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CREATIVE DESIGN UNDER PRODUCT LIFECYCLE CONSTRAINTS – THE FUTURE OF PRODUCT DEVELOPMENT

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Abstract

Advances in product development concepts have shown the trend to the integration of different development phases through integrated product data model and collaboration technologies. Future product development processes will take all aspects of the whole product lifecycle into account. At the same time, interaction and communication technologies will allow people with different knowledge backgrounds and dealing with different aspects of a product work together to achieve the best product design. This paper sketches a future vision of product development with emphasize on the support of creative design. We call it direct digital design.

Keywords: Product lifecycle engineering, product development concept, creative design, conceptual design, advanced engineering environment, intuitive interaction and collaboration

1 Introduction

A product has to meet different requirements from individual stages of the product lifecycle: it has to fulfil certain functions with high quality, the price must be at competitive level, operation and service must of low cost, and environmental issues become more and more important too. Consequently, product development has to deal with these different requirements. The goal of product lifecycle engineering design is to take all these into consideration in the early design stages already [8]. Approaches like design for manufacturing, design for serviceability, design for environment, etc. are developed and partially implemented. It is of common understanding that future engineering environments have to offer seamless, end-to-end engineering design capabilities encompassing the entire lifecycle of products and missions [14].

According to the common known design theories (e.g. [15],[19],[20]), product design is an iterative process consisting of several steps, typically: task clarification, conceptual design, embodiment design and detailed design. The most design decisions are taken in the conceptual phase, where divers ideas are generated, discussed and concepts are selected. Embodiment design and detailed design concentrate more on turning ideas into technical solutions. Traditional product development concepts focused on product functions. The primary aim was quality improvements and direct cost (development and manufacturing) reduction. Lifecycle engineering extends the horizon to the total product lifecycle including operation, service and recycling/disposal.

At the same time, information technology support for design and engineering is developing too (Figure 1). Most industrial companies have introduced 3D CAD and product data management (PDM) system. Even though people from different product lifecycle phases are still supported by different tools (CAD, CAE, CAP, etc.), which typically require special skills, collaborative engineering are more and more practised using product lifecycle management (PLM) and networking tools.

