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Process Integrated Creation of Product Instructions

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Abstract

Product instructions are becoming more and more important within the different business processes (starting with the innovation process and ending with the service process) in order to attain high quality and efficiency of the work performed by a company. The possibility to integrate mechanical, electrical and software aspects into a 3 dimensional, interactive product instruction is crucial for the shortening of throughput times and costs together with an improvement of product quality. The scope of this paper is to demonstrate a technical approach which allows on the one hand to use product data directly from the innovation process. On the other hand the integration of mechanical, electrical and software aspects into one 3 dimensional interactive product instruction is realized.

Keywords: 3D CAD Model, PDM/PLM, Digital Product, product instruction, animation, Virtual Machine, simulation, machine control

1 Objectives

Technical documentations, instructions and presentations are gaining more and more importance. Especially for products consisting of mechanical, electrical and software components (control systems) instructions integrating the various aspects of the mentioned domains are required.
Traditional technical instructions are based on paper consisting of drawings (partial in 3D) and textual explanations. By this kind of instructions it is not possible to simulate and to discuss a planned machine concept within the development process or to explain a machine concept to a customer.
Objective of this paper is to demonstrate a new technology for creating and using 3D interactive instruction manuals. 3D CAD models are used to create virtual models that can be linked with machine control and simulation systems.

2 Requirements and Needs

For the different processes in a company the requirements regarding technical instructions or presentations are different. In the following the most relevant aspects will be discussed:
Within the **innovation process**, especially in the development process, it is important to bring the different design disciplines: mechanical, electrical and software engineering, together. For an over all optimization of a product, an instruction and discussion plattform is needed which reflects the various aspects out of the mentioned disciplines in an easy and intuitive way. Especially the following aspects have to be covered:

- simulation and illustration of the planned machine set up in order to optimize the over all system

- simulation of the general machine concept in order to optimize the coordination of mechanics and machine control

In the **secondary development process** products are adapted to the customer's specific requirements. Modifications are conducted in order to improve the product (or to eliminate problem areas).
Like in the development process the mentioned design domains have to be linked very closely by appropriate instruction technologies. The following aspects are important:

- conceptual evaluation of possible solutions for customer specific adaptations
- simulation of the customer specific needs
- optimization of the machine concept

In the **sales- and quotation process** it is very important to communicate the functional principles and possiblities to adapt an offered product to the customer's needs. Only when the customer and the sales person understand the possible functionality and extensions of the product the loops within the sales & quotation process and the following engineering effort can be reduced. The necessary aspects are:

- functional presentation of the machine concept
- configuration of the mechanics and control system
- verfication of a selected configuration

Within the **purchase- logistic- and manufacturing process** possiblities for an easy identification of used parts by the logistic staff help to shorten the throughput times and to improve quality. Simple illustrations of the product functionality are needed to improve the product quality. This goal can be achieved by 3dimensional, interactive assembly instructions.

3 State of the Art – Future Requirements

The current situation is characterized by

- high function standing CAx-tools, which provide possiblities to model the mechanical (by mechanical CAD-Systems) and electrical behavior (by electrical CAD-Systems) of a product
- simulation tools by which the control system of a product can be simulated
- product life cycle management systems (PLM-Systems) , which allow the management of all product data over the complete life cycle
- Web based training tools for the communication of product know how to various target audiences

However there are a lot of isolated solutions for the different problems available. At the moment there are no technologies or methods available to integrate these isolated applications and to use these integrated product data within the various business processes.

To clarify this there are some examples in the following mentioned:

- By the kinematic packages of modern 3D CAD systems it is possible to define kinematic models and to simulate the system behaviour by bringing in force, acceleration and speed. However this input is completely independent from the input by the several actuators controlled by the controlling system.

