SOFTWARE TOOLS FOR SUPPORTED CAD-MODELING OF MASS CUSTOMIZATION PRODUCTS

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Abstract:

In terms of mass customization, there is an increasing necessity to integrate the customer within the product development cycle. So far the customer input was reduced to define the basic tasks and requirements through information gathered by the sales and marketing departments. In terms of the new approach standard product development cycles are adapted in order to meet the new requirements. In the stages of solution principle search and module structuring the enhanced information has to be gathered. During the following phases the products have to be pre-thought and pre-designed by modeling highly flexible and informative CAD-data using the functionalities of modern CAD-systems to define interdependencies and constraints within the product structure. These definitions lead to a set of degrees of freedom, which later on offers an individualization range for the customer. Supported by a software tool the engineers extract the developed degrees of freedom and create an flexible database file. This file is used by the customers in a configuration software, to define their own, individualized product via the internet on a client server based process. While the definition process is visualized at all times the modification information is stored in a new database file.

1 Introduction

Fast technical progress, increasing internationalization and the resulting intensification of competition characterizes the situation of manufacturing companies at the beginning of the 21st century. Due to demographic changes customers demand highly individualized consumer goods, at prices comparable to those of mass produced goods. These goods need to be available within shortened delivery times. Mass Customization is one way to satisfy these new customer demands for more individual and adaptive products [11]. The aim of Mass Customization is to configure and produce individual products for each customer with an acceptable increase of costs [10].

For this reason the **C**ollaborative **R**esearch **C**enter (CSR) 582 "Mass Customization" was founded at the Technische Universität München. This project consists of several sub projects in the fields of business administration, product development and production. The sub project that is presented here, deals with new concepts for modeling and analyzing individual products.

The research aims at developing a software tool, which enables customers to define their own individual products within a CAD-structure. It will be possible to modify single geometries as well as whole parts or modules. Furthermore attributes like functionality, material or color will be changeable as well. The individual product is visualized at all times in order to give the user an appropriate feedback of their actions. During the configuration process the product should be analyzed, using semi automated software modules. All changes are done within the structure of the CAD-data. Therefore at the end of the interaction process a complete CAD-model will be available. This is absolutely necessary for further steps in the product development cycle. Using this evaluated data it becomes possible to map the product structure to assembly sequences and techniques [7] or even derive process plans for the manufacturing of single parts [6].

2 Other Approaches

In this chapter approaches from two different positions are presented. On the one hand there are commercial and non commercial, user interface equipped configurators (e.g. in the internet), while on the other hand there are approaches for integrating more and more information within CAD-models in order to build up highly flexible product structures. As the software tool presented in this paper is based on such CAD-models, as well as having its own customer interface, application and approaches of both areas are presented.

2.1 Flexible CAD- models

There is a multitude of different approaches for more flexible product structures represented by CAD- models. Many authors deal with the parametrization of the product model using the functionality of state of the art CAD Systems [1,2,12]. By using constraints, formulas and rule bases, interdependencies between different elements of the product are modeled, aiming at reducing costs and time on further developments. Cox [4] is stating these benefits on different examples while Hochgeladen [5] presents another industrial application by developing a parameterized mobile phone cover. Other approaches deal with the exertion of product family or platform architectures [13,14]. They offer a fundamental basis for the design of flexible product models. However these approaches are for educated engineers and designers in order to improve the quality of the CAD- data, instead of offering modification possibilities for technical unskilled customers.

