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Approach for Automated Product Modeling Using Knowledge-Based Design Features

Stéphane Danjou[1], Norman Lupa[2] and Peter Koehler[3]

[1]University of Duisburg-Essen (Germany), stephane.danjou@uni-due.de
[2] University of Duisburg-Essen (Germany), norman.lupa@uni-due.de
[3] University of Duisburg-Essen (Germany), peter.koehler@uni-due.de

ABSTRACT

The globalization of the markets, increasing complexity and diversification of products as well as product and process innovations as central factors of business competition have forced companies to create new strategies of product development. This paper points out the possibility of standardization in the modeling phase in consideration of calculation results and conceptual design activities. The introduced approach is based on user defined features (UDFs) as knowledge carrier, whereas these UDFs have full control over the model setup, initialized by a few input parameters. In consideration of company specific model properties, the augmentation of UDFs with knowledge provides all information required regarding the shape, function and manufacturing of the product for all phases of the product life cycle. By means of an exemplary realization of the illustrated concept this paper makes the approach accessible to the reader. Finally the paper will be concluded with prospects in future challenges of the automation of the product development process.

Keywords: knowledge based engineering, automation, feature, product modeling.
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1. INTRODUCTION

The fact that products are getting more and more complex and particularly the growing number of interdisciplinary interdependence increasingly led to a renunciation of the traditionally strongly sequential oriented design process in the past few years. Stress of competition comes along with time pressure which emphasizes the necessity of new methods for an accelerated product development process. More than ever companies try to cope with these requirements by standardizing design procedures as far as possible. In this connection design standards assure protection of know-how as well as compliances with company specific specifications and guidelines for subsequent design processes.

In the past years, the operational division *Power Generation Oil & Gas and Industrial Applications* of the global acting company SIEMENS followed this trend-setting technique. Components of an impeller design have successfully been unitized and recorded in design standards. Lay out design data from a variety of computation departments (thermodynamics, mechanics, etc.) enabled a sophisticated automatization of the 2D design process by evaluating design standards with the help of FORTRAN applications 25 years ago. Even if by definition this had nothing to do with knowledge based engineering (KBE), this procedure guaranteed the almost fully automated generation of technical documentation and therefore represented an important step towards an accelerated development process.

In the course of a 2D/3D CAD reorganization in the company, a joint project between SIEMENS and the *Institute of Product Engineering* at the University of Duisburg-Essen (Germany) has been founded. The implementation of KBE techniques into the design procedure for selected compressor components (shafts and impellers, see Fig. 1) made up the essential project objective.

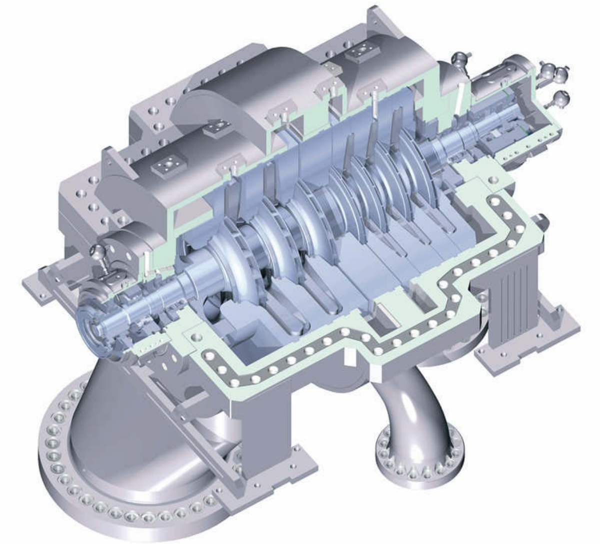

Fig. 1: SIEMENS single shaft compressor STC-SH (source: SIEMENS Corp.).

Design activity as the veritable core process of the product development plays a decisive role for the maintenance of competitiveness and therefore has to meet highest demands. Primarily this will affect miscellaneous aspects like the acceleration of the product development process, the compliance with company specific specifications and guidelines as well as the associated warranty of product and process reliability by standardizing the design process [3],[4].

2. ANALYSIS AND SYNTHESIS OF DESIGN PROCEDURES

The design respectively optimization of a product frequently requires both an analysis and a synthesis. Latter is of immense importance because notional into detail disaggregated single product components will be assembled to a unit in consideration of a pre-constructed multidimensional catalog of objectives (Fig. 2).