- More and more companies are working with 3D-CAD systems. And yet instructions for assembly, installation and service consist mostly of 2 dimensional descriptions of 3D CAD explosion drawings and textual explanations for each step. Within hyper medial documents it is now possible to integrate 3D CAD viewing tools and digital videos.
  Nevertheless the creation of this kind of instructions is very expensive. Furthermore the continuous update within the change process of the product is not directly possible and much more expensive.

The objective is to offer an instruction platform, that on the one hand makes it possible to unite the different engineering disciplines (essentially the integration of mechanics and control). On the other hand the product data produced in the innovation process should be able to be used directly. In the center of interest stands the structured data production in the innovation process and their use in the downstreamed enterprise processes. On this basis the user-specific preparation, updating and medium-didactical intermediation of product knowledge in the Product Life Cycle takes place. Therefore the advantages of modern information and visualization technologies should be used for product instructions.

4 Basic Principles

4.1 Digital Product

At the Swiss Federal Institute of Technology in Zürich (ETH-Zürich) the concept of the so called „Digital Product“ [6] was developed in the last couple of years (figure 1).
The concept of the digital product targets on a consistent, well structured product- data- and information structure. All product data describing a physical product as close to reality is saved in a dedicated database. The product data is generated within in the development process. In the following business processes the product data will be supplemented, modified and be trimmed. Accordingly the generation and the structure of this product data takes place with the goal of an optimum support of the various business processes.
Thus profit from these structured data business processes can be realized in sales- and quotation, purchase and logistic, manufacturing, assembly or service.

The goals of the concept of the digital product can be summerized as follows:

- Support of the innovation process, especially the design process:
  Goal is a market driven product structure and modularisation. Modern CAx- and visualisation tools provide the possibility of an early product verification and optimization. These developing product data are stored in a manner that they can be used by the following business processes. A various number of coordinated methods like the configuration matrix [7], the information and process matrix [8] helps to achieve this goal.

- Usage of the modularisation and product data in the following business processes:
  Thus enterprise processes gain profit as for example in manufacturing, assembly, sales, customer, logistics, service from these data, because they can access the information of the digital product at any time and pull efficiently their use from it.

- Optimization of the secondary development:
  New needs, weak points, experiences of the product obtained by the several business processes flow back into the development process. By the integration of product data as well as the business processes into a closed information flow, a product can be

improved permanently and the updated product data can be used within the business processes.

