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FUNCTIONAL PRODUCT DEVELOPMENT – DISCUSSING KNOWLEDGE ENABLING TECHNOLOGIES

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1. Introduction

The concept of functional products affects the business as a whole. The hardware will be offered to customers as one part incorporated in a total offer. The offer as a whole compromise services related to and/or designed into that hardware. The product development level will be affected, this emerging development process is called Functional Product Development (FPD). To meet the expectations the concept of functional products has to affect the design phase of the hardware in particular. The expectations from industry on the concept of functional products can be, e.g., increased ecological awareness due to remanufacture of the hardware, shared business risks, responsibilities and boosted knowledge due to the collaborative efforts, provision of added value to customers and accordingly also to gain competitive advantages [Alonso-Rasgado et al, 2004].
The purpose in this paper is to discuss new demands on computer tools to support decisions in FPD. To do that, a tentative picture of changes in product development motivated by the concept of functional products has to be outlined to serve as a basis for the discussions. Computer tools to support decisions in engineering design are commonly used by design teams. Today, these tools are considered to be internal and support engineering specific knowledge. However, FPD insists on collaboration between companies to achieve additional knowledge. Furthermore, engineering design activities in FPD need collaboration on a day-to-day basis despite distance.

1.1 Background

A shift in view, captured in the concept of functional products, can be found within the manufacturing industry in Sweden. Traditionally, manufacturing industry focus on providing excellent goods, i.e. hardware, compromising services as add-ons. Services occur on an aftermarket and a major part of the profit is made on activities such as maintenance and spare parts. Over time the competition has increased in the aftermarket activities for manufacturing industries. One trigger for the concept of functional products can be found in the interest to control the aftermarket activities for the hardware. One characteristic for the concept of functional products is that the ownership of the hardware is not transferred to customers, even though the hardware as such is, thereby the companies provide customers with functions or does functional sales. The responsibility and availability of the functions provided by hardware remains with the provider as well as the responsibility for maintenance and spare parts. The aftermarket is in that way owned by the provider and competition is decreased. Hence, the shift in view is a move towards providing services taking a lifecycle commitment for the hardware as well as optimising the availability of its function in the customers' system. To gain

economies of scale and to be able to provide customers with a more encompassing offer collaboration in a business to business environment is needed. Efforts to accomplish collaboration are the organisation into alliances or partnerships in extended enterprises.
The hardware providers strive to offer a guaranteed level of availability to the functions provided by the hardware. The reliability and maintainability of the hardware in relation to the customers use of it has to be taken into account in the design process. Thus, a thorough understanding of the customers' processes, the performance of the hardware and the use of the hardware in these processes as well as the customers' needs has to be understood in early phases of product development. Decisions in early product development phases concern, for example, conditions in the environment which will affect the hardware, how the hardware will be operated or manoeuvred, should the hardware be upgraded due to technological advances and if so when should that be done. All in all, the new business scenario drives the importance to understand downstream knowledge in early phases to support decisions for the total offer. This makes new demands on knowledge enabling technologies for FPD interesting to discuss, which is the purpose of this paper.

2. Methodology

The background information for this paper has emerged from the interaction with industry people engaged in a functional product research project. The overall project is called Functional product development in a distributed virtual environment. Four sub-projects focus on communication, computer tools and knowledge needed for the development of functional products. In this paper material generated in all subprojects were brought together to provide a more encompassing view on the concept of functional products and in particular on the new demands on computer tools used in collaborative settings. Computer tools are here broadly defined and range from information and communication tools (ICT) to engineering design specific tools. Material, presented in figure 1, has been generated in meetings, workshops and in interviews with project affiliated industry partners.

