A Method for Rapid Virtual Assembly Generation from Physical Devices

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Abstract. The creation of virtual assembly models for these devices would be a valuable supplement for the purpose of education. To reduce the time and human resources in the creation of virtual assembly models, this paper presents a rapid virtual assembly generation method based on physical devices, which employs a 3D scanner for raw 3D data acquisition, GEOMAGIC DESIGN X, ANARK CORE WORKSTATION and VIZARD as software tools for the creation of virtual assembly interaction. The experimental results show that this method can rapidly visualize physical devices, shorten development cycle and reduce development time and cost.

1. Introduction

Virtual assembly is one of the important directions of virtual manufacturing technology research which aims at improving the quality of products and related process design in the whole life cycle from the perspective of product assembly. It comprehensively utilizes computer-aided design technology, virtual reality, computer modeling and simulation technology, information technology etc., to create a virtual reality interaction environment with a strong sense of reality. Users can interactively carry out product design, assembly operations and planning, inspection and evaluation of product assembly performance in a virtual environment and thereby develop a reasonable assembly plan.

Many studies have suggested that employing virtual technologies in education increases students’ learning performance. The immersive environment has brought students protagonist experience hence to improve their academic performance and motivation [1-3], collaborative and social skills [4], cognitive and psychomotor skills [5]. In the meantime, expensive devices are usually only available in limited number in universities and are not freely accessible to students. The availability of virtual models visualizes the structure of these devices and facilitates the delivery of knowledge.

Despite the above advantages, the creation of a virtual assembly model is a complicated and time-consuming process. It may be a comprehensive application of virtual reality technology, computer technology, reverse engineering, 3D reconstruction and product design etc. Among them, the key determining technologies are assembly modeling technology, operational positioning technology based on geometric constraints, and interactive assembly process planning and evaluation technology.

Assembly modeling is the foundation and the major information source for virtual assembly. Unlike ordinary 3D modeling in CAD environments, assembly modeling needs to enclose additional information for assembly purpose such as geometric constraint and event control information.
Banejnee et al. [6] from the University of Illinois in Chicago, USA, proposed a scene-based assembly information modeling method for virtual assembly, which encapsulates the priority constraint of each component and event control in the component node of the scene graph. The virtual assembly system inspects the constraint status of the related component node during the process of interactive assembly sequence planning to avoid prohibited operations. Liu Zhenyu et al. [7] from Zhejiang University proposed a hierarchical information model for virtual assembly environments, which stores the part design information from CAD systems in a medium file so that it can be read and retrieved by virtual assembly systems. The part information is divided into a part layer, a feature layer, a geometric layer, and a display layer, and the hierarchical relationship of the part information is organized via data mapping and constraint mapping. Wang et al. [8] from Nanyang Technological University organized geometric object models using BSP-Tree in their virtual system for industrial application. The triangular meshes comprising geometric models are effectively segmented, organized and then represented and stored in vml files.

Operational positioning technology based on geometric constraints defines the operational and positioning constraints in virtual assembly via geometric relationships. S. Jayaram et al. [9] from Washington State University first proposed the idea of constrained positioning, which addresses the issue of components precise positioning in virtual assembly through the constrained motion of components and the solution of constraints. They also studied the issues of geometric constraint recognition, confirmation and contact during their development of the VADE system. Richard et al. [10] of Heiriot-Watt University in the United Kingdom proposed an approximate capture and collision capture method to tackle the precise positioning issue in a virtual assembly environment.

Interactive assembly process planning and evaluation technology provides a feasible planning and verification method for device virtual assembly. Wan Huagen et al. [11] from the CAD/CG state key laboratory of Zhejiang University proposed a user-guiding disassembly method in the virtual reality CAD system. Based on the principle that the procedure of assembly is the reverse procedure of disassembly, Z.P.Yin et al. [12] from Shanghai Jiaotong University developed the assembly sequence planning and evaluation system which generates all the possible assembly sequences via geometric reasoning based on the initial assembly sequence and priority constraints.

Despite the research progress and achievements in virtual assembly, the complex expression of assembly models and the poor compatibility between CAD systems and virtual assembly systems remain as two challenges which hinder the rapid development of a virtual assembly system. In order to address the above problems, this research proposes an innovative method which utilizes a modern 3D scanner, the ANARK CORE WORKSTATION and the VIZARD virtual reality software to realize rapid development of a virtual assembly model from physical devices. The main contribution of this research is that the proposed method greatly simplifies the development of virtual assembly from physical devices by evading the definition of complex geometric constraints and dividing the procedure into three steps: 1) 3D data acquisition, 2) assembling definition, and 3) generation of virtual assembly.

The rest part of this paper is organized as follows: second part details the proposed method; the third part discusses the advantages and disadvantages of the proposed method; the last part concludes the paper.

