AN ASSEMBLY TOOL TO SUPPORT THE DESIGN OF COMPLEX PRODUCTS

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1 Abstract

The traditional process during embodiment design is mainly based on 2D-assembly drawings and text documents. The contents for these documents depend on the individual knowledge of the employees in the design and assembly department. Many iterative steps are needed between the designer and the assembler in order to generate the necessary detailed assembly documents. This process depends on the individual experience of the employees and cannot guarantee consistent data management.

Even with the use of 3D-CAD Systems in the mechanical industry, this situation has not changed yet. However, by the efficient reuse of 3D models and the use of current IT (Information Technology) products, the assembly process of complex machines can be significantly improved. This paper presents an approach how to use standard VR (Virtual Reality) technologies [1], [3], [5], [7] with 3D-CAD models to support the assembly process.

In an early stage of design, assembly tests [10] can be made to show both, possible design errors as well as complex and very expensive assembly sequences. The ideas of the designers can be easily visualized by the assembler using VR-technology. The communication between the design and assembly department are improved and lead to a continuous exchange of knowledge and experience [9]. Moreover the assembly sequences can later be used in other departments as sales, maintenance or training.

All data are stored in a Product Data Management (PDM) system which ensures correct and updated information management. The use of standard VR technology, for example VRML (Virtual Reality Modelling Language), enables a cost-efficient software solution in comparison to other IT products.

2 Introduction

The traditional assembly process in the mechanical industry is based on 2D – assembly drawings and text documents. Figure 1 shows a general form of the usual process of creating assembly instructions. The process can be divided into several iterations. The demonstrated task allocation for design and production planning can vary in the different companies.

The development of the necessary assembly documents starts with the design that defines the geometrical form, structure and functionality of the product. In a series of iterations the specific knowledge of the assembler is added to the assembly documents during prototype
and pre-production series assembly. Only during the last iteration - the series production – are documents for assembly completed.

![Diagram of assembly process](image)

Figure 1. General form of the usual process of creating assembly instructions

The analysis of the assembly process demonstrates that the generation of the assembly instructions is an iterative process that takes place at a late stage of product design. In addition, information concerning the assembly process is defined twice. First of all information is defined by the designer who also has to keep in mind assembly aspects, and by the assembler himself. In order to reduce this ineffective double work, the knowledge and experience between assembler and designer have to be transferred constantly in both directions.

3 The virtual assembly

The use of 3D models and user friendly software can basically help to solve the communication problems between the design and the assembly department. Our proposed concept with the integration of VR-techniques is presented in Figure 2 and described below.
Figure 2: VR-supported assembly process

3.1 Communication platform for assembly & design

The objective of the new concept is to create a communication platform between the design and assembly departments. The core element is built by a PDM system, that can support and manage the assembly drawings and part lists. All drawings and part lists can be generated by the design department and directly be transferred to the assembly department. Furthermore, the process of assembly is replaced by 3D assembly animation. The designer has to transfer the assembly models of the CAD into animation software. The software enables him to animate the CAD-models with several features including assembly or disassembly of the model. Moreover, the animation sequences can be transferred to the assembly department and vice versa using the PDM functionality.

3.2 The virtual assembly process

The generation of the assembly instructions is based on the data of Digital Product. The Digital Product [12] is defined by all information that represents the product and occur during the product life cycle. Within early stage of design this information is typically 3D CAD data, sheets and text documents that describe the characteristics of the product as well as the assembly instructions itself.

The assembly instructions that are forwarded from the designer to the assembler are based on digital data only. This means that no parts have been ordered nor produced when the assembler checks and revises them. Errors in construction that appear at this stage can easily be reduced at low cost.

In addition to the graphic assembly sequences the assembler typically adds written instructions which now can be recorded digitally and related to the appropriate assembly step.
The complete assembly instructions including comments and changes is re-integrated into the design department that corrects it accordingly. This process is repeated for each part group until all assembly instructions are completed.

Virtual assembly-based instructions can help the designer and the assembly planner team define the different working steps and recognise problems like insufficient assembly space, but there will still remain new problems arising the real assembly process. For this reason, feedback from assembly to design remains necessary during series production in order to make further corrections and improvements.

3.3 Reuse of assembly animations

Our last aspect within the presented concept aims at reuse of the assembly animations.

Single assembly steps are stored separately and are related to the geometry objects by the PDM system. This allows for quick modifications of the single assembly steps to create other applications such as service instructions. The assembly sequences can, for example, be shown in the opposite direction and thus become disassembly instructions. For company sections such as sales, marketing, service or internal training these animations can easily be used to create product visualisation.