3. Knowledge Integration in Functional Product Development

The integration of hardware and service specific knowledge into FPD can be accomplished by knowledge enabling technologies. But, the integration into knowledge enabling technologies is challenging. Skills, interactivity and connectivity in relationships are in focus within the knowledge area of services [Vargo and Lusch, 2004]. Knowledge related to services is expressed in terms of advices and know-how, i.e. tacit knowledge [Shostack, 1982]. Due to the tangibility of hardware the knowledge area focus on for example geometric and material characteristics and conversion of energy. Such knowledge is complex, but can be measured and transformed into rules and procedures, i.e. explicit knowledge. From a technical view reliable, relevant, in time, controllable and verified information can be provided in some cases. One dilemma in the design of computer tools is that they support different sets of problem areas. These areas are treated as separate issues and the computer tools are seen as internal specific tools. One challenge for computer tools to support FPD is to integrate different knowledge areas. Due to the integration of tacit knowledge, FPD design teams have to act on good-enough information. Hence, another challenge for computer tools to support FPD is to minimize the tacit elements and to provide support for taking in a readiness level in good-enough information [Alonso-Rasgado, Thompson et al, 2004 in Nytomt, 2004].
The concept of functional products includes a long term commitment to provide the customer with specific functions needed. The provider has to continuously make decisions on maintenance, upgrade of hardware and technological advances. To develop or remanufacture the hardware or not is decisions that depends on questions for example about costs, profits and the commitment as such. To increase the quality and reliability in the decisions as well as in the commitment the provider has to be able to simulate those scenarios in the design process. To develop functional products the computer tools has to convey down stream knowledge, from more than one company, to be enabled in early design phases to facilitate life-cycle commitment. Knowledge is described as contemporary organisations most important resource and enabling technologies, e.g. virtual manufacturing and ICT are critical for the performance of flexibility in development processes. Thus, enabling technologies has to make it

possible for companies in the extended enterprise to share and gain knowledge without loosing intellectual properties.

The ability to simulate the hardware and service knowledge integration early in the design process is needed to support decisions. Simulations have to take standard component simulations (mechanical properties, manufacturing etc.) as well as total lifecycle simulations into account. Knowledge Based Engineering tools (KBE) is used in industry to decrease lead time by automating routine work, thus the time saved can be spent for several iterations in the synthesis-analysis phase [Pinfold and Chapman, 2001; Bylund et al, 2004]. The use of several iterations in conceptual design increases the quality of design by gaining a wider solution space and this seems also important for FPD.

A key to achieve and realise FPD is collaboration between companies. These efforts insist on enabling technologies to support collaboration, this is today technically feasible though the enabling tools are not readily available. A place and/or space for knowledge sharing can be discerned in the virtual environment in terms of a knowledge market place. The extended enterprise is in the following discussion used to exemplify a network facilitating global connectivity; our focus is on technologies facilitating that connectedness.

4. Towards Functional Product Development

Design engineers manage a broad range of knowledge and information. The engineering design process is knowledge intensive and incorporate relational complexity as well as complexity related to the hardware as such.

The tentative picture of foreseen changes for functional product development, figure 1, simplifies engineering design activities as if the processes at left and in the middle is outdated. It is important to understand that the new situation that is outlined here is building up a tentative picture of a new additional future, thus the past is *not* obsolete. The total offer business model is one among several that the companies have to manage.

The first three rows, in figure 1, organisation, strategies and goals, exemplifies changes in the industrial context. The last row represent a research context, where the box at right are the focus for the overall project of FPD in a distributed virtual environment.