2. Another section of your paper

Generally, the generation of virtual assembly from physical devices can be achieved in 3 steps. The first step is to acquire the 3D point cloud from the physical device and then convert the point cloud data into CAD format file. This step can be realized via a 3D scanner and a 3D format converting tool such as GEOMAGIC DESIGN X which is capable of processing 3D point cloud data into the STL format file and CAD format files. The second step is to give assembling definition for each detachable part of the CAD model of the physical device. The 3D data transformation software ANARK CORE WORKSTATION was used in this study to do the above work. The third step is to create the virtual assembly interaction. The VIZARD virtual reality software was used in this study to realize the
interactivity. This study employed a self-made 3D scanner, GEOMAGIC DESIGN X 2017, Anark core workstation, and VIZARD to realize the virtual assembly modeling and interaction based on physical devices.

Figure 1. The workflow of the proposed method.

2.1. 3D Data acquisition

3D Data acquisition is the process to digitize the spatial coordinates forming the contour of the physical object. The 3D scanner used in this study is a self-made device with one LG HW300TC projector and two CRASHCAMTM CC-4010 high speed cameras. It is based on the working principle of active stereo matching which projects fringes comprised of grad codes to an object to acquire the stereo pictures, and then the triangulation is used to calculate the 3D coordinate of each homologous point from the stereo pictures. The working principle of the 3D scanner is depicted as below:

Figure 2. The working principle of the self-made 3D scanner.

In this study, the above 3D scanner was used to acquire the raw 3D data, i.e. point cloud, of the components of a turbo engine. Each part of the turbo engine was scanned to acquire the point cloud as the source data to be converted into CAD format.

Figure 3. The 3D point cloud of the cover of the turbo engine.

2.2. Format conversion

The 3D point cloud files cannot directly be processed by most CAD software. Therefore, the 3D point clouds need to be converted into STL format first to generate 3D models consisting of 3D meshes. Then these STL format files need to be further converted into CAD format files with the help of some manual edit. In this study GEOMAGIC DESIGN X 2017 was chosen to complete the above two steps due to its excellent performance in dealing with reverse engineering from 3D scanned data.
GEOMAGIC DESIGN X, launched by the 3D systems company, is the software which provides a complete Scan-to-CAD solution for a variety of reverse engineering applications. It also provides good compatibility with the popular CAD software SOLIDWORKS.

![Image of GEOMAGIC DESIGN X](image1)

**Figure 4.** The IGS format CAD file acquired via GEOMAGIC DESIGN X 2017.

2.3. **Defining detachable parts**

Once each part of the device has been converted into CAD format files, the definition for each detachable part can be done via ANARK CORE WORKSTATION. It is the software capable of creating lightweight 3D Technical Data Packages from native SOLIDWORKS Parts and Assemblies. ANARK CORE WORKSTATION allows the setting of attributes for each part in the assembly so that these metadata can be later interpreted in the virtual reality software VIZARD.

For a component to be considered detachable and moveable, it must be attached with some of the tags marking these applicable actions. These tags must be interpretable in VIZARD and they can be included in an instance name in ANARK CORE WORKSTATION. Some of the predefined VIZARD assembling tags are trans, rehome, backface etc. For example, this study uses the trans=[AX,AY,AZ] tag to allow the translation in all directions for the radiator component.

![Image of ANARK CORE WORKSTATION](image2)

**Figure 5.** The assembly tag setting in ANARK CORE WORKSTATION.

2.4. **Creating interactive virtual assembly application**

The newly tagged CAD file can be optimized and exported as a Collada file by using File -> Export CAD File option. This .dae format CAD file can be imported into the VIZARD software for the purpose of rapid creation of virtual assembly interaction. The VIZARD software is the comprehensive virtual reality platform for researchers which offers the functionality of virtual
assembly creation based on .dae format CAD files with VIZARD compatible assembling metadata definitions. It also provides seamless link with virtual reality or augmented reality devices such as MAGIC WAND from WORLDVIZ and RIFT from OCULUS.

VIZARD provides a PYTHON based template, known as “CADManipulator.py”, for the rapid creation of virtual assembly interaction. In this study, the exported .dae file generated from the above steps were copied to the working directory and its name was replaced into the template’s MODELLIST variable. Then the virtual assembly interaction could be launched by running the “CADManipulator.py” file. The assembly manipulation screen is shown in Figure 6.

Figure 6. Import of .dae file into VIZARD to create virtual reality interaction.

Figure 7. The manipulation screen for the created virtual reality interaction.

3. Conclusion and future work

The proposed method significantly simplifies and hastens the process of virtual assembly creation from physical devices by bypassing the complex settings for geometric constraints, operational positioning, and assembly process planning. The experimental results show tremendous time and manual work can be saved using the proposed method. Although some manual effort may be needed in the transformation process from STL file to CAD file, this process is much easier than the similar process in reverse engineering due to their difference focus. In the process of reverse engineering careful manual edit of curved surfaces is generally required, especially when the output CAD file is meant to be used for milling purpose. While in the process of virtual assemble model transformation, the focus becomes the separation of detachable components hence the need for manual work is greatly reduced. The results also show the intuitive virtual assembly experience can dramatically boost students learning interest and shorten learning curve. In the future, the feasibility of using deep learning to further simplify the process of creation of virtual assembly models will be explored.

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