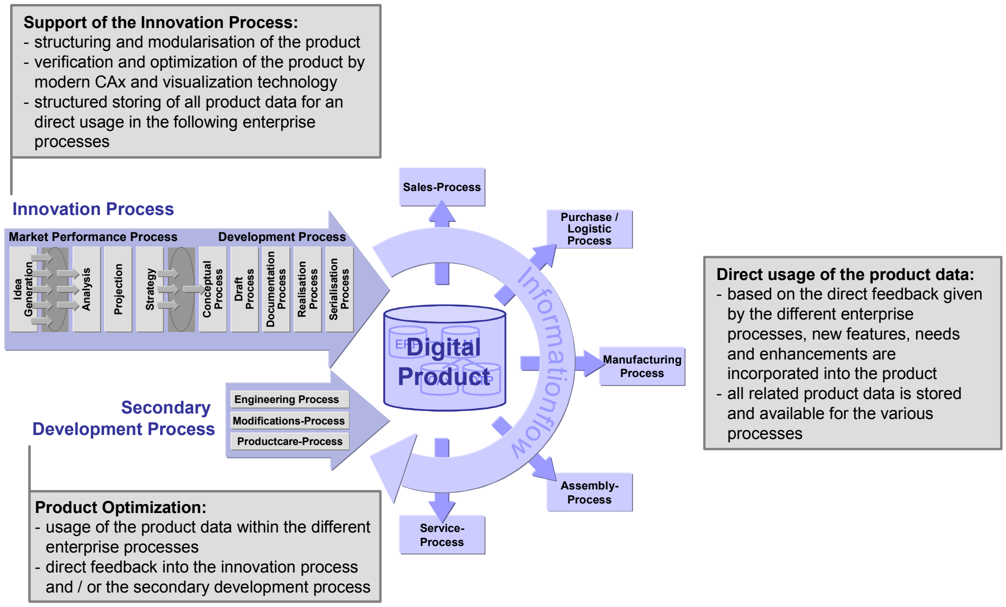

Figure 1. Concept of the Digital Product

4.2 Digital Product – Concept for Product Instruction

Based on the concept of the digital product the concept for product instruction is defined. The goal is to reuse all product data, especially 3D CAD data for setting up product instructions. Changes in the product, performed within the secondary development process can directly be adapted in the generated product instructions.

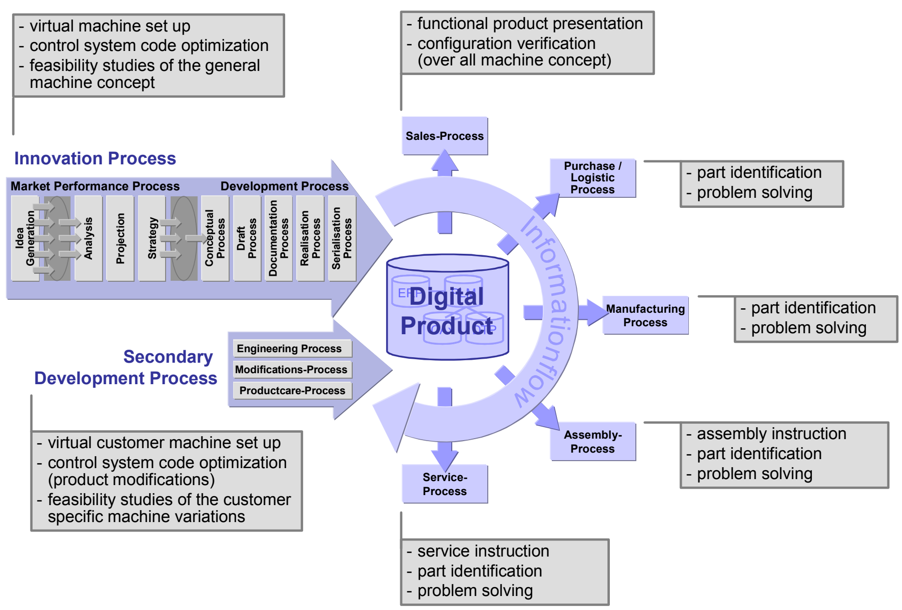

Figure 2. Benefits of a product instruction based on the Digital Product

5 Technical Realization

The technical realization of the described concept requires a software tool that offers most diverse product information (e.g. geometry, text, pictures, movements..) for the appropriate user groups or enterprise departments. The largest information content of a technical product is obtained by means of geometry and functionality [3]. Accordingly the software tool has to possess the ability to represent the geometry of a product as well as functionality or characteristics necessary for the enterprise process. The spin off enterprise Intelliact AG of the ETH Zurich developed the software products Mediator and Instructor, which make the necessary product information available for the different enterprise processes on the basis of a single virtual model.

5.1 Virtual Model

The software concept of the Mediator and Instructor software is based on a single virtual model, which can be supplemented with different other information and tools. In figure 3 the linkage of the different software modules as well as the data flow are shown.