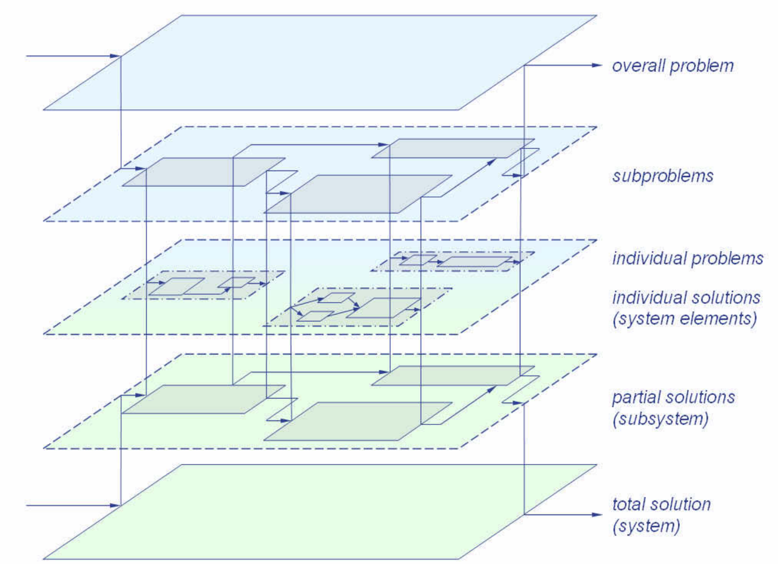

Fig. 2: Analysis and synthesis with regard to problem and system structuring.

Exactly these (re-)defined design objectives must cope with modern and purposive requirements. In the case of 2D/3D CAD changeover usually no new design objectives will be defined, but it is essential to submit hitherto existing processes to a careful and critical examination regarding up-to-dateness and modernity [3]. Well proven techniques and methods for 2D design can turn out to be totally useless for 3D development. As a result, in the course of an implementation of 3D product modeling it is necessary to analyze design processes and subsequently to subject these to synthesis operations, considering 3D CAD system specific requirements. At this point, it is not satisfactory to overhastily create CAD models in order to generate a technical documentation as exclusive final process objective. In times of 2D CAD utilization, technical drawings represented the primary intention of design departments. Meanwhile these documents shrivel to an increasing degree to by-products since the introduction of modern 3D CAD technology. Significant objective of 3D CAD employment is the product model as knowledge carrier with respect to geometry, production and manufacturing information, assembling and so forth as well as a master model for the validation and safeguarding of design results (*Finite Elements Method*, *Multi Body Dynamics*, *Digital Mock-Up*, assembly simulation, etc., see Fig. 3) [3],[8],[10]. Beyond it the product model serves as a basis for downstream processes (NC manufacturing, *Rapid Prototyping*, casting, injection molding …).

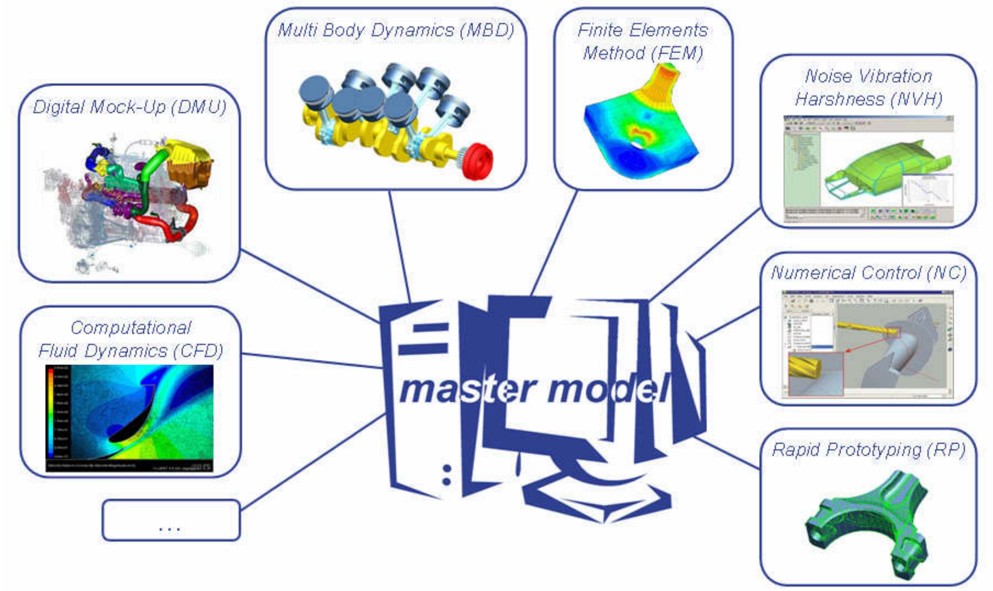

Fig. 3: Master model as basis for downstream processes.