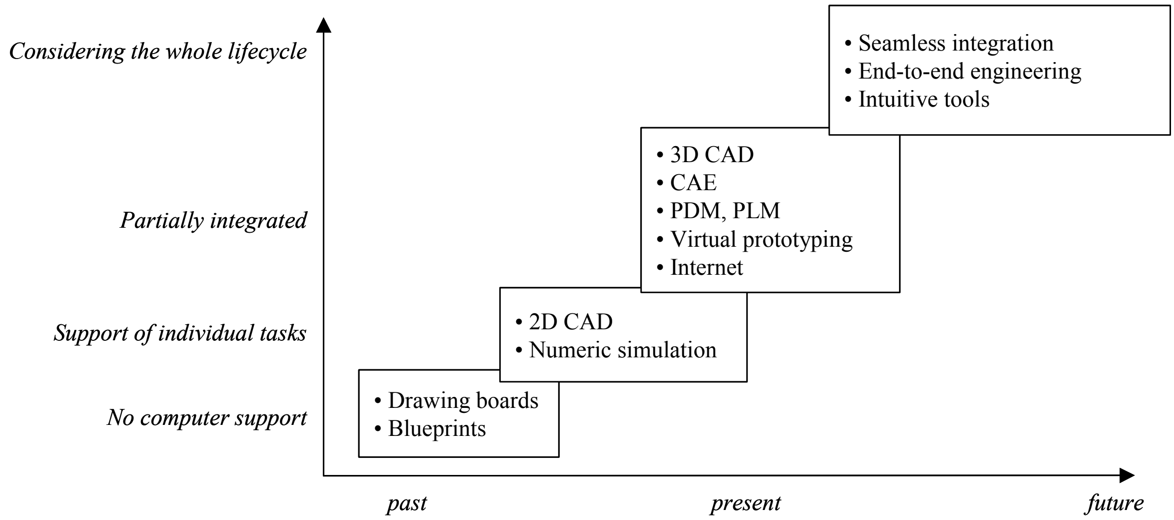

Figure 1. The continuous development of design and engineering support

The vision of seamless, end-to-end engineering design would imply that boundaries between the traditional design stages disappear. Interdisciplinary teams would work with flawlessly integrated data sets and tools to develop simultaneously the product and processes. These tools would offer the possibility for people with different technical background and skills work intuitively with the data sets, which contain complex and different kind of information about the designed product and processes throughout the whole lifecycle of the desired product. We would perform end-to-end product engineering in an integrated environment utilizing advanced interaction and communication technologies.

Imagine if we had a kind of material, where anyone can model parts, put them together and every other person understands intuitively what he has created. You can “weigh” it in several contexts according to the requirements on the desired product: stiffness, manufacturability, production cost, environmental impacts, … just what you want to “see”.

Suppose, we had wires and blocks, where we can model complex systems regardless whether it is electric circuits, electronic devices, chemical processes, bio-molecular structures, etc. Everyone with basic domain knowledge can use them. Thus, people can use very intuitive metaphors (from his perspective) to do design without the need to learn complex menu structures, settings and commands.

We could call this vision “direct digital design” – designing product functions and processes directly using intuitive metaphors on a digital product model. Is this vision achievable? What are the necessary steps towards this vision? In this contribution, we discuss the essential aspects related to these questions and propose a concept supporting “direct digital design”.

2 Product lifecycle considerations

In consideration of product lifecycle requirements, the objective of product design is a product with optimised processes throughout the whole product lifecycle. Lifecycle engineering, or lifecycle management, seeks to incorporate product lifecycle values into the early stages of design. These values include functional performance, manufacturability, serviceability and environmental impact (Figure 2).

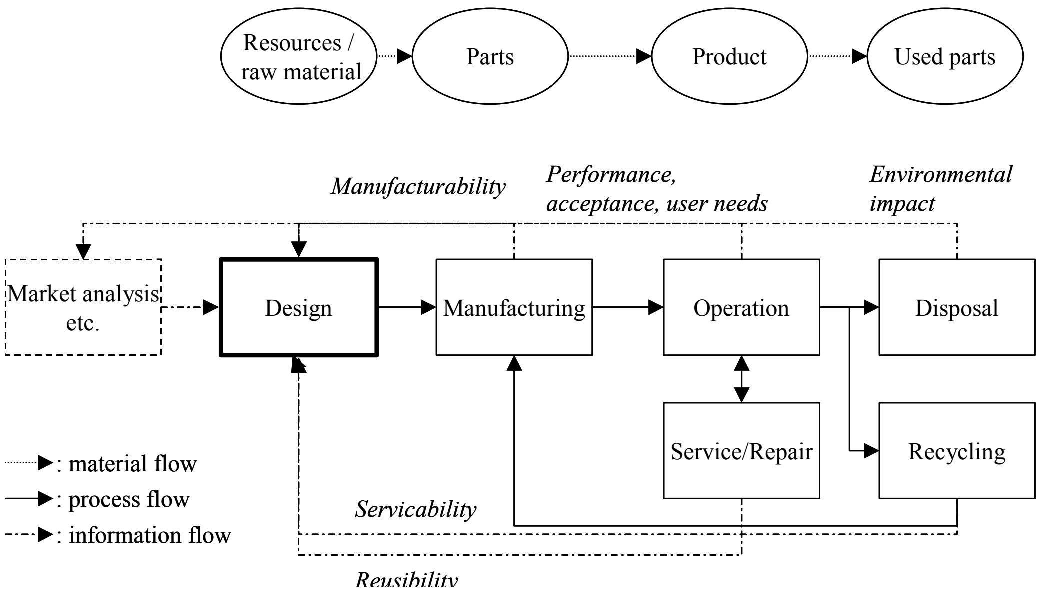

Figure 2. Product lifecycle processes and their impact on design

Lifecycle management techniques including lifecycle assessment, lifecycle inventory, lifecycle cost estimation, are being applied in the industries to collect information about the product lifecycle. The use of these information in product design is however rarely, or very limited. This is because detailed life-cycle assessment models and information are often not available, and in addition, analysis of lifecycle data is very time consuming. Some researchers therefore propose to develop approximate qualitative models for the simulation of product lifecycle scenarios in order to provide that information even in the conceptual product design (e.g. [6],[7]).

