Virtual Product Development as an Engine for Innovation

F.-L. Krause, H. Jansen, Chr. Kind, U. Rothenburg

Fraunhofer Institute for Production Systems and Design Technology, Division of Virtual Product Creation, Berlin, Germany
Institute of Machine Tools and Factory Management, Department of Industrial Information Technology, Technical University Berlin, Germany

Abstract
Innovation is one of the most important phenomena for the further development of industry and the resulting effects on society. Over the last fifty years the speed of changes has gradually increased. To be able to participate in this world of fast changes, it is necessary to thoroughly think about the current methods of product development and its future issues. A number of research activities are illustrated to show important future directions of development.

Keywords
Virtual Product Development

1 Success through Innovation

Innovation is one of the most important phenomena for the further development of industry and the resulting effects on society. Over the last fifty years the speed of changes has gradually increased. To be able to participate in this world of fast changes, it is necessary to thoroughly think about the current methods of product development and its future issues.

Innovation is the result of a number of different processes. In all cases it cannot be decoupled from invention. Innovation is the successful implementation of an invention on the market. The initial idea can be generated by research, can come from an inventor, a supplier, can be a follow-up of customer demands, or may be a necessary reaction to new regulations. An invention describes the technical realisation of this conceptual idea. Finally, it will become an innovation after the proof of its market acceptance.

These processes have to be taken and put into context with the ongoing demands of current trends such as: global product development and production, keeping export leadership position, replacement of pure mechanical functionality of products by mechatronic solutions, and distributed development. Furthermore products alter to become more sophisticated, more individual and complex. On the other side partially products tends to be simply according to target group. Also a change concerning the ownership of products can be observed. For some products it is more interesting to buy the output of them than to own them, like parts instead of a machine tool. This integration of products and services requires new procedures in development of both to provide appropriate and aligned solutions depending on the underlying business model.

The further evolution will definitely depend on the view to innovation and the performed strategy. It was shown in the field of CAD/CAM that companies who did not see the need for 32bit computers lost the ability to sell the so called turn key systems. The storage tube was not replaced by new technologies by some market leader. Instead of this products in automotive industries, aerospace, and mobile phones are examples for successful innovations.

Unfortunately the important meaning of innovation is still not recognised by many companies. Most of the large companies are aware about its importance. But only exceptionally a specific role and process within the company is installed in order to promote innovation in a structured and controlled way. A recent study processed at IPK revealed that also SMEs know about the meaning of innovation, but do not actively pursue process approaches or install tools to enhance innovation.

2 Approaches for Innovation Support

2.1 Controlled Speed for Product Development

In the last decade numerous approaches have been investigated in order to realise shorter product development times. Shortened lead times and time to market are very often used expressions. The situation has changed. Depending on the effort it is possible to accelerate processes dramatically. The system speed can be above what can be handled by complex non deterministic processes. Systems can run in some cases in an automatic mode without the direct control of designers. There are the extremes of automatic and interactive design, Fig. 1.

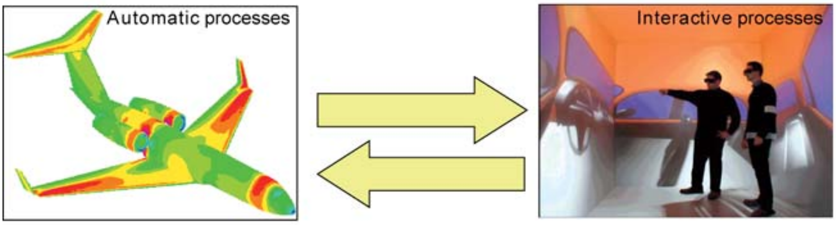

Fig. 1: Automatic vs. interactive processes

Taking a look back to the task of product development in the year 1850, the work was mainly done on the shop floor. This was an integrative approach, as it was performed by the foreman, who was responsible for the design and process planning of tasks. The work could be realised in a very close distance to the machines and the assembly places. To speed up tasks these could be performed with extra effort.

The benefits of integrative approaches were lost, when the rules of Taylor had been introduced for production. Comparing the current situation, there are similarities of to-day with 1850. After 150 years, a revival of integrative work with other means such as CSCW, Video-Conferencing, or Virtual Reality (VR) is applied.

The flexibility of controllable speed is supported by the capability to use integrated process chains based on PDM systems and to further intend Digital Master instead of only product models. The Digital Master comprises all relevant data which are certified for the mandatory usage in product and process questions. This is not yet state of the art at industry, but it can be seen that the solutions are coming closer, as the demand is expressed from more and more companies.