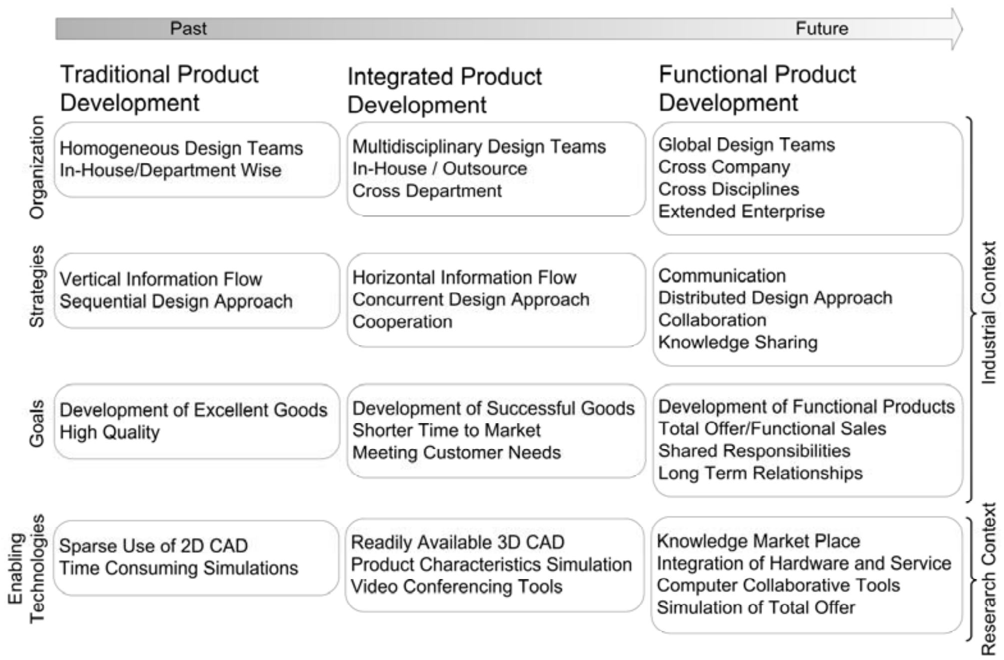

Figure 1. Towards Functional Product Development

4.1 Traditional Product Development

In figure 1, at the left side, a traditional view on product development is presented. The goal is to develop excellent goods having a focus on high quality. To achieve this goal strategies used can be exemplified with sequential design approach and homogeneous design teams. Information flows in this scenario can be compared with the ‘over-the-wall’ process. The activities are disconnected and a body of information is built up to encompass complete information about the hardware at each stage. Objectives in a sequential design approach are to break down tasks, activities and goals into sub-tasks, sub-activities and sub-goals. The formulation of a clear task, structured procedures, constraints and boundaries has to be done. The use of enabling technologies were sparse, computer tools were expensive and not fully adapted to every day use. However, 2D Computer Aided Design (CAD) tools were used. At this point the research and development of CAD and simulation tools was focused on matching the computer performance which was very slow. Computer simulations were often used to verify the design in a late stage in product development, not to support the design.

4.2 Integrated Product Development

In the middle section an integrated product development approach sets the scene. Multidisciplinary design teams works across functional borders within the company and suppliers are contracted to provide additional solutions in a cooperative business-to-business context. The goal is to provide the market with successful goods, faster than the competitors. Excellent goods are still important, but over time customers take this for granted and start to search for factors which differentiate the hardware from those of competitors. Thus, customer orientation to understand customer needs is introduced and customisation of products needs to be addressed. The product development process is described in a parallel way, where the activities starts concurrently and encompasses several iterations between the activities. Thereby, the information flows can be described as horizontal. That is knowledge and information is gradually built up into a product specification to manufacture the hardware. The goal is to establish the specification as soon as possible, by fighting changes and influences that might challenge it. In each phase alternative solutions can be thought up; the design team is therefore urged to diverge and converge in each phase. The move from vertical information flows to horizontal and continuous flows of information in integrated product development means that the body of information is incomplete and requires good computational support.

The availability of computers and its processing possibilities are increasing rapidly. Designers are introduced to CAD programs utilising 3D-technology used to design components and assemblies constituting advanced product models where users can share the virtual prototype using PDM systems. The same digital representation is used as a basis for simulation of performance, manufacturing, etc. 2D CAD is still commonly used in some areas. Simulation software and mathematical algorithms are improved and better supported with simulation programs, both integrated with CAD software as well as standalone software. Now simulations of both product and manufacturing characteristics are commonly used in the development process. Complete product model simulations are rare, but becoming more common due to increased computer power and digitalisation of more aspects of the product model. User interfaces are simplified and made more intuitive, still a large part of the design processes are repeated for each new product.

The outsourcing of activities and the initial impacts of globalisation calls for cooperative work despite distance. An additional support introduced in the 80s was video conferencing services. Over time, research and development of video conferencing services has added a new dimension to distributed design teams which can share sketches and talk “person to person” without loosing body language. Industrial practice on video conference is generally limited to videoconferencing between two or three dedicated conferencing rooms, combined with application sharing and shared document repositories. The audio and video quality is generally low due to bandwidth restrictions and poor interoperability between conferencing systems.