2.2 Existing configurators

Configurators on the world wide web are well known for defining any kind of products. The most popular ones are found in the car industry (e.g. www.daimlerchrysler.com). In these configurators customers are enabled to define their personal cars by choosing different components out of building sets [9]. In those configurators there is no possibility to adopt single parts by changing geometrical elements or defining single measures. Up to a certain level this possibility is given in other areas like in the furniture or the clothing industries. In the clothing industry personal data is derived by doing body scans on customers [3]. With this data tailored shoes, shirts or suits are produced to fit the individual customer. Another approach was developed by the furniture industry. They offer homemade “CAD- systems” to allow the customer the configuration of personalized products via the internet [8]. Most of the time these systems are based on building sets as well. Furthermore they have been specially designed for special products and mainly focus on non mechatronical products. Whereas the main focus in this research project is on a great variety of mechatronical products. Therefore new methods to handle different, highly complex products have to be found.

3 Customer Interaction

The key point of this research is the integration of customers within the product development cycle and therefore within the value adding process [11] (see figure 1). That way, it becomes necessary to either reduce complexity of the development process or to design analyzing tools to deal with customer inexperience. In this project both approaches are followed, whereas the analyzing tools are still very rudimentary and are not dealt with in this paper.

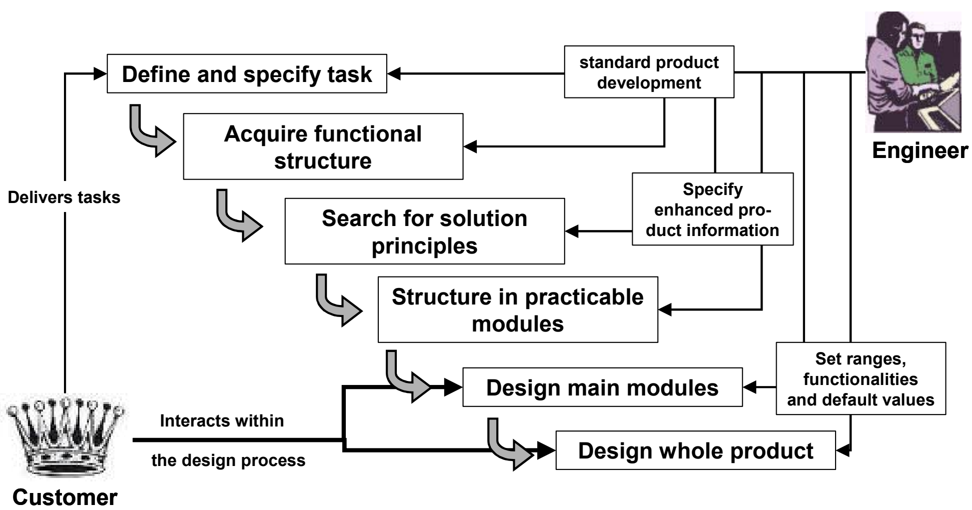

Figure 1: Integration of the customer within the product development process

In order to guarantee an efficient product, a flexible, parametrical CAD-model is used as a reference. This product is developed by a team of engineers, using an adapted version of the standard product development cycle [15].

The first two steps are almost similar to the standard methods. The engineers have to define and specify the needed tasks and acquire a basic functional structure. Using known methods, the handling of a multitude of extra information based on the new requirements for individual products is already necessary at this stage. The next two steps consist of searching solution principles and structuring the product in practicable modules. New methods to pre-plan possible variations and modification of the product structure are used within these steps. Product properties like degrees of freedom (see 3.1) have to be derived and a flexible meta-model of the product model has to be designed [6]. While preparing the product in the last two steps (main module and product designing) ranges, functionalities and default values have to be set in order to ensure redundancy. By setting default values for the modeled degrees of freedom, a totally specified product is guaranteed whether there is any customer input or not.

This is the point where customer interaction starts. By choosing and modifying modules, parts or single measurements the customers are directly involved in the product development cycle. For defining his individual product they use the offered degrees of freedom for personal adjustments. If they likes to modify their product in a way not offered by the given set of variables, their request is forwarded to a team of engineers who decide at what costs and efforts their requirements can be implemented. In iteration steps they will now try to adopt the meta-model in the required way.

For the interaction process, software tools were developed to extract the needed degrees of freedom and offer a user interface. These tools will be described in the following sections.