Other methodologies in the context of product lifecycle consideration in product design include design for production, design for manufacturing, and service-driven design. In these areas, methods and tools were developed and partially commercially used. However, they are still separate processes and mostly not integrated with each other. New approaches attempt to combine design methodologies with interaction and communication technologies in order to enable designers and other people collaborate effectively (e.g. [1],[11],[17]), and so to integrate different aspects into the design process.

3 People and views

Each one involved in the product lifecycle has his/her special view on the product (Figure 3). Because of the different cultural and technical backgrounds and skills, it is often difficult to tell each other their special views, or to understand the special views of other people. But this is very important for considering product lifecycle constraints. Requirements from the different stages of the product lifecycle are collected from the people who are involved in these stages. They must also confirm the fulfilment of these requirements. Therefore, product design involves not only design and simulation engineers, but also more and more people from later stages of the product lifecycle. Traditionally, requirements collection are done prior conceptual design phase. In the future, this will happen seamlessly and simultaneously to the product design. Future design environments have to support the representation, presentation and communication of these different views of different people.

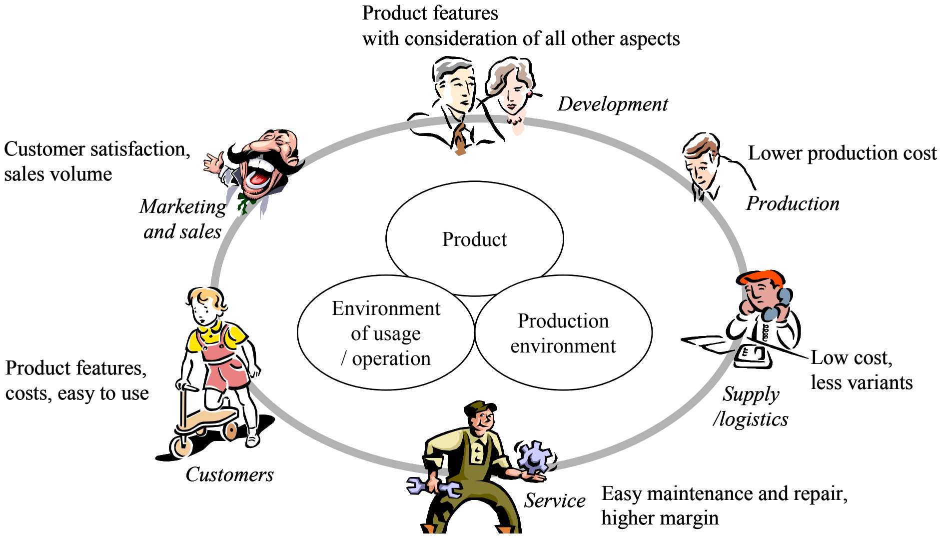

Figure 3. Examples of people and views

The very first requirement on a product is the fulfilment of users needs. In addition, the fulfilment of functional and other requirements in the operation phase of a product reflects in user acceptance and user satisfaction. Customers are therefore important not only because they pay for the product, but also because their experiences are the best and most extensive proof of the design.

There are different approaches of using customer inputs in product development [3]. In most cases, marketing people are the channel for customer feedbacks. However, customers may be involved more directly in product development if they had the possibility to easily express their expectations and experiences. Virtual show rooms like they are used in automotive design and furniture design are examples of providing realistic experiences for and gathering inputs from the users. This can be combined with requirement analysis tools in order to provide immediate input for product design.