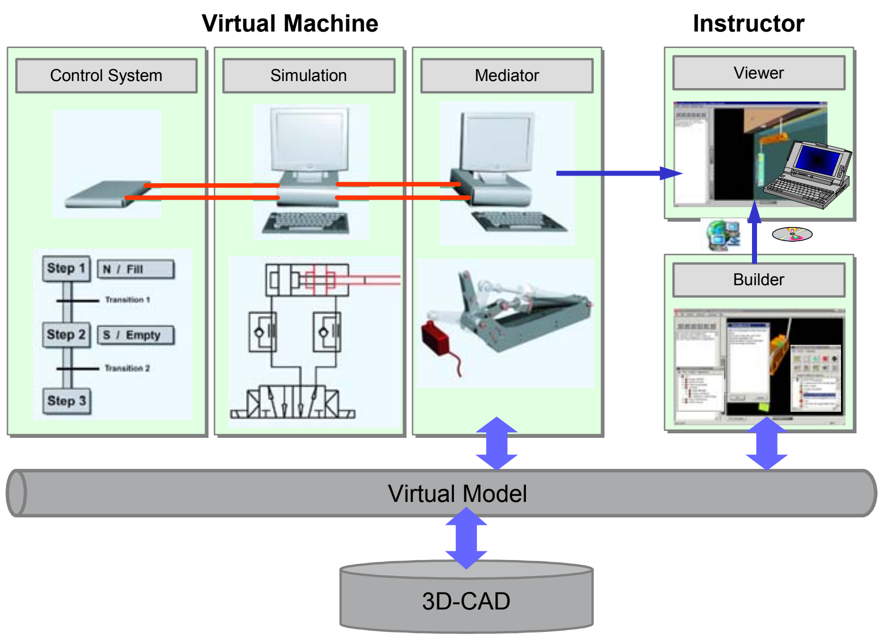

Figure 3. Concept of the process integrated product instruction on the basis of a virtual model

The 3D CAD model represents the database of the geometrical product information. The technical designer converts the CAD data into a virtual model, which consists of a static, surface-based 3D model [3][4]. In a second step this model can be provided with further information for a defined process. For the first start-up of a machine including the control the Intelliact AG offers the structure of a virtual machine [1]. In this case the virtual model is supplemented with the movements of the mechanical actuators and sensors. A further application scenario is the use of the virtual model for the representation of assembly and service procedures. In this case the model is loaded into the Instructor software and supplemented by the necessary assembly or service animations. The virtual model has now a defined interface to a simulation and contains animation sequences for the assembly or service process. In a further step the virtual model can be used also for training courses. The training course scenarios can be realized with the help of the virtual machine running a CNC programm for example. The operational sequences and movements of the objects are parallelly recorded and converted afterwards by using the Instructor software into defined animations and provided with additional textual information.

5.2 Virtual Machine

A product instruction with the help of the virtual machine aims at the technical ranges of an enterprise. Hereby the virtual machine is a digital counterpart to a real machine, focused on the interaction of control and machine, thus control logic and sensors/actuators are the center of attention.

