantitative elements were used as direct input variables within the cost model user interface (see figure 3), the qualitative elements were used to derive the risk range applied within the @risk software for production of 3 point estimates.

Analysis of historic project cost data and informal workshops with relevant experienced personnel allowed the CER's for use within the model to be developed. The author had determined from discussion with PFG personnel that a model with basic inputs and variable cost drivers would be the most acceptable option for model operation. It was possible (through statistical analysis and expert opinion feedback) to define that two specific input elements could be used to produce output cost estimates; it should be noted that the output cost estimates are as follows:

A-Cost estimate to decommission a facility.
B-Cost estimate for building a processing plant for relevant ILW.
C-Cost estimate for building a storage facility for relevant ILW.

The input for A was defined as the total volume (M3) of the actual facility to be decommissioned, this data can be readily obtained from building records and facility specifications. The input for B & C is the volume (M3) of ILW which is produced by the decommissioning activity, this would be readily available from plant inventory and radiological surveys, therefore by inputting the two volumes defined the user can calculate a cost for each of the elements A, B & C.

The calculations carried out by the model for each of the elements A, B & C is summarised as follows:

A-Decommissioning

- Definition of main CER based on volume of facility.
- Allocation of estimated costs across a standard WBS

B- Processing plant

- Definition of the main CER based on construction cost and active cell (processing zones) volume of the facility.
- Definition of a cost driver for the site conditions/construction constraints based on a factor applied to normalised plant.
- Definition of a factor to convert the volume of the plant into a representative area.
- Expert opinion definition for a relationship of the ILW volume to the active plant cell volume.

C-Storage plant

- Definition of initial CER based on plant construction cost in relation to total plant volume.
- Definition of a factor to convert the ILW volume into a corresponding total plant volume.
- Definition of £/m3 rates for high, medium and low complexity ILW.
- Definition of a factor to convert the plant volume into relevant plant area for development of a cost within the model.

At this stage the model is operating using two discrete input parameters; applying the quantitative cost driver variables further enhances this. These were derived from questionnaires and interviews, the decommissioning cost drivers are summarised below in table 3.

Table 3: decommissioning cost drivers

Radiological cost drivers
Robotic operations
Manual & suited operations
Manual & mask operations
Developmental cost drivers
Untried procedures & techniques
Standard procedures and mock ups
Standard procedures

Factors derived from the analysis of historic data were produced and are used as multipliers applied to base data within the model to allow a cost variance to be produced based on the combination of any of the above cost drivers.

For the construction of the processing and storage plants it was determined that the main quantitative cost drivers were those shown in tables 4 and 5.

Both Process & Storage plants:

Table 4: process & storage plant cost drivers

Site Conditions
Typical Build
Difficult build

This represents the building conditions i.e. on a clean site with access for construction equipment we would classify as “typical build”, for a contaminated site with restrictions for construction (e.g. other building proximity, lack of access for construction equipment) we would classify “Difficult build”.

Storage Plants only

Table 5: storage plant cost drivers

ILW waste type/condition
High complexity (requires crane movement, rad assay, high shielding, security)
Medium complexity (requires high shielding)
Low complexity (low shielding)

Factors derived from the analysis of historic data were produced and are used as multipliers applied to base data within the model to allow a cost variance to be produced based on the combination of any of the above cost drivers.
A further enhancement to the Processing and storage plant elements was to allow the user to define which component parts of a standard facility were to be incorporated within the construction requirements, the user has the option to estimate the cost of a plant based on the following criteria:

- **Maximum plant requirements**-Includes costs for all elements of the WBS.
- **No dedicated services or office needs**-excludes costs for ventilation systems and office support.

- **No dedicated services, maintenance or office needs**-excludes costs for ventilation systems, office support and maintenance cells.
- **Minimum plant requirements**-basic facility with receipt and processing cells only

Figure 3 shows the models input interface for the aforementioned elements, specific help on the cost driver elements is available to allow the user to confirm actual requirements for model operation:

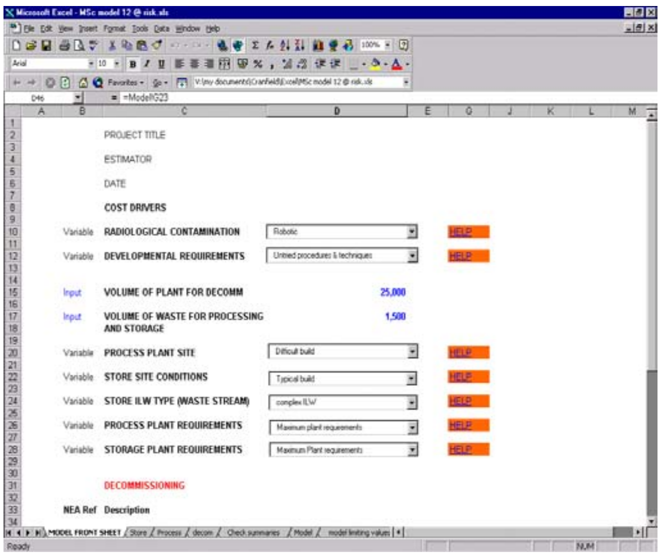

Figure 3: cost model input

As an example, the corresponding (three point estimates) model outputs associated with the storage facility are shown in Figure 4

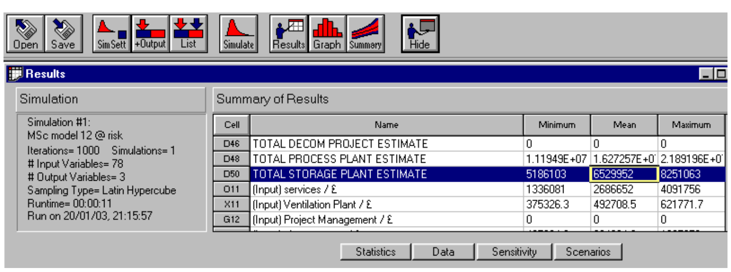

Figure 4 cost model outputs (Storage facility)

4.0 PROTOTYPE MODEL VALIDATION

Case studies are a useful vehicle for allowing an objective evaluation of the data collected and used within the prototype model. This allows the model to be validated in terms of both accuracy of output and the level and usefulness of the relevant input data. This section therefore describes the process of validation in terms of the case study project.

Data was obtained from contractors involved directly with project management of decommissioning and waste management projects. Due to a lack of project data for test cases the model was validated using minimal sample cases supported by expert opinion by use of questionnaires and semi structured interviews (Buffalano 1976).

The projects available for use as test cases consisted of 1 off decommissioning project, 1 off processing plant and 1 off store. The relevant output data is summarised at table 5.

Table 5: cost model test cases

Project (plant)	Actual cost (£K)	Model £k min	Model £k (mean)	Model £k Max
Decomm	**40,000**	36,868	**43,005**	49,084
Process	**262,000**	133,434	**182,977**	238,539
Store	**5,822**	5,186	**6,530**	8,251

The 3-point estimates output from the model is compared with the "actual cost" of the specific projects, all figures are normalised to accommodate common economic date points.

Once the test cases had been carried out it was necessary to discuss the output from the model in relation to the known costs incurred for the test case projects. Based on the outputs summarised at Table 5 and access to the model during discussion the following observations were made through semi structured interviews using supporting questionnaires, these were further enhanced by carrying out an informal workshop on the model operation. This was considered to be a more open environment where discussion among individuals highlighted their individual knowledge and experiences.

The basic layout of the input sheet was considered acceptable and simple enough to use with basic logic self explanatory, the supporting help files were considered a useful addition.

The cost driver variables and process and store main component options were also considered valuable additions as they allow the user some degree of flexibility in the overall facility infrastructure.

The basis of the cost drivers and cost relationships used to derive the costs in respect to the volumetric inputs were analysed in significant detail, each of the £/m3 rates used for decommissioning, processing and storage was

discussed in order to determine if they were realistic representations of the conditions stated as the basis for the model output. This was carried out in parallel with operation of the model using notional base volumes, the feedback from the personnel indicated that the cost output represented acceptable levels of cost on the decommissioning and store output. More specifically they would correlate with a BNFL equivalent class C estimate (+- 30%), this is considered more than acceptable for the optioneering basis of the estimating model requirements.
The output from the processing plant had the largest variance and this was discussed in detail, it was considered that further analytical work would be required to confirm the reasons for the variance, it was notionally assumed that additional cost drivers may be responsible, this would be a valid area for future research.

5.0 DISCUSSION AND CONCLUSIONS

The main output of this research is a cost model which can produce an estimated value for decommissioning a facility and construction of waste processing and storage facilities for resultant ILW. The output can be further enhanced by analytical risk software allowing production of a 3 point estimate, the main inputs for the model is the volume of plant to be decommissioned and the volume of ILW requiring processing and storage. During the literature review stage of this work it has been noted that research is also being carried out in relation to compilation of databases associated with decommissioning costs and procedures. It may be of value in future research to assess the possibility of aligning this type of model with the output from these databases. It was anticipated at this stage that a more fully validated model would be available, delays were encountered in gaining access to detailed sources of cost information applicable to this research. Facilities of the type required are certainly not in abundance in comparison to more standard facilities, future research associated with an expanded set of datasources possibly encompassing European and North American facilities may be viable and useful. It is anticipated that further research associated with the prototype model will allow future enhancement and adaptability against a more extensive database allowing the production of budgetary type estimates driven by the volume of material for processing and storage.

In conclusion, the main research output has been:

- Identification of cost drivers applicable to integrated decommissioning projects.
- These can be further defined as quantitative and qualitative cost drivers.
- Development of a prototype model using logically derived CER's.
- The research demonstrated that a combination of expert opinion analysis and case studies allows development of reasonable estimates for concurrent nuclear facility planning requirements and strategic cost analysis purposes.

The research presented in this paper contributes to developing a concurrent cost estimating environment within the nuclear industry.

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NEW PRODUCT DEVELOPMENT IN A VIRTUAL ENTERPRISE

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KEYWORDS
New product development, virtual enterprise, innovation network

ABSTRACT

This paper describes a case study of new product development in a virtual enterprise. The objective is to locate areas that require further research and contrast the case with existing literature concerning successful inter-firm product development. Our study illustrates that new product development, measured by time, cost and product performance, can be successful in innovative networks comprising of several companies with different size. However, there are also problems that may become evident once the charm of novelty has disappeared. Coordination and communication becomes complex as the number of participants increases, and it is not clear that the collaboration will benefit all the parties. The paper starts with an overview of different forms of collaboration, followed by introduction of the framework to be applied in the analysis. Thereafter the case is described, and finally, the discussion crystallizes the contribution of the study.

BACKGROUND

In research and development, inter-firm collaboration is not a new phenomenon. Trott (2002) lists typical forms of strategic alliances. Licensing agreements, joint ventures and research consortia emphasize alliances based on contractual agreement in order to meet a common goal. According to a more liberal view, a strategic alliance is an agreement between two or more partners to share knowledge or resources, which could be beneficial to all parties involved. Supplier relations, collaboration and innovation networks represent this category in Trott's list. Because of their basic nature, the difference between non-contractual alliances is vague. Furthermore, there are several interpretations of innovation network. To some extent, it is a question of semantics, but nevertheless, each definition can help us understand the features of networked operations.

Some networks evolve from long-standing supplier relationships, whereas other networks can be viewed more as a temporary web, in which firms coalesce around one firm or a business opportunity. Typically, virtual enterprise is defined as a temporary network of independent companies who come together quickly to exploit fast-changing opportunities (Jagdew and Browne 1998, Christie and Levary 1998). A closely related term is extended enterprise, which is defined by Childe (1998) as a conceptual business system that consists of a purchasing company and suppliers who collaborate closely in such a way as to maximize the returns to each partner. The extended enterprise does not necessarily comprise the entire supply chain, but a group of companies within it. Childe states that a company becomes a virtual enterprise, appearing to its customers as a supplier of goods and services, but with no internal production activities.

According to Jagdew and Brown (1998) the extended enterprise can be considered as a subset of the virtual enterprise. Virtual enterprises form and reform based on market needs. They are usually project-based, operate in niche markets, and tend to have a shorter lifespan compared to extended enterprises. Information technology in virtual enterprises acts as an integrator as opposed to a facilitator in extended enterprises.

RESEARCH DESIGN AND OBJECTIVE

The research objective is to locate areas that require further research by contrasting the case with existing literature concerning successful inter-firm product development. Our case describes new product development (NPD) carried out by a virtual enterprise. A large company producing industrial electro-mechanical devices established a spin-off enterprise with only three employees to complete the innovation that wouldn't have originally suited to the mainstream of other company products.

The case description is based on multiple interviews with the CEO of the spin-off company. This is complemented with public and internal documents available. Also several interviews with other companies involved to the network were made to contrast viewpoints of different participants and how they perceived their role in network.

We use framework by Sivadas and Dwyer (2000) survey of organizational factors influencing NPD success in internal and alliance-based processes. They tested their model using data collected from two different industries, semiconductors and health care. Because of the multi-industry approach and large sample size, we find their model suitable for the main framework in our case analysis This model, complemented with some additional aspects found from literature, is used to analyze the similarities and differences between the case study and the body of knowledge.

According to Sivadas and Dwyer, NPD success is a combination of cooperative competency and complementarity of partners. Cooperative competence is composed of trust, communication and coordination. The six factors that affect NPD success indirectly via cooperative competency are governance structure, administrative mechanisms, partner type, mutual dependence, innovation type and institutional support.

Concerning governance structure, Sivadas and Dwyer found that whether NPD is conducted internally or externally, cooperative competency is an important construct that contributes to NPD success. Their empirical evidence clearly supported the meaning of mutual dependence on cooperative competency. Concerning administrative mechanisms and institutional support, they found only partial support. Partner type (competitors or non-competitors) and innovation type (radical or incremental) were not statistically connected to cooperative competency.

CASE

The idea for the NPD project discussed in this case came first outside of the large company. The invention was considered to be worth a second thought, as it was estimated to be innovative and have potential in some market segments. They decided to test the feasibility of the new product concept idea and make a working prototype of the device to do some measurements, and for possibility to learn something new by investigating its properties.

The company didn't have applicable internal resources available for producing the prototype, so they decided to buy some mechanical design from external engineering office and manufacturing from a rapid prototyping firm. The first demonstrative version of the prototype was built in less than two months.

After having the physical product and seeing the promising test results, the company realized that the concept design was worth more detailed investigation. A market research was made to locate the right market segment while the company was thinking how to continue with the product development process, because the product was nevertheless significantly out of the mainstream of company products.

The market research indicated that the product concept could have potential in future. The company decided to locate potential component manufacturers and find a responsible unit inside the company for further research and development. However, none of the business units wanted to take the responsibility of the project ownership. Finally, after searching for different alternatives, the management decided to form a new small spin-off enterprise to develop and commercialize the new product. This was regarded as a best alternative to fully utilize the otherwise limited resources. The idea was to use as much external expertise in developing process as possible.

There were several typical reasons to use the fully networked product development in this case. Firstly, the large company couldn't have allocated enough internal resources for doing it all by themselves as most of the people were committed to other projects. Secondly, the separation by spin-off was made to make sure that internal forces wouldn't turn the product to be too similar one with the existing ones. The large company had some expertise in the business, but the new concept and product differed from the traditional products significantly. It was realized that there would be some other companies in the field to better understand how to technically develop this kind of device effectively.

The first task in the process was to build up the initial design network. Due to the active efforts of the project manager, CEO of the new spin-off company, this process took less than months on the whole. The idea of a new kind of innovation network and design process also made companies more willing to participate. The spin-off company itself consisted of only three employees with backgrounds in marketing and product development. Their primary objective was to create a highly responsive virtual network of efficient companies representing best knowledge in the field of their core competencies. Main issues to steer participant selection were the skills of the companies and their flexibility and swiftness to response quickly to design changes.

The participants initially selected to the network were the firms that had been involved in producing the prototype. Other firms included at this stage to the design network were familiar to the spin-off company members at least in organizational level and in some cases also in personal level. Because of the good experiences in past projects they were known to own the qualities needed both in technical excellence and also in ability to work as an efficient partner in a virtual enterprise.

Selected network members also suggested new members based on their own contacts. This made partner selection for spin-off company easier, as the three member group couldn't have known all the suitable participants for detail level design. Suggested partners were mainly accepted to participate because the project manager trusted the judging ability of the existing network partners.

In five months, the network consisted of close to all the participants required in the life cycle of the innovative product development from the concept design to the manufacturing and after sales services. As the design project made progress, the requirements for tooling and manufacturing became evident, and gradually tooling and manufacturing firms were chosen to the project. This early involvement was made to guarantee better design for manufacturability. On the whole, there were sometimes more than hundred people from dozen of companies designing the product simultaneously.

Altogether, close to thirty companies participated in the NPD. Four of these companies were purely focused on design, one of them being large in size and the rest being small and medium sized enterprises. Other companies were participating more as manufacturing or infrastructure providing companies, although they were also expected to share their intelligence about product design, which had also been one of their selection principles. Three of these companies were large in size, the rest were SMEs. All the four key design partners were regional, but some participants in the network were also from Germany, China, Sweden and Russia.

After the network was formed in the beginning, it had only very small changes during the process. Even though the ownership of the spin-off company changed in the middle of the hasty project, the virtual network continued its operations. None of the participants left the project in advance or was reluctant to co-operate with others. Only one participant had to be changed due to the lack of knowledge and improper machinery and equipment. As the design and production get along, one new participant, a subcontractor of an existing partner, was chosen to the network for keeping all the participants involved to the design process on a regional basis, as it was seen the fastest way to do product updates.

Although the spin-off enterprise was prepared to offer adjusted deals, the contractual agreements on transactions were conventional, with the exception that they did not include penalties concerning delivery time. Penalty clauses were only seen to have negative impact on close and innovative relationships, which were seen to be based on mutual trust and willingness to give their best efforts. However, contracts of patents and intellectual property rights were made and agreed to belong to the spin-off enterprise. This decision, along with the modular design structure, was made to guarantee that the virtual enterprise would not be paralyzed if some participant would leave it.

To ensure better communication in network, a start-up meeting was held to make sure that everyone shared the same vision and goal. The purpose was also to familiarize participants with each other so that mental barriers for direct communications would vanish. The people truly responsible for the design and manufacturing innovations were to know each other, not just the middle managers of the companies. The whole forthcoming NPD process was demonstrated to see where the possible bottlenecks would be and how to communicate in case of problem situations.

In the beginning all the communication in the project happened through the project manager. Later on the network partners also started to communicate with each other directly, yet throughout the project everyone always informed project manager about such design changes that might have effect on the total performance of the product.

For enabling cooperation technically, the network needed to decide which communication technologies to utilize. Not surprisingly, requirements for the ICT solution were demanding. All the companies involved needed to have a real time access to all the information created and collected throughout the project. The solution was also expected to be easy to use and configure, secure, support product life-cycle management and versioning, and to have a fair price. Finally, network decided to choose two different internet-based systems. Both of them were independent from network and offered by application service providers. The design network primarily utilized shared document management, whereas the manufacturing network mostly used the distributed product data management system.

Days of the spin-off project manager went mostly by coordinating different partners though e-mail, telephone and chosen ICT solutions. He wanted to make sure that everything went smoothly and that there were no breaks in communication. Even though there were no penalty clauses about delivery times in network, this didn't really mean that there was no control of the participant actions. In one occasion project manager couldn't contact a foreign partner through telephone or e-mail in a couple of days, so he took the very next flight abroad and was waiting by the door of the company next morning for the responsible people to come to work. However, on the whole the project manager's intention was rather to champion the partners than to act like a lurking big brother.

The companies in virtual enterprise also showed independent initiatives by numerous actions. The number of design enhancement suggestions was considerable and partners also explained others how to reach better solutions. Expectations for the product success was very high among some network members, as they already made investments for the manufacturing lines during the design process without any guarantee of product success in the market.

Design and prototyping process was surprisingly fast according to the partners involved. It took only three months until the final product prototypes were ready for measurements and testing, which was two months less than estimated in the beginning, and only one third of the time in comparison with the traditional in-house design projects. The design concept was modular, so in the end there were actually three different end products, each of them having several versions available. Final products were ready in eight months, which was two months less than expected. Although the original design was done very quickly, the changes in design details took more time than expected.

The NPD project was considered to be a success. The final products met all the technical requirements and in some details even surpassed the expectations. Despite of that the final product costs were only 20% higher than expected. In later derivative product revisions, the price was estimated to be in par with the original estimations. On the whole, in comparison with the traditional existing products offering the same features, the new devices were substantially more inexpensive and smaller.

During the NPD project the network has worked without any major problems. None of the participants vanished away leaving others in network into trouble during the process. However, despite the technically solid products, the market expectations haven't been reached yet. Traditional industrial buyers are somewhat doubtful about the concept and they tend to hesitate in integrating this technology as part of their final products. It is not clear whether the product concept will eventually be a success and whether the virtual enterprise will be reactivated to develop new models of the device.

DISCUSSION

Referring to the results presented in the previous paragraphs, the development project can be considered successful. However, the market success of the product has not yet been proven. Partially, the fact that the ownership of the spin-off company has changed during the NPD-process, may have caused the delay in full market introduction. In the framework of Sivadas and Dwyer (2000), ownership is linked to institutional support, which is conceptualized by clarity of agreement about resource allocation and resistance of senior management to the project. Lack of resistance contributed to the cooperative competency only in health care industry, whereas clarity of agreement about inputs significantly enhanced cooperative competency in both contexts.

Administrative mechanisms comprise of formalization, centralization and clan control. A clan system is governed by shared values and norms reducing the needs of bureaucratic control devices. Sivadas and Dwyer found a positive relationship between clan control and cooperative competency. They also found that cooperative competency is associated positively with formalized relations, i.e. the use of explicit rules in the relationship. On the other hand, they could not confirm any relationship between centralization and cooperative competency. Centralization, the concentration of decision-making authority, is typically assumed to have negative impact on communication, innovation success and general effectiveness. Our case supports the idea that successful NPD in a virtual enterprise requires a right mixture of formalization and clan control. The central role of the spin-off enterprise was necessary, and there is no evidence that it would have impaired innovativeness.

As observed by Vyakarnam and Handelberg (1997), networked innovations with entrepreneurial teams combining different personalities, knowledges, skills and backgrounds are more likely to accomplish an innovation than homogenous teams. Sivadas and Dwyer also confirmed that NPD success in the semiconductor industry is related positively to activities that complement and build on partners' core competencies. Our findings are also in line with both of these results. Thus, it can be stated that in some cases combining together complementary external heterogeneous expertise is a practical strategy to achieve NPD success.

Sivadas and Dwyer state that the type of product innovation to be made, radical or incremental, should have no effect on overall cooperative competency. However, some of the participants implied in interviews that they participated to the project with more enthusiasm because the product itself was interesting. Thus, the radicality of the new product made the development more interesting.

Another aspect to be considered is the radicality of design process itself. So far the virtual enterprise concept has been regarded more or less like a test bench by the companies. The whole network involved has been participating the process with enthusiasm because of their own willingness to learn more about a possible new way to develop products. Therefore Hawthorne effect may have influenced the final results. If the virtual enterprise would become a common working method in NPD, this enthusiasm and also innovativeness could partially be lost.

Another classification on whether the virtual enterprise is a good solution for new product development in virtual networks is presented by Chesbrough and Teece (1996). They state that the more systemic the device to be designed, the harder is the design process in network. In our case, the product structure was modular and autonomous, which made developing of mechanics and electronics simultaneously much easier.

According to Sivadas and Dwyer, highly mutually dependent alliances foster higher cooperative competency than others. Chesbrough and Teece, in contrary, state that most successful virtual companies are far from egalitarian. In our case, however, neither of these earlier results was observed. The companies involved were not dependent on each other and yet they all cooperated efficiently in harmony. Neither were the participants in network competitors, although according to Sivadas and Dwyer, cooperative competency is not dependent on wherever companies are competitors or not.

According to our case, the number of other companies to be orchestrated has to be kept limited by one participating firm. If the network is to collaborate more efficiently, some other parties have to take more responsibility of some sub-issues. However, the companies in our case stated that there should still always be one clear integrating point somewhere in the innovation network. This is quite the opposite of the observations made by Sivadas and Dwyer suggesting that centralization as administrative mechanism impairs cooperative competency. Our case research findings are rather in line with Chesbrough and Teece arguing that more centralized virtual enterprises are often more effective.

Typically, innovation network participants consist of traditional supplier-customer relationships where the trust has been built during the previous contacts. The idea is to get the suppliers involved to the design process as early as possible so that their design and manufacturing knowledge can be utilized to achieve better product design and manufacturability. The earlier the design problems are found and mitigated, the more will be gained in product costs, project management, quality and time (Ragatz et al. 1997). According to the partners interviewed, these goals were also reached in this case.

Keeping manufacturing at least partially separate from design has its strengths and weaknesses. If the manufacturing is kept separate, it can easily be copied and transferred to other geographic locations. However, when the participating company has involved both in design and manufacturing, the activity in R&D work has to be compensated fairly if the intent is to change partner in future. Otherwise, it would be unrealistic to assume these companies to enthusiastically participate in design and innovation process. In this case the manufacturing companies were aware, that most of them would loose their position in network, if the product turned out to be successful and the mass-production of the device began.

The companies involved to the project regarded it as a learning opportunity for innovation networks. However, if the product will turn out to be a market success, their attitudes will probably become more business-oriented, and the companies involved in design network will become more willing to share the profits For supporting joint innovations, commonly accepted risk sharing and rewarding models are needed to articulate what win-win relationships really mean in practical terms. The models used so far have been applied to only few companies and their feasibility has not been tested in R&D projects or innovation networks.

Another aspect to take into account is that the product would change the existing market. As the owner of large company has a strong position in the market, it doesn't want to necessarily cannibalize its own markets by introducing the product as early as possible. However, delaying the new product full market launch to the estimated optimal time in future regarded by spin-off company may cause problems for manufacturers in network as some of them have already invested capital for new manufacturing equipment.

There was also one other success factor recognized by participating companies. The ICT solution chosen was flexible and modestly priced yet having all the required features. In some cases, as also stated by Brunnermeier and Martin (2002), interoperability of information costs may become an exhaustive obstacle especially for smaller firms if larger companies require others to maintain specific systems for sharing product data. This was estimated to cause $1 billion costs only in US automotive industry.

CONCLUSIONS

This paper illustrates that new product development can be successful in innovative networks comprising of several companies with different size. In this case, the overall costs in design were much smaller than they would have been with traditional methods, and the time reduction was also considerable. The findings in case were mostly in line with earlier research, although there exists differences and also new aspects to be taken into consideration.

Despite of the positive experiences, the management of a virtual enterprise has many problems that may become more evident once the charm of novelty has disappeared. Orchestration and communication with a large number of companies becomes an exhausting task for project manager. The project is also very dependent from the efforts of the single project manager having all the tacit knowledge, and therefore the coordination should be more process oriented. Although win-win relationships are frequently emphasized, it is not clear that the collaboration will benefit all the parties. We find the role of more explicit agreements and thorough understanding of sharing costs, benefits and risks crucial in the future, since the requirements for extended collaboration tend to increase especially the risks of suppliers in the network.

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WEBSCAN, an Internet web engine for benchmarking

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KEYWORDS
Portal, benchmarking, logistics

ABSTRACT
The paper describes the characteristics of a website called Webscan, which has been set up to support scientific research on benchmarking among SME's. It currently features a logistic benchmarking questionnaire, based on a causal model. The paper describes both the technical setup and the process flows of the website between the portal provider and the university. It also details the contents of the questionnaire database. Finally, indications about the results and the planned research on the database are given.

INTRODUCTION
The organizational goal of a company is to make money and decisions nowadays should be translated into a more competitive stance. Only the strong survive or better: only the smart prosper. That is why each organization should question regularly their long-standing practices and traditional management concepts to see if they still fit in a world that competes on product distinctiveness, price, quality, time and due date performance.

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. The link between best practices and performances has been established by (Voss, 1995). Therefore, best practices are suggested actions for organizations striving for excellence. This model - called "context-practices-performances framework" - was proposed by (Ho and Duffy, 2000) and refined for use in a logistic 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 chains. This paper addresses this need as will be explained further.

Benchmarking focuses on what best practices are available and ensures an understanding of how they are performed. It also triggers action by showing companies where they are lagging and by how much. 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). The benchmarking process will set targets for the top-level objectives of the company. For manufacturing companies four main objectives have emerged from numerous literature sources: Flexibility, Reaction time, Quality, Return on Assets (the latter being a specific way of looking at Cost).

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 on large companies, and are fairly expensive to use. This inspired the authors to set up a publicly available benchmarking database, aimed at SME's, and accessible through a web browser on the Internet.

Benchmarking in itself can make a company realize that improvement actions are needed. This however does not guarantee that a company knows how to improve, or which best practices to choose from the numerous ones that emerge from a benchmarking exercise. We had extensive experience with a concurrent engineering benchmarking model, that provides companies with a list of over 200 best practices they could enhance, but leaving them little more in terms of guidance (Van Landeghem et al., 2000). Further statistical analysis to discover significant practices is under way, but obtaining the necessary amount of input data proved to be very time consuming, and prone to a local support team for each area under study (Van Landeghem and Roels, 2001).

Replicating this approach to benchmark logistic performance, our research group developed a causal model to remedy this lack of guidance (Van Landeghem and Persoons, 2001). The causal model - called "Logiwatch" - links 188 different best practices to 66 performance measures, which support the main objectives mentioned above. To anticipate the data entry problem, we decided to embed this causal model into a web site, thereby opening up access to a wide group of companies.

This paper further describes the set up of the operational module *Webscan*, the *Webscan* process flows and related information flows and some future ideas on exploitation. The conceptual model of the Logiwatch content has been outlined earlier in another paper (Van Landeghem and Persoons, 1999).

THE OPERATIONAL MODULE WEBSCAN

Webscan has been modeled as a web based tool to meet any questioning and benchmarking needs. It provides a framework to guide companies how to benchmark. This generic setup forms a cost effective approach, as any type of benchmarking content can be handled. In this paper the setup and results of a logistical benchmark Logiwatch is treated.

Given the advance of the virtual economy, it was quite trivial to develop the ideas in Internet technology, i.e. on a portal with registered domain name *Webscan.be*. The homepage with the *Webscan*-logo attracts potential customer-companies and invites them to benchmark themselves with the best-in-class companies of their sector in a few dedicated steps : register your company, fill in the different questionnaires grouped by sections (fig. 2), and finally submit your answer list. The basic report is produced automatically. The advanced report, with results from the causal model, are sent back to the customer-company in a pdf-formatted evaluation report (with graphics and action plan).

Technically the portal communicates with a web server that controls the *Webscan*-business processes and manages the data to and from the database server. Because of security reasons, the benchmarking database resides on a separate server, without any direct link to the identity of the submitting companies.

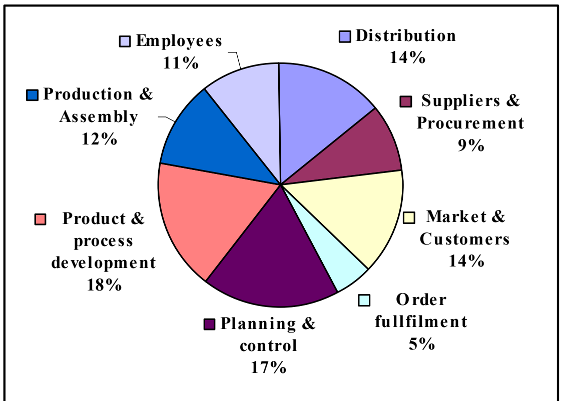


Figure 1. Best practices per section in Webscan

The operational heart of the benchmarking website consists of a "questionnaire engine". This is a scripting module, that accepts any questionnaire, as long as it adheres to a standard format, and is available as a MsAccess database. The questions themselves can be of different types. The main characteristics are:

- A total of 350 questions are grouped into 8 sections, as indicated in figure 1. A section constitutes the smallest unit that can be browsed through. Questions within one section can be reviewed and updated by different persons in the company. When all sections are completed, the final responsible person will submit the whole questionnaire, thereby locking all sections from further updates.
- There are 4 types of questions (table I). The CMM type is based on the well-known 5 scale capability maturity model. On top of that any question can be answered as "Not Applicable", and a free comment field is also available (fig. 2).
- The order in which questions are presented is governed by pointers. This allows to skip questions, by using conditional pointer adresses, based on the level of the answer with respect to upper and lower bounds. This way unnecessary questions are avoided and the time needed to fill out the questionnaire is minimized.

Type	**Description**	**Allowed values**
CMM	Capability Maturity Model	0 1 2 3 4 5
YN	Yes / No	Yes = 1 No = 0
NUM	Number as input	Long integer
FREE	Free text	---

Table I. Question types allowed by web engine

THE WEBSCAN PROCESS FLOWS

As illustrated in figure 3, the whole Webscan process has been divided into 3 distinct process flows: the Secure Login process, the Filling-out and Submission of a questionnaire, and the Reporting process.

The Secure Login process is a key element to the success of Internet-based benchmarking. To be able to use the data in a benchmarking process, detail and correctness are a must. This means companies must be fully confident that security will not be breached. In Webscan, companies must first register. They receive a unique ID through email, to the designated responsible within the company. This ID will be the only identification that is attached to the answers of the questionnaire. The master file containing company identifications and ID's is encrypted, password-protected, and any access is fully logged. The file will be used automatically by the website to generate the email, notifying the user that the results are available for download. Only a handfull of persons can actually access this master file. The whole security process is supervised by a steering committee, which includes representatives of the target companies. Also, the master file is registered with the Federal Committee for the Preservation of Privacy, a watchdog set up by law in Belgium.

When a user wants to fill out a questionnaire, he uses his ID to log in (see fig. 3). He then selects which one of the sections he wants to fill out or review (fig. 2). With this ID code any person in the company can fill out his part of the questionnaire from his desk. This enhances the accuracy of the answers, as each unit manager can treat his domain of expertise. The overall responsible person, who made the registration, also receives a second master ID, which allows him to submit the questionnaire, once all sections have been duly filled out. The submission triggers the transmission of the answer file from the Webscan server to the Logiwatch server, residing at the university. The actual file transfer process is done by an FTP daemon, residing at the university server, which scans the output directory at regular intervals.

The reporting process will process any incoming files, by storing them into the main database, and then compiles statistics. This processing is done within Excel, using VBA macro's. The output is then converted into PDF files. There are two types of output reports: a basic report and an advanced report.

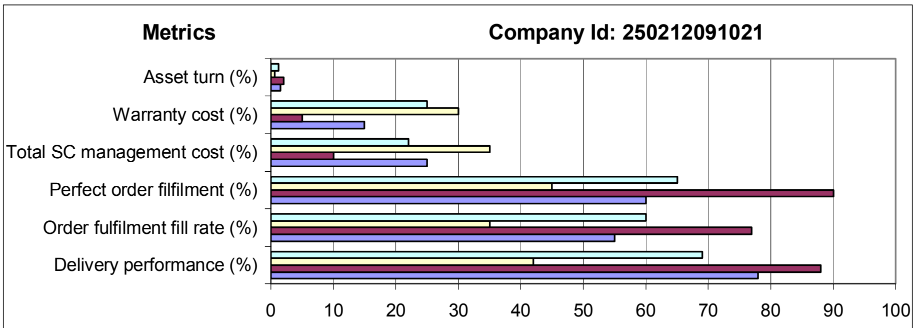
The basic report contains:

- A comparison of the scores on the use of best practices, by section, with the other companies in the database. The database is characterized by the highest, lowest and median score, over all companies. Also the percentile ranking of the company's score is reported.
- A comparison of the performance measures, according to the same principle.
- The same data, but now compared with the companies in the same industry sector.

The advanced report contains:

- A list of best practices that are most likely to improve the performances of the company, based on the causal model. Some explanation is provided.
- When the same company has filled in questionnaires on previous occasions, a comparison is made to indicate evolution patterns. The same is done with the database, such that one can compare one's rate of improvement with the general improvement tempo.
- More refined distributions of key measurements from the database in order to better judge one's own position versus the database.

The reports are stored in pdf format on the website host, and an email is sent to the registered person in the company, using the secure master file to match the ID code with the email address. The company can then inspect the report files on the site and download them (see fig. 3).



	Delivery performance (%)	Order fulfilment fill rate (%)	Perfect order filfilment (%)	Total SC management cost (%)	Warranty cost (%)	Asset turn (%)
average	69	60	65	22	25	1,2
worst	42	35	45	35	30	0,6
best	88	77	90	10	5	2
company	78	55	60	25	15	1,5

Figure 4. Example of benchmarking report

WEBSITE HOSTING

At the moment Webscan focuses on the logistical operations of a company, through the Logiwatch questionnaire. But it is quite obvious that this operational module can easily be extended to other vital operations within the company, such as Human Resources or Product Engineering.

WEBSCAN BASED RESEARCH

The first aim of the benchmarking website is to provide objective information to SME companies, about their performance level, and the directions in which they should evolve. The first type of research therefore will be aimed at longitudinal scopes of the database, to indicate patterns, evolutions in time, and idiosyncracies. For instance, in comparative research that was done on a concurrent engineering database, it was found that Italian SME's are significantly more active in CE than their Belgian collegues. It should be clear that these types of findings are also very interesting for the policymakers in the government, because it provides them with an objective measure of success regarding their industrial policies.

A second type of research will be geared towards refining the causal model. The current model is based on literature research (Domenech and Van Landeghem, 1998; Van Landeghem and Persoons, 1999). As soon as sufficient records will be available in the database, more quantitative relationships will be extracted from it. Among the methodologies that can be used for this we envisage statistical factor analysis, expert rules, and neural networks. The significant relationships will then be compared to literature-based causal model. Patterns that match, will then also be quantified, and will provide the benchmarking companies with strong indicators for further success. Patterns that do not match will require further investigation, and could indicate deviations of the database sample from the literature samples.

CONCLUSION

With this project the Industrial Management Department, Faculty of Engineering of the Ghent University stimulates the SME to participate in an anonymous audit, comparing themselves on logistical operations with best-in-class performers, supports them with a feedback evaluation report and helps them in setting up an action plan. This will enable them to grow steadily and controlled to a much better performance and eventually to world class levels.

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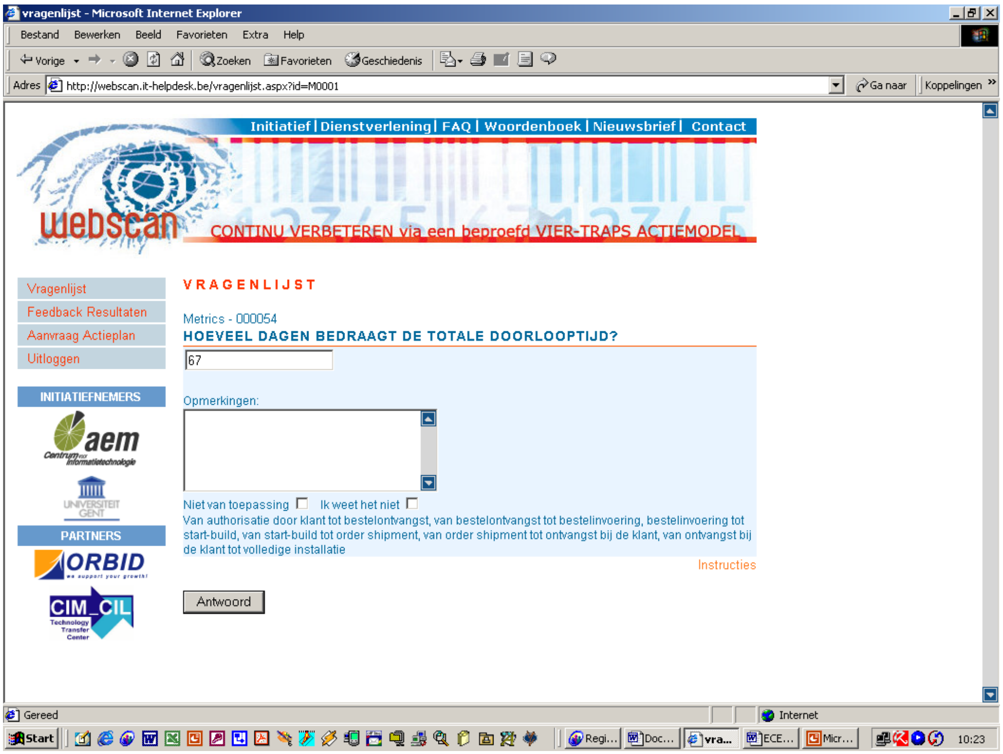

Figure 2. Screenshot from web page with benchmarking question displayed (in Dutch)

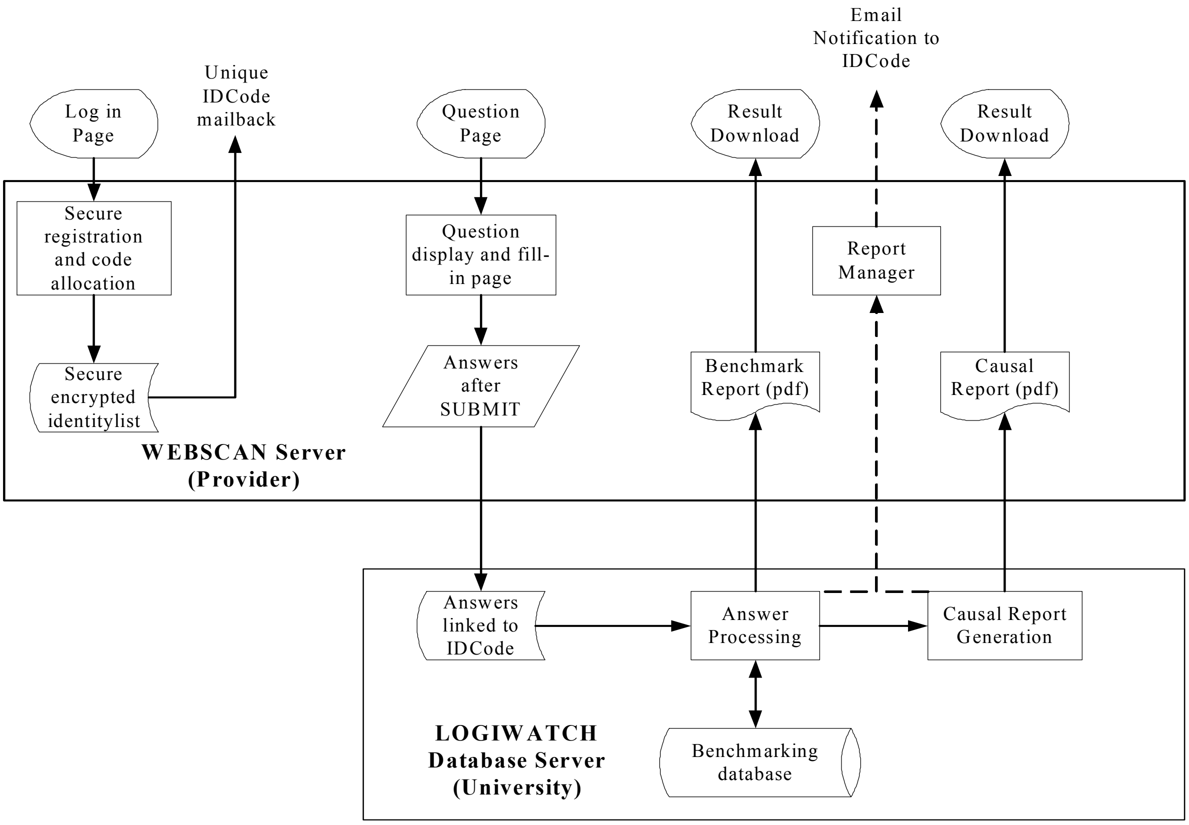

Figure 3. WEBSCAN system architecture and process flow

LIFECYCLE-ORIENTED DESIGN MODEL

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KEY WORDS

"DESIGN FOR X", KNOWLEDGEWARE, "DESIGN FEATURE", PPR, "CONCURRENT ENGINEERING".

ABSTRACT

The purpose of this paper is to introduce a model of lifecycle-requirement-oriented product design. Aiding computer resources and design concepts applied during the development and manufacturing activities supports this model.

The practices regarding the design concepts to be addressed are often of the designer's intellectual property only, and the information generated during the different lifecycle phases are not efficiently integrated. This paper presents a form of oriented information integration and the storage of this intellectual capital into computer resources, as well as the publication of these best practices within the enterprises.

Information integration and knowledge storage are realized by means of the incorporation of the design concepts into the aiding computer resource functionality used during the product lifecycle.

INTRODUCTION

The product development activity has been supported for more than 20 years by computing resources, which are applied to design, production planning, and manufacture, among others.

Simultaneously with the computing resources, product development concepts are also used, thus leading the designer to conceive the product based on the best possible conditions regarding manufacturability, assembly, reliability, etc.

Considering the aiding systems for design development (CAD-Computer Aided Design) currently available in the market, these do not have the product development concepts, used by designers, incorporated into their functionality, that is, the development method of any product is the designer's intellectual property. The engineer or designer simply uses the CAD system to aid him/her in the geometric product development, but it does not assist him/her with regard to the product conditions for its proper manufacturing and conditions that meet further phases of its lifecycle.

Through the practical knowledge of how the computing resources and the product engineering concepts are applied, the need for incorporating the product development concepts into aiding engineering systems is identified, thus supporting the designer in developing products oriented to the needs of their lifecycle.

The Information Technology has been searching the incorporation of these design concepts into their aiding systems, such as the CATIA V5®, Dassault Systèmes, which offer these conditions. However, the users and their managers should know this possibility and realize the possibility of the incorporation of these internal concepts into the product development systems.

At present, there are several computing systems in the market that support the companies in developing their products, from their conception to their manufacturing planning, however, the incorporation of the product development concepts does not exist. Also, there is no integration of the information generated by these different systems used at the phases of the product lifecycle.

Well known CAD systems used in the market, such as Auto CAD®, MicroStation® and CATIA V4® (currently used by most of the automotive and aviation industries), they do not offer product development functionality oriented to the future needs of milling, manufacturing, and so on.

Another well known system that at the design phase has the purpose of foreseeing aspects of the product, which are relevant for future phases of its lifecycle is the DFMA®, Boothroyd Dewhurst, Inc. It is certainly one of the major products in this category, but it works independently of the product development systems, not benefiting from whole intelligence behind the geometric product development. Unlike DFMA®, the CAD system does not benefit from the project concepts oriented to the needs of the product lifecycle.

Similarly to DFMA®, T-Systems' CAPP® System is also an important production planning system, but it does not have the information integration with the product development systems, and the CAD systems themselves do not use the CAPP® System concepts.

The examples of systems provided to he market and used during some phases of the product lifecycle show a "gap" with regard to the integration of different phases' lifecycle. The information is not being duly integrated and the technical knowledge required to be applied to different systems is not incorporated into the product development systems, thus resulting in the development of products without the proper analysis of compliance with future phases of their cycle.

Based on the aforementioned requirement, the purpose of this work is to introduce a model to incorporate into product development systems, the concepts and technical knowledge related to several phases of the product lifecycle. This way, product-manufacturing problems can be foreseen. Designers will be provided with better product development conditions and the technical knowledge will be stored into computing resources, also enabling the publication of this knowledge among the members of a team, company or project.

"DESIGN FOR X" AS SUPPORT OF CONCURRENT ENGINEERING

Among the methods employed for product development, Concurrent Engineering is considered as an optimal environment for this activity. Its main goals are quality enhancement, cost reduction, lead-times compression and flexibility improvement, thus increasing the enterprises' productivity and effectiveness (Huang, 1996). The fulfillment of these targets is made possible by the cooperative working mode of multidisciplinary teams, enabling to consider a product, process and/or system design needs, from conception to disposal.

When addressing the product from conception to disposal means to address the "product lifecycle" (Dieter, 1991). Product lifecycle is the term employed to include all the development phases of a new product, such as its manufacture, distribution in the marketplace, and even the way it will be disposed in the environment.

Aiming at bringing the needs of different phases (which a product is submitted to) closer to the design phase, a product design concept designated as "Design for X" (DFX) is employed. DFX is one of the most effective approaches to Concurrent Engineering implementation, thus enabling - through its product-lifecycle-requirement-oriented design method - the use of available resources of an enterprise in the best way possible.

The "X" in the term "Design for X" is a variable that represents the phase of product lifecycle, that is, the DFX concept is made up of different methods dedicated to different product lifecycle phases. As an example, the *Design for Assembly* (DFA) method is highlighted, that has its application focused on product assembling processes.

The DFA concept (Bedworth, 1991) is used considering still in the design phase, the main primary factors related to the subject product, including part symmetry, size, weight, fits, orientation, form features, etc. The main primary factors related to the assembly process are also considered at this same design phase, such as inserting, handling, gripping, orienting, special tooling and equipment, etc. The careful assessment of different application possibilities, of different aspects, in a same product, results in better design decisions regarding the easiness of the assembly process.

In sum, "Design for X" is a philosophy and a methodology that propose to help companies in the way they manage product development, aiming at making them more competitive.

For this work, it is important to use the *anticipation* concept of DFX in information generation related to the product lifecycle phases, defining a new integration of the information generated by different phases and computing resources involved in the product lifecycle.

ORIENTED INFORMATION INTEGRATION

In its great majority, the *integration* approaches to Engineering aiding systems is handled merely as a connection interface between different systems employed and a file format that meets both the input and the output system, that is, the information generated by a particular phase of the product lifecycle should be recognized (read) by the subsequent phases.

This type of *conventional* integration is noticed analyzing the integration between a CAD (Computer Aided Design) system and a CAM (Computer Aided Manufacturing) system. The input for a CAM system is the geometric model generated by design engineers by using a CAD system. However, in this CAD model there is no information regarding product manufacturing, but only geometric information.

Unlike this *conventional* integration form between systems, the proposal is the generation of different product lifecycle information, automatically and simultaneously with the geometric product information. If necessary, this information will be later on refined and/or supplemented by the specific system employed by a particular phase of product lifecycle. This integration is designated as *oriented* information integration.

By applying this proposal of integration into the design phase, information pertaining to the product geometric aspect would be generated, namely the main function of a CAD system, however, this geometric information would already be automatically associated with information regarding the product manufacturing process, such as milling machine, cutting tools, technological data, milling strategies, etc. In this case, as benefits of such integration is highlighted the CNC programming process optimization and design reworking reduction, in order to adjust the product to its manufacturing process. Information regarding product manufacturing is applied still in the design phase, that was previously collected, studied, optimized and stored in relational way to basic product development geometry (holes, grooves, chamfers, etc.), transferring feasible data to be executed by the CAM system.

However, the provided example deals only with information integration of design and manufacturing phases, and this *oriented* information integration should be considered at any phase of product lifecycle, and may associate information regarding assembly, inspection processes, impact of the product over the environment, etc.

INFORMATION ASSOCIATION THROUGH FEATURES

Need for a data type

In the automated generation of information related to the product lifecycle as well as to its geometrical model, these different pieces of information (e.g. manufacturing and design information) is handled as being *encapsulated*, that is, only one information package that is internally inter-related. For the storage of this information in computing resources, it is necessary to define a data type that supports the characteristics of this information.

To better understand the required data type so, as to enable the storage of this information, the concept of *feature* is used. In this work, feature is addressed as a data structure that supports this type of interrelated data.

The Feature Concept

Different usage of the term *feature* was described during its research. A feature may be defined in some cases as being just “a region of interest in a part model”; some times it may be defined as “a region, which could be machined with one machine operation”. However, a common definition is provided for this term (Claassen et al., 2000):

“Feature = Form-Feature & Semantics”. This is a definition that divides a feature into its two main portions. The description of these two portions may be found below:

Form-feature is the grouping of geometric items that are logically related. They describe the geometrical form of a feature. The form of a feature may be frequently described through parameters. A simple example of parametrical description of geometrical entities is a “hole”. It may be described through parameters such as diameter, depth and conicity angle. Besides these geometrical parameters for hole definition, information is still necessary on hole construction, such as a reference plane and the exact hole position.

Semantics is the most difficult portion to be described, but this is the special reason for the *feature* technology. Semantics is related to the meaning of feature with technological information associated with it. The semantics part of the *feature* is made up of 3 information types:

- Data attributes: These are the parameters to be assigned to geometric aspects of the feature, or even tolerance specifications of the feature;

- Rules or methods: this is the information determining the feature behavior and instructs it, through methods and checks, in order to fulfill the desired functionality. In a mathematical way, the feature fits in the need for its application;

- Relations: relationships are the elements that link different existing information in a feature. These relationships may be considered as a “feature mapping”, that would groups all information related with it.

Application of the Feature Concept

The two main divisions of a feature (form-feature and semantics) is the core property to apply this type of data structure on the lifecycle-oriented product design model.

In short, the form-feature division is the product geometry containing all necessary definitions to establish the product form and semantics is related to the product lifecycle information added to the geometric information. Within the product lifecycle, different features may be identified, such as: design features, manufacturing features, assembly features, quality features, etc.

Taking as an example the manufacturing phase, the geometry of a hole is related to its manufacturing process, adding to the geometric model, information regarding the milling process, as well as the necessary resources to its execution.

The possible relationship between information regarding *products, processes,* and *resources* is then evidenced. The product geometric model is naturally related with its manufacturing processes, as well as to the processes that regard its respective resources.

THE PPR CONCEPT

Within the context of Product Engineering, the geometrical development of a product is started (in most situations) with the use of aiding computer tools, as already mentioned, the CAD system that has as its main function to generate the digital product model. However, the proposal is to assign to the CAD system other tasks, besides geometric *product* development, such as, simultaneous generation of information regarding the product manufacturing process.

The product manufacturing *process* is the necessary process grouping to make a particular product, in accordance with its design specifications. For instance, milling, injection, inspection, assembly and quality processes. These processes are performed through specific *resources* that allow the execution of their corresponding processes.

Objectively, the PPR (Product, Process and Resources) concept is summarized in the intrinsic relationship among products, processes, and resources.

According to Duffey & Dixon (1992), the relationship between Products, Activities, and Resources (PAR) is considered as the tripod for product execution, where the intrinsic relationship among these three information classes, is basically explained by the need that certain products demand specific processes and these processes demand specific resources to enable its execution (Huang, 1996).

Currently, the above exposed concept by Duffey and Dixon remains valid, but important enterprises in the engineering and manufacturing industries treat the naming of the tripod as PPR (Products, Processes, and Resources) that has the same meaning in this context.

APPLICATION OF THE PPR AND FEATURE CONCEPTS TO THE PRODUCT-ORIENTED DESIGN MODEL

The product-oriented design has the support of computer systems assisting to the product lifecycle, which, when not used with deep foundation on important concepts of product development, good design results are not achieved.

The *feature* and *PPR* concepts should be used together with the computer systems assisting to product lifecycle. The software used should contain functionality that allows the application of these concepts, thus making it possible to achieve good design results.

The PPR concept is used to establish the relationship of these different information classes. The information regarding products, processes, and resources are stored in Engineering and Manufacturing databases, respecting the hierarchical levels and relationships among the different information classes.

The feature concept is used to establish the form under which information will be associated by using a computing system. Considering a *feature* as a data type, the product geometrical data occupy the Form-feature part and, the process and resource information occupies the Semantic division of the feature.

The process of feature creation for application in design requirements is executed with the support of professionals who have deep knowledge of design and manufacturing needs. The *knowledge* developed by these professionals is stored in computing resources under the form of features, as following described in details.

KNOWLEDGE REPRESENTED BY FEATURES

In the context of this proposal model, *knowledge* refers to the experience developed and accumulated for years by designers and engineers. This knowledge is a particular property of those who develop them. Not for personal reasons, but due to the difficulty of making them public to other professionals involved in the same activity. This way, the enterprise becomes vulnerable to the loss of this precious “intellectual capital” internally developed, since the employees who leave the company take along the developed knowledge. For many enterprises this intellectual capital is the key of its business and its price is immeasurable.

Given the necessary importance of keeping the knowledge developed inside an enterprise, information technology also helps product engineering in this aspect. However, a data type capable of supporting the *knowledge* developed inside an enterprise is necessary. At this point, the feature data type is used in meeting the needs to storage the knowledge. Therefore, the *feature* is the computing representation of experiences developed inside an enterprise.

KNOWLEDGE STORAGE

To enable *knowledge* storage, it is necessary to previously identify it and capture it, and then to implement it in computing form, and later on, it will be directly associated with design specifications. This association takes place through the creation of rules, reactions, checks, and formulas that interact with the designers at the product development phase.

Some benefits are achieved with the use of this process of knowledge storage. For example, the possibility offered to designers and engineers of automatic and recurrent usage of already captured information, gaining time in design activities. This time saving may be used for previous detailed analysis of design specifications, generating results with better quality and cost reduction through the elimination of unnecessary rework activities.

The previously described problem regarding the difficulty to keep intellectual capital inside the corporation is eliminated, as the knowledge is stored in computing resources and is not any more retained by a limited number of professionals. The captured *knowledge* is not any more associated (built in) with a sole design, but may be used in many ones. Therefore, design specifications become more consistent and uniform within the enterprise (Bukowitz et al., 2002).

KNOWLEDGE PUBLICATION

After the *knowledge* storage procedure, it may be reused and divided among other experts at the enterprise or, in a more comprehensive way, employees not necessarily of the same enterprise, but members of the same project that are authorized to access this information.

Turning previously explicit *knowledge* into explicit practices is an efficient way to transform specific *know how* into corporate knowledge, spreading it across the corporation.

The *knowledge* so far described may be defined as *best practices* developed within an enterprise, that means, quality assurance, design consistency, and design error reduction (Bukowitz et al., 2002).

The *best practices* may be identified and captured at any phase of the product lifecycle to apply them into the design phase. The rules, reactions, checks, and formulas that are forms to represent *knowledge* in a computing resource will be developed in accordance with the need of the product lifecycle phase at hand, and may be the best practices performed in milling, assembly, quality, inspection, disposal processes, among others.

RESULTS

The proposal presented in this work regarding the incorporation of design development concepts into aiding computing systems is becoming mature due to software packages that are still very recent in the market, but that signalize the possibility of this practice.

The final results highlighting the implementation efficiency of DFA (Design for Assembly) techniques in functionality of a CAD system have not yet been developed, however, there are sound results that show the efficiency of the knowledge storage and reuse method, as well as the utilization of DFA techniques in project development (this technique can be even used in manually developed designs without the support of aiding software packages).

The results presented through the use of these techniques, even if not incorporated into a CAD system, signalize the efficiency in the development of products oriented to their lifecycle. Consequently, the results to be achieved will be much more effective when these techniques are incorporated into CAD resources.

Following there is a DFA application case realized in an electric engine (see Figure 1) with the purpose of reducing the assembly time of this product and consequently its cost (Huang, 1996).

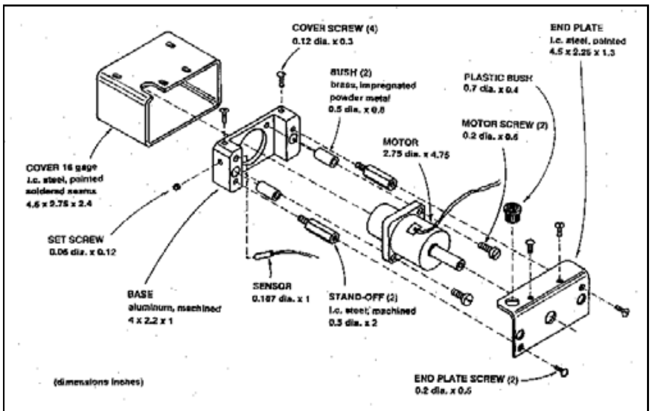

Figure 1: Initial Design of motor-drive assembly

The implemented DFA techniques in this redesign process had the purpose of achieving the best product assembly ratio, reducing its number of components, joining parts, eliminating parts, and offering more appropriate assembly conditions. See the following figure 2:

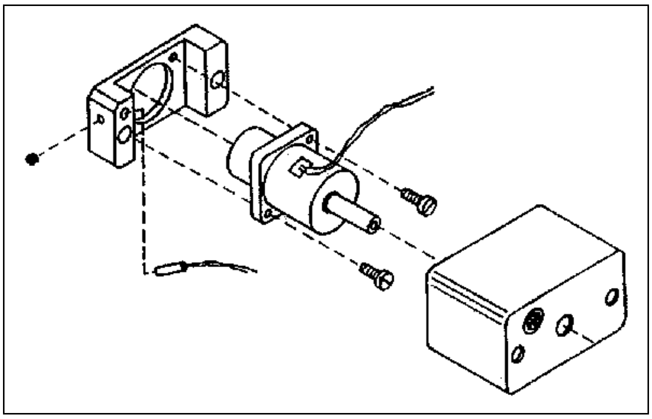

Figure 2: Redesign of motor-drive assembly following DFA analysis

See Table 1 comparing the old product version (Proposed design) and the new configuration, where the items that make up the product and its cost in both versions are presented:

Table 1: Comparison of part costs for motor-drive assembly design and redesign

Proposed design		Redesign	
Item	Cost $	Item	Cost $
Base (aluminium)	12.91	Base (nylon)	13.43
Bush (2)	2.40*	Motor screw	0.20*
Motor screw (2)	0.20	Set screw	0.10*
Ser screw	0.10*	Plastic cover + tooling	8.00
Standoff (2)	5.19		
End plate	5.89		
End plate screw	0.20*		
Plastic bush	0.10*		
Cover	8.05		
Cover screw (4)	0.40*		
Totals	**35.44**		**21.73**

The next case that signalizes the efficiency of this lifecycle-oriented is a benchmark performed between conventional product development software and another one with the storage technology and knowledge reuse.

This benchmark was performed at a company developing and manufacturing jigs and fixtures for the automotive sector, focusing on the time of geometric change in its digital products. Upon running this benchmark, the time of the geometrical changes was compared (see Table 2) by using conventional software (CATIA V4®) and a "knowledgeware" software (CATIA V5®). The results were extremely expressive when comparing one another (Fouger, 2002).

Table 2: Generative Jigs and Fixtures design is a knowledge practice

	Auto-Jig P58-UC1A2 Clamper Type	Auto-Jig P58-UC1B1 Jig orientation	Auto-Jig P58-UC1A7 Hinge Position
	Switch width of std cylinder from X mm to Y mm	Reorient the entire Jig and respect all constraints	Change the standard Arm Length (with modification of standard finger mounting)
Conventional SW	**10 mn**	**5 mn**	**20 mn**
Knowledgeware SW	**0.5 mn**	**0.5 mn**	**1 mn**

SUMMARY

Through this paper two major aspects for the product design activity were addressed, namely the concepts and the computing systems that support the product development. In spite of the presented concepts and the computing systems being already used for the product development process, the presented methodology searches for a *joint* utilization of these two aspects, where the design concepts oriented to the lifecycle are already inserted in the functionality offered by the assisting computer systems.

Another important issue emphasized in this work, is the aim of this methodology in *anticipating* the solution of eventual problems that may be identified during the product lifecycle, thus developing the design of any product oriented to the requirements of its lifecycle phases.

The purpose of this paper and other related initiatives is to provide the companies with excellence conditions for their product development methodologies, by using on a synergy basis their product development concepts, their aiding computer systems and their valuable intellectual capital.