A new dimension of performance in product development will be available with the upcoming grid computing [1]. Although Moore's law will remain still valid in the coming years, it is important to see that grid computing can deliver an important contribution to increase computing power even on demand. This could mean that also SME's could have such computing power available for the enhancement of product development processes. The need for more computational power emerges from raised requirements for the representation of real world physics in computer internal representations. That makes it necessary to have larger amounts of data manageable and run more complex programs for simulation, evaluation and verification, Fig. 2. Grid computing cannot serve for real time purposes without delays. However it provides high performance services to companies which otherwise cannot afford these on a conventional basis. It will be a challenge, to develop this kind of services which can be also used by SMEs to make use of the capability of grid computing. The biggest challenges may be the close to real time performed visualization including modified VR-techniques.

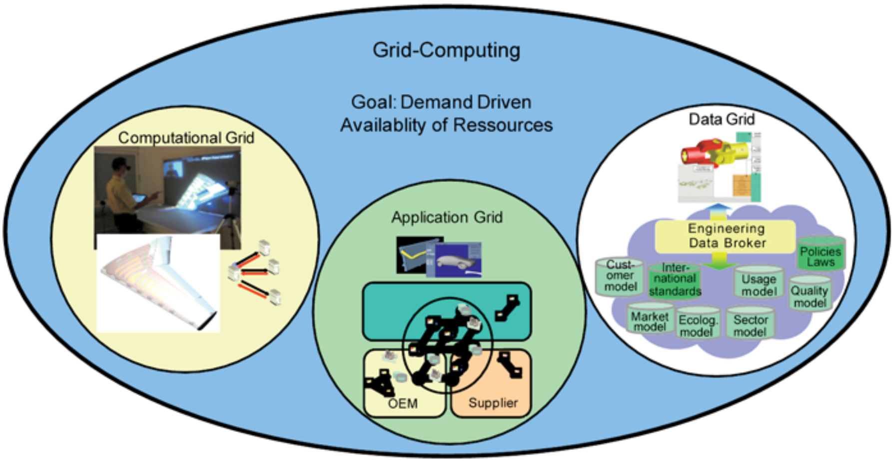

Fig. 2: Grid computing

To be able to adjust the product development speed to an objective schedule due to the competition or the customer needs, it is more and more necessary to further develop the ability of predetermining the product development time. Simple calculations have always been used, mathematical optimization tools are not really available due to the lack of sufficient process models. Therefore simulation seems to be an ultimate method. It can help to adjust to the needed development time, as by stochastic data the simulation is able to present a spectrum of probable times. By the possibility to select one of the probable times, the process parameters which have caused the result can be traced back. Therefore it becomes reality to make use of these data for controlling the process. Besides of this result, also cost estimates can be performed and the necessary number of feedbacks can be utilised to measure quality data, Fig. 3.

The application of object oriented Petri-nets is a proven concept for this simulation [2]. It cannot only be utilized for complex products in mechanics. Research work has shown the ability for using it for mechatronics products as well as for distributed product development processes.

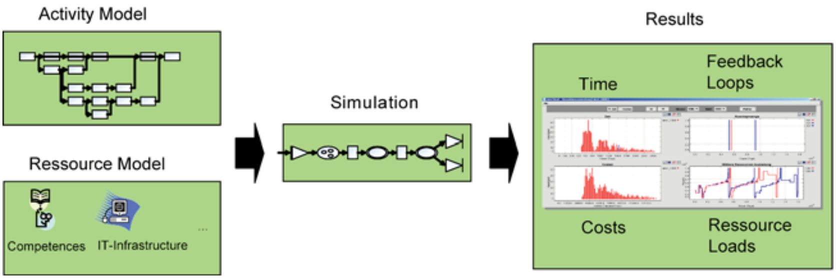

Fig. 3: Simulation of product development processes

There are a number of further questions related to the control of product development speed. What is an economically reasonable interval of product development times for a given product? How is it possible to adjust the product development with the needed product production and assembly time to come up with the demanded results? Is there a cost optimal solution, which gives time demands for the different sub processes? What about the time situation concerning the number of suppliers? Is there an optimum for this number? Will there be a method which makes the simulation of product development and the necessary project management compatible?

2.2 New System Functionality as a Driving Force for Innovation

It is not unusual, that designers are confronted to apply more than 15 different systems to fulfil their tasks. It can be doubted that it really makes sense, to come up with an even larger number of systems for providing more functions. The opposite is nevertheless true. The reason for more functionality is coming from the demand, to support the product development processes even in cases where it is not really possible to-day and nevertheless to ease the use of this system world. In the following, a number of research activities are illustrated to show important future directions of development.