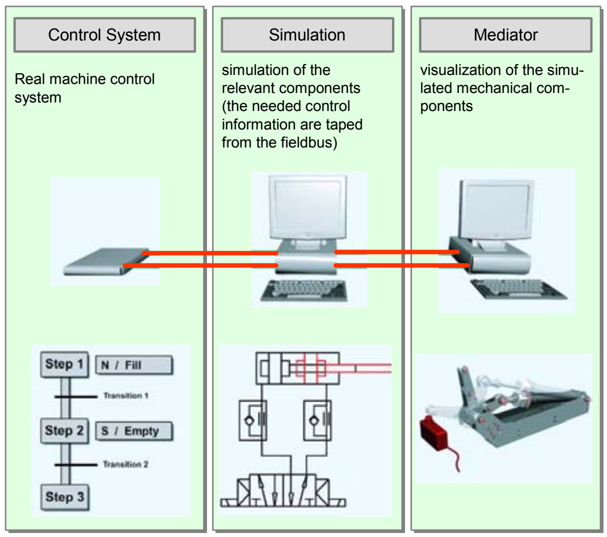

Figure 4. Concept of the virtual machine

As shown in figure 4, the virtual machine consists of the three parts: control, simulation and visualization. The machine control is connected to the simulation PC via a TCP/IP or a field bus connection [1]. After the start of the control the different actuator signals are released according to the programmed control logic. The signal simulation receives these signals and passes them on to the appropriate simulation models. The mainly digital control signals (e.g. for a pneumatic cylinder) release the computation of further signals in the simulation model. In the case of a pneumatic cylinder for example, the stroke of the cylinder is computed. Depending on the position of the cylinder sensors (e.g. limit switches) can be linked, which then release signals. These sensor signals are recommunicated to the control, which releases the appropriate control procedures. Parallel to this movement information e.g. the cylinder stroke are passed to the Mediator software. The visualization software reads the signals continuously and demonstrates the corresponding object conditions [2]. Due to the movement of an actuator further sensors can be released by means of collision control. Those signals are recommunicated to the control, too.

5.3 Instruction

The Instructor software makes it possible to create product instructions on the basis of 3d models and additional textual informations. In figure 5 the work behavior and data flow are represented.

As show in figure 5 out of the CAD-System the three dimensional model is imported into a so called “instructor builder”. In this builder the different parts of the model are animated and combined with textual explanations. All textual information can be exported into a xml file, which can be sent to translation offices. With the import of the translated text, each discribtion is placed to the sequence it belongs to.

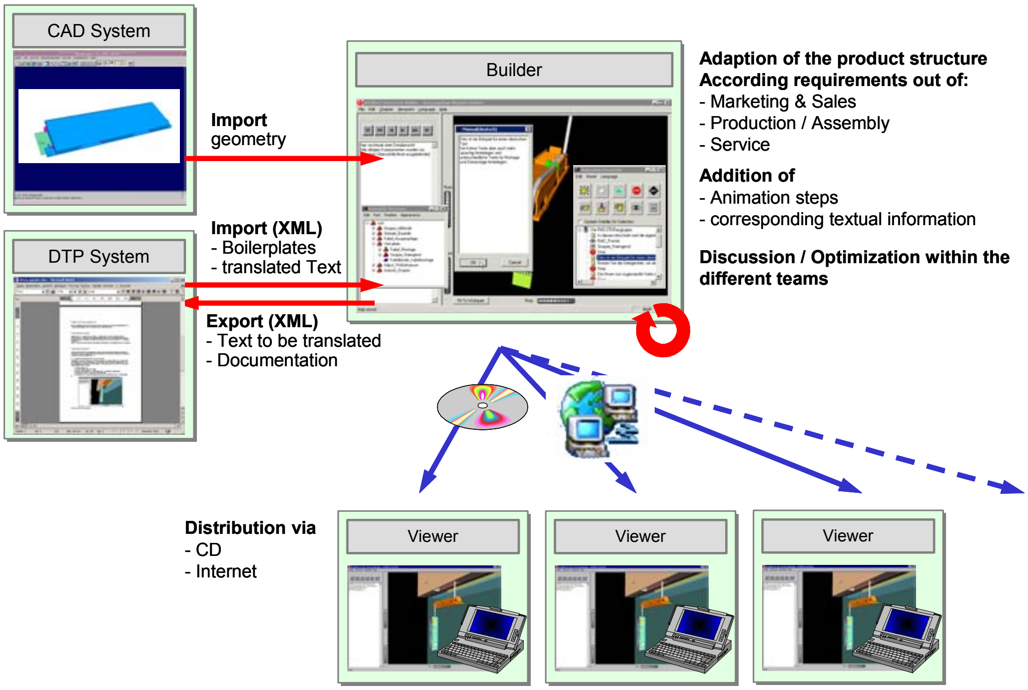

Figure 5. Creating product instructions with the Instructor Tool

This instruction generated out of CAD data and text information can be published into a special 3D viewer - the "instructor viewer", which can be distributed by compact disc or the Internet. The viewer is very simple to use. Like a tape recorder the user can “play” the instruction manual by stepping through the defined sequences. The user has the possibility to interact with the instruction by flying through the assembly within the viewer or by the definition of the animation sequences [5].
To demonstrate the use of the two software tools Mediator and Instructor some applications are shown in the following.