At this point first potential benefits of 3D product modeling become apparent whereas the yield is significantly determined by applied techniques and methods considering velocity and stability of the design process as well as the structured and goal-oriented use of the knowledge resource to its full potential. According to experience, especially the transformation of collected business know-how into an adequate product model produces the most difficulties.

Within the scope of the joint project, the entire design process of compressor shafts and impellers has been analyzed in close collaboration with employees of SIEMENS. Based on the results, a suitable modeling concept for 3D CAD has been developed. It considers both functional and non-functional requirements. At the end of such a 3D CAD oriented "revision" many times one can benefit from time reductions and potentials for optimization. In addition, compliances with product specifications, which were subject to continuous modifications over the years, will be guaranteed. Furthermore violations of design regulations will be detected in order to resolve them without any consequences.

3. IMPLEMENTATION OF KBE IN THE DESIGN PROCESS

The conceptual design of knowledge based product modeling always raises the same question, which only can/should be answered in holistic consideration of the product development process and with the acknowledgement of all occurring interdependencies [7]: Where and by which means knowledge has to be deposited in order to access relevant information, necessary for the creation of a purposive master model? Finally the applicable selection of adequate representation structures for the enterprise resource knowledge turns out to be the important point.

As a matter of principle, companies are in a position to fall back on numerous local solutions to record and protect their knowledge. In the past 15 years knowledge base systems (KBS) as *PHPKB Knowledge Base*, *KB Organizer*, *Lessons Learned Server*, *General Knowledge Base* and others have been developed for a professional knowledge management. Knowledge base systems which enclose the design process, particularly computer aided design (KBE), have their seeds in the 80s (*ICAD*), temporarily became less important and again are of substantial interest since the end of the 90s. Last but not least, due to efforts of system providers to launch PLM (product lifecycle management) suitable products on the market [1], miscellaneous KBE solutions like e.g. *STONErule*, *Knowledgeware* (replacement of *ICAD* – Dassault Systèmes), *Pro/TOOLKIT* (PTC), *Knowledge Fusion* (UGS) as well as *Pacelab* (Pace), *GDL* (Genworks), *YVE* (TECNEOS), *Driveworks* (HCV Data), *AutoLISP* (Autodesk) and *Kadviser* (Kadetech Industries) have been developed for the integration into the CAx environment. The type of interconnection to the CAD system is the significant differentiating factor. Some KBE systems come up with an own modeler which is leading initially to knowledge processing and product modeling, independent of the CAD system. Interfaces enable the import and export of CAD geometry. However, such stand-alone solutions always implicate the risk of interface issues [9]. Other KBE systems represent a direct integration into the CAD system or customization (see Fig. 4) using available application programming interfaces (API). In this manner, with the help of a KBE application the CAD system, including the graphical user interface (GUI), can be customized to company specific needs. Whether as stand-alone solution, customized system or integration, the question of an applicable KBE concept has to be answered very differentiated and is highly geared to the product, which is intended to be developed, as well as to the existing process flow.