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EMBEDDED SYSTEMS DESIGN
FROM MECHATRONIC TO CONCURRENT ENGINEERING

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Mechatronic, Concurrent Engineering, embedded system, hard/software codesign

ABSTRACT

At a first glance mechatronic and concurrent engineering are two different approaches in product design and development. A deeper investigation shows, that there exists a very close relation between mechatronic and concurrent engineering. The latter can be understood as an extension of the very engineering driven concept of mechatronic. Starting from the definitions of mechatronic and concurrent engineering this paper shows, how they fit together. This is demonstrated on some case studies out of the field of automotive.

INTRODUCTION

Since the development of the first integrated circuits more than 40 years ago, microelectronics based on more or less powerful micro-controllers play an essential role in consumer goods of our everyday life, even if in a lot of products the electronic is not noticed by the user. It is estimated that about 30 billion micro-controller based embedded systems are in use in consumer products (Göhner 2000). This spreading of microelectronics is a result of its versatility and cost-effective production. Because being a constituent part of a more or less complex product such electronic systems are called embedded systems.

For engineers dealing with the development of embedded systems the design and realization becomes a challenging task. The role of microelectronics has changed from a separate part which is added to an existing product to a full integrated component. The design process of the embedded system is not a stand-alone task, on the contrary it must be seen in a very close relation with the development and the whole life cycle of the designated product.

MECHATRONIC

One important reason for the success of Japanese companies in the 1970s and 1980s was the systematic integration of microelectronics into their products. This was not really a new concept but a result of the technical evolution. The new electronic components allowed an improvement of operations as well as new functionality and this two options were consequently used in new products design.

Meanwhile the combination of electronic, information and mechanical engineering is well established as *mechatronic*. It is worth mentioning, that mechatronic originally was an trademark, owned by the Yaskawa Electric Company, and was released in 1982 (Kyura and Oho 1996).

The classical treatment of mechatronic is very technology centered and usually comprises the three components electrical and mechanical engineering as well as computer science (Isermann, 1995). It is obvious, that this three main fields influence each other (see figure 1), and that this interaction must be reflected in the design process.

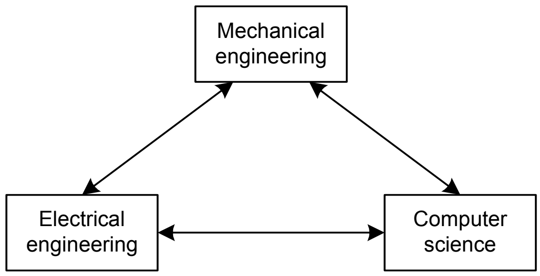

Figure 1: Classical treatment of mechatronic

CONCURRENT ENGINEERING

Another key point for the success of japanese industry, especially of its automotive branch, was discovered to be *concurrent engineering*. It is defined "as a systematic approach in designing a product, that simultaneously considers all elements of the product life cycle, from conception through disposal, to include consideration of manufacturing processes, transportation processes, maintenance processes, and so on" (Blanchard and Fabrycky 1998). The result of concurrent engineering is a reduction of the time, a product needs to come on market. Unlike as with mechatronic companies often use concurrent engineering without explicit stating they are doing.

Treating mechatronic in the framework of concurrent engineering is not very common, and only a few publications are dealing with this point (Bradley et al 1991, Kamm 1996, van Brussel 1996). For a product, which has to be successfully introduced in the market, not only the engineering design (i.e. functionality) is important, also considerations concerning management, costs, marketing, usability, maintenance and manufacturing must be taken into account. Following Bradley et al 1991 this leads to the extension of the classic mechatronic triangle shown in figure 2.

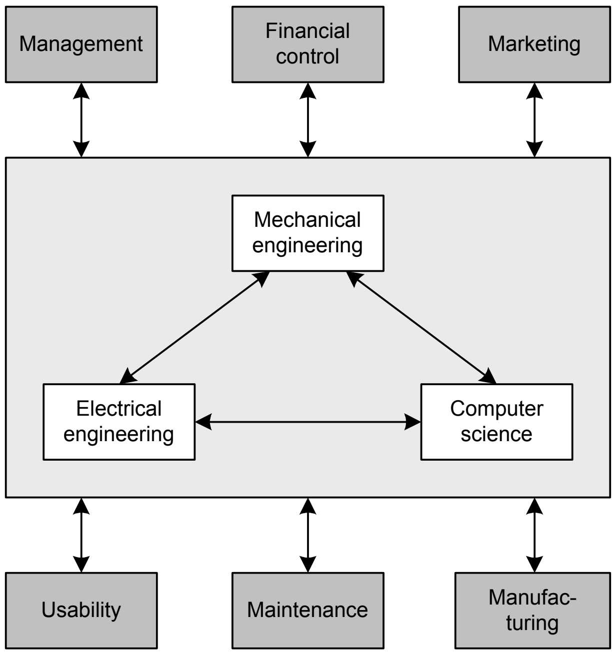

Figure 2: Concurrent Engineering view of mechatronic

EMBEDDED SYSTEMS

The design of the embedded system is a crucial point in the development of many products. It must interact with a mechanical structure, playing an active role of the products functionality. Due to its software there exists the possibility to be flexible, and often new features are implemented with the replacement of the software.

On the other side, the new possibilities could become a severe drawback. During the development of products with embedded systems the management is forced to have a look on things engineers often do not care.

To reduce costs, both of development ant production is obvious and leads often to the realization of the second best solution, as the best one is too expensive.

A more dangerous aspect is marketing. The versatility of embedded systems allows the realization of features which are not necessary or even worse not useful. A good example for this fact is the implementation of a clock function in a lot of consumer goods, even it is not needed. It is important to have the functionality which is needed from customers and not which is feasible.

For the costumer the usability of a device plays an important role. While the operation of a video recorder is a recurrent example of a poor quality user interface, meanwhile a lot of other products including embedded systems are hard to use. Some functions are often not used by the customer, because their operation is to difficult.

Maintenance must also undergo a change. Due to the microelectronic components and the included software the qualification of the maintenance staff must change. The run of service cases must often undergo important changes.

PRACTICAL EXPERIENCES

As concurrent engineering is widely influenced from the automotive industry (Hartley 1998), some cases of the interaction of electronic components on the design and the operation of cars are discussed.

Drive by wire

At the moment a lot of effort is done into drive by wire operated cars. The usually mechanical solutions for the brakes, the steering and so on should be replaced by means of electronic (Betz 2001, Kassakian 1996). This concept has big impact on a cars design, and leads to the development of a number of new technologies. An example of such a design and implementation is given by Ruh et al 2001.

To get full electronic operation in a car, a powerful real time communication is necessary. Existing technologies like CAN do not fulfill the requirements. New protocols like TTP and FlexRay were developed and are on its way of implementation in hard- and software.

Beside the technical implementation, the drive by wire concept could also affect other areas of the car design. In a steer by wire system would be no longer need for a steering column, which allows changes in the design of the drivers seat.

Power supply

The power supply is also a part which will undergo enormous changes. Nowadays used 12V electric system are not able to deliver enough power for the growing number of actuators and other energy consummating devices. Big effort was made in the development of a new standard, leading to a voltage of 42V and different concepts of its implementation (Kassakian et al 2000). One consequence of this new supply voltage is that the power supply modules of existing components must be adapted. This also leads to new electronic components (Graf 2001).As the effort is very high, for first implementation a combination of 12V and 42 V supply voltages is an alternative, having advantages and drawbacks.

If the functionality of a car depends more and more on electronic systems, the operation must be guaranteed even if the car us not used for a longer time or after an accident. What happens with an electric operated parking brake, if the cars battery is running out? Will passengers be able to open the doors after a crash?

Reliability

A marketing aspect of introducing such new systems is the reliability. Software becomes more and more a dominant factor in cars equipment, and it must be reliable. The case of rebooting the system in sharp downhill turn is not acceptable (Berger 2002). But even if engineers spend a lot of time (and money) in developing reliable systems, market must accept them. Potential costumers are afraid of loosing control over their car, not being aware, that also in existing cars systems failure will probably have a big impact. Its not hard to imagine what happens if an antiblocking system will fail.

Glove Box

Usability is also important, but often not taken into consideration. One example is an upper class car having a glove box with an electrically operated flap. This seems to be very nice, in every days use it is not very practical. The opening and closing is only possible, if the ignition key is inserted and turned on.

CONCLUSIONS

In today's product development basic functionality and production cost are not the only important factors. Concurrent engineering is a framework, allowing the incorporation of several "side aspects" in a products life cycle. Therefor it can be seen as a possible extension of mechatronic.

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BIOGRAPHY

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Continuous Improvement in IT Project Management

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KEYWORDS

IT Project Management - Project Management Approaches - IT Risk Management – Organizational Change Management

ABSTRACT

Project management has been an issue for the last fifty years. Much has been learned about how to run projects – from fatal project failures as well as from highly successful best practice examples. However, despite all the experiences made and all the knowledge collected the failure rate of projects, especially in the IT environment, is still extremely high.

It is therefore not surprising that many companies try to improve the efficiency and effectiveness of their project management, often by spending enormous amounts of money on the development of project management manuals and for project management trainings. However, experience has shown that manuals are mostly not read and the proposed methodology is seldom "lived" and the one time training initiatives often do not bring the expected improvements.

The objective of this paper is to discuss various aspects of a continuous improvement approach to IT project management. The suggested solution includes a comprehensive framework for IT project management which is based on experience from a truly global company with a complex IT project environment. The paper also stresses the importance of an ongoing IT risk management as an integral part of project management. To show how the suggested framework can be implemented in reality, a practical example from DaimlerChrysler is outlined and further suggestions for enhancement are provided.

PROJECT MANAGEMENT – OLD WINE IN NEW HOSES

Project management (PM) is not a new topic at all. Nevertheless, most companies still struggle today to continuously improve their project management because the ratio of failed projects to successful projects (in time, quality, and budget), especially in the IT environment, is still poor (see figure 1). Studies have shown that as much as 80% of all (IT) projects fail [1]. About 31% of the IT projects are cancelled and 53% limp to completion [3]. This is rather surprising given the fact that projects mostly start with enthusiasm, belief and commitment. But what goes wrong?

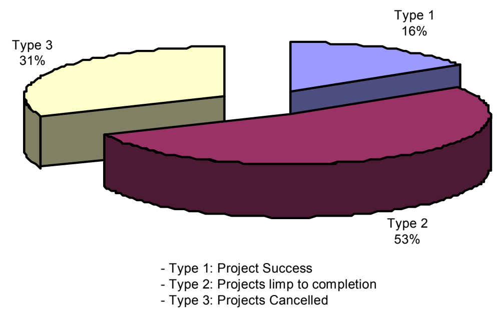

Figure 1: Project Failure Rates (Standish Gruop)

Research results reveal that while there is no single cause of project failure, several factors typically contribute to project failure [1]. One of the most critical issues throughout an IT project seems to be project management. Approximately 75% of all IT project failures are attributed to poor PM [4]. Issues such as lack of experience of either the project manager or the team members, insufficient (top) management support for the project, tight budgets and high time pressure as well as the vast amount of coordination that has to be accomplished between many different perspectives such as customers (clients), IT strategy, design and programming as well as quality assurance, play an important role in this regard.

Taking into account, that PM is not new at all and that there is a huge market for project management training and coaching, this is a significant finding that raises the question why we are still often not able to bring our projects to an successful end.

This paper argues that a comprehensive view on project management is required to continuously improve PM in complex organizations. After a brief look at how PM developed in the past, a comprehensive framework for PM is presented. Based on this framework some key factors for success are pointed out and described in more detail. A special focus is put on IT risk management which is often considered a one time task at the beginning of the project and then neglected as the project goes on. The paper then describes an example of how such a comprehensive framework for continuous improvement of PM was implemented at DaimlerChrysler. It closes with an outlook on further developments in the PM field.

PROJECT MANAGEMENT - PAST AND PRESENT

The roots of PM

The basic idea of project management was developed by the US military during World War II (see figure 2). Closely involved in the development were also governmental bodies trying to solve complex organizational issues by using this new form of organizing tasks. After the war the military continued to use and improve project management as it had been a successful approach [7]. One of the first industries to successfully apply the new approach to organizing tasks was the aerospace industry. From there it spread to all other branches of private industry [8].

Over the time, a common understanding developed, that project management is the art of directing and coordinating human and material resources throughout the life of a project by using modern management techniques to achieve predetermined objectives of scope, cost, time, quality and participant satisfaction[1].

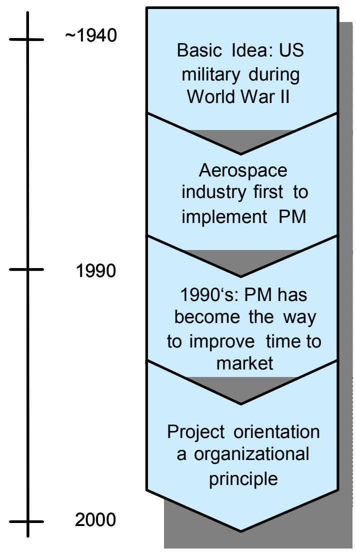

Figure 2: The Roots of PM

During the 1990´s project management has become the way to improve time to market. At that time, organizations realized that effective PM is more than just planning and scheduling. As a result, project offices have arisen out of organizational needs to provide the infrastructure and support necessary to run a „projectized" enterprise [6]. Today, there are a number of branches that organize no longer along functional hierarchies but reorganize their employees according to the projects running at the moment. This form of organization is typically to be found in consulting and some areas of engineering, e.g. construction of industrial sites such as refineries.

Project management as an approach to organizing complex tasks can only be successful if a suitable environment is created. There are several prerequisites for successful project management. First of all, it requires a cooperative management approach and an open organizational culture which supports the

[1] Definition is based on the PMI view. Established in 1969 and headquartered outside Philadelphia, Pennsylvania USA, the Project Management Institute (PMI) is the world's leading not-for-profit project management professional association, with over 95,000 members worldwide.

delegation of tasks and responsibilities. Furthermore, cooperation across organizational borders as well as team work without focus on hierarchical position and status must be possible and as their necessity a shared understanding by all parties involved.

A variety of PM approaches

Over the years different approaches to PM have been developed in the companies. On the one hand, some companies focus strongly on methodological issues and provide their employees with PM manuals describing step by step in great detail what has to be done. As experience has shown in many companies, these attempts to improve and standardize PM are often not very successful. This is on the one hand often due to the fact, that many top managers think that PM can be bought „out of the box“. They engage an external PM trainer who introduces his methodological approach, often without even considering the specific culture and surrounding of the organization.

On the other hand, the missing tool support forces the project managers to build their own support means, very often Excel sheets, for planning and monitoring their projects, thereby not only reinventing the wheel but also wasting valuable time.

From an other perspective we can see that, some companies take a strongly tool-based approach, requesting their project managers to use a specific tool, e.g. such as Microsoft Project or Artemis, thereby often focusing on the resource and budget planning approaches implemented in the tools, leaving all other aspects of PM in the hand of their project managers. The tool-based approach can be very successful if all project managers are very experienced and know exactly what they do. However, a situation like that is hardly found in reality.

Furthermore, there are companies combining both approaches, often supporting their „own“ PM approach with company specific tools that support parts of or the overall PM process (see figure 3). These companies often focus on specific key factors they consider relevant for project success and support them accordingly.

At DaimlerChrysler a similar approach was taken. The next chapter first describes the comprehensive framework for project management which was developed based on research findings as well as practical experience from years of project management in the IT organization of DaimlerChrysler. In the second part the ProFIT Initiative is presented to give an example of how to implement such a framework in a global company.

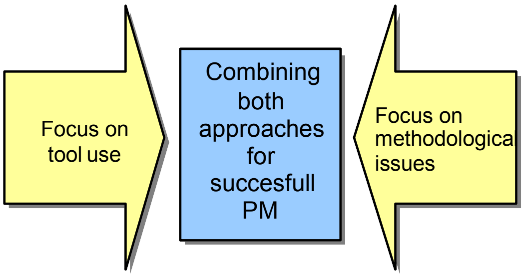

Figure 3: Different PM Approaches

ON THE WAY TO SUCCESSFUL PROJECT MANAGEMENT

A Comprehensive Framework for Project Management

As pointed out in the last chapter project success is neither simply linked to using the „right“ tool nor to applying the „right“ methodology. As research has shown it is a combination of many different factors. Factors typically identified to cause project failure are for example:

- Poor scope management
- Poor monitoring and control
- Poor skills of the project manager
- Poor communications management.

On the other hand, many studies point out the same key success factors for projects, often also described as best practices [1, 7]:

- Clear definition of purpose and scope (project planning and monitoring)
- Use of tools and techniques to manage complexity
- Selection of a well-skilled and respected project leader
- Open and clear communication with stakeholders
- Project organization and project culture.

When you melt these two lists together you can see interesting things: The research reveals that the activities that may lead to project failure, if properly performed, can contribute to project success [1]. From that the conclusion can be drawn that there is obviously a limited number of factors to consider and improve that will at the same time decrease the likeliness for failure and increase the chance of project success.

Apart from that insight, there is another issue we believe to be important for improving project management. Very often the topics discussed above are viewed separately if problems occur, forgetting that in a system all parts are intertwined and closely related. We therefore developed a comprehensive framework for PM (see figure 4) in order to understand how different aspects in the project play together. This overall perspective helps us to identify key topics and relevant points for improvement.

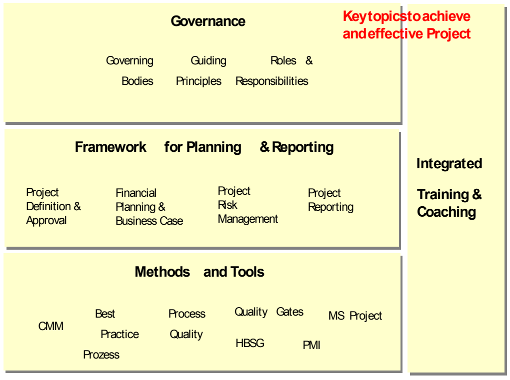

Figure 4: Key topics to achieve an efficient and effective Project Management

This overall perspective is especially important in complex global companies which have grown over the years and have to integrate a diverse number of separately developed approaches. As it is hardly possible for the big global companies to develop a „new“ PM approach from scratch, overall efficiency and effectiveness can only be achieved by continuously improving the existing approaches, thereby strongly focusing on the integration aspect. Under „governance“ we understand the general rules and principles that create the setting for PM in a company. In our understanding governance covers four primary dimensions which include the primary elements of effective governance. These are: Guiding principles (e.g. define SLA for deliveries in projects), governing bodies (e.g. decision boards for predefined topics), key processes (e.g. budget and forecast expediture), and roles and responsibilities (e.g. steering committees, councils).

Within the PM environment created by these high level settings, the projects go through their life cycle. On this level an overall framework for planning and reporting seems to be a key to success. Based on our experience, we identified four critical topics: standardized project planning and approval, financial planning and use of business cases, standardized project reporting and project risk management (see next chapter).

The basis for the specific project work is use of methods such as the use of qualiy gates and measurements for process quality, and tools, e.g. MS Project. However, from our point of view, it does not really matter which tool or methodology is used in a company. The most important prerequisite for project success is a shared understanding on all hierarchical levels of what the key issues in regard to project management are in a specific environment and what needs to be done to improve the situation.

The bracket that should hold together these three blocks of the overall PM perspective is an integrated training and coaching approach. Especially in global companies that have grown over the years a standardized project management training is hardly to be found. Historically grown, organizational units typically engage the PM trainers they have been working with for years, each of them teaching his specific approach to PM. Therefore, employees moving from one organizational unit to the next have to „relearn“. Furthermore, very often the consulting companies apply their own approaches to projects they are running in the customer organization requiring the employees of the customer to adapt to their methodology.

In our understanding a standardized approach to PM training should be developed to include all important aspects related to governance, planning and reporting, as well as specific tool training and methods, e.g. for risk management.

Risk Management to Improve Project Success

One of the key issues to improve project success, is a well-founded project risk management. Very often risk management is simply viewed as part of overall PM activities at the beginning of the project. This view does neither take into account the importance of risk management for the project success nor its necessarily ongoing character.

Whereas corporate risk management is generally driven by legal requirements and focuses on financial risks, project risk management is concerned with the identification and mitigation of project risks. This should be ensured by implementing a three step approach (see figure 5).

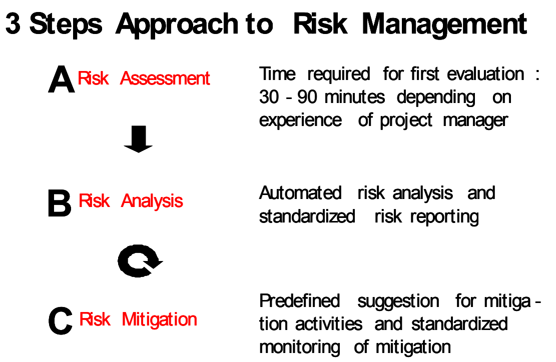

Figure 5: Three step approach to project risk management

The first step is concerned with identifying the project risks and assessing their importance in regard to relevance and urgence of mitigation. Here checklists including all major risk factors sorted into different risk categories can be used to increase speed and ensure that all typical risk factors are considered. During the second step the identified risks are analyzed and prioritized. If step A is supported by a tool, step B can often be done automatically. The following figure shows a tool-based risk analysis, pointing out which risk factors are most critical.

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The last step, risk mitigation, is an ongoing activity. For all risks with a high priority, activities have to be defined and monitored in order to decrease the risk or to develop fall back strategies if the risk cannot be avoided. This again, can be supported by standardized suggestions for activities to be taken, if a company has developed a knowledge base for project risk management.

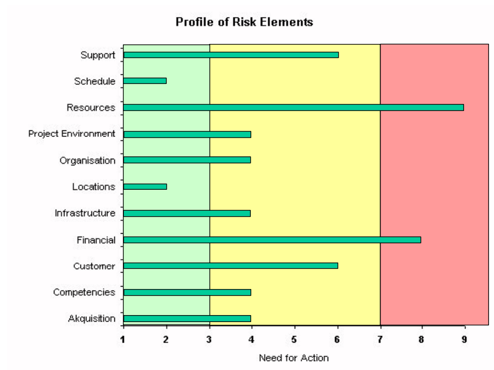

Figure 6: Automated Risk Analysis

THE PROFIT INITIATIVE

This chapter provides an example of how the described framework can be implemented in a company. Especially in the increasing number of global organizations and alliances that require significant investments in IT, improvement of PM becomes a critical issue. On the one hand the IT project budgets become bigger and bigger and on the other hand, there are a number of new challenges due to the global character of the organizations, e.g. [2]:

- Overcoming distance and communication barriers
- Resource commitment problems
- Dealing with language difficulties such as multilingual IT development and support
- Addressing cultural nuances and sensitivities
- Additional risks and stakeholder issues associated with multi-country projects
- Contractual, licensing, tax, and legal issues that come into play with a global project.

At DaimlerChrysler, the first attempt to implement an IT-wide project framework started right after the merger. The goal was to integrate all existing PM activities into one major tool and implement it through a bottom-up approach. This initiative failed due to its complexity.

In 2002, a new initiative called ProFIT (Project Framework for IT) was started in order to improve the efficiency and effectiveness of PM in the IT organization. Three key issues were identified:

1. Transparency on project progress: Time, quality, resources, scope, risk
2. Reuse of best practices based on project ocumentation in MS Project
3. Project approval based on business case calculation.

This time, a top down approach was chosen to generate overall acceptance and buy-in for the initiative. The first steps taken were concerned with improving transparency for top management levels by introducing standardized reporting on all key projects in a common reporting database. Usually, reporting would be the outcome of a PM process and tool and is implemented last or can be done on a click of a button. However, it was easier to integrate all top management requirements for one project reporting tool than agreeing on one PM process bottom up taking into account the variety of the many existing ones in a large global organization such as DaimlerChrysler IT. With a defined and agreed outcome of how projects should be reported, it was then possible to convince stakeholders of the need for improvement in their current PM activities and got them to take a supportive role in the implementation of the new approach.

After evaluation of the main PM tools available on the market, it became apparent, that all of them required a more or less bottom up implementation with reporting as a result. Therefore none of these PM tools could be deployed. However, since Lotus Notes is the standard collaboration environment at DaimlerChrysler, it was decided to develop a reporting tool in-house on Notes.

Together with the rollout of the reporting tool, guiding principles and responsibilities for project reporting were implemented. The pressure to adhere to the new rules was build up on the different hierarchical level by the top down approach. The CIO regularly discusses the project reports with her directors thereby holding them responsible for the correctness of the reports. They again hold their direct reports responsible for the correctness and so on down to the level of the project manager.

Now that project managers saw that top management was actively using the new standardized project reports, they started seeing a benefit in having also a standardized planning process and a tool that was automatically linked to the reporting tools to avoid double data entry.

A planning database was rolled out to increase the value add of the overall solution through a standardized project planning approach,

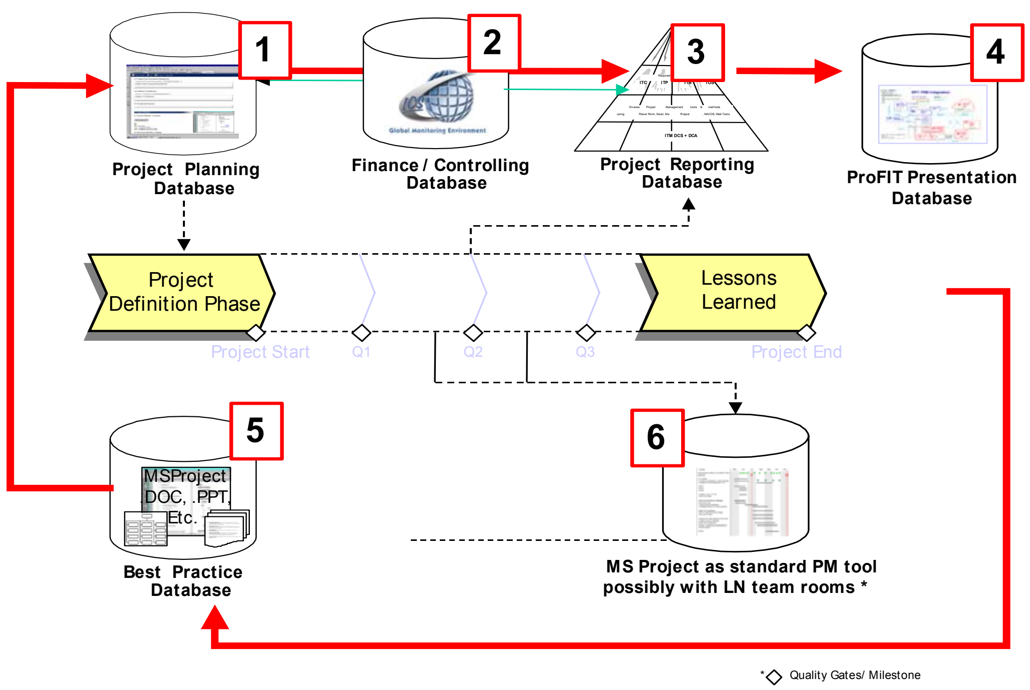

Figure 7: Framework for Planning , Business Case based Approval, Reporting and Best Practice Reuse

providing the project manager with guidelines and tool support to save him/her time and increase the quality of his planning.

As a next step a Lotus Notes database to support budget planning was provided to support project planning and reporting. Thus an integration platform with the corporate budget planning systems - many of them based on legacy systems or SAP - was set up. Again, immediate process optimization for the project managers was achieved as standardized procedures can be applied and with a great potential for additional savings once the full integration with the financial systems has been completed.

In the future improved tool support for the overall framework (see figure 7) will be provided. This will include an integration of MS Project 2002 into the ProFIT solution and a business case tool that will automatically use the data entered into the budget planning database for generating a business case for a specific project. Furthermore, a tool to support the three step approach to risk management will be developed based on the existing paper-based knowledge base.
Best Practice examples will be collected in a Best Practice Database and will support the project manager during the planning phase and published information and presentations about projects will be stored in a Presentation Database.

The following figure 8 shows the ProFIT user interface with the all the linked databases as described before.

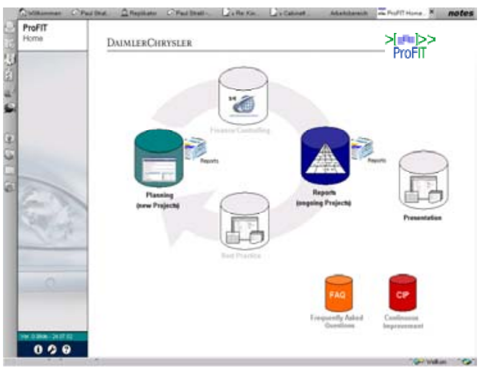

Figure 8: ProFIT user interface

Continous Improvement

One basic "design element" of the ProFIT initiative was to aim for a CMM level 5 in the course of the initiative itself to set a best practice reference. This includes that the users not only take over the ownership of ProFIT but also drive improvements continuously. Therefore additionally to the above mentioned databases a *continuous improvement database* (CIP) is the basis for further development and a *frequently asked questions* database (FAQ) provides support for the users in case of questions (see figure 8). Both of them are linked with all the other ProFIT databases providing a highly efficient way for continuous improvement of the PM process itself, technical enhancements of the solution and "self"-learning (e-learning) capabilities for the users.

Prior to the roll-out a common communication concept was developed, including slide presentations, flyers, an information letter from the CIO to the entire IT organization, WEB pages and a "road show" to explain the concept to the users in a "hands-on" way.

The training concept is modular and not only includes general PM training modules in regard to methods, but also modules focusing on the use of the ProFIT tools to improve PM as well as modules providing specific tool training for example for MS project.

Implementation Concept

The approach taken to implement the overall framework in the IT organization of DaimlerChrysler can be characterized as follows:

- generally only an 80% solution is to be implemented with 100% quality
- stepwise introduction with parallel enhancement of functionality and an increasing number of users
- every three month a new deliverable.

The first principle was based on the experience, that the last 20% of finishing an IT solution generally requires 80% of the overall capacity/budget. Therefore, a decision was taken to aim at the 80% solution but of course providing the required functionality.

The second principle was the stepwise introduction in two dimensions (see figure 9).

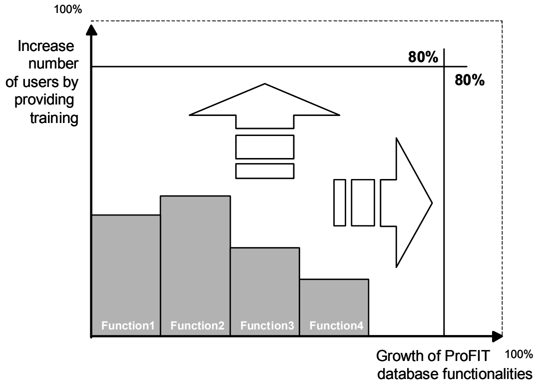

Figure 9: Project progress along two dimensions

The figure shows the project progress along two dimensions: functionality and number of user groups. Functionality describes the functional capabilities of the solution, the number of user groups depicts the rollout progress. The dimensions are independent of each other. If the project goes well, they should both increase steadily. In regard to the functional enhancements, the third principle described, was applied in ProFIT: every three month new functionalities were provided based on requirements and suggestions collected systematically from the users and documented in a continuos improvement process.

A positive result of applying these principles is that a clearly defined goal is reached within a short time. This short-term focus on results requires precise planning and implementation and leads to an effective work atmosphere because all project members are forced to closely monitor their own timelines.

Over the last year a lot has been achieved. A standardized reporting has been introduced worldwide and is used in all IT units. It is no longer only used to report the key projects to top management but is also applied on lower hierarchical levels to improve transparency in all IT units. Some IT units are already using the financial planning database and all others will follow soon. All IT units intend to use the planning database in the future. The rollout is planned for the first half of 2003.

SUMMARY AND OUTLOOK

This paper has presented an overall framework for IT PM and has provided an example of how such a framework can be implemented. The example has shown that PM initiatives are complex organizational and cultural change programs. Very often PM implementation is attempting to move an organization from a dysfunctional PM to one that offers significant cost savings and other benefits.

PM implementation is very much like any process improvement project – complex, fraught with risk of failure, associated with new procedures, responsibilities, roles, organization and culture changes [5]. The degree to which the organization will change depends on the degree to which the organization desires and is ready for change. As agents of change the people who lead the PM implementation must identify change possibilities and chart a course that implements a PM process that minimally disrupts the existing organization while providing the maximum possible performance improvement.

Using the ProFIT concept and the proven approach as described in this paper the CMM level 3 could be reached within the entire corporation setting even the stage for further optimization toward higher CMM levels.

Even though major achievements have been reached at DCAG, a lot needs to be done in the future. Apart from rolling out the new components including the PM training concept and spreading the use of the solution to all parts of the global IT organization, also a some new ideas are being considered.

In order to increase organizational learning the idea of a project manager pool for coaching purposes is being discussed. The underlying idea is that, experienced project managers at one point in time are no longer willing to take on new projects because they have had enough stress. On the other hand, young unexperienced project managers often lack a person of their confidence to discuss their projects with. Bringing these two groups together in a way that the new project managers gets an experienced coach for regular discussions will be a means to hand on lessons learned and to implement a continuous learning process based on company knowledge and experience.

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BIOGRAPHY

The author Paul Stratil, age 41, is Senior Manager for Information Management of DCAG. He is responsible for integration activities within the ITM Organization, with a dual key focus. One key activity is setting up a PM framework and a project office in order to increase efficiency and effectiveness of IT projects. The other key activity is to initiate and set up a strategical dialog within the IT division about ITs role and future focus on how to support the corporate strategy of cooperation with other companies.

In more than 15 years, the author has gained conceptual knowledge and practical experience in the optimization of business processes as system analyst and in-house consultant and was in charge of IT at DCIndonesia as General Manager. Paul Stratil worked for the Passenger Car and Commercial Vehicle Divisions of DaimlerChrysler in Germany, Spain, Brazil, Turkey and Indonesia.

Over the last nine years, the author has published several articles and papers for international conferences to contribute to the scientific discussion on the above mentioned issues.

SUPPORTING TECHNOLOGIES

SYSTEM DYNAMICS SIMULATION MODELLING OF THE PORT MANAGER PLANNER

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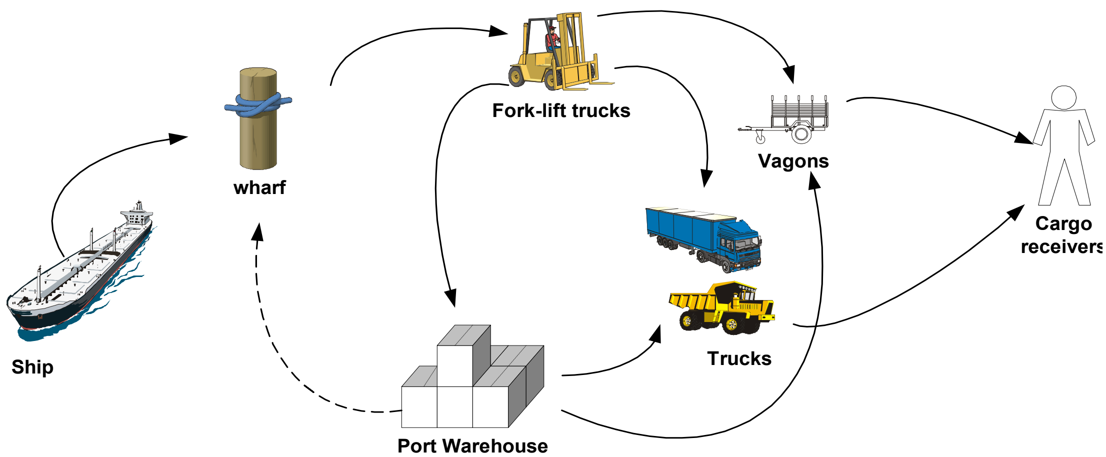


Structural model of material flow of the cargo

KEYWORDS
System Dynamics, Modelling, Transshipment system, Heuristic optimization, Continuous and Discrete Simulation, Port manager Planer.

ABSTRACT

The methodology of System Dynamics (Prof dr. J. Forrester – MIT), e.g. relatively new scientific discipline, in former educational and designer practice showed its efficiency in practice as very suitable means for solving the problems of management, of behaviour, of sensibility, of flexibility and sensibility of behaviour dynamics of different systems and processes. Port is place of interlace of different kindle of cargo, and play important role in shipping process, connecting different type of traffic in one united system, and form interrupted traffic chain. The aim of this paper is: to show the efficiency of System Dynamics Simulation Modelling during the study of the dynamics behaviour of the port-transshipment system, and to find optimal solution for transshipment with regard to type of the cargo and size of traffic of the cargo, direction and dynamics of arriving and shipping the cargo.

1. INTRODUCTION:

The System Dynamics Modelling is in essence special, i.e. "holistic" approach to the simulation of the dynamics behaviour of natural, technical and organization systems. Systems dynamic comprise qualitative and quantitative simulation modelling, and the concept of optimization of dynamic systems and processes is based on so call "heuristic" procedure. Meaning that on the method of manual and iterative procedure, which is automatized with the help of fast digital computer, named "heuristic optimization" (retry and error!). This simulation model is only one from the large number of made and educationally and practically used simulation models for education and training of young students – mariner, which use so call "white box" philosophy of investigation of complex systems, as distinguished from "black box" approach! All simulation models made in last decade of past century on Maritime faculty Split, Croatia, are the component of scientifically macro project called: *Intelligent Computer Simulation of the Model of Marine Processes.*

2. SYSTEM DYNAMICS MODELLING OF THE PORT-TRANSHSHIPMENT SYSTEM-PPL

Fundamentally, unloading of any kind of cargo can be divided in:

- ship arrival to the berthing position,
- unloading the cargo from the ship to the shore,
- transport of the cargo from the shore to the wagons, trucks and warehouses.

Unloading/loading of the cargo in port is complex dynamics process with two subsystems:

- Unloading/loading of the cargo in port (BUTUL),
- Surrounding environment (OS).

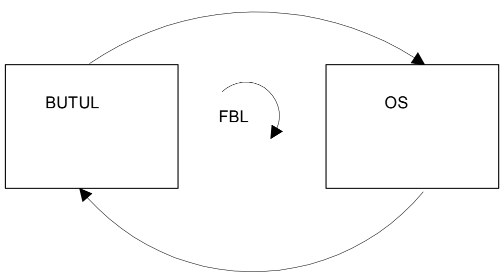


Figure 1. Rudimentary structural model of the Port-Transshipment System

Subsystem BUTUL have at least four sector i.e. subsections:
1. State of occupation of the berth,
2. Number of the cranes (on the ship and on the shore), which are objective at disposal,
3. Number of the fork-lift, which are objective at disposal,
4. Warehouses (number and the area that are at disposal).

Subsystem OS have at least four sector i.e. subsections:
1. Waiting ship (on the berth or in arrival),
2. Engaged wagons capacities,
3. Engaged trucks capacities,
4. Consignee (receiver) of the cargo.

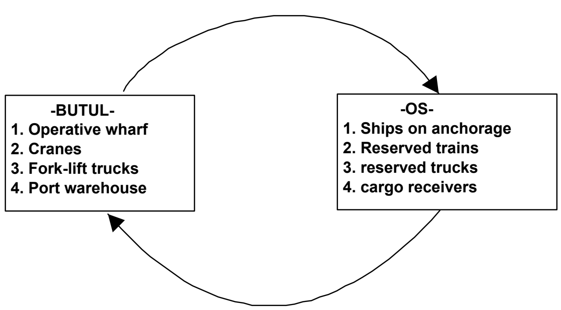


Figure 2. Structural diagram of depending BUTUL and OS model of the Port Transshipment System

This example of PPL presents the “semi-indirect system of cargo reloading”, with the preference to “maintaining the process of cargo unloading interrupted”, because it is in the financial interest for the ship owner! In other words, if during the day (24h) equipment that has been reserved in advance for loading and unloading of cargo (such as crane, fork-lift truck, railway vehicle, road vehicle and space in warehouse) become insufficient, port-transport manager must give an order to stop the unloading of the ship. The unloading of the ship can start again when new equipment i.e. available transport capacities are reserved (in this case railway and road vehicle).

In this short paper, it is impossible to give a complete model of the port transhipment system, mental-verbal model, structural and flow diagram has been presented in MITIP 2002, Savona, Italy, complete flow diagrams of PPL has been presented in MEET/MARIND 2002, Varna, Bulgaria and complete elementary structure and logics expert-inteligent complex function SKLOK, SKLOW and SKLOS has been presented in WMC'03/ICEE'03, Orlando, Florida, USA.

3. COMPUTING SIMULATING MODEL OF THE PORT TRANSHIPMENT SYSTEM

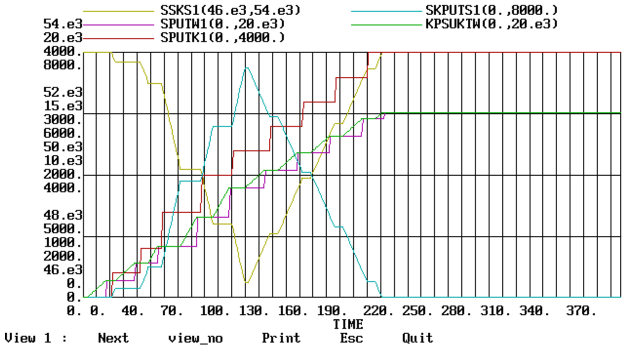
3.1. Scenario of the simulation of PPL-a

This model includes putting to shore and unload of the ship on the berth, transshipment of the cargo on the wagons with subsection of logical management built in it, transshipment of the cargo on trucks also with subsection of logical management, an at the end transshipment of the cargo to the warehouse.

In this paper, cause of its largeness, we will present only zero scenario with initial conditions:

- ship is on the berth 1,
- unloading of the ship have been started in time T=0,
- Transshipment of the cargo with cranes, and the number of cranes are D1= 2+STEP(2,47)-STEP(2,119), i.e. the capacities of the cranes are 50*D1,
- Transshipment of the cargo on the fork-lift, and the number of fork-lift are V1= 2+STEP(2,47)-STEP(2,119), i.e. the capacities of the cranes are 50*V1,
- Transshipment of the cargo with fork-lift from the berth to the gate and transshipment on the wagons, and the number of wagons are W1= 56+STEP(40,71)-STEP(40,119),
- transport of the cargo on the trucks, and the number of trucks are K1= 20+STEP(10,47)-STEP(10,95),
- transport of the cargo in the warehouse, and capacities of the warehouse are 54000.

Graphic results of simulation:



where are:

SSKS1=state of available warehouse capacities,

SPUTW1= summary display of the loaded cargo on the wagons,

SPUTK1= summary display of the loaded cargo on the trucks,

SKPUTS1=state of the cumulative display of the loaded cargo to the warehouses,

KPSUKTW= cumulative display of the state of the loaded cargo on the wagons.

Based on presented simulation dynamics of behaviour of model in complex scenario it is possible to conclude:

- It is possible to simulate daily speed of unloading the ship and shipping the cargo from shore using STEP function, also it is possible to simulate daily need for trucks and wagons, and in that way avoid necessary wait for new trucks and wagons and also to avoid stoppage of unloading the ship or sipping the cargo from the port warehouse.
- Also, application of STEP function enable to control all relevant data, daily and current data, follow the unloading and shipping the cargo, state of the cargo at the port warehouse, available capacities in port warehouse, etc...
- Based on obtained results it is possible to analyze state of the system at any wonted moment in time.

4. CONCLUSION

The application of System Dynamics Simulation Modelling Approach of the complex marine dynamic processes, which the authors, together with their graduate students, carried out at the Maritime Faculty University of Split - Croatia seven years ago, revealed the following facts:

1. The System Dynamics Modelling Approach is a very suitable software education tool for marine students and engineers.
2. System Dynamics Computer Simulation Models of marine systems or processes are very effective and successfully implemented in simulation and training courses as part of the marine education process.

In this short presentation are given all necessary information for expert and possibility to acquire additional information about the same system in fast, scientifically based way of investigation of complex system.

Which means:

" Do not simulate behaviors dynamics of complex system using so called "black box" approach, because practice of education and designing of complex system confirmed that is better to simulate using so called "white box" approach, e.g. System dynamics Methodology!"

Authors

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BIOGRAPHY

Ante Munitic was born 08. 26.1941. in Omis, near Split, Croatia! He received his first BSc. in Electrotechnics Engineering in 1968, and his second BSc. in Electronics Engineering in 1974; his MSc. degree in Electronics/Organization /Operational Research/Cybernetics Science in 1978, and his Ph.D. of Organization/Informatics Science (exactly: System Dynamics Simulation Modeling) in 1983. He is currently a University Professor of Information/Computer Science at the University of Split, Croatia. Prof. Munitic has published over 90 scientific papers on system dynamics simulation modeling, operational research, marine automatic control system and The Theory of Chaos. He has published several books (as there are: "Computer Simulation with help of System Dynamics" and "Marine Electrotechnics and Electronics Engineering", ...). Today, he is professionally active university professor and scientist in the System Dynamics, Relativity Dynamics, System Dynamics Analogous Processes, Theory of Chaos and Informatics Scientific area.

INTEGRATION OF VIRTUAL REALITY AND CAD BASED ON OMG'S CAD SERVICES INTERFACE

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ABSTRACT

The work presented in this paper concentrates on questions of integration CAD and Virtual Reality (VR). The crucial dilemma is the kind of data handled in both systems: CAD systems on the one hand operate on semantically rich data, where assemblies, parts, features or topological entities can be created and modified. VR systems, on the other hand, mainly operate on dumb triangles.

As VR and CAD will remain different areas that will be slow in merging together, we have to find a way to combine both technologies in a single system for VR-based CAD. The first step in this direction is the identification and evaluation of interfaces. In this context, the authors examined the CAD Services interface of the Object Management Group (OMG). The interface not only allows read access to tessellated data, topology and features; it also supports modification of data – especially design features.

A software prototype was implemented based on Autodesk's Mechanical Desktop (MD) as a backend CAD system, a partial implementation of the CAD Service interface and ZGDV's VR Framework JSTB, based on Java 3D. The resulting application can be used to visualize arbitrary MD models in an immersive VR environment and interact with the design features of the models. To replace the backend system with any other commercial CAD systems, only the CAD Services interface has to be re-implemented to work on a new set of API functions.

The prototype demonstrates the feasibility of this flexible and integrative approach, where a commercial CAD system is linked to a VR environment. Even though the complexity of the models that can be handled in real-time is quite limited in this prototype, the evaluation identifies a high potential of the CAD Services interface. Based on this work, improvements to the interface can be formulated to overcome current limitations of the OMG specification.

INTRODUCTION AND STATE OF THE ART

Virtual Reality is one of the key technologies to support Concurrent Engineering concepts and, in doing so, shortens the development phase for complex products. VR is especially useful as a means of communication where engineers specializing in various responsibilities or disciplines can discuss aspects of the (still) digital product in an effective and intuitive way.

To increase the potential for streamlining the product creation process, it is desirable to use VR not only as a visualization tool but also for interaction with the underlying model. Although it is not adequate in most cases to change the shape or position of single geometric entities (this is better performed in a traditional CAD system), it is quite useful to make consistent changes at higher semantic levels: Varying product configuration or changing parameters of a technical solution are steps toward this direction.

It is obvious that we need "intelligent virtual products" for this approach, where the product structure and the model of single parts reflect the design rationale and the variable combination of parts. Beside product data management systems for handling meta data and relationship, the concept of features is especially useful in this context. Features offer a powerful means towards knowledge-based engineering, where changes to the model can be performed at higher semantic levels.

By extending the focus of a VR session from visualization and review to change and optimization, we can avoid frequent switching from a VR environment to a traditional engineering workplace on the desktop.

This outline of a streamlined process gives rise to a series of organizational and technical challenges, including:

- process re-organization
- responsibilities
- quality assurance
- usability
- data exchange

In this paper we concentrate on the aspect of system integration with a strong focus on CAD and the VR system. The typical architecture as presently established is illustrated in figure 1 (first case). It shows two autonomous systems that are loosely coupled via a one-way offline data exchange from CAD to VR. This model is slightly simplified because it does not recognize the function of preparing the CAD data for VR usage by reducing the data volume or re-organizing data structures in order to support performance optimization algorithms such as detail on demand or level of detail.

We find this architecture in commercial VR systems for industrial applications, e.g. the VRcom virtual design 2 software (ref. VRcom 2002). Furthermore, there are research prototypes of hybrid systems, where CAD and VR are merged to form a single application. The ARCADE system from Fraunhofer (de Amicis and Stork 2000, Stork 2000) is a prominent example for this approach.
Both existing approaches have significant drawbacks: the offline coupling does not support communication of changes back into the CAD system and the merged CAD/VR introduces a completely new application that does not allow the reuse of existing CAD or VR systems.
The remainder of this paper presents an open approach based on standardized interfaces, where existing CAD and VR systems can be linked via a bi-directional online interface.

CONCEPTS OF INTEGRATION

This chapter introduces basic concepts of the CAD Services specification and presents our three cornerstones of integration:

- timing level (horizontal coupling)
- level of data (vertical coupling, orthogonal to timing level)
- adaptive technology to integrate CAD functionality into VR

OMG's CAD Services

OMG's CAD Services propose an interface standard for Mechanical Computer-aided Design (CAD) systems which enables the interoperability of CAD, Computer-aided Manufacturing (CAM) und Computer-aided Engineering (CAE) tools. This standard interface reflects a distributed product design environment which includes a variety of different CAx systems.
A CAD Services V 1.1 "Revision Task Force" was set up by the Domain Technology Committee of OMG in April 2002 to handle further issues. A "Request for Proposals" for CAD Services V 2.0 interfaces was written by some members of the product & process engineering workgroup (OMG/DTC/ManTIS [Manufacturing Technology & Industrial Systems Task Force]/WG PPE.). (ref. OMG/MFG)
The CAD Services interface provides access to representation of data in today's CAD systems at different levels, e.g. concept of parts and assemblies, parametric modeling and features. Supported presentations of the geometry comprise representation by lines and faces, Boundary Representation (BREP), Non-uniform Rational B-splines (NURBS) and by tessellation. Because CAD Services are based on the CORBA technology, they are independent of any system platform and programming language. CAD Services are therefore suited to heterogeneous environments. When using the CAD Services interface, one system plays the server role and the others will play the role of the client. Client systems can connect to the server system and then request CAD data provided by the server system.
OMG's specifications for the engineering domain have been extensively used by the authors in previous work (Lukas/Nowacki 2002) and have proven to be a sound foundation for complex integration projects. CAD Services V 1.0 was the current version at the time of implementation and all statements in this work refer to this version (see also Vahl 2002). An overall view of CAD Services is given in table 1.

Functional Level	Associated Data
Logic	model, entities, parts and assembly
Topology	BREPs only
Geometry	tessellation, NURBS
Semantics	features for parts and topology for elements

Table 1: Functional Levels of CAD Services and associated data

Suitability for Integration

CAD Services offer access to models composed of parts and assemblies. As already mentioned, VR systems should not be used for precise creation of or positioning of points, edges, surfaces and so on. However, high level operations that make use of internal relationships and constraints in the model are a promising level to interact with. The feature-based design, as supported by most of the modern CAD systems, was identified as the ideal approach for supporting interaction with CAD data in VR environments because features offer more than highly user-centered terminology, also using terms from the field of construction. Furthermore, feature-oriented operations refer to objects which can be directly mapped to an object-oriented virtual environment.

The CAD Services interface in version 1.0 provides features for all topological elements. However, the standard does not specify semantics for a predefined set of features. This generic approach offers maximum flexibility but poses a problem with regard to interoperability in heterogeneous system environments.

Horizontal Coupling

Following Dix (Dix 1993) VR systems are a specific form of Interactive Systems. An Interactive System is composed of a loop containing the user (U) and the core system. These two are connected via input and output channels. Complex input and output channels and real-time requirements are characteristics of VR systems. (Real-time typically means 20 Hz update for the visual channel and 500 Hz for the haptic channel to create smooth sensations.) To connect both systems, we had to change the shaping of the loop. Here we present four alternatives:

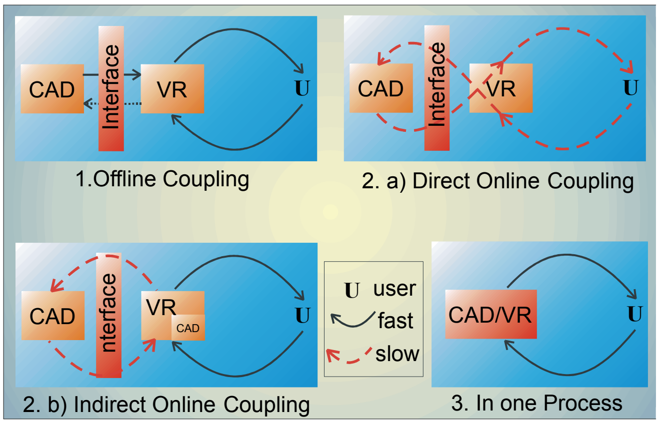

Figure 1: Concepts of Horizontal Coupling

1. *Offline Coupling* is characterized by an initial export of the geometry data into a representation format suitable for VR (e.g. VRML). After this data has been imported into the VR system, the user can only navigate through this constant model. Because the model used for presentation is only a dumb subset of the CAD model, additional information has to be represented in parallel data structures or back-transformation must occur. This back-transformation is very expensive and in most cases not possible at all.
2. Using *Online Coupling*, both systems are connected via an API. Here we can distinguish between two cases:
   a) *Direct Online Coupling:* The user requests are passed directly to the CAD system. The response time is determined by the sum of the component times. The only task for the client is to propagate requests and visualize results.
   b) *Indirect Online Coupling:* First, the VR system provides an immediate but inexact presentation of the changes. Subsequently, the geometry is updated by an exact result of the CAD system. This procedure depends on a VR system that mimics CAD functionality. For practical purposes, only a subset of CAD operations is re-implemented by the VR system.
3. *In one process:* If we do not use external interfaces (e.g. OMG's CAD Services) and the VR system is an integrated part of the CAD system, the VR system can directly access the computer-internal representation of the CAD model. This will guarantee the shortest response times and full coverage of CAD functions. However, this is not a generic approach towards integrating CAD and VR. It will always result in vendor specific solutions.

Both concepts of online coupling require a sophisticated application programming interface to the CAD system for direct access to the internal model. This interface should not only provide accuracy and flexibility but also support the creation and deletion of objects as well as read and write access to features.
For our prototype, we rely on online coupling. A hybrid approach was chosen, where some interaction is implemented via the direct alternative (e.g. revolve feature operation) and other interaction uses indirect online coupling to guarantee immediate feedback.

Vertical Coupling

The concept of Horizontal Coupling of the CAD and VR systems should be complemented by an orthogonal concept for Vertical Coupling. This concept allows a data-related view at the coupling levels and is based on the Computer Graphics Reference Model (ISO 1992). The general model of a graphics pipeline introduced in this case provides us with a means for identifying the adequate coupling level.

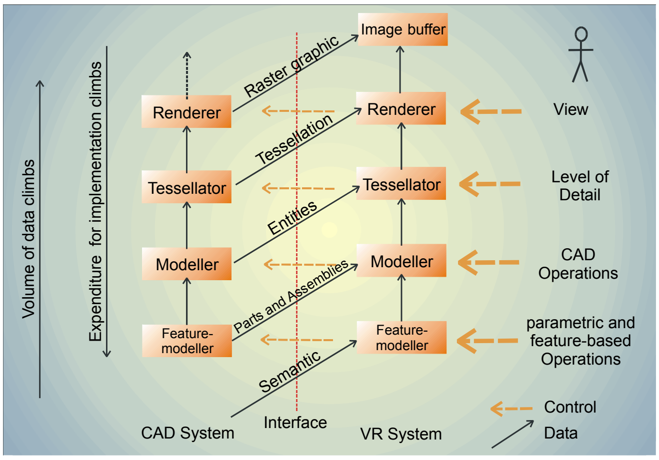

Figure 2: Levels of coupling a CAD and VR system. Vertical Coupling.

Figure 2 illustrates the vertical graphics pipelines and potential coupling points between CAD and VR systems. Both systems typically have a complete pipeline; the level at which we cut one pipeline and hand-over the data to the other system determines the integration concept.
Following our integration approach, the functionality of the backend CAD system is always accessed via the front-end VR, where we can identify three alternatives (according the horizontal coupling):

- The VR system acts on its own without contacting the CAD system (e.g. for navigation in the model).
- The VR system acts as a modeler and sends a request to the CAD system simultaneously. Thereafter the CAD system will provide an exact solution.
- The request is forwarded to the CAD system without any design activity by the VR system.

Coupling at the level of the image data as a raster graphic is not suitable. Although CAD systems provide for the rendering of scenes, this does not occur in real-time and will not support interaction. This is one of main drawbacks which force us to link CAD with VR systems.
The level of tessellation (triangles in most cases) is quite interesting for the presentation because the tessellated objects can be presented immediately and without high computing costs. It also meets the visual requirements. The level of detail, e.g. the degree of tessellation, can be controlled as a function of time. In this way, an adaptive visualization can be reached with algorithms such as. progressive refinement or region-of-interest.

Design objects are composed of several objects with graphical representation, so-called entities. In choosing this level as a coupling point, all relevant entities of the model have to be transmitted from CAD to VR.
However, the VR system does not know the element's affiliation to design objects and it is therefore difficult to execute design operations on the CAD model. It is not possible to perform an operation in the VR system simultaneously, because the VR system's model consists of geometric elements without design properties and context. For example, it is not possible to establish the relationship between entities and parts in order to change the position. After an operation, the updated entities have to be re-transmitted by the CAD system. In this case, all forms of entities such as curves and faces must be presented by the VR system.
Structuring in parts and assemblies creates an abstraction, which summarizes content-matching entities. Parts enable the mounting of parameters and feature data as semantic information. In addition, the topology of parts or rather their geometry can be traversed. Because feature data and parameters are associated with parts, they can be extracted from a part.
The semantic level provides a more compact description of the CAD models than the geometric level. In many cases, it is sufficient to provide the type and shaping of a feature instead of the resulting complex geometry. To achieve consistency between the VR and the CAD model without additional transmission of geometry data, the corresponding operation has to be executed on the VR model. That is why the VR system has to "know" the meaning of features. To use the advantage of a very compact data volume after changing the design, feature-oriented remodeling has to occur. The VR system therefore has to be provided with extensive information and abilities. Given that interaction should be limited to changes of features and parameters, it is necessary to control the feature modeler via the interface.

Integration of CAD Functionality into VR

It is doubtful whether the requirements would be met by Online Coupling and complex CAD operations from a low response time up to real-time, which means that the following requirements are not compatible with each other:

- Complexity of operation
- Level of detail in a presentation (bounding box, BREP, low tessellated, high tessellated [highest resolution will be provided at a later stage])
- Degree of interactivity (direct manipulate interaction or direct entry interaction)

Each of these requirements demands capacity and time in terms of resources. The performance of actual (affordable) computer hardware is still not able to meet all requirements. A trade-off between these criteria is unavoidable. The priority given to these requirements depends on the specific application context and cannot be solved in a general way.

To make things even more complex, CAD operations differ greatly in complexity from the viewpoint of VR systems. An operation can apply easily if the geometry itself is retained. This holds true for transformations such as translation or rotation operations. Contrary to this, morphological operation can be very expensive such as the application of a chamfer or a drilling. At this the geometry of a part or an element of a part will be re-calculated. Either the CAD system does this slowly and precisely (at the direct coupling) or we have to enhance the VR system with small CAD modules performing fast and fuzzy calculation (at the indirect coupling). The latter reduces the response time, which is crucial for VR interaction.
The degree of detail is another way to decrease the response time. It is possible to transmit and show a primitive body, such as the bounding sphere or bounding box, as a proxy. These preliminary bodies only give information about the position, orientation and dimension of an object.
If we can control the degree of tessellation, we would be able influence a trade-off between the detail and speed level. The tessellation takes place in the CAD system. This means that the total time consists of the time for calculation and the transmission time. The idea outlined above can also be used to simulate simple CAD operations with few (correct) details, e.g. the length scaling of a flat bar disregarding the ratio of its drillings.
VR interaction must occur in real-time so as to maintain the illusion of the virtual world. However, not every CAD operation must be executed in real-time as long as the VR tools still react with a minimal response time. For this reason, we can distinguish between:

- Direct manipulative interaction that can be handled in real-time.
- Direct entry interaction, where the user initiates a complex operation. While the operation is executed in the background, the VR system is still tracking the user and updating the scene.

IMPLEMENTATION

This chapter gives an overview of the two major components developed for integration: the first is an extension to a commercial CAD system – transforming it to a CAD Services server. The second is a client application built on top of a Java-based VR framework.

CAD Services Server for MD 6

A plug-in for Autodesk's Mechanical Desktop 6 implements the CAD Services interface in the server role. It has been developed as an ARX module (ARX = AutoCAD Runtime Extension). The following list presents the CAD Services modules implemented:

- CadConnection
- CadMain
- CadFoundation
- CadGeometry
- CadBrep
- CadFeature
- CadUtility

The *CadConnection* module supplies the important *CadServer* and *CadSystem* interfaces. The only task for the *CadServer* is to deliver initial information about the native CAD system and provide functions for authentication and setting up the connection. In this way, authorized and interested clients can access a *CadSystem* object. Implementation of the *CadSystem* interface offers high-level functionality enabling a client to open and operate on a CAD model. This interface also provides a mechanism to execute native operations which are not defined by the CAD Services specification. Furthermore, a mechanism to list various CAD models is available.

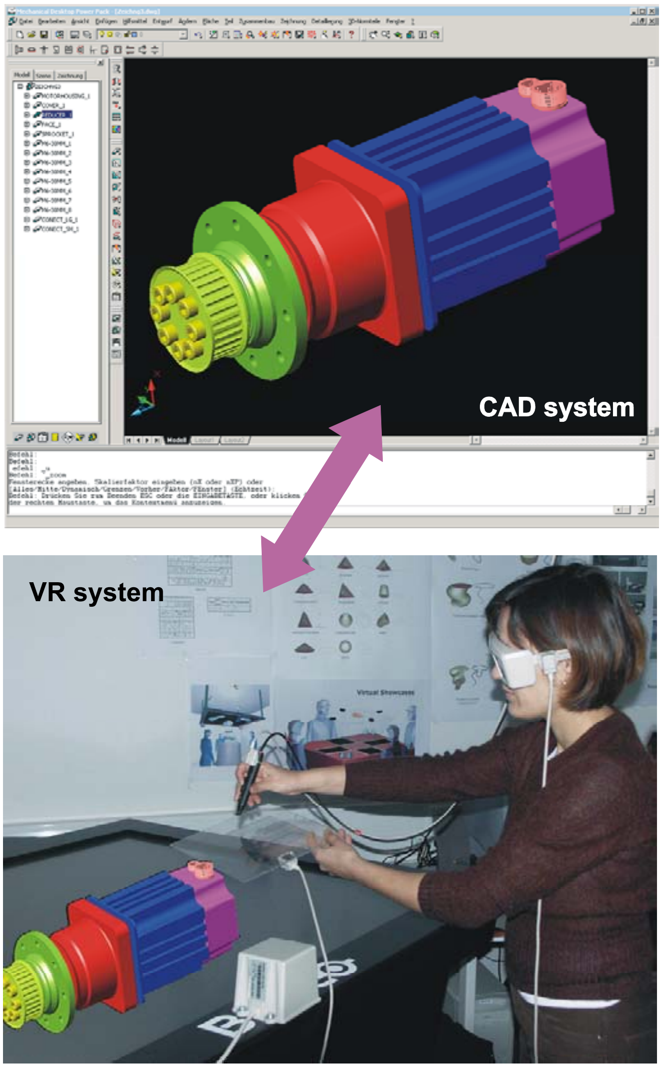

Figure 3: Coupling of the CAD system Mechanical Desktop and the Java Studierstube

The *CadMain* module ensures that each part and each assembly taken from the CAD system is represented by an instance or a reference relating to the *Model* interface. If the *BrepEntity* type has been submitted as a parameter, the *Model* gives back one *BrepEntity*.
The *CadFoundation* module is used by the *Entity* interface. An entity is an object representing a graphic component. The *Entity* interface is the super interface for various geometry interfaces such as *CadCurve* or *CadSurface* as well as all topologic interfaces. These derived interfaces are extended from the *CadBrep* interface.
Similarly, the *DesignFeatures* interface is produced from the *Entity* interface.
The *CadBrep* module contains Boundary Representations (BREPs). These models yield parametric features able to regenerate the shape through *CadFeature* interfaces. The *CadBrep* module contains semantics as a design feature, topology as BREP and geometry as tessellation or NURBS. Each object of a class is provided from the *BrepEntity* interface and has arbitrary design features (*DesignFeatures* interface). Features are composed of parameters, which have a name, a value, an arithmetic expression and flags for properties (e.g. read-only or suppressed). The topology is retrievable for each part and linked to a geometric representation. An exact representation or an approximation can be requested for every BrepEntity, e.g. bodies or shells. Parameters can be set for the exactness of a tessellation or NURBS. Although tessellation data consists of big structures, the additional expenditure of CORBA communication is small due to a low number of structures and necessary CORBA calls. By virtue of this, the transmission speed has no influence and is negligible compared to the time for creating the tessellated data.