4.3 Functional Product Development

For the concept of functional products the term *product* changes due to the integration of service and hardware to be understood as more encompassing than merely a physical artefact. Traditionally, in the left part of figure 1, the product term is comprehended as strictly a physical artefact. In the middle section the focus is not on an integrated product, rather on the process. However, the product term is mainly understood as a physical artefact in integrated product development. In FPD a physical artefact is designed and manufactured, but the customer will not own that artefact. The customer buys the functions provided by the artefact and accordingly comprehends the product as more than a physical artefact.

At the right in figure 1, the integrated development process is expanded cross companies to compose FPD, and an extended enterprise can be discernable in the interconnectivity. The extended enterprise can be interpreted and understood by the actors within it as a shared context for knowledge creation, knowledge sharing and knowledge integration [Huang and Newell, 2003]. FPD calls for collaboration with companies holding additional knowledge. This motivates the relationships to move from *cooperation*, i.e. the strive to coordinate the working tasks within a design project having different objectives for the efforts, to *collaboration*, i.e. the united efforts to achieve a mutual goal. In a cooperative approach all competences hold by the actors in the extended enterprise is not used for the benefit of the customer. However, the collaborative approach use all competences for the benefit of the customer, thereby the knowledge related to customers is also achieved by all actors. The new demands on enabling technology for FPD is discussed in the following based on the right bottom box in figure 1.

Integration of hardware and service knowledge into the product development process is challenging due to the nature of knowledge focused. Some service related knowledge can be considered as tacit knowledge expressed in advices and know-how as well as it is related to aspects about who to trust. Some hardware related knowledge can be considered as explicit knowledge expressed in rules and procedures. Despite being difficult to identify, service knowledge insists on being formalised to be captured into computer support tools. Furthermore, it is not straightforward what service knowledge that is useful to integrate into product development. The integration and collaborative approach calls for adapted, communicating and/or coupled computer technologies. The potential for simulations to support decisions regarding integration seems high since several scenarios varying from worst case to best case can be performed.

Computer collaboration tools include distributed engineering tools to support co-located design teams as well as engineering design specific tools such as KBE tools. KBE tools provide decision support internally in companies today. The move toward FPD creates higher demands on collaboration between companies. KBE tools coupled into a system between companies increase the possibilities to provide solutions in the design process. For example, information about the machine equipment can be shared with other companies to increase the manufacturing process solution space. Companies can use KBE tools to automate pre-processing like meshing, run simplified Finite Element simulations or by adding machine cost into the KBE tool so the designer will know how much the manufacturing will cost in machining hours. Thus, cost in machining hours can be compared within the extended enterprise and decisions to collaborate or not concerning the specific task can be made.

Functional reasoning simulations in engineering design are suggested to support new structures and/or rules of combinations being incorporated into a knowledge base [Chakrabarti and Bligh, 2001]. By expanding the commitment related to the hardware, the company offering functional products must monitor and support the hardware during its entire life-cycle. Feedback from actual use must influence the service and the design of next hardware generation.

It is important to understand that a total offer can trigger technology development processes at collaborating partners. The results from these processes, e.g. a new service or software, can be an offer by itself. If software is to be offered and used in the extended enterprise the functionality has to be general enough to be useful for several partners in the extended enterprise.

Distributed engineering tools are used to support meetings as well as the actual design work. Members of a co-located design team are separated by many barriers including distance, time, organization, culture, language and different technical disciplines. Not only formal information such as documents, geometry models and other product data must be exchanged – it is also important to support the informal information sharing and creation of social capital (knowing who knows and knowing who to trust) [Larsson, 2005] considered natural in a co-located team. Distributed engineering work can be divided into two levels (1) integration (e.g. data management and infrastructure) and (2) interaction, i.e. ICT tools that create a shared workplace across locations and supports interaction between people.