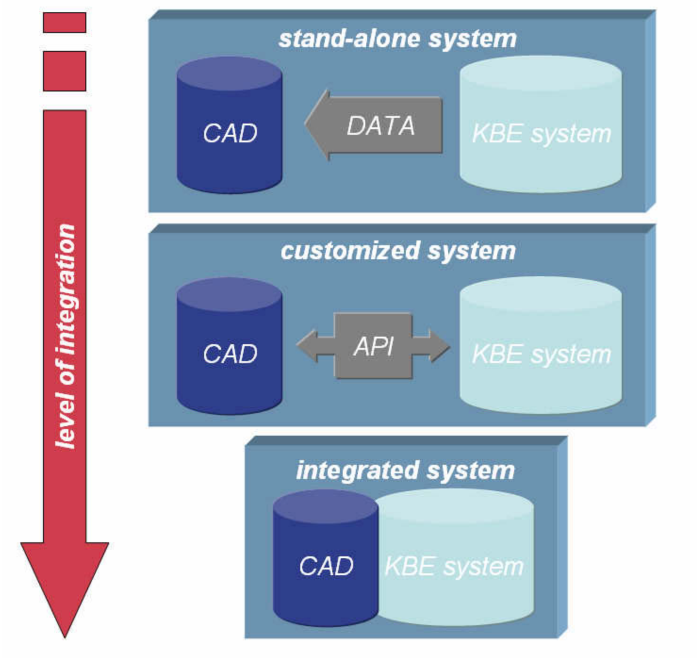

Fig. 4: Possibilities of KBE system integration.

By this means, as part of the joint project an intensive concept development phase with respect to all interrelations (product structure, workflow, flow of information, CAD functionality, etc.) led to an integrative solution. Unlike previous KBE solutions, necessary design knowledge shall not be anchored in the application itself, but rather be distributed to the relevant product components respectively product segments (design units). The KBE application simply initializes and controls the automated CAD model setup. The processing of the intrinsic knowledge takes place in the model itself without need to deposit necessary information in there.

4. MODULAR KNOWLEDGE BASED MODEL CREATION

In the case of standardized products to the greatest possible extend, it would seem the thing to modularize component parts [14]. According to existing design standards the modularization enables the definition of self-contained modeling units, which can be divided into fixed and variable model zones. That will lead to a robust CAD model setup and encourages further usage due to the standardized model creation [12]. However, a modular model creation only makes sense if product variants resemble in their geometric characteristics. Selected compressor components possess that characteristic as well (see Fig. 5) so that it seems to be reasonable to perform a model setup with the help of user-defined features (UDFs). Furthermore, indeed these components are subject to geometric similarity but partly significant topological modifications. This makes simple parameterization of the parts impossible and leads to a modular setup with subsequent integration of product and process specific knowledge.

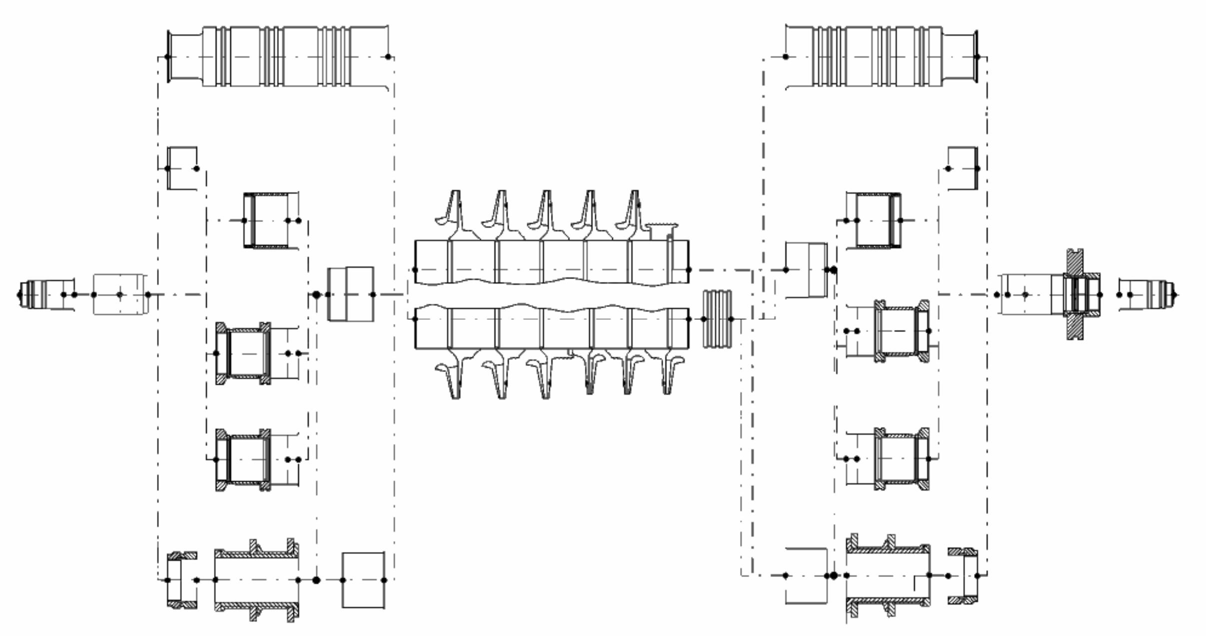

Fig. 5: Compressor shaft as an example of product modularization (source: SIEMENS Corp.).