VR Front-end

The developed CAD Services Client is a VR front-end that can be connected to any CAD Services server. Visualization and interaction are implemented on top of ZDGV's VR framework *Java Studierstube.* With *PIP and Pen,* the framework offers a two-handed interaction metaphor: the user holds the PIP, a transparent rectangular plexiglass panel, with his not-dominant hand. The dominant hand holds the Pen – preferably a transparent button-featured pen. Both devices are tracked to obtain information on position and orientation. A virtual equivalence exists for both instruments. A GUI with widgets such as buttons, sliders etc. can be projected as the virtual PIP. The Pen is represented in the virtual environment by way of a small green cone. This cone can be used to interact with the widgets on the PIP whereas the user will feel the resistance of the pen against the Plexiglas. This unpretentious form of force-feedback supports the imagination in the same way as a painter using his palette for mixing colors.
Following this metaphor, the Virtual Table (VT), which is used as a stereoscopic output device, corresponds to the easel and the visualization of objects is the artistic result of the painter's work. (ref. figure 3). The interaction with PIP and Pen has been developed under the Studierstube project by the technical university of Vienna. (Schmalstieg and Encarnação 1998)

RESULTS

Our work demonstrated the feasibility of our integration approach. Using a commercial CAD system as a basis, we were easily able to provide a server extension that offers the standardized CAD Services API. Even with a Java-based implementation, we can interact with the CAD model in a virtual world – matching real-time requirements for simple models, at least. Furthermore, the PIP and Pen metaphor was shown to support engineering scenarios in an intuitive and efficient manner. We did ascertain a number of obstacles and open questions during implementation and analysis, however, this chapter presents results in the areas of functionality, performance, adaptive technologies and interaction restrictions.

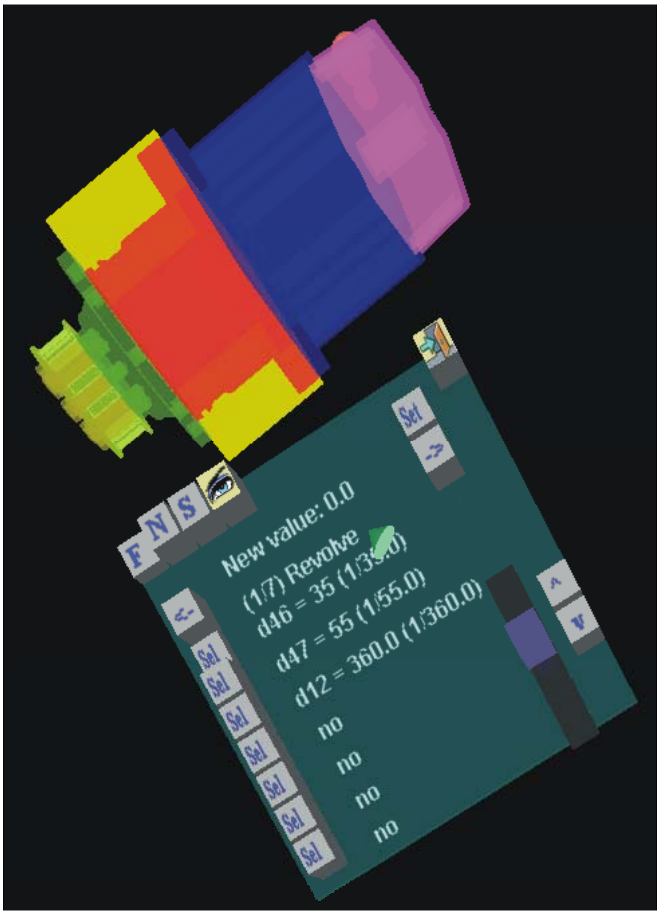

Figure 4: VR interaction to control features of the model

Functionality

The CAD Services interface offers sufficient functionality for the visualization and feature-orientated manipulation of CAD models. It provides for tessellation of bodies, parts and assemblies as well as the reading and writing of feature data. Features are not supported completely, nor does the interface enable the classification of features. Regardless of this, there is a generic possibility for reading, writing and regeneration. The VR client collects the label and functionality of a feature from the native CAD system, which means that the client depends on the concrete underlying CAD system. By virtue of this, the "imitation" of CAD operations by the VR client is not applicable in a general manner.

Although this CAD interface was developed for other purposes, it can also be applied in the context of Virtual Reality.
CAD Services uses CORBA technology, which offers heterogeneous platforms and is independent of a programming language. This allows us to implement the CAD Service Server in C/C++ as a requirement of the CAD system *(Mechanical Desktop)* and to use Java on the client's side because CAD Services Client is based on *Java Studierstube*. Additionally, the client and server can easily be distributed to two computer systems.
The implementation costs to integrate the CAD Services interface into Mechanical Desktop were quite high. The logical layer was represented in the Mechanical-API and the geometry and topology layer in the ObjectARX-API contained in AutoCAD. The complexity and lack of clarity of these APIs stem from the extensive functionality as well as inconsistencies between the different APIs, e.g. in the type of referencing objects or being based on the non-object-oriented programming language *C*. If CAD Services are widely accepted by the vendors, such an API could become a standard feature in the same way as the present VRML export.
In contrast, the CAD Services interfaces containing fewer functions than Mechanical Desktop are well-structured and we had no problems accessing the data from the client's Java implementation.

Following the subdivision in different functional levels of the CAD Services (ref. table 1), some adaptive technologies can be integrated to minimize the data transfer and to handle bigger models.
At the logical level, the position of each part and the shape and dimensions of its bounding body are contained in the model so that it is possible to determinate whether a part is laying inside the view frustum or not. Furthermore the client can decide to load a part depending on the intersection calculation which is also supported by the CAD Services interface (occlusion culling).
Using the topological level, BREP surfaces can be selected for loading and showing dependent on their normal vector.
At the geometrical level it is possible to select whether a geometry has to perform a tessellation or not. Besides, the degree of fineness can be chosen dependent on a region (region-of-interest) or dependent on the time (progressive refinement). (see table 2)
Further below in this paper in the VR client implemented technologies will be represented.

Logical Level (e.g. on parts)	**Topological Level** (e.g. on BREPs)	**Geometrical Level** (e.g. on tessellations)
level-of-detail, view frustum culling, occlusion culling	backface culling	region-of-interest, progressive refinement

Table 2: Possibilities to integrate technologies for adaptive visualization

Performance

A series of measurements was carried out in the context of prototypical implementation to evaluate the quality of the implementation.
The measurements reveal that the real-time requirement of the overall system depends mainly on the underlying CAD system. The communication claims from 6.5 % (slow computer, slow network) up to 24 % (fast computer, optimal network) of the total time.
The duration of a feature operation in the CAD system depends on the type of an operation. The application of a revolution feature is more expensive than that of a translation feature. The time taken by an operation considerably influences the system's response time. Real-

time execution of time-intensive operations that are directly coupled and directly manipulated is not possible. As long as these operations are to be performed in real-time, they have to be executed by the VR system.
In contrast to the fact that tessellation of a part or surface produces one sole structure that can be transmitted by one CORBA call, the BREPs are transmitted by separate function calls for each body, each shell, each face and so on.
As expected, the reading of the topology as BREP takes a long time. The time needed to read a BREP of a part is approximately ten times longer than the time for reading the tessellation. The BREP can be an interesting alternative for the visualization of objects because this representation is available instant past a CAD operation. This can therefore be an attractive proxy object if tessellation were to take too long.
Realization of the proposal integrating a single structure of a part's BREP can enhance the possibility of real-time interaction with a CAD system via CAD Services.
Direct Online Coupling as well as Indirect Online Coupling could make use of detail reduction. Three levels are imaginable:

- The bounding body is shown.
- A low degree of tessellation (for direct coupling), simplified calculation of geometry in the client (for indirect coupling)
- High degree of tessellation

The concrete CAD system does not provide for any change in the degree of tessellation. Visualization of the BREP can therefore be an interesting alternative to display an operation result quickly.
The current implementation supports the providing of a bounding body, i.e. a box as a proxy representation. However, this variant is not adequate for a large number of operations. As the simplified rebuilt geometry calculations are dependent on the native CAD system, it is necessary to specify the features.

Adaptive Technology

Adaptive visualization is not provided for directly by CAD Services. Nonetheless, this interface is sufficiently granular to prepare data using this technique, which reduces time without overly disturb the quality.
Three methods have been integrated into the CAD Services Server:

- Locality of Changes
- Reduction in the Degree of Tessellation
- Operations on the Client

The changing of a feature does not influence the overall model, which means that it is sufficient to re-read the geometry of a part.

There are two options for reading a tessellation that can be used if changes are even more local. On the one hand, it is possible to tessellate a whole body while, on the other hand, the same method exists for single surfaces. We can, however, greatly increase the communication overheads in this case: we presently need a high number of expensive CORBA calls for many faces because of the slow BREP interface. With a small number of face changes, this kind of transmission is faster, especially as time is also required for tessellation in the CAD system. Initial tessellation should be performed for an entire body, after which the new geometry should be re-read for the changed faces only.

Decreasing the degree of tessellation is another possibility to meet the real-time requirement for real-time interaction between the user and the overall system. This decreases the tessellation time of the CAD system.
Unfortunately, it was not able to influence the degree of tessellation of the Mechanical Desktop system. The only way to influence tessellation was the definition of start values to guarantee the success of tessellation for complex geometries such as tight curves. Using CAD systems' integrated tessellators, another problem occurred. In some cases the geometry of the view model was not shown correctly due to the poor tessellator. To eradicate this flaws we have to use an external tessellator (equipped with CAD Services APIs for a simple connecting to the set-up).
The decrease in detail up to the representation of bounding bodies and simultaneous processing of CAD operations in the client and server was translated into practice.

A second possibility to reach real-time criteria for interaction is to use the PIP as a number-block to enter numerical values in the traditional manner.
The client can only estimate the amount of time needed for a concrete operation. The expected tessellation time would be derived from the initial tessellation time. (On the assumption that changing one or more parameters does not drastically change the number of polygons from the tessellation.) The positioning and scaling of parts are easy to perform in a virtual environment. Although the concept of Indirect Online Coupling is easy to implement for positioning and scaling, this operation is also performed quickly by a CAD system, so it may be possible to use the Direct Online Coupling to meet the real-time requirement. Other types of feature-oriented manipulation, such as building bodies by extrusion or rotation, placing and applying drillings etc., are very time consuming. If this functionality is implemented in a client, it is dependent on a concrete CAD system by virtue of the incomplete feature interface referred to. Standardizing the features and building a taxonomy for them is an important task for future research and standardization.

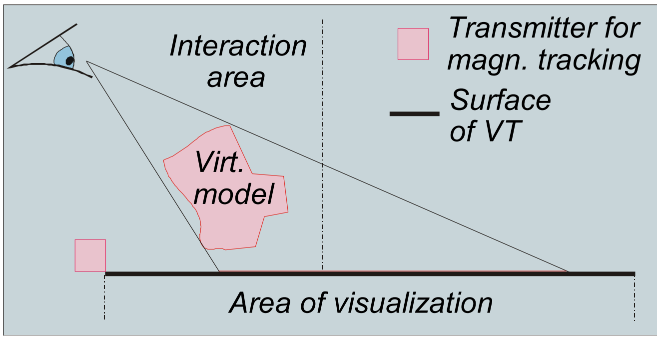

Figure 5: The area of interaction and visualization on the Virtual Table.

Restriction of Representation and Interaction

The design object used for the tests contains more or less 15,000 triangles. There was no significant latency in the interaction. Using models with more than 60,000 triangles has shown the limitations of the VR system. This performance border can be moved by using current high-speed graphic cards, distributing the rendering to one computer per channel and relying on C++ VR frameworks.

The fundamental problems of magnetic tracking were also evident on our set-up. The reduction of the magnetic field increases in a cubic ratio to the distance. High interferences occur in the last third of the table surface, making it impossible to interact with the model in this area. For this reason, the positioning of the virtual objects is concentrated in the front part of the output device (ref. Figure 5).

SUMMARY & OUTLOOK

This paper has presented an integrative approach to bring together the still separate application areas of CAD and Virtual Reality. To support the engineer who has to handle complex 3D models, commercial CAD systems can be enhanced with an additional, alternative user interface based on VR technology. Different integration concepts, including horizontal and vertical coupling and optimization by adaptive technology, have been discussed and various problems and areas of further research identified.

Online coupling is a major characteristic of our approach. It is the basis for bi-directional coupling where we do not only navigate in a virtual product but also change parameters of the model. Using OMG's CAD Services API, we can do this in a generic way – independently of a concrete CAD system for the most part.

Generality of the approach is still limited by a lack of standardization in the area of features. Ongoing work in the STEP community will hopefully solve this problem in the near future, so that a specification of features can be included into future versions of the CAD Services interface by the OMG.

Even though the actual version of the standard and the implementation is based on CORBA, the approach is even more general. Future OMG standards will use Model Driven Architecture (Soley and OMG 2000) where the interface is specified in an abstract manner via UML and can be mapped to concrete technologies such as CORBA, J2EE or .NET.

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BIOGRAPHIES

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Matthias Vahl graduated in computer science from University of Rostock. He joined the Computer Graphics Center Rostock as a research assistant in 2002. His current research interests are in the area of Virtual Reality and Computer Supported Cooperative Work.

ENGINEERING DATA MANAGEMENT AND INFORMATION MODELLING

Long term preservation and retrieval of product knowledge within aerospace industry

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Keywords: product data, digital long term archiving, aerospace industry, ISO 10303

1. Motivation – digital long term archiving of product knowledge

Rising technological dynamism of aeroplane systems (e.g. avionic) plus increasing cost sensitive customers are particularly reflected within Europe by an increasing trend towards virtual development co-operations of complex and long lasting aeroplanes. So that today's types of development co-operations in aeroplane industry lack valid information about the current development statuses because of sub-optimal data quality within cross company IT-environments (Karcher, Knarr, Jungkunz 2002).

In accordance to legal issues a system-neutral archiving of aerospace product data (e.g. geometry) must be guaranteed with aeroplane enterprises necessary for a flight permission until at least 3 years after the last aeroplane was scraped.

In industrial practice this means a long term archiving timeframe of usually more that 50 years (e.g. Tornado, MIG 29, Eurofighter). But also in the light of product knowledge (knowledge to develop successful products) preservation and reuse of product data a comprehensive long term archiving concept for digital product information are of central importance at EADS-M.

In this light previous attempts for long term archiving of product information in the aircraft industry can not be successfully applied any more. Because of this the project LOTAR (Long Term Archiving and Retrieval of Product Data in Aerospace Industry) was set up by leading aerospace development companies (Airbus, EADS-M, MTU und Dornier Fairchild) together with the ProSTEP-iViP association.

The aim of this project is to develop methods, scenarios, applications and process modules for the aerospace industry, that support the digital long term archiving and reuse of product data inclusively 3D-Geometry. The main tasks incorporate:

1. Consolidation, common understanding, coupling of the demands
2. Development of a strategy and a preferred attempt
3. Recommendations for processes and data models
4. Definition and implementing of application projects

Within a cooperation between the ProSTEP AG and the Institute for Information Technology in mechanical engineering (*it***m**) of Technical University Munich digital long term archiving fundamentals of product information were addressed to support the LOTAR project group.

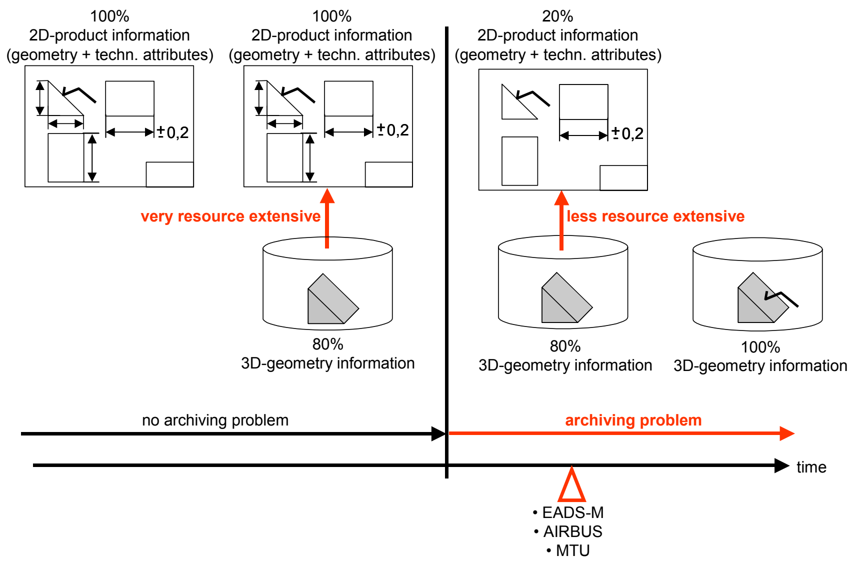

figure 1: Long term archiving problem of product information

In the beginning the deliverables of an entire/complete product geometry description (2D-product models) were created by using construction boards or by using first applications of CAD-systems (see figure 1, from left to right). Later this was substituted by manually supplemented 2D-product models derived from 3D-product models that had to be (dimensions, surface descriptions). Because the 2-D drawing described a geometry entirely, it could be successfully used as master for long time archiving (e.g., microfilm), up to this moment.
Today the entire product information is shared by 2-D- as well as 3-D geometry. This means, the current 2-D descriptions, because it does not entirely describe the product information, can no longer be successfully applied as a master for long term archiving. Because it is expected that the trend towards an entire/complete product information description within 3-D product models increases previous/established long time archiving approaches must be rejected.

2. Possible long term archiving variants and their basic problems

Within the framework to support a long time archiving of digital product information within distributed, multidisciplinary aeroplane development co-operations, the following fundamental solution variants are possible:

1. **Product warehouse** (= physical storage of all build product/aeroplane variants)
   Advantages: can be immediately established
   Disadvantages: on the basis of high expenses to be expected for the production / manufacturing and storage of all previous product variants a physical product part warehouse rather represents an interim solution; because of this, if other approaches for long term archiving product information are to be aimed this would result to a physical long time archiving on microfilm of a 2-D geometry derived from a 3-D-geometry or digital long term archiving; if digital long term archiving is aimed, this can be potentially established by hardware and software archives, a continuous 3-D conversion, or a neutral data format plus specified archiving processes.

2. **2D-geometry derived from 3D-geometry and stored on microfilm** (= physical storage of all build product/aeroplane variants)
   Advantages: can be immediately established; less resource intensive that a product warehouse; good legal proof-ability as long as the signature and the product data build up an inseparable unit => contract character
   Disadvantages: a fully but resource intensive supplements (e.g., surface descriptions) of 2D-model is required

3. **IT-hardware- and IT-software archive** (= digital storage of all build product/aeroplane variants)
   Advantages: can be immediately established; less resource intensive that a product warehouse; good legal proof-ability as long as the signature and the product data build up an inseparable unit => contract character
   Disadvantages: high costs for IT-system maintenance and administration are expected; hardware and software museum (of original IT-system environments)

4. **Continuous 3D-conversion from one software version to the next** (= digital storage of all build product/aeroplane variants)
   Advantages: can be immediately established; less resource intensive that a product warehouse
   Disadvantages: low legal proof-ability as long as the signature on product data is not updated any time product data is converted; in generally a high failure rate is to be expected with the continuous conversion of product information (e.g. corrupt geometry models may occur); with a continuous re-potting it cannot be guaranteed that the geometry representation is still the original one

5. **Neutral data format & specified archiving processes** (= digital storage of all build product/aeroplane variants)
   Advantages: less resource intensive compared to the above approaches; automation of archiving processes is feasible; good legal proof-ability as long as the signature and the product data build up an inseparable unit => contract character
   Disadvantages: can not be immediately established; stable and public law/regulation accepted data format to be defined + specified and reliable archiving reference processes

Finally, by weighting/ranking of advantages and disadvantages of the above described solution variants, the project participants of LOTAR decided to establish a neutral data format to be specified plus an archiving reference processes to be specified. In the context of archiving processes to be defined the research projects AIT/7704 (Advanced information Technology in design and Manufacturing), MOSLA (Maturity of standard for Long Term CAD Data Archiving), OCLC/RLG (Working Group on Metadata for digital Preservation) and OAIS (Open Archival information system) were benchmarked on the basis of an requirement analysis by the aeroplane manufacturers EADS-M, airbus and MTU. In the context of a neutral data format to be defined the product data representation approaches VDA-FS (Surface Interface VDA), IGES (Initially Graphics Exchange Specification), VDA-IS (VDA IGES Subset), DXF (Drawing Interchange File Format), SET (standard d'Echange et de Transfert) and STEP (Standard for the Exchange of Product Model Data) were also benchmarked on the basis of an requirement analysis by the aeroplane manufacturers EADS-M, airbus and

MTU. In the context of the LOTAR project the OAIS model (ISO 14721) was chosen as a long term archiving process reference e.g. because of a extensive and neutral archiving system description of typical long time archiving scenarios as well as STEP (ISO 10303) as a reference for a neutral long term archiving format e.g. because of extensive possibilities to 2-D-, 3-D-, product structure and configuration information representation.

3. Possible long term archiving problems of product geometry while using STEP

Although -as outlined above- archiving of product model data via a neutral and standardized data format represents the most comprehensive approach and the ISO 10303 is considered as its most suitable reference at present, problems may still arise while using STEP. The problems appear especially while archiving product data because in contrast to data exchange the performance characteristic features and data model concept of the receiving geometry system (e.g., CAD-system for viewing and upgrading archived data) are not typically public.
Although within data exchange, e.g., precision of geometrical data can be adjusted between the sending and the receiving IT-system, is not possible while archiving, because only the sending system (archive data producer) is known. This can lead to a case where product models would be imported and displayed incorrectly or even so corrupt that it can not be loaded to a viewing IT-system at all.
Particularly during transmission between CAD systems of various precision heavy geometry model failures can be caused as a short illustration of the following two examples should outline (Bock and Strobel 2002).

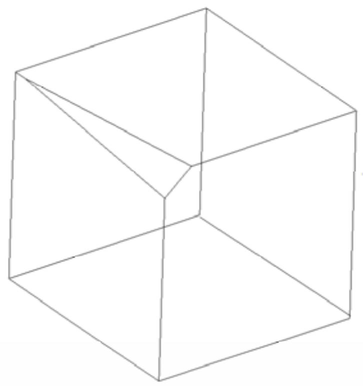

figure 2: mini-boundary-curves within solids

1. Mini-boundary-curves within solids (see figure 2):
Mini-boundary-curves represent geometric elements that fall short of a specific geometrical expansion. Mini-boundary-curve occurrences are thereby the result of different effects. Most likely this is however caused by improper or even incorrect product modelling and on the other hand by transmitting data to a CAD system with low precision. Such an incorrect product modelling can be caused, e.g., by intersection of two solids penetrating themselves only a little.

Consequences:
1. Because of the topological interactions of a solid at least two surfaces are affected.
2. The surface of a solids can burst, i.e. the solid is mathematical faulty.

2. Cracks within surfaces (see figure 3):
Crack within surfaces represent areas where the position steadiness of two neighbouring surfaces is not given. Crack within surfaces can appear, in this connection, with a too large distance as well as with an overlap of surfaces. Furthermore, cracks within surfaces like mini-boundary-curves can occur by transmitting data to a CAD system with low precision.

Consequences:
1. Holes within surfaces can appear
2. If the data is used for NC treatment, the work piece cannot be manufactured
3. Topological connections within surfaces can get lost.

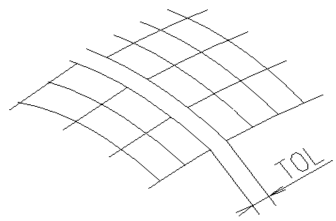

figure 3: cracks within surfaces

Summarizing the above illustrations, the following conclusions with respect to a data format change for long term archiving can be derived:
1. 3D with high quality of geometry modelling like surface modelling in accordance with the BREP-method, or generative volume modelling (solids within CSG models) can cause recovery problems within CAD systems if surfaces are not closed, particularly if the exacted tolerances or geometry representations are not adjusted to each other.
2. To avoid the just described product data recovery problems, it makes sense to think about a particularly robust data format plus quality assurance steps along the archiving process (see figure 4)

4. Solution approach – LOTAR

LOTAR intends that archiving processes to be specified support the conversion and search (for visualization and reuse/further use) of product information exclusively from PDM-and CAx systems.

Thereby, the specification of LOTAR archiving processes must be unambiguous enough to satisfy legal directives and on the other hand must offer different options to guarantee the applicability of the LOTAR standard among many aircraft manufacturers and under different application scenarios. As a result, certificated IT-tools and IT-interfaces, data storage mechanisms and the use of digital signatures are part of the LOTAR specification. The attempt with respect to a neutral LOTAR data format to be specified intends that subsets of ISO10303 (STEP) are defined which should guarantee the unambiguously of specified product data representation methods contained, to guarantee maximum degree in clarity with respect to product information to be (geometry as well as technical attributes).

A within the framework of ISO standardized LOTAR data model is prioritised in order to give generally access to the semantics of stored product information, as well as to guarantee a maximum of IT-system independence. In this connection recommendations are also given to the minimal data model abstracts to be used depending on various industrial demands. To limit data redundancy various possibilities to instantiate the LOTAR data model with converted product data should be expelled.

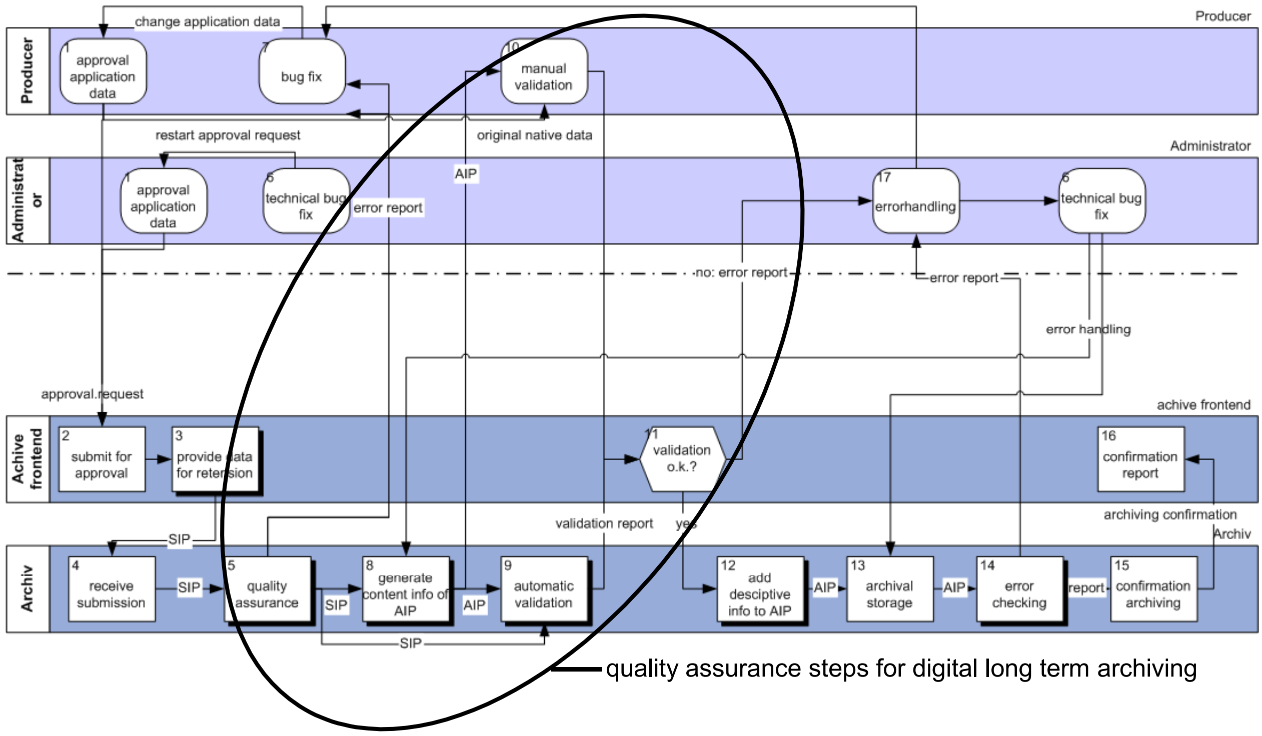

figure 4: Conceptual LOTAR archiving reference process (Project LOTAR 2002)

5. Summary and outlook

The article illustrates that a high-quality long time archiving of digital product information is of central importance for European aircraft manufacturers. Previous long time archiving attempts of product information must be scrapped. Among other things this was motivated because of the technological change from 2-D to a 3-D representation. In this context the article sketches a possible solution for the digital long time archiving of product information developed within the framework of the LOTAR project and to be internationally specified in context of AECMA. Since LOTAR addresses typical long time archiving problems, the project results can be also applied to other industrial branches.

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PDM-system tuning to support project knowledge creation

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Keywords: aerospace industry, project management, reuse of existing digital product information

1. Motivation – creating new project knowledge more efficiently

Data such as digits or characters can be measured as output or input of a database, computing device or a data link (Bohn 1994), (Wehner 1999), (Langenberg 2000). Information can be retrieved by bringing data into context. Information is organized context related data and gives meaning to the person analysing the data (Bohn 1994), (Wehner 1999). Knowledge that has to be distinguished between explicit and tacit knowledge (Aulbur, Haas, Stautz 2000) goes beyond information. Knowledge structures doing. Knowledge develops by using information for a certain purpose e.g. predictions, causal associations, or prescriptive decisions about what to do. Knowledge is not a static model of the real world, but represents dynamic structures which support subjectively to cope with concrete tasks (Bohn 1994), (Wehner 1999).

As it is estimated that up to 80% of the product success lies within the development area (Schinzer 1999), (Buergel 1996) characterised i.e. by limited resources, time restrictions, interdisciplinary co-operation, dynamism and high insecurity (DIN 1991), (Litke 1993) project knowledge (knowledge to establish an successful product on the target market) gains importance. To establish a successful product a continuous process to plan, organize, monitor and control all project aspects is required - traditionally within the responsibility of a development project management (ISO 1997).

To support a development project management an immediate project interference e.g., on the basis of problem-/risk situations (e.g., progress beyond expectations) during project execution and to initiate comprehensive actions, it is not only necessary for the development project management to be provided with reliable and logical product knowledge about the current project performance progress (e.g., work order progress, personnel costs) (see figure 1), but also with likely but possibly implicit causes (e.g., increased design time for 3-D models) in case of project target abnormalities (e.g., project delay). So far an efficient support of a development project management on the basis of an efficient supply of reliable (e.g., concerning actuality) and comprehensive (e.g., all relevant resources were considered) project knowledge about the current development project status (e.g., project is 100% on track) as well as implicit causes in case of project target abnormalities is e.g. because of high product- and process complexity usually difficult to established, very resources intensive (Karcher, Knarr, Jungkunz 2002) or all project management relevant aspects can not be addressed, despite of using IT-tools for project planning (e.g., MS project) or project controlling (e.g., SAP R3).

In general multiple digital product life cycle information (PLC-information) already exists within established and usually enterprise-specific customised information administration systems (e.g., product data management-, engineering resource planning and document management systems). Therefore, in context of this article no further domains specific description, analysis and interpretation of project management relevant product knowledge (e.g. via neural nets/expert systems) according to rather intuitive/empiric methodologies is in the focus but rather the question to what extend typical development project management decisions can be supported by interpreting already existing digital PLC-information into product knowledge. Besides this, typical IT-system environments of today rather follow a strategy to store PLC-information within established information management systems (e.g., effectivities in PDM-systems) separately from PLC-information relevant to the development project management. Furthermore, a partly not up to date PLC-information basis and additional maintenance expenditures are accepted, up to now.

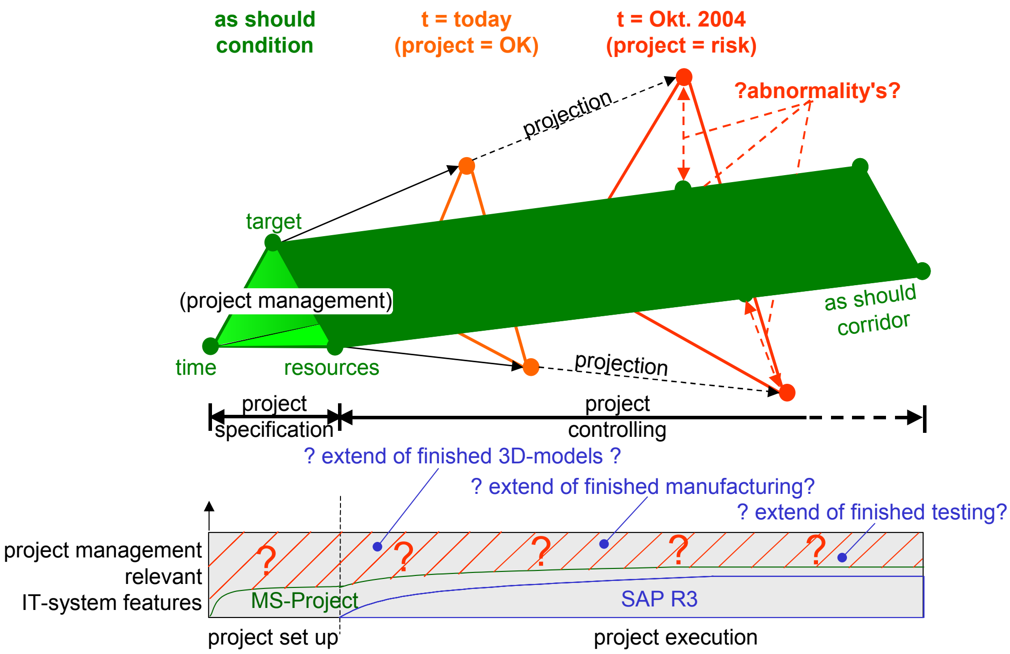

Figure 1: Project abnormalities of initially specified project condition along project execution

2. Problem – efficient supply of reliable project knowledge about the current project status

Still, development projects of innovative products (e.g., aeroplane developments) are typically characterised by multinational project partners, a increase of involved project staff, a rising product variant variety, high product complexity and process dynamism. Combined with today's rapid technological change of IT-tool features this is reflected by exploding volumes of product life cycle information. In this light, it is estimated that enterprise information stored in databases double every 5 years (Schinzer 1999). In addition, strong and complex dependences exist between these sets of product life cycle information, managed within established information administration attempts such as Product Data Management Systems and Document Management Systems. Particularly because of these typical but critical circumstances it is undisputed that reliable and comprehensible knowledge about the current project status (e.g., 60% the product features are already developed) plays an important role to efficiently and effectively manage development projects. Up to now, however, this typically requires a high expenditures for implementing and maintaining suitable IT-support tools, or the project situation is characterised by never "up to date" statements.
A PDM-system concept can be described as an approach for managing product data of all product life cycle phases based on the so-called integrated product model. The integrated product model represents a logical integration platform for software systems used within a product life cycle (Anderl and Trippner 1999), (Wirtz 2001). Compared to other established information administration like document management (concept for the administration and structuring of digital and non digital documents and their metadata (Karcher 2002)) various valuable information can be found within PDM-systems, required to aggregate project knowledge relevant statements about the current project status via milestone-trend analysis diagrams (e.g., schedule abnormalities) and progress diagrams (e.g., finished work orders). Certainly, typical ERP systems develop among other things statements about resource demands, however, this is typically based on manually maintained information, with corresponding negative effects about statement quality and / or statements are based on information abstracts from production IT-systems with corresponding negative effects on the completeness of the product information necessarily to be considered. However, using the PDM-system concept as an information basis for a continuous aggregation of project knowledge and likely cause-effect chains, deficits also arise:

1. The current PDM-system philosophy contains so far no analysis patterns for project knowledge since the concept was established to integrate product life cycle information particularly according to product structure relevant aspects

2. The PDM-system concept contains no project management principles such as the kind of product life cycle information to be considered/ not considered

3. The PDM-system concept has to be extended by consistency test mechanisms (e.g. all relevant product life cycle data has been maintained)

4. The PDM-system concept misses productive IT-systems related information (e.g., man hours, engines running times and extents of machinery

utilization) managed by ERP-systems, but also needed to development project expense diagrams or personnel cost diagrams.

3. Approach: tuning PDM-system with project management relevant principles

Central task of a project management is to specify and control project/product parameters (see figure 1)
Recognised project parameter abnormalities can be caused by i.e. unrealistically specified project/product parameters (e.g., milestones too closely set), unpredictable product changes or project execution mistakes (e.g., sub-optimal resource utilization). To better cope with this situation e.g. progress diagrams, milestone-trend analysis diagrams and workload diagrams have been established in industrial practice to support project controlling.
These diagrams do not only represent standardized reference graphics of computed product life cycle information to visualise current project condition, they partly serve as indicators of possible causes in case a risk-/ problem situations occurs, too.

The following overview shows examples of how metadata of typical PDM-systems can be compiled to above described reference diagrams:

1. Progress diagram relevant information is represented by typically work order related metadata such as "id", "status" and "release date" (see figure 2).

2. Milestone-trend analysis diagram relevant information is represented by typically milestone related work order metadata such as "release date" and "status". However, a work order object requires to be extended by metadata such as "planned expenditures".

3. Workload diagram relevant information is represented by typically part related metadata such as "release date" and "status". However, metadata has to be extended by "start date" and "expenditures".

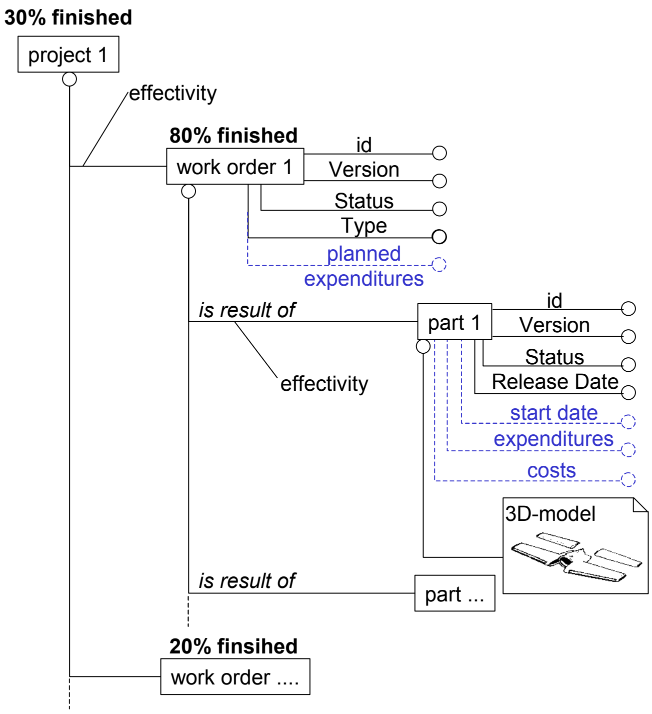

figure 2: Abstract of a typical PDM-system product structure <u>including</u> reference model related extensions

4. Use case: Project status Eurofighter

The EADS, second largest aerospace enterprise of the world, develops and maintains at the military division high performance aircrafts such as Tornado and Eurofighter in typically multinational projects. The Eurofighter (EF-Typhoon) is divided into four multinational building sections.
The development of aircraft systems like the flight control are within the responsibility of a particular project partner, by means aircraft systems typically span several building sections. However, manufacturing of aircraft systems (e.g. cables and harnesses) is within the responsibility of building section owners. Furthermore, the final assembly of all building sections and "final testing" of all aeroplane systems is in responsibility of the project partner who's air force ordered the aircraft. According to the above described project conditions as they are also illustrated in chapter 1 it is assumed that this kind of aeroplane development projects are suitable as a sufficiently complex use case examples for previously introduced

solution approach. The following example thereby intends to illustrate how metadata of the customised PDM-system Team Center used at EADS military aircraft division in Germany can be computed to a progress- as well as a work load diagram (see figure 3). A so-called work request represent a change demand, initiated by the shop flour of EADS military aircraft division in case of a assembly problem caused by a incorrect product design, occurs. This work requests are administrated by the construction department within the PDM system Team Center as so-called work order objects.

Progress diagram relevant metadata/ information can be found at this work order objects (CR-STATUS = Life cycle state of the work order object, CR-STATUS Date = creation date of the work order – see figure 3). Summarizing the planned, finished as well as the open work orders objects according to a specific date, a workload diagram can be created, too.

According to figure 3 Eurofighter work orders were almost finished, entirely. In addition, a positive tendency appears for the development project, because the percentage of not finished work orders objects constantly decreases until the end of the project plus fewer product changes (= new work orders) were set off.

The use case illustrates that reusing existing digital data from PDM-systems compiled to progress workload diagrams can efficiently support resource planning at EADS military division without using high expenditures on IT- and human resources. Furthermore, the diagrams give a valuable reference for planning future capacities of similar aircraft development projects (e.g., Maco).

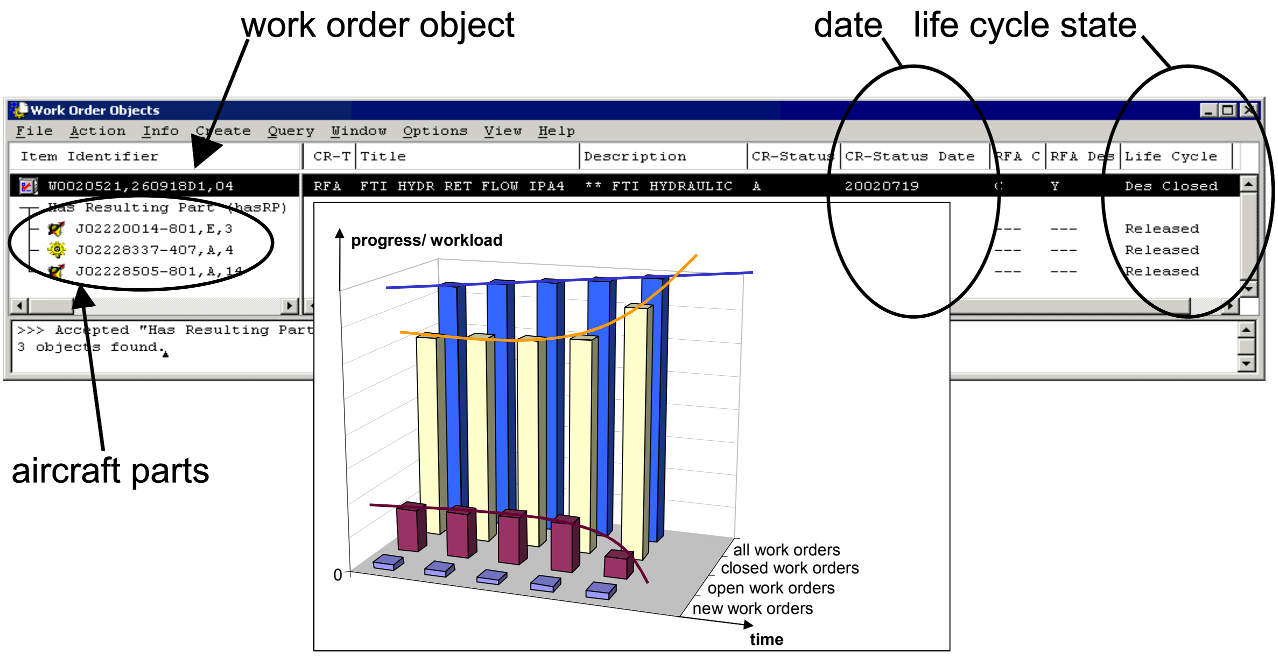

figure 3: An integrated progress- workload diagram aggregated from existing PDM-system information

5. Summary and outlook

The article illustrates that project knowledge (knowledge to establish an successful product on the target market) plays an important role at EADS military division Germany. However, due to i.e. rising product complexity and information volume the creation of new project knowledge still requires typically high expenditures on human resources to create valuable project knowledge. As a result the paper presents an approach for reusing existing digital product data to create new project knowledge. To illustrate the approach the article later presents a IT-system successfully used at EADS military division Germany creating new project knowledge in order to support aircraft project controlling.

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KNOWLEDGE-BASED AND AGENT-SUPPORTED MODELING IN THE FIELD OF PARAMETRIC 3D-CAD SYSTEMS

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Integration of geometrical data and product definition, corporate technical memory, knowledge-based engineering (KBE), knowledge-based 3D-CAD systems, software agents

ABSTRACT

Current research activities aim to enhancing parametric and feature-based 3D-CAD systems towards representing, processing and distributing knowledge. This paper describes the fundamental ideas concerning knowledge integration in the field of parametric 3D-CAD systems. A discussion of state-of-the-art 3D product modeling is presented followed by an insight into the research on 3D-CAD components considering knowledge-based engineering (KBE). A summary of current implementations of knowledgeware in the leading 3D-CAD systems is included. Further research and development activities of the Department of Computer Integrated Design (DIK) on knowledge-based modeling methods are addressed. In addition, a current research project is presented which includes the development of adaptive and knowledge-based 3D-CAD design components. The management of the knowledge-based methods developed in the research project has to be implemented by means of agent technology. The paper concludes with a view of integrated knowledge processes and knowledge representations in the field of 3D-CAD components.

INTRODUCTION

For an innovative and efficient product development process the use of modern parametric 3D-CAD systems is of increasing importance. In 3D-CAD systems digital geometrical models of products are generated, which can effectively be used in subsequent processes (e.g. production processes). Basically in the internal digital data structure of a 3D-CAD model geometrical data, parameters, constraints and the modeling history are represented. Additionally, the feature technology enables the models to be developed by means of defined zones of geometry with embedded semantics (e.g. drillings, slots). In the technological leading 3D-CAD systems further non-geometrical information (e.g. attributes concerning files, elements or parts, computations, materials, notes, optimization goals etc.) can be stored additionally in the data model of the parts and assemblies. The integration of geometrical and non-geometrical information into the 3D-CAD models allow embedding product specific knowledge and design know-how into the models. Additionally, methods of digital mockups (DMU) can be used to apply further investigations or simulations to the 3D models. Furthermore the effective implementation of an integrated process chain is primarily based on the data, information and the knowledge represented in the 3D-CAD model.

The department of Computer Integrated Design (DIK) is investigating methods and tools for developing, managing and reusing catalogs or libraries of knowledge-based components. By means of the intelligent components, 3D-CAD models can be subsequently modeled and configured. The reusability of the knowledge-based CAD components is of utmost importance. Thus, design knowledge can be integrated into the CAD models being managed and updated continuously in the enterprise. Consequently the knowledge-based CAD models and components represent an important fragment of the knowledge base of an enterprise. For the co-operation-wide management of these knowledge-based CAD models product data management (PDM) systems, engineering data management (EDM) systems or product lifecycle management (PLM) systems can be used to supply product data as well as means for process representations. The data models of the product data management systems are configured with adaptation to international standards. For an effective and efficient product development process the re-use of CAD components and their configurations for different application contexts is an enormous challenge. Implemented once it will implicate substantial economic savings in the enterprises.

3D PRODUCT MODELING

Modern 3D-CAD systems support the modularity of subtasks, enable different levels of abstraction within the model and provide design interfaces with feature-based and parametric modules including constraints and parameters. Attributes describing element and file properties as well as non-geometrical parameters (e.g. materials, notes) can be stored in the data model of the 3D parts and assemblies. By means of the integration of geometrical and non-geometrical data in the 3D models it is possible to embed data concerning the product structure and the product logic of the models (Figure 1). Thus, besides the geometrical structure of a 3D-CAD product model information and product specific knowledge can be represented by means of structured modeling techniques and methods for accumulating the model data. In various research projects methods have been developed at DIK for classifying the transparency and complexity of 3D-CAD models in order to optimize the re-use of CAD-models with its constraints and to understand the underlying complex model structures as well as the modeling process itself (Anderl and Mendgen 1998) (Mendgen 1998).

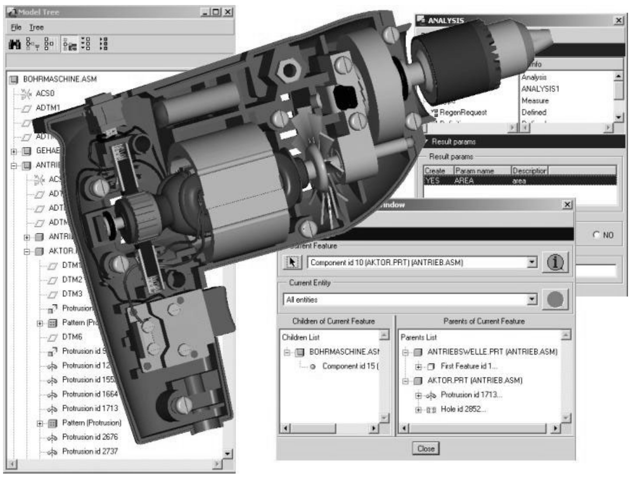

Figure 1: 3D-CAD-model used in the Research Project and Fragments of its Constraint Structure.

The modeling process of the 3D-CAD-models is strongly supported by the use of features, enabling technical semantics, relations and boundary conditions to be integrated into the CAD models. Current research activities are dealing with investigating modeling techniques for developing a 3D-CAD master model from which several representations can be derived for satisfying different design goals (DfX, Design for X).

KNOWLEDGE-BASED PARAMETRIC 3D-CAD COMPONENTS

The Department of Computer Integrated Design (DIK) currently investigates methods for modeling intelligent design components with geometrical and non-geometrical constraints in order to store knowledge and to establish well-defined interfaces of the components. The following definition illustrates the main goals to be probed further into.

A 3D-CAD design component is an implemented and re-usable template of a 3D-CAD model, which can be configured via one or more well defined interfaces. The component is represented by a certain internal condition due to a documented modeling process and can be integrated into a (superior) context.

For example the actual context of a component can be provided by an assembly. The administration of the CAD specific knowledge-based components must be implemented in catalogs or part libraries integrated into the 3D-CAD system. The underlying scheme of a design component is modeled to fulfill the requirements of a certain level of abstraction defined in the conception of the component. The conception specifies generic instances of the component which can be configured due to a certain context. Several methods which can be used to model parts and components in the context of the assembly can be used to integrate the components into a certain context. These methods can be summarized under the term *Design in Context* and are particularly supported by modern 3D-CAD systems (e.g. assembly features or skeleton models). For establishing an increasingly powerful management of 3D-CAD design components new methods have to be developed according to the application of software components in the field of software engineering. Of course the reusability of components is not ensured by simply using component technology. Reusability must be thoroughly considered during the development of the structure of the 3D-CAD design component and its access interface. The internal structure which is necessary for building up knowledge-based components requires new methods of structuring and modeling 3D-CAD components. With special attention on the 3D-modeling process the research activities of DIK are based on international research projects concerning the general field of knowledge-based engineering (Gero 1998) (Rude 1998) (Handenhoven and Trassaert 1999) (Ullman 2002).

The exchangeability of 3D-CAD design components is facilitated by the encapsulation of complex system structures behind simple access interfaces. For example the designer shall be enabled to initiate complex changes of the shape of a CAD model simply by changing a non-geometrical initial parameter if the appropriate calculations and constraints are modeled between the parameters of the geometry and of the model.

However a general methodology for modeling knowledge-based 3D-CAD models and components does not exist and has to be developed. In the following this research field will be discussed in detail.

CURRENT IMPLEMENTATION OF 3D-CAD KNOWLEDGEWARE

The different market and technology leaders in the field of parametric and feature-based 3D-CAD systems are undertaking great efforts to provide knowledgeware technologies. The various systems are equipped with specific capabilities and technologies. In the following a summary of the most important technologies of the various vendors are summarized. Consequently no single 3D-CAD system offers all the technologies qualified below. 3D-CAD systems examined in the research project are CATIA V5, Pro/ENGINEER and Unigraphics.

As a basis for all knowledgware applications constraints, parameters, formulas and rules as well as design tables are used. Furthermore, parametric data sheets permit the declaration of arbitrary hierarchical parameter structures which can be linked to the geometrical model. Some systems offer knowledge-based templates, rule bases and design sets that can be used to represent individual fragments of the comprehensive logic of controlling the product design. The so-called behavior modeling or engineering optimization technology enables to embed design goals or specifications extending the models by analysis features for the control, adjustment and optimization of the design. For the automation of some specific industrial processes so-called assistants are provided, in which process specific knowledge for selected applications is stored. With their assistance explicit design processes (e.g. computation of gear units) can be implemented in the form of design samples, sets of rules, optimization and strength calculations. Reference and skeleton models support top-down design methods. The integration of programming languages (procedural, object-orientated or logic) into the 3D-CAD models is increasingly supported. With this technology computations, examinations and configuration logics as well as user-defined features can be integrated into the geometrical models. Particularly, rule catalogs comprising a certain subset of information are transferable to other CAD components. One approach provides a knowledge navigation tool that can be used to access CAD-models from a knowledge-driven aspect provided by an integrated "Application Programming Interface". Embedded programming languages that can be used not only for the coupling of relations with the geometry but also for the generation of geometrical features or complete CAD models are in the initial stage of the development. Using this upcoming technology in the future a mapping shall be provided correlating geometrical and logical representations of a 3D-CAD model.

How to establish system independent elements of knowledge-based CAD functionalities (KBE, knowledge-based engineering) is described in (OMG 2001).

RESEARCH AND DEVELOPMENT OF KNOWLEDGE-BASED 3D-CAD MODELING

In product development and design the accumulation, processing and preservation of knowledge with the help of parametric 3D-CAD systems is of great importance. Methods for modeling knowledge-based 3D-CAD components equipped with an appropriate modularity are prerequisites for managing the complexity of product design tasks. It is crucial to embed the knowledge processes into the everyday work of the design engineers and into the CAD-modeling process. Flexible knowledge methods must be developed for integrating the CAD-driven knowledge processes into the general product design process. The architecture for integrating the knowledge processes has to support a flexible and modular provision of a guided assistance for the designer.

A current research project at the Department of Computer Integrated Design (DIK) deals with "knowledge-based and agent-supported modeling in the field of parametric 3D-CAD systems". The project was started in October 2002 (ID code An 265/6-1). It is funded by the DFG (Deutsche Forschungsgemeinschaft) a central national public funding organization for academic research in Germany. The goal of the research work is the development of methods and tools for knowledge-based modeling in parametric 3D-CAD systems. The main focus is to research the use of the 3D-CAD model as a medium for representing knowledge and to develop its representation structures by means of modeling strategies. The knowledge-based CAD models have to be designed for embedding the highest possible content of semantics of the integrated product knowledge. In addition new methods have to be developed for building up complex knowledge-based solution components being flexible, adaptive and re-usable during the processes of product development. Furthermore a modular and context-oriented knowledgebase has to be integrated. The CAD-based knowledge processes are developed or derived regarding specific knowledge processes qualified below.

The second purpose of the research project consists of managing the developed methodology for knowledge-based modeling of 3D-CAD models by means of agent technology. For this reason agent-supported methods and tools have to be developed, representing an integral part of the processes. Modeling agents will provide methods for assisting the engineer in composing a well-structured knowledge base within the 3D-CAD models. For this reason agent-supported methods and tools have to be integrated both into the modeling processes and technologically into the 3D-CAD system. Figure 2 illustrates the basic system architecture, the level of integration of the agent and its interaction with the user.

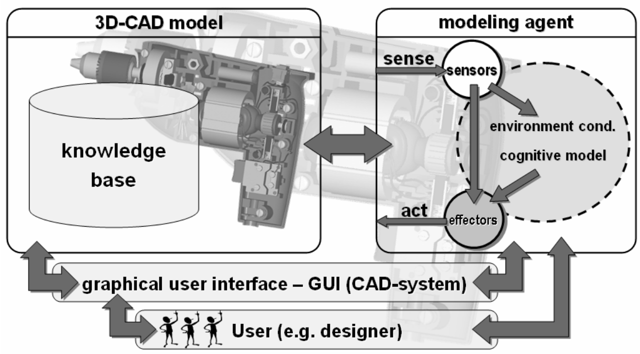

Figure 2 – Architecture for integrating a Knowledge-Based Modeling Agent into the 3D-CAD-system.

The modeling agent is monitoring the designer's modeling process of a 3D-model (e.g. of a part). The behaviour of the agent and its interactions are controlled by the offsets of its internal cognitive model and the "environment" model being monitored which in this case is equivalent to the CAD-model. The internal model is the abstract representation of the knowledge-based modeling methods and structures identified and explored in the first phase of the research project. The "environment" model is the current model instance (part or assembly) designed by the user of the CAD system. On the basis of this internal model (cognitive model) in relation to the CAD model developed by the designer the agent optionally assists the designer in embedding well structured knowledge into the CAD model. Concerning the methods which have to be developed and supported the research project is restricted to the CAD object types *part* and *assembly*.

Part of the research is also the extension of the stated methods towards adaptive 3D-CAD design components for their use in different applications of the process chain. For different purposes, individual design components or models have to be changed and adapted to fulfill external requirements of e.g. FEM (finite element method) computations, multi-body-simulations (MBS) or the derivation of manufacturing data (e.g. for NC programming). Today, such adjustments of CAD models or components are carried out manually in parallel by the different user groups (e.g. designers, computation specialists) involved in the product development process. Consequently further research activities aim to support or replace this manual adaptation process by methods of knowledge-based engineering (KBE) according to the extended definition below.

An adaptive 3D-CAD design component is equipped with active methods to recognize a certain context the component is embedded in. Based on methods of knowledge-based recognition of the context the component is able to derive conclusions (inferences) for autonomous self-reconfiguration according to the present context. Various mappings of the internal data model and the interfaces of the design component (according to different contexts) must be updated and stored in the component in order to reuse the knowledge in case a certain context (or context similarity) reoccurs in the process chain. An adaptive 3D-CAD design component must be extended by methods for updating and administering several context models, which are based on a flexible core template.

Concerning knowledge-based modeling an architecture for integrating knowledge processes and knowledge representations is presented in Figure 3. Different knowledge processes require different methods e.g. for the representation and identification of knowledge. The interaction of users and agents with different roles must be developed. Parts of the knowledge building blocks in Figure 3 are based on (Probst et al. 1999). Some building blocks for supporting the knowledge-driven 3D-CAD modeling process have been added.

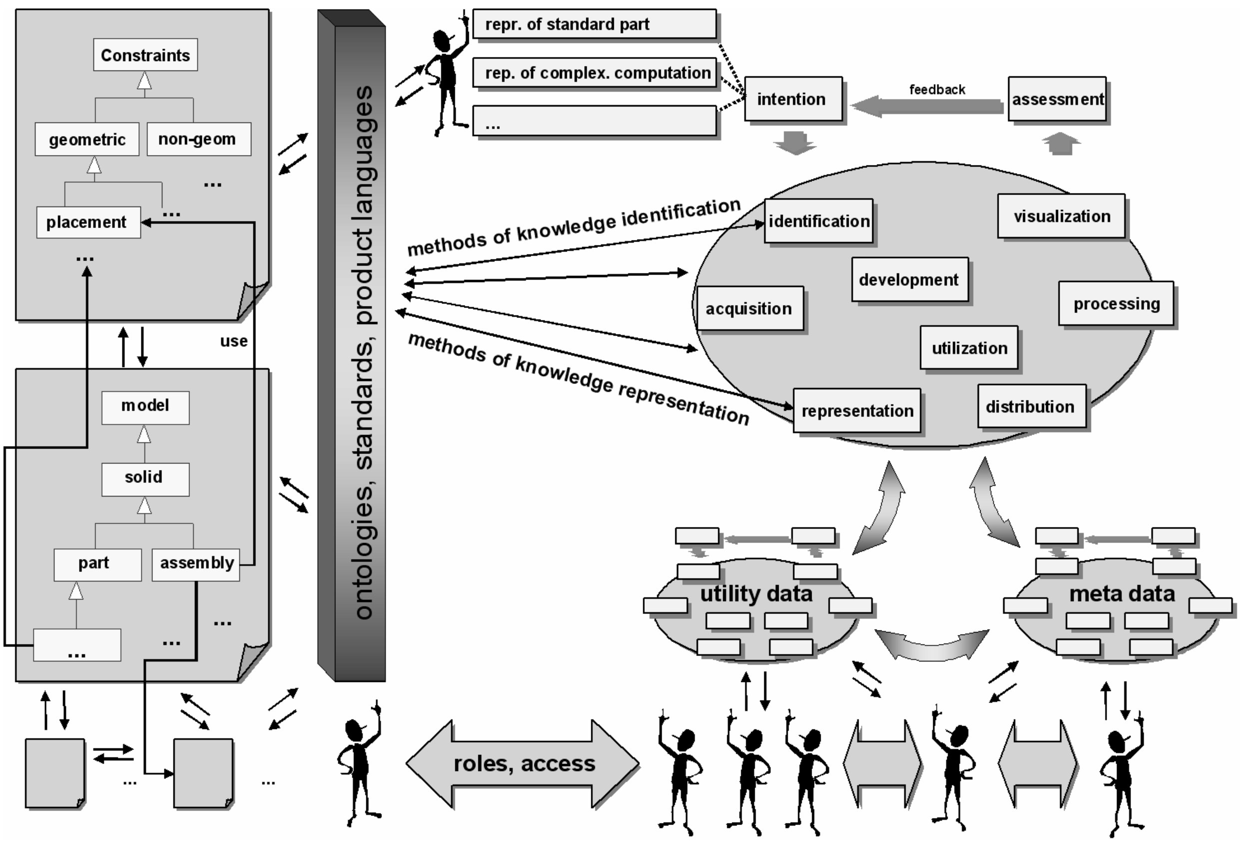

Figure 3 - View of Integrated Processes and Representations for Knowledge-Based 3D-CAD modeling.