The early phases of product development are often dominated by styling. This is a domain, which is inherently important due to the emotional effects on customers and the way of differentiation between brands. Styling in our days also has to be seen under the capabilities of manufacturing. As frontloading is a general demand for better, more effective product development, it is necessary to see also the usability of computer internal styling modules for the evaluation by physical simulation like CFD. A big benefit occurs if the same model can be used for simulation and for the first manufacturing steps, e.g. Rapid Prototyping. Another benefit arises from a styling model that can be generated in the computer with means which are accepted by the styling designer. The first steps into the direction of integrating a styling tool into the commercial CAD-world is promising, as NURBS surfaces can be generated, but are still not available in a sufficient quality. Subdivision technique has the potential but requires to be further developed to come closer to the goal [9].

The interaction of the styling designer with the model has to be based not only on the visualization of intermediate styling steps, but also needs to provide forces as if the styling designer would model on a real clay model. By this, the overall styling process accelerates significantly due to the cut down of process phases. Force feed-back is on its way, as first promising research results are there. It will take some more effort to be able to present an integrated process chain for these styling and design tasks. It could be thought of integrating as well converse engineering task.

Another system functionality is driven by the demand to support an integrated engineering and management of requirements during the whole development process. A direct coupling of requirements with product functions by using constraints aims to automate the further concretization like embodiment. This way of processing is of big interest for industry and leads to a number of advantages in adaptive and variant design [3].

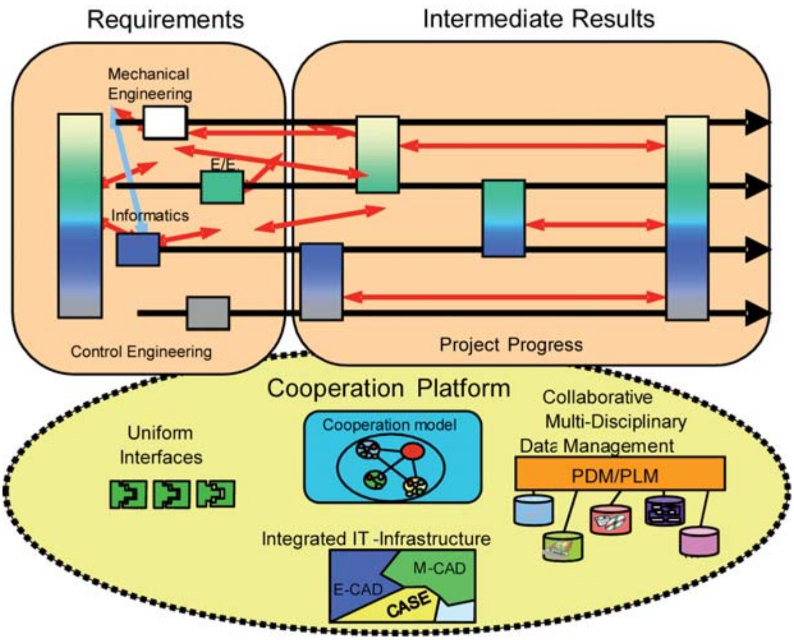

Fig. 4: Cooperation platform for mechatronics

Another challenge is to open the current system world support mechatronic engineering. In this case the requirements have to be distributed to mechanics, electronics and software. It seems that such a task only can be fully handled if a cooperation platform for mechatronics exists, Fig. 4, [6].

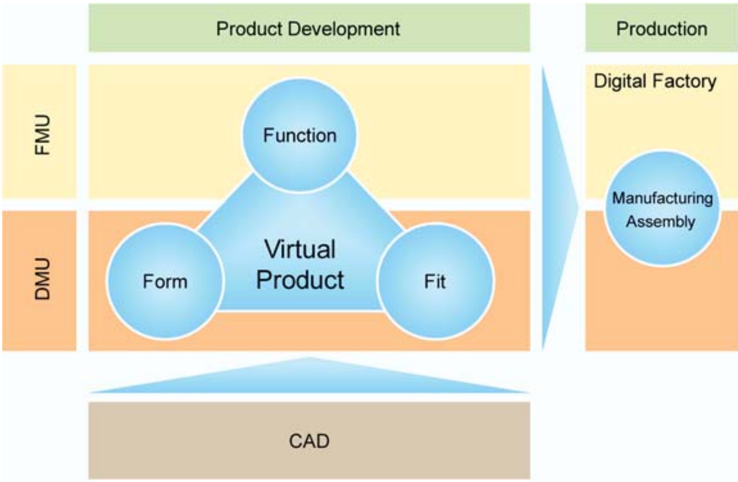

Fig. 5: Relations CAD, DMU, FMU, and Digital Factory

Another area of new functionality is the world of CAD, Digital Mock-Up (DMU), Functional Mock-Up (FMU), and the Digital Factory [4]. The relation between CAD and DMU is obvious, Fig. 5. A CAD-model is used and simplified in its shape representation for generating the DMU model. Thereby DMU functionality is focused to support visualisation and static analysis such as collisions predominantly. Actually only some simulations as kinematics and ergonomics are provided. Physical properties are not represented in DMU. Physical phenomena like heat transfer, electricity, vibrations, etc. are not investigable in DMU.