6 Product Instruction - Applications

The described concept of a process integrated creation of product instructions was verified by a number of Swiss companies. In the following chapters industrial applications show the capabilities and daily life usage of the Mediator and Instructor software.

7 Development Process

During the development process the technical realization of the product is the center of attention. On mechatronic products (combination of mechanics, electrical connection, computer science) the question is to be clarified whether all components work with one another in the intended way. A possibility for the early answer of this question exists in the conversion of a virtual machine.
Figure 6 represents the example of a unit from a textile machine of the company RIETER Textile AG, which was converted into a virtual machine. In this case the geometry was

exported from the 3D CAD system Unigraphics (as vrml) and loaded into the Mediator software. Subsequently, the model structure was modified, so that the individual construction units can be moved as independent mechanical parts. The Mediator software offers the computation of kinematic loops as an additional feature.

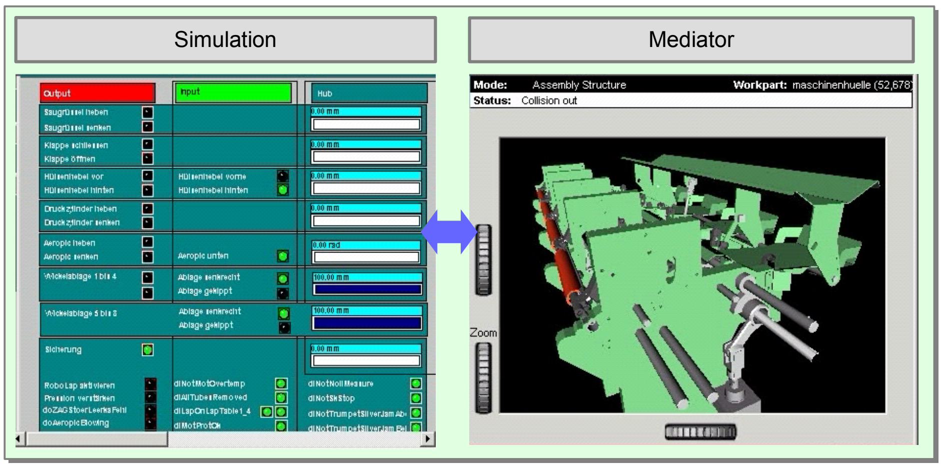

Figure 6. The Virtual Machine realized for a textile machine

For the representation of the movements of the different construction units only the actual actuator input (e.g. cylinder stroke) is necessary.Furthermore the signal simulation was added and all signals connected with the control and visualization. In the right part of figure 6 signal statuses of the actuators (outputs) and the sensors (inputs) as well as the positions of the pneumatic cylinders are represented. With the realization of the virtual model the control code could be checked and procedure errors in the program code discovered and corrected quickly.

7.1 Sales & Quotation Process

In sales and marketing the substantial characteristics of the product must be communicated to the customer. On complex and modern mechatronic products this is very difficulty to realize with static pictures or videos.