In the depicted architecture the building blocks serve as a fundament for the development of knowledge-driven methods. As specified in Figure 3 knowledge goals can differ enormously. For example the goal can be the modeling of a generic family of standard parts with an embedded production logic due to standards. Another goal could be the integration of complex computation methods into the CAD model requiring a strong coupling between geometrical and computational parameters. The varying goals during the knowledge process can only be satisfied by a selection from an appropriate set of methods derived from the building blocks. Appropriate methods for supporting the knowledge processes *identification*, *acquisition*, *development*, *distribution*, *processing*, *representation*, *utilization*, and *visualization* must be explored and provided.

An ontology represents the framework for the knowledge-based structure of the CAD components and integrates required standards and product languages. The objects of different hierarchies and taxonomies of partial modeling aspects must be cross-linked by means of a semantic net for representing various contexts. Depending on individual knowledge processes different partial methods must be employed, e.g. when creating a knowledge-based component from scratch (acquisition, representation), or propagating a standard component for common use in the enterprise (distribution). In Figure 3 three different hierarchical levels of representation and identification structures are shown - the level of the ontology, the meta data and the utility data. Different users possess different roles and access rights. Particularly, the utility data as well as the meta data are subjects of a very dynamic development, and most users work directly on the level of the utility data of the 3D-CAD models. Partially automated or supported by a smaller user group specialized on data retrieval the accompanying processes of the meta data production and administration are executed.

The ontology as well as product languages represent the highest level of the depicted architecture providing a comprehensive framework. Change requirements affecting the ontology and their partial models will change the framework for the processes of the utility data and meta data and must be handled very deliberately.

CONCLUSIONS

Knowledge intensive methods gain increasing importance in the processes of product development. Parametric and feature-based 3D-CAD systems strongly support these requirements providing efficient technologies and product development tools, which support the developer in different phases of knowledge-intensive processes. Despite these demands a general methodology for modeling knowledge-based 3D-CAD-models and components does not yet exist. Knowledge-based methods in the field of 3D-CAD modeling must be explored to support the development and administration as well as the configuration of embedded knowledge. Advancement affecting this research field will help to handle the increasing complexity as well as to establish a corporation-wide basis of design knowledge.

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THE APPLICATION OF WEB-BASED TECHNOLOGIES IN PRODUCT DATA MANAGEMENT AND MANUFACTURING SYSTEMS INTEROPERABILITY AND DATA EXCHANGE

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KEYWORDS

XML, XMI/Stream, UML, PDM, Manufacturing Systems.

ABSTRACT

As the use of web-centric technology matures within the current market, one of the most widely used standardized data exchange formats is XML (Extensible Markup Language). This is due to the fact that XML-wrapped data can be used and understood by any application that is XML-enabled. This is one of the main factors this paper aims to exploit in order to tackle the problem of improving manufacturing product development in a distributed and collaborative environment within the World-Wide-Web. The objective of this paper is to investigate how XML and the proposed standard XMI (XML Metadata Interchange) can be used as the mediation for associating a commercially available Product Data Management (PDM) system and a manufacturing system, which consists of manufacturing and design domains. In particular, the focus of this paper is to emphasise the way in which systems interoperate and deliver data solutions to enterprise information challenges.

INTRODUCTION

Nowadays, the majority of engineering and manufacturing companies have most likely invested in Computer-Aided Design (CAD), Computer-Aided Engineering analysis (CAE), and Computer Aided Manufacturing (CAM) software tools to aid the product development activities. In general, the purpose of procured tools is to enhance the tasks within the respective disciplines of design, analysis, and manufacturing. Industry has benefited from improved quality, lower cycle times, and reduced costs in each discipline. However, little progress has been made to enable information to be effectively managed or communicated from discipline to discipline, and this is a requirement to realize the expected cost, schedule, and quality benefits.

One of the problems is the lack of use of modern technologies in early design and manufacturing phases and also the effective information distribution to support product development activities. Examples of these activities include manufacturing process planning, workflow analysis, knowledge management, product design and process modelling. It has been claimed that conceptual design has an impact of over 70% of the life-cycle cost of a product and, 70% of the time being wasted on searching for information during product development stages (Welsh et al. 2000), (Ni and Lu. 2002). Additionally, manufacturing processes display ever growing complex and dynamic behaviours due to increasing product complexity and distributed and collaborative engineering demands. It is therefore, the issues on the application of the web-based technology of XML and XMI that must be addressed in order to ease the obstacles on system interoperability and data exchange. A conceptual architecture is introduced as a means of bridging the gap between the application of PDM and the Manufacturing and Design Domains for the benefit of collaborative work teams. Such technologies will enable work teams to interface and develop, review, analyse and reuse design and manufacturing knowledge and information/data modelling within a manufacturing enterprise

USES OF WEB-BASED TECHNOLOGIES AND DISPARATE TOOLS

The research described herein is presented as part of a collaborative project between the University of Durham, Cranfield University and industrial partners. The software tools used to explore the feasibility of operational improvement are the utilisation of web-centric supporting technologies (such as XML and XMI), the Unified Modelling Language (UML), Java Programming Language, the CAPABLE System and a state-of-the-art PDM system. The CAPABLE system is based upon the CAPABLE Aggregate Process Planning System developed by the Design and Manufacturing Research Group, Durham University. The PDM software is of the proprietary system Windchill.

Application of XML

XML is the universal format for structured documents and data on the World-Wide-Web. It is a Meta model for data exchange supported by major industry rivals including IBM, Microsoft, Oracle and Sun. It is an open standard, platform independent, license free, vendor neutral and is strongly supported throughout the Internet. XML also allows the developer to freely describe structured and unstructured data and their relationships (Widergreen et al. 1999). There are several other benefits and features such as acting as a mediator for accessing many forms of data. Thus, it can be used to mediate structured and unstructured data on the Internet due to its flexibility to support integration between disparate data sources (Lowery. 2001).

XML allows automatic enforcing of semantic constraints (Duboz. 2002). Furthermore, XML is simple to implement and very powerful at describing entities. The XML specification describes XML *documents*; a class of data objects stored in computers, and partially describes the behaviour of XML processor programs used to read such documents as well as provides access to their content and structure. XML documents are composed of *entities*, which are storage units containing text and/or binary data (Connolly 1998). Text is composed of character streams that form both the document character data and the document markup. *Markup* describes the document's storage layout and logical structure. A well-formed XML document is unambiguous, so that a browser or editor can read the tags and creates a tree of the hierarchical structure without having to read its Document Type Definition (DTD) (W3C. 2002).

There are many applications that use XML in the research community, for example, the database interoperability (Bouneffa. 2001), the integration of applications (Xu and Degoulet. 2001) and (Villa. 2001), the use of XML for Integrating Modeling Architecture (IMA) framework through the use of Document Type Definition (DTD). XML is becoming widely used for representing both the process and the content information when deploying models. Process information includes the messaging infrastructure and workflow control that guides the process execution (Carlson D. 2001). While XML is a good way to share data, for this project, something more is needed to share the object built in the Manufacturing System, which is defined in UML. Hence, a new standard XMI (XML Metadata Interchange format) from the Object Management Group (OMG. 2002) is used for sharing objects using XML.

An Introduction to XMI

The intention of XMI (XML Metadata Interchange) is to propose a way to standardize Extensible Markup Language (XML) for users to exchange information about Metadata based on the following points:

- Information about what a set of data consists of
- How it is organized, and
- How any set of metadata is described so that users across many industries and operating environments can see the data in the same way.

Furthermore, XMI is intended to help users and developers using Unified Modelling Language (UML) with different languages and development tools and the semantically rich Meta Object Facility (MOF) to exchange data models and sharing complex information (OMG. 2002), (Dirckze. 2000). XML bridges part of that gap by providing the building blocks for "serializing" UML data textually. However, XMI will be the driving force for a more powerful solution by capturing and expressing the relationships defined by UML (Laird. 2001).

One application by Anagnostaki et al. 2000, describes an effort to create a common document-oriented architecture for the interchange of medical data in health care telemedicine applications. This particular research utilized XMI to provide the meta-model, which specified an open information interchange for object-oriented models and data using XML. The XMI specification in this case integrates XML with UML and MOF specifications by providing a standard way to convert objects into XML. The author’s inspiration to apply the relevant technologies into engineering applications is based on this effort.

XMI Eases the Problem of Systems Interoperability

In reality the applications of the different tools used in this research makes it very difficult to achieve the objective of interoperability due to the fact that the software tools often cannot easily interchange the information used with each other. One of the obstacles is due to the difficulty of understanding the semantic used in individual applications. However, according to (OMG. 2002), the application of XMI can ease this problem by:

- Providing a flexible and easily parsed information interchange format. In principle, a tool needs only to be able to save and load the data it uses in XMI format in order to interoperate with other XMI capable tools. There is no need to implement a separate export and import utility for every combination of tools that exchange data.

- The makeup of an XMI stream is important too. XMI is intended to be a "stream" format. That is, it can either be stored in a traditional file system or streamed across the Internet from a database or repository. As illustrated in Figure 1, it contains the definitions of the information being transferred as well as the information itself. Including the semantics of the information in the stream enables a tool reading the stream to better interpret the information content.

- A second advantage of including the definitions in the stream is that the scope of information that can be transferred is not fixed; it can be extended with new definitions as more tools are integrated to exchange information.

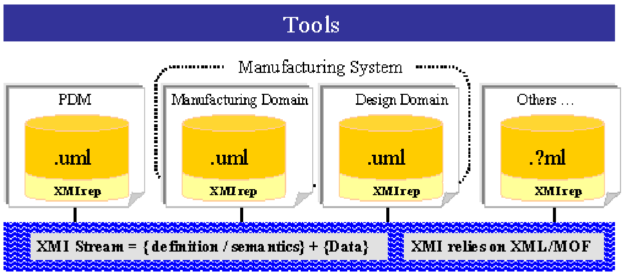

Figure 1: XMI Stream in PDM and Manufacturing Systems Interoperability

The Manufacturing System

The manufacturing system consists of a Manufacturing Domain and a Design Domain. The Design Domain is under development at Cranfield University. As for the Manufacturing Domain is being developed at the University of Durham and consists of the CAPABLE Aggregate Process Planning system and commercial software tools which will be briefly introduced at a later section.

The CAPABLE system is used to generate preliminary process plans (Bramall et al. 2001). The infrastructure of the CAPABLE system is shown in Figure 2, which illustrates the main components in a UML representation. CAPABLEObject is the highest level of the system, which supports all major data models such as resource, process, process planning, product models and knowledge based system. In addition, CAPABLEObject uses Serialisation to identify the type of object that is being dealt with and holds the path of the directory where objects of this type should be stored in the databases. However, in order to use it more effectively the output of the results (or the objects) must be XML-enabled so that it can be used to integrate with disparate systems and Internet technologies using XMI Streaming in order to distribute information in a collaborative environment.

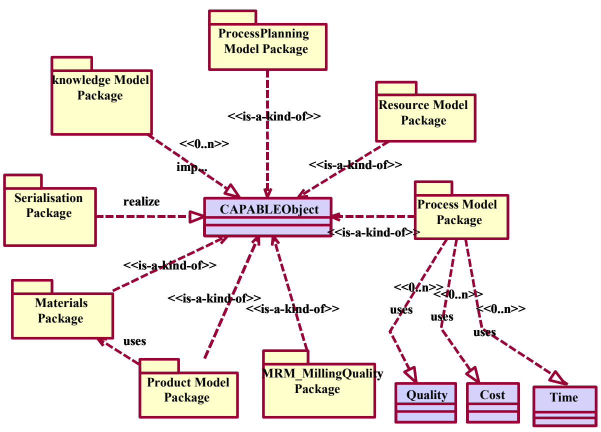

Figure 2: CAPABLE System in UML Representation

Windchill PDM System

PTC's Windchill PDM system provides a Web-based environment for the creation, management, and evolution of product and process information. Its core capabilities enable users to collaboratively develop and share data in a controlled environment. The system itself encompasses various functionalities, the functions which are specifically applicable for this project are introduced as follows (PTC Windchill, 2001):

- *LifeCycles*

LifeCycles are interactive objects that require check-out and check-in for modifications, hence, enabling the user to create, update, view and changes as well as to define the state of each task.

- *Workflows*

Workflow processes determine what happens within each task and also facilitates delegation of tasks to specific members within the team as well as adding their own "mark-ups".

- *Version Controls*

This offers Version control for the design and the ability to see the history or "evolution" of a design through all its iterations.

- *Visualization*

This allows different types of product-related information to be viewed throughout the enterprise as well as the ability to interrogate and 'markup' CAD formatted files and on-line conceptual reviews.

- *Windchill Cabinet*

The Windchill Cabinet helps by storing information in a cabinet and folder hierarchy i.e. displaying information from general to specific topics and providing methods of locating information appropriately.

- *Customisation factor*

This includes object-oriented software development tools such as Java and Unified Modelling Language (UML).

THE INTEGRATION 'WRAPPER'

This is the proposed architecture, as illustrated in Figure 3, which consists of different components used in this research. The deployment of the Windchill PDM provides an 'integration wrapper' for the entire integrated system. It supports an online distributed and collaborative environment with specific functions including product data/document management, version control, workflows and lifecycle management. The term 'wrapper' means wrap different data into a common format i.e. XML. An Oracle database server is employed to handle requests, knowledge and model information as well as deploy Windchill PDM functionalities through the use of Java Database Connectivity (JDBC).

The main interfacing mechanism of the Windchill PDM is managed by running a Windchill Applet with a servlet to support a Manufacturing System so that it can

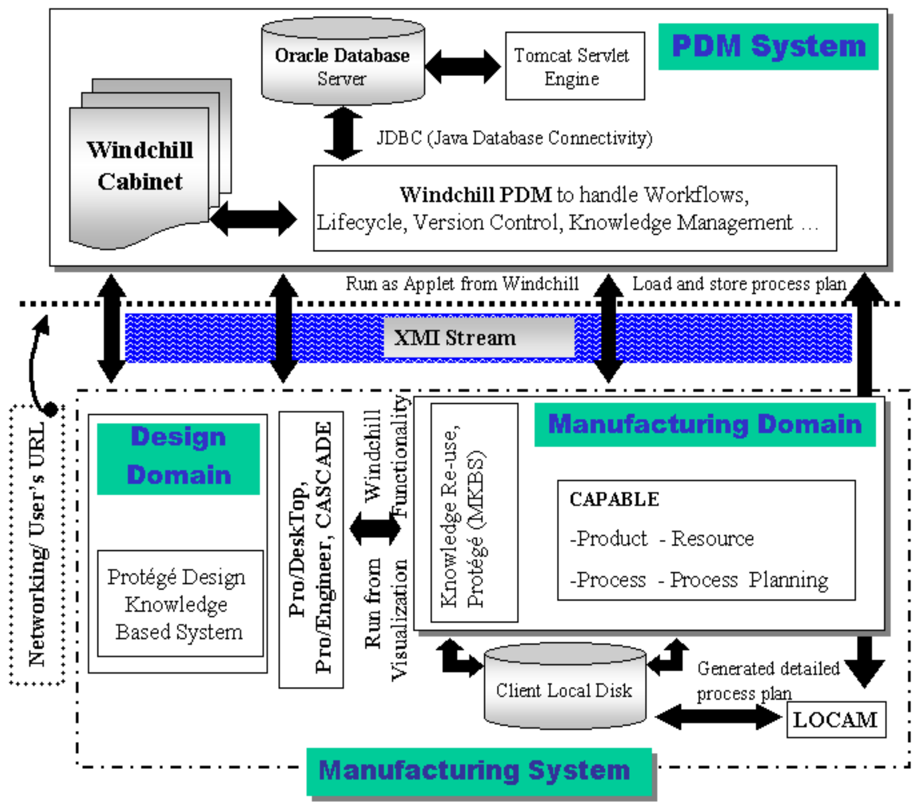

Figure 3: The PDM Integration Wrapper

communicate with CAPABLE Process Planning. Tomcat [1] deploys as a servlet container in conjunction with a Web server, such as Apache [2] to support Java based and XML implementations. XMI is being deployed as the interfacing media between PDM and the Manufacturing System for data interchange i.e. the XMI Stream. This recommendation enables interchanging portions of XML documents while retaining the ability to parse them correctly and, as far as practically concerned, it can be formatted, edited, and processed in useful ways. More importantly, as described previously, the deployment of XMI enables interchange with object-oriented models such as the CAPABLE Process Planning Engine, PDM Workflow analysis and data using XML for capturing and expressing the *relationships* that UML expresses.

There are two other pieces of third party software that will be deployed within the research including CAD systems (Pro/Engineer, Pro/Desktop and Open Cascade Solid Modeller) as well as LOCAM (a manufacturing planning system). All CAD systems are being used as solid modellers to display the image of the product through the Windchill Visualization functionality. LOCAM is used to generate process plans at the final stages of product design and development. In addition, it has the ability to take STEP AP224 files generated by the Product Model and outputs XML formatted process plans through the Windchill PDM.

A TYPICAL SCENARIO IN A TIME-BASED DEPENDENCY

Figure 4 depicts the interactions of product design and process planning activities supported by a PDM system in a time-based dependency scenario. The principle of the illustration shows a customer product requirement as it reaches the conceptual design stage at the Design Domain. As a result, a new product definition is being generated and delivered to the Windchill PDM Cabinet for updating the product requirements. By associating the requirements with the new design knowledge, a redesign may be requested at this stage. Subsequently, an updated product definition will be generated in the Design Domain, at the Enterprise Resource Update level within the PDM. The newer versions of the product definition and resource requirements are again updated and transferred to the Manufacturing Domain, i.e. this results in a 'mirror image' of information to be sent to the Manufacturing Domain through the XMI Stream.

It is at this stage that the CAPABLE Aggregate Planning Engine is used to generate a process plan. The Process Planning Engine (PPE) within the CAPABLE System captures the information of this output. The new process plan is then being delivered through the XMI Stream to the PDM system for Plan/Review, and subsequently is being readied for release. The application of XMI and XML in this scenario improves the quality of both design and

[1] **Tomcat** is the official Reference Implementation for the Java Servlet and JavaServer Pages technologies.

[2] **Apache** is a public-domain open source Web server.

More information can be found on: *http://jakarta.apache.org/*

production decisions. In addition, the efficient management of product and process knowledge from the early stages of design should result in the reduction of product development lead times and an increase in production efficiency.

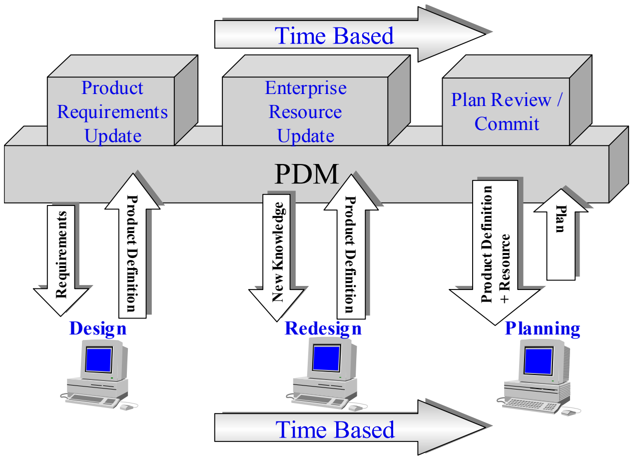

Figure 4: A Typical Scenario in a time-based dependency

CONCLUSIONS AND FUTURE PRESPECTIVE

This paper has outlined the links between PDM and Manufacturing System by utilizing advanced web-based technologies. The significance of using XML and XMI Stream to support systems interoperability and data exchange has also been highlighted. It is necessary to identify the data being used as input and output in every model in order to make an XML representation of them. This representation permits the comparison of data at the semantic level for model connection in a very simple way. Subsequently, an example of mapping UML to XML by using the OMG XMI standard will be implemented as the project progresses. This is particularly important in that it will prove and demonstrate the ability of handling distributed and collaborative product development information exchange by using the proposed tools.

ACKNOWLEDGEMENTS

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INTERDISCIPLINARY MODELING FOR LOGISTICS DESIGN

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Design Methodology, Systems Thinking, Multi-disciplined Team-Working, Logistics

ABSTRACT

In this paper a conceptual model is defined that can be used for the innovative design of logistic systems. The model is constructed by using the systems approach in a formal and fundamental way. It turns out that the model complies with the 'hard systems approach', positioned in a trajectory according the 'soft systems approach'. By this the model is an interdisciplinary tool that serves as a common frame of reference and decision making platform for the different disciplines involved. It enables unambiguous communication. Conceptual modeling of each separate discipline including their different monodisicplinary goals, is reflected by this single model.
The model also serves as a facility to save design conditions and decisions for future innovations. The model forms the basis to build "shared memory".

INTRODUCTION

One of the recurring problems in any large scale design project is the relation between the multidisciplinary design and the mainly monodisciplinary participants. For example the complaints about information systems that do not live up to the expectations keep pace with the growth of automation. Machines (whether automated or not) often don't deliver the performance as was promised during the design phase. The performance of a system in reality differs significantly from the simulation results during the design project. Such a mismatch between the intentions of the decision makers and the perceptions of the simulation experts can only be explained by assuming a communication problem

Nowadays all disciplines use some kind of a 'system' concept to deal with complex problems. For example organization science considers organizations as combined *social, technical and economical systems*; Logistics emphasizes an integrated approach to deal with an *operational system*; Information technology developed several approaches for the design of *information systems*. They all construct conceptual models to formulate problems and find solutions. However there are significant differences between conceptual modeling of each discipline. The conceptual information model of a system is quite different compared to a conceptual logistic model of the same system. Apparently conceptual modeling is part of the discipline itself.

These differences in system perceptions can be avoided by considering conceptual modeling a generic interdisciplinary activity rather than a multidisciplinary activity. The term "interdisciplinary" denotes cooperation with a common goal (and by this a common perception of the system). This goal is and stays the starting point for all activities during the design project and project management serves this goal. An interdisciplinary approach generates discipline specific concepts starting from a single system concept, a multidisciplinary approach generates a system concept starting from discipline specific concepts.

During the last half of the 20th century the systems approach emerged as an interdisciplinary approach to study "systems". It opens the way to a generic conceptual way of modeling logistic systems, thereby avoiding the jargon and specifics of separate disciplines. In this article the systems concept will be elaborated the other way around. Starting with a general concept, a conceptual model for logistic systems will be derived until the level, where single disciplines have to become specific.

A SYSTEMS APPROACH FOR LOGISTIC SYSTEMS

The systems approach evolved as a generic interdisciplinary approach during the last decades to investigate and describe "systems", not only by studying the elements but by emphasizing the relations between the elements. The systems approach supports decision making by formulating problems 'in terms of systems'. A system is defined as a: "set of elements that can be distinguished from the entire reality, dependent on the objective of the researcher. These elements are mutually related and (eventually) related with other elements in the entire reality" [in 't Veld, 2002].

In literature systems approaches are classified in different ways (see a/o Whitmore [1998], [Wigal, 2001], [Daellenbach, 2002] and [Williams, 2002]). The classifications range from dividing systems approaches according the researcher's subjective or objective system perception to dividing systems approaches according the system's complexity level. All these classifications show that the theoretical development of the systems approach mainly took place in what is called the 'General Systems Theory' (GST) and in Cybernetics.

Applications of the systems approach are divided into three categories: 'hard' systems approach, 'soft' systems approach and 'critical' systems approach ([Flood & Jackson, 1992]).

Hard systems approaches consider a system logically based and capable of unbiased description. They are characterized by the modeling of purposive systems in order to optimize a performance or required objective. The basic assumption, whether or not implicitly, is that the problem is stated right and unambiguous. Typically hard systems approaches are Operations research, systems analysis, software development, database design and systems engineering.

The soft systems approaches consider a system a subjective perception: dependent on the observer the same system is presented in different ways. The observer himself may also be part of the system and may have his own objectives besides the system's objective. Soft systems approaches therefore are mainly aimed at the understanding and the formulation of these so-called ill-defined problems and address the "what" question instead of the "how" question.

The critical systems approach emerged in the 1980's and "sits somewhat uncomfortably in the overlap between sociology, organization theory, systems thinking and by extension management science" [Daellenbach, 2002]. This approach looks at the methods developed by hard and soft systems approaches from the perspective of existing social structures and aims to define the conditions for their applicability. The contribution will result in a better definition of preconditions for problem statements and the period of validity of solutions.

The hard systems approach is in fact part of the soft systems approach. Once the stakeholders reach agreement on the problem statement (a consensus on subjective perceptions), methods of the hard systems approach can be used to solve the problem. Recapitulated briefly, the soft systems approach aims to state the right problem and the hard systems approach aims to solve the problem right.

The design process of a logistic system requires a soft systems approach to deal with different perceptions. The design process starts with a so-called ill-defined problem. The first steps of the process must lead to an agreement on the objectives and conditions. By then it is called a well-defined problem. Using a hard systems approach only, would pass over the proper objective definition and will lead to:

- *accepting system boundaries as given*. For example looking at the effect of economic lot sizes, if one does not take the environment of the total supply chain into account, the savings may be smaller than the extra costs [Christopher, 1998].
- *Considering elements as being naturally defined*. If one regards an organization as a system, often the existing departments are regarded as the elements. But the departments are the result of design processes in the past. By doing so, the assumptions and starting points of these earlier design processes are implicitly imported into the new design process with its new objectives and in a changed environment.

Now the problem is to find a system concept in a hard systems approach, which can be generally applied within the design process of a logistic system, taking the soft systems approach into account, and which can form a more or less lasting framework for specification and review of logistic systems.

Such a system concept will be called a *conceptual system model*. Only a small number of such conceptual models has been defined. Checkland [1981] positions the use of these models in his Soft Systems Methodology (SSM), the most widely used and accepted soft systems approach. SSM is shown in the figure 1 below.

The methodology consists of 7 steps. The first step is the recognition of an unstructured problem situation. Initially 'rich pictures' are made to describe and discuss the problem. Rich pictures are combinations of text and pictures expressing the situation in terms of the researcher and problem owner. Rich pictures use draughts of elements, structures, processes and environment. In step 3 the rich pictures are analyzed and 'root definitions' are defined by abstraction. Relevant systems are distinguished in which activities are formulated. A number of activities is declared absolutely necessary for the system and these are the root definitions. A correct root definition satisfies the so-called CATWOE principle. It states explicitly the Customers, the Actors of the activity, the Transformation performed by the activity, the World view (Weltanschauung) of the activity, the Owners and the accepted preconditions from the Environment. The root definitions are used to construct conceptual models in step 4. In the next step these models are compared with reality as described by the rich pictures. The comparison leads to the identification of feasible and realizable changes. These changes determine the actions required to improve or solve the problem situation.

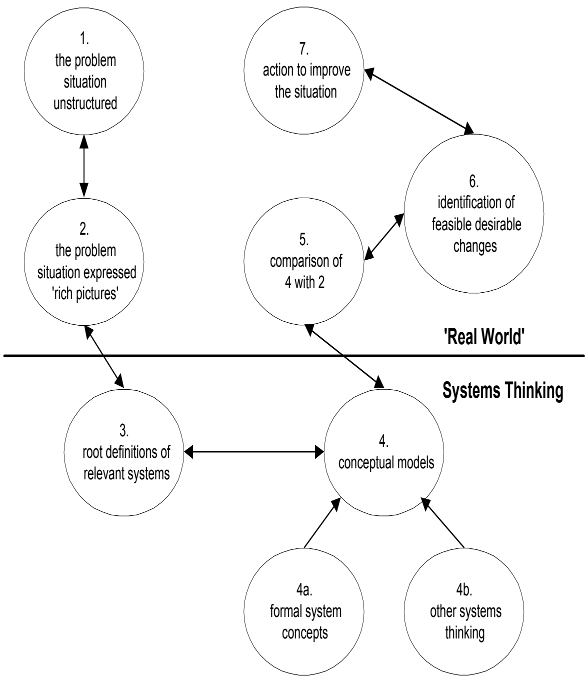

Figure 1. The Soft Systems Approach

One of the main shortcomings of SSM is that the objectives of the activities are missing in the CATWOE principle; the very same objective, which was found to be the expression of subjective 'perception'. To apply the hard systems approach in the conceptual models the objectives must be preserved by defining the elements as 'functions' rather than as 'activities' or 'tasks'. This leaves only a few models to be considered for constructing a conceptual model of a logistic system:

- the Formal System Model of Macauley (1996)
- the Viable System Model of Stafford Beer
- the Steady State Model of in 't Veld
- the Control Paradigm model of De Leeuw.

The Formal System Model (FSM) of Macauley (figure 2) represents a Human Activity System and to be a "formal" system there must be:

- some mission
- some measure of performance
- a decision making process
- mutual interaction between the elements
- a wider system or environment

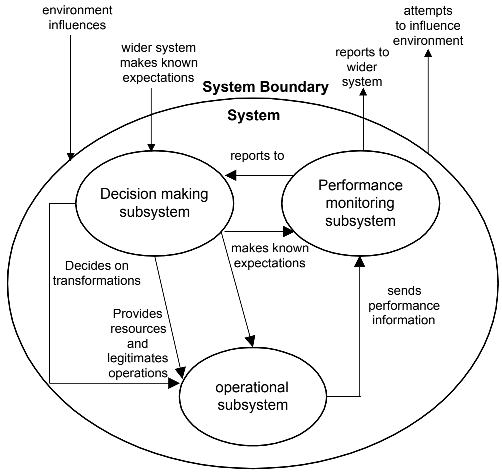

Figure 2. Formal System Model [Macauley, 1996]

- decision making resources
- stability or an ability to recover.

The Viable System Model (VSM) of Stafford Beer [1985] is shown in figure 3 and consists of functions to be present in any viable system.

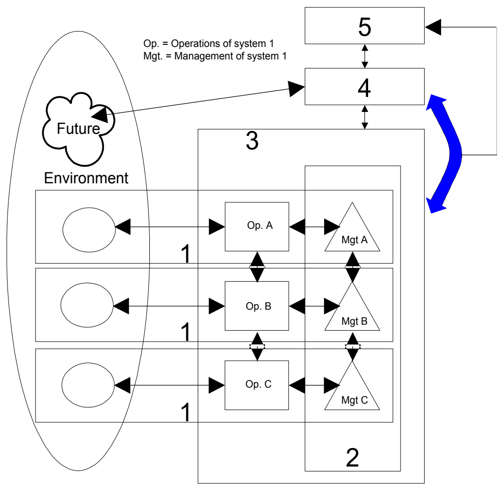

Figure 3. Viable System Model

Viable systems all have the same pattern of functions. This pattern should not be considered an organization structure but a function structure. Beer distinguishes five functional groups. He calls them systems, because each functional group is a viable system on its own. The systems are:

1. System 1: Implementation consisting of execution, operational management and environment
2. System 2: Coordination of operational systems
3. System 3: Internal control. This system preserves the purpose of the organization, "here-and-now".

4. System 4: Intelligence deals with the future environment: “there- and-then”. It makes propositions to adapt the purpose.
5. System 5: Strategy and Policy. This system is responsible for the direction of the whole system.

In ‘t Veld [2002] defines two separate models:
The steady state model for repetitive processes and the innovation model for innovation process. The steady state model is (simplified) shown in figure 4.

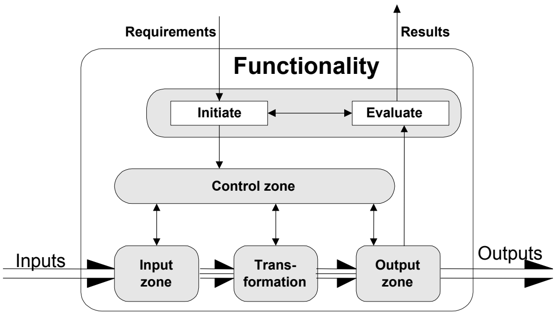

Fig. 4. The steady state model [Veeke,Ottjes, 2000]

The steady state model consists of a structured set of functions, expressing which contribution is repeatedly delivered to the environment in a controlled way but not how this contribution is achieved in a concrete way. The set of functions is itself a function again, which makes the model recursive. The model contains:

1. A transformation function, by which input is transformed into a desired output.
2. An input zone to identify, qualify and quantify the input flow.
3. The output zone analogously qualifies, quantifies and identifies the outputs to be delivered to the environment.
4. The control zone corrects disturbances in input, throughput and output by means of feedback, feed forward and repair of deficiencies. The actions of the control zone are directed towards these standard values.
5. The initiation - evaluation zone delivers the standard values for the control zone with respect to the facets quality, quantity and lead time; it is the translation of the requirements entering the function from a higher echelon, into manageable rules and standard values for these facets.

In ’t Veld distinguishes subsystems and aspect systems: a subsystem includes a subset of the elements, but all relations, an aspect system includes all elements, but only a subset of the relations. An aspect system covers a particular flow of elements. The steady state model is a model for one single aspect where the elements are functions. Examples of an aspect system are the product flow, the job flow, the resource flow and the data flow.Several aspect models are required to completely model a system.

The control paradigm (figure 5) of de Leeuw [1982] consists of a controlled system and a controller. Both the controlled system and the controller interact with the environment. De Leeuw describes a number of conditions for the control to be effective:

1. There must be an objective.
2. The controller must have a model of the controlled system to predict the effect of control actions. During the process of control this model can be refined.
3. The controller needs information about the environment and the state of the controlled system.
4. The controller needs sufficient possibilities to control.
5. The controller must have sufficient capacity for information processing at its disposal.

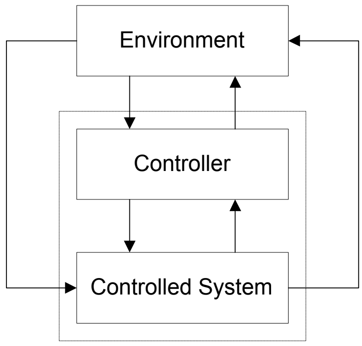

Fig. 5. The control paradigm [de Leeuw, 1982]

Control actions can be executed both directly (internal control) and indirectly through the environment (external control).
For both types of control de Leeuw distinguishes:

1. Routine control: actions within the scope of the current model of the controlled system.
2. Adaptive control: actions, which change the structure of the controlled system.

Strategic control: actions, which result in a change of the objective of the controller.

All conceptual models are related to open purposive systems and can therefore be applied to logistic systems. VSM and the control paradigm distinguish explicitly:

- functions to maintain a stated objective (objective keeping)
- functions to adapt to a new objective (objective adaptation).

So therefore a logic distinction will be made between:
- a logistic system being an open system with objective keeping facilities
- a design process being an open system that creates a logistic system on behalf of a desired objective adaptation.

The hard systems approach concentrates on the logistic system with a stated objective, a soft systems approach emphaiszes the design process where concurrent (or even conflicting) objectives arise as a consequence of different perceptions.

Common characteristics of the conceptual models
- they are empty with respect to resources and tools
- All elements are systems again
- Every system fulfills a function in its environment by satisfying a need
- All models clearly distinguish control (decision making) functions and operational functions. It's a "paradigm" indeed.

Only the steady state model defines the border between system and environment to be a boundary zone containing functions to fit the flow elements for transformation or delivery by the system. Furthermore the steady state model represents the required functionality for one single aspect of the system. The design of a multidisciplinary product requires several steady state models, one for each aspect. Each aspect will be reflected by a single flow of elements. Finally, the steady state model is the only model where "something is produced". It not only shows the function structure but it also includes the process by which input elements are transformed into output elements. This gives a strong connection to the usual way of process thinking in logistics.

As a conclusion a conceptual model of an objective keeping system (logistic system) has to meet the following conditions:
- The system fulfills a function to satisfy a need of the environment and is by this purposive.
- The elements of a system are systems again
- Each system consists of a control subsystem and an operational subsystem
- The model distinguishes aspects, being subsets of the relations. More than one aspect can be modeled by including more product flows.

The system will be the same as the function it fulfills from now on. The elements will therefore be functions also. A function description must be determined by means of abstraction from the physical reality. It is not important "how" something is done, but "what" and "why". This offers two adavantages:
- it stimulates to be creative and to radically change the way of realization in a structured way.
- The basic assumptions and choices made during the design process stay clear and accessible for future design projects. This construction of "memory" prevents the ïnvention of the wheel"once again and excludes the implicit assumption of superseded conditions.

THE "PROPER" MODEL OF A LOGISTIC SYSTEMS

The logistic system is a subsystem of the organization as a whole; it contains a subset of the elements, but includes all the relations. Approaching logistics from the viewpoint of the primary function three aspects will be included in the conceptual model. First of all the "product" as a flow of elements to be transformed. To make a product "resources" (people and means) are required. To be able to use them, they must enter the system and they will leave the system as used resources. The third aspect is the flow of orders; without customer orders no products will flow and no resources are needed. Orders are transformed into handled orders.

In the conceptual model the processes are shown in a structure including control functions. Control in this sense consists of initiation, evaluation, feeed back, feed forward and repair f deficiencies.The whole system function delivers some kind of performance and therefore the model is called PROcess PERformance model or "PROPER"-model.

At the highest level of aggregation the PROPER model is represented by the figure below.

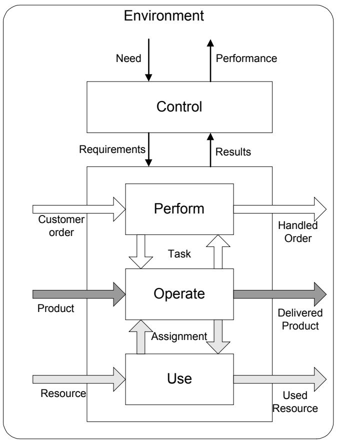

Figure 6. The PROPER model of a logistic system

Performance will be expressed in terms of productivity, effectiveness and efficiency.

These criteria are used during real operation of the system, but also during the design of a system to evaluate design alternatives. The properties are used for three different purposes [in 't Veld, 2002]:

1. strategic: to select between alternative resources. In this case the criteria are expressed in terms of "results in view" and "expected efforts".
2. tactical: to determine the best way to use selected resources. This best way is reflected by "standard results" and "standard efforts".
3. operational: to determine the operational performance. Now the "real results" and "real efforts are clear and compared to the standard values defined at the tactical level.

THE PROPER MODEL AND LOGISTIC PRACTICE

During the last decade material management and physical distribution are integrated in "supply chain management". In terms of the systems approach integration means extending the systems boundary and considering the whole as a system to be controlled again.
At the end of the nineties the Supply Chain Council (SCC) developed a so-called reference model for this integrated approach of logistics: the Supply Chain Operations Reference Model [SCC, 2002]. This model supports the evaluation and improvement of the performance of the supply chain, organization wide. It emerged from the combination of Business Process Reengineering (BPR), benchmarking and process measurement. SCOR contains:

- All customer interactions starting from order entry up to paid invoice (see order flow in figure 6)
- All material transactions (see product flow in figure 6)
- All market interactions, starting with the determination of aggregated need up to the execution of each separate order (see control in figure 6).

The model describes four levels of supply-chain management:

- Level 1 contains five elementary management processes: Plan, Source, Make, Deliver en Return; The objectives of the supply-chain are formulated at this level.
- At level 2 the five processes are described more precisely by means of three process categories: 'Planning', 'Execution' and 'Enable'. The basic idea is that each of these three categories can be distinguished in each of the processes. The execution category of Source, Make and Deliver is further divided into 'Make-To-Stock', 'Make-To-Order' and 'Engineer-To-Order' types. In this way a complete scheme of 26 possible process categories is created. Any company is able to configure its existing and desired supply chain with this scheme.
- Level 3 shows, which information (and software) is needed to determine feasible objectives for the improved supply-chain.
- Finally level 4 addresses the implementation. Level 4 changes are unique, so specific elements are not defined; only guidelines and best-practices are described.

SCOR is a reference model: contrary to a conceptual model it classifies all logistics activities; it aims to improve rather than to innovate. All existing configurations can be modeled, currently non-existing solutions cannot as it turns out from the most recent addition of 'return'.

Plan, source, make, deliver and return are management processes and are part of a control function. To decide to which control function they belong, a short explanation of each is given below.
Plan: is demand and supply planning and management. It balances resources with requirements and establishes/communicates plans for the whole supply chain. It manages business rules and supply chain performance.
Source: takes care of the supply of stocked, make-to-order, and engineer-to-order products. It schedules deliveries, receives, verifies and transfers products, it manages inventories, capital assets, incoming products, supplier networks, import/export requirements, and supplier agreements.
Make: concerns the execution of make-to-stock, make-to-order, and engineer-to-order production. It schedules production activities, manages in-process products (WIP) , performance, equipment and facilities.
Deliver: covers order, warehouse, transportation, and installation management for stocked, make-to-order, and engineer-to-order products. It includes all order management steps from processing customer inquiries and quotes to routing shipments and selecting carriers. It also includes all warehouse management from receiving and picking products to load and ship products.
Return: is the return of raw materials (to supplier) and receipt of returns of finished goods (from customer), including defective products, and excess products.

Comparing these descriptions with the functions and aspects of the PROPER model of figure 6 shows that:

- There is no strict distinction between aspects in SCOR. Source, make and deliver in particular contain parts of each aspect; to put it differently, each aspect contains a source, a make and a deliver process.

- The control of the product flow is split up between make and deliver. Make takes care of stocks-in-process, while deliver emphasizes warehousing at receipt and shipping.
- Plan contains both the long-term planning and balancing and the daily coordination of the flows.
- Return represents a complete product flow. In terms of the PROPER model it is a subsystem within the product aspect.

Literature on logistics usually distinguish purchase logistics, production logistics and physical distribution. These areas can be mapped one-to-one to the Source, Make and Deliver functions of figure 7. It is remarkable to see that the field of logistics is divided into functional areas instead of flow oriented areas. Terms like order logistics, product logistics or resource logistics are not encountered in logistic concepts.

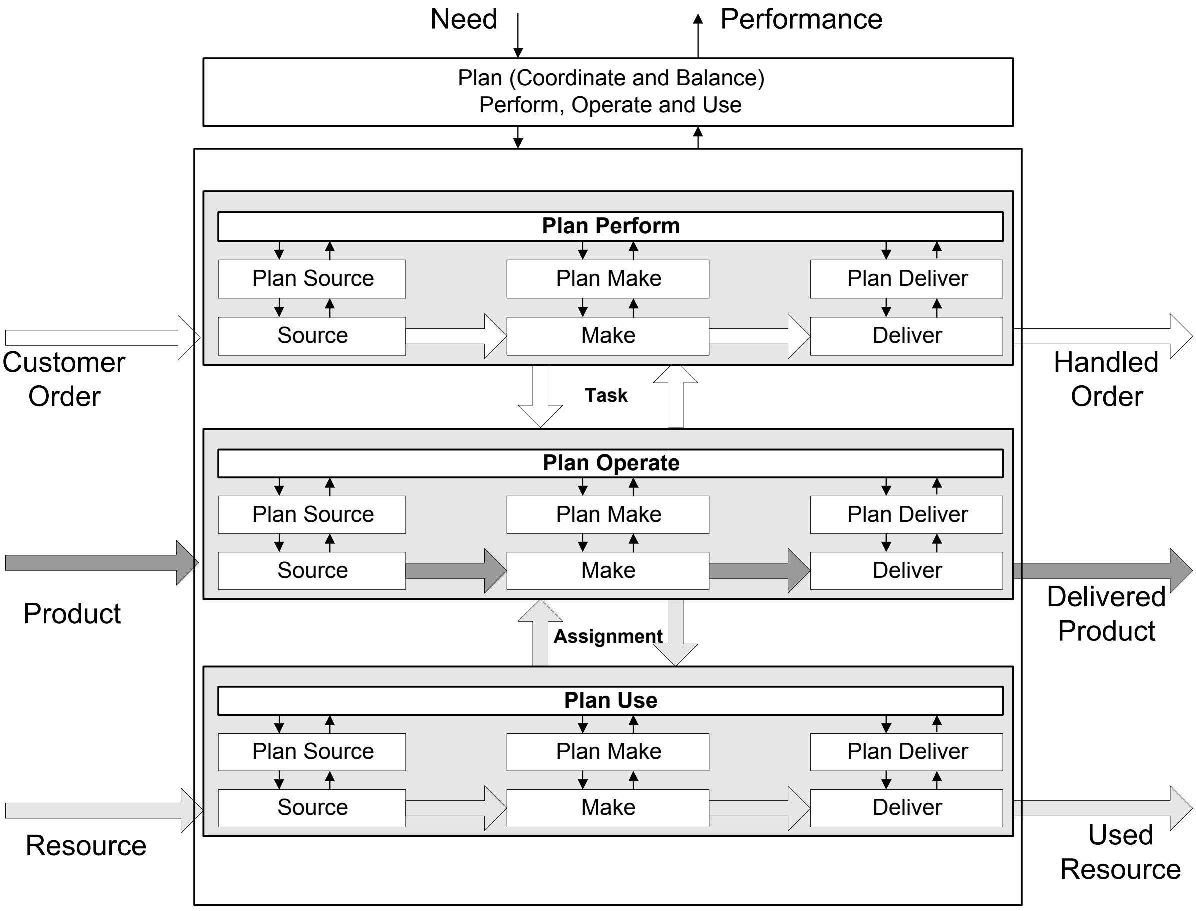

Figure 7. Common functions in the PROPER model

As argued before the distinction between aspects is important, because they reflect disciplinary backgrounds and perceptions. It must be clear whether decision-making concerns the order flow, the product flow or the resource flow, in order to enable correct objective settings. Each flow is controlled by its own control system coordinating the source, make and deliver control functions. Each flow oriented control system again must be coordinated with the other aspects by a control function at the next higher echelon.

Including the basic processes source, make and deliver finally leads to the PROPER model for each aspect of a logistic system as shown in figure 7.

CONCLUSIONS AND FUTURE RESEARCH

In this paper the conceptual interdisciplinary PROPER model has been defined that can be used by all disciplines involved for the design of a logistic system. The model is a common frame of reference to support communication and decision making by different monodisciplinary approaches. The model is also used to record conditions, decision and assumptions that lead to the final design.
The model is primarily used to better fit the expectations on the performance of a design with the performance in reality. Using the model will not automatically lead to better designs, although a correct expectation may lead to reconsider decisions in an early stage of the design project.

The model has first been used at the start of the large design project FAMAS.MV2 to study the future land extension for container handling in the Rotterdam port area (Veeke, Ottjes, 2002). At this moment it is being used as a starting point for a planned research project to construct a virtual industrial system at the Delft University of Technology, where several research groups will be involved e.g. organization, technology, logistics and information technology.
Meanwhile the model has been extended with a so-called 'process description language' to extend communication on the conceptual model to the time-dependent behavior of the system (see Ottjes, Veeke, 2002). In this way a connection is established to the field of simulation and is the validation of simulation modeling supported for situations where no real system exists yet. A correct connection requires a pure process interaction approach by the simulation platform. An example of such an approach is found in TOMAS (Tool for Object oriented Modeling And Simulation) that can be found at the web site www.tomasweb.com.

Finally the conclusion is drawn that the field of logistics is rather function oriented than flow oriented. Further research is required to investigate if a flow oriented approach is able to enhance the logistic achievements.

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PROCESS MANAGEMENT

CONCURRENT ENGINEERING FOR INTELLIGENT SIMULATION

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Dear God, Search and research our world, made by Your Right, and help us complete it. Orthodox Pantocrator

KEYWORDS

Simulation, Intelligence, Hierarchy Types.

ABSTRACT

Intelligence is complementary to faith = (intuition, inspiration, imagination) and it needs (conscience, adaptability, intention). Conscience simulation demands transcending the present limits of computability to what we call simulability, by an intensive effort on extensive research to integrate essential mathematical and physical knowledge guided by philosophical goals. Applying "Divide et Impera et Intellige" to hierarchy types reveals their comprehensive constructive importance based on structural approach, symbolic meaning, object-oriented representation. Formalizing hierarchical descriptions, using the formalism of categories, we create a theoretical kernel that can be used for self-organizing systems. A way to begin is hierarchical analog-digital simulation. Simulability is computability using the power of continuum. There are enough positive signs for this from analog electronics, control systems, mechatronics. Real progress towards this way of computation needs unrestricted mathematics, integrated physics and thinking by analogies.

Einstweilen bis den Bau der Welt Philosophie zusammenhält, erhält sich das Getriebe durch Hunger, Furcht und Liebe.
Friedrich Schiller

INTRODUCTION

Conscience is self-awareness of individual faith and intelligence, as well as of the relation to the local context (society) and to the global one (universe). It is called by the need for self-organization under self-control and demands more than discrete simulation, i.e., continuous simulation (Blum et al. 1998). Evolution is conditioned by the conscient construction of correspondingly intelligent agents to manage the lower stages, as industry enabled the mechanization of agriculture followed by the concentration on economics. Evolution implied a multiple "Divide et Impera et Intellige" for conscience, associated to generating the *components* lacking at start, of the mind containing only intuition an adaptability, then assisted by them:

- individual-social-universal conscience→*inspiration*
  (subjective-contextual-objective) ↓
- space-time (structure-behavior) → *imagination* ↓
- discrete-continuous (natural-real) → *intention*
- beauty-truth-good (art-science-technology)‾.

Evolution also needs teamwork and understanding other specialties; this calls for philosophy-oriented dialog. Concurrent engineering is an example, but is not enough.

Das schöne wahre Gute. Johann Wolfgang von Goethe

1. Mathematics discovers and studies fundamental types of structures: (algebra, topology, order), fundamenting (construction, orientation, understanding). These are rarely separately used, example of correct and complete integration to be followed by science and technology (Niculiu and Cotofana 2002).
2. Physics should integrate its fundamental forces theories, but also, as chapters, all others natural sciences and the social sciences, leading them to really apply mathematics. Social sciences study a universe, as complex and nondeterministic as the natural one, so mathematics is at least as important to them as for natural sciences. This way, science would also be a better inspiration source for mathematics (Traub 1999).
3. Engineering has to be closely related to mathematical approach and integration of parts, not only to mathematical techniques; as reality contains the abstract ideas, even if physics could explain everything discretely, the power of continuum can not be forgotten, i.e., analog engineering should not be neglected in modeling and simulation (Keutzer et al. 2000).

The convergence process of evolution demands struggle against time, with structure as ally. Conscience (Amoroso et al. 2000.) needs, more than discrete recurrence, continuous feedback. Social and individual conscience are mostly divergent nowadays, i.e., we only performed "Divide et Impera", neglecting "et Intellige". It's high time to correct this by concurrent engineering in every of the three worlds that we use for different perspectives of the reality.

Human = human (Humanity); human : Faith $\times$ Intelligence $\rightarrow$ Faith $\times$ Intelligence;
Humanity = (Set of humans, eternity / evolution-oriented Structure).
evolution : (Hunger, Fear, Love) $\times$ (Technology, Science, Art) $\rightarrow$ (Technology, Science, Art).
Mathematics $\subset$ Art = Human :: beauty-oriented activity (Science, Technology).
Physics = natural Science $\cup$ social Science = Human :: truth-oriented activity (Art, Technology).
Technology = Human :: good-oriented activity (Art, Science).
The history of the common measure could be synthesized along the following line:
... $\leftarrow$ Philosophy $\leftarrow$ ... $\leftarrow$ Culture $\leftarrow$ specific Knowledge $\leftarrow$ Economics $\leftarrow$ Force.
Simulation $\in$ Behavior $\times$ Structure $\Leftarrow$ Knowledge // "$\Leftarrow$" stands for "implies"
Knowledge $\Leftarrow$ Intelligence :: information() // "::" stands for "Class :: method"
Imagination $\Leftarrow$ | Intuition - Conscience | // "()" stands for "depending of"
Intention $\Leftarrow$ | Inspiration - Adaptability | // "| x -y |" stands for "difference between"
Conscience $\Leftarrow$ reflexiveAbstraction (Intention)
Adaptability $\Leftarrow$ simplifyingAbstraction (Imagination)

Figure 1: General concepts and their relations

SEARCHING FOR CONSCIENCE

We oversimplifiy in order to move towards intelligent simulation (Fig.1). Although we claim the relations are intuitive and hope they are inspired, to begin, we neglect the essential but too primitive to understand intuition and inspiration, so (see further) formalizing reflexive abstraction by the knowledge hierarchy type and simplifying abstraction mainly by the simulation hierarchy type, it follows that:

Conscience = knowledge(simulation(Conscience)) (1)

i.e., a fixed-point relation suggesting that we could model conscience associating to any hierarchical level of the construction process a knowledge level. To solve the fixed-point problem we have to build a metric space where knowledge $\circ$ construction is a contraction, i.e., elements implied in the construction should get closer to one another in the formal understanding of the formal construct. If, even in the sketch, we consider general functional relations between the essential parts of the faith-assisted intelligence, it results:

Conscience = knowledge (intention (Inspiration,
simulation (imagination) (2)
(Intuition, Conscience))))

A generic modeling scheme defines the model universe, e.g., a mathematical theory, a programming paradigm. Every entity has behavior (relations to other entities) and structure (internal relations). Behavior can be functional (context-free) or procedural (context-dependent). An algorithm is an entity that can be computer simulated, so it represents computability, bottom-up (construction, design, plan) or top-down (understanding, verification, learning). The algorithmic approach is equivalent to the formal one: If a sentence of a formal system is true, then an algorithm can confirm it. Reciprocally, for a verification algorithm of the mathematical sentences, a formal system can be defined, that holds for true the sentences in the set closure of the algorithm's results towards the operations of the considered logic. Hilbert's formal systems, Church's λ-calculus, Kleene's recursive functions, Post's combinational machines, Turing machines, Chomsky's grammars, Markov-algorithms, are the best-known (equivalent) formalisms for computation (Hofstadter 1979).

The alternative ways followed to extend the computability are:

- Heuristics - risking competence for performance, based on imagination and confined to the mental world.
- Natural parallelism - remaining at countable physical suggestions, so in the Nature.
- Hierarchical self-referential knowledge - needing to conciliate the discrete structure of hierarchy with the continuous simulation.

All hope to open the way to Reality. They concentrate respectively on the mental world of the good managed by technology, the physical world of the truth researched by science and Plato's world of the beautiful abstractions discovered by art. Intelligence in evolution is the faculty to hierarchical reflexive:

- synthesize/ analyze/ modify abstract objects, i.e., ideas;
- analyze/ modify natural objects and synthesize/ modify artificial objects in the physical world;
- synthesize/ analyze/ modify representations for the mental world (Penrose 1994).

We follow the (mathematical) paradigm of intelligent simulation by functionally modeling the behavior for intelligence simulation. The integration between discrete and analog is again needed, for a most soft adaptability and for conscience simulation as continuous recurrence, i.e., analog reaction. Knowledge hierarchy keeps a discrete self-control over a continuous self-awareness of the discrete self-organizing by reconfiguration.

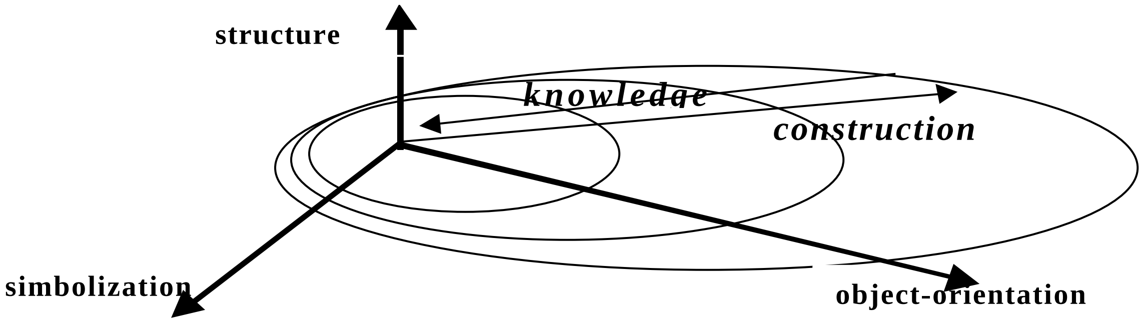

Figure 2: H - diagram

HIERARCHY TYPES

Knowledge and construction hierarchies co-operate to integrate design and verification into simulation; object-oriented concepts are symbolized to handle data and operations formally; structural representation of behavior manages its realization. Hierarchy types open the way to simulate intelligence as adaptable conscience, by integrating the system and the metasystem. Hierarchy is the syntax of abstraction. As there are more kinds of abstraction, there are also more hierarchy types (Niculiu and Cotofana 2002).

Coexistent interdependent hierarchies structure the universe of models for complex systems, e.g., hardware/ software ones. They belong to different hierarchy types, defined by abstraction levels, autonomous modules, classes, symbolization and knowledge abstractions. Abstraction and hierarchy are semantic and syntactical aspects of a unique fundamental concept, the most powerful tool in systematic knowledge; this concept is a particular form of "Divide et Impera et Intellige"; hierarchy results of formalizing abstraction (Fig.2). The knowledge hierarchy type offers a way to model conscience. The first idea is to consider/ remember that reality is more than nature, as the continuum of IR is more powerful than the discrete universe of IN. Understanding and construction have correspondent hierarchy types: their syntax relies on classes, the meaning on symbols, and their use on modules. The theory of categories offers formalism for hierarchy types. Constructive type theory permits formal specification and formal verification generating an object satisfying the specification.

Example: The classical activities in complex systems simulation, that regard different levels of the construction or knowledge hierarchy, can be expressed symbolically then represented object-oriented and simulated structurally (Fig.3). Complex simulation needs consistent combination of mathematical domains and an intelligent compromise between consistence and completeness (Zeigler et al. 2000).

METAKNOWLEDGE

Recurrence of structures and operations enables approximate self-knowledge (with improved precision on the higher levels of knowledge hierarchies). Recurrence is confined to discrete worlds, while abstraction is not. This difference suggests searching for understanding based on mathematical structures that order algebra into topology (Fig.4). A continuous model for hierarchy levels, without loosing the hierarchy attributes, would offer a better model for conscience and intelligence.

Knowledge is based on morphism mapping the state-space of the object-system onto the internal representation of the simulator. An intelligent simulator learns generating and validating models of the object-system. Therefore: representation for design and verification should be common; the algebraic structures on which the different hierarchy types are based on should be extended to topological structures; the different simulation entities should be symbolic, having attributes as: type, domain, function. A topology on the space of symbolic objects permits grouping items with common properties in classes. A dynamically object-oriented internal representation results, that can be adapted to the different hierarchy types. Topological concepts, as neighborhood, or concepts integrating mathematical structures, as closure, can be applied in verification and optimization, for objects and classes as well. The hierarchical principle should be applied to the object of knowledge as to the knowledge structure itself: it mediates the action of a paradigm on an environment. The simulation environment prepares a framework for representing entities and relations of the system to be simulated (designed/ verified), as well as general knowledge about the simulated universe. Knowledge-based architecture bases on separation of representation from reasoning. An intelligent system, i.e., capable of reflexive abstraction, reasons controlled by problem specification and by solving strategies. These are derived from a higher level of knowledge, representing approach principles, which are structured by an even higher level containing abstract types.

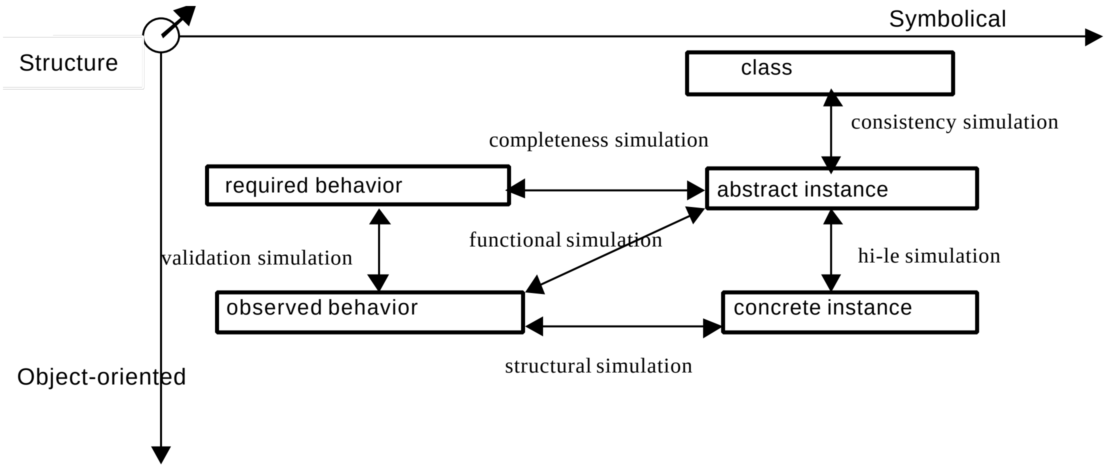

Figure 3: Hierarchical Simulation Paradigm: representation

An object-oriented simulation framework permits the representation of different knowledge levels, each having a concept hierarchy, possibly abstraction/ structure/ symbolization leveled. Knowledge-based architecture, both at environment and simulation component level, ensures flexibility of the framework realization, by defining it precisely only in the neighborhood of solved cases. For representation, this principle offers the advantage of open modeling. The user describes models, following a general accepted paradigm that ensures syntactic correctness, leaving the meaning to be specified by user-defined semantic functions that control the simulation. For example, a module in an unfinished design can be characterized by constraints regarding its interaction to other modules; the constraints system is a model, open to be interpreted, thus implemented, differently, adapting to criteria in a non-monotonic logic.

All simplifying hierarchies contribute to the reaction, while knowledge hierarchy stores, analyses, locally integrates, informs the awareness realizing parts and globally integrates. Interlevel relations in a knowledge hierarchy can be interpreted as planning (top-down) and learning (bottom-up).

Explanation is a key concept for knowledge-based systems. It can be expressed as proof in a deductive system, whose axioms are the equations constraining component models and input signals, theorems are simulation results, inference rules represent logic and domain-specific calculus. Using constructive logic, e.g., intuitionistic predicate logic, behavior/ structure of the system can be extracted from the proof.

REFLEXIVE ABSTRACTION

Mathematics contains structures that suggest to be used for self-referent models. The richest domain in this sense is functional analysis (Rudin 1973), which integrates algebra, topology and order: contractions and fixed points in metric spaces, reflexive normed vector spaces, inductive limits of locally convex spaces (Ageron 2001), self-adjoint operators of Hilbert spaces, inversable operators in Banach algebra.

Let $(U, \{H_i \in S_h\})$ be a universe, structured by different hierarchies H_i and S_h the set of hierarchies defined on universe U; let $H = (Rel\_eq, \{(Level_j, Structure_j): j \in S_l\}, Rel\_ord, \{A_j: j \in S_l\})$ be a generic hierarchy, with S_l the set of hierarchy levels, Rel_eq the equivalence relation generating the levels, $Structure_j$ the structure of level j, Rel_ord the (total) order relation defined on the set of hierarchy levels and the relation of abstraction $A_j \in \{ (x,y) | x \in Level_{j-1}, y \in Level_j, j \in S_l \}$. U is a category, e.g., containing Hilbert spaces with almost everywhere-continuous functions as morphisms, enabling different ways to simulate self-awareness. A hierarchical formal system could be defined as:

1. $(U, \{H_i \in S_h\}), card(U) > \aleph_0$ // hierarchical universe
2. $\Sigma = F \cup L \cup A \cup K$ // functional objects
   $F = \{f \mid f : U^* \to U\}$ // global functions
   $L = \{f \mid f : Level_j^* \to Level_j\}$ // level structures
   $A = \{f \mid f : Level_j^* \to Level_{j+1}\}$ // abstractions (3)
   $K = \{f \mid f : Level_j^* \times Level_{j+1} \to Level_{j+1}\}$
   // knowledge abstractions
3. $I = \Sigma^* \cap R$ // initial functions
4. $R = \{r \mid r : \Sigma^* \times R^* \to \Sigma \times R\}$ // transformation rules.