If the used UDFs contain the entire necessary information, one can renounce an "omniscient" KBE application because that would lead to a highly component specific application. Therefore it would be impossible to create different components unless appropriate KBE solutions for each product component would be available. By distributing knowledge to each UDF, the KBE application provides data transfer to initialize and to instance the UDFs and therefore controls the model setup. This will happen independently of information content and thus of the type of component. Finally, this had been realized within the scope of the joint project by programming a KBE application named CUMDA (Common UDF-based Modeling and Drawing Application) in the CAD system NX (*UGS*) with the help of *Knowledge Fusion* as NX specific knowledge ware (Fig. 6).

Now the fundament for the creation of 3D CAD models is the definition of UDF input data (input parameters) as well as the provision of information about Boolean operations and UDF positions. The requested information can be obtained from a file of the computation department or a manually composed ASCII based file (data file). The compliance with a predefined data structure simply is the only necessary precondition. The KBE application CUMDA imports the data file, analyzes the content and distributes the input parameters to all relevant UDFs. These input parameters can represent classification characteristics like main dimensions, parameters or identifiers. With the help of that information, the particular UDFs can build up a connection to the database and request relevant data. The knowledge encapsulated inside the UDFs determines the amount of retrieved data, the point of origin and further processing. For this reason, mere knowledge processing takes place exclusively in the user-defined features. In contrast the KBE application simply serves for initialization, organized setup of part sections to the entire model and preparation of collected information for downstream partial models (e.g. drawing model). In this context one can talk of a certain type of self-organization of the part because there is no need for outer interference to supply the features with geometry data and semantic information. That does not imply that variations of design standards are not permitted. At any time, the user has the opportunity to influence the entry of input parameters and therefore the geometrical shape or alternatively to make modifications to the CAD model subsequently. Despite a high level of automation the designer is marginally subject to limitations. In addition to the high flexibility the presented modeling concept is characterized by wide applicableness which is reflected in provision of neutral information. Because of the fact that the information content, necessary for the initialization of the UDFs, normally consists exclusive of classification characteristics, this data can be used in same format for downstream processes as well.