4 A Software Concept for Defining Individual Products

As stated in the introduction, all modification should be adopted within the CAD-data. Therefore it became necessary to use a software interface for CAD systems. As CATIA V5 from *Dassault Systems* is the CAD System of our CRS, it was decided to use the software interface CAA(Api) for CATIA V5. After implementing first software prototypes to test the power of different functionalities within this software interface several difficulties could be derived. One of the biggest problems was the necessity of designing a new

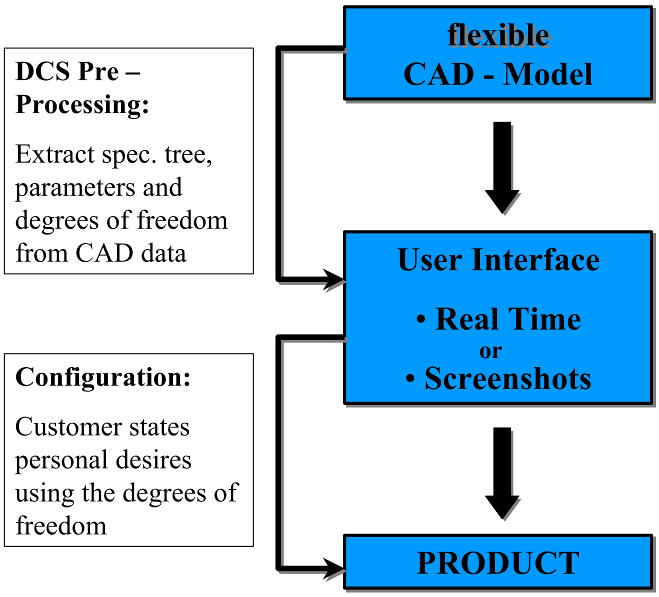

Figure 2: Pre-Processing and Configuration of Individual Products

software for every new product. In order to deal with the amount of rules and restriction respectively increased with the flexibility of products, this leading to an unacceptable increase of costs. Therefore a new approach has been developed. Using parameterized CAD-models as a reference, a software tool generates individual user interfaces for different products by adapting neutral source code (see figure 2).
In this user interface the customer can choose between different degrees of freedom to configure his individual product. Meanwhile product dependent restrictions are supervised by the knowledge ware functionality of the CAD-system in the CAD-model. This becomes possible by integrating all necessary information in the product model of the CAD system (see 2).

4.1 Definition of Product Properties: Degrees of Freedom

The first step of the concept shown in figure 2 is to pre-process the flexible CAD-model to an user interface, which allows the customers to modify their products. This step is supervised by an engineer and scans the CAD-data, to extract the specification tree, parameters and constraints. The gathered information is stored in a MS Access database and can be handled in three different ways:

- as single elements of the database table,
- being structured in a tree view object or
- being directly dealt with in the CAD file.

Using the first option the engineer picks the desired element, specifies it and saves it as a newly created degree of freedom to another database table. During the specification he sets ranges, a default value, a significant name and gives a short description of the newly generated degree of freedom (figure 3-1). All this information is stored as in the newly created database table (figure 3-2).

As more complex parts and products can easily reach several thousand elements, the second option is used to structure the gathered information. Therefore a parser scans all elements, sorts them by modules or parts and stores them in a Visual Basic Tree View object. This objects visualizes the information in a way commonly known by using for example, the MS explorer (see figure 3-3). After choosing one element of the tree, the designer is offered a list of up to 5 related elements to pick and specify.

