New potentials for virtual product creation by utilizing grid technology

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ABSTRACT
Efficient virtual product creation combined with predictive engineering requires high-capacity computing and communication technologies as well as fast and transparent supply of knowledge, information and data. For this purpose, grid technologies offer great potentials for virtual product creation. One objective of grid computing is to perform more realistic simulations for better prediction of effects with reduced costs. This paper describes the approach and methods how engineering analysis problems in product development and manufacturing can be solved in the flexible context of CAE applications and grid computing infrastructure. The presented results are partly achieved in a joint project with partners from research and industry.

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1. Predictive engineering in virtual product creation

For virtual product creation the impact of predictive engineering is increasing continually. The ability to predict behaviours of products as precisely as possible throughout the entire product development process would significantly enhance product readiness and quality at start of production, during lifetime customer usage and for potential reuse of product systems at lifetime end. Due to digital product models it is possible to simulate products before a physical prototype is built. Increasing the quality of prediction capabilities presupposes an increase of simulation complexity. This includes not only to simulate individual components of the product according to today’s standard but also to process the product holistically including all relevant component and system interactions. Also additional simulation parameter with more variation should be taken into account. Furthermore, more and precise simulations would enable the possibility to optimize products for the fulfilment of requirements and to optimize material or energy consumption. The prediction is not limited to product characteristics and behaviours. In addition simulation of manufacturing processes is possible according to full digital factory paradigms. For example the validation of manufacturing processes with regard to tolerance information is theoretically possible, but often lacks enormous computer resources to calculate not only most likely combinations but also tricky and worst case scenarios and in combination with flexible parts. These simulations and optimizations are rarely done because of the lack of enough compute capacities. Even today, many physical prove-out tests are still necessary for proper validation.

To further enhance product development it is necessary to take into account much more design alternatives in the future. To do this predictability of the influence of alternative designs is required.

Another area where physical prototype tests are still needed in significant numbers is the validation of product models with respect to product function and mechatronic interplay. These are necessary to pass project milestones with respect to legislative regulations and/or critical safety functions. However, the current situation in industry is under change: in several cases virtual simulations are accepted for validation already. In the aircraft industry, for example, simulation results are used more often, e.g. stress tests of the structure in the approval process for the regulatory authorities of new aircrafts such as Boeing 787[1]. In car industry, the state authority TÜV in Germany has meanwhile accepted digital visibility studies for passenger car mirror systems (side and back mirrors) based on CAD embedded eye point calculations for all relevant human percentile populations in combination with the modelled parametric mirror adjustment ranges. Every physical prototype saved offers cost and time advantage. Both saving opportunities are very important for a successful and in time introduction of new products: Lower development costs and shorter time to market, which in terms of life time revenue is even more important than the reduction of development costs only.

In addition, the development of products requires fast and transparent supply of data, information and knowledge. Different product models are necessary to realize holistic simulations, which have to be available for engineers. Also, both, design and CAE engineers need appropriate simulation applications to run those complex computing jobs.

For these purposes, grid technologies offer a great potential for virtual product creation. Especially in virtual enterprises they give access to various resources, e.g. applications, data and compute resources. Grid technologies are already used in the scientific
community today. Now it is necessary to enable these technologies for industrial applications such as product creation.

2. Potentials of grid technology

Virtualization is the key term of future information systems. In complement to existing distributed systems, grid systems of the next generation virtualize information and computing services by hiding technical details of the specific distributed implementation behind user interfaces. From a data processing point of view resources should be available wherever you are. The electric current in the power grid for example is available on every electric socket. The origin of the ‘grid’ term clarifies this perception. The user can only see the electric socket from which he obtains the desired service. But the user cannot see details which are necessary for the allocation of the computing power, data and application.

Foster defines grid computing as follows: ‘Grid computing is concerned with coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organisations’ [2]. The most common grid classes are computing, data, and application grids. Thereby the computing grids present the traditional form. Complex computation is separated into piece parts which are computed through the grid.

One of the essential factors in the product development is the availability of required product relevant data for all involved persons. This includes product data which is retrieved in the phase of product development, the generic data and the product knowledge. Usually this data is not centrally managed, but distributed across different locations. Grid technology provides the chance of a simple and transparent access to these different information sources. A data grid can be understood as the integration of different data managing systems to supply the user with knowledge, information and data.

An application grid should have the ability to choose the desired programs from an inventory of existing applications. If necessary it has to build a complex application system from the inventory which offers an optimal solution to a given problem. All these resources are made available through a transparent grid access layer, as shown in Fig. 1.

Furthermore grid technologies should simplify the setup of virtual enterprises. The IT-systems of OEM supplier chains build a business overlapping grid, in which each user can access needed resources for virtual product creation. Here the interoperability becomes important as it was subject of previous projects like INTEROP-NoE [3] and ATHENA [4,5]. Also this sharing is possible for all kind of resources: computing power, data, applications and many more.