Service engineers and production managers have again different views. They do not focus on the functionality of a product, but on the efficient execution of their own tasks: production/manufacturing planning, manufacturing, commissioning, maintenance and repair. For example, manufacturing planning has to optimise the manufacturing process including designing the manufacturing facilities. They have a plant-oriented view. But service people have to care about the problem solving as well as the part logistics. Their view is focused more on the failure situation and the related parts and processes.

Last but not least, product development involves specialists responsible for different design functions. Traditionally, there are geometry and layout designer, electrical system designer, simulation engineer and manufacturing planer. Each group works with special tools (CAD, CAE, CAEE, CAM, CAP, etc.). The product has different features with special importance to these people. They have different way of thinking. To efficiently collaborate with each other, they must be able to easily communicate their views.

4 Collaboration and communication

A central point of future product development is therefore collaboration and communication. This is based on consistent, integrated data sets and on tools that support the collaboration (Figure 4).

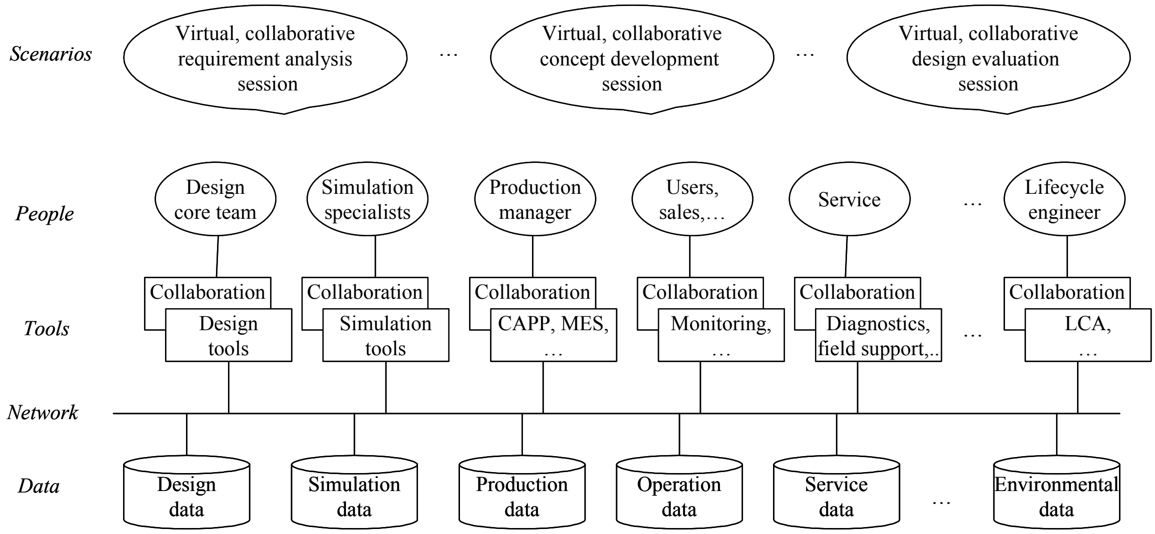

Figure 4. Key elements of collaboration and communication

Traditionally, only data about the designed product are stored, made available for the product development team and archived for later product development projects. With product lifecycle management, information coming from all product lifecycle phases is to be integrated, including sales, operation and service data about sold/installed products. Product data management technologies are extended to manage more complex and more dimensional data. Upon this data management, tools used by different people throughout the product lifecycle are integrated, including requirement analysis, reverse engineering, production planning, resource planning, logistics and traditional design and simulation systems. A recent AMR report [2] gives an overview about current status of commercially available systems from the key suppliers like PTC, Dassault and SAP. Even though the commercial systems have limited functionalities and often cover only partial aspects of a product's lifecycle, there is a clear trend to stepwise implementations in the industries.