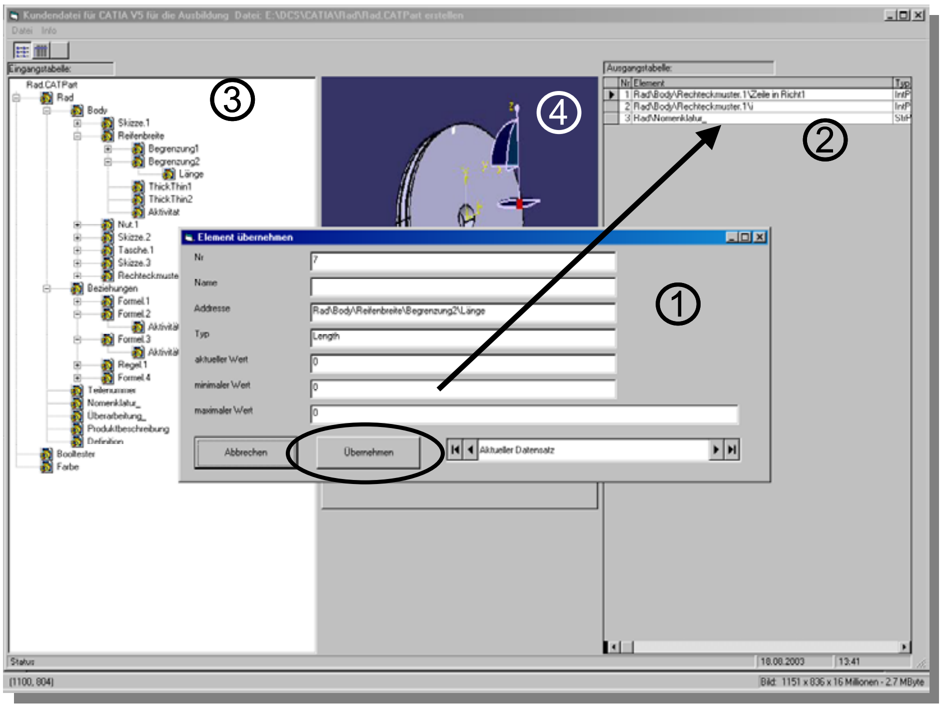

Figure 3: Software tool for setting Degrees of Freedom

The last option is to pick the desired element directly within the CAD-model. After clicking on the related

screenshot (figure 3-4) the software user interface changes to the CATIA user interface. Having direct access to the CAD-product structure, the engineer can either choose by clicking directly on the visualized CAD-element or use the specification tree to determine the specific information. As soon as an element has been chosen, the user interface changes back and the engineer is once again asked to create a degree of freedom by specifying all important information.
As stated earlier the gathered information is stored in a newly created database table. Additionally the name of the related product and a link to the CAD-file is stored as well. This way all necessary information for the creation of the product dependent configurator is saved.

4.2 Configuration Process via Internet using Winsock

To enable customers to define their individual products, the option of using their personal computers is one of the main software requirements. Therefore it became necessary to develop a client-server concept in order to allow customers a definition process via the internet. As an average customer normally doesn't use any CAD-systems, an independent client, communicating with the CAD-application on a central server had to be implemented. As CATIA offers no interface to a network connection (like winsock), a server application was implemented to work as interface between the client and the CAD-system (see figure 4).

To start the configuration process the potential customer needs two things. On the one hand he needs the product depended database file and on the other hand he needs the application to translate the information from the database to an user interface. This way he only has to install the software once and can then download a variety of different reference products as database files. These are the files created by the engineers as shown in section 3.1.

As soon as the user has selected his reference product to adopt, the related CAD-file is opened within the CAD-system on the server and a first screenshot is send to the user interface. Furthermore the database file is scanned for degrees of freedom which are added to a VB combo box of the client. So far three different types are differentiated:

- length, angels
- Booleans
- colors, materials

Now the user selects a single degree of freedom from the combo box and by determining the related type, appropriate buttons are activated by the system. Therefore in the case of a length unit, a scrollbar showing the default value and the possible range is displayed whereas a Boolean results in the activation of two tick boxes. If the customer desires the modification of color the MS Windows standard GUI for the choosing of colors (known from several MS products) is shown.

