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Digital Aircraft Assembly Process Technology Simulation and Visualization System

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Abstract: The main purpose of the digital aircraft assembly process is to ensure the high assembly accuracy of aircraft products, flexibility and reduce the assembly time. Also, reduce the assembly and manufacture error of tooling (Jig/Fixture) design for particular aircraft products. Generally, the aircraft product assembly process is complex, and it performs through the assembly and disassembly process. Regarding the complexity of the aircraft product assembly process, this research illustrates the systematic analysis of the simulation and visualization technology for the aircraft assembly process. This research introduces key technologies and solutions to realize the aircraft's assembly process visualization system. Then assembly simulation environment is implemented based on virtual reality modelling language (VRML), network, assembly process simulation, and visualization of assembly process documents. The digital aircraft assembly process technology has been divided into simulation and visualization systems in this research. The simulation process includes manufacturing factors, assembly objects, assembly sites, process equipment, tools, and devices. The visualization system visually processes the assembly simulation results and then outputs the processed results in the workshop workplace. It includes the related simulation results and adds necessary text technology to make it easier to understand the concept using visualization techniques to process the results. The research has practical value in the modern aircraft industry to propose an aircraft product simulation process based on computer-aided 3D design.

Keywords: Aircraft Assembly, Assembly Process Simulation, Visualization of Assembly Process Documents, Virtual Reality Modelling Language

1. Introduction

The aircraft assembly process is different from the assembly of general mechanical products. The aircraft assembly process contains thousands of parts and components, and these parts have complex structures and low rigidity, and many parts need to be coordinated [1]. In the assembly process, many assembly frames with large dimensions, complex structures and high accuracy requirements are used to ensure the quality of the products [2]. The labour of assembly work accounts for 50% to 60% of the total workload of aircraft manufacturing and is the key to the entire aircraft development cycle [3].

The modern aviation manufacturing industry has carried out a lot of work in the digital technology of aircraft manufacturing and has achieved specific results [4]. At present, in the development of the model, the design unit has applied digital design technology to varying degrees according to the models and characteristics developed by the model to realize the complete three-dimensional design of the aircraft or its components and establish the corresponding digital prototype model. On this basis, realize the virtual assembly of parts or the whole machine, simulation of motion mechanism, assembly interference check, strength analysis, etc [5].

The current simulations based on the establishment of digital prototypes are mainly aimed at the rationality of the aircraft design, the functions, and the aircraft's performance. To test the rationality of the appearance and structure of the aircraft design theory, the design department conducted a geometric prototype-level simulation to simulate the geometrical stability of the aircraft. The main purpose is to test the assembly's geometric constraints and interference problems.

Although these simulations carried out by the design department contain to a certain extent non-geometric information such as the craftsmanship and materials of the aircraft manufacturing process, there is still a large amount of information in the aircraft manufacturing and assembly process that is ignored, mainly in the following aspects: Analysis of the site and process equipment used in the process; analysis of the tools, equipment, devices, etc. used in the assembly process; analysis of the movement of personnel in the assembly process [6].

Therefore, it can be concluded that the geometric performance simulation performed by the design department is very different from the simulation of the assembly process. The information ignored in the above geometric simulation process must be fully considered in the aircraft assembly simulation process. The assembly process simulation is a more complex and higher-level simulation.

2. Aircraft Assembly Process Simulation and Visualization System

The simulation system module of the simulation and visualization system mainly simulates the assembly process, including the simulation of parts, process equipment, devices and equipment [7]. In the assembly process simulation, various factors of the assembly process are fully considered. The main functions of the simulation system are as follows.

1. Provide a method for establishing a human-machine interactive assembly scene. The basic operations generally include translation, rotation, exchange, insertion, deletion, alignment, interference inspection and elimination, etc. The above methods can establish the assembly scene model.
2. Parts and components are driven by motion, which drives the parts and components to dynamically simulate the assembly process following the predetermined assembly path and assembly sequence.
3. Engineering analysis indicates the analysis of the feasibility of the assembly path, interference and collision inspection, tool accessibility, assembly space operability, assembly efficiency, etc.