To apply DMU methods for the development of virtual prototypes, it should be possible to include functional property data into the DMU, which is by that turned into a FMU. FMUs will be able to be used to describe the functional and not only geometric behaviour of objects [5]. In the first steps this will be mechanical properties, but soon followed by everyone, what is necessary for mechatronics. It is very interesting to see, that the Digital Factory is already a domain specific FMU. The capabilities of simplified geometry are connected to factory functions like material flow and manufacturing processes.

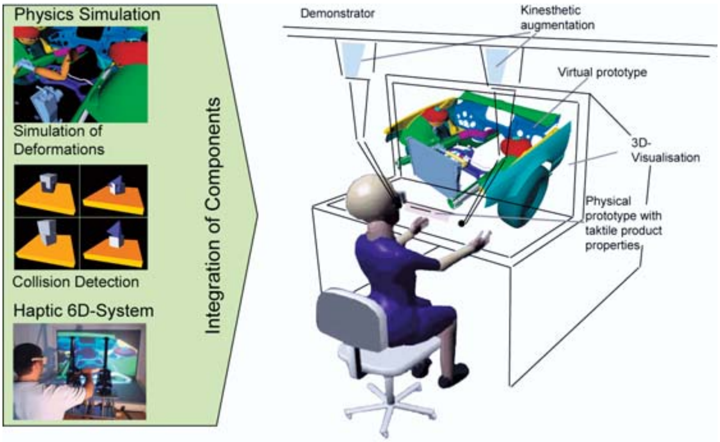

Fig. 6: Virtual Try-out & Training

Virtual and Augmented Reality are heading for new horizons in product development. Scalable presentations and stereoscopic viewing make the impression of VR-presentations realistic. The development of systems for interaction and feedback to the CAD-world show the potential of this field, which still needs research. But the required reality in VR is not yet reached. Also the combination with force feedback in kinaesthetic augmented systems will enhance the capabilities for example for Virtual Tryout, Fig. 6. In future it might not be necessary to have the high priced VR-Systems in use as a combination of VR and CAD may be available. The term VR-aided design is already used.

2.3 Computer Integrated Product Development Methods are a Basis for Process Innovation

Methodologies for design have been used since a very long time, unfortunately without the success which would have been necessary for industry. Nevertheless they have been used widely for educational purposes. Reasons for the less success than expected can be derived from the distance of some methods to practice. Especially the lack of customization potential is one of the obstacles.

Nowadays the usage of computers in product development is very common. In some cases the change from conventional design to computer support is performed in just copying conventional methods into the usage of software systems. This does not take into account the potentials of computerized systems at all.

The usability of computer integrated methods is very high. However, without computers they could not be applied. To name some: FEM, Knowledge Processing, DMU, VR, Fuzzy Logic and Neural Networks are all known very well for a while. The lack is their integration into a computer oriented design methodology. There would be even a chance of customization for the singular methods. As design methodology describes processes of product development, it should be generated a set of computer integrated methods. The important question is which is appropriate for a particular class of products. One demand should be mandatory: The designer should be able to select the methods according to his needs in respect to the product.

To go a step forward, it would be desirable, that the designer could make use of a system world, which is called “Case for CAD”. As application systems on top of commercial basic CAD-systems generate a very high speed compared with the usage of the basic system only, there would be a big benefit to make such systems available for designers.

The idea would be to give the designer tools for describing the planned design process as well as the structure of the product he or she is working on. From this description requirements are derived which are used as search basis in a repository which might be a specific data base or even the World Wide Web. Assuming there would be a standard for subroutines, it would be possible to collect the needed functionality on the web. A system editor could help to generate the demanded software system out of this. It would be interfaced with the used basic CAD system. This means the designer could make use of tailor made application software that is even adapted to the current process status and also takes into account the maturity of the product model. Designers should not become programmers, but certain under standing for the capabilities and demand of software systems should become an essential part of their education.