For example, considering self-adjoint operators as higher-level objects of the knowledge hierarchy, these levels can approach self-knowledge in the context of knowledge about the inferior levels as of the current one, and having some qualitative knowing about the superior levels. The correspondence problem, i.e., to associate the knowledge hierarchy to the simulation hierarchy, is managed by natural transformations over the various functors of the different implied hierarchies.

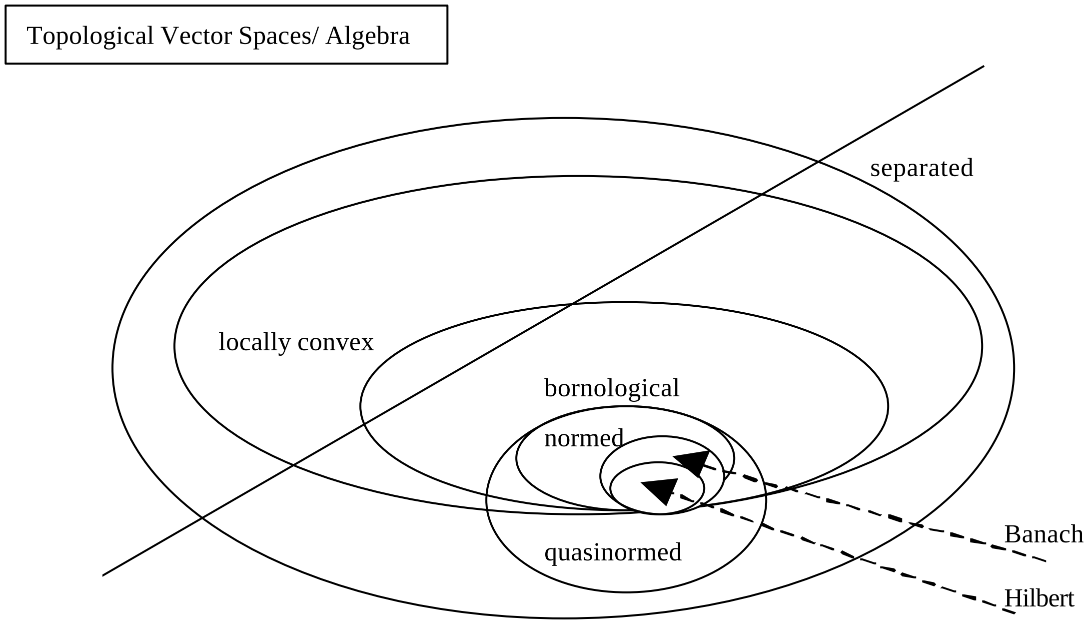

Figure 4: Topological Spaces

To complete the simulation of the intelligence's components, intention is first determined by human-system dialogue. Further than modeling conscience to simulate intelligence there will be searching to comprehend inspiration, using:

- Lebesgue measure on differentiable manifolds
- non-separable Hilbert spaces.

Perhaps even mathematics will have to develop more philosophy-oriented to approach intuition.

CONCLUSIONS

Formalizing hierarchical descriptions, we create a theoretical kernel that can be used for self-organizing systems. Evolution needs separation of faith and intelligence, understanding and using consciously more of faith's domain, integrating them to human wisdom, to be divided further to get more human. Metaphorically phrased, our problems are: *God is unique, Uncountable are His ways,* perhaps *Countable are His plans.*

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BIOGRAPHIES

Tudor Niculiu, Associate Professor, Electronics Faculty, "Politehnica" University of Bucuresti., is looking for hierarchical integration of different domains, as hard-soft, discrete-continuous, electrical-nonelectrical, in order to simulate intelligence for intelligent simulation; therefore he formalizes hierarchies and researchs the computability limits.

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AUTOMATED CONSTRUCTION OF MODEL OF CONCURRENCY IN BUSINESS PROCESS MODELING

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

ABSTRACT

This paper shows possibility for automated construction of model of concurrency in business process modeling. It is hard examine a business process and construct model of concurrency manually. We are developing method that allows constructing the model of concurrency automatically. As an input data for the method we use the specification of inputs and outputs for activities included in a process. From this specification we can construct higher dimensional automata represented by Chu spaces.

INTRODUCTION

When we want model a business process we should know what activities define the whole process. Later we would like to identify concurrency, e.g. if an activity A can run parallel with an activity B. This paper describes the method that needs to know what inputs and outputs are required by activities included in the business process and based on that initial information we are able to capture concurrency. It is easier to determine inputs and outputs for activity A than determine if activity A can run parallel with activity B. When we use description of inputs and outputs for activity, we can search for hidden dependencies between activities and we are able to specify the whole structure of business process.
As a model of concurrency we use higher dimensional automata that allow display results in a form easily understandable for business engineers. We use higher dimensional automata represented by Chu spaces to fulfil above mentioned goal.

HIGHER DIMENSIONAL AUTOMATA (HDA)

Classic automata model concurrency of event (activity) A and event B as automaton that perform event A and afterward event B or perform event B first and afterwards event A (see Figure 1). Automaton in both case 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.

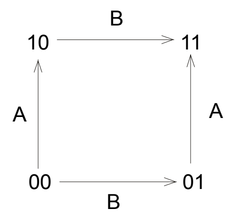


Figure 1: Standard Automata

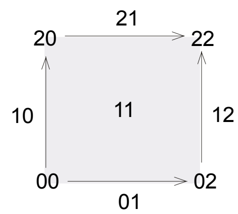
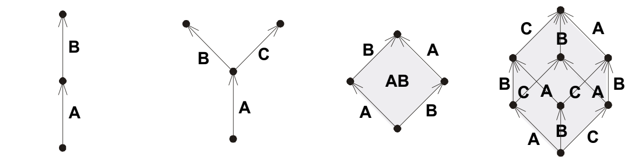


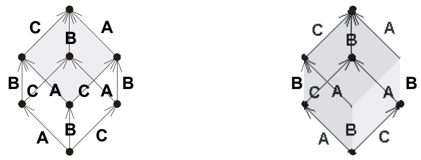
Figure 2: Higher Dimensional Automata

Higher dimensional automata (Pratt 1991) append *n*-dimensional space for *n* concurrent events. For two events A, B we append 2-dimensional space (surface) (see Figure 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 substitute with three-value fuzzy logic (0, ½, 1) as well.

The basic compositions of events are drawn on Figure 3. Case a) describes sequence of event A and event B. Case b) describes choice between event B and event C. First event A is performed afterwards event B or event C is performed. Case c) describes *true* concurrency of event A and event B. Case d) describes *true* concurrency of event A, event B and event C. This higher dimensional automaton contains 3-dimensional space. Three dimensional space is represented by interior of 3-dimensional cube. Case e) describes process where event A and event C cannot run concurrently until event B is not finished. Higher dimensional automaton is consists of edges and vertex of 3-dimensional cube and one surface. Case f) describes process where event B can start at same time as event A or after event A is started. Higher dimensional automaton is consists of filled 3-dimensional cube, but one surface is gone.



a)sequence of two events | b)choice between two events | c)concurrence of two events | d)concurrence of three events



e)event A and C can run concurrently afterward event B is finished | f)event B can start at same time as event A or afterward event A is started.

Figure 3: Basic examples of Higher Dimensional Automata

Another example of higher dimensional automaton is drawn on Figure 4. This higher dimensional automaton describe following process:
First event A and event B are performed. They do not depend on order of event A and event B, but event A and event B cannot run concurrently. Next event C is performed. Afterwards event D and event E are performed. Event D and event E can run concurrently. Red curve shows one of possible paths of real process. Path describes following behaviour: Events are performed in order A, B, C at first. Afterwards event D and E are started at same time. Event D is finished before event E.

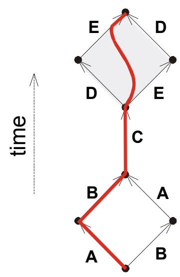


Figure 4: Higher Dimensional Automaton with marked Path of real Process

CHU SPACE

Chu space is a matrix over a set Σ. It is formalized in (Pratt 1999) 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 (see Figure 5). 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 Σ ={0, ½, 1}.

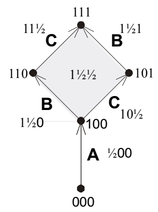


Figure 5: HDA example, where event "A" is performed first. Subsequently events "B" and "C" are performed concurrently

Chu space for higher dimensional automaton from Figure 2 is shown in Table 1. Another example of higher dimensional automaton is shown on Figure 5. Vertexes, edges and surfaces are labelled with corresponding column from Chu space shown in Table 2. Chu space for higher dimensional automaton with more than 3 events is shown in Figure 6.

Table 1: Chu space for HDA from Figure 2

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

Table 2: Chu space for HDA from Figure 5

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

If we use Chu space for representation of higher dimensional automata, we obtain algebraic operations defined in (Pratt 1999). These operations represent different composition of two processes (Pratt 2000).

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 $t(b,(x,y)) = s(b,y), \forall b \in B$.□

Choice between process **A** and process **B** is represented by operation $\mathbf{A} \sqcup \mathbf{B}$ defined as follows:

Definition 3

Let $\mathbf{A} = (A, r, X)$ and $\mathbf{B} = (B, s, Y)$ be Chu spaces. Chu space $\mathbf{A} \sqcup \mathbf{B}$ is defined as $\mathbf{A} \sqcup \mathbf{B} = (A + B, t, X \times Y)$, where $t(a,x) = r(a,x)$, $t(b,y) = r(b,y)$ and $t(a,y) = t(b,x) = 0$. □

Sequence of process A and process B is represented by operation **A**;**B** defined as follows:

Definition 4

Let $\mathbf{A} = (A, r, X)$ and $\mathbf{B} = (B, s, Y)$ be Chu spaces. Chu space **A**;**B** is defined as $\mathbf{A};\mathbf{B} = (A + B, t, Z)$, where $t(a,(x,y)) = r(a,x)$, $t(b,(x,y)) = s(b,y)$, $Z \subseteq X \times Y$, $(x,y) \in Z$ even as $x \in F_A \wedge y \in I_B$, F_A is set of final states of process **A** and I_B is set of initial states of process **B**. □

We define final states as states where no event can occur and initial states as states with no input events.

Other definitions for Chu space algebra are defined in (Pratt 1999).

CONSTRUCTING MODEL OF CONCURRENCY

Let us explain method of constructing model of concurrency in our example from the domain of business process modeling. Let us imagine a business company and worker requesting new computer (product). First we have to define activities from this process.

Approval of request – a worker makes request to purchase product and manager approves this request. **Selection of supplier** – worker selects suppliers from register of suppliers. **Appraisal of price of request** – worker estimates price of requested commodity. Afterwards the following three scenarios can occur. If price of request is under first limit, then first scenario occur and worker realizes purchase. If price is over first limit and under second limit, then second scenario occur and manager confirms purchase order. If price is over second limit, then third scenario occur and director selects best supplier. **Realization of purchase** – worker purchases commodity. **Selecting of best supplier** – director selects best supplier for requested commodity. **Make out purchase order** – worker makes out purchase order for selected supplier. **Confirmation of purchase order** – manager confirms purchase order for selected supplier. **Place copy of purchase order in files** – worker places copy of purchase order in files. **Hand over of purchase order to supplier** – worker hands over purchase order to selected supplier. **Deliver commodity** – supplier delivers ordered commodity. **Takeover of commodity** – worker takes over commodity from supplier.

Now we have to define objects (documents) included in our process. These objects are inputs and outputs for activities included in process. Object from our process are listed below:
request to purchase commodity, approval request, request with price, request with price under first limit, request with

Table 3: Table of required inputs and produced outputs for activities

	1: purchase order		2: confirmed purchase order		3: purchase order passed to supplier		4: copy of purchase order		5: stored copy of purchase order		6: request to purchase commodity		7: approval request		8: request with price		9: request with price under first limit		10: request with selected supplier		11: request with price over second limit		12: commodity		13: delivered product	
	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out
1: Approval of request											X			X												
2: Selection of supplier													X			X										
3: Appraisal of price of request															X			X		X		X				
4: Realization of purchase																	X							X		
5: Make out purchase order		X						X											X							
6: Selecting of best supplier																				X	X					
7: Confirmation of purchase order	X			X																						
8: Place copy of purchase order in files							X			X																
9: Hand over of purchase order to supplier			X			X																				
10: Deliver commodity					X																					X
11: Takeover of commodity																								X	X	

selected supplier, request with price over second limit, commodity, purchase order, copy of purchase order, stored copy of purchase order, confirmed purchase order, purchase order passed to supplier, delivered product, product.

Next we define input and output objects for each activity included in process. This data can be organized into table, where rows correspond to activities and pairs of columns correspond to object produced or consumed by activity (see Table 4).

From Table 4 we derive set $A_{inObjects}$ of objects required as inputs to activity and set $A_{outObjects}$ of objects required as outputs from activity for each activity $\boldsymbol{a} \in \mathsf{A}$, where A is set of all activities included in process. In our example we have sets:

$$A^1_{inObjects} = \{o^6\}, \quad A^1_{outObjects} = \{o^7\},$$
$$A^2_{inObjects} = \{o^7\}, \quad A^2_{outObjects} = \{o^8\},$$
$$A^3_{inObjects} = \{o^8\}, \quad A^3_{outObjects} = \{o^9, o^{10}, o^{11}\},$$
$$A^4_{inObjects} = \{o^9\}, \quad A^4_{outObjects} = \{o^{12}\},$$
$$A^5_{inObjects} = \{o^{10}\}, \quad A^5_{outObjects} = \{o^1, o^4\},$$
$$A^6_{inObjects} = \{o^{11}\}, \quad A^6_{outObjects} = \{o^{10}\},$$
$$A^7_{inObjects} = \{o^1\}, \quad A^7_{outObjects} = \{o^2\},$$
$$A^8_{inObjects} = \{o^4\}, \quad A^8_{outObjects} = \{o^5\},$$
$$A^9_{inObjects} = \{o^2\}, \quad A^9_{outObjects} = \{o^3\},$$
$$A^{10}_{inObjects} = \{o^3\}, \quad A^{10}_{outObjects} = \{o^{13}\},$$
$$A^{11}_{inObjects} = \{o^{13}\}, \quad A^{11}_{outObjects} = \{o^{12}\},$$

where $A^i_{inObjects}$, $A^i_{outObjects}$ are sets for activity with index i and o^i is object with index i (see Table 4).

For each activity $\boldsymbol{a}$ we derive set of activities that have to be performed before activity $\boldsymbol{a}$. There can be more than one set of activities. If all activities from some of these sets are finished, activity $\boldsymbol{a}$ will be perform. These sets are defined as follows:

$$A^i_{before} = \{P \mid P \subseteq \mathsf{A}\},$$

where P is set of "prerequisites" for activity $\boldsymbol{a}^i$. Activities included in set P produce all objects required as input to activity $\boldsymbol{a}^i$. Set P cannot contain unnecessary activities. We defined this condition formally as follows:

$$A^i_{inObjects} \subseteq \bigcup_{\forall a^k \in P} A^k_{outObjects} \wedge \forall a \in P : A^i_{inObjects} \not\subset \bigcup_{\forall a^k \in (P-a)} A^k_{outObjects}$$

From condition mentioned above we derive followed sets for our example:

$$A^1_{before} = \{\ \}, \quad A^2_{before} = \{\{a^1\}\}, \quad A^3_{before} = \{\{a^2\}\},$$
$$A^5_{before} = \{\{a^3\},\{a^6\}\}, \quad A^6_{before} = \{\{a^3\}\}, \quad A^7_{before} = \{\{a^5\}\},$$
$$A^4_{before} = \{\{a^3\}\},$$
$$A^8_{before} = \{\{a^5\}\},$$
$$A^9_{before} = \{\{a^7\}\}, \quad A^{10}_{before} = \{\{a^9\}\}, \quad A^{11}_{before} = \{\{a^{10}\}\}$$

For each activity $\boldsymbol{a}^i$ and $A^i_{before} \neq \{\ \}$ we derive fuzzy formula

$$after\left(a^i_S, \bigvee_{\forall P \in A^i_{after}} \left(\bigwedge_{\forall a^j \in P} a^j_S\right)\right),$$

where a^i_S is state representation for activity with index i (see Table 4). Fuzzy function $after(a_S, b_S)$ is defined as follows:

$$after(a_S, b_S) = \begin{cases} 0 & \max((1-a_S), b_S) = 0.5 \\ \max((1-a_S), b_S) & \max((1-a_S), b_S) \neq 0.5 \end{cases},$$

where a_S represents state of activity $\boldsymbol{a}$ and b_S represents state of activity $\boldsymbol{b}$. Values of input variables belong to set {0, ½, 1}. Where 0 indicates activity not started, ½ indicate activity in progress and 1 indicate finished activity. This function returns *true* (1) only if input variables fit condition "Activity $\boldsymbol{a}$ is performed after completion of activity $\boldsymbol{b}$.**"** else return *false* (0).

Let us see fuzzy formulas derived for our example:

$$after(a^2_S, a^1_S), \quad after(a^3_S, a^2_S), \quad after(a^4_S, a^3_S),$$
$$after(a^5_S, a^3_S \vee a^6_S), \quad after(a^6_S, a^3_S), \quad after(a^7_S, a^5_S),$$
$$after(a^8_S, a^5_S), \quad after(a^9_S, a^7_S), \quad after(a^{10}_S, a^9_S),$$
$$after(a^{11}_S, a^{10}_S)$$

After activity "3: *Appraisal of price of request*" arise three scenarios. We add three ad hoc conditions to separate them:

$$\neg\left(notFalse(a^4_S) \wedge notFalse(a^5_S \vee a^6_S)\right),$$
$$\neg\left(notFalse(a^5_S) \wedge notFalse(a^4_S \vee a^6_S)\right) \vee after(a^5_S, a^6_S),$$
$$\neg\left(notFalse(a^6_S) \wedge notFalse(a^4_S \vee a^5_S)\right) \vee after(a^5_S, a^6_S),$$

where function $notFalse(a^i_S)$ is defined as:

$$notFalse(a^i_S) = \begin{cases} 0 & a^i_S = 0 \\ 1 & a^i_S \neq 0 \end{cases}$$

With fuzzy formulas derived above we can easy find higher dimensional automaton corresponds with process. Each activity has three states (0-not started, ½-progress, 1-finished). If we have n activities, then there exist 3^n combinations. Each combination can be represented as part of n-dimensional cube. If combination do not contains value ½ (no activity in progress), then it represents vertex of n-dimensional cube. If combination contains exactly one value ½ (one activity in progress), then it represents edge of n-dimensional cube. Similarly combination with exactly two values ½ represents surface. Generally combination with exactly n values ½ represents n-dimensional space. All possible higher dimensional automata with n activities are part of n-dimensional cube. If we want obtain higher dimensional automaton for process with *n* activities, then we have to select combinations that fit all formulas derived above. If combination is *true* (1) for all formulas, we select this combination. Selected combinations can be organized as Chu space, where columns correspond to selected combinations and rows correspond to activities. Such kind of Chu space can be understood as higher dimensional automaton. Higher dimensional automaton from our example is part of 11-dimensional cube. (see Figure 6).

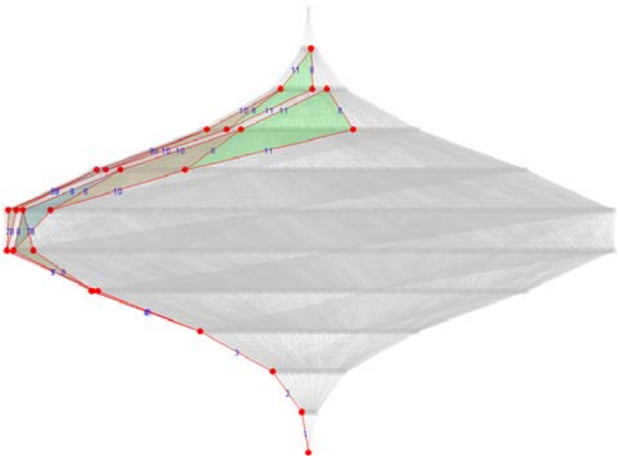


Figure 6: HDA for our example

Higher dimensional automaton from Figure 6 can be redrawn in 2-dimesional space (see Figure 7). We can see clearly three scenarios in the process. Red curve shows one of possible paths of the real process. Surfaces represent concurrent execution of two activities and edges represent one activity in progress. Label assigned to edge describes index of activity (see Table 4). Nodes represent waiting states of process. Based on rules mentioned in chapter "Higher dimensional automata" we can interpret HDA shown on Figure 7. For example, second scenario can perform at most two concurrent activities at same time. Activity 8 can run concurrently with activities 7, 9, 10, 11. Higher dimensional automaton shown on Figure 7 is more understandable for business engineers than for example Petri Nets used in (Vondrak et al. 1999). However we can derive corresponding Petri Net for all higher dimensional automata as well. If we use higher dimensional automata, we obtain clearly understandable picture of process and we do not have to lose advantages provided by the Petri Nets.

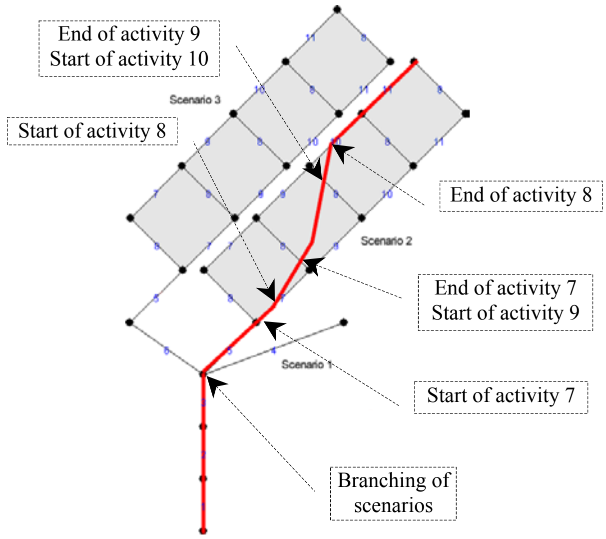


Figure 7: HDA for Figure 6 with nicer layout of vertex.

CONCLUSION

The presented method enables to construct concurrent model of business process based only on the specification of inputs and outputs of activities. For that purpose we used HDA represented by Chu spaces with the following operations defined: concurrency composition, sequence composition, concurrency composition with synchronization, choice between two processes. 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 layout of nodes representing states for dimension bigger than 3.

The described method is the part of fundamental research that is carried out at our department of computer science. Right now there is no real life example implemented because of the reasons mentioned above.

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A STRUCTURAL-PROCEDURAL APPROACH FOR DESIGNING ADAPTIVE MANUFACTURING SYSTEMS

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KEYWORDS

Business process reengineering, Synthetic environments and simulation, Total quality management, Global optimization techniques and hybrid approaches.

ABSTRACT

A new approach for designing the structure and the control procedures of a manufacturing system is presented. The resulting system allows to recuperate the investments to implement the new structure and, in addition, is robust to variations in the efficiency requirements of the market.

INTRODUCTION

A flexible or adaptive manufacturing system is one that is able to cope with changing circumstances or instabilities caused by the environment. Recently, Beach et al. (2000) have built a conceptual framework that integrates different research on particular aspects of flexibility. This framework distinguishes two types of flexibility: System flexibility at the strategic level and operational flexibility at the operational level. The goal of this paper is to present a new approach for designing manufacturing systems so that they acquire these two types of flexibility.

The new approach, named structural-procedural approach (SPA), is applied to re-design an apparel production system that makes garments whose managerial attributes do not satisfy the ones desired by the target market. At this point, note that the managerial attributes of a product are the characteristics that said product inherits from the manufacturing system efficiency, for example: the product delivery delay, the rate of defective products, the product cost and the product variety.

THE STRUCTURAL-PROCEDURAL APPROACH

The design of a manufacturing system structure consists of specifying the nature and size of its productive resources. The latter interact creating the managerial attribute patterns of the products made by the system. In addition, the design of the manufacturing system control procedures consists of specifying the steps for calculating the system inputs, allowing it to make products with the managerial attributes desired by a turbulent target market. The SPA is illustrated in Figure 1 and includes the two types of designs above. The SPA is an adaptation of industrial control skeletons (Kamen, 1999) to manufacturing system design.

The SPA is useful to re-design the current structure of a manufacturing system that makes products whose managerial attribute patterns differ from the ones desired by the target market. As indicated by the dashed lines in Figure 1, the design of a manufacturing system structure is done by solving pseudo-neural networks that indicate the ideal generic structure to make products that respect the managerial attribute patterns desired by the target market. This ideal structure is then progressively degraded to obtain a new structure that is between the ideal and the current structures. The degraded structure that balances the improvement investments with the saved poor efficiency costs (with respect to the ones of the current structure) is named satisfying structure. The satisfying structure can be generated by solving qualitative optimal control models or by a trial and error exercise supported by discrete simulation models (Macedo, 2001).

As indicated by the continuous lines in Figure 1, the design of the manufacturing system control procedures is done in the following way. First, a discrete simulation model of the manufacturing system with the satisfying structure is built. This model includes the state variables, the managerial attributes (which are some selected state variables) and two types of system control inputs: Internal stabilization inputs and target market adaptive inputs. Second, the simulation model is subject to internal turbulences (for example variations in the speeds of the machines and operators) and the principles behind KANBAN and CONWIP are used to calculate the system feedback inputs that allow the resulting managerial attributes to follow the dynamics around the pattern desired by the target market (Kamen, 1999). Third, the simulation model is subject to target market turbulences (for example strong variations in the typical ordered quantities and their desired managerial attributes) and the principles behind local operations management models (Askin, 1993) are used to calculate system feed forward inputs that allow the resulting managerial attributes to follow the new patterns desired by a turbulent target market. At this point, note that the procedures used to generate these feedback and feed forward inputs are designed by trial and error using the discrete simulation model above to evaluate the managerial attributes that result from a tentative procedure.

APPLICATION

An apparel production system makes a typical product portfolio in 10 days and with 11% of defective products whereas the target market requires it in 5 days and with 1% of defective products. The SPA approach was applied to re-design the current structure and control procedures of this production system so that it satisfies the target market desired managerial attributes. The resulting satisfying structure is described in Table 1,

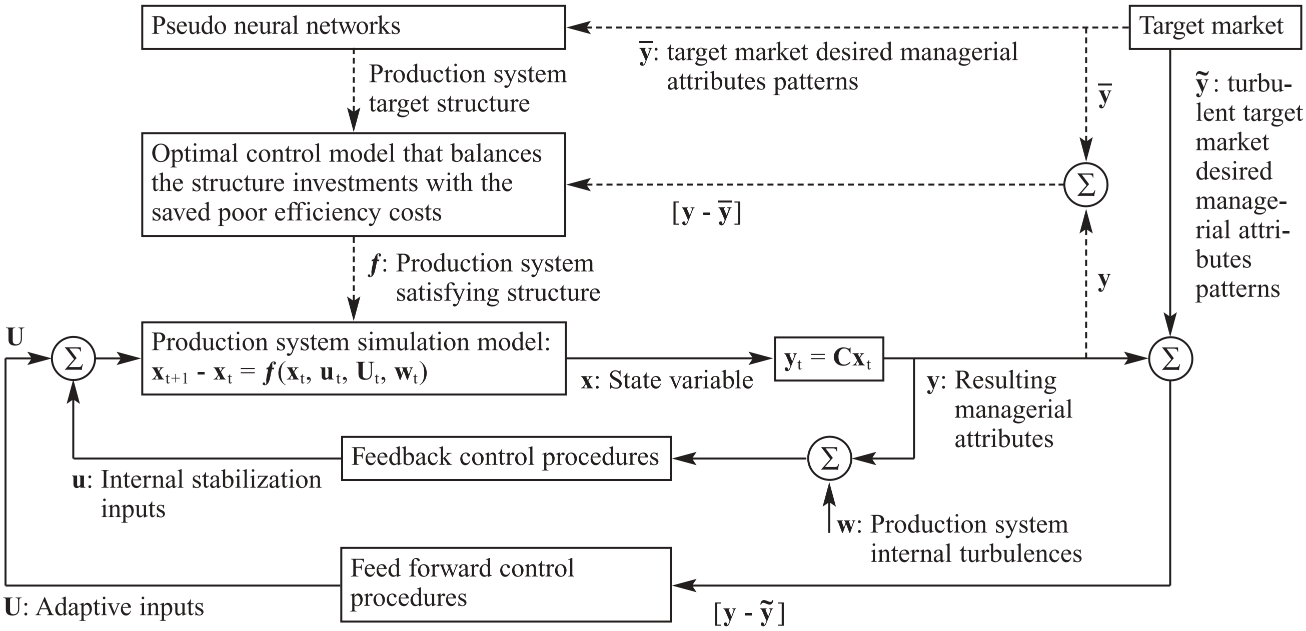

Figure 1. Structural—procedural approach for designing an adaptive manufacturing system.

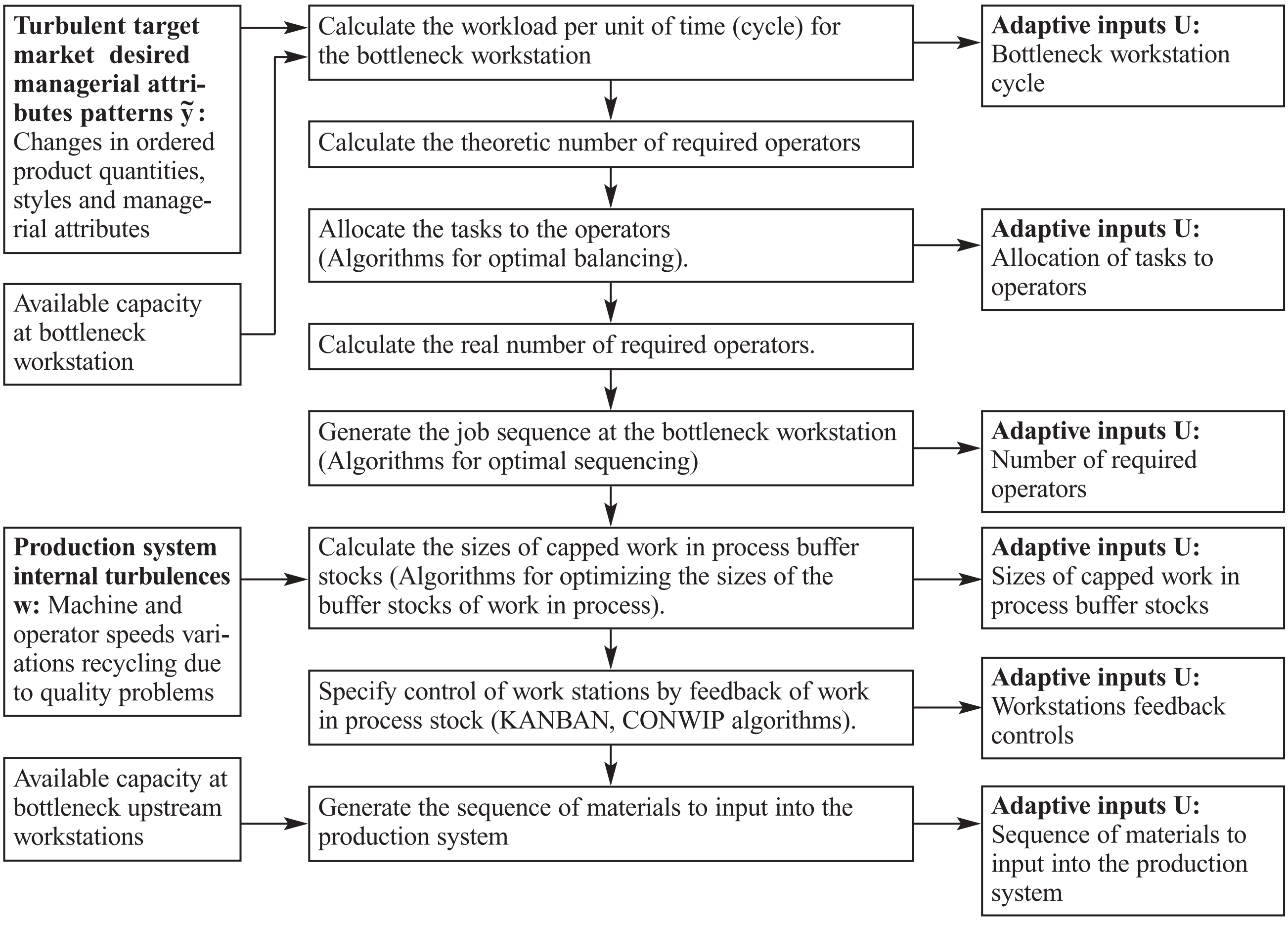

Figure 2. Satisfying integrated procedure for generating the adaptive inputs. The latter allow the production system to make products with the turbulent target market desired managerial attributes patterns.

Improvements	Current structure	Ideal structure	Satisfying structure
1. Increase exploitation of products similarities	Functional layout with random production flows for similar products	Cellular layout with family production flow	Cellular layout with family production flow
2. Decrease specialized operators	One cutting operator and 5 specialized sewing operators	One cutting operator and 5 polyvalent stand-up operators	One cutting operator and 5 polyvalent stand-up operators
3. Increase continuous handling	Size of sewn and moved lots = 15 polos so that time to attach a lot = 0.5 min/lot	Size of sewn and moved lots = 1 polo so that time to attach a lot = 0 min	Size of sewn and moved lots = 5 polos so that time to attach a lot = 0 min
4. Increase workload balancing	No balancing of sewing operators workload	Balancing sewing operators workload (cycle = 2.67 min/polo)	Balancing sewing operators workload (cycle = 2.67 min/polo)
5. Increase capping of work in process stocks	No capping of work in process stocks	Capacity of: S3_3_buffer = 5 polos, S3_9_buffer = 5 polos	S3_9_buffer ≤ 5 polos S3_3_buffer ≤ 5 polos
6. Increase control of operator work-stations by feedback of bottleneck stock	No control of workstations	Cart_placket, cart_front are loaded only if S3_9_ buffer ≤ 5. Cart_sleeve is loaded only if S3_3_buffer ≤ 5.	Cart_placket, cart_front are loaded if S3_9_ buffer ≤ 5. Cart_sleeve is loaded only if S3_3_buffer ≤ 5.
7. Increase efficient sequencing of orders at bottleneck workstation	No procedure used for efficient sequencing of bottleneck workstation	At machine S2_5 sew fabric_v, fabric_j, fabric_r, with same thread color vjr; then sew fabric_g, fabric_b with same thread color gb	At machine S2_5 sew fabric_v, fabric_j, fabric_r, which require thread color vjr; then sew fabric_g, fabric_b which require thread color gb
8. Increase production sequencing that easiness synchronization between sections	No procedure for sequencing orders so as to minimize cutting set-up time	Cut fabric_v with style S; fabric_j, fabric_r, fabric_g with style M; fabric_b with style L.	Cut fabric_v with style S; fabric_j, fabric_r, fabric_g with style M; fabric_b with style L.
9. Decrease machine settling time to reach operating conditions	Cutting settling time is 30 min for each style because the marker is traced on site by hand	Cutting settling time is 0 min for each style because the marker is generated on site by a CAD system	Cutting settling time is 5 min for each style because the marker is done on advance but requires manual adjustments on site
10. Increase zero defect inspection mechanisms	Buttonholes and buttons positions are found by eyesight at machines S3_1 and S3_2 so that 5% of polos are defective	Buttonholes and buttons positions are found by laser beams at machines S3_1 and S3_2 so that 1% of polos are defective	Buttonholes and buttons positions are found by laser beams at machines S3_1 and S3_2 so that 1% of polos are defective
11. Increase process control points based on customer expectations	Quality control is not done at machine S2_11 so that 10% of plackets are resewn	Quality control is done at machine S2_11 so that 2% of plackets are resewn	Quality control is not done at machine S2_11 so that 2% of plackets are resewn
Total investment in improvements	$0	$50 275	$28 275

Table 1. Investments required to improve the current structure of the apparel production system.

its implementation requires an investment of $28275, however, this structure allows to save $31310 per year of poor efficient costs (obtained by running the discrete simulation of the apparel system). This satisfying structure allows to make products with the managerial attribute patterns required by the target market, as indicated in column 3 of Table 2. In addition, the values of the internal stabilization inputs and target market adaptive inputs obtained by applying the satisfying control procedures (Figure 2) are in columns 2 and 4 of Table 2. These inputs allow the apparel system to make products whose managerial attributes patterns are close to the ones desired by a turbulent target market (upper part of columns 2 and 4 of Table 2) as confirmed by the delay and defectives achievement indexes that are close to 100% (bottom part of Table 2).

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Internal disturbances **w**	Market turbulence $\tilde{\mathbf{y}}$	Typical product portfolio $\bar{\mathbf{y}}$	Market turbulence $\tilde{\mathbf{y}}$
Machine S2_11: - Percentage of good polos = 98% (cycle time = 0.17 min/ polo) - Percentage of resewn polos = 2% (cycle time = 0.34 min/polo) Machines S3_1 and S3_2: - Percentage of good polos = 99% - Percentage of rejected polos = 1%	Required delay: 960 min (2 working days) Required % defectives: 1% Ordered quantities: 25 polos fabric_v style S 25 polos fabric_j style M 25 polos fabric_r style M 25 polos fabric_g style M 25 polos fabric_b style L	Required delay: 2400 min (5 working days) Required % defectives: 1% Ordered quantities: 150 polos fabric_v style S 150 polos fabric_j style M 150 polos fabric_r style M 150 polos fabric_g style M 150 polos fabric_b style L	Required delay: 2880 min (6 working days) Required % defectives: 1% Ordered quantities: 250 polos fabric_v style S 250 polos fabric_j style M 250 polos fabric_r style M 250 polos fabric_g style M 250 polos fabric_b style L
Adaptive inputs **U**:			
- Product portfolio routing	All products follow the process flow of the cell	All products follow the process flow of the cell	All products follow the process flow of the cell
- Product lot size	1 polo	5 polos	8 polos
- Bottleneck workstation	Machine S2_5	Machine S2_5	Machine S2_10
- Cell cycle	6.37 min/polo	2.67 min/polo	1.91 min/polo
- Allocation of sewing machines to operators	operator_1 (S3_3; S2_11; S2_10; S3_9; S2_5; S3_5) operator_2 (S2_4; S2_3; S2_2; S3_2; S3_1; inspection)	operator_1 (S3_3; S2_11; S2_10, S3_9); operator_2 (S2_5); operator_3 (S3_5; S2_4, S2_3); operator_4 (S3_1; S3_2, S2_2); operator_5 (inspection)	operator_1 (S3_3; S2_11; S2_10); operator_2 (S2_5); operator_3 (S3_9; S2_5); operator_4 (S3_5; S2_4); operator_5 (S2_3; S2_2; S3_2; S3_1); operator_6 (inspection)
- Number of required operators	2 sewing operators and 1 cutting operator	5 sewing operators and 1 cutting operator	6 sewing operators and 1 cutting operator
- Sizes of capped work in process buffer stocks	S3_9_ buffer ≤ 2 polos S3_3_ buffer ≤ 2 polos	S3_9_ buffer ≤ 5 polos S3_3_ buffer ≤ 5 polos	S2_11_ buffer ≤ 10 polos
- Sequence of materials introduced into sewing cell	Fabric_v; fabric_j; fabric_r; fabric_g; fabric_b	Fabric_v; fabric_j; fabric_r; fabric_g; fabric_b	Fabric_j; fabric_r; fabric_g; fabric_v; fabric_b
Internal stabilization inputs **u**:			
- Control of workstations supply by feedback of work in process stocks	Cart_placket, cart_front loaded if S3_9_buffer ≤ 2	Cart_placket, cart_front are loaded only if S3_9_ buffer ≤ 5. Cart_sleeve is loaded only if S3_3_buffer ≤ 5.	Cart_placket loaded if S2_11_buffer ≤ 10
Achievable product managerial attributes **y**:			
Production delay (min)	1000 min	2425 min	3400 min
Percentage of defective products	1%	2%	1.5%
Delay achievement = Required delay/ Achievable delay	960 min / 1000 min = 96%	2400 min / 2425 min = 99%	2880 min / 3400 min = 85%
Defectives achievement = Required % defectives/ Achievable % defective	1 % / 1 % = 100%	1 % / 2 % = 50%	1 % / 1.5% = 67%

Table 2. Apparel production system inputs generated by the satisfying integrated procedure. The achievable product managerial attributes are obtained by running the simulation model with the satisfying structure, the internal disturbances and the ordered quantities included in the target market turbulence.

ADAPTIVE MANUFACTURING MODELS FOR PRODUCTION PLANNING

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KEYWORDS
Modelling, Computer Automated Process Planning (CAPP), Optimisation.

ABSTRACT

Successful products are those that meet their requirements, are delivered on time and within their allocated budgets. This goal is more likely to be met if all stages of the development lifecycle are considered together. Integrating product design with manufacturing analysis is the goal of a CAPP system developed at the University of Durham. This paper firstly describes the product, process and resource modelling aspects of the system, and how a designer can use the tool to bring a variant of an existing design from the conceptual stages through to detailed design. It goes on to describe how the tool is integrated into a commercial Computer Aided Design (CAD) platform, and finally describes the optimisation procedure used by the planner to generate realistic process plans for analysis.

INTRODUCTION

In the last few decades the product design process has been revolutionised by the use of CAD tools, but the increased potential can lead the designer into the trap of beginning detailed product design before consideration has been given to the manufacturability of the product. This can result in a design which is difficult to manufacture. In contrast, early analysis of manufacturing options can yield refinements that help control costs, product quality and time to market.

Production planning is the identification of all the manufacturing steps needed to make a product. CAPP systems take a product definition and derive a plan. This paper outlines an approach to "Design for X" based on CAPP. Adaptive, multi-level and *aggregate* product models are defined, based on CAD feature definitions and integrated with a CAD environment. Their counterpart process and resource models are discussed in the next section, and lastly there is a detailed exposition of the production planning methods used: plan representation, decoding, simulation and optimisation.

RELATED WORK

Traditional methods for analysing manufacturing scenarios taken from operations management, such as critical path analysis (Maylor 2003) and linear programming (Stevenson 2001), use fairly coarse models to identify bottlenecks, optimize variables and identify the best manufacturing options. The CAPP approach represents scenarios at the level of individual products, processes and resources, and results in a manufacturing plan, amenable to further analysis. The ILOG scheduler uses mathematical programming and constraint techniques. Much of the literature dealing with CAPP concentrates on exemplar scheduling problems - job-shop and flow-shop problems - and efficient approaches to generating solutions. Klein (Klein 2000) describes scheduling heuristics that use simple priority rules which efficiently encode valid process schedules. Tormos (Tormos and Tova 2001) shows how optimisation strategies can make use of these heuristics to efficiently explore the problem space.

ADAPTIVE MODELLING

Optimisation of process plans makes use of a plan representation consisting of various processes and resources. These elements need to be modelled in software and at a high enough level for the designer to be able to make a manufacturability assessment of an early design. It is also desirable for them to be integrated with the CAD platform the designer is using to develop the product, with the benefit that the product definition will be fully accessible.

Product Modelling

A manufacturing assessment of early design requires a manufacturing planning view (Bidarra et al. 2002) of a feature based product model, in which the features are manufacturing form features and not design features which may not correspond to any single manufacturing process. In early design not much information exists in this view of the product, but it is during early design that consideration of manufacturing factors does the most to take risk out of product development.

A design might be a modification of another product, and be highly detailed apart from the features that were modified or added. Because of this, the approach supports the use of several levels of detail in the same design. The three levels identified and supported are called:

- *Structure-based*
- *Feature-based*
- *Tolerance-enriched*

The three levels allow a design to progress gradually towards a fully detailed state, while permitting the generation and analysis of manufacturing plans. Because different subassemblies can be at different levels and still allow a manufacturing plan to be generated, variant design (Pahl and Beitz 1996) is supported.

A new component begins at the *structure-based* level. Its main dimensions, assembly interfaces and material options are defined, along with any knowledge or attributes particularly relevant to this class of component. Detailed geometry is omitted at this stage because it is not necessary for the generation of a "rough-cut" manufacturing plan. In the current implementation structure-based features are modelled as "user features" stored in catalogues, with parameters that are of interest exposed and knowledge statements modelled as parameters that don't alter the form of the feature. These features have a programming language type and can be accessed in the same way as native solid modelling features through the CAD platform's Application Programming Interface (API).

Feature-based level components are those that have all their geometry defined. They may still have their structure-based attributes but are treated differently by the manufacturing planner because no geometrical information is missing.

Tolerance-enriched level components have all details complete, particularly ASME Y14.5M geometric tolerances and other standard annotations such as surface roughness.

Process and Resource Modelling

Complementing the virtual product models are software components modelling all the processes and resources in the production scenario. Unlike product models these have no basis or equivalent in a typical CAD document; they have to be fully implemented in software as standalone components.

Optimisation requires repeatedly evaluating candidate manufacturing plans. This is done by simulating an *aggregate virtual factory*, with virtual manufacturing steps operating on a virtual unfinished product, of which these models form a part.

Structure-based process models are used in association with structure-based features. Because these have incomplete geometry, their process models are very simple; relationships defined by equations or table based mappings giving values for feature quality, process cost and process timings. These should be derived from previous measurements of process performance. Their simplicity precludes the use of resource models, so no structure-based resource models are defined.

Feature-based process models do make use of resource models. A manufacturing plan derived entirely from feature-based design elements or better can be analysed in terms of the commitment of factory resources from the given resource scenario, and a more accurate cost estimate can be made. Measures of quality are also enhanced as more detailed processes are assigned to more detailed product features.

Tolerance-enriched process models work in much the same way as feature-based, but deal in detail with tolerances and standard annotations. Evaluations for feature quality are most affected by these considerations.

Vertical Integration

The technology is integrated within a CAD environment so as to be useful to designers. This also gives many benefits to the software developer: solid modelling; visualization; file management; user interface components; interoperation with standards such as STEP; and product data management (PDM) systems are all available without the effort of creating a full implementation from scratch.

Many of the leading CAD vendors now aggressively advertise their API and support for third party "specialized applications". The Pro/Engineer line of solid modellers now boasts of being built upon the "foundation" of the "Granite" kernel, the same software, interfaces and libraries used by third parties. CATIA V5, the platform selected in this research, claims to have an "open standard architecture".

Both of the above platforms provide Component Object Model (COM) bindings and support for Java and C++. CATIA V5 provides an elaborate set of constructs to a developer working in C++: interface inheritance; component inheritance; and extending an existing component with a new interface (either by adding to the components data or an optimised version adding no data).

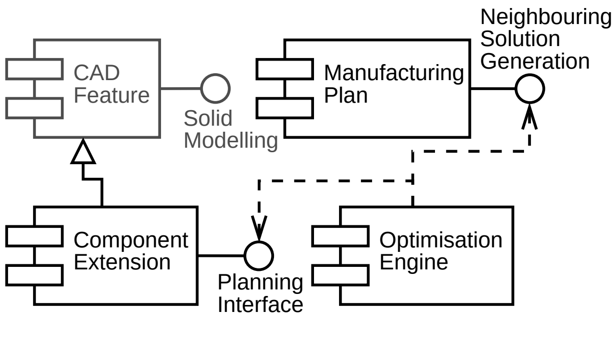

Figure 1: Extensions to the CAD Environment

Figure 1 is a UML component diagram ("lollipop" notation) showing how planning interfaces are added to solid modelling features and used by the manufacturing planner. Native CATIA V5 features - and structure-based, user-defined features defined in catalogues - are extended to support a planning interface that allocates the processes and resources that will be used to manufacture the solid modelling feature represented by that component.

History-based solid modellers allow the retrieval of the status of the work in progress after the creation of each feature. When the manufacturing planner calls on the planning interfaces, it uses this function to reduce the problem space. It excludes impossible combinations of feature, process and resource by checking firstly that the randomly selected process is feasible for the feature, and then that the resource is suitable for the process. Removal features, for instance, require a process that removes material, and similarly suitable milling or cutting resources must be allocated to a removal process.

Native solid modelling interfaces are in use currently, but for the technology to become portable to new CAD platforms, new interfaces deriving from the NIST Core Product Model (Fenves 2002) are envisioned. A compact layer of standard solid modelling interfaces would be the only software that would need porting effort in the event that the technology was to be implemented in another solid modelling environment.

PRODUCTION PLANNING

Using these aggregate models, an optimal or near-optimal production plan needs to be derived. Determining how good a candidate production plan actually is requires it to be simulated in an aggregate virtual factory. Exploring the search space of possible production plans requires a representation of these plans to be devised, with accompanying procedures for decoding into a production plan and evaluating its fitness for purpose under certain criteria.

Decoding and Simulation

The representation of the production plan is chosen to be compact, and so that an optimisation procedure can easily generate neighbouring solutions that meet the all of the validity constraints. A plan consists of; a manufacturing view of the product models and an initial state for the work in progress; an assignment to each manufacturing feature of a set of processes, with both operational parameters and special parameters for decoding into a plan; and to each process is allocated a set of resources and their initial state.

Processes are both conceptualised an implemented as a series of process events, separating different processing phases. For example, a milling process would by default be in an “inactive” state, followed by an event which set the machining resource into a operational state, from which would follow a “material removal” phase, before another event, ending that phase by changing the resource settings. Each event has a set of operational parameters, governing what action is to be taken at the time the event occurs. Each event also has a priority, which helps the decoding procedure extract a production plan meeting all of the production constraints.

Given this representation, the decoding procedure works in tandem with the evaluation procedure by proceeding as follows:

1) The initial state of the work in progress and resources is converted into the aggregate virtual factory simulation state.
2) The process event that can activate at the earliest time is chosen. If there is more than one of these, the one with the highest priority is chosen.
3) The event interrogates the simulation. If its validity constraints are not met, this step is taken with the next eligible event in the above ordering.
4) The event is added to the schedule, activates, and the simulation is altered to reflect its effect.

The work in progress and resources are software components exposing interfaces, so that they can be queried by process events. The processes themselves are also available as a part of the simulation, as a very common process constraint is that certain events cannot happen in certain phases of the process.

Scheduling

In the operational research literature, the resulting schedule of events is sometimes called an *active* schedule (Gonçalves et al. 2002; Wang and Zheng 2001), meaning that no process could have an earlier start time. This property is desirable because the optimal process plan, evaluated under certain criteria[1], is always to be found in the set of active schedules. The above method of scheduling, when dealing with a standard job-shop problem, normally results in a *semi-active* schedule. However the same problem and solution converted into an event representation always results in an active schedule.

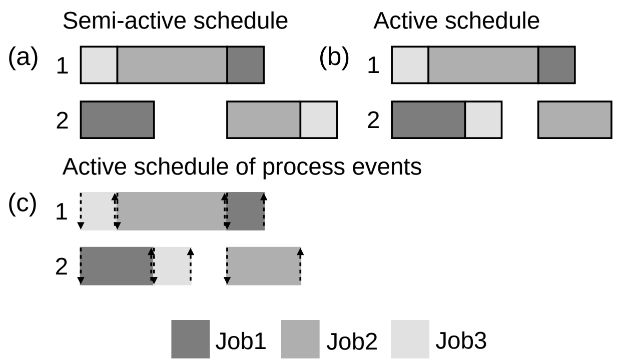

Figure 2: Active and Semi-Active Schedules

Figure 2 illustrates this with a comparison of schedules from a simple job-shop problem (Wang and Zheng 2001). The machine sequence matrix is

$$M = \begin{pmatrix} 2 & 1 \\ 1 & 2 \\ 1 & 2 \end{pmatrix} \tag{1}$$

the processing time matrix is

$$T = \begin{pmatrix} 1 & 3 & 1 \\ 2 & 2 & 1 \end{pmatrix} \tag{2}$$

and the solution, a priority list of jobs, to be decoded is s = (1, 3, 2, 2, 1, 3). A simple decoding heuristic - adding the job with the earliest start time after the finish time of the previous job on the machine - gives the semi-active schedule (Figure 2a). A more complex algorithm that gives a job the earliest possible start time, regardless of the finish time of

[1] *Regular* criteria, meaning the value never decreases if a process starts at an earlier time.

the latest job on the machine, gives the active schedule (Figure 2b). If the problem is converted from *blocks* of time into one where each process has a start event and finish event [s = (1S, 1F, 3S, 3F, 2S, 2F, 2S, 2F, 1S, 1F, 3S, 3F)], then the simple decoding heuristic of adding to the schedule the earliest event with the highest priority and satisfied constraints can be used. This attains an active, and in this example an optimal, schedule (Figure 2c).

The property of never having to look backwards in time to find a place on the schedule for an event to be added means that the simulation only ever moves forward. The aggregate virtual factory simulation is therefore fully available to every event that becomes a candidate to be added. It can be completely interrogated in any way the event finds necessary to meet its validity constraints. These constraints normally have to do with the condition of the work in progress or resources. In the above job-shop example, none of the job finishing events could have been added until their corresponding job starting events had been added. While the start events would have reported to the scheduler that they could start immediately, the finish events would have reported that they could be added only at a fixed time after their job start time.

Evaluation Criteria

Like the other elements of the system these are designed to be "plug-in" software components; selectable and upgradeable. Extra criteria, specialized for a specific enterprise of classes of enterprise, could be written by a third party as they need only expose a well defined interface and rely on interfaces provided by the aggregate virtual factory simulation. However, several standard criteria would be almost universally used.

Cost can be derived from a consideration of the resources committed and otherwise used up during production, set against the expected profits to be made and declared. In this way cost is essentially a simulation of the enterprise's balance sheet. Many projects might treat this as the only important criteria, especially if extended to include the effects of quality and delivery.

Quality reflects the extent to which a feature is likely to be non-functional due to defects. In our implementation this is recorded as Defects per Million Opportunities (DPMO), 3.4 DPMO being a six sigma level of performance. Delivery metrics can be used to reflect the time taken to manufacture a product, throughput and latency, or time to market.

Optimisation

In possession of an encoding for a manufacturing plan, and the means to produce an evaluation of its performance, the resulting problem space of possible solutions is to be searched for the optimal or a near-optimal solution. Multi-criteria combinatorial optimisation problems of this type often have stochastic search techniques applied to them. These methods - such as simulated annealing (SA), genetic algorithm (GA) and tabu search – are able to find nearly optimal solutions without having to enumerate every possible solution, but without "getting stuck" in one part of the search space even if it is not "well behaved".

The approach taken in this research is to optimise using an SA algorithm (Aarts and Korst 1989). This works by starting with an initial solution. A neighbouring solution is generated from this existing one; in this case some process event priorities or parameters would be changed, and in addition a feature-process-resource assignment may be changed or replaced. If the new solution is better than the old one, it is accepted and the cycle begins again. If it is worse, it is not automatically rejected, but a decision is made with the probability of acceptance given by

$$\exp\left(\frac{E_i - E_j}{k_B T}\right), \qquad (3)$$

where T is temperature, a parameter that starts high and approaches zero as the number of iterations increases, k_B is the *Boltzmann* constant, E_i the evaluation of the old solution and E_j the evaluation of the new one. This ability to jump from one solution to a seemingly less promising one, with the probability going to zero as time goes on, prevents the solution becoming stuck at a local maxima.

The problem space is further cut down by two sets of constraints: those preventing unfeasible combinations of feature-process-resource being assigned; and validity constraints implemented by process events interrogating the state of the simulation.

CONCLUSION

A general purpose "Design for X" tool based on CAPP and integrated into a commercial CAD environment has been described in this research. A modelling approach which is adaptive, by virtue of being component-oriented, has been employed. Optimisation based planning techniques have been shown to be applicable to producing near-optimal process plans for analysis of manufacturing options.

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PEOPLE, MODELLING THEIR PERFORMANCE IN MANUFACTURING PLANTS

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Manufacturing, Modelling, People, Performance

ABSTRACT

Manufacturing system design is an ongoing activity within industry. All design processes include some form of evaluation, and a popular means of evaluation is computer based simulation. However, current simulation tools do not provide the designer with the capability to evaluate the impact that differing types of people, working environment and task characteristics, are likely to have on system performance. This paper explores this topic and proposes a research agenda to provide human performance modelling capabilities for manufacturing system analysis.

INTRODUCTION

The factory is a working environment created by engineers. This environment affects the way in which the people who work within it perform, and hence influences the competitiveness of the business. Similarly, the type of people working within a factory moderates the impact of the environment. In spite of much work by the social sciences, engineers are still ill equipped to understand the effect of such relationships on the factory they are designing.

Simulation techniques provide a possible solution. These techniques are frequently used by engineers to model manufacturing systems during the design and re-design process. Currently, their capability favours the technological components of a system, such as machines, conveyors and equipment. However, if this capability could be extended to realistically represent the performance of people working within a system, then this would be a valuable aid to engineers.

This paper summarises a vision of a methodology that enables engineers to model relationships between people, their working environment, and subsequent performance. This methodology will be encapsulated within a computer-based tool that will work directly with computer simulation packages that are widely used by engineers in manufacturing system design. Having justified and described this novel modelling approach, this paper then proposes a research strategy for realising these capabilities.

BACKGROUND: MODELLING WITHIN THE PROCESS OF MANUFACTURING SYSTEM DESIGN

The research presented in this paper has set out to improve modelling as an aid in the process of manufacturing system design. This section sets the context to this work. First, to clarify the focus of this research the industrial problem is summarised. The second section highlights the important contribution that people can make to manufacturing system performance. Finally, a review of the literature describes how human performance is treated in conventional modelling tools.

THE INDUSTRIAL PROBLEM

Ford Motor Company has over 200 manufacturing plants world-wide, 16 are in the UK. Engineers at Ford, like those at other successful manufacturing organisations, are constantly involved with the design and re-design of manufacturing operations. These engineers follow a manufacturing system design process that commences with understanding the business need, and concludes with the operation of a new manufacturing facility.

The exact form of the stages in such a process may vary across organisations, but there is always a point when some form of evaluation takes place to see whether a proposed manufacturing system design is likely to fulfil expectations. This evaluation may be based on a combination of judgement, bargaining and analysis. A common analytical decision support tool is computer-based simulation. Companies invest heavily in such tools; for example Ford almost always carries out simulation studies on new facilities at the design stage (as illustrated in figure 2.1).

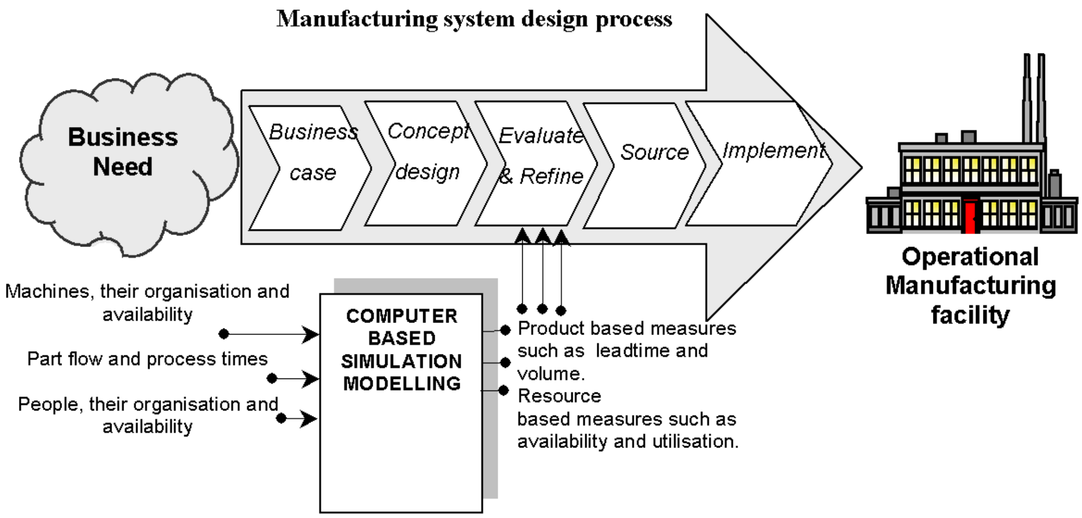

Figure 2.1: The manufacturing system design process

The problem is that current forms of computer based simulation fail to tell engineers as much about the system as they need to know. The analysis is limited to assessing the impact of such factors as machine rates, breakdowns, conveyor speeds, the number of direct workers and their shift patterns. As a consequence simulation tools often over estimate the capacity of a manufacturing system. There are many other factors that affect the subsequent performance of the manufacturing facility that engineers are ill equipped to analyse, and many of these are human centred. For example, simple environmental factors such as heating, light, and noise all have an impact on the performance of people. The engineer will make decisions that determine such environmental factors within a factory, such as positioning heavy machinery, locating assembly lines, and routing services, but these will be done without full knowledge of their effect on people working within production.

The Health and Safety Executive provide standards, but these are straightforward environmental boundaries that must not be exceeded. Similarly there is a wealth of knowledge in the wider socio-technical and ergonomics literature about the affect of environment, human factors and behaviour, but frequently this is in a form and language that the practising engineer has difficulty understanding.

THE HUMAN CONTRIBUTION TO MANUFACTURING SYSTEM PERFORMANCE

There is a wealth of social science literature that is relevant to manufacturing system design and performance. The following brief excursion into this literature, illustrates both the potential human factors knowledge available to the manufacturing system designer, but also the difficulty in assimilating such know-how to be valuable to the practising engineer.

As early as 1935, Lewin (Lewin 1935) suggested that the behaviour of a person is a function of their personal characteristics and the environment within which they exist. Since then many studies have investigated the relationships between environmental conditions and the performance of direct workers. For example, considerable empirical work has focused on physical factors such as light, noise and temperature (Bonnes and Secchiaroli 1995). A broader view of the environment has been taken by researchers such as Furnham and Schaeffer (Furnham and Schaeffer 1984), who investigate the fit between a person and their somatic and psychological environment and the consequent stress levels.

The behaviour of the individual has itself been central to many studies. Singh and Srivastava (Singh and Srivastava 1981) established that morale is positively related to performance. Similarly, direct relationships with performance have been examined by authors such as Yitzhak and Ferris (Yitzhak and Ferris 1987) who found that task identity was related to job performance, and also Shapira and Griffith(Shapira and Griffith 1990) who investigated relationships between values and beliefs. More recently, Wall et al (Wall et al) examined the impact of operator control of machinery. They found that it related to higher job satisfaction levels and lower perceived levels of work pressure. Folkard (Folkard 1996) describes how the alertness of an individual varies during a working day, Parker and Wall (Parker and Wall 1996) have explored the psychological perspectives of job design in modern manufacturing, and Furnham (Furnham 1992) has investigated the relationship between personality and performance at work.

Like many disciplines, some areas have received greater attention than others. For example, experimentation and data collection methods have been a special area of interest since the seminal works of Roethlisberger and Dickson (Roethlisberger and Dickson 1947). Similarly, considerable work has been carried out by researchers such as Tranfield et al (Tranfield et al 1999), relating initiatives in human resource management to the performance of the firm. They focus on such topics as task orientated routines, team working and empowerment. Practice illustrates the value of such work, where the better manufacturing companies, such as Toyota, will build this continual improvement process into their culture.