The assembly process simulation requires constructing a new simulation environment, and the performance requirements for software and hardware will be very high. If the assembly process simulation software is built for the assembly workshop or each workplace, this will inevitably cause a heavy burden on the company. It is not even possible under the current circumstances [8]. In addition, the assembly workshop does not require a "complete" assembly process simulation. It needs more assembly process simulation and simulation results that are converted into a visual form and then released in the corresponding assembly workshop workplace to meet the needs of the workshop [9]. Therefore, the visualization system converts the simulation results into a format that is easy to excess in the assembly workshop workplace through the network [10]. For different people, the visualization system plays various applications.

1. For designers: Display coordination routes, assembly diagrams and interference check results, etc., for designers to evaluate assembly plans and change assembly designs.
2. For craftsmen: display coordination routes, assembly diagrams, mandatory technological schemes, the technical status of parts and assembly parts, etc., for checking assembly process documents.
3. For assemblers: display the worksite, the animation of the assembly process, the involved parts and the technical status of the parts, etc., to understand the work content and guide the assembly operation.
4. For inspectors: display coordination routes and assembly tolerances, etc., as the basis for inspection.

3. Research Methodology

The overall system architecture is shown in Figure 1. The aircraft assembly process simulation and visualization system are mainly composed of two parts: simulation and visualization systems [11].

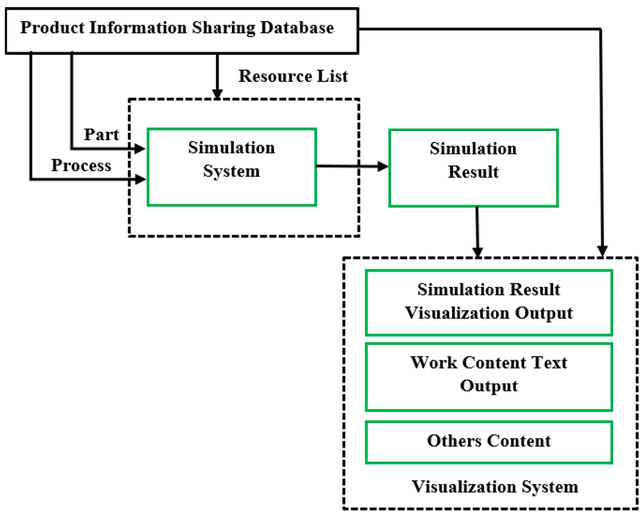

Figure 1. *Aircraft assembly process simulation and visualization system.*

3.1. Simulation System

The simulation system simulates the aircraft assembly process. The simulation process fully considers related manufacturing factors, including assembly objects, assembly sites, process equipment, tools, and devices [12].

3.1.1. Assembly Model Acquisition Module

Since aviation companies generally use Dassault Systems for product development, the simulation system is based on

Dassault Systems DELMIA secondary development, which is conducive to sharing product CAD model information. The simulation system consists of the following modules [13].

Take the rudder assembly as an example. The operator designates the system to read the rudder assembly model and rudder assembly chart from the product information sharing database [14]. The rudder assembly model includes the assembly area, the specific assembly constraints (Constraints) relationship between the part models [15]. According to the assembly diagram and analyzes the assembly sequence, the system decomposes the rudder layer by layer. Then determines the sequence of assembly simulation processing according to the bottom-up method (order from part to the component, order from component to rudder) and uses the system's assembly process to generate the simulated function. The first is the lowest-level assembly simulation, which means assembling a single part and a single part.

3.1.2. Interactive Assembly Process Generation and Simulation Module

This module is responsible for assembly simulation processing, generating assembly scenes and determining assembly paths.