Collaborations are more and more supported with distributed and internet-based systems too. Besides general collaboration tools like e-mail, messaging, conferencing and application sharing (e.g. NetMeeting, PCAnywhere, Interwise), tools for distributed, collaborative viewing of CAD/CAE data (e.g. OneSpace) are already used in the industrial practice [13]. Such collaboration tools combined with product data management / product lifecycle management systems would provide the possibility of collaboration throughout the product lifecycle processes.

5 Virtual prototyping extended

Collaborative design in a multidisciplinary team, especially in the early design phase, requires not only the possibility to view the CAD models, but also to visualise and manipulate different non-geometric features of a product. Interactive digital simulation and visualisation of product functions, known as virtual prototyping [5], is being used in the industries for design reviews [4] [16]. The principle of virtual prototyping is to simulate a realistic environment with the designed product, which allows people to view and to manipulate the product in an intuitive manner. Besides the product geometry itself, 3D representations of related data like simulated flow fields, can be part of the virtual environment too.

This principle can be extended to the simulation and visualisation of use cases, of the lifecycle processes and of the behaviour of a designed product in the desired use scenarios. We can define semantic models of all product and process features. These semantic models would be mapped to appropriate presentation models. A simulation engine would make these models dynamic and behave intuitively (Figure 5).

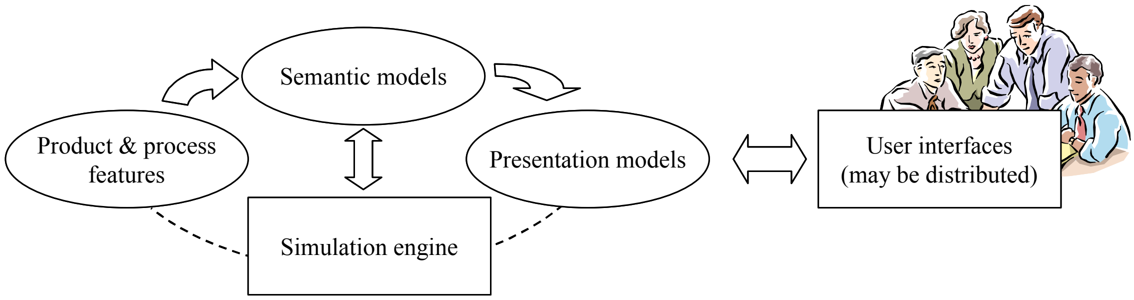

Figure 5. From features to views

Besides the simulation models used in today's systems like FEM, design features, manufacturing features, assembly features, event-based manufacturing process models, etc., which can be easily visualised in combination with the product itself, other semantic models can be developed. For example, use scenarios could be constructed and visualised in form of virtual 3D environments to analyse and visualise user requirements. How a product would be used, how it would behave in the operational environment, what are the impact of the product on the environment, etc. are all of high importance and can be modelled as scenarios. These scenarios can be mapped to a virtual 3D environment. The key idea is to bring any aspects in relation with an intuitive understandable representation that allows easy manipulation without the necessity of learning special tools. In this way, a very effective communication platform for interdisciplinary product development can be made available.

Of course, an intuitive understandable representation is not always based on 3D objects. Abstract forms like graphs and sketches are often intuitive as well, depending on the knowledge and skill of the people. In general, we prefer to use multi-modal presentation and interaction instead of either monologue textual, 2D or 3D ones. Future virtual environment technology will be multi-modal ([9],[18]).

6 Direct digital design

Summarizing the above discussions, an environment supporting "direct digital design" would comprise the following components:

- Integrated data sets, including description of the product and all related processes, and including data collected from the lifecycle of this and other related products;
- Interface to detailed planning, analysis and simulation systems, as some of the product and process features need to be derived from the collected (raw) data;
- Simulation and visualisation engines, to obtain an virtual environment containing easy understandable representations of product features and scenarios;

- Multi-modal, intuitive user interface(s), which allow people to easily view and manipulate the product features

Direct digital design is based on the simulation of scenarios. The key elements of a scenario are the desired product, the targeted environment, the lifecycle processes and the people involved in the processes (Figure 6). We need data models for the description of these elements and their relations. We could generalize the feature-based methods and combine them with the aspect-object concept described in [10].