When considering the social science literature, there are however two barriers that must be overcome for this work to be exploited at the stage of manufacturing system design. First, the work needs to be brought into the context of the company hosting the design activity; engineers and managers want to know the impact of 'their' practices on the likely performance of 'their' organisation. Second, the practitioner has to sift through this information and prescriptions to establish and order the knowledge relevant to themselves. Both of these barriers call for a method of bringing together the relevant social science knowledge, and representing this in a form that complements the manufacturing system design activity.

MODELLING WITHIN THE PROCESS OF MANUFACTURING SYSTEM DESIGN

The manufacturing system within many factories is a complex operation consisting of extensive interactions between people, information, materials and machines, for the purpose of producing a wide variety of products. Manufacturing system design and redesign is an ongoing activity within industry. Organisations are continually being pressurised to change their manufacturing facilities, technologies, methods, people and the products they produce. Most manufacturing systems are complex, and so major design or redesign is a demanding task. The engineers and managers who are faced with this task can find guidance in recognised principles of good manufacturing system design (Suresh and Kay 1998), they can learn from observations of successful organisations (Womack et al 1990), and they can tailor this knowledge to their own organisations using structured analysis and design methods (Mills et al).

These design methods all have some form of evaluation, usually based on a combination of analysis, judgement and bargaining between the practitioners involved (Mintzberg et al 1976). An analytical tool that is a valuable aid to manufacturing system design is simulation modelling. In this situation, modelling usually means applying a technique such as Discrete Event Simulation (DES) (Carrie 1988), and (Robinson 1994). Such a technique is used to build a computer-based animation of the manufacturing system design being considered. This simulation is a coarse replication of the dynamic behaviour of the proposed system; it produces numerical performance indicators, and enables the practitioner to make informed judgements about the proposed system.

Simulation models are usually used to undertake a comparative analysis of system designs. Here, the practitioner, where possible, first builds a model of the existing manufacturing system (Law and Kelton 1991). This model is then tested and refined until it demonstrates acceptable validity. Alternations are then made to the model to replicate the proposed changes to the manufacturing system. Comparisons are made between the behaviour of these models, and these are taken as indications of how the performance of the real system will alter. The understanding and predictions they enable are a significant aid to the engineer and manager faced with a design problem.

These techniques are however limited in the range of analysis they can support. Techniques such as DES, are most frequently used to model the elements of a manufacturing system that are highly deterministic in their behaviour, usually mechanical equipment such as machines, conveyors and robotics. For example, DES is used by automotive manufacturers to assess the effects of machine production rates, set-ups, and breakdowns on such measures as product lead-time and volume. However, as the elements of a manufacturing system become less deterministic in their behaviour, then techniques such as DES have to rely on the practitioner being well skilled in data collection techniques and statistical analysis methods, and also sufficiently knowledgeable about the nature of the selected relationship to apply and interpret these techniques.

This is especially a weakness when considering the human element in manufacturing system design, and in particular the 'direct' worker. Currently, manufacturing system modelling techniques, such as DES, treat people as a simple resource that has limited availability. In a typical simulation model, 'labour' is defined as a resource that is needed by activities such as 'machining' and 'assembly' to take place. Then, by varying the general availability and priorities of the labour resource, the model can be used to determine the required number of workers, shift patterns and routines. This however, is the limit of the analysis supported by such modelling techniques. Modelling aids do exist to consider such human issues as ergonomics. There are also general guides on work place design, such as those enforced by the Health and Safety Executive. Such considerations however tend to be made at the later stages of manufacturing system design, when the scope for alteration is limited. Other than this, the practitioner faced with the design of manufacturing systems has to overly depend on institutionalised practices, their experience and judgement. In this situation of uncertainty, the only contingency open to the engineer is to be conservative in expectations of production capacity, and risk over specifying a system and as a consequence cause sub-optimal capital investment. This gap is the target of the work described in this paper.

Other modelling techniques do exist to aid manufacturing system analysis. Baines et al (Baines et al 1998) examines schematic representations (e.g. $IDEF_0$), mathematical modelling (e.g. Queuing Theory), and other simulation techniques such as System Dynamics (SD). Of these, SD is a powerful, if occasionally overlooked, technique for manufacturing system modelling (Baines and Harrison 1999). This technique can be a helpful aid to the practitioner seeking to dissect and represent complex relationships. However, to construct a model the practitioner still needs to have some semi-structured knowledge of the subject relationship. SD provides useful building blocks, but does not intrinsically provide any greater insight into human performance modelling than techniques such as DES. Finally, some specialist simulation aids do exist to consider human ergonomics, though these tend to concentrate on spatial analysis late in the design process.

An inability, to adequately model the behaviour of people in manufacturing environments is therefore a major limitation to current modelling techniques, especially as those employed in direct production routines remain central to competitiveness. There is an important need to expand the capability of modelling to include the relationships between people, their working environment, and their subsequent performance in terms of productive routines. This will be a valuable aid to engineers and managers involved with manufacturing system design or redesign.

THE VISION: HUMAN PERFORMANCE MODELLING AS AN AID TO MANUFACTURING SYSTEM DESIGN

Manufacturing system design and re-design is an ongoing activity within industry. Simulation tools are frequently used as decision support aids in this design process. Such simulation tools treat people as mechanistic resources, and model them in much the same way as they model machines. Yet, people do not perform like machines. As a consequence, where system performance is largely dependent on humans rather than technology, simulation may be an unreliable decision support aid. The challenge to research is to extend simulation capabilities to overcome this limitation.

Our vision is to enhance simulation capabilities with a technique termed Human Performance Modelling (HPM). Figure 3.1 illustrates how HPM could be integrated into the design process, to complement existing simulation techniques (though as discussed in section 5 this may not be the only role for HPM). We envisage that a HPM model would be formed to represent the people in a manufacturing system and how those particular people react to the environment created around them within the factory. We have encapsulated this intention within the following research aim:

> "To create a modelling tool which will enable manufacturing system designers to understand the relationships between people, their environment and predict the effect on their performance"

The following section describes our first attempt to realise such a modelling capability.

THE EXPLORATORY STUDY

The first step in realising the desired modelling capabilities has been to conduct a pilot study. In this pilot, the goal was to provide a useable methodology that engineers and manager could use to form models of the relationships between descriptors of the working environment, descriptors of the direct workers, and the subsequent performance. Our approach was to construct a computer modelling tool based on an Artificial Neural Network (ANN). The theoretical framework from this tool was developed from the work of Lewin (Lewin 1935) & Briggs Myers (Briggs Myers 1980). This tool was written in Visual Basic and linked directly with Witness, the simulation software sold by Lanner. Then, a five step methodology was developed to guide the application of the ANN tool and so to construct a model. These five steps were:

Step 1. Define core tasks and performance indicators, and collect data about current state. Describe the behaviour of the workers in the facility in terms of core production tasks. For each routine, establish the relevant performance indicators and measure the steady state values.
Step 2. Define environmental experimental variables and collect data about current state. These are the aspects of the physical working environment within the facility that are to be modelled, for example temperature, light, noise, etc. For these variables it is necessary to establish values corresponding to a steady state performance of the system.
Step 3. Establish personality profiles of the production people. Using a personality assessment based on Briggs Myers22, determine the profile of each production worker. These can then be grouped into stereotypes.
Step 4. Collect relationship data and train the modelling tool. Observe similar core tasks carried out, either by different types of people, or for different working environments. One method here, is to observe how performance values for a specific task vary, as people and the environment change over a working day or series of days. Training of the ANN can then take place.
Step 5. Experimentation with model. Once validated, a user should be able to vary the value of the experimental values and observe the effect in terms of the performance indicators. Within the scope of the model, this should show how the design of the working environment can affect the performance of direct workers.

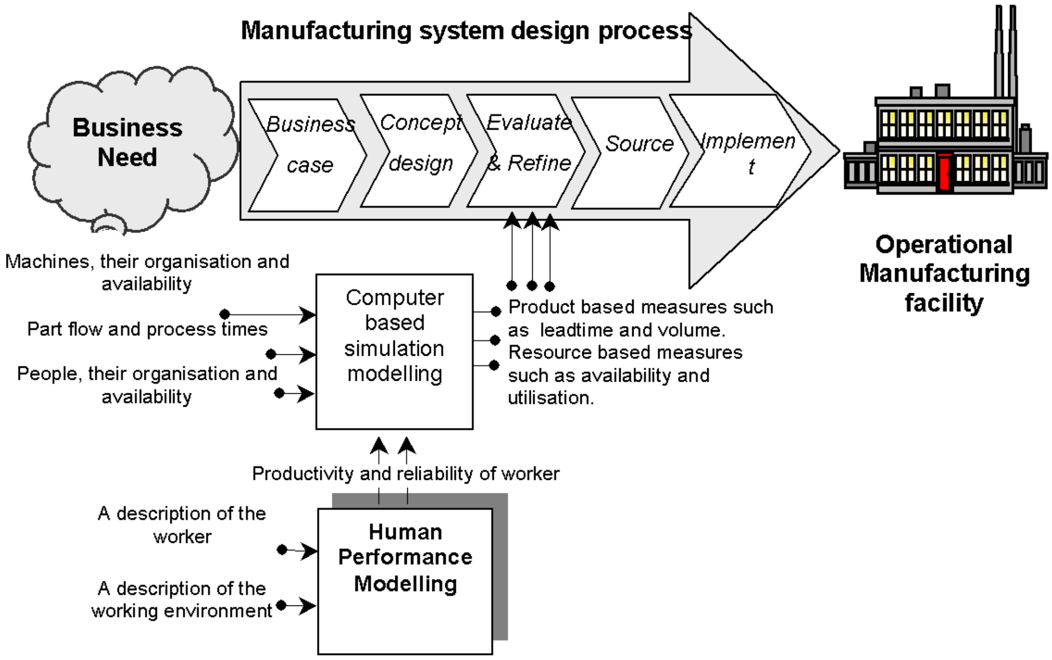

Figure 3.1: Human Performance Modelling as an aid to the manufacturing system design process

For example, 'assembly' might be the core task, the performance indicator might be 'cycle-time' and the steady state value might be 15 minutes

The pilot study was carried out at the Ford Bridgend plant in South Wales. The methodology was applied to form a model of a department of 20 people. First, the required outputs from the model were defined as performance against core production tasks (eg: Pick & Place, Fastening). Then the experimental variables for this model were defined. Environmental variables were; noise, ventilation, temperature, daylight & cleanliness. The personality profiles of people within the department were determined, and in this instance two main stereotypes (Introvert and action orientated; Introvert and thinking) were predominant. The model was populated by gathering data about the behaviour of some 125 assembly workers, of the same personality stereotype and carrying out similar tasks, but within differing manufacturing environments. A schematic representation of the subsequent model is given in figure 4.1.

As shown in figure 4.1, the key psychological parameters input to the model were based on the extent of a person's introversion, and this was scaled value from 1 – 100. The key environmental values were related to physical working conditions, such as noise, temperature, etc. Most of these values could be measured in absolute terms, such as decibels or degrees Celsius. However, for variables such as cleanliness, a scaled value was again used. The key output variables were cycle time variance and error rate, and these were given for the core production tasks.

Credibility and reliability was then tested with Ford engineers and managers. The process used was to present the model, its purpose and method of execution, to a selection of engineers and managers at Ford. They were then asked to assess the validity of the model predictions against their own experiences, and in this way comment on credibility and reliability of the predictions.

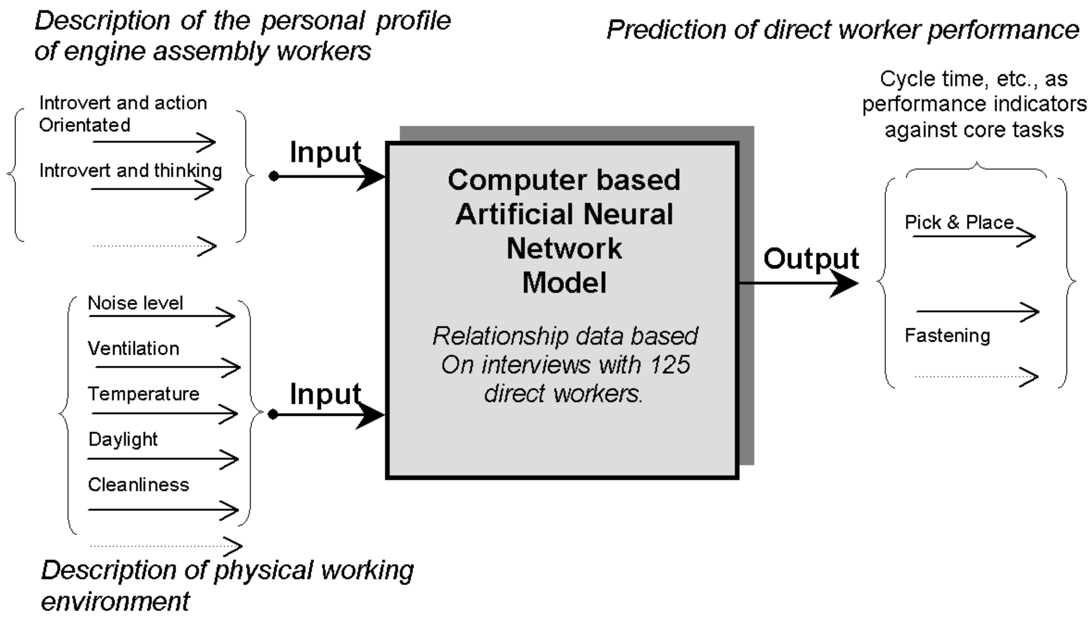

Figure 4.1: The structure of the pilot model

Although promising as a pilot study, this methodology has many simplifications and assumptions. The principal weakness of the pilot work was taking the personality profiles of people as a singular view of person type. The danger is that personality may be a poor measure of how well a person may perform, and it may be better to take an account of broader characteristics of the workforce, such as demography and cultural issues. In hindsight, a more robust approach would have been to consider the characteristics of a wider population, and then if useful and feasible, breakdown a population into smaller groups of individuals. This leads on to subsequent concerns with data collection, ensuring that the right data is collected, and that it is collected in a rigorous manner.

Other issues were raised with the modelling context. An increasing number of studies have highlighted the dangers associated with artificially bounding a change event in order to monitor that change, rather than positioning the event within the wider environment and over different time scales. A limitation of the pilot methodology was therefore that it gave no guidance to the engineer or manager on how to interpret the results of a model, and hence its value in making an informed judgement.

The strongest component of the work was understanding the need of the practitioner, and establishing a pragmatic method of expressing the modelling challenge. On this basis, we have confidence in the principle of capturing and expressing the relationships between physical environmental conditions and worker behaviour.

In conclusion, the issues raised above illustrate that there are many challenges that this theme of research needs to address. Although the theoretical framework needs to be refined, the pilot has made an important first step in this area, having gone someway to establishing a generic methodology and illustrating the potential value.

CONCLUSIONS

This paper has presented a case for Human Performance Modelling, as an aid to the process of manufacturing system design. A conceptual methodology has been outlined, along with an initial pilot study. This framework is itself embryonic, as there are undoubtedly many other issues that need investigation but are not covered here However, the intention here has been to stimulate a debate around this emerging research topic, and hopefully this paper has gone someway towards this goal.

ACKNOWLEDGEMENTS

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Current areas of research and collaborations are:-
With Lanner and Luminova - enabling Manufacturing Engineers with out time and skills to build simulation models in normal 2D and Virtually.
With Cranfield University – Researching the feasibility of modeling the effect that people and the environment have on Production Output.
With Warwick and Aston University looking at the effect of Human Decision making and the inclusion of AI in simulation.

SYSTEM DYNAMICS MODELLING AS AN AID TO MANUFACTURING SYSTEMS DESIGN

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Within industry, many large companies make extensive use of computer simulation models to predict the performance of their manufacturing systems under different conditions and so to choose the most favourable manufacturing strategy. Due to the complexity of many manufacturing systems, the simulation task is often very time consuming process, requiring specialist software, knowledge and skills. This paper promotes the use of System Dynamics to this modelling challenge, by describing the design of a computer tool tailored to manufacturing system modelling

INTRODUCTION

Modelling is often used in detailed design of manufacturing systems. However, only the Discrete Event Simulation (DES) technique has been adopted by most companies. This maybe limits the scope of simulation to a detailed analysis technique and therefore consumes a lot of time and effort. Therefore, to promote the use of simulation to take decisions in a more aggregate way, this paper investigates System Dynamics (SD) as an alternative technique to build models for manufacturing systems.

The methodology used includes: In the first stage, a literature survey was carried out, to identify the elements involved in SD. The comparison between SD and DES demonstrated the opportunity presented by SD in assembly systems. Some simplifications were required in order to create a tool that evaluates some parameters used in real systems. A simulator was built using Visual Basic as programming language and was tested against commercial DES and SD packages using simplified models from Ford Motor Company. With these data, the outputs of the model were analysed to check its functionality.

The paper is structured as follows. Section 2 provides a background to System Dynamics, explaining the origin of this technique. Section 3 argues for a dedicated SD modelling tool, and Section 4 discusses the construction of such a tool. Finally, conclusions and further work are drawn on the usefulness of the System Dynamics methodology within the context of manufacturing system design.

BACKGROUND: MANUFACTURING SYSTEM MODELLING TECHNIQUES

SIMULATION

Simulation techniques have been used in industry for many years, but the increase in the power of computers has expanded the scope of simulation tools, as well as facilitating their use in smaller companies. One definition of computer simulation is the following:

> "The practice of building models to represent existing systems, or hypothetical future systems, and of experimenting with these models to explain system behaviour, improve performance, or design new systems with desirable performances" (Khoshnevis 1994).

Computer Simulation is a technique that uses the computer to model a real-world system, especially when those systems are too complex to model with direct mathematical equations without disturbing or interfering with the real system. In manufacturing, simulation can be applied to any system that has entities moving through it, and where data can be obtained on some of the variables of the process. The main advantages of simulation arise from the better understanding of interactions and identification of potential difficulties that simulation offers, allowing the evaluation of different alternatives and therefore, reducing the number of changes in the final system. On the other hand, simulation packages can be expensive, time and skills consuming when developing a good model and validating it. A good technique is required in the simulation process to obtain valid result

DISCRETE EVENT SIMULATION

DES concerns the modelling of a system as it evolves over time by a representation in which the stated variables change instantaneously at separate points in time. Here an event is defined as an instantaneous occurrence that may change the state of the system (Law and Kelton 1991). This type of simulation is concerned with the start time and end time between the changes (events), and not in the time between. Basically, three principal elements can be distinguished, which allow the user to build most common models: "Parts or entities", "buffers of queues" and "machines or activities". Kay (Kay 1999) defines event as *"an attempt to change the state of the simulation"*. DES can deal with both scheduled and consequential events. The main difference between them is that scheduled events occur after a period of time and the consequential ones may or may not occur depending upon the state of simulation.

SYSTEM DYNAMICS

Created in the 1960s by Dr. Jay W. Forrester of the Massachusetts Institute of Technology, System Dynamicss (SD) was first used to simulate a simple inventory control system (Forrester 1989). There have been numerous definitions of SD. The following one is extracted from Wolstenholme (Wolstenholme 1990):

"A rigorous method for qualitative description, exploration and analysis of complex systems in terms of their processes, information, organisational boundaries and strategies; which facilitates quantitative simulation modelling and analysis for the design of system structure and control".

SD is rooted in the engineering traditions of control theory and feedback analysis (Alfield 1999). The SD approach to model building emphasises system structure rather than collection of data. Martin (Martin 1997) defines "system" as a collection of elements that continually interact over time to form a unified whole and "dynamics" as the change over time. Ellis (Ellis 1999) summarises SD as a technique for constructing models that focuses on interdependencies, feedback effects, time dependencies, and causality in the object that is being represented. A typical SD model is built using the following elements of:

Levels. Levels represent the state of some element of the system at the point in time that the measurement is taken.

Rates. Rates represent the change of some element of the system across a specified time interval.

Converters. Converters are "intermediate" variables, which relate levels to rates, or rates to other rates. They are used as information links through the system, improving the decision making task.

The power of quantitative SD has been significantly enhanced in recent years by the development of the desktop computer and associated software like iThink, Vensim, Powersim or Dynamo. The implementation of SD can be divided in two separate phases, based on the identification of a problem or cause for concern (Wolstenholme 1990). These are as follows:

Qualitative System Dynamics: This phase of the method is based on creating cause and effect diagrams or system maps. The feedback structure of a system is a direct determinant of its behaviour over time.

Quantitative System Dynamics: This is the more conventional and traditional phase of SD. It involves deriving the shape of relationships between all variables within the diagrams, the calibration of parameters and the construction of simulation equations and experiments.

SD gains much of its power as a problem solving method from the fact that similar patterns of behaviour show up in a variety of different situations, and the underlying system structures that cause these characteristic patterns are known (Kirkwood 1998a). Richardson and Pugh (Richardson and Pugh 1981) give a formal definition of feedback loop.

"A feedback loop is a closed sequence of causes and effects, that is, a closed path of action and information"

It is necessary to emphasise the importance of feedback in the SD technique. Feedback in systems causes nearly all the dynamic behaviour (Zhu 1996). For more information, refer to (Albin 1996) and (Albin and Choundhary 1996), who analyse in detail different scenarios of both positive and negative first-order feedback loops, [5,7], who analyses the effect of constant flows into the system and (Stanley et al 1996), who analyse the more complex situations in which combinations of feedback are present.

The most common notation used in SD diagrams is the "Levels and Rates" (also called "stock and flow" diagram). As shown in Figure1, this notation consists of three different types of elements, increasing the information provided to the user: Levels (or stocks), Rates (or flows) and Information.

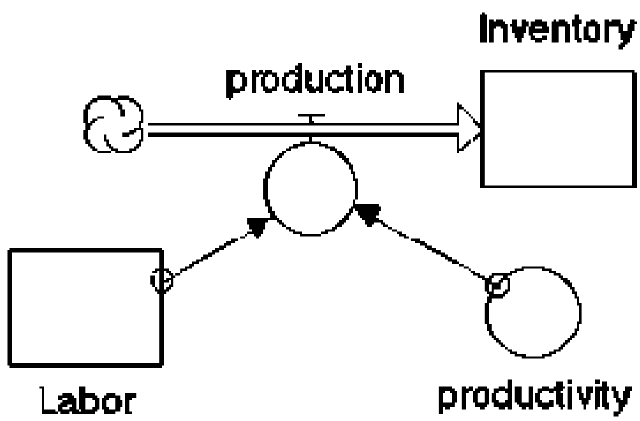


Figure 1: An example of "Levels and Rates" diagram

To completely specify the equations for a process model, it is necessary to give the initial values of each stock and the equations for each flow. In a manufacturing situation, typical equations can be:

$$\text{Levels: WIP} = \text{Initial} + \int_0^t \text{production}(x)dx$$

Rates: If WIP <= 1000 then production = 25/min; else production = 0.

The key factor involved in calculations is the Delta Time (DT), or time interval between calculations. As a summary, Zaraza (Zaraza 1998) says that in general, it should use the longest DT possible that allows accurate model behaviour.

AN OPPORTUNITY OF SYSTEM DYNAMICS WITHIN MANUFACTURING SYSTEMS DESIGN

THE CHALLENGE OF DETAILED EVALUATION

Once the problem is defined and the final solution is guided, "Detailed Evaluation" is used to find the final solution. To do that, the different alternatives to be considered must be very detailed, allowing the calculation of the consequences that each solution will have on the product or process that is being designed. In manufacturing companies, DES tools are used in this stage of the decision chain. It is important to highlight the large amount of data required at this stage of the decision chain, due to the necessity of finding the "best" solution. Simulation time is also quite high due to the extensive use of statistical functions and the complexity of the interactions between the components of the model.

The challenge of Intermediate Evaluation

"Intermediate evaluation" aims to reduce the large variety of solutions and parameters considered after the "Coarse Evaluation", simplify them and therefore reduce the time required to find the optimum solution in the "detailed evaluation" stage. The accuracy of the outputs provided in this stage of the decision chain does not allow the user to determine precisely which is the "best" solution, but helps in the reduction of the different alternatives obtained from the previous stage. The data required in this stage is simpler (only aggregate data is necessary) than the data used in the final step.

Most companies leave this stage of the decision chain, jumping from the initial stage (coarse evaluation) to the final one (detailed evaluation). It is usually done because the line between the three kinds of evaluation is not clear, and the beliefs of accuracy evaluations are synonymous to better results. In addition, the rare existence of specific tools to model manufacturing systems in an aggregate way and with an intuitive environment has eliminated this step from the decision chain.

Figure 2 shows the different steps to obtain a result and the appropriate tool to use in each one.

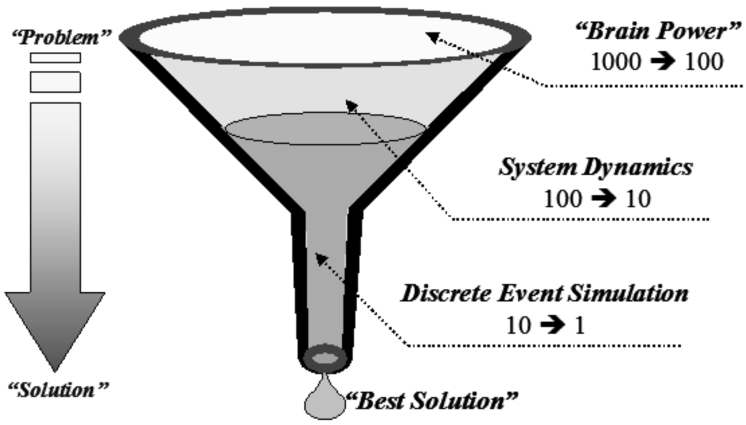


Figure 2: Steps in the decision chain

EXPLORING THE CONCEPTUAL FIT BETWEEN "INTERMEDIATE EVALUATION" AND SYSTEM DYNAMICS

In this scenario, SD technique can be fitted as the successful modelling technique to perform "intermediate evaluation". SD forces the user to view a manufacturing system at a relatively aggregated level of detail, helping the evaluation of strategic changes to a manufacturing system. This gives SD modelling great potential for overcoming the limitations of traditional simulation and analysis techniques.

Another strength that SD can offer in this stage of the decision chain is its system orientation. This makes SD ideally suited for the analysis of manufacturing dynamics systems. Within this area, it is particularly suited to the analysis of the manner in which information flows impact the behaviour of systems.

AN OPPORTUNITY FOR SYSTEM DYNAMICS TOOL FOR MANUFACTURING SYSTEMS

Although flow diagrams are one of the strengths of SD, it may have been one of the reasons for its delay to its application to manufacturing systems. Flow diagrams are not as clearly associated with manufacturing facilities as other forms of simulation. For example, although DES based tools like Witness required more data, their implementation in the market have been fast, because their user interface allows the understanding of the process simply by having a glance of the model.

The development of a new tool based on the principles of SD, and focused on modelling manufacturing scenarios, should provide an efficient way to analyse manufacturing systems quickly and accurately. It will allow using the power of SD logic but providing a new user interface, which matches simulation and real manufacturing systems more closely. This new tool should allow the user to model the manufacturing plant quicker, due to the aggregated information required, and also due to faster simulation, due to the less complexity of the embedded algorithm.

The originality of this work will arise from the tailoring of SD to manufacturing system modelling, and incorporating suitable performance measures for this task. This will provide an alternative technique to DES tools for system modelling that can be practically applied, and hence should improve the exploitation of modelling by industry.

CREATING A SYSTEM DYNAMICS MODELLING TOOL TAILORED TO MANUFACTURING SYSTEM DESIGN

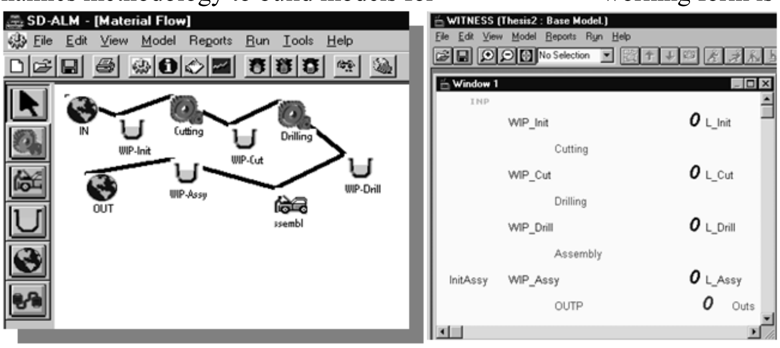
The aim is to create an alternative tool based on the System Dynamics methodology to build models for manufacturing systems faster and in a more intuitive manner, according with practitioner needs.

The built software attempted to establish a solid base to analyse the compatibility and applicability of SD into manufacturing modelling. Therefore, only some of the multiple parameters that can be measured in manufacturing systems were implemented in the tool. These were Volume and Machine rates. The measurement of these two parameters of the system allows the identification of other useful parameters, like machine utilisation, queue length and bottlenecks, in an indirect way.

To simplify the system, flows will be considered as linear, in which a given machine has only two neighbours, one at the front and the other at the back. In modelling the system, only stocks and rates are allowed. Machines will also have linear rates, allowing their use in constant speed, not considering warm up periods or under utilisation.

In order to choose correct developing software which best satisfies the application needs, the different alternatives available in the market were analysed. Considering the strengths and weaknesses of the different tools as described above with the requirements of the modelling tool, Visual Basic has been chosen to build the modelling tool.

The modelling tool has a user interface based on "Multi Document Interface (MDI)" applications approach. It consists of a main form, which contains the rest of the forms that the user is going to interact with. It provides a clear environment by incorporating the common functions and standard buttons in a main form, and leaving the specific functionality to the child forms. An example of the working form is shown in the Figure 3.



RATES		
Element	Quantity	Cicle Time
IN	2	18 sec.
Cutting	1	40 sec.
Drilling	1	25 sec.
Assembly	1	20 sec.
OUT	1	10 sec.
LEVELS		
Element	Initial Val.	Max. Value
WIP-Init	0	100
WIP-Cut	0	200
WIP-Drill	0	500
WIP-Assy	0	200

Figure 3: Example of one model used for testing the tool. A) SD. B) Witness

The most important child form is the Material Flow form. In this form, the user builds the model with the tools provided. This environment includes a grid, to aid in the positioning of the components and also includes some basic "drag and drop" facilities, allowing the relocation of the components in the screen. It also includes the basic tools to build models like "pointer", "machines", "operators", "stocks", "connectors", etc.

Tools based on SD technique require data in an aggregate form. In the modelling stage, the tool only requires the "quantity" and "cycle time" for each machine and operator and "initial" and "maximum capacity" for stocks. To run the system, the user must introduce not only the simulation time but also the resolution of the execution, defined by Delta Time (DT).

The analysis of the report and the two graphs also allows the user to identify bottlenecks, machine utilisation, and queue lengths. Bottlenecks can be easily identified analysing the "Rates / Time" diagram. In a linear system, the bottleneck is that machine which has the smaller rate. Using the same graph, machine utilisation can also be calculated. It is done by simple adding the time for which the machine is working, and multiplying it by Delta Time. To calculate queue lengths, is necessary to analyse the "Stocks / Time" diagram. Considering a linear flow, the queue length will be calculated by simply adding all the stocks of the system.

CONCLUSIONS

The study has revealed that SD is a useful technique to apply in manufacturing systems, due to the ability of the technique to offer adequate results even with aggregate data. It can be incorporated in actual decision chains, covering the hole existing between first drafts and final decisions.

The correct application of SD in simulation tasks can reduce the modelling time due to the simplicity of the data required, allowing the user to create models that can show the whole scenario of the manufacturing time in only a part of the time required doing this with DES tools.

The main advantage of the developed tool with respect to actual SD tools is that it focuses on manufacturing systems offering a environment which is simple to use and intuitive even for inexpert users. To test the tool, the same model has been built in a comparitive DES tool and compared, this will be the topic of our future work.

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Workflow Mining: A Case Study from Automotive Industry

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Abstract

Workflow-based release and change-management processes play an important role in concurrent engineering. The definition of an adequate workflow model is a time consuming and error prone task, which we propose to support by the use of a new technique called workflow mining. We derive a motivation for the use of workflow mining from new results from organization science. We give a technical overview of the workflow mining system **InWoLvE** that was realized at DaimlerChrysler Research and Technology, and finally we present the results of the first application of **InWoLvE** in the context of a project concerned with the improvement of a software change management process.

1 Terminology

In the following paper, the standard terminology suggested by the Workflow Management Coalition (WFMC) (Coalition, 1999) is used.

According to the WFMC, a *business process* is a set of linked activities that realizes a business objective. In contrast, a *workflow* is the automation of a business process, in whole or part. Hence, a business process and a workflow differ in that the business process is not necessarily concerned with IT support.

According to the WFMC (Coalition, 1999) a *workflow management system* is a system that defines, creates and manages the execution of workflows through the use of software, running on one or more workflow engines, which is able to interpret the process definition, interact with workflow participants and, where required, invoke the use of IT tools and applications. The process definition - we also use the term *workflow model* - is described in a language that depends on the concrete workflow management system used. We call a software system that implements a workflow regardless of whether it was implememted using a workflow management system or not a *workflow application.*

2 Workflow Mining in Workflow Application Development

Over the last decade organizational science has developed a theory that explains the role of information technology in organizations (Orlikowski and Robey, 1991; Orlikowski, 1992, 2000). This theory has been used by Kleiner (Kleiner, 2003) to study the life-cycle of workflow applications and the related software development process. In this section, we describe this life-cycle and the identified development steps briefly. This enables us to explain the role of workflow mining in workflow application development as a tool to improve the development step of eliciting a prevalent work practice.

2.1 The Life-Cycle of Workflow Applications

Figure 1 describes the outline of Kleiner's model: Managers are concerned with organizational goals and operationalize these goals in form of business processes (this work is often done by external consultants). Thereby, they draw on their knowledge and assumptions about work practice and their knowledge and assumptions about how the organi-

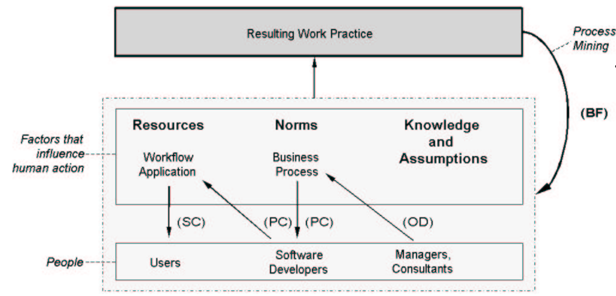

Figure 1: Life-Cycle of Workflow Applications (adopted from Kleiner (2003))

zation works most efficient under the current constraints. This development step is called the *organizational definition (OD)*. Software developers use the business process descriptions as a basis to design a workflow and eventually a workflow application. During this design process, they stay in contact with the users to better fit the design to the users' needs and, on the other hand, stay in contact to the management to comply to the financial and time conditions. The software developers' design choices are mainly influenced by their technical background, that is, their knowledge and assumptions about standard designs, best implementation platforms and so on. This development step is called the *physical construction (PC)*. After product delivery, users are confronted with the new application. They now use the application's features with respect to the situation at hand and with respect to their knowledge and assumptions about how to use the application. Users are human and therefore have a certain freedom to choose to use some features or not. What they eventually do with the application to get their daily work done is called the *social construction (SC)* of the workflow application.

When users work on a business process, not every activity is necessarily processed with the workflow application. The *resulting work practice* in the life cycle model in figure 1 is thus a set of activities, each processed in a certain time interval — partially processed using the workflow application and partially processed otherwise. Now, the important point is that *to enter the next development cycle in order to improve the organizational's efficiency (back-flow (BF) in figure 1), we need to understand the resulting work practice and further, we need to understand where and why this work practice differs from the target business process* the managers and consultants envisioned. Based on this knowledge, one of the three areas will be changed: *(i)* the target business process, *(ii)* application features (new ones, bug fixes etc.), *(iii)* users (e.g., training) or their work practices. With this development step the life-cycle is closed and starts all over again.

2.2 The Role of workflow mining

Now, the role of workflow mining can be explained as a tool to understand the prevalent work practice ('resulting work practice' in figure 1). Usually, this elicitation is done by 'manually' interviewing or observing users. Now, workflow mining is concerned with machine based elicitation. In this approach, logged activities and their related time intervals are taken as input. Then, AI based algorithms are used to elicit a workflow model out of this set. The limitations of this approach are clear from the life-cycle model presented. Since workflow mining is based on logs of activities, the non-system processed activities are not taken into account, nor is it possible to generate knowledge about why the work practice deviates from the target business process. But nevertheless the generated models provide valuable feedback that can be used as a basis for further analysis. This knowledge is generated with zero costs and it provides an objective picture of how the work was actually done. This is in contrast to traditional analysis techniques which often provide subjective knowledge based on perceptions and opinions.

3 The **InWoLvE** workflow mining system

In this section we give a short overview of the **InWoLvE** (*In*ductive *Wo*rkflow *L*earning *v*ia *E*xamples)[1] workflow mining system (Herbst, 1999, 2000b,a, 2001). **InWoLvE** solves the worklfow mining task in two steps: the induction and the transformation step.

[1] The name **InWoLvE** should also express that the main purpose of our system is to involve the end users of a workflow application much better into the definition of the workflow model.

3.1 Induction

In the induction step a stochastic activity graph (SAG) (Herbst, 2001) is induced from the workflow log. The induction algorithm can be described as a graph generation algorithm (`InduceUniqueNodeSAG`) that is embedded into a search procedure.

The search procedure borrows ideas from machine learning and grammatical inference (Parekh and Honavar, 2000). It searches for a mapping from activity instances in the workflow log to activity nodes in the workflow model. The search space can be described as a lattice of such mappings. Between the mappings there is a partial ordering (more general than/more specific than). The lattice is limited by a top or most general mapping (every activity instance with name X is mapped to one single activity node with name X) and a bottom or most specific element (the mapping is a bijection between activity instances in the log and activity nodes of the workflow model). Our search algorithm searches top down starting with the most general mapping for an optimal mapping. More specific mappings are created using a split operator. The split operator splits up all activity instances mapped to the same activity node of the model in two groups which are mapped to different activity nodes. This is done by renaming activity instances. In the example shown in figure 2 the activity instances with names A and C of workflow log E_1 are split in A, A', C and C' using two split operations.

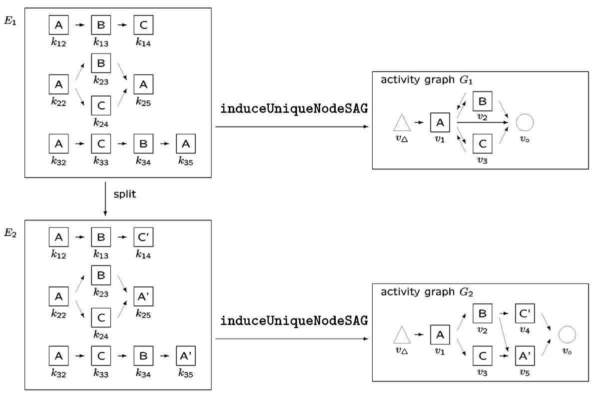

Figure 2: The split operation

The graph generation algorithm `InduceUniqueNodeSAG` is called for a fixed mapping from instances to activity nodes and it generates a stochastic activity graph for this mapping as indicated in figure 2. It is very similar to the approach presented in (Agrawal et al., 1998). The main differences are a slightly different definition of the dependency relation and two additional steps for inserting copies of activity nodes where required and for clustering activity nodes sharing common predecessors.

The search algorithm applies beam-search. The search is guided by the log likelihood of the SAG per sample. The calculation of the log likelihood requires a stochastic sample. This means that the induction algorithm handles n workflow instances sharing exactly the same ordering of activities as n different cases. Using this information **InWoLvE** is able to calculate not only the likelihood of the SAG but also the probability of tasks and edges. This information is useful to distinguish common from rare behavior.

3.2 Transformation

In the transformation step the SAG is transformed into a block-structured workflow-model in the ADONIS format. This step is needed because the stochastic activity graph provided by the induction phase does not explicitly distinguish alternative and parallel routing. The transformation phase can be decomposed into three main steps:

- The analysis of the synchronization structures of the workflow instances in the workflow log,
- the generation of the synchronization structure of the workflow model and
- the generation of the model.

Details of the transformation steps are given in (Herbst, 2001).

3.3 Architecture

The overall architecture of **InWoLvE** is shown in figure 3. It implements the induction and the transformation algorithms outlined above - which are called `splitPar` and `SAGtoADL`. Furthermore two induction algorithms - called `splitSeq` and `mergeSeq` have been implemented. **InWoLvE** also includes another transformation algorithm `SFAtoADL`, which is also restricted to sequential workflow models. The **InWoLvE** prototype was completely implemented in Microsoft Visual C++. It understands input files containing the example set E in three different formats. It accepts event traces in the APF-format, which is the native format of the ADONIS (Junginger et al., 2000) business process management system, it accepts simple ascii-files, where each workflow instance is encoded as a character string and it supports the common XML-format, which has been defined by different workflow mining researchers in a standardization effort. As output **InWoLvE** produces a workflow model in the ADL format, which can be imported by ADONIS.

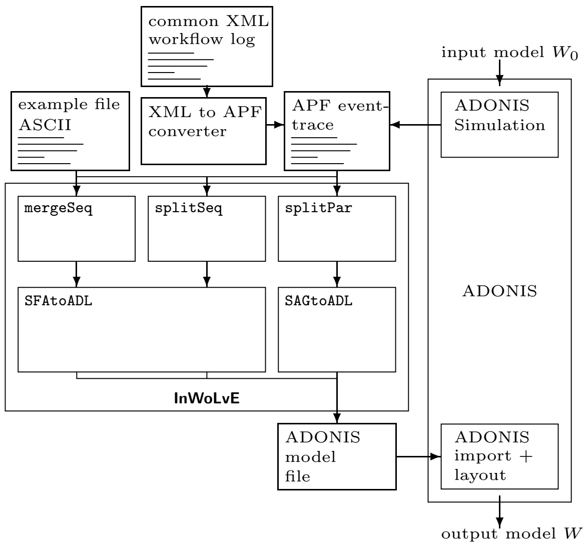

Figure 3: Architecture of the **InWoLvE** prototype

Further details and additional aspects like a transformation from the SAG to a well-behaved petri net, an additional split operator for dealing with noise and the results of the experimental evaluation are described in (Herbst, 2001).

4 An application to a software change management process

In a case study we applied **InWoLvE** in a real workflow project. The overall goal of the project was to improve the existing change management process for electronic control units of gasoline engines and to create a workflow application to support the new process. The old process was supported by a change management system that was implemented on the basis of Microsoft Access. The main deficiency of the old process and the old system was, that it offered only little support for software changes that affected more than one software development project. Basically the same change request data had to be re-entered for every project affected by the change. A first design of a new process supporting multiple projects had already been created by a number of users of the old system and a small group of process engineers.

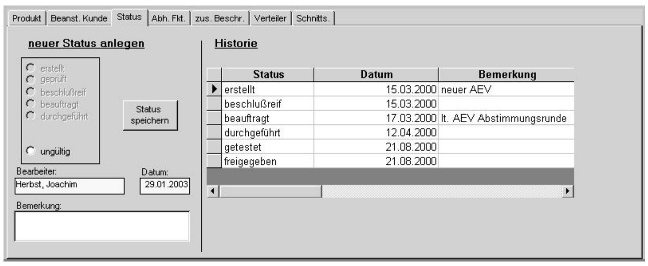

Figure 4: Workflow log of the software change management system

Although the old change management system was not realized on the basis of a workflow management system - no explicit workflow model was visible - the old change management system did store detailed workflow logs for every single change request that was performed using the system. Figure 4 shows an example for such a workflow log. The workflow log contained - among others - information about the activity that was performed or more precisely the state that was reached after performing a certain activity ("Status"), the date of the state change ("Datum") and a comment ("Bemerkung"). We extracted this log information from the database and using simple transformations we translated each workflow instance to an ascii-string (e.g. "ERBDGF" for the instance shown in figure

4), so that it was readable for **InWoLvE**. The result of applying **InWoLvE** to this workflow log is shown in figure 5.

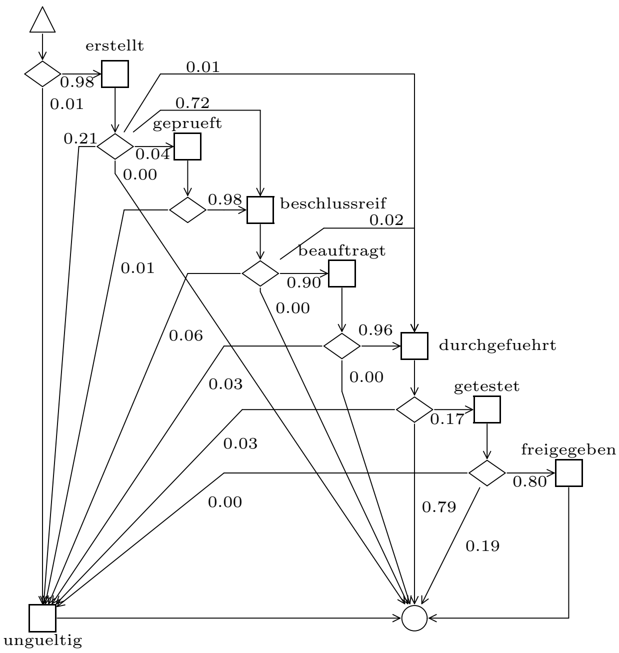

Figure 5: The software change management process

The application of **InWoLvE** provided us with an explicit model of the existing software change management process as it was actually performed at almost no cost. The analysis of this workflow model uncovered two facts that were surprising at the first moment.

- It seemed that the step for checking the change request which normally leads to a state "checked" ("geprueft") was skipped in a high percentage of cases.
- Furthermore people seemed to skip the final tests and release in almost 80% of all change requests.

We discussed the results with users of the system and finally found out that the workflow model driving the execution of change requests had been changed some years ago. At that time a step for checking the change requests had been inserted into the process. This was to improve the quality of the change requests reviewed by the change control board. This step was also part of the first design for the new process. At the same time the steps for testing ("getestet") and releasing ("freigegeben") the software were removed from the workflow model.[2] These two steps were also part of the first design for the new change management process. Obviously none of the users and process engineers involved in the design of the new process had remembered that these steps were removed for a certain purpose. After discussing this point it was decided that the reasons for removing these two steps were still valid. Consequently they were also removed from the new workflow model. In this way the application of **InWoLvE** helped us to improve the quality of the first design of the new process.

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[2] This certainly does not mean that these steps were actually skipped but they were performed and documented in another system.

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COLLABORATIVE CE-ENVIRONMENTS FOR VIRTUAL TEAMS

MODULAR REQUIREMENT MANAGEMENT IN PRODUCT DEVELOPMENT

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KEYWORDS

Product development, systems engineering, requirement management.

ABSTRACT

The development of innovative products which are in line with customer requirements and technological changes is one precondition for sustainable competitiveness. Especially in collaborative product development projects it is essential that every party knows about the requirements concerning products and services. Product development projects are characterized by iteration loops for clarifying of not clearly specified requirements. In industrial practice, only 50% of the companies specify the requirements always in systematic requirement specifications and manage them during the product development process. Changes in requirements during product development are not administered in requirement specifications. On the other hand, if requirements are not feasible the requirement specifications are not adopted. This leads to high changing efforts during the late stages of product development, when the misfits of requirements and product properties are detected.
At the WZL a methodology for modular requirement management has been developed that integrates the requirement management in the product development process in an efficient way by a modular structure. The Modular Requirement Management is implemented in an IT-Tool to allow an efficient use of the methodology. The modular structure and pre-instantiation of several requirement classes ensure that designers are provided with appropriate requirement specifications.

SYSTEMATIC REQUIREMENT MANAGEMENT - A KEY SUCCESS FACTOR

Clear customer requirements are the basis for an effective and efficient product development. The consequent transformation of customer requirements into product properties has to be ensured to make the market success of products possible.
During the product development process constraints from different disciplines, e.g. manufacturing, assembly, suppliers, have to be considered. One possibility is the establishment of cross-functional development teams, another possibility is the integration of already known constraints into the requirement specification process. In industrial practice, both possibilities are combined to various degrees.
Hence, the following definition for requirement management can be used (Stevens and Martin 1999): (1) to know what the customer wants (quality), (2) the solution efficiently meets these requirements (conformance).
The latest survey by the WZL at producing companies showed that successful companies follow a clear requirement management strategy in product development (Figure 1). Either they use requirement specifications for all development projects or they use requirement specifications only for their big projects. Less successful companies show a not systematic way of deploying requirement specifications.

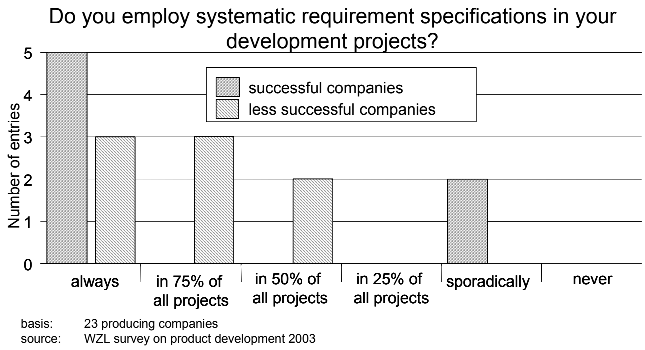

Figure 1: Survey Result – Usage of requirement specifications

By systematic analysis and management of customer requirements, successful companies can concentrate their efforts on productive development activities. The survey showed that successful companies have a higher degree of development activities while less successful companies have more coordination, change and information search activities (Figure 2).

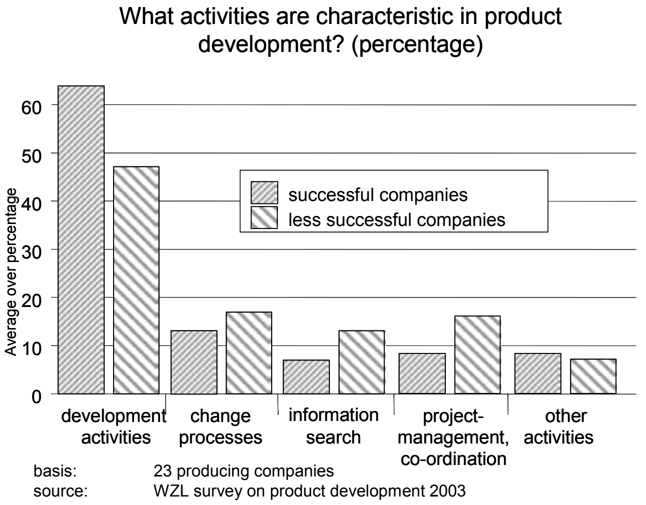

Figure 2: Survey Result –Activities in product development

The non-productive activities (change processes, information search, co-ordination) are mainly information flow related. Concerning the information flow the major weak points are incomplete information and information that is not provided in time (Figure 3). Also successful companies have these problems albeit at a minor degree. To support the efficient information flow in companies different IT-systems exist.

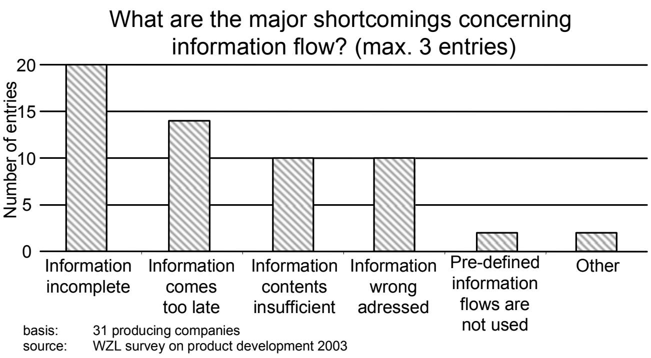

Figure 3: Survey Results – Shortcomings in information flow

In industrial practice, different requirement management systems exist. Most of them have been developed to manage software projects. They have been adopted to meet the requirements of other products. The methodological basis for most systems is systems engineering.

STATE OF THE ART IN SYSTEMS ENGINEERING

In the early phases of product development projects the systems engineering discipline dominates the efforts (Figure 4) (Stevens and Martin 1999).

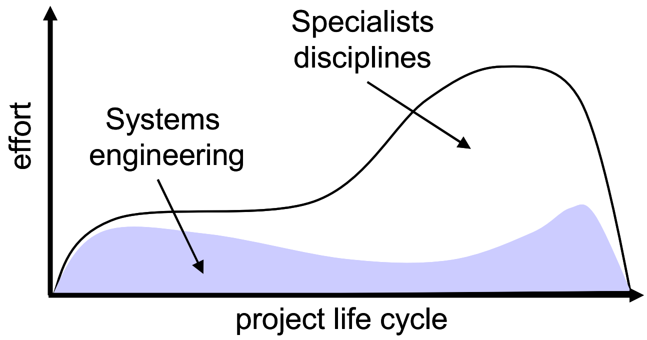

Figure 4: Project life cycle (Stevens and Martin 1999)

During these phases the requirements are defined. The requirement specification represents the basis for the following phases. In Figure 5 the model of the Institute of Electrical and Electronics Engineers (IEEE) is displayed (IEEE 1994). This model shows the detailed consideration of requirement specification process and the different verifications.

Characteristic for the phase models is the waterfall character. In most cases assessment steps are located at the end of development projects. Inconformances to requirements and not achievable requirements are detected to late. There are also shortcomings concerning the consideration and re-use of already existing knowledge and requirement specifications.

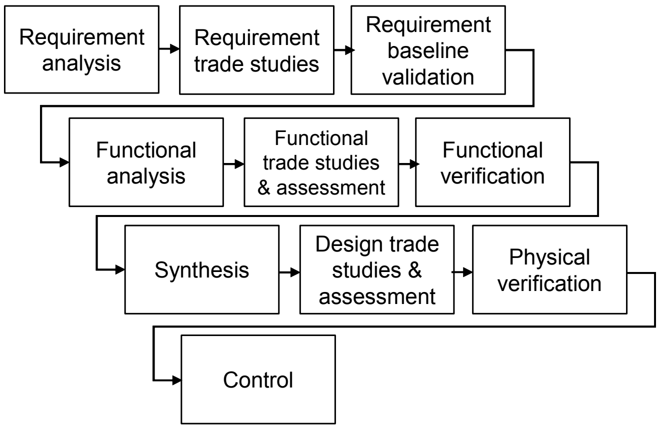

Figure 5: Systems Engineering process model activities (IEEE 1994)

In later phases the specialist disciplines dominate the efforts in product development. In those phases, changes cause much higher efforts for their realization. The survey showed that the "late" disciplines in the process chain cause the same amount of changes as customers, marketing/sales and design (Figure 6). Thus, requirement management can only leverage the efficiency if the aspects of those disciplines are considered.

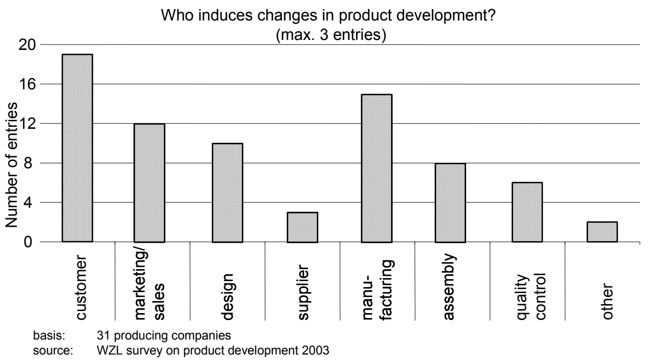

Figure 6: Induces changes in product development

Hence, the method for Modular Requirement Management should guarantee that all necessary information is collected at an early stage. The verification of information and feasibility of requirements has to be assessed as early as possible. Information and knowledge from the whole process chain has to be provided and integrated. The completeness of information has to be ensured by a consequent re-use of already existing requirement specifications and the methodological support of the requirement specification process.

MODULAR REQUIREMENT MANAGEMENT (MRM) IN PRODUCT DEVELOPMENT

Product requirements are a model of the customers' problems that have to be solved by the product. The basis for the Modular Requirement Management (MRM) is the early and continuous integration of requirement specifications in the product design process (Figure 7). The methodology is based on different levels of detail for the product definition. The activities set up the cycle planning, engineering and assessment. By assessing the results and verifying the requirements, early detection for possibly necessary adoptions either of the product specifications or of the requirements is possible.
In a first step, customer demands are collected and classified. In the engineering phase, system requirements are specified according to the customer demands and from the company's point of view. The requirements on the main system level are clarified and checked. The second step starts with planning the product structure and the product teams that are responsible for product elements. In most cases a product structure exists and can be modified concerning some modules and/or structural elements.
The requirements are assigned to product structure elements. Additional requirements concerning only elements of the product structure are added. Afterwards the structure is checked for accordance with system and customer requirements. The more detailed planning of components and adaptation of requirements and project plans follow. Then the detailed design starts according to the actual requirements. Before this, it is possible to verify the requirements by checking the actual status with customers, suppliers and other internal departments. For this the requirements for the different layers of the product structure can be provided. After detailed design the design verification follows.

For the efficient support of the MRM an IT-System has been implemented. On the one hand it allows finding already existing requirement specifications and on the other hand it ensures the consistency of the requirements and the assignment to products or components.

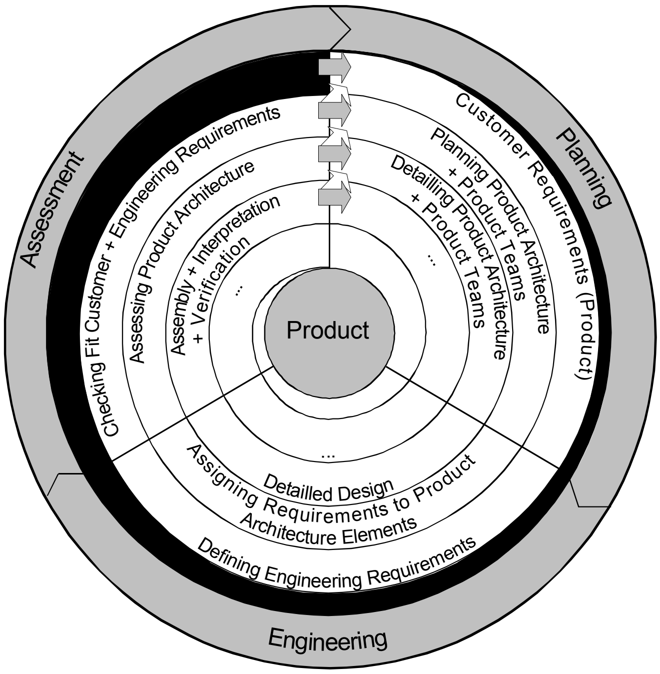

Figure 7: The modular requirement management approach

INDUSTRIAL CASE STUDY

The described methodology has been applied in a bilateral co-operation between the WZL and an international automotive supplier. There the implementation of MRM already demonstrated its benefits in pilot projects. Due to essentially diminishing coordination activities a significant reduction of the efforts in the development as well as the buying departments was realized.
The reason therefore is the possibility by using the introduced method to develop redundancy-free and complete specification sheets with minimal efforts through the reutilization of the existing elements. Basically, through the standardized principles for the composition of the specification sheets in the form of restriction catalog, the developed method and templates, the know-how of the concerned departments will be documented by the specification sheet. Further the use of the developed method induces standardization by the composition and documentation of the specification sheets, which positively affects the effectivity and efficiency for all the concerned external and internal development partners (Eversheim et al. 2002).
In this scope the implementation of the software solution is considered as a major success factor. Storing all requirement specifications in a central database enables the reuse of formerly issued specifications and vitally assists in carrying out the methodology.

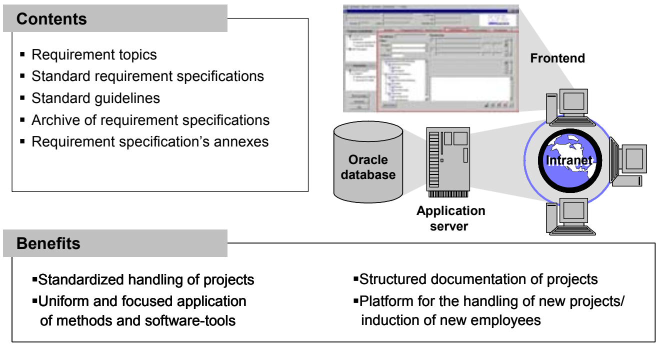

Figure 8: Architecture of the MRM-Tool

Designing the IT-tool as a server application makes an installation of any client software dispensable and every PC-user that is connected to the enterprises intranet gets immediate access via a standard internet browser. A corporate standardized documentation of the requirement specifications is ensured by the tool because complete documents incl. all norms, guidelines and annexes are automatically generated based on the contents of the database.

BENEFITS OF MRM

A consequential implementation of the described methodology leads to a significant reduction of aberration risks. This is based on entirely and systematically prepared requirement specifications. Increased use of the supplier's development competence by external tender of predefined development problems is enabled.
With the existence of a certain similarity between the actual and previous input information the reutilization and modification of an existing specification sheet is more efficient than creating a new. The effort needed for the revision of the existing specification sheet decreases with the increasing level of similarity, whereas the effort to determine the similarity level must be considered. Here the described methodology allows the optimal choose at all times either a new creation or a reutilization is efficient.
Through the strict separation between the external predetermined specifications and the contents of the resulting specification sheet, innovation brakes are prevented. The statement "We have been always doing that!" is as a basis of a design decision not valid anymore.
Through consequential documentation of all decisions during the development process of the specification sheet, revisions of the requirement specifications are clearly more efficient.
An automated preparation of changing histories, open point list etc. is available to assist the project management.

ACKNOWLEDGEMENTS

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PRACTICAL APPLICATIONS AND EXPERIENCES

INTEGRATION OF FAULT-TOLERANCE AND ENERGY FLOW TREATMENT INTO THE SIMULATION-BASED DEVELOPMENT PROCESS

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KEYWORDS
Fault-tolerance, Power net, Middleware, Development process, Simulation, EAST/EEA

ABSTRACT

Future X-by-Wire systems will require both fault-tolerance and a reliable power supply. These properties or sub-systems, which have been developed so far as system-specific and often separate from the application, must be integrated in the future into a universally applicable development process in order to ensure a seamless process.

This is possible by using a model-based software development process. By adding simulation models of the vehicle electrical system and the hardware architecture (redundancies, for example), system behavior can be evaluated as a whole, and its interactions with other systems can be analyzed even in early phases of development.

The aim of this paper is to show the extent in which the simulation-based approach supports the developer in system design with regard to fault-tolerance and power management, and whether or not a seamless development process can be implemented by means of the automated code generation associated with such an approach.

The findings obtained for this are described using an X-by-Wire research vehicle as an example.

INTRODUCTION

In the automotive chassis domain there is a trend to replace mechanical or hydraulic components with electro-hydraulic or electromechanical components, in order to improve the active safety and enable the introduction of new comfort functions (Hedenetz 2001). These so called X-by-Wire systems add new requirements on the electronics of vehicle systems especially if there is no mechanical backup in case of a failure.

Two major requirements of such future X-by-Wire systems without mechanical backup are fault-tolerance (fail operational behavior) and highly dependable power networks. Because the complexity and the interaction of automotive systems are rising, these two requirements have to be treated in a formalized way during the complete development process. It is of utmost importance to combine the functional evaluation with the evaluation of fault-tolerance and energy flow because the influences of these different parts on each other depend on the algorithms which are carried out. On the other hand, it must be possible to develop these different elements of vehicle systems in a distributed way, so that specialists for each element can be appointed. To enable a combined analysis phase of the interdependencies of vehicle systems it is necessary to develop a common evaluation platform in a development process where all the elements of the system can be analyzed (Heintel and Ruh 2002). With this combination a much higher test coverage can be realized.