In addition, new developments of the future can also profit from this new concept. As the animation sequences can be divided into sub-sequences they can be formed themselves according to a new part group configuration [1] and be reused again. Only the order of the different animation objects has been changed.

4 Technology and software architecture

In this chapter a software tool that was developed at the centre of product design of the ETH of Zurich is presented.

The requirements for such a tool are as follows:

- easy integration into the value chain
- simple and fast embedding into the software environment of a company
- task-orientated and user-friendly implementation of the interaction.

In order to fulfill these requirements the standard visualisation format VRML (ISO/IEC 14772-1) [8] was used. The geometrical data of CAD systems can easily be generated by an interface and imported into the software tool. Furthermore, it is possible to achieve acceptable frame-rates at middle class object complexity with a standard PC.

The software tool presented here is based on the VRML program interface EAI (External Authoring Interface) which consists of a library of Java classes that enable the modification of VRML objects during run-time. The communication between EAI and VRML is realised as an interprocess communication between the java applet and the VRML-plug-in of an Internet browser. Therefore, interaction is possible by mouse just as in a CAD program. The latter enables navigation around the object as well as being able to select the chosen objects within
the same application window. The detailed information for animation of objects can either be stored in a separate file or saved together with the geometry in a new VRML file.

Figure 3 shows the complete architecture and data management concept of the software. As explained in the description of the concept two different types of users have to be taken into consideration.

On the one hand there is the designer who develops the assembly instructions and on the other hand there is the user, e.g. the assembler, a trainee, a maintainer. The user observes the assembly sequences and acts accordingly. The assembling tool also consists of two different applications: one builder application for the designer and one viewer application for the end-user.

All necessary data of the builder and viewer applications are consistently stored and managed in the PDM system. The builder application adds animation data, textual notes and explanations to the geometric data. The geometric data can again be called and visualised by the viewer application.

![Figure 3: Complete architecture and data management concept](image)

4.1 CAD Interface

Nowadays, most modern CAD Systems are available with a VRML 2.0 interface. Focussing on details, however, these interfaces show different quality standards in their output format. The formats mainly differ in the conversion of CAD part structure into a VRML object hierarchy. Further differences can be found in the identification of objects. Some converters retain the CAD numbering system while others change them for example to consecutive numbers [12].

Generally speaking the CAD part hierarchy normally does not fit the assembly structure. This fact leads to the necessity of restructuring the VRML hierarchy. Therefore it is important to easily identify the different part groups by names and stage within the structure.
4.2 Builder application

The builder application serves to create assembly sequences through animation and text information. Since most design departments use a different product view than the assembly department, it is necessary for the tool to offer facilities in order to group, rename and restructure the object hierarchy. The objects can either be transferred from the CAD as single parts or assemblies.

The first step consists of the generation of assembly relevant part groups (figure 4) that can be handled together. Since in the CAD system the part groups are mostly represented in assembled condition, they first have to be disassembled with the tool. One assumes that assembly and disassembly sequences show the same contents although in different directions. The movement of disassembly originates from the animation of the assembly instructions in opposite direction.

If additional, non-CAD related objects (e.g. supplier parts) are needed, they can be imported and with the existing part group structure using a mating function.

The creation of animations is based on the definition of a start and end position of the part group or single parts as well as the type of motion (translation, rotation or a combination of both). Every single step can be defined and saved.

Each assembly process can be accompanied by text information and description. This can be displayed by an individual HTML frame other than the plug-ins. The text contains information that can rarely be visualised in geometric forms as for example, used specific hand tools or various details like torque for screw fixing.
4.3 Viewer application

In the viewer application the informational text and the different animation sequences are shown in a two-part browser at the same time. The user can hereby choose between a step-wise or a continuous run. Critical comments or notes can be added at any time within the appropriate text window. This information is retransferred to the design department in order to improve the assembly. This leads to further improved communications between design and assembly department.

5 Conclusions

The customer imposed reduction for product development time and the increasing requirements on product quality are enforcing companies to restructure their whole product development process and also the assembly process.

The concept presented above (including the software tool) shows that current CAD technology and standard visualisation formats can establish and improve communications between design and assembly. This results in shorter development and realisation working time. Furthermore, the resulting assembling sequences can be used for sales purposes, training and service.

The software tool has been verified by several companies in different departments. Satisfying results have shown the possibility for further development of the software tool for commercial use.

References


[10] Deneb Robotics; USA: factory simulation, telerobotics, software; http://www.deneb.com