1. Assembly scene generation: According to the parts to be processed, the system reads the corresponding process files, analyzes the process files to obtain the information of the tools and process equipment to be used, and transfers the corresponding tools and equipment and the mathematical models of the process equipment accordingly. The operator then uses human-computer interaction to establish the assembly site model based on the actual situation of the worksite. The system checks and evaluates the site layout in real-time, and the operator dynamically adjusts the layout plan to obtain the best layout plan. Then save the scene model into the product information sharing database [16].
2. Assembly path generation: The operator determines the assembly path of the part or component according to the process plan and uses the human-computer interaction method to calibrate the assembly path in the assembly scene. Then the system performs motion constraint processing on the part model and imposes motion constraint conditions, including constraint conditions such as the degree of freedom of the part model motion, the part model motion speed and the motion time. The movement of the part during assembly mainly includes translation and rotation. The reference coordinate of the translation movement is defined in a total coordinate system, and the rotation coordinate is defined in part. Then the system will perform collision detection on the assembly path to eliminate interference and determine the feasibility of the assembly path [17].
3. Simulation of positioning and clamping: Unlike the assembly of general mechanical products, aircraft assembly uses a large number of various fixtures to ensure assembly quality. Therefore, the aircraft assembly process simulation must include the positioning and clamping process of the parts. The positioning and clamping process simulation is mainly to simulate the parts or determine the positioning process of the parts in the fixture based on the clamping method of the assembly. The simulation process is also generated using human-computer interaction [18].
4. Accessibility analysis of assembly tools and equipment: The system will automatically analyze the assembly instruction list to obtain the assembly tools and equipment required for each assembly action when calibrating the assembly path. Then transfer the digital model of the corresponding tool and equipment into the assembly scene. The operator will calibrate the corresponding tool and equipment route and perform the tool's motion constraint processing for the system's final analysis tool [19].
5. Simulation motion drive processing: After the motion constraints of parts, tools and equipment are determined, the system will drive the processing of moving parts such as parts, tools and generate corresponding driver programs to drive the motion of the moving parts to realize the dynamic simulation of the assembly process [20].

The system forms the assembly path planning file. It saves the assembly path and the movement path and movement constraints of the tool and equipment into the product information sharing database. In this way, the assembly simulation result is formed by the assembly scene model and the assembly path planning file. The assembly simulation result is the basis for generating the assembly simulation animation in the client browser.

3.1.3. Assembly Simulation Visual Processing Module

The visual processing of assembly simulation is to convert the result of assembly simulation formed by the previous modules into a file format that can be transmitted on the network and demonstrated by the client IE browser in the workshop and workplace [21].

VRML is currently a better Web-enabled data format for describing product modelling, conceptual design data, assembly, and manufacturing process simulation and has been supported by many CAD software. Therefore, the VRML format is selected as the storage file format of the assembly model. This module converts the product data model and assembly scene model into VRML format files and stores them in the product information sharing database [22].

3.2. Visualization System

Visualization is to process the assembly process's simulation results visually and then output the processed results in the workshop workplace. At the same time, the related work content is output in the form of text (hyperlink). It is possible to break away from the original simulation platform, see the related simulation results, and add necessary text technology in the simulation results that make it easier to understand the simulation concept using visualization techniques to process the simulation results. The visualization system adopts the Browse Server structure that can access on the local area network [23]. The visualization system consists of the following modules:

1. Assembly simulation results and process file acquisition module: This module is responsible for reading assembly path planning files, assembly process files, and product assembly models and assembly scene models in VRML format from the enterprise product information sharing database. This module runs on the server and transmits relevant files to the client according to the client's request [24].
2. Assembly process animation generation module: This module runs on the client-server, and the JAVA applet program is embedded in the HTML page. But, the animation of the VRML scene is realized through JAVA. The system controls the corresponding VRML scene to generate the assembly process animation based on the assembly simulation result file, which mainly includes the parts currently entering the assembly, the parts entering and exiting the rack, positioning and clamping, and the use of tools and equipment. And can simultaneously display the relevant process documents, operating procedures, tolerances of the current assembled parts [25].
3. Assembly process file browsing: The visualization system outputs and displays the simulation results of the assembly process in the workshop workplace and outputs the related work content in the form of text (hyperlink). The main output work content includes the work content summary, work parts list, equipment list, and the work to be done (using technical specifications/standards, procedures, and status achieved) [26].