In this paper the possibilities and advantages of the integration and combination of fault-tolerance and energy flow treatment will be analyzed and discussed as part of the development process of vehicle application software.

SIMULATION-BASED DEVELOPMENT PROCESS

Besides its potential in the reduction of costs and of development time a promising approach of future development processes is the simulation-based process. This process enables the development results to be validated from early phases (because of front loading) until the implementation phase of the product by using automatic code generation.

Currently, this process is mainly used for the development and evaluation of functional algorithms of vehicle applications. In a first step the algorithms are modeled and their functionality is validated. After validation, code implementing the algorithms is generated for the appropriate electronic control units (ECUs). During a concluding integration step the generated code is linked with other software parts needed for the execution and loaded into the memory of the appropriate ECU.

Today mainly the application algorithms of one separate ECU are validated. Distributed open and closed control loops are not well supported. (Ruh et al. 2001) introduced a further validation step: the global simulation step (see Figure 1).

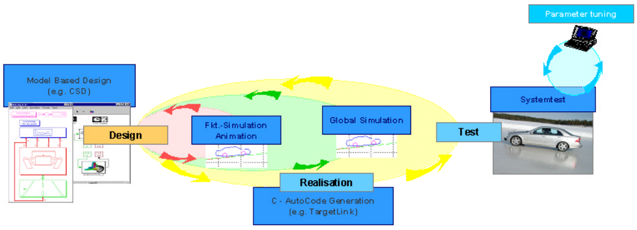

Figure 1: Simulation-based development process in 3 Steps

This simulation step provided a global validation of distributed cooperatively working ECUs before the code generation step. Realizing a simulation kernel for the underlying communication system enabled the analysis of latency time effects on the functional algorithms.

Based on this solution the fault-tolerance and energy flow treatment will be integrated in the simulation-based development process.

FAULT-TOLERANCE TREATMENT

At the present time, chassis applications are mainly characterized by the fact that they show a fail safe behavior. With the introduction of future X-by-Wire systems without mechanical backup, this will fundamentally be changed. These systems may cause major damage in case of failure. Therefore, a paradigm shift from fail safe to fail operational units has to take place. These facts lead to the requirement concerning electronics, which is known as fault-tolerance.

Fault-tolerance is a feature of a unit which is realized by an appropriate hardware and software combination. Nowadays, the first units implementing this feature are proprietary and each are developed nearly from scratch. By standardizing hardware components realizing fault-tolerance and implementing the software parts in lower layers than the application in a predefined way, a significant simplification of the development of such units can be achieved. The development of application software and the implementation of fault-tolerance can be separated. Therefore, the application designers can focus on the functional design and specialists of fault-tolerance can design the fault-tolerance behavior of specific parts of vehicle systems.

Fault Tolerant Middleware

Due to generalization and a potential standardization, this “lower” layer has to be common in the whole vehicle system and the configuration has to be based on one common knowledge base (a database, in general) to avoid inconsistencies. This layer is called fault-tolerant middleware for embedded vehicle electronics.

In literature various of these kinds of middleware are introduced (e.g. (Beckert 1995), (Murray 1998), (Birman and Marzullo 1990), ...), but none of them fulfills the automotive requirements concerning efficiency, required resources and costs. Therefore a new automotive capable middleware has to be developed.

In order to save costs and to reduce the risk introducing new technologies in vehicles a migration path based on existing solutions has to be provided. In case of a fault tolerant middleware todays software architecture has to be the basis. Figure 2 shows a generic software architecture of the automotive industry based on standards defined in the OSEK/VDX consortium (OSEK 2003) and the manufacturer software initiative (Lange et al. 2001).

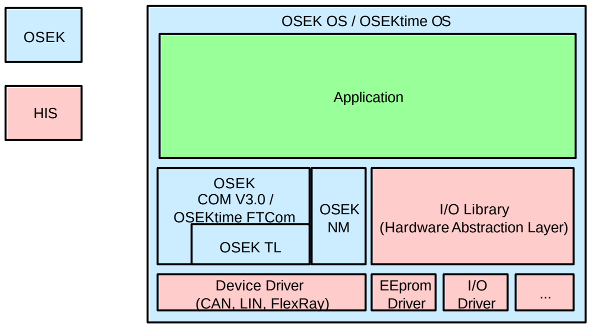

Figure 2: OSEK based software architecture

The European project EAST/EEA (ITEA 2003) has developed a general (not fault tolerant) middleware on top of the previous introduced so called basic software modules (see Figure 3).

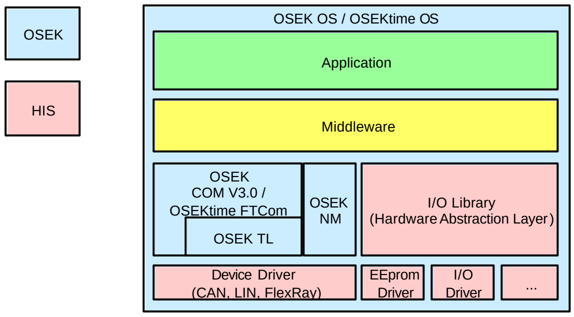

Figure 3: EAST-EEA middleware architecture

However, introducing efficient fault-tolerance requires more than one layer in this architecture. Because of that it is not sufficient to enhance the functionality of the middleware by specific services. Figure 4 shows extensions of the EAST-EEA software architecture only enabling a distributed fault-tolerant agreement (e.g. (Echtle 1990), (Cristian 1991), ...) of redundant ECUs:

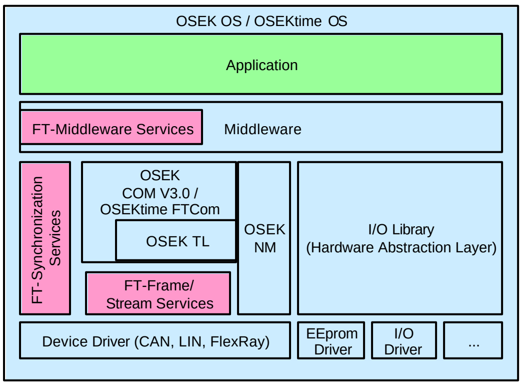

Figure 4: Automotive capable fault-tolerant middleware architecture

FT-Middleware Services: In this module the interface to the service is implemented (data access point, status information, etc.), further on signal based mechanisms of the agreement process (e.g. voting, signing, verification, etc.) are realized.

FT-Frame / Stream Services: These services handle (if possible) complete frames due to efficiency reasons (e.g. signing, verification, routing, etc.).

FT-Synchronization Services: These services provide a fault-tolerant synchronization mechanism (if not provided by the communication system a specific protocol has to be implemented) to enable the synchronized activation of processes on the distributed ECUs.

For a complete fault-tolerance support, various extensions have to be defined. By implementing them between standardized, already used software modules or inside new ones (like a middleware), the handling of fault-tolerance is considerably simplified and at the same time, a migration path from todays technologies to future ones is provided. If any unacceptable risk is detected during the development process at any time, the new technology can very easily be replaced by well tested technology, removing the new parts out of the software architecture.

Introduction of Fault-Tolerance Treatment into the Simulation-Based Development Process

Besides the simplification of the realization of fault-tolerant components, the introduction into the simulation-based development process is considerably simplified due to the use of a standardized middleware. Only the interfaces to that layer have to be provided in the simulation environment. For the validation, an extra simulation kernel can be implemented or the code running in the respective ECU can be used. As a result, the application designer is enabled to use and evaluate the functionality and the fault-tolerance behavior of a specific application at the same time without needing a complete knowledge of the fault-tolerance mechanisms used. The configuration of the fault-tolerance layer is done by the fault-tolerance designer and provided in the form of configuration files or the middleware code.

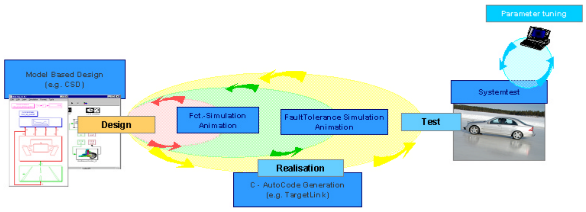

Figure 5: Simulation-based development process with respect to fault-tolerance treatment

For the validation of fault-tolerance it is necessary to simulate distributed ECUs. Therefore the simulation step of fault-tolerance behavior can be integrated in the global simulation step (see Figure 5). Here the fault-tolerance behavior of specific ECUs can be simulated in co-operation with the behavior of all other ECUs. It is therefore a more general view and due to that the global simu lation step can be replaced by the fault-tolerance simulation step.

However, the simulation of fault-tolerance mechanisms, such as agreements, is impossible without the co-operative simulation of the fault-tolerance layer, the communication system used, and the operating system implemented in the respective ECU. Agreements are implemented through different ECUs. Therefore, latency times due to communication systems and software layers providing communication mechanisms have a significant influence on the agreement itself, especially on the time needed for reaching an agreement. In highly dependable X-by-Wire systems the quality of the control algorithms depend on these latency times. As a result, the timing and functionality of the communication layers, the communication system and the fault-tolerance layer have to be co-operatively considered. The timing of the software layers depends on the operating system and the respective configuration. Therefore, the behavior and timing of the operation system has to be simulated as well.

Realization

For an evaluation of the concept described above, different toolboxes for the commonly used development environment Matlab™/Simulink™/Stateflow™ have been implemented at DaimlerChrysler AG Research and Technology.

The model is implemented based on the prototyping hardware used and the RealTimeWorkshop™ (RTW) which is used for code generation. The toolbox SIMCOM™ is used for the simulation of the communication system used (FlexRay). A simulation kernel of the time triggered operating system OSEKtime has been implemented, enabling the synchronized execution of tasks on distributed ECUs together with a simulation kernel of the fault-tolerant middleware. Finally, a tool has been implemented helping implementing redundant ECUs by automatic model generation and fault-tolerant middleware configuration (FT-Gen). Figure 6 gives an overview of this tool chain.

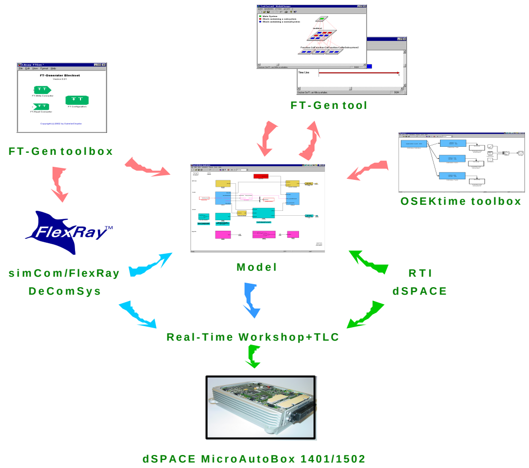

Figure 6: Evaluation tool chain for fault-tolerance treatment in simulation-based development processes

Experiences

With the development process introduced in this chapter an X-by-Wire application has been implemented and the fault-tolerance behavior has successfully been validated. Because of the possibilities of fault injection the behavior of the functionality in case of errors and faults can easily be validated. But a renunciation of formal methods like FMEA, FTA, etc. cannot be achieved.

One of the main advantages of this process besides the validation was the automatic code generation of the complete ECU code. Not only the functional code could be generated, also the basic software code could be configured and generated without any further linking or compiling.

Challenges of the proposed solution result from the simulation environment Matlab™/Simulink™/Stateflow™ and the configuration process of a fault-tolerant middleware layer:

1. In Matlab™/Simulink™/Stateflow™ it is easy to implement a time-triggered simulation kernel or an event based one. To be able to simulate a complete OSEKtime OS a mixture of both is required: static time triggered tasks and event based interrupt service routines. To solve this problem the simulation kernel has to check continuously, whether an event occurred or not (polling). The more accurate the simulation, the more calculation power is required. Therefore a proper abstraction of the timing has to be defined. This timing abstraction depends on the application. Mostly the minimum inter arrival time of interrupt service routines is a well suited choice.

2. Mechanisms realizing fault-tolerance behavior like agreement processes consist of various different actions which have to take place at specific points in time. The configuration process of this kind of software layers therefore differs from currently used basic software modules. For that reason, it is a major challenge to establish a migration path.

ENERGY FLOW TREATMENT

Just as cars are stand-alone systems, the available amount of electrical energy is limited – no electrical energy can be supplied from outside. All software functions and their consumer loads are sharing this limited resource. This results in a high degree of interdependence of all in-vehicle functions, e.g. an uncontrolled high energy consumption of comfort functions (heating systems, for example) might reduce the availability of electrical power for X-by-Wire systems. Therefore, the need for a highly dependable power supply and the increasing number of electrical functions demand an electrical energy and function management especially according to the importance of these functions.

As a result of the growing number of electrical functions and mechatronics in the vehicle, disturbances in the power network will lead to significant negative effects in addition. These disturbances within the power network, resulting in particular from high current gradients, have to be avoided. For that reason, the functions have to be designed in such a way that their current profile is compliant to those of other functions and to the power network.

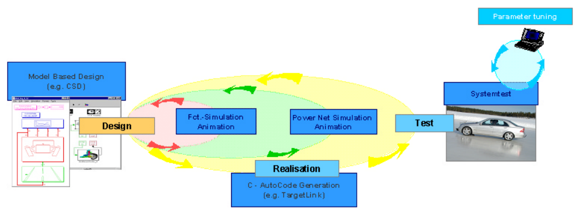

Figure 7: Integration of the energy flow treatment into the simulation-based development process. The integration is realized in the same process step as the global simulation step.

The electrical energy management and the compliance of the current profiles of functions have to be treated by the function designer. As the functions are developed by use of a simulation-based development process, the treatment of the energy flow has to be integrated into this software development process (Figure 7). For that reason, a simulation environment has to be supplied and simulation models of the functions and consumer loads which have to be validated, need to be implemented. Doing that the behavior of the system with reference to the energy flow can be observed.

However, the simulation of the energy flow, resulting from the algorithms implemented in the considered functions, is impossible without the co-operative simulation of the energy flow between the central components of the energy backbone, such as the alternator or the lead-acid battery, and the consumer loads. For that reason, the simulation environment has to include simulation models of these central components of the electrical power network. A typical topology of the electrical power network is shown in Figure 8.

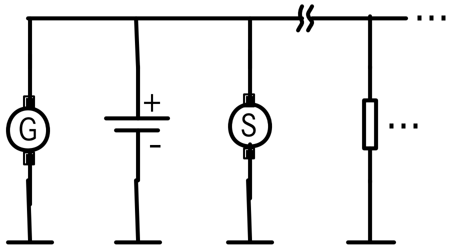

Figure 8: Typical topology of the electrical power network. On the left side, the central components of the energy backbone (alternator, battery, starter); on the right side, the supplied consumer loads.

The most important component for a simulation environment of the power network is the lead-acid battery. The lead-acid battery is a very complex system, and it takes a great effort to describe its internal processes and its behavior in the electrical power network in a simple, but correct manner.

Possible realizations of a simulation model of a lead-acid battery are discussed in (Mauracher 1996), (Caselitz and Juchem 1998) and (Buller et al. 2002). The model realized within the scope of this work is based on the impedance spectroscopy method as it is described in (Buller et al. 2002). Using this approach, the lead-acid battery is considered as a black box. Impedance spectra of the battery are recorded in many stationary operating points. For evaluation, these impedance spectra are plotted in the two-dimensional complex plane. This representation permits the extraction of a circuit equivalent and a graphical estimation of the according parameters (Figure 9).

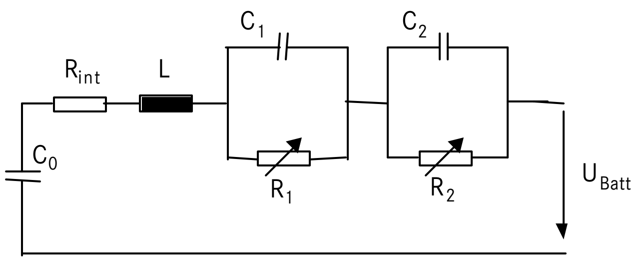

Figure 9: Simplified circuit equivalent of a lead-acid battery

A simulation model based on the simplified circuit equivalent shown in Figure 9 is sufficient for a simulation of the short-time behavior of the electrical power net as focussed in this simulation environment (Buller et al. 2002).

The simulation model of the alternator is based on the assumption of an ideal electrical machine with a time constant of the control loop representing the load response behavior of a real alternator. A more detailed description of an according model structure can be found in (Raffel and Orlik 1999).

An electromechanical braking system (EMB) was chosen exemplarily as consumer load for the prototypical realization of the simulation environment of the electrical power net because it represents a typical X-by-Wire system. The actuator of the EMB consists of a brushless DC motor, a planetary roller gear, a spindle, the caliper, and the brake pads. The mechanical torque, resulting of the brushless DC motor, is hereby transformed into a clamping force by the gear and the spindle.

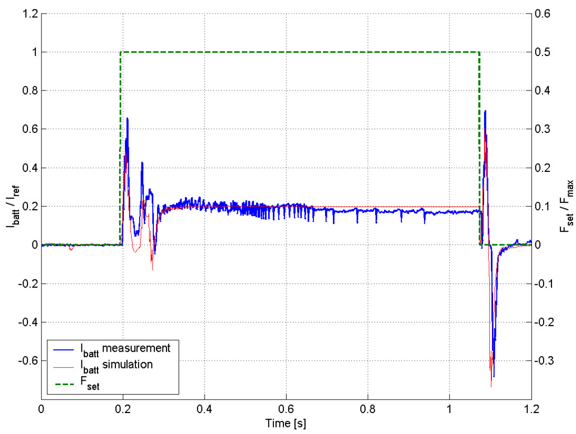

Figure 10: Measurement and simulation of the actuator current for a square pulse of the clamping force.

For the simulation of the dynamical behavior of the EMB actuator, the electrical parameters of the brushless DC motor, the friction, the stiffness, and the inertia of the mechanical components have to be considered (Schwarz et al. 1998) and (Schwarz 1999). Furthermore, the simulation model has to include the software components supporting the control of the actuator. Figure 10 shows a comparison of the simulation with measurement data.

To be able to simulate disturbances within the power network resulting from further consumer loads installed in the vehicle, these additional consumer loads are added to the simulation environment. Because the behavior of these consumer loads is not directly influenced by the functional software algorithms under development, they can simply be represented by their typical current profile. This simplified description is sufficient to simulate the non-linear base load of the power network.

To complete the simulation environment, a simplified simulation model representing a wire, which is implemented as a pi-element and a configurable consumer load, were added.

With these components, a simulation environment is provided, enabling the software developer to build a simulation model of the electrical power network and to consider the effects of the implemented application specific software

(Figure 11). The prototypical simulation environment for the energy flow is realized as a library for Matlab™/Simulink™/Stateflow™, the power net library.

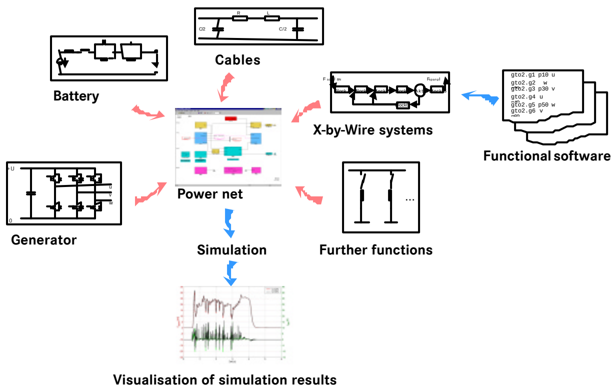

Figure 11: Principle of the simulation environment for the energy flow treatment.

The overall system functionalities such as energy and function management or driving dynamics functions are developed by the use of a simulation-based development process, i.e. the software is modeled graphically and validated by simulation. After this step, executable code is generated out of these models. For a simulation-based development of such a distributed application, it is mandatory to exchange the models between all partners. Due to IP-rights, it is unacceptable to provide fully analyzable models of the algorithms of these software components to the OEMs or other suppliers. To solve this problem, these algorithms have to be integrated into the simulation environment as binary code, which include the complete functionality but cannot be read (except by disassembling the file) by the partners (Ruh et al. 2001).

By use of the energy flow simulation environment, the behavior of the consumer loads and interactions between the functions and the power network can be simulated and analyzed by the function designer in early phases of the development process. Furthermore, the function designer may investigate signals and values inside the system that cannot even be measured in a prototype.

Experiences

The benefits of the integration of the energy flow treatment into the simulation-based software development process can be demonstrated by means of the development of an X-by-Wire system. The prototypical power net library described above was used for simulation and optimization of the driving dynamics software during the development of an X-by-Wire system. Therefore, four instances of the simulation model of the EMB were applied to the simulation of the driving dynamics (Figure 12). Each model of the EMB receives its set value of the clamping force from the driving dynamics software. The actual clamping force is given to a simulation model of the car. On the other hand, the simulation models of the EMB are coupled with a model of the electrical power network. All utilized components are included in the power net library.

After achieving satisfying simulation results, the software code is generated and compiled automatically out of the driving dynamics model (so called auto-code). This software can then be tested in a research vehicle.

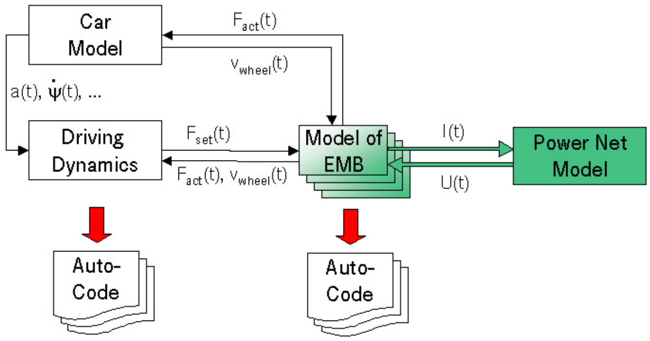

Figure 12: Simulation environment for the development of an X-by-Wire system, including energy flow simulation (in green color) and automatic code generation.

By studying the first results of the dynamic energy flow simulation of an ABS braking (shown in Figure 13), one can see many peaks in the current profile according to frequent changes of the clamping force set-point of the actuator. To improve the compliance of the current profile of the EMB to the electrical power network, the control algorithm of the driving dynamics control has to be modified and optimized.

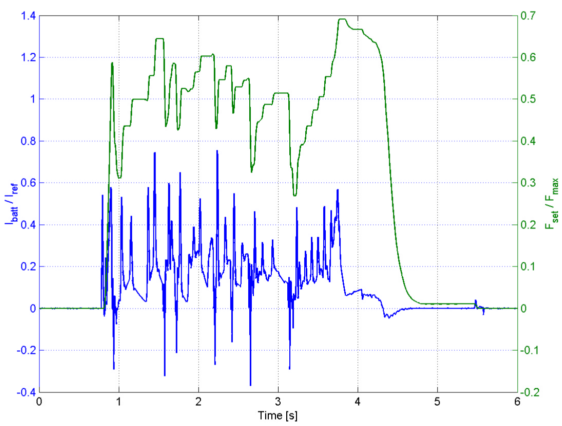

Figure 13: Current and clamping force of one actuator using a conventional ABS (simulation results of an ABS braking on wet road).

The current profile was smoothed by leveling the profile of the clamping force set-point using the new approach of a tire slip controller for the driving dynamics software as described in (Luedemann 2001). The results are shown in Figure 14. In comparison to the profiles achieved with a conventional ABS shown in Figure 13 one can see the smooth profile of the current and the clamping force of an ABS braking on ice.

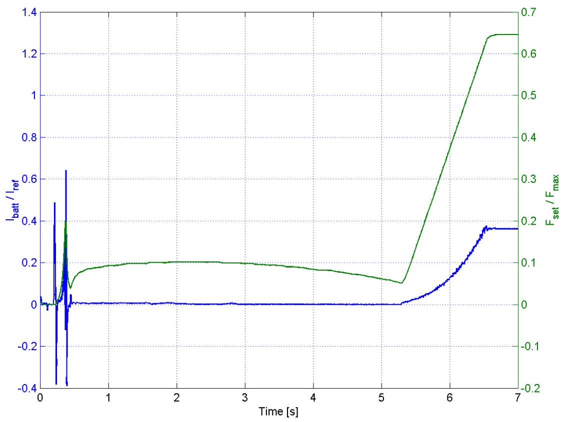

Figure 14: Current and clamping force of one actuator using an ABS based on a tire slip controller (simulation results of an ABS braking on ice).

This system optimization potential was identified in an early phase of the development. Using the dynamic energy flow simulation, this work can be done during the simulation phase of the system development, without needing to build a prototype. As a result, the development time can be shortened significantly.

The advantages of the simulation-based development process not only include the possibility of evaluating development results in early phases. By use of an automatic code generation process the development process will be further shortened and errors due to the manual implementation of tested models (breaking in the development process) will be reduced significantly.

INTEGRATION OF FAULT-TOLERANCE AND ENERGY FLOW TREATMENT

In the previous sections the advantages and challenges of the treatment of fault-tolerance and energy flow have been analyzed. An added value could be achieved by combining these two extensions of the simulation-based development process in one process step. Figure 15 shows the integration. The global simulation step has been replaced by the co-operative simulation of fault-tolerance and energy flow treatment.

The integration of the energy flow treatment enables the detailed optimization of control algorithms concerning global system aspects (the electrical power supply) and the optimization of the local and global control algorithm.

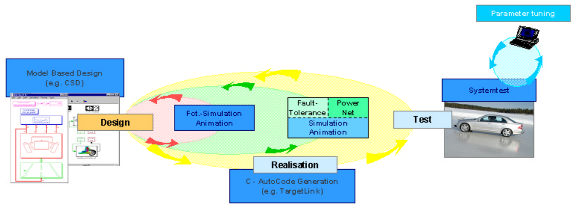

Figure 15: Global simulation-based development process including fault-tolerance and energy flow treatment.

Due to the need of the consideration of distributed ECUs, the integration of the fault-tolerance treatment enables the distributed simulation of control algorithms including associated effects such as latency times ?t_{lat} and fault-tolerance. Further on the complete software (functional and basic software parts) can be generated and configured for each ECU. Figure 16 describes the principle of the combined simulation environment for the development of an X-by-Wire system.

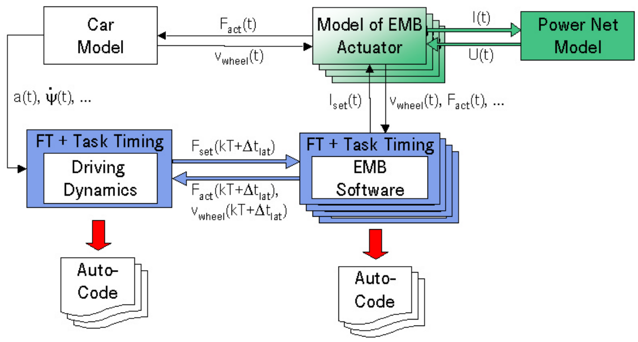

Figure 16: Combined simulation environment for the development of an X-by-Wire system, including fault-tolerance treatment (in blue colour), energy flow simulation (in green color) and automatic code generation.

Combining these two concepts enables the simulation of the interaction, the timing and the electrical power consumption of distributed control systems such as X-by-Wire systems. For that reason, a detailed global control optimization concerning energy-flow, timing and fault-tolerance can be achieved in order to increase the dependability of single parts of the system (ECUs, etc.) and global resources (electrical energy). Additionally, optimized code for distributed highly dependable controllers running on fault-tolerant ECUs can automatically be generated for systems depending on the dependable supply of electrical energy (X-by-Wire systems).

By that way a seamless software development process of X-by-Wire systems is achieved.

SUMMARY

Future X-by-Wire systems will require both fault-tolerance and reliable power supply. These properties or subsystems must be integrated in the future into a universally applicable development process in order to ensure a seamless development process.

The introduced integration of fault-tolerance and energy flow treatment into the simulation-based process permits the evaluation of the system behavior as a whole. Interactions with other systems can be analyzed even in early phases of the development, when the costs for changes are comparatively low. Due to the possibility of evaluating a greater number of parameters and physical values, a better understanding of system behavior can be achieved. Further on, the benefits of a simulation-based implementation and evaluation of fault-tolerance and energy flow treatment are the shortening of the development time and a higher test coverage which could be achieved.

A first prototype of the simulation-based development process with integrated fault-tolerance and energy flow treatment realized by the authors was shortly introduced. This protoype has been realized as toolboxes and libraries, extending the development environment Matlab^{TM}/ Simulink^{TM}/Stateflow^{TM}.

By means of the utilization of this prototype for the development of a research vehicle, a seamless software development process for X-by-Wire systems has been validated. The extent to which the simulation-based approach supports the developer in system design, with regard to fault-tolerance and electrical energy management, has been shown.

Currently, improvements and extensions of the simulation environment are in progress.

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BERND HEINTEL was born in Stuttgart, Germany in 1973. He studied electrical engineering in the field of information technology at the University of Stuttgart. He obtained his diploma in 2000. Since 2000 he is a Ph.D. student at Research and Technology of the DaimlerChrysler AG in Esslingen, Germany. In his Ph.D. thesis he deals with dependable power networks for future X-by-Wire systems.

CONCURRENT ENGINEERING TO ENHANCE COMMUNICATION AND COLLABORATION IN DESIGN AND PRODUCTION

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KEYWORDS
Concurrent Engineering, Virtual Environment, Hard Tissue Implants, Collaborative Design

INTRODUCTION

In our project regarding virtual design and production of ceramics implant for human bone, we use reverse engineering approach to prepare digital models for human bone with complicated and irregular shape. Using 3D scanners of direct/indirect scanning machines, digital data is collected and digital models are prepared. During the scanning procedure, position of object bones should be controlled dynamically to obtain the accurate data for digital model. For this position control, an automatic rotation control unit is available, and which is commonly used. However, the unit provides only one directional rotation at the vertical axis, which does not cover the data scanning of our bone samples. Therefore, we have created a special supporting jig for our objective based on our design. During the design and production process of the jig, we have used a concurrent engineering approach, using digital/physical mock-up for communication as well as design and evaluation. This paper describes the concurrent engineering approach which we have taken to create the special jig, and clarifies what we have learned from this case study. The paper also discusses what we can do to enhance the communication and what we should do.

DESIGN AND PRODUCTION OF HARD TISSUE IMPLANTS

As for the hard tissue implant of ceramics, a variety of shapes of various sizes are available. From several candidate products prepared beforehand, the most suitable one is selected at the time of surgery and used for the operation. Although a variety of product ranges is provided by manufactures, shape customization has to be made to fit the portion. Since it is not possible to reshape the implant to fit the complicated shape of damaged portion, the damaged portion of the bone in operation must be reluctantly reshaped to apply the products prepared. Ideally, implant should be properly designed to fit to the damaged portion, but actually it is not the case.

To design the shape of implant for each damaged portion, preliminary operation is required to obtain the physical data around the portion. However, it gives heavy burdens to the patient in terms of both mental and physical points of views. Our project focuses on collaborative design on hard tissue implants without preliminary operation. Using a 3D digital bone model created in a virtual environment, a custom-made shape of ceramics implants can be prepared in a timely manner. In the project, we have created a special jig presented in this paper.

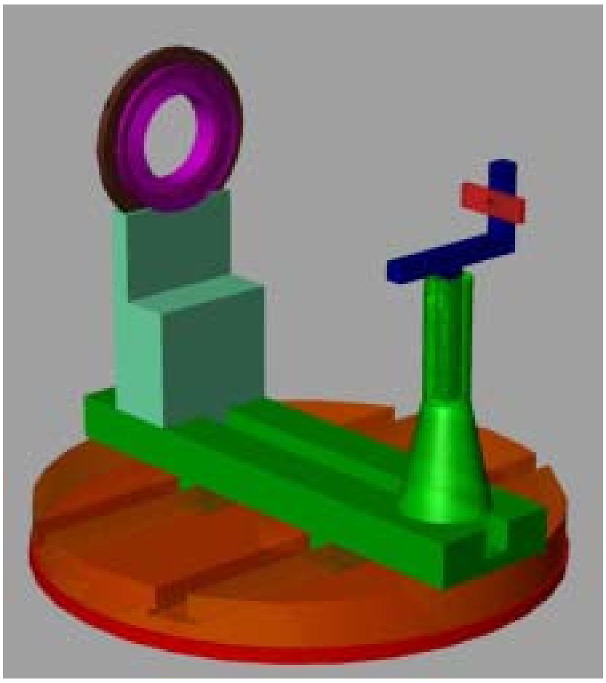

Figure 1: Rough sketch of special jig

DESIGN AND PRODUCTION OF SPECIAL JIG

Rough sketch modeling stage

In the project discussion regarding data scanning on human bone with complicated and irregular shape, we came to the conclusion that we should invent a special supporting jig to keep a sample bone in any stable position to obtain accurate data. First thing what we did was to make a rough sketch of the device which meets our purpose, and then we made a rough 3D modeling as shown in Figure 1, from which mechanical drawing for the jig is also available.

Technical staffs of our department normally process and produce based on mechanical drawing, in any shape and in any materials. If we are in a position to complete the mechanical design and prepare the mechanical drawing based on the design, they can produce the target product without any problem. In this case, however, we cannot complete the design in the beginning, because the special jig is a quite new device for us and we were not sure how to make it. What we only had a rough idea about the jig, from which we made the rough 3D modeling as shown in Figure 1.

Discussion stage

Using the rough sketch model and its mechanical drawing, designers and technical staffs had a very close discussion how to implement the device. For our discussion, we have used a concurrent engineering approach, which means that designing, evaluation, prototyping, and production were conducted in parallel. As a result, final design of the special jig was being formulated during the discussion, during which evaluation on the design was fed back to the design and reconsideration on the design was repeated whenever we found any amendments.

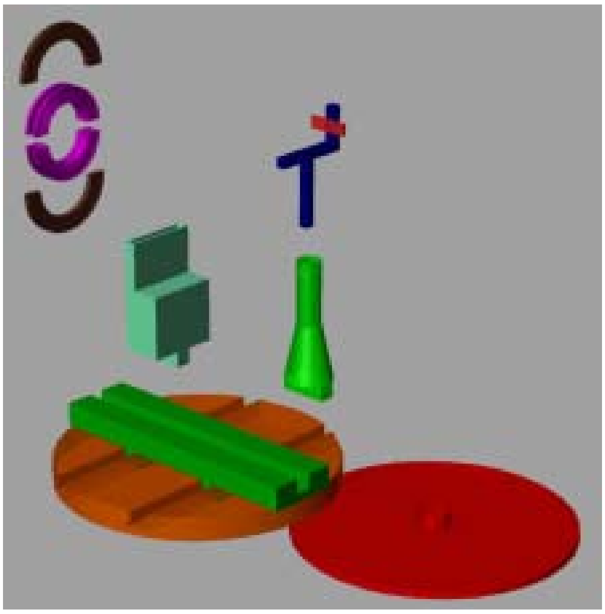

Figure 2: Exploded view of rough design

Figure 2 shows the exploded view of the parts in the jig at the original rough design. Part 1 in the figure fixes a sample bone, of which rotation should be controlled. The idea of fixing the sample and at the same time rotating it was clear but we were not sure how to implement it. The part 2 in Figure 2 shows a supporting bar, of which shape was a column shape. It is possible to prepare the column shape, but it takes time and cost to make it. We did not have any specific reason to specify the shape, which came from just a rough sketch. In this way, discussion had been continued over the 3D drawing on hard copy and also via the network.

Designing stage

Detailed and accurate design was gradually established based on the rough 3D model, and its CAD model was also prepared as shown in Figure 3.

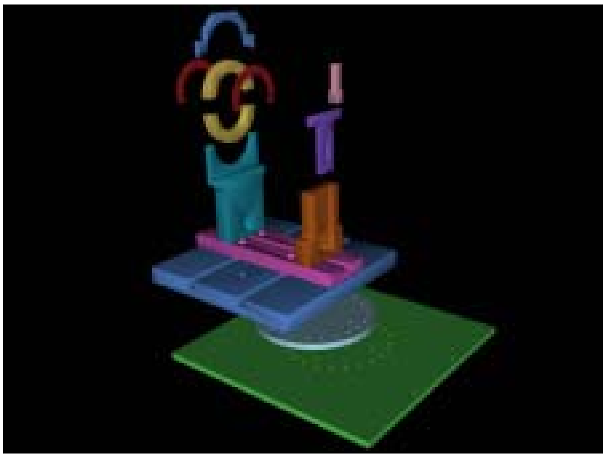

Figure 3: Detailed design of the jig

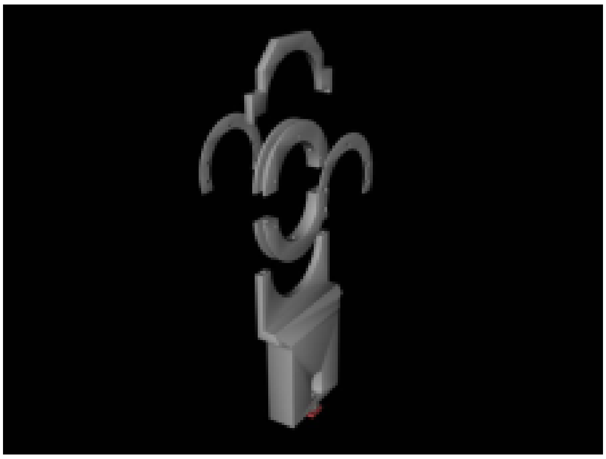

Figure 4: Detailed design of the supporting part

The implementation of the ideas, which were not clear in the original drawing, was also made clear. For example, Figure 4 show the detailed CAD model of the supporting part which was created after the technical discussion. As in the original idea of design, this part fixes the sample bone and at the same time its rotation is available, which means that the objective was achieved.

Production stage

In parallel to the discussion and evaluation on the design of special jig, its production was also under way. Since processability and productionability of the design were well under study during the production, time-to-the-production was shorter than we had expected, which was mainly because reproduction or revision was mostly avoided thanks to the concurrent engineering approach. For example, Figure 5 shows the actual parts production based on the design shown in Figure 4.

Figure 5: Actual parts based on the design

RESULTS AND DISCUSSION

Starting from our idea with 3D rough sketch model, we have created the special supporting jig as shown in Figure 6, which will be used in our implant project. In this section, we report on the results which were obtained from the experience of design and production of the special jig.

Concurrency in design and production

We had some requirements on the jig and also had some rough idea about how to implement it, but it was not possible to prepare the detailed design in the beginning, which means that its production was not possible. During the discussion in the technical meetings which took place on an ad-hoc basis, detailed design of the jig was gradually formulated, and when it is formulated, the production was completed at the same time. So the design and production were carried out almost in parallel.

Figure 6: Final production of special jig

Importance in role of modeling engineer

Software engineer with enough knowledge about the modeling played a very important role in our case, and enhanced the communication between designer and technical stuff of production. It may be possible to provide software system to all of the participating members and let all of them directly use the system. However, the same results will not be obtained in that case because all of the members do not always use computer systems in general. Basically, computer systems to enhance concurrent engineering are importance. However, without software engineer such as modeling engineer in our case, who plays an active role to intermediate members from different sections, good communication will not be available. As a result, concurrent engineering had not been enhanced at least in our case study.

Communication issue

In the typical process of design and production in our department, production starts only after the mechanical drawing is prepared and delivered it to the technical staffs. Comments and feed-back from the technical staffs are important and they are considered in the design, but it is not on real time basis. Communication between designers and technical staffs are typically conducted based on the mechanical drawing. In our concurrent engineering approach, we have used 3D model for our discussion in our technical meeting. Modification and updates were dynamically made on the model, and visually confirmed its results. Communication was much easier when we use computer graphics images based on the model, rather than using only a mechanical drawing.

Time issue

Since the members involved in the study also belong to several projects and tasks, it is not possible to mention the actual time for design and production for the jig. We can only say that design and production time were very much reduced. Time consuming is typically occurred from failure of design, which requires reproduction of all or part of the product. Although the design of the jig was quite new, significant failure in production was not observed in this case study. This is because when we identified any problem in the design, we revised it during the discussion, and updated the design before we actually made any processing.

CONCLUDING REMARKS

The paper reported what we have learned from our experience using concurrent engineering approach for design and production of the special jig. In the beginning we had a rough sketch idea but we were not sure how to make it. Thanks to the communication and collaboration among members of the study, we finally created the jig. Without concurrent engineering, communication and collaboration may be possible, but they were surely enhanced by the approach we took in the study.

ACKNOWLEDGEMENTS

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Configuration Management in Concurrent Software Engineering – a Case Study

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KEYWORDS

Software development, CM, CE, distributed teams, satellite measurement chamber, software processes

ABSTRACT

Configuration management takes on a magnified role, particularly in software projects consisting of distributed test and development phases and accompanied by frequent changes in requirement during such phases.
The paper deals with a case study of an antenna measurement system with a substantial software development component and how lack of base-lining for the system configuration, inadequate change control and overall inadequate configuration management led to increased time, cost over-runs, feature creep and, naturally, reduced quality. The lessons learnt and the measures put in place to control these factors and to bring the development back on track are also discussed.

1.Introduction

The configuration management umbrella, consisting of people, processes and tools, has to clearly support parallel design and development, especially in a distributed development environment with an accelerated change cycle. The analysis of the impact of these frequent changes on the different modules has to be thorough, especially if the distributed test and development occurs over very brief periods, making it too cumbersome to replicate the code at all locations at all times. Change control and above all the necessity of base-lining the system configuration assumes paramount importance. Additionally, a commitment from all involved parties to stringently follow the defined processes is very necessary.

A. The Project

The project in question involved developing an antenna measurement system to be used in compensated compact ranges for antenna measurements and tests. The system required a data acquisition, data processing, data analysis and data presentation software package to be delivered as a part of the system. The system was developed in parallel by two teams situated in geographically different locations – complete system concept, design and development was done in Germany, outsourced software development in India, commissioning and installation at different end-customer locations.

The period of system development from design to disposal was one and a half years. The software development was envisaged to be one year. The team responsible for the complete system concept, design and development (Team A) consisted of domain experts in the area of radio frequency test and measurement, hardware and system concepts. The software development team (Team B) consisted of software developers in C and Java with a working knowledge of visualization components. An in-house domain expert assisted Team B with domain concepts.

Fig. 1: GUI of the antenna measurement software

The entire measurement system consisted of several hardware devices including positioners, RF sources, receivers, multiple channel controllers, RF switches, etc. which had to connected in a specific manner to create the required system. The software would automate the testing by controlling the devices for the different types of tests and acquire raw data, process and analyze the data and present it to the user in a visual format. This would help the user to determine whether the antenna was achieving the desired performance.

The high level requirements for the software ran up to several thousands, each further getting broken down to several explicit and implicit requirements. The development followed a clear iterative model with regular feedback sessions. The software was tested offshore with a very rudimentary simulator of the hardware set-up with arrangements to do a more complete test after certain logical milestones in Germany, whenever the final set-up could be replicated.

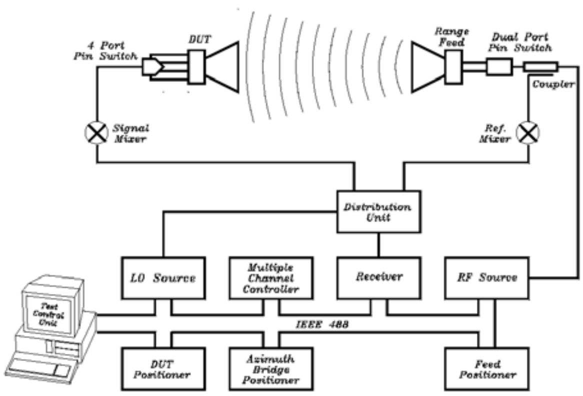

Fig. 2: Block Diagram of CCR Test Set-up

The complete tests in Germany involved one developer from Team B performing joint tests with a domain expert from Team A. During these short phases lasting a week or two, copies of existing code were taken by the developer onsite to accommodate any immediate bug fixes and changes requested by the domain expert. This minimal period of testing with the complete hardware set-up necessitated immediate changes to the code. At the end of the testing, the changed code was brought back.

The development team used a freely available tool called CVS for configuration management. CVS encompasses all aspects of configuration management by allowing base-lining, versioning, tagging, retrieval, comparison reports, etc.

The final deployment was at the end-customer locations.

B. The Problem Definition

Configuration management is above and beyond just the usage of a tool and has to do more with people and the underlying processes that they follow.

The system hardware and test configuration of the set-up was under development and was itself a changing entity and therefore was not base-lined. The lack of proper base-lining clearly affected the development in terms of the rework in all aspects of the development, from requirements analysis through design and implementation to testing.

Additionally, during the onsite test phases, the domain expert from Team A, unaware of the complexities of developing a large software system, would request several changes and desire an immediate implementation to check the feasibility of incorporating certain features. This was done in addition to ad hoc bug fixing. Therefore, the testing periods in Germany became more of an extreme programming case and led to the generation of multiple versions of code with various features scattered in these different versions. In addition, there was no focal point for accepting these changes.

The onsite developer used to incorporate these changes in the limited time available, which left him no time to document what changes had been made and where they had been made. Though he communicated these changes regularly to the rest of the development team, they would continue parallel development in India without doing a thorough analysis on how these changes would affect other modules within the software. The mainstream development did not stop during these phases due to the immense time pressure in the project.

In attempt to satisfy Team A and to make the software bigger and better, the basic configuration management processes were forsaken and no attempt was made to educate Team A regarding the necessity to manage versions, do base-lining, document changes and follow clear configuration management processes.

In due course it became clear that the development team began losing track of what changes had occurred in which version. The result was a chaotic situation where Team A found that some bugs corrected during the previous test phases were resurfacing especially during deployment. Members from Team B were called to the deployment sites to again rectify these errors, which further added to the confusion.

2. Configuration management processes and tools

Configuration Management (CM) is an essential step of the software engineering process. A common misconception is that CM only covers the management of different versions of code. However, the scope is much broader. Configuration Management extends to all kinds of artifacts like documents, test cases, review data, measurements etc. A crucial step is to define the right base-line, i.e. the set of artifacts and deliverables which should fall under stringent configuration management.

Configuration management is, of course also closely coupled with the change request and change management process. Ultimately the major drivers for different software versions are

- the removal of defects after testing
- the incorporation of new requirements and changes in requirements (both functional as well as non-functional)

Numerous tools for configuration management are available. Some come as stand-alone packages which can be integrated into a specific tool landscape while others are closely coupled with other software engineering tools. Apart from the basic version control functionality these tools often include support for parallel and concurrent development, release management, build automation and process automation.

The following list gives an overview of important and popular CM tools:

- AccuRev/CM from AccuRev http://www.accurev.com
- AllChange from Intasoft http://www.intasoft.net/

- AllFusion CCC/Harvest from Computer Associates http://www.ca.com
- eChange Man from Serena http://www.serena.com
- Change Synergcy/CM from Telelogic http://www.telelogic.com
- The Concurrent Versions System (CVS) from all public projects in domain GNU Public License Owner(s): Derek Price
- Rational® ClearCase® from Rational Software http://www.rational.com
- PVCS Dimensions from Merint http://www.merant.com
- Visual Sorce Safe from Microsoft http://www.microsoft.com
- Enabler from Softlab http://www.softlabna.com/
- Razor from Vsible Systems http://www.visible.com
- TRUEchange from McCabe http://www.mccabe.com
- Quartlet from SCM Labs http://www.scmlabs.com/
- Borland® StarTeam® from Borland http://www.borland.com

3. Lessons learnt in the case

The situation clearly taught the following lessons:

- The complexity of the software to be developed was clearly underestimated
- Definition of configuration management processes and educating all involved parties of the processes with a clear agreement that come what may, these would be adhered to, was missing
- Deployment environment must be replicated at the development site
- No unknown changes can be made to the deployment environment
- Impact analysis of every change to related modules have to be thorough and have to be documented
- A focal point for accepting/rejecting changes is vital to keep track of the changing system
- A well defined release process has to be agreed upon by all involved parties
- Most importantly, there has to be a base-line definition with a common understanding of all artifacts, and the base-line has to be accepted by all involved parties

4. Corrective measures

With the above lessons learnt, both Teams A and B decided to take corrective measures to bring the project back on track and the following measures were to be taken:

- Jointly agree on a configuration management process
- Changes to the deployment environment would be communicated to all parties and also made part of the base-line configuration
- No bug fixes would be done on the fly during testing and there would be a pre-test phase to do a documented bug fixing
- No ad hoc changes would be asked for during the testing and every request would be categorized, at least broadly, as a bug or a change request and would be analyzed before action was taken
- A change control board would be set up to do the above and the board would also act as a focal point for tracking all the changes
- Release process would have to be clearly defined and accepted by both parties

The development Team B decided to implement CMM Level 3 configuration management processes to arrive at a suitable process definition to achieve the above.

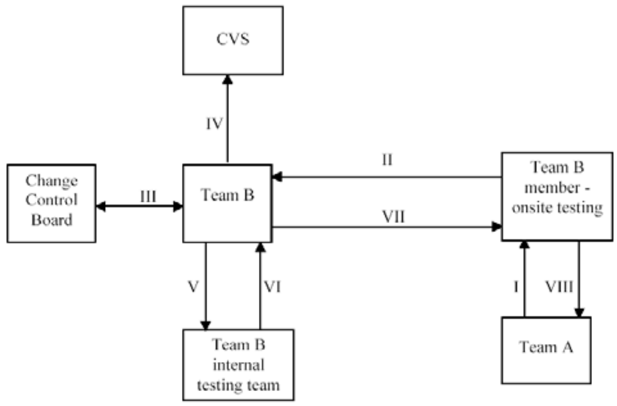

Fig. 3: Process Flow for Change and Bug Management

A. Change and Bug Management

I. Team A requests changes/reports a bug through Team B member working onsite
II. The onsite Team B member will send the change request/bug report to Team B. If changes to the software are made, then the prototype release is also sent to Team B.
III. The change request/bug report will be forwarded to the CCB (Change Control Board) and, on evaluation and approval from the CCB, remaining steps will be followed.
IV. Team B will make the change and update the configuration management tool along with the supporting documents
V. A release will be made for internal testing.
VI. Testing team will test the software w. r. t. changes and report if any bugs are found. Steps IV to VI will be repeated until there are no bugs.
VII. The changed files will be sent to the Team B member onsite.
VIII. Team B onsite member will make a release to Team A

B. Release Management

Three types of releases were categorized, each dealing with the amount of change to the software:

- Major release (release given for acceptance testing)
- Feature-based release (release given whenever a new feature is implemented)
- Releases with bug fixes (release made whenever bugs reported by the client are fixed)

5. Summary

Cooperatively addressing the problem, the teams arrived at a configuration management and release management process, which was accepted by all parties. Making any change to the software during the onsite-testing phase was avoided and even if changes were made and a prototype release was given for feasibility testing, it would not be part of the main code stream and would be discarded if the changes/bugs were not passed by the CCB. During the onsite testing phase all development activities of Team B would be stopped. If at all any parallel development was required, a separate branch would be started in the configuration management system and merging the mainstream with this parallel stream would be subject to approval by the CCB. The implemented process clearly eliminated the problems that were faced during the earlier phases and was considered a worthwhile investment of time and effort.

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Collaborative Working within the Aeronautical Supply Chain: the CASH Model

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KEYWORDS

Concurrent Engineering, Collaborative Working, Aeronautical Supply Chain, Extended Enterprises.

ABSTRACT

This paper presents the results of CASH, a Growth project co-funded by European Commission (N° GRD1-2000-25102) and fifteen european small and medium enterprises (SME). CASH stands for Collaborative working within the Aeronautical Supply cHain (Hochon, 2002) and has allowed to define a pragmatic approach for deploying collaborative processes within aeronautical SME in the aim of promoting Concurrent Engineering within the European aeronautical supply chain (Pardessus, 2001). This approach is described hereafter and some selected test benches experimenting this approach are presented.

THE CASH MODEL

A lot of technical works in Computer Supported Collaborative Working (CSCW) and Extended Enterprises (EE) domains have defined and experimented many models with common goals:

- better communication between team members, teams and organisations;
- concurrent engineering for reduced time delay in driving project;
- better competition within a supply chain (logistics, manufacturing and marketing).

CASH project has added costs reduction to these goals and has focused its contribution in defining a very pragmatic, generic and low cost effectiveness approach for the deployment of business-oriented collaborative processes within SME but also large enterprises. The main requirements filled by this approach are:

- a generic approach that needs thin customisation for setting up collaborative processes in a given business (for example: project management, digital mock-up design, distributed product data management services,…);
- an organised and secured access to external sources related to technical, economical and commercial data;
- heterogeneous tools and databases inter-operating transparently across platforms.

Considering these requirements and future challenges (Hertrich and al., 2001), the CASH consortium has defined a model so called "CASH Model" which aims at focusing on the main features when deploying collaborative working environment for a given business (product design, product configuration management, project management, …).

Mostly, the implementation of a collaborative environment requires identification of the business functions to be deployed. The state of art realised early during the project has highlighted the fact that in deploying collaborative working environments, the effort is more concentrated on the technical features of these environments; this behaviour brings on a lot of problems when using them. We notice that the business processes are not well studied and therefore, the environments are not well adapted.

We have put a special emphasis on the business processes and we have identified the following four phases:

1. The business functions that require collaboration,
2. The collaboration functions to be deployed,
3. The data to manage during collaboration sessions,
4. The information and communication technology (ICT) infrastructure needed for managing these data and collaboration functions.

Taking into account these phases, we have defined a model which allows to focus on each of these phases when necessary. For each phase, three main axes are considered: processes, methods and tools. Collaboration implies mostly many actors belonging to different companies: in this context, security is one of the main concern of collaborative environments. All these topics are integrated in the defined model that is depicted by different layers as shown in the following figure and described hereafter:

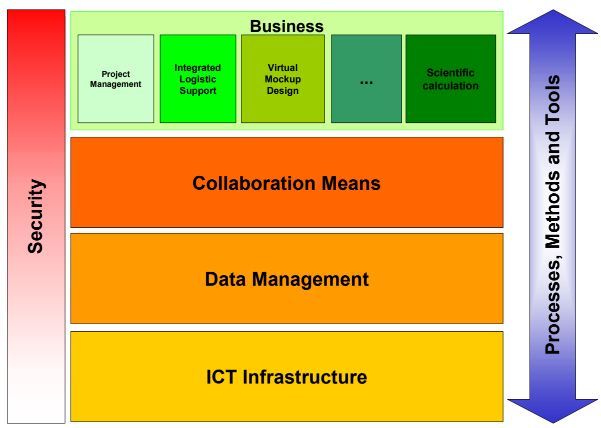

Figure 1: The CASH Model

"ICT Infrastructure" layer

This layer allows to specify the information and communication technology infrastructures needed for defining secured network taking into account existing local network areas of partners involved in the collaboration and different possible scenarios. It addresses **technological** and **organisational** elements related to communication and basic technology.

As already mentioned in (Hochon, 2002), ICT is the heart of business and Internet has become the star of communication as the new medium for communicating with customers as well as business partners. With Internet, the extended enterprise (EE) network is reachable all over the world and the logistical issues of adding new connections are eased.

In order to reduce considerably the costs of setting up secured private networks, our work has been based on deploying secured networks using Internet and Virtual Private Networks (VPN), creating **Internet-based virtual private networking**.

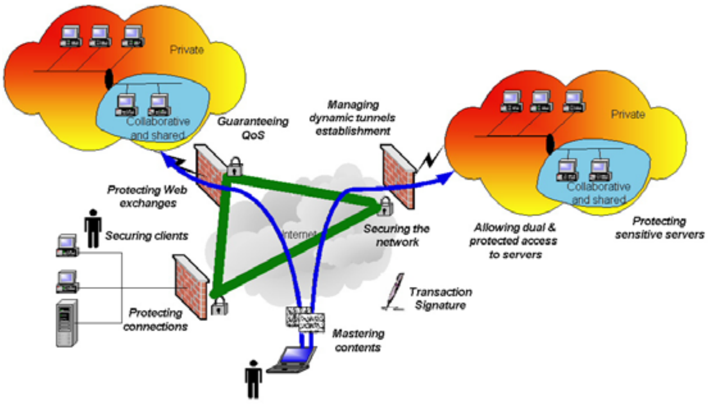

Figure 2: Internet-based Virtual Private Networking

Security aspects within an Enterprise are related to a number of issues, varying from physical to IT related security. Three approaches are presented below:

- **physical security:** like locks on doors, guards, the necessity to wear clearly visible badges, etc. This type of security measures is intended to restrict access to the physical ICT infrastructure to selected persons.
- **IT security:** within this context divided in local and remote IT security, deals with secure data transfer and access rights and permissions on systems and applications. ***Local IT security*** relates to an organisation's internal IT security. ***Remote IT security*** relates to data transfer security and securing the outside access to systems and applications. Remote IT security distinguishes between access from inside and from outside of the organisations within the Extended Enterprise.
- **Common IT security:** the scope is restricted to Extended-Enterprise specific remote IT security, whereas physical and local IT security are more of a company's private business. Common IT security approach provides useful answers to the IT security challenges. The philosophy taken within this approach is that every organisation is different, and security policies differ per organisation. The Common IT security approach within Extended Enterprise only serves as an extension to the IT security policy that is already in place within the organisation. It is not intended to modify what has already been established, but to merely enable organisations to extend their IT security policy in the leanest and most efficient way. The Common IT security approach enables reliable, secure communications within the Extended Enterprise. Additionally it also deals with high-level rules on access to systems and applications from outside of the organisation.

Protection of the internal/private network is also covered. The protection of everything that should not be accessible either from within or outside of the Extended Enterprise, is taken care of. The most characteristic aspects of the IT security approach are the Virtual Private Network (VPN) and the Project Zone (PZ). Organisations within the Extended Enterprise are connected through a VPN which is a collection of encrypted tunnels, that can be created on nearly all types of connections, such as the internet or leased lines of a Wide Area Network (WAN). These encrypted tunnels make it effectively impossible for third parties to monitor or analyse the data traffic between two organisations. Firewall systems set up the encrypted tunnels.

Besides connecting the different organisations of the Extended Enterprise, also **policies** should be implemented for sharing the data between the different organisations. The challenge is to decide with whom you want to share what. Clearly, company confidential information should be kept completely shielded and shared information available to the selected partners within the Extended Enterprise. Therefore we introduced the concept of Project Zones. A Project Zone is a zone within an enterprise having its own project specific security measures. The Project Zone is only accessible for project trusted Entities. Servers and applications that are shared within the Extended Enterprise will be hosted in Project Zones. The Project Zones are as safe as own private network, but can be set-up with different security policies. This enables secure sharing, without enabling outside access to the private networks. So, extending company's networks with Project Zones, the Common IT Security Approach truly forms an extension to an organisation's current IT Security policies. Every project can set up its own Project Zone, for which the project specific security policy can be implemented.

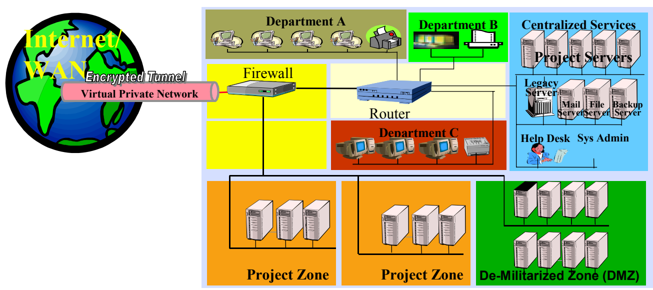

Figure 3: Project Zones architecture

Access from outside the Enterprise is provided in a similar manner as the secure communications between organisations. When connecting to the Extended Enterprise from outside the Extended Enterprise, a system configured according to the common IT security policy with access to the Internet (e.g. through a service provider) is sufficient. The system will then have to establish itself as a trusted site for the Extended Enterprise. The security policy describes exactly how the outside system needs to be configured in terms of security. It prescribes firewall settings and required encryption technology to set up an encrypted tunnel for connecting with the Extended Enterprise.

In the context of deploying ICT for Extended Enterprise, this layer allows to define the security policy and then to identify technological solutions suitable for this policy.

"Data Management" layer

This layer allows to identify the data to manage and how to manage them in an efficient way. It covers issues related to information storage, archiving, configuration and structuring for exchanging and/or sharing. At this level, different solutions for managing data have been analysed:

- **Remote file systems**: The managing of the files of different kind is one of the basic operations at the base of each mechanism of data exchange; consequently the characteristics of the used file systems have an influence on the performance of the exchanging processes. Teams that are located at different places have to access to the same data. These data must be stored in an "unique file system" available for all collaborators. Different technologies allow the implementation of such solutions: ***peer to peer technology*** (as example, Groove is a powerfull tool based on this technology), ***hosted solution*** and ***web-based file systems*** (as example, eRoom is a collaborative environment based on these technologies).
- **Product data management** (PDM): Enterprises that pointed out collaboration as a major strategic orientation in their business optimisation should keep in mind that access to data and data processing will be multiplied. If an adequate data organisation is not set up, the expected productive gains will be lost in data search and manifold inconsistency and replications. PDM systems aim at helping the design engineers freeing them data management. In addition, the overall organisation gains by accumulating and capitalising the experience. The PDM systems are dedicated to product lifecycle oriented organisations. At the opposite of the ERP systems that deals with the management of material and financial flows, the PDM systems deal with the problematic linked to product definition. The term "definition" covers any data describing the product (design data, sourcing data, cost estimation data, and so on). Apart from this business point of view, the PDM systems manage these data along the product lifecycle, from the requirements collection till the in-service support. Environments like Windchill, ProjectLink or OPDX offer hosted solutions.
- **Knowledge Management**: The knowledge can be exchanged in the implicit form among a team that have a common culture and have a direct exchange, for example during a meeting in which experiences are described and discussed. All the techniques for the collaborative working can be used. Normally knowledge management is an internal topic; this means that each company manages its personal know-how. For this reason, it is not very important for small and medium enterprises (SME) to integrate the internal knowledge management with the one of big enterprise. That means that SME is normally completely free to choose the personal way of managing the knowledge. Once the knowledge has become explicit, the IT can help in order to find the knowledge necessary in a specific situation. All the tools and techniques that allows to store (file system, database, etc.), to search (traditional query language or innovative), to index (data structure definition), to gather, to classify, to summarize information are useful in this phase.

In the context of deploying ICT for Extended Enterprise, this layer allows to identify what kinds of data will be exchanged or shared and therefore to define the exchange/sharing protocols.

"Collaboration Means" layer

This layer allows to identify what are the adequate collaboration means within a set of collaboration functions. It is associated to elements related to information sharing and exchange, collaborative activities (synchronous and asynchronous) and workflow management. Collaborative activities are mainly concerned with collaboration and communication in a synchronous and/or asynchronous manner. Communication needs are generally covered by synchronous collaboration tools when an immediate answer is required. Some asynchronous tools complete the solutions for communication when answers are not expected immediately. So, at this layer, are analysed different collaborative applications that can be easily and at low cost implemented in SME depending on the functionalities they provide.