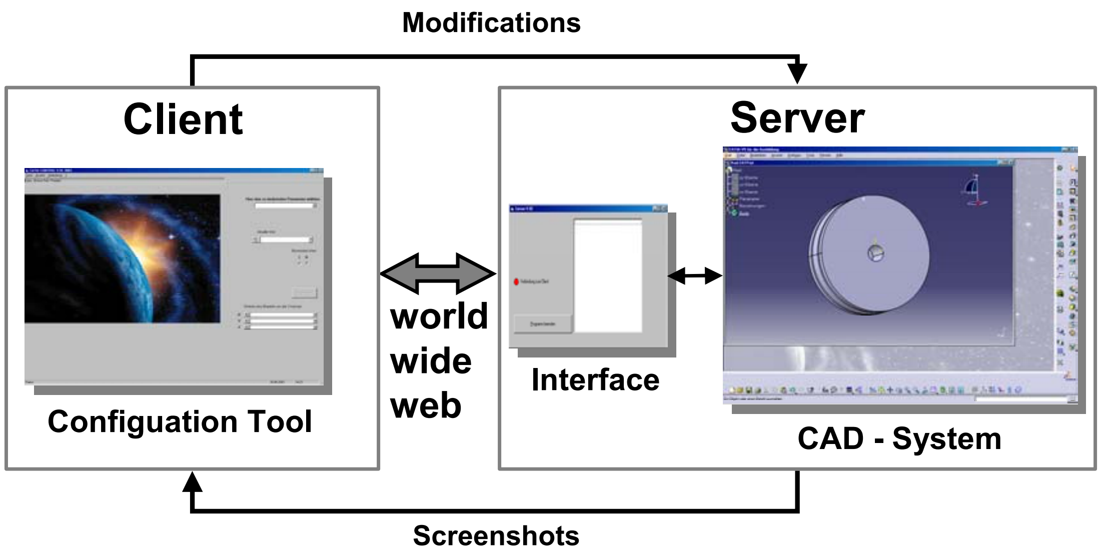

Figure 4: Client – Server Concept

All modifications are sent to the server application which uses the CAD-software interface to translate the information in the CAD-model. During this step, rules based on the CATIA knowledge-ware, analyze the input in terms of implemented restrictions to guarantee a robust product. If the modification is accepted, the server application will take a screenshot of the new model and send it via the internet connection to the client, where it is presented to the user. This way the customer can create his own personal product step by step. Additionally the modified degree of freedom is stored in a user dependent database. Using this newly created database it is possible to rebuild the personal product from the reference product at any time.

Once the configuration process is complete all databases are closed and the newly created CAD-file is saved in a user dependent directory on the server. Using this file, the information can be mapped to a process plan in order to produce the individual product in one or more of the mini-factories.

5 Conclusion and Future Work

This paper presents a new concept to integrate the customer in the value adding process in order to design mass customization products. Existing software tools proved to be too simple as well as too specialized on single products as shown in section 2.2. By adopting standard product development cycles additional information is stored within CAD-models. Using these CAD-models as a reference, engineers are, supported by a newly developed software tool, enabled to define certain degrees of freedom containing information about ranges, default values and dependencies. This information is stored in a database file and forwarded to the customers. By using these files and a product independent client application the customers are enabled to modify their products via the internet. Their input is analyzed by the CATIA knowledge ware and their progress is visualized with the use of screenshots. CAD-data is retrieved at the end of the configuration progress, which builds the basis for process planning and automated production within the mini-factories.

In the future it should be possible to define interdependencies between single elements with the same tool that is used to define the set of degrees of freedom. This way the engineers don’t have to know every single functionality of the CAD-system, but are efficiently guided through the dependencies definition process by a software tool. Furthermore the visualization of the configuration process is rather rudimentary using two dimensional screenshots. Concepts are being developed to use the vrml-fileformat and special plug-ins for internet browsers to achieve a three dimensional visualization.

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