Grid technologies enable the demand oriented utilization of resources. Companies do not invest in additional substantial IT infrastructures. Instead the existing ones will be used more efficiently. And if there are not enough resources available in the company, external ones can be allocated. Especially for users in SME “small and medium-sized enterprises” grid technology provides the possibility to use applications with a high resource requirement without having to order a license and administrate these products permanently. In this way the user can perform complex computations in order to enhance simulation results by considering additional parameters. They also can be used to shorten the duration of product development by speeding up the computation. Additionally, the following new simulations could be realized, even for small and medium-sized enterprises:

- holistic simulation, e.g. simulation of the complete vehicle with more physical parameters,
- more frequent simulations for the validation of intermediate results,
- optimization processes with many simulation steps are possible.

Through the use of grid technology new fields of applications will be possible in future. These are for example evaluation of design alternatives, determination of product behaviour in the digital factory and verification of mechatronic systems.

3. International grid projects and activities

All over the world, there are many different projects in the research area of grid technologies. Every project has its own focus, some are more fundamental research oriented, others are application oriented, but only a few of them have industrial background.

At the moment, the biggest grid infrastructure is provided by the ‘Enabling Grids for E-sciencE’ (EGEE), which were founded by the European Commission [6]. About 10,000 scientists are using this infrastructure with approximately 80,000 CPUs for approx. 300,000 calculation jobs per day [7]. Several international projects around the world are connected to EGEE and use their computing resources. Further examples for big grid computing projects are: TeraGrid (USA) [8,9], Open Science Grid (USA) [10], Earth System Grid (USA) [11] and int.eu.grid (EU) [12].

In Germany there is the D-Grid initiative, which was founded by the German Federal Ministry of Education and Research (BMBF) in March 2004 and which bundles many activities in this research area [13,14]. The aim is to design, build and operate a network of distributed integrated and virtualized high-performance resources and related services to enable the processing of large amounts of scientific data and information. There are two phases with a third one currently starting. The focus of the first D-Grid projects between 2005 and 2008 were the IT services for scientists. They were designed and developed by the ‘early adopters’ of the computer science and scientific computing communities. In the second group of projects from 2007 till 2010 IT services for scientists, industry and business are being developed.

4. Grid technology for collaborative product development

4.1. Objectives

One of the joint projects of the second phase of D-Grid initiative is ProGRID (‘grid technology for collaborative product development’) [15]. The consortium consists of four software providers, one end user company and two Fraunhofer research institutes. The main objectives of the project are to utilize grid technology for collaborative product development and to demonstrate its advantages by means of selected use cases. The enabling of realistic and holistic simulations and more frequent calculations for validation of product models are some of the demonstrated advantages. One focus of the Fraunhofer IPK is to enable simulation services in grid environment for CAE and simulation data management system.

Efficient product data sharing is another objective. Even in one company the data for the simulations is distributed in different information bases, e.g. PDM system, file system and material databases. The engineer has to know from where he/she retrieves the data and needs access to all of these systems. In collaboration this becomes even more complex. Typically, products are developed in ‘virtual enterprises’ consisting of manufacturers,

Fig. 1. Transparent usage of resources with grid technology.
suppliers and engineering service providers. Here more people and more data management systems are involved. Therefore, one important focus of the project is the development of a collaboration environment with an integrated simulation data management system for all data, which is necessary during the CAE processes. This collaboration environment also enables a transparent access to grid technologies.

4.2. Approach

With the aim of facilitating the communication between manufacturer, suppliers, engineering service providers and variant developers, the continuous and consistent availability of product and process data has to be improved. This is relevant for all stages of development, i.e. product planning, design and verification. To achieve this, PDM systems and simulation environments need to be tightly networked. In a distributed environment this will ensure that model states are in sync and that only current part models are being exchanged and evaluated. To be able to access simulation models and data, a simulation platform should be provided, comprising a web-service interface that allows access to simulation projects, models and results. Likewise, a collaboration platform will allow the transparent and integrated usage of grid services. Based on a developed data model to structure CAE information and used in automotive industry scenarios. It will take care of connecting simulation data (consisting of simulation models and results) with corresponding PDM data (product structure and associated CAD models). In the research project an existing basic platform has been extended with interfaces to a grid middleware to provide a complete grid-based collaboration platform, as shown in Fig. 2. The platform utilizes the existing Grid Middleware and security mechanism taken from currently running D-Grid infrastructure projects.

Modules for pre- and post-processing, as well as simulation and optimization, will be added as services for numerical analysis. By having access to simulation and PDM information, it can be ensured during pre-processing that CAE models are always matching the current state of the CAD models.