The integration level is focused on the integration of the low-level communication structure, involving the exchange and synchronization of data and information between different systems and partners within the extended enterprise. Here, one aim is to support the persistent storage of data, version control of design documents, and to show the current state of the design process. Information is closely connected to intellectual property within a company. So, information must be exchanged with partners within the extended enterprise, but not outside this partnership.

On the interaction level, computer collaborative support is viewed from a *people* perspective.The diversity in cultures and competencies of the global team can be seen as a valuable asset that adds to the creative power of the distributed design team. One challenge for global product development is to support collaboration within global design teams, where diversity and competencies of the whole team can be utilized and where team members can think together and share information and opinions instead of merely dividing work [Törlind et al, 2005]. Accordingly, all competences hold by the actors in the extended enterprise is used to achieve the mutual goal to provide customers with the contractual functions.

The trend on internet based tools has also changed collaboration. Instead of utilizing dedicated conferencing rooms the engineer can today collaborate from their workplace using software based communication tools such as IP- telephony, video conferencing systems and application sharing. The use of tools supporting informal communication such as instant messaging and blogs has increased in industry.

Simulation of total offers has to take all vital aspects of the offer into account in the conceptual design of the hardware. Simulations in the concept phase are useful to raise risk awareness and increase knowledge about the total offer potential. Due to the implementation of a broader use of simulations, simplicity in use without renouncing the security and trust in the computational support is important. The integration of services into product development insist on fast and flexible simulations, since services are partly co-produced with customers just as needed and at a time and place of the customer's choosing. Simulation of total offers gives an understanding of how decisions affect the offer, the hardware and the service and makes it possible to understand the effects in real time. The result from the simulations has to provide useful information for people holding different expertise ranging from engineers to market and purchase people. To take into concern the design of all these aspects simultaneously governs for close collaboration between divergent knowledge areas.

Knowledge Market Place represents a virtual place for achieving additional knowledge. Core competences from the parties in the extended enterprise can be shared within this interconnectivity. Core competences or knowledge and the conventional hardware are different things. Core knowledge is related to the design process as such, e.g. the capability to run simulations applicable to a range of features, the capability to model and simulate components and relationships. The total offer and/or product development may include some areas that are not supported in-house or areas that are recognised as missing, but can not be exactly described. Additional knowledge is needed from external sources and the knowledge market place offers such resources. It is crucial to know who to collaborate with. If the total offer incorporates customised hardware, the answer to that question has to be found in each business case. However, one dilemma is if the additional knowledge is not explicitly expressed; how can it be found? Techniques for data integration and exchange can be used to create the information exchange within the knowledge market place, it is however impossible to store all information in one place, so technologies must combine and integrate relevant data from many sources and present it in a form that is comprehensible for the users.

It is technically feasible to create a knowledge market place which can provide additional knowledge to companies. Yet, core knowledge is used to design and develop the offer, hardware and services. Core knowledge are intellectual assets crucial to the company's ability to become and remain viable and competitive. As part and parcel of the business, questions about gains and losses need to be addressed. What knowledge sharing gives the best pay-back. This issue has to be considered in monetary terms, but also in knowledge boosting terms. The collaboration and sharing of knowledge should increase the in-house competences, not drain it. Core knowledge must also be protected in such a way that partners can utilize the specific simulation knowledge without revealing the core knowledge of the simulation process.

5. Conclusions and Further Research

In this paper the purpose was to discuss new demands on computer tools to support decisions in FPD. It has been argued that knowledge enabling technologies can support decisions in the early concept design phase as well as through out the functional product life-cycle. Companies interested in FPD are suggested to identify hardware and service specific knowledge to be able to feed input into the design of supportive enabling tools. Company specific knowledge can be made available for use, both within the company and across company boundaries, in the extended enterprise by knowledge enabling technologies.

The challenge is to share knowledge without draining it and increase company competitiveness . In plain text; sharing knowledge should be a win-win situation. Barriers to overcome are; identify what to share, how to share it, to find a mutual interface where collaboration can occur. This in turn are new demands on knowledge enabling technologies.

Further research in this area would consider development of tools and technologies for FPD as well as an exploration of tacit knowledge related to product development .

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