Some **synchronous functions** studied are the following:

- **Audio conferencing**: this functionality is based on the use of telephone between two or more interlocutors.
- **Chat**: this basic functionality is essentially synchronous e-mail exchange, which permits non-audio based real-time communication.
- **Whiteboard**: this is a common area between several participants where images can be copied, annotations added and sketches made.
- **File transfer**: provides the capacity to transfer files between computers that can be immediately checked and discussed.
- **Video conferencing**: the main benefit of this type of solution is to see facial expressions.
- **Desktop sharing**: the purpose is to display areas of the computers desktop to remote collaborators so as to illustrate a point or a problem or to share the use of the computers.

- **Application sharing**: functionality which allows a piece of software held on one machine to be shown to someone using another computer. Some solutions allow transfer of control on the shared application.

Some **asynchronous functions** identified are the following:

- **FTP**: This functionality permits users to transfer the files they want to share to a disk space on the local network or the Internet.
- **Email**: this functionality is already used in most of companies and aims at sending electronically messages with or without attached document to others.
- **File sharing**: this functionality permits a team to share files over the networks.
- **Forum**: this is an online service that allows discussion group.
- **Calendar and scheduler**: functionality that enables to record events and appointments on an electronic calendar. Scheduler enables groups of users connected to a network to coordinate their schedules.

At this level, depend on the collaboration processes, these different solutions can be merged and used together. Some environments integrate different of these solutions (as example, Webex and Netmeeting). Whzen seeting an Extended Enterprise, this layer allows to focus on how to work together and to identify collaboration functions needed.

"Business" layer

This layer is dedicated to the business and allows to focus on the requirements of a given business when setting collaboration. The different scenarios and processes needed are defined at this level. Within the processes, the collaboration processes are identified and highlighted through information interfaces. When actors deploy different processes, synchronisation of collaboration processes are needed and blocking points due to interface items must be solved.

This business layer covers the technical elements of industry specific activities for design, development, industrialization and operation. For example, the design of an aircraft implies sub-systems designers, work packages designers, components designers, … and at each level, different lifecycles are identified. ENHANCE[1] project (Braudel and al., 2001) has focused its effort in the harmonisation of the different lifecycles at different levels in the supply chain.

This part has been covered by an experimentation realised in the frame of the CASH project in order to assess the effectiveness of the model and its applicability to SME. The next section introduces this experimentation.

EXPERIMENTATION THROUGH TEST BENCHES

The experimentation of the CASH model has been realised through five specific test benches in different business areas, covering different stages of the aircraft life cycle: project management, digital mockup design, scientific calculation and integrated logistic support.

The experimentation through such test benches allows to evaluate the common methods developed in the context of CASH. The approach used in this experimentation is characterised by:

1. analyzing the current situation and the desired evolution,
2. performing the experimentation,
3. analyzing the results with respect to the current baseline and
4. measuring improvements.

A common CASH platform has been developed in order to offer common collaboration functions to the different test benches and therefore to minimize the effort of implementing the same solutions by different members of the Extended Enterprise. In the context of the project, the consortium constitutes the Extended Enterprise and the partners are members. Their geographic locations are dispatched in Belgium (Louvain-la-Neuve), France (Toulouse, Tarbes, Paris, Guyancourt), Italy (Milano, Roma), Portugal (Lisbon), and Romania (Bucharest, Craiova). Each partner is connected to Internet (through service providers) and has its own ICT infrastructure and security policy.

Setting an internet-based network, private to the consortium, has required the definition of a consortium security policy. At a second level, the technical aspects have been analysed in accordance with the defined security policy. This task relies to "CASH model ICT infrastructure" layer deployment. For each test bench, a project zone has been defined and virtual private network technology has been deployed.

The second layer "CASH model Data management" deployment has permitted to identify the kind of data to exchange or share within the whole project and within each test bench. Both peer to peer and hosted solutions have been experiemented according to properties of data (format, size, …).

The "CASH model Collaboration means" deployment has been realised by identifying different kinds of collaboration. Vertical collaboration implies a task leader and its contributors (who act as sub-contractors) while horizontal collaboration implies different partners working together on a given task. These two types of collaboration need different technological solutions. Different collaboration functions have been selected for experimentation in different test benches.

The "CASH model Business" deployment has allowed to formalise the way of working of each partner involved in the test benches. Different actors roles have been defined and collaboration rendez vous have been also initiated. For

[1] ENHANCE is an European project realised between April 1999 and June 2002 by the European major actors in Aerospace. It aims at defining Concurrent Engineering and Extended Enterprise common standards for European aeronautical supply chain (http://www.enhanceproject.com).

each of these synchronisation points, synchronous or asynchronous collaboration functions have been identified.

The deployment of the CASH Model results in the implementation of a platform which architecture is outlined below:

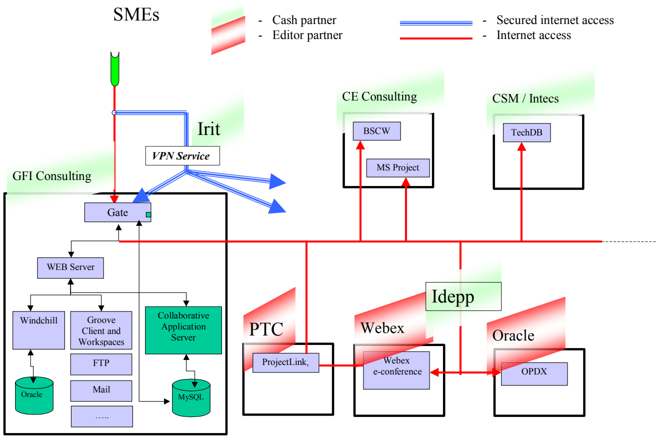

Figure 4: CASH distributed platform

The different test benches are under experimentation and relevant positive feedback have been already recorded.

CONCLUSION

The CASH model has been developed in order to establish a conceptual and technological framework and is defined in full compliance with the results of ENHANCE project (ENHANCE, 2002). The different commons defined within this project are then matched to the CASH model.

In this paper, we have presented in detail the CASH model by highlighting the different layers. For each layer, processes and methods have been identified and analysed. Security is a transversal function applicable to all four (4) layers and devoted to the enacting of confidentiality provisions in the collaborative work environment. The experimentation of this model has been also presented and demonstrates the originality of this pragmatic approach that can be adapted both to large and small enterprises involved in an extended enterprise. The technical innovations of this project lie in:

- Confirming the link between Concurrent Engineering and Collaborative Working. Nevertheless, collaborative working can be deployed without concurrent engineering processes.
- Experimenting at SME level the deployment of collaborative environments for different businesses with success and connecting these SME to large enterprises that can be contractors/clients or technology/services suppliers.
- The data exchange between aeronautical major enterprises and/or SMEs using collaborative working means (sharing information through collaborative working tools).

The CASH project originality is situated in the ambition to bind aeronautical major enterprises information systems and SMEs ones using Internet as network support. This is the current scientific and technical stake of the industrial areas due to the exchange world-wide and CASH project has turned this stake in reality in aeronautical area. Most of the consortium partners do not have high technological network. Nevertheless, using well-defined security policy has allowed a quick deployment of a secured extended enterprise oriented network. At this level, no difference has been highlighted compared to large enterprises network.

The deployment of business processes have been more complicated because in SME, such processes are not formalised. Except some synchronous collaborative sessions organised, it is difficult to change the behaviour of workers for a long time. So the cultural aspects are very important to integrate in collaboration experimentation.

CASH project has reached its objectives, regarding the definition of a pragmatic approach for deploying collaboration within SMEs. The defined model is enough generic to be applied for any type of enterprise. It is not only a model but also a methodological approach for collaborative working deployment. The experimentation of the model has raised some blocking points related to the difficulty to change some habits in order to comply with new rules of working.

The perspective of our research will focus on how to embed application of cultural rules in technological solutions for a better collaboration within an extended enterprise.

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BIOGRAPHY

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He has been involved in the specification, design and realisation of several technical information systems in the aerospace area (product data management systems, configuration management systems, system engineering, …).
He has also managed several european projects (essi, craft, esprit and growth programmes) and at this time, is managing a project dealing with Collaborative working within the aeronautical supply chain (16 european partners; budget: 3.4 millions of euros) in compliance with ENHANCE (European Project managed by AIRBUS).

LATE
PAPERS

DISTRIBUTED CONCURRENT ENGINEERING MODELING FRAMEWORK

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ABSTRACT

The new manufacturing paradigms, such as agile manufacture and lean production are leading our civilization towards the new generation of concurrent enterprises involving virtual enterprise architecture and concurrent engineering extended methodology. Continuing adaptation to the market can only be achieved efficiently if the planning and control processes are both optimized horizontally (Automatic Control Systems) and vertically (Management Control System). The desire improvement in performance and the realization of global enterprise objectives require a tight integration of the units of the enterprise. The present paper is concerned with a research activity aiming to focus on formal modeling framework. The acronym FABRICATOR stands for University pilot for Virtual FABRICA (factory). The project is based on Intelligent Multiagent Systems, Object-Oriented Software Technology and Network of Multimodeling platforms (e-manufacturing, e-design and e-business) involving concurrent engineering methodology developed for three geographically dispersed sites within POLITEHNICA Campus and Intranet/Internet infrastructure systems for advanced communication.

INTRODUCTION

The different views describe the global research effort that focuses on the requirements of manufacturing in the digital era. Next Generation Manufacturing Systems ***(NGMS***) (Kosanke et al 1998), Advance Manufacturing Systems (***ADMS*** ((Fabian 1998), Dynamic Extended Enterprise (***DEE***) (Browne 1998), Intelligent Manufacturing Systems (***IMS)*** (Brussels 1999) or ***Concurrent*** Enterprise (***CE***)(Pallot et al. 2000) are based on the new models: agile (Kidd 1994), holonic (Arai et al. 1999), fractal (Bischoff .1998), bionic, virtual (Smirnov 2001). Future manufacturing systems will result from both emerging Information and Communication Technology (ICT) and the new management science approach. They will share some characteristic proprieties: autonomy, multidisciplinary team work, integrated approach for product-process-system design and the re-thinking of man's position and role, will be agile as organization and virtual as geographic distribution and alliance. An important requirement for all post-CIM manufacturing systems is the ability to capture knowledge from multiple disciplines and store it in a form that facilitates re-use, sharing, and extensibility. The manufacturing environment is typically seen as a large, complex, man-made system of heterogeneous, interrelated activities. Designers, planners, operators, and workers are organizationally integrated within the manufacturing system. The convergence of disciplines around the extended control domain involves real time control, embedded control, networking control (Metakides 2001), mobile communication (Antoniac 2001) (e.g. M2M-machine to machine), multi-modeling and simulation driven design for complex automation systems.

An important part of the project is concerned with an ICT support platform for Virtual Enterprise (VE). A VE is considered as a temporary and dynamic alliance (i.e. with variable "geometry") that appears in response to a business opportunity and which is disbanded on the completion of this business process (Camarinha 2000). A number of both base and auxiliary facilities and services can be identified. Potential partners' selection and negotiations agreements could be supported by the contract-net approach of the Distributed Artificial Intelligence community. The definition of network topology and approach to co-ordination for auxiliary functionality to monitor and parameterize the network behavior are supported by PRODNET II, ESPRIT Project 16. One of the important issues here is the identification of "who will perform this function" in this "democratic" value chain (Katzy 2000).

During the operation of a VE by Web interconnection among partners from e-commerce to points of sales and crossing all intermediate nodes (manufacturers, distribution centers, etc.) there are some important goals to be achieved: the efficiency of orders flow, follow-up of orders evolution, management and exchange of order information among partners, distributed and dynamic scheduling, quality information, and even distance learning.

Starting with the general requirements, the main contributions are directed to the development of model-based architectures. These architectures focus on a single enterprise entity, do not fit with needs of virtual enterprises, but they can be useful in both giving a general overview of the global structure, in its multiple views, of a generic industrial enterprise (a potential node in the virtual enterprise) and suggesting an approach for VE Reference Architecture. Some of them are still sustainable like CIM. OSA / Open System Architecture for Computer Integrated Manufacturing (Kosanke 1998), PERA – Product Enterprise Reference Architecture, GRAI – Integrated Methodology, GERAM-IFIP/IFAC Generic Enterprise Reference Architecture Methodology, GLOBEMAN 21 (Vesteragen 2000).

In the specific area of Virtual Enterprise some attempts have already been made in order to establish Reference Architectures. The most significant is NIIIP (National Industrial Information Infrastructure Protocols).

DCE MODELING FRAMEWORK

Last year [ECEC'2002] our team has presented a paper (Stănescu, 2002) to introduce the new 7x7x7 cube-based general modeling framework for Distributed Concurrent Engineering (D.C.E).

After 12 months of intensive research aiming to consolidate it we could offer the version 3, whose X and Z-axes are depicted in Figure 1.

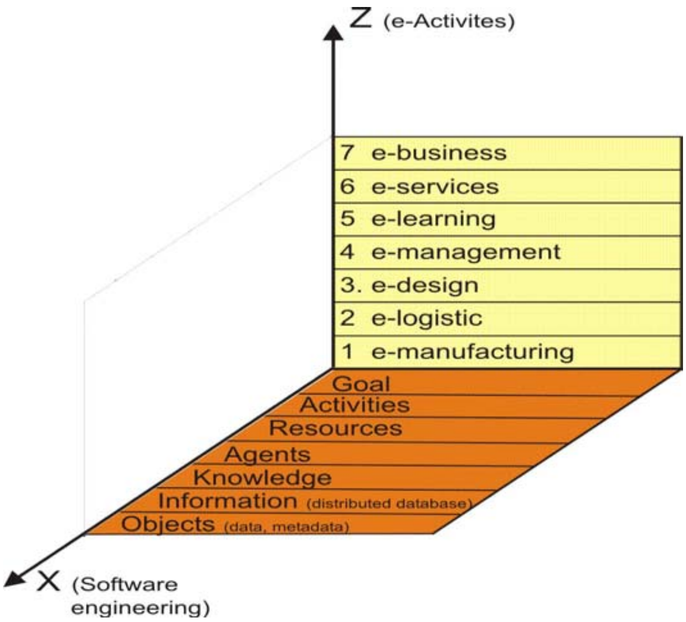

Figure 1. The 7x7x7 cube

While the Y axis (Systems of Systems) represents:

1. Metasystem (Virtual Enterprise)
2. Hypersystem
3. Systems (Supply Chain Management, Enterprise Resource Planing ans.)
4. API (Socketable software applications)
5. Requirements model
6. Functional model
7. Implementation model

Due to constrained publishing space (short paper) we invite everybody to contact us at http:/www.cpru.pub.ro or to exchange ideas, remarks and proposal for co-work with the occasion of ECEC sesions.

CASE STUDY

Handling scale

Many modeling solutions claim to scale. This is essential in an e-business environment, where one system alone handles hundreds of millions of transactions per day. There have been several examples where the problem of scale is being managed by grouping related things together.

To create an e-business relationship between a person and a resource, several intermediate steps are created. Working backward from the resource:

- The application designers, planners, business customers etc. collect related actions into action sets
- The business process designers then collect action sets from several applications (and there may be more than one from each application) into a process (shown as profile 2 in figure 2)
- The job designers (usually line managers) then organize their people to do a set of business processes (shown as roles in figure 2)
- Each person will have a number of roles, possibly from more than one manager – their collection of roles will make up their 'profile1'

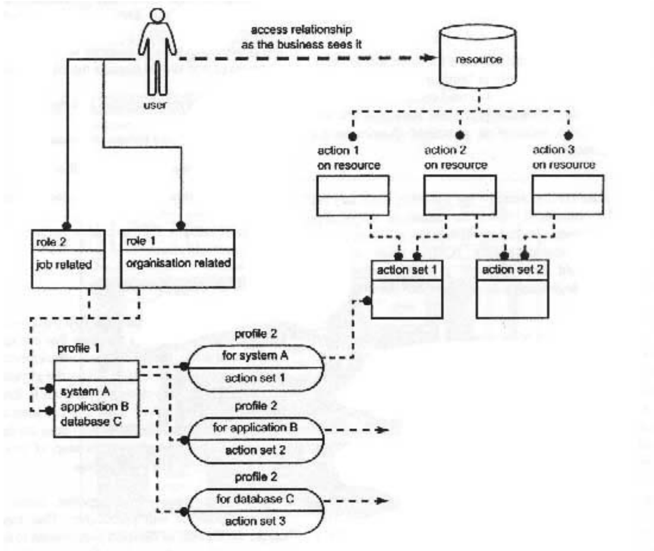

Figure 2. Access relationships

A technology transfer is planned to be developed between Human Resources Training Center at University POLITEHNICA of Bucharest (HRTC at UPB) and the greatest joint venture car manufacturer company in Romania, Renault-Dacia.

Our e-design platform, described in figure 3, has been developed in an academic environment and is oriented towards both large companies (Renault-Dacia), SMEs and Research Institutes (Romanian Research Institute for Aeronautics&Space). It is already involved in IST 5th Framework project ENHANCE II.

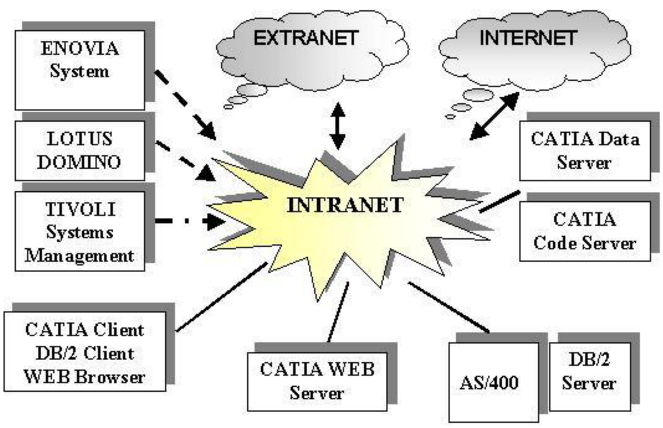

Figure 3. e-design platform

CONCLUSIONS

A Distributed Concurrent Engineering general modeling framework was developed within University POLITEHNICA of Bucharest in order to facilitate the Technology Transfer towards large companies & SME in the Romanian economy.

A first pilot is addressing the cooperation project with Renault-DACIA car manufacturing company.

Our e-business/e-design/e-manufacturing is more appropriate for a new concept (Stanescu et al. 2002) named e-Enterprise.

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DIGITAL PROCESS PLANNING APPLIED TO PRODUCT ENGINEERING INTEGRATION

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KEYWORDS

- Digital Factory
- Process Planning

SUMMARY

This paper presents the accomplishment of initiatives by the Brazilian branch of a world class manufacturing company towards the corporate project Digital Factory to promote the global process integration and technology transfer.

Potential benefits and a short successful case with digital tools application will be described.

There is a briefing of the strategies for the efficient solutions introduction and the recommendation to use the raised branch potential as a platform of experimental application for future solutions.

INTRODUCTION

The aim of the Digital Factory project is to support the complete engineering cycle by meeting the development and the production requirements that belong to the complete product creation process [1].

The project has begun in the middle of year 2000 and taken advantage of previous, successful initiatives, but isolated ones, which were applied in different phases of the engineering cycle.

The idea is based on the concept that, since the beginning of the product cycle, all the engineering steps will be supported, planned and optimized before they are accomplished, through the IT resources assistance. Such resources should also be capable to organize, maintain and distribute the knowledge based on previous projects.

OBJECTIVE

The main objective is to support the virtual analysis into relevant processes of the whole chain, which influences the factory operation [fig.1]. That analysis should be conducted before developing, building, testing, planing, producing and selling the product to the market, in such a way as to increase the quality level and reduce the time of the activities. It is also wanted to innovate, increment and standardise the process planning to guarantee the expected results.

SCENARIO

As an initial scenario, it was recognised that the available solutions were focused on structure and document data as a result of the industrialisation process planning instead of the planning activity. The alphanumeric data management is obvious, but without geometric base, looking at the product and not at the process.

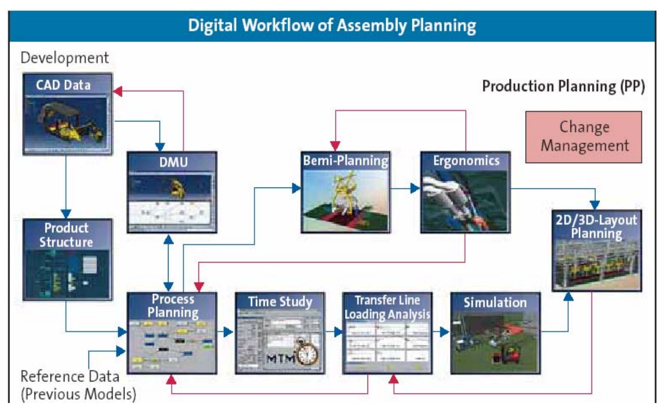

Fig.1. Cycle of the assembly planning

The interest for the planning process resides in the wide and deep evaluation of alternatives that lead to the best configuration for the production. This requirement is not supported nowadays. To fulfil it the expansion and integration of the successful solutions is required.

This action cannot be confused with the simple introduction of software in the related activities, not even with the sole addition of new functionalities to the IT systems. In fact, there are a basic process mapping need and a workflow revision to refine the interaction among the involved parts in the engineering process.

The complete introduction of the Digital Factory allows the company to accomplish short development time and engineering processes improvements through simultaneous activities.

CORPORATE DEVELOPMENT METHOD

With this scenario, the completion of a process of product creation [2] is extremely important to:

- quality planning for new products introduction
- monitoring of the corporate development process
- application monitoring of the project handbook
- evaluation of the prototypes quality
- demonstration of maturity degree of new components
- prevention of problems based on the production

The Digital Factory project is exactly conceived to support these points. The migration effort for mapped, optimised and unified procedures, which equally involves a great education process, brings significant results for the integrated development of products. It should be added that the conventional procedure maintenance has been acceptable while this environment is not completely implemented.

The product creation process should describe and determine the times for all the activities or sub-processes, from the concept to the production, through the steps of manufacture planning and utilities availability inside the plant, logistics and suppliers integration. All these sub-processes are linked to each other by an input and output data flow.

The main process control is accomplished through quality gates, whose previously defined exit criteria are measured and evaluated by both the user and the provider of the information, in terms of the quality and activity achievement, so that it is possible to manage the project progress.

When the quality gates are precisely defined, internal and external partners with correlated activities know exactly what should be provided and also the required quality level.

DIGITAL FACTORY

The production principles follow a description of interdependent activities [fig.2], which directly contribute to the accomplishment of the general process described in the corporate model. This way, the Corporate Development Method is firmly supported by the concept of Digital Factory.

The concept of Digital Factory determines the compliance with some basic guidelines, so that is possible to achieve the expected results concerning time and cost reduction in the cycle of engineering processes planning, with quality increment, as well the precision and agility in the decision making. They are:

- **Processes Standardisation**

In recent years the dedicated solution development has been usual. The current availability of equipment and resources allow the process planners to develop wide, integrated solutions through the introduction of typical parameters of the engineering process previously mapped and analysed [3].

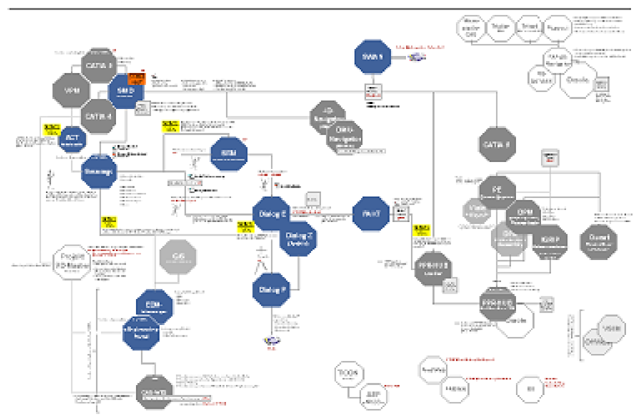

Fig.2. Current solutions mapping

- **Data Integration**

This guideline determines the domain of the data generation, handling, and management to satisfy updating and consistency requirements [4].

It is the technical column of the Digital Factory that controls all geometric and alphanumeric data coming from development and production places, besides corporate systems. EDM and ERP systems still do not manage this integration task entirely. Therefore, temporary solutions have been used.

- **Workflow Management**

The sole data integration does not ensure that the requested information will be available at the right time, at the right place, with the right quality and to the right user.

Because of a product program complexity, the distribution, monitoring, planning and execution of several sub-processes should be ensured. In order to achieve this, the engineering workflow should be defined.

In an ideal way, there is the automatic notification of relevant information or changes that occur. Consequently, not only the process progress documentation, but also its availability and maturity in real time is obtained.

- **Automation of Engineering Cycle**

Amount of data can be automatically extracted from the available volume in digital environments. This way, routine tasks with low intellectual request and controlled risk can be accomplished without additional effort.

EXAMPLE OF AN EFFICIENT SOLUTION

Here we mention the manufacturing simulation at robot-operated cells [fig.3]. The applied solutions are a part of the manufacturing cycle, in that the simulation of cells presents the advantages for off-line programming, collision analysis in path definition, process time optimization and required investment quotation. It has inserted a relevant flexibility to the engineering process, mainly to the resource definition and standardisation to be applied.

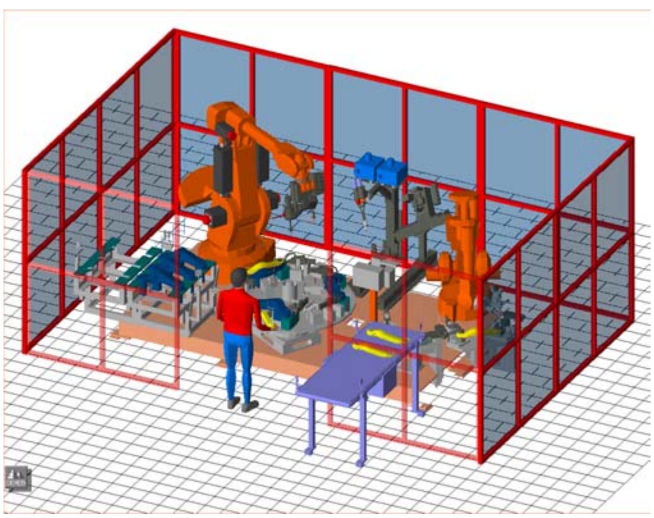

Fig.3. Robot-operated cell

Nowadays, those IT solutions have been interlinked. Until 2005 the target is to obtain a complete previous preparation of planning and production, with total virtual verification of the vehicle and its processes.

The main characteristics of this portion of Digital Factory project are at a compilation phase and will be added in the final work.

CONCLUSION

There are full conditions to introduce the corporate Digital Factory project at the company.

The need for changes to the corporate culture due to previous experiences has been also verified to facilitate the successful technology introduction.

The strategy should be detailed so that the proven advantages can be introduced in the operational plans of each company division as a corporate standard of engineering process.

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E-BUSINESS AND E-COMMERCE EMERGING STRATEGIES

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KEY WORDS

Information system, Information technology, E-business.

ABSTRACT

Information system has been around since the beginning of the time; information technology (IT) is relatively new comer to the scene. It became a strategic factor needed for organizations to succeed in business and have the opportunity to grow.

Many organizations are experiencing a new way in doing business; it is simply a digital process transaction which creates e-business strategies to deal with the market opportunities. Also, the study highlights on the two main functional strategies and their implications on organizations activities, which are business-to-business and business-to-consumer strategies.

The main finding of the study was the IT and its emergent strategies are strategic factors to be adopted through integration with major organization strategies in order to achieve the set targets.

INTRODUCTION

Although information systems (IS) of some form or another have been around since the beginning of time, information technology (IT) is a relative new-comer to the scene. The facilities provided by such technology have had a major impact on individuals, organizations, and society. There are new companies that can afford the luxury or benefits of Ignoring IT and new individuals who would prefer to be without it... despite its occasional frustrations and the fears of failing to implement the approach right.

An organization may regard IT as a 'necessary evil, some tiling that is needed in order to stay in business, while others may see it as a major source of strategic opportunity, seeking proactively to identify how IT- based information systems can help gain them a competitive edge. Regardless of the stance taken, once an organization embarks on an investment of this kind there is little opportunity for turning back.

This study is conducted to put the focus on the chronicle cycle of IT and IS, analyze the strategic driving forces of IT, highlight on the emerging strategies of e-business and e-commerce; and their functional strategies (business-to-business and business to consumer).

THE EMERGENCE OF INFORMATION TECHNOLOGY AS A STRATEGIC ISSUE

As IT has become more powerful and relatively cheaper, its use has spread through out organizations at a rapid rate. Different levels in the management hierarchy are now using IT, where once its sole domain was at the operational level.

The aim now is not only to improve efficiency but also to improve business effectiveness and to manage organizations more strategically. Electronic commerce and electronic business were emerged due to the highly development in IT, managerial tasks become more complex so the nature of the required activities for business is changing within The business functions and its suppliers on one hand, and with business customers on the oilier hand.

IT STRATEGIC FORCES

There is a growing requirement for integration of information flows at Individual and departmental levels, and cross processes and organization boundaries, which poses a variety of complex challenges. Communications capability is expanding all the time, as wide and local area networks flourish and (the number of external sources of information increase. IT was introduced to improve, simplify and speed business transactions on one side and communications in the business domain on the other side. The stake of senesces here is how to marriage IT with corporate and business strategy.

According to Lucas, IT is "the combination of computers and communications including all types of computers from desktop workstations to super computers and all types of networks, also fax machines, pagers, and communications modes like cable, satellite, and wireless" (Lucas, 1997).

A key task of top management is formulating corporate strategy. Though, strategist managers would ask the following questions: can it continue this activity at a high level of performance?, what opportunities for new directions are available?, and what are competitors doing?.

After all, a firm can continue its present course, maintaining momentum where it is doing well. Alternatively, the corporation can dramatically change its strategy by deciding among competing alternatives for new ventures.

There are three levels of integration 0!'information technology with corporate strategy, as shown in Table (1).

At the lowest level of integration, we Find independent information systems that help the Firm implement, strategy to improve efficiency.

The second level of integration is characterized by policy formulator systems designed to aid the strategic planning process. In this ease, the system helps formulate the plan but it is not a part of an end product or service produced by the firm.

At the third level, the technology its self becomes a part of policy execution-it expands the range of strategic alternatives considering by the firm. At this level technology bears an integral relation to a company's strategic thinking by helping to define the range of possibilities.

TABLE: LEVELS OF INTEGRATION OF INFORMATION PROCESSING TECHNOLOGY

Level of integration with strategy	Primary objective	Secondary effect
Independent.	Operational efficiency.	Managerial information.
Policy formulation.	Aid repetitive decision making.	Butler understanding of problem
policy execution.	Offer new products, market, directions.	Change the decision making process.

(Lucas, 1007: 103)

A number of strategically important forces affect the pace and effectiveness of progress in using IT. The importance or weighting of each factor varies over lime, and will also vary from one organization to another, one industry to another, and considering the size of a given organization; which implies that one ft suit doesn't fit all.

The following factors are strategically considered:-

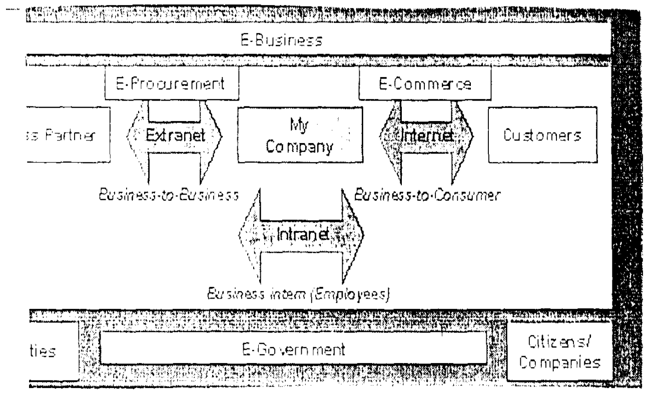
the capabilities of the technology, the economic of using the technology, the application's that are feasible, the skills and abilities available to develop and use the applications, the pressure on the particular organization or it's industry to improve performance and the ability of the organization to make appropriate judgements about the deployments of IT and the associated resources (Ward and Griffiths, 1999).

These factors can strongly be related to the success or failure of the IT strategy implemented, it is obvious that IT decision-makers will look at those factors as driving momentum or potential influences in the business market (IT Environment).

Galliers et al. examined many potential influences driving the environment of IT strategy in four aspects through structuring the Environment.

The following potential influences are;

IT' opportunities; These do not indicate only hard ware, lint also the capabilities of contractors and available



(Schubert, 2000)

services. As IT expands and breaks into sub-specialization, organization scanning to evaluate the capabilities of contractors and available services. As IT expands and breaks into sub-specialization, organizations might want to use some from of technology scanning to evaluate the capabilities.

The position in the industry, also including competitive and cooperative forces at work or in the industry, such as market segmentation and barriers to entry or existing electronic Data interchange.

The nature of the organization includes simple to measure factors such as the size and the financial results of the company, but also factors more difficult to express, such as the organizational structure, the nature and clarity or the corporate strategy and the a wariness and attitude of senior management towards IT.

The IT resources reflect past investment in systems, hard ware, procedures and people. They are the results of previous information strategies and now determine the competence of the organization to realize the chosen strategy. A specific category is formed by the resources available for the information strategy process, in terms of time, manpower and organization attention (Galliers; 2000).

	Technological Environment	Organizational Environment
External Environment	IT opportunities	Position in Industry
Internal Environment	IT resources	Nature of the organization

Gallicrs& Oil icrs, 2000:08).

A strategy of a corporation forms a comprehensive master plan stating how the corporation will achieve its mission and objectives (Wheelen and Hunger, 2000).

By implementing a fit strategy for a certain business, it will maximize competitive advantage.

Many organizations are experiencing a new revolutionary way in which business is conducted. It is simply a digital process translation, which creates E-business strategies to deal with the market opportunities.

The two E-business main strategies are: business to business strategy and business to consumer strategy.

Schubert draws a model representing the main strategic functions of E- business, he sets three categories under E business models:-

The Internet, which represents E commerce strategy, resulting in functional strategy (Business to Consumer).
Extrant, which represents E procurement strategy, resulting in functional strategy (Business to Business).Internet, which represents Business Item (employees). Schubert E-Business Module

E-BUSINESS AND E-COMMERCE STRATEGIES

They are terms that are some times used interchangeably, and some times they're used to differentiate one vendor's product from another. But the terms arc different, and that difference matters to today's companies. E- COMMERCE is simply any business transaction that takes place via digital processes over a network; also it can looked at it, as a commercial Activity that takes place directly between a business, it's partners, or it's customers through a combination of computing and telecommunications technology (Trepper, 2000; inland revenue, 2001).

It's a model designed to sell products and services in other words, directly generate revenues. (Guki, 2000).

E-Commerce, however is really much more than just exchanging product or services for money over the internet it an Enabling technology that allows businesses to increase the accuracy and efficiency of business transaction processing it is also away (or organizations to exchange information with customers and vendors to the benefit of every one involved. It will likely replace the movement of papers within and between organizations, as well as between customers.

On the other side of the equation, the Electronic business strategy is taking place as an internal process to support such activities. Barters stated that "E-Business includes E-commerce but also covers internal processes such as production, inventory management, product development, risk management, Finance, knowledge management and Human resource" (Bartels, 2000). Therefore, E-Business is away of increasing business efficiency just as traditionally. New premises or machinery would be (Brock, 2002).

According to Jupiter Research, IT people cant explain or define the difference between E-business and e-commerce, let us alone understand the implications of having an internet, intranet, and extranet presence. E-business is using internet-related technologies in any business activity, including sales, marketing, purchasing human resources, etc; while e-commerce is a subset of e-business related to marketing or selling, products and services (Szymkiewiez, 2001).

Regardless of these different point of views we see that E-business success requires that companies deal simultaneously with technical and business challenges. Full integration is the only long-term solution, and it's achievement must never be delayed awaiting the existence of better systems.

There fore E-commerce progress can achieved by meeting two questions; what does e-commerce offer the customer? How it can offer more to the customer than currently available through conventional means?

THE E-FUNCTIONAL STRATEGIES:

Many companies have designed a complete and sophisticated e-commerce strategy than organizations can depend on to help them achieve success outline. They concentrate to achieve such success through selecting and implementing (lie right products and services which are designed to create a powerful, integrated, and stable environment to help companies establish stronger ties with customers, business partners, and within the Business Functions it self.

These products and services arc covering abroad range of e- functional categories, including corporate purchasing, value chain trading and direct marketing, selling, productions, finance, and Human resource.(Bartels, 2000; Trepper, 2000).

BUSINESS-TO-BUSINESS & BUSINESS TO CONSUMER STRATEGIES:

Business to Business electronic commerce strategy implies that both the sellers and buyers arc business corporations, while business-to-consumer electronic commerce implies that the buyers are individual consumers.

Business-to-business covers a broad spectrum of applications that enable an enterprise or business to form electronic relationships with their distributors, resellers, suppliers, and other partners.

Business to-business applications will offer enterprises access to the following sorts of information:

Product-specifications, prices, sales history.

Customer-sales history and forecasts.

supplier-product line and lead times, sales terms and conditions.

Product process-capacities, commitments, product plans.

Transportation-carriers, lead times, costs.

Inventory-inventory levels, carrying costs, locations.

Supply chain alliance-key contacts, partners' roles and responsibilities, schedules.

Competitor-benchmarking, competitive product offerings, market share.

Sales and marketing-point of sale, promotions.

Supply chain process and performance- process descriptions,
performance measures, quality, delivery time, customer satisfaction. (Turban & Others, 2000).

Therefore, the result of penetrate such sorts will give the organization a clear vision and strong market position to take a advantage in using these information in it's strategic business planning. The examining of environmental changes which bring about new opportunities and pose new threats, beskle assessing the internal strengths and weaknesses is very beneficial where adopting B2B strategy.

Lucas looks at business to business as an agent of change by emphasizing" This could result in much greater control of cash flow we will be able to do transactions online without having to go off-line for payment initiations, 1 think it would change things dramatically for our customers, partners, and employees particularly when they doing transactions" (Lucas, 2002).

Business to business functional strategy is vital to be integrated with the business strategy, since this is very important and decisive tool to meet specific targets such as lead time, cost reduction, information sharing and access to information, etc

BUSINESS -TO-CONSUMER

While the term c-commerce refers to all online transactions, B2C stands for "business-to-consumer" and applies to "any business or organization that sells its product or services to consumers over the internet for their own use (1'allon, 2002).

When most people think of B2C e-commerce, they think of Amazon.com, they online book seller that launched its site in 1995 and quickly look on the states major retailers.

B2C has grown to include services such as outline banking, travel services, outline auctions, health information and real estate sites.

A basic fact of internet retailing is that all web sites arc created equal as far as Hie "location, location, location" imperative for success in retailing is concerned. No site is any closer to its customer. This makes it vital that business Find ways to keep customers.

Coining back to their stores. The key to this goal is to optimize (actors such as:

Performance and Service. People don't want to be kept waiting when browsing, selecting, or paying for products in an electronic stores. A site must be efficiently designed for ease of access, with sufficient server power and telecommunications capacity.

Personalization. Personalizing your shopping experience encourages you to make return visits. Many sites register you as a customer or have you fill out a personal interest profile.

Socialization, diving online customers with similar interests a felling of belonging to a unique group of like-wavered individuals helps build customer loyally and value.

Look and feel. Web sites can offer you an attractive virtual store front. This way range from providing an exciting shopping experience with audio, motion, and striking graphics, to a more traditional look and feel, including a virtual shopping mall or related web sites.

Incentives. Web site stores must offer shoppers incentives to buy and return.

Security and Reliability. As a consumer of a web, you must feel confident that your credit card, personal information, and details of your transactions are secure from unauthorized use (O'brien, 1999).

From the results obtained, the following can be concluded: IT developments lead to tremendous changes in organization's way of executing their transactions, therefore implementing the right approach is very essential to success in today's business, there are many Strategic market forces affect the pace and effectiveness of progress in implementing IT approach, E-Business and E-Commerce arc terms used interchangeably, but some times they're used to differentiate one vendor's product from another; though many models view that E-Business is containing E- Commerce and other emerging E-functional strategies and Business-to-Business and Business-to-Consumers arc very vital functional strategies for activating E-Business through considering aspects such as cost, lead time, supply chain, or access to information.

THE STUDY RECOMMENDS THE FOLLOWING VIEWS.

Organizations should consider the right lit between corporate, business, and IT strategy when they pave for IT approach.

Managers should think strategic in today's Changing Business environment; and have to have clear strategic vision to cope with IT emergent necessities.

E-Business strategies become vital in toddy's business, there for managers must analyze why some companies fail to implement it right.

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International Cross Brand Collaboration in the Automotive Industry

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KEYWORDS

Collaboration – Value Chain in an Automotive Company – Role of Information Technology – Challenges – Systematic Approach

ABSTRACT

Historically, collaboration in the automotive industry has focused upon fragments of the value chain where market specific solutions were utilized to achieve local competitive advantage. For example, in order to better access new markets, automotive manufacturers collaborated with local partners in the area of sales and after sales.

Ever increasing globalization of the marketplace has produced considerable changes in company strategy. The traditional approach of establishing local isolated facilities within specific markets has all but vanished. What we experience today is that collaboration has adopted a more global flavor – which addresses the entire value chain and commonly occurs between internal company brands or even former competitors. The trend towards collaboration has also been accompanied by a number of strategic initiatives – such as the use of shared parts and development of joint projects. Such cooperation is an important part of many company's corporate strategy which can improve cost efficiencies, provides access to new markets, and allows faster time to market for products.

Although the benefits of following such a strategy are substantial, they are achieved only with certain challenges, namely: complex and cost intensive interfacing between processes and systems of separate partners, as well as increased maintenance and operation costs. The key focus for the view of IT Management is put onto fully supporting and enabling optimization goals of the company with IT technology. Therefore the topic Cross Company Activities plays a major role and respective projects are being set up. The project execution needs to be split into two phases. During the first phase a central coordination is needed by a central department in order to set up the various IT division involved in a harmonized way. After phase 1, phase 2 "Decentral Coordination" will be pursued by one of the IT areas mostly affected and challanged by Cross Company and Global Cooperation Activities.

In this paper, which describes the results of phase 1, we consider collaboration from the perspective of the entire value chain of a automotive vehicle project involving several partners. In this context, this paper aims to address such questions as:

- *What are the key challenges that collaborative business models impose upon supporting processes, IT systems and IT organization.*
- *What are the interdependences of challenges in different areas of the automotive value chain ?*
- *What would be a suitable approach to identify and address known challenges at an early stage of a proposed collaborative vehicle project.*

In discussing these issues, we suggest an approach that promotes a vital dialogue between the parties involved in such project, namely the IT and business organizations. Furthermore, given the increasing usage of common projects we discuss the impact of this strategic direction upon the IT organization and their ability to support the changing needs of the business.

I. INTRODUCTION

The automotive market represents a very competitive environment which has steadily undergone a process of consolidation over the last few years. Regulatory forces have played a key role in this development through a general trend towards increased globalization of the market place and the removal of trade barriers. Where historically, fragmented markets have led to local production and development activities, these are now increasingly being conducted with a global perspective. For example, vehicle production is now typically coordinated between widely distributed facilities, marketing focuses upon developing strong internationally recognized brands, and standardized back-office processes are employed on a global basis [ANE99].

A changing competitive environment and increased customer focus have also prompted automotive companies to offer an increasingly sophisticated variety of products and associated features. Segmentation of the market place through the development of niche products not only places the automotive manufacturer under greater pressure to exploit cost efficiencies, but also to deliver technical innovation and superiority (e.g. Telematics, Mobile Computing, Online Safety Systems) [EAL00].

In developing and sustaining competitive advantage within such a dynamic environment, the corporate strategy must focus upon a number of key issues which include strong brands, a broad product range, global presence, and technological innovation (refer to Figure 1).

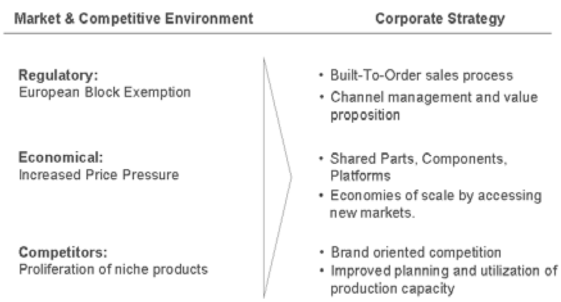

Figure 1: Competitive Strategies.

Operationalizing the corporate strategy

As Automotive OEM's pursue these strategies, they are acutely aware that they must ignificantly improve cost efficiencies. One approach that automotive companies adopt in reducing cost is to exploit benefits between vehicle products. At the most fundamental level, the sharing of common parts between products provides the company with increased economies of scale within procurement or manufacturing. By progressively extending the level of commonality between vehicle products, a company can achieve ever higher cost savings, as depicted in Figure 2.

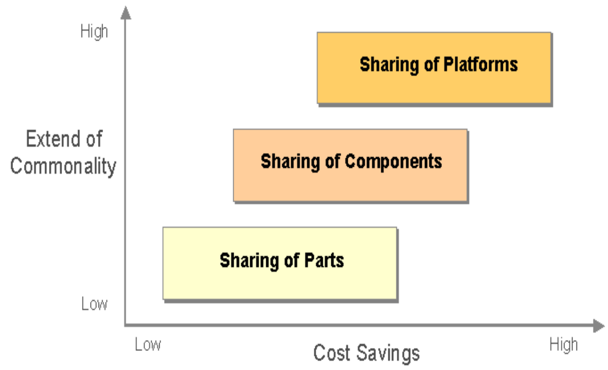

Figure 2: Sharing of common parts, components, and platforms between products.

As always care must be taken in exploiting these potential benefits in order to avoid potential dangers such as product cannibalization, and the loss of market share. The construction of different vehicle products through common platforms or a high percentage of shared parts could result in the vehicles loosing their brand distinctiveness for the consumer. This is especially true where these products are targeted at similar market segments [S&P02].

As a means to access new markets, share development costs, and exploit economies of scales, vehicle manufacturers have intensified collaboration between brands and companies in virtually all areas of the value chain. The extent of this collaboration can range from simple sharing of common parts, components etc, to the joint development of complete vehicles. Inevitably, this results in an increased number of vehicle products that are engineered, manufactured, sold or serviced through collaborative activities between two or more partners – companies or business units. We denote such collaborative product projects as "Cross-Brand".

Along with the increased levels of collaboration come new requirements and challenges for the processes, applications and organization supporting these cross-brand activities. As such, IT has an important role to play in enabling the realization of such collaborative ventures.

II. HISTORICAL PERSPECTIVE ON COLLABORATION

Collaboration within the automotive industry has evolved over a period of several decades. As Figure 3 reflects, such collaboration has been motivated by numerous objectives and as such has taken many different forms characterised by the type of collaboration, the partners involved, and their respective roles.

Figure 3: Aspects of collaboration in the automotive industry

Research and study conducted during the last few years into the topic of collaboration in the automotive industry has principally focused upon fragments of the value chain and aspects such as:

- **Engineering**: Simultaneous engineering was employed in an attempt to integrate the design and manufacturing activities and introduce parallelism in working practices. The attendant benefits of this approach included: reduced lead times and cost, as well as improved quality [BSH98].
- **Manufacturing**: Establish local manufacturing facilities with external partners to collaboratively manufacture parts, components or even entire vehicles. This was primarily an attempt to avoid trade barriers and to establish brand identity in the respective local markets [SBK00].
- **Sales & After Sales**: Collaboration in the area of sales and after sales with local or regional partners to access new markets and achieve scaling effects [SHB99].

Such activities, focusing on specific aspects of the value chain, have significantly improved performance in each of the areas addressed [BHS97]. As an example, the simultaneous engineering efforts have led to reduced engineering costs, shorter development times and improved transparency of engineering processes.

The approach adopted by this paper in addressing the topic of collaboration within the automotive industry is instead slightly different to that historically adopted. We have considered collaboration from the perspective of the entire value chain of a commercial vehicle project and aim to answer questions such as:

- What are the challenges along the entire value chain that existing collaborative business models impose upon supporting processes, IT systems and IT organization ?
- What are the interdependences of challenges in different areas of the automotive value chain ?
- What would be a suitable approach to identify and address such known challenges at an early stage of a proposed collaborative vehicle project ?
- Would such an approach continue to be suitable in the light of the changing strategic direction of the automotive industry ?

III. THE IMPACT OF CROSS-BRAND COLLABORATION

Over the last few years, the number of vehicle projects where several brands or companies collaborate along the value chain have significantly increased.

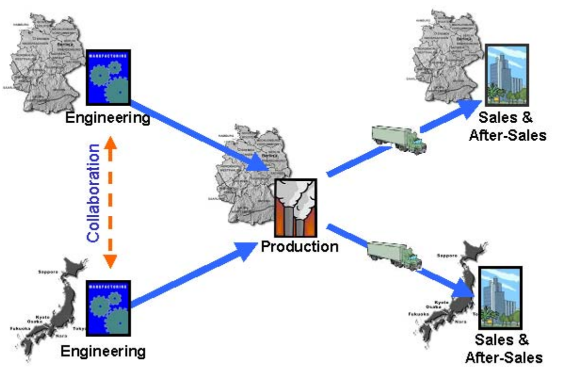

Figure 4: Example of a collaborative cross-brand vehicle project in the automotive industry

Although the intent behind these collaborative activities may in many cases be similar, the impacts that they have upon the supporting processes, systems and organizations can vary dramatically on a project by project basis. For example, Figure 4 depicts an example of an cross-brand vehicle project where two partners collaboratively engineer a single vehicle. Such a product is subsequently manufactured in a shared production facility and sold through the separate, brand specific sales channels.

Such collaboration between separate brands within the engineering area of the automotive value chain imposes challenges upon supporting processes, IT systems and IT organization. These challenges principally result from the need for communication between different processes, applications, and organizations of historically separated brands or companies. In the above case, where collaboration is focused upon engineering, IT must typically facilitate the integration or interfacing of design, documentation, and change management processes, as well as enabling the exchange of design and parts information.

In general, the "challenges" to collaborative cross-brand vehicle projects can be classified into two categories as depicted in Figure 5.

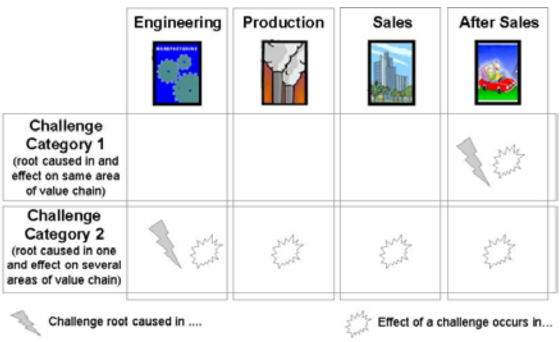

Figure 5: Categories of challenges along the value chain impeding cross-brand collaboration.

The first category comprises of challenges which result from decisions made in the same local part of the value chain. Consider the situation where brand A wishes to cost effectively gain access to a market in which brand partner B has an existing dealership network. One approach that could be adopted would be to utilize this existing infrastructure, yet avoid process integration or interfacing issues by simply collocating brand A's sales systems in the existing dealerships. Although this solution quickly provides low presence in a new local market, it potentially results in a number of challenges – common warehousing, and the ordering of shared vehicle parts. For example, a customer wishes to order a spare part for his brand A vehicle although this item is apparently out of stock car. Even though this may be a shared part between both vehicle brands, the completely separate sales processes and systems prevents identify whether compatible parts are immediately available through brand B's inventory. In effect, information sharing between the brand specific sales processes is not possible since there is no available mechanism to cross reference or exchange information between the different brands specific sales systems.
Considering this from the perspective of the automotive value chain, the business decision and resulting challenges are confined to the sales and after-sales area.

The second category comprises challenges which are witnessed in one or more functional areas as result of decisions made in one upstream area of the value chain. Consider collaborative engineering, as depicted in Figure 4 and the challenge of using shared parts between separate brands along the entire value chain. Typically such a shared part, say a light bulb, is defined during the collaborative engineering process. The two partners agree to use the same light bulb but historically, each partner maintains a dedicated number or identifier for the light bulb in the companies documentation system. The effect of this approach being that these separate numbers must now be cross-referenced in order to be able to clearly identify the light bulb as both a shared part and other compatible parts manufactured by brand partners. This challenge impacts several areas in the value chain. For example, consider production systems that wish to pool inventory during the shared manufacture of different brand partner vehicle. Alternatively, consider after-sales processes wishing to identify the availability of alternative compatible spare vehicle parts.
Considering this from the perspective of the automotive value chain, the business decision is made within one distinct areas of the value chain yet its repercussions are felt in several downstream areas.

The first category of challenges – those that result from business decisions made within the same organizational areas of the value chain – are addressed by that same organizational area (e.g. sales or after-sales). In contrast, the second category of challenge are much more complicated to solve because expertise from several areas of the value chain is required. In addition, questions of responsibility and coordination in addressing these types of issues need to be considered. Furthermore, challenges to cross-brand vehicle projects are typically addressed and solved on a project by project bases through the isolated use of customized "point" solutions. However, the repeated reoccurrence of many such "challenges" in different vehicle projects necessitates a more systematic course of action.

Several approaches have been suggested to address process and system challenges caused by changing business strategies and needs – some of which being more radical in nature that others [CHA95].

Figure 6 depicts one such approach focused upon improving the support that IT provides collaborative vehicle projects.

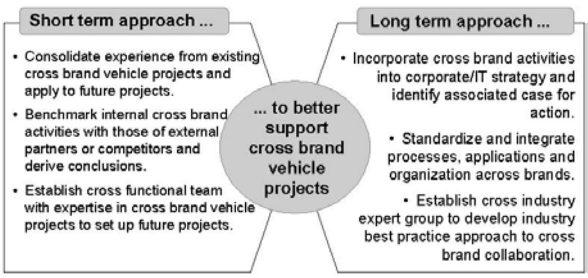

Figure 6: Possible course of action to better support collaborative vehicle projects.

In this paper we elaborate upon the short-term aspects of this approach in order to address the many challenges to cross-brand vehicle projects.

IV. SYSTEMATIC APPROACH

In order to identify the potential "challenges" imposed by a given collaborative business model at an early stage of the vehicle project, a supporting framework has been developed for use by business and IT project leaders. The objectives of the framework are threefold:

- Quickly identify "challenges" that are typical for their chosen collaborative model.
- Identify proven long-term solutions to these challenges in a proactive and timely manner.
- Achieve this at an early stage in the lifecycle of a business project.

The Approach

This framework begins with the selected business model, which provides a useful basis through which the impacts upon the supporting processes and systems can be identified.

Figure 7: Approach.

The first step involves categorizing the business model associated with the proposed vehicle project based upon a "Library of Business Models". This library contains experience gathered through cross-brand projects conducted during the last years. For each project, the business model has been decomposed into a modular form, and the associated challenges identified.

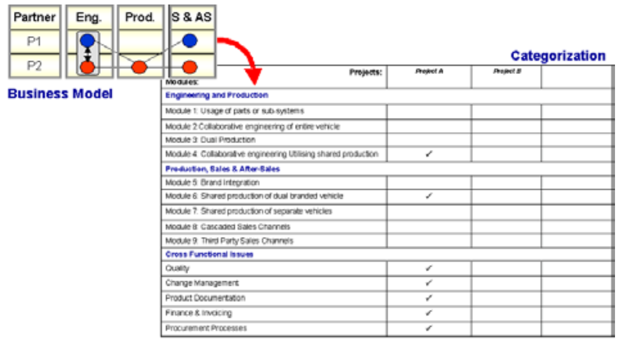

Figure 8: Step One: Classify the business model.

The second step – identify known challenges – is achieved by mapping the modular parts of the business model to the set of associated challenges.

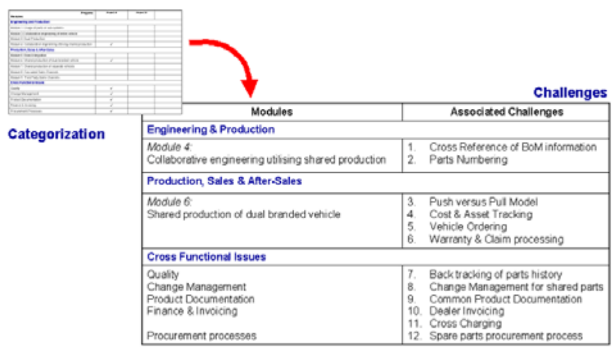

Figure 9: Step Two: Identify known challenges.

Finally, a set of proven solutions or guidelines can be determined for the identified challenges.

Area	Challenge	Solution	Suitable as long term solution
Sales & After Sales	Different Docum. &	Standard system and process - standard system X applied	Yes
	Quality	Standard system and process - standard system Q applied	Yes
	Parts Warehousing	Parts Consolidation in common Warehouse -parts of different brands in a common warehouse	Yes
	Vehicle Ordering &	Localized Interface Solution -specific interfaces to process vhicle order (both man.&autom.)	No, sufficient for current project but not long term solution if volume/dealers increase
	Warranty&Claim Processing	Localized Interface Solution -specific interfaces to process warranty/claim issues	No
Finance, Procurement, Supply	Dealer invoicing	Customized Interface -specific interfaces for dealer invoicing	No
		Standard Company system -standard system Y applied	Yes
	Cross Charging	Customized Interface -use supplier payment for company payments	Yes, but expensive process
	Cost & Asset Tracking	Various Interfaces -detailed solution not yet defined	No

Figure 10: Step Three: Identify proven solutions.

This approach promotes a vital dialogue between both the IT and business people working on a cross-brand vehicle project. By utilizing this systematic approach, business project leaders can identify potential challenges to their specific vehicle project at an early stage of the project life cycle. This enables the business project leaders to improve the overall project planning and to better plan the involvement of IT. By proactively involving the IT organization at an earlier stage in the project lifecycle promotes the deployment of common and reusable solutions reducing subsequent maintenance and operations costs.

Example of the Practical Application

As a practical example for the application of the aforementioned approach consider the planning phase of a vehicle project.

The business project leader of a cross-brand vehicle project has to make a decision on how to best introduce a vehicle product to a chosen market. The strategy is to access a new market with an existing vehicle product in the most cost efficient and timely manner possible.

In order to decide upon an approach which meets the aforementioned criteria, the business project leader has to evaluate several options. Some key factors that influence his decision are:

- Minimize overall cost of product introduction (especially cost associated to IT).
- Leverage experiences from similar vehicle product introductions.
- Reduce time to market and risk by reusing proven applications and processes.

In order to most cost efficiently sell the existing vehicle in the new market, the business project leader plans to leverage existing dealerships that are already selling vehicles of another in-house brand in this market. Being aware of the fact that such an integration of sales and after sales processes between two brands may result in both business and IT challenges, he wishes to further investigate what effects these challenges would have on the project. As a basis for this, the business project leader tries to identify the impact of the chosen business model upon the supporting processes and systems, as well as potential solutions and a rough estimate of the associated implementation costs.

In order to do so, he leverages the approach described in chapter IV. Focusing on the sales and after sales aspects of the business model, he categorizes his selected business model – sales and after sales process integration – within the "Library of business models". Based on this categorization, he is provided with an overview of the associated challenges impeding the progress of cross-brand vehicle projects built on his chosen business model. He is now able to compare the frequently occurring business and IT challenges of this approach with those of other alternative business models. Step three, provides him with a set of existing solutions or guidelines to effectively resolve the potential challenges and a rough estimate of the associated implementation costs.

During this process the following information is provided to the project manager:

- Expected challenges for the chosen aspect of the business model which was investigated (e.g. sales and after sales process integration).
- Available solutions or guidelines.
- Rough estimate of associated implementation costs.

The selection of an appropriate business model for a new product introduction is influenced by a variety of factors. However, based on the information provided through the aforementioned process, the business project leader is able to evaluate several options based upon a base of collected cross-brand experience.

V. SUMMARY & OUTLOOK

Summary

The globalization of companies has considerably changed over the past few years. Instead of only buying or forming new local partner companies, cooperation with global partners or even with former competitors has became an important part of the corporate strategy [SHB99]. The resulting increased levels of collaboration along the entire value chain may lead to benefits with improved cost efficiency, better access to new markets, and faster as well as more cost efficient time to market processes.

As always such benefits do not always come without potential dangers – product cannibalization, complex and cost intensive interfacing between separate IT systems of partners, and increased maintenance and operation costs where customized "point" solutions are utilized. For this reason, each player pursuing such cross-brand strategies must thoroughly analyze the objectives but also the associated risks and challenges.

The most effective and efficient means of collaboration along the entire value chain is difficult to achieve – especially where several partners are involved with different corporate cultures, languages, and working methods.

In this paper we suggest an approach to support cross-brand collaboration which focuses on:

- Determine the "challenges" that are typical for the selected collaborative model.
- Identify proven long-term solutions to these challenges in a proactive and timely manner.
- Achieve this at an early stage in the lifecycle of a business project.

This approach focuses upon providing practical short-term support for project leaders and is based upon the corporations most valuable asset: "Experience"

As a first step, the business model of a proposed vehicle project is categorized based upon a "Library of Business Models" which contains the collected corporate experience of existing cross-brand projects. The second step – identify known challenges – is achieved by mapping the modular parts of the business model to the set of known challenges. Finally, as a third step, a set of proven solutions or guidelines can be determined for the identified challenges.

The suggested approach provides business project leaders of cross-brand vehicle projects with an early inside into potential challenges associated with such projects, and facilitates a vital dialogue between both the business and IT organizations.

Outlook

The approach described in this paper provides decision support for both business and IT project leaders of collaborative vehicle projects – where two or more partners collaborate along the automotive value chain. The practical application of this approach has been proven to improve the initiation, planning, and deployment of such collaborative vehicle projects.

We therefore envision that such an approach will become increasingly important as the number of cross-brand automotive projects continues to climb.

This increase is due to many reasons, which include changes in regulatory forces, such as the European block exemption, or increased product individualization which drives the transition from "Built-To-Stock" (push) to Built-To-Order (pull). In order to achieve shorter cycle times in an Built-To-Order environment and reduce inventory level, increased integration of sales, production, and engineering processes between collaborating partners is required.

The changing strategic direction towards increased levels of collaboration between competing companies (e.g. the collaboratively engineered SUV of Volkswagen and Porsche) can also be observed. The necessity to maintain commercially separate functioning legal entities, imposes restrictions upon how closely the underlying processes, systems, and organizations can be integrated. Such a fundamental change in the type of collaboration inevitably creates an increasingly challenging environment for the business and IT organizations. For example:

- With technological know-how as a competitive advantage, will partners continue to be willing to share more and more of this information ?
- Can the conflict requirements of sharing an increasing amount of information between collaborative partners be satisfactorily aligned with their need for security ?
- In light of sales collaboration, will a partner continue to be willing to open its markets to a competitor even if his market share decreases

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BIOGRAPHY

The author Paul Stratil, age 41, is Senior Manager for Information Management of DCAG. He is responsible for integration activities within the IT Organization, with a dual key focus. One key activity is setting up a PM framework and a project office in order to increase efficiency and effectiveness of IT projects. The other key activity is to initiate and set up a strategical dialog within the IT division about ITs role and future focus on how to support cooperations with other companies.

In more than 15 years, the author has gained conceptual knowledge and practical experience in the optimization of business processes as system analyst and in-house consultant and was in charge of IT at DCIndonesia as General Manager. Paul Stratil worked for the Passenger Car and Commercial Vehicle Divisions of DaimlerChrysler in Germany, Spain, Brazil, Turkey and Indonesia.

Over the last nine years, the author has published several articles and papers for international conferences to contribute to the scientific discussion on the above mentioned issues.

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