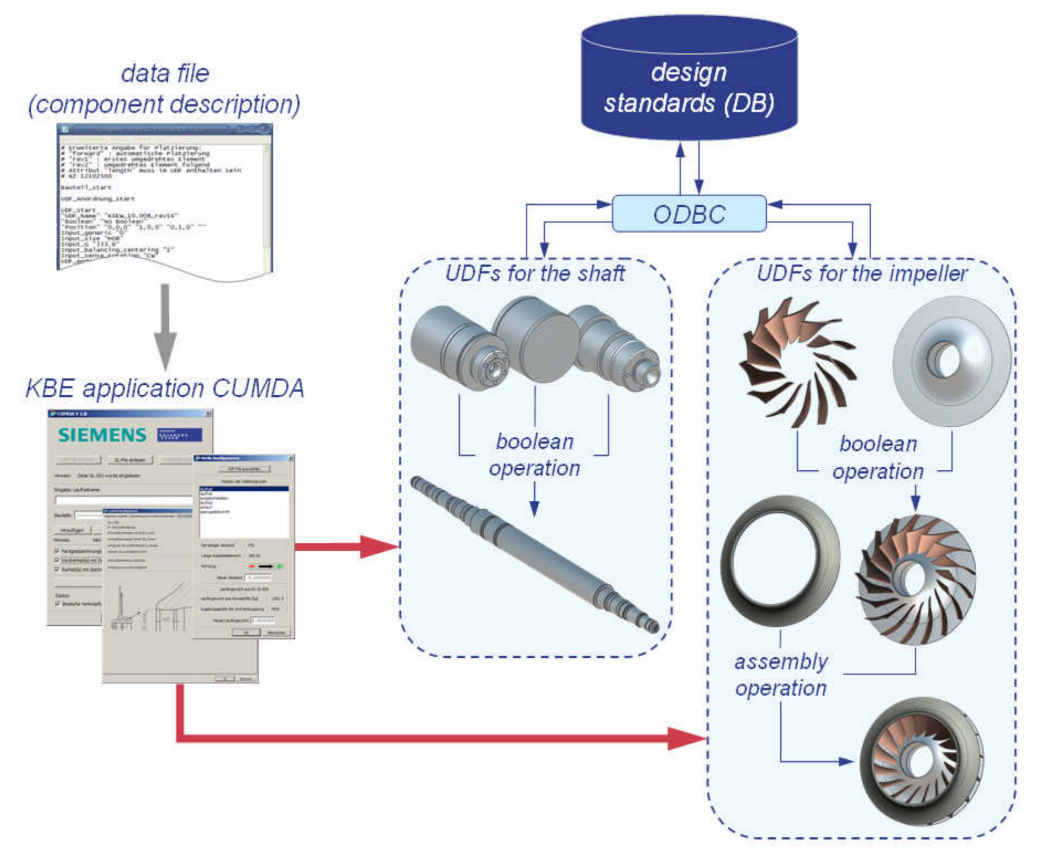

Fig. 6: Feature based model creation with the KBE application CUMDA.

The presented approach of a modular knowledge based CAD modeling process turned out to a successful data management of product specific layout and design data without redundancy. Furthermore, the model setup has been standardized and the modeling process respectively the product development process as a whole could have been reduced significantly. Whereas the conventional 3D product modeling process for a compressor shaft and one impeller requires approximately 10 days, the KBE application CUMDA delivers the same result within 1.5 hours. Both approaches include the collation, arrangement and adjacent assignment of necessary information as well as the modeling process including drafting and eventually necessary rectification work. That leads to a meaningful time reduction of up to 95%. Considering that numerous compressor rotors have up to 10 impellers, the significant economization is getting even more obvious.

Another advantage of the introduced modeling concept is the possibility of infinite deposition of information into the UDFs. The integration of product and process specific knowledge into the product model finally enables the transfer of knowledge to different company divisions at an early stage (see Fig. 7) and therefore ensures ever updated access to object relevant information as well as the reduction of redundant data sets and the preparation for downstream processes [3]. To use the information in different company divisions and therefore from different perspectives, further efforts will be essential in the future to provide stored information in a context-sensitive manner thus according to required perceptions of the users [13].