Similarly, it is possible for the numerical solver to directly apply the mass trim, which means to account for parts and passengers not being modelled by using additional masses. An essential requirement of manufacturers and variant developers is to be able to quickly assess and analyze the current state of development. In this regard it is necessary to have facilities for transferring huge amounts of data fast and conveniently. Beyond those objectives, the project will focus on improving the utilization of compute services through remote visualization and data compression techniques, as well as fault-tolerant execution of complex workflows in grid environments.

4.3. Use cases

On the basis of five future-oriented use cases the project will show the advantages of the new Grid infrastructure for virtual product development. Three scenarios are dealing with the topics virtual verification and structure optimization. These will cover important aspects like part optimization and reliability validation, fluid dynamic optimization as well as multi disciplinary structure optimization. In addition, an application scenario connecting product data management (PDM) and CAE systems is specified. This is to ensure smooth data flow between product development and virtual validation. The primary topic of the fifth application is a collaborative product development as well as a collaboration environment. In this paper the last two use cases are focussed.

4.3.1. Integration of PDM and CAE

One of the primary goals of ProGRID is the realization of a simulation data management (SDM) system. The SDM system is the central data broker, which manages all relevant information for the simulation processes. It has access to all other data management systems. Depending on external requirements, it copies the necessary data to its own data base or it stores references to this data. The SDM system is integrated into an environment, which enables the access to grid computing resources. Fig. 3 shows the structure of this scenario. When a simulation job is created, the Grid Gateway collects all necessary data from the SDM and data management systems and transfers it to a special grid storage system.

4.3.2. Collaboration environment for virtual verifications

Products are developed in teams – and today, these teams consist of members from different companies and disciplines. So one scenario of ProGRID is this distributed development and application. The main focus here is a central collaboration platform with data management and direct access to grid resources and application. Therefore the SDM and grid gateway solution of the previous use case is extended by functionalities for this collaborative scenario, as is shown in Fig. 3.

4.4. Intermediate results and findings

During the past period of the project the concepts were developed and a first prototype is realized which demonstrates the first three use cases with their different kind of calculations. For this first prototype the complete environment has to be setup, including the simulation data management, the user interfaces and the grid gateways.

The grid technology was widely used, but mostly in the fundamental research like high energy physics, chemistry or astronomy. Therefore, industrial requirements were not considered enough as strong requirements for security. The standard grid middleware and the implemented infrastructures have not solved this problem sufficiently yet. This comes along with an acceptance problem in the industry.

The two different software worlds are another challenge: In fundamental research mainly open source applications are used,
whereas in industry commercial applications dominate. It will be
complicate to use existing licence models in grid infrastructures, if
the applications are available on big clusters and are seldomly used
only. For utilization of grid technology in the industry new licence
and business models have to be realized like per use models.

For that reason, the project ProGRID demonstrates technically
how the usage of grid technologies in the product development on
the basis of simplified use cases with less critical requirements. Others
questions like legal issues, accounting, security, business and
licence models are not solved as these were not scope of the
project. ProGRID collects these requirements and give them to the
D-Grid community.

In addition to this there are two conceptual problems which
have to be solved by grid computing infrastructures. If a company
buys a high-performance computing system, it evaluates which
system architecture is the best suitable one. In the grid there are
many compute clusters available, but it is difficult to define an
architecture which solves the problem best.

The second conceptual problem is the enormous amount of data
to run the simulation processes. For example in one year a vehicle
manufacturer produces data up to 100 terabytes. On company
compute clusters the engineers have direct access to the results and
can chose, which data is necessary to store. This is not possible in
grids, today. It depends on several factors like internet bandwidth,
amount of data and concrete use cases, whether internet connect-
cations become a limiting factor for the use of grid technologies.

One additional disadvantage of existing Grid infrastructures is
the high latency for calculating jobs. The time for scheduling, data
staging and so on take at least several minutes. Real time or at least
interactive applications are not possible.

4.5. Expected results and conclusions

ProGRID already shows some fundamental concepts and
implementations for enabling grid resources for CAE applications,
today. To have the grid functionality implemented in the work
environment of the simulation data management system gives the
user an easy access to grid computing resources. For the future it
will be necessary to have this integrated grid access available in
more tools to better support the product creation process.

The software prototypes in ProGRID support the necessary
functionalties for the defined use cases. On basis of these
scenarios, ProGRID gives an outlook how a solution for CAE could
look like. The use cases are the basis for further evaluation of the
possibility for the use of grid technologies in industrial practice. At
the end, the project will give input for the grid community about
necessary features which enable grid computing for industry.

For the future three main research and development activities
have to be done to enable grid technology in the virtual product
creation further on. First the grid technology itself has to be
improved. The focus has to be on better usability and security
functionalties, e.g. integration of Digital Rights Management
systems. In addition, engineers have to define their requests for
grid technology and have to specify their requirements. Last but
not least, enhanced business models for resources providers are
missing. Problems like sharing of software licences and accounting
of the services are not sufficiently solved yet. At the end, the project
will give input for the grid community about necessary features
which are needed to use grid computing in industry.

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