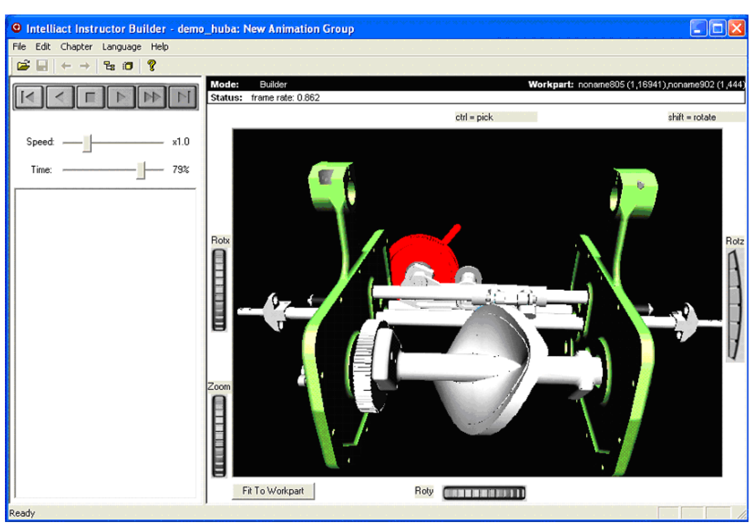

Figure 7. Sales animation of a gear

Figure 7 shows an application of the company RIETER Textile AG. The represented gear is available as an additional option for a spinning machine which means additional costs for the customer. In order to clarify the increase in value of this gear to the customer, an animation of the functional behavior in the Instructor software was created.
The influence of the red marked construction unit on the movement behavior of the gear is importent in this case and can be represented by the animation simply and intuitively. The simple interaction with the tool enables even the customer to face the problem on a professional basis and offers him the necessary decision basis for a possible purchase.

7.2 Assembling & Service

The assembling and service process is based on technical information. Today these data are conveyed in the form of 2D assembly drawings. For the interpretation of these drawings special training is necessary and often misunderstandings or questions are generated due to ambiguous or missing data.

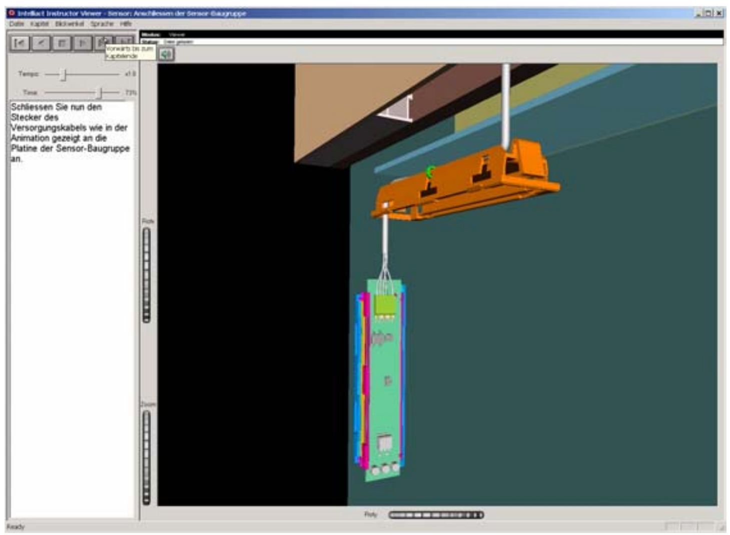

Figure 8. Assembly animation of a door system

In figure 8 the assembly animation of a doorsystem is represented in the Instructor software. The individual assembly steps can be reconstructed simply and intuitive on the basis of the animation and additional textual informations in the left window. Since the handling of the parts can be observed in the 3D model, misunderstandings concerning the identification and usage of the parts are excluded.
Through a pilot project with a manufacturer of automatic door systems, the potential of an integrated instruction production was verified. The realization showed that the expenditure of time for the production of the assembly instruction could be reduced of over approx. 50 %. During the production of the assembly instruction two problems were identified and had to be solved by the design department (one of the problems was a not accessible screw). These problems would probably not have been noticed within a 2D-assembly instruction.

8 Conclusions

The applications demonstrate that the realization of a digital product concerning product instructions is efficiently possible on the basis of the software tools Instructor and Mediator. With the help of a Virtual Machine any control problems e.g. the setting-up of the machine

for a new working part or the optimization of the control software can be accomplished promptly and without any risk.
Additionally with the Instructor tool intuitive and meaningful product instructions can be produced at minimum effort on the basis of digital data. The employment of the software is possible starting with the internal use in the construction over sales models up to complete assembly and service guidances. Several savings can be obtained, like the reduction of translation costs, production costs for the training courses and constructional errors being discovered and solved promptly.
By these new concept and tools companys can achieve great benefits for their over all business processes.

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