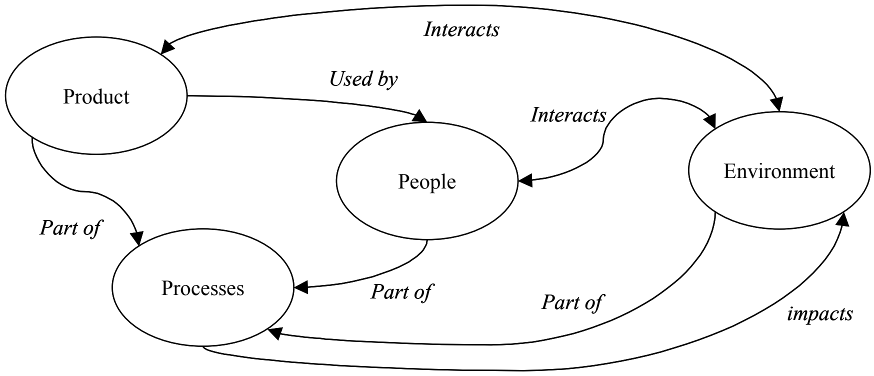

Figure 6. The key elements of a scenario for product design and their relations

Feature-based methods in design and engineering started from geometry descriptions and are extended/adapted to the description of functional and manufacturing features. Still, they are concentrating on the product itself. The aspect object concept is a generalized product and process description. Each real-world object is described with a so-called aspect object. An aspect object can have several aspects associated. These aspects contain data as well as methods for handling these data and for generating appropriate views on the object. These aspects can also describe the processes around the product.

The data set we use in the product development stages, either integrated or stepwise, is always a subset of the data about the product and related processes throughout the product lifecycle. However, this subset is partly interrelated, partly derived from other subsets. Product features are in general described with some of such interrelated data sets (Figure 7).

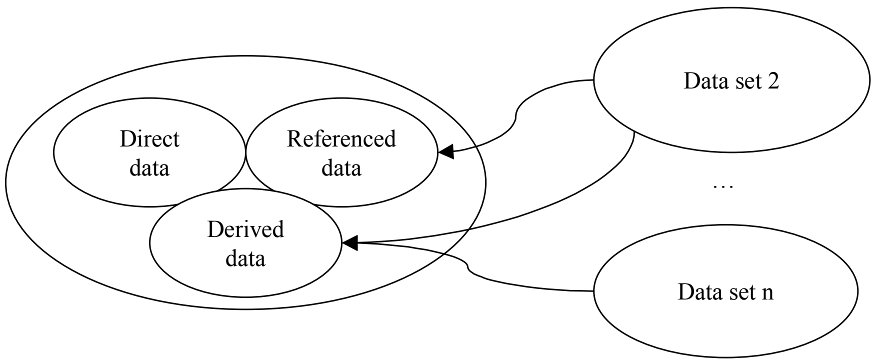

Figure 7. Interrelated data sets

With the seamless integration of product lifecycle processes, this will become valid for all data subsets used directly for each of the sub-processes. The implementation of such kind of complex, multidimensional data model requires a suitable concept of data management that supports flexible data structuring and data referencing. This is in some extend supported by today’s product data management systems. International standardisation and implementation efforts around STEP [12] will provide the ground stone for better integration. The data integration platform in the future will be a product lifecycle management system consisting of seamlessly integrated subsystems. The data sets can be physically distributed. But the total system will allow real-time access of the individual data sets. Based on such a product lifecycle management platform, all systems concerning the different phases/sub-processes of the product lifecycle can work efficiently together. Information from the whole product lifecycle are available and the product lifecycle constrains can be considered in the product development.

We recall, that our vision is to enable every one involved in the product lifecycle to sketch his view easily in an intuitive way without to learn the usage of special tools or methods. We therefore emphasize here the need of advanced virtual environment technologies to build the user front-end of future engineering environments. As discussed in the above section, the simulated virtual environments are representations of the different scenarios of interest for the product development. They include multiple features of the product and processes, and have to provide also multiple views on these features.