Quite another success factor can be derived from further development of product models. As earlier described, product models are carriers of all relevant product data in the factory. Because of the more and more upcoming demand for the capability to do all steps of the product life in advance by virtual means, a new partial model becomes necessary [7]. This is the so called product condition model. It is a data collection over the life of a product. It gives information about the need for maintenance as well as repair. It can warn about upcoming situations and it can document. The product condition model is of help for the user but also for the developer. The developer can have access to the data of singular products or can get accumulated data as feedback from the field. This new method should become part of a computer integrated design methodology as soon as possible.

2.4 Key Technologies and their Amplifiers are Innovation Enablers

It is of strategic importance to analyze for two demands and capabilities. For this the method of roadmaps has been used since several years. For a company it should be mandatory to develop a roadmap concerning the own products every two to three years and to maintain that continuously. To find out about the further evolution of useful technologies for product development, it makes sense to perform road map studies in about the same time frame. In 2006, the Berliner Kreis performed a neutral roadmap study concerning the topics complexity, mechatronics and collaborative engineering and for 13 other topics with influence to product development [8]. The interesting results give strategic input to decisions to be made about methods and systems. The time span has been 10 years, but it is clear that the experience has to be repeated for getting guidance through the many available opportunities.

3 Conclusions

The ability to change is one of the most important issues for survival. It can be phrased that to innovate is a tool to change self-determined. Changing is often a creation of a crisis, but a planned crisis is always better than a crisis generated by the outside world, like the competitors. Innovation in processes and methods as well as in tools can support the innovation of products in a dramatic way. Business opportunities are no longer only dependent on time, quality and costs, but also on the ability to innovate. Innovation is one of the best tools in society to cope with the demands of sustainability as well as with the demands of employment. Not innovation by chance is therefore the goal, but planned innovation in product development. For this fundamental research and applied research are twin demands of the future.

References

1 Krause F.-L, Hayka H, Gärtner H, Langenberg D (2004) Potenziale der Grid-Technologie in der Produktentwicklung (Potencials of Grid-Computing in Product Development). ZwF (99), Issue 9/2004

2 Krause F.-L, Kind C, Biantoro C (2006) Modelling and Simulating of Distributed Development Processes of Mechatronic Products by Means of Petri Nets. In: Gu P, Xue D, Ramirez-Serrano A, Park S, Fletcher D (Eds): Proceedings of 16th CIRP International Design Seminar, Kananaskis, Alberta, Canada, pp 694-701

3 Krause F.-L, Baumann R, Kaufmann U, Kühn T, Leemhuis H, Ragan Z, Swoboda F (2003) Computer Aided Conceptual Design. In: Proceedings of 36th CIRP-International Seminar on Manufacturing Systems. Saarbrücken, Germany, 3.-5.6.2003

4 Krause F.-L, Anderl R, Weber C, Rothenburg U, Wöhler T, Bierwerth M, Wanke S (2006) CAD – DMU - FMU. In: Krause F.-L, Franke H.-J, Gausemeier J (Eds.): Innovationspotenziale in der Produktentwicklung (Innovation Potentials in Product Development). Carl Hanser Verlag, München, Wien, pp. 117-128

5 Krause F.-L, Rothenburg U (2005) Advanced Product Validation using Functional DMU. In: Bley H, Jansen H, Krause F.-L, Shpitalni M (Eds.): Advances in Methods and Systems for the Development of Products and Processes, 2nd German-Israeli Symposium on Design and Manufacture. Berlin, 07.-08.07.2005, Fraunhofer IRB Verlag, Stuttgart, pp. 73-80

6 Krause F.-L, Hayka H, Langenberg D (2006) Actual and Future Needs for Collaborative Design Reviews. In: Proceedings of International PACE Forum - Collaborative Visualization. Darmstadt, 15.-17.11.2006

7 Krause F.-L, Jungk H, Kind C (2007) Product Life Cycle Planning and Tracking. In: Seliger G. (Editor): Sustainability in Manufacturing – Recovery of Resources in Product and Material Cycles. Springer, Berlin – Heidelberg – New York, pp. 183-192

8 Krause F.-L, Franke H.-J, Gausemeier J (2006) Innovationspotenziale in der Produktentwicklung (Innovation Potentials in Product Development). Carl Hanser Verlag, München, Wien, 235 pages

9 Gross N (2005) The FIN algorithm - Using Subdivision Techniques for Geometry Design. In: Proceedings of the 8th IASTED International Conference on Computer Graphics and Imaging (CGIM 2005). 15.-17.08.2005, Honolulu, Hawaii, USA, pp. 49–53