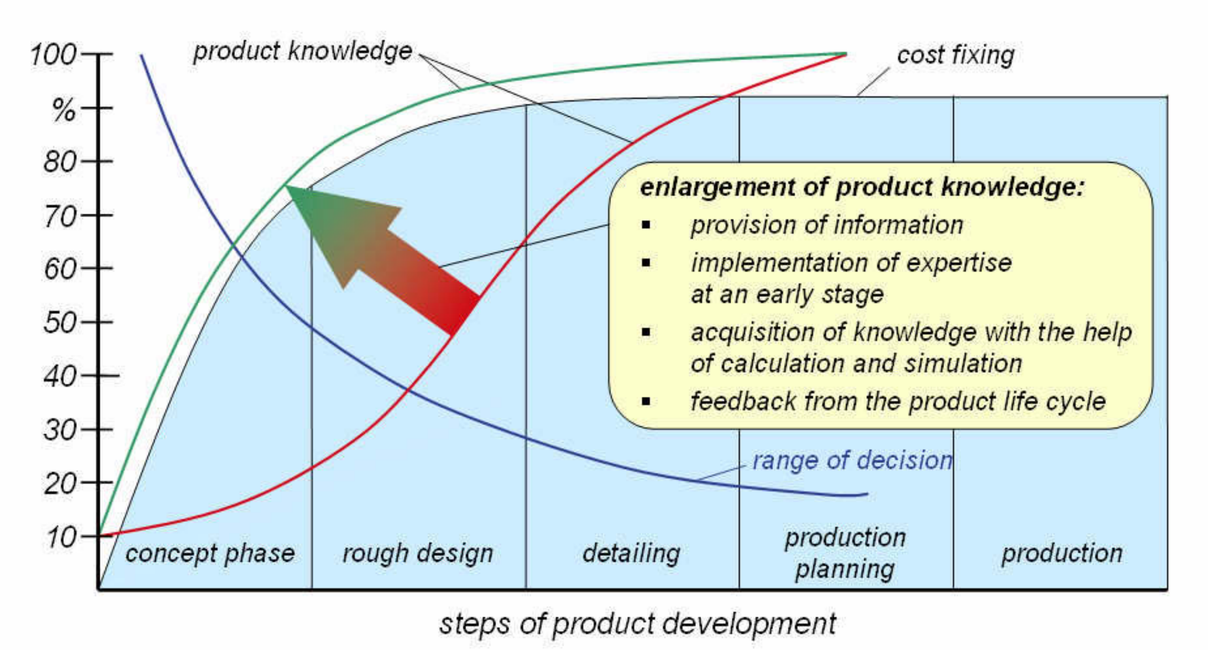

Fig. 7: Provision of product knowledge in the development process (according to BOEING COMPANY).

5. TRENDS OF KNOWLEDGE BASED DESIGN

Up to now the consolidation of CAx engineering tools (CAD, CAE, CAM, etc.) among each other, not to mention with computer systems for mercantile order processing (PPS, ERP, CRM, …), hasn't been accomplished satisfactorily [1]. Therefore further endeavors will be necessary to benefit from the potentials of an accelerated product development in the sense of product lifecycle management [11]. An interesting and already in other disciplines (e.g. information technology, IT) established approach is the setup of an ontology (formal form of knowledge representation, [2],[5],[6]) which enables the exchange of knowledge between different IT systems respectively systems and users and therefore different contexts. As a result, the ontology based product development will upgrade the knowledge based design with context-dependent knowledge management (Fig. 8). The effective access to knowledge content of different sources as well as different usage requires a uniform language to describe the content of knowledge. Hence, further developments will aim for formalization and transfer of knowledge into a universally interpretable language.

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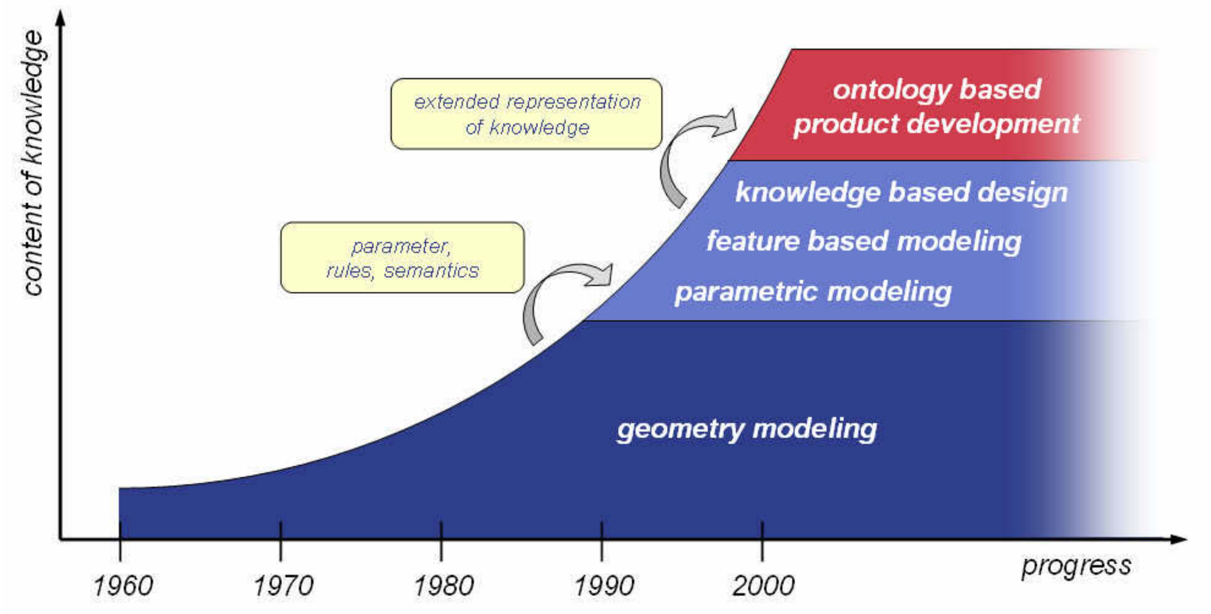

Fig. 8: Development of computer-aided design process.

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