Such complexity cannot be solved with a single simulation engine. Therefore, there will be several simulation engines, probably each for one single aspect. And at the same time, to provide multiple views, we need again several visualisation engines, probably each for a single view. The network of simulation and visualisation engines will create at the end a multi-modal virtual environment that allows combining the different views on the product and processes or easily switching between them. A scenario synthesizer needs to be developed to intelligently manage the interrelationships between the data, the simulation and the visualization engines (Figure 8).

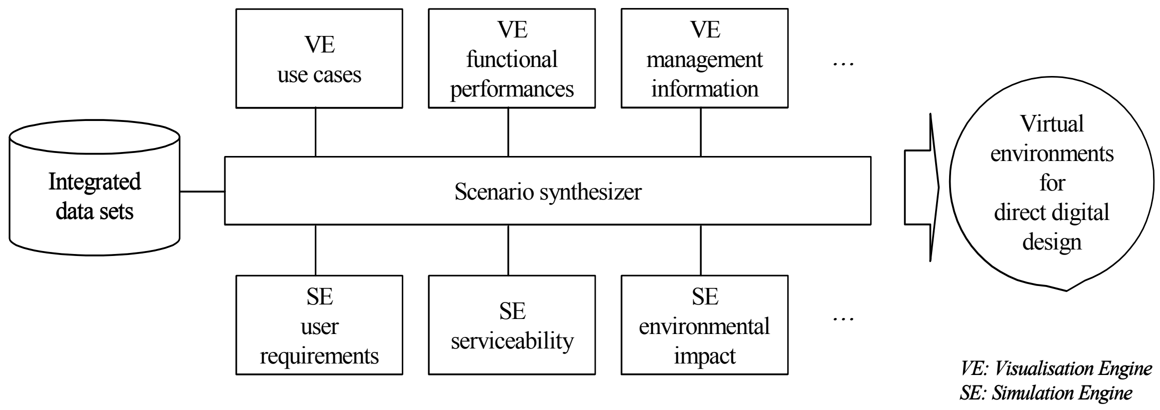

Figure 8. The generation of virtual environments for direct digital design

We generalized herewith also the meaning "multi-modal" to multiple features, multiple views and multiple interaction channels. An interaction metaphor that is feasible to the individual scenario is to be provided by the system. As mentioned before, the interaction metaphor must fit to the purpose of the scenario as well as to the backgrounds and skills of the people. Attempts to copy natural 3D interaction methods to virtual environments for industrial applications often fail. This is not only because of the difficulty to simulate real worlds and to build the interaction devices, but also because natural 3D navigation and interaction (e.g. flying, walking, grabbing) is not efficient for exploring complex products and complex information spaces. Instead, intelligent combinations of textural, 2D and 3D interaction methods can help us in providing intuitive and easy to use user interfaces. At the end, all people can concentrate on the idea, on the concept and on problem solving itself rather than on the usage of tools.

7 Closing remarks

For quite some time now, product design is no more straightforward creation of geometries and/or diagrams. Dfx (design for manufacturing, design for cost, design for …) methodologies have been introduced in recent years more and more to the industrial practice. CAD tools are including more and more functionality. The more functionality the CAD tools provide, the more complex is their usage. Design remains a job for specialised and skilled people. However, product design under product lifecycle constraints is an interdisciplinary work involving different people and complex situations. We need design methodology and tools, which support creative teamwork.

In this paper, we discussed different related issues and proposed a concept for supporting creative design in an interdisciplinary team considering all phases of the product lifecycle. This is a vision for the future of product development. We know, that developments in all of the sub-areas are necessary to achieve this vision. We do not expect full implementation in short term. With this paper the author want to stimulate discussions and further R&D, and to encourage colleagues both from academic institutes and from the industries to stepwise, incremental, but continuously develop and deploy emerging technologies and concepts. In this way, we will be stepwise closer to our vision.

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