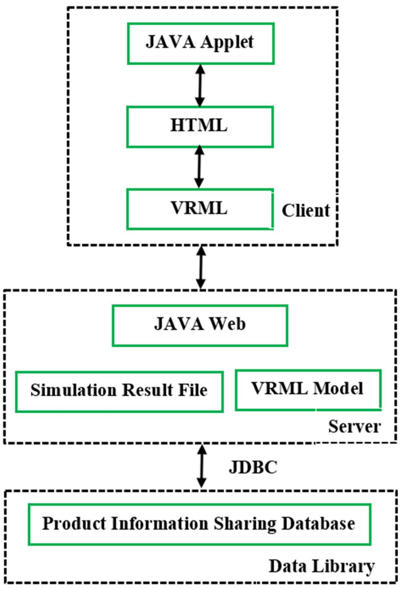

Figure 2. *Visualization system flow chart.*

The assembler can select a specific part with the mouse in the browser window. The system will display the process file related to the part, the assembly constraint relationship between the part and other parts, and the animation of the assembly process accordingly. In this way, the assembler can quickly understand the content of their work. It can browse and consult relevant information during assembly, which plays an essential role in improving assembly efficiency and ensuring assembly quality.

4. Result and Discussion

VRML format files are browsed by adding a VRML plug-in to a web browser such as Internet Explorer. VRML provides an EAI (External Authoring Interface) to enhance its interactive capabilities. EAI defines an interface for communicating with Applets in external HTML pages. Its basic idea is to put the JAVA applet and VRML on the same Web page. Establish a browser object in the JAVA applet to identify a unique VRML scene and obtain a reference to the defined node in the VRML scene. The domain value of the reference node is used to achieve a dynamic effect. In this way, the JAVA applet can control VRML scenes and interact with other media such as HTML and network control to realize an interactive assembly visualization environment.

```
# VRML V2.0
DEF Assembly Transform{ //nodeObject
rotation x y z angle //ISFRotationObject
translation x y z //ISFVec3fObject
children{
shape{
gemotry IndexedFaceSet{
coord coordinate{
point []
}
}
}
}
```

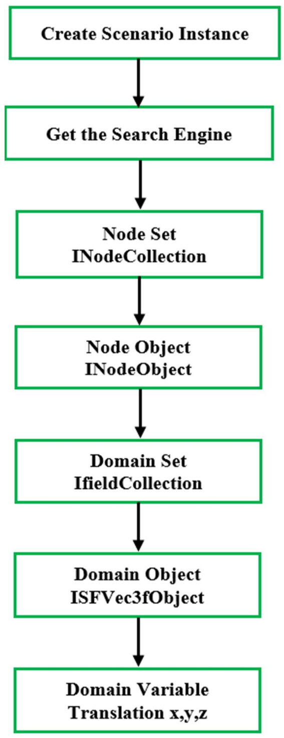

Figure 3. *VRML hierarchical relationship.*

Figure 3 shows the VRML scene hierarchical relationship. VRML scenes generally include search engines, geometric modelling nodes, appearance attribute nodes, scripts and animations, etc. Among them, geometric nodes have basic solid geometric nodes such as cuboid, cylinder, cone, etc., and the "index surface" is surrounded by patches to form a solid Set" geometry node. The VRML format product model output from CAD software adopts "IndexedFaceSet" (indexed face set) geometric node description, and the basic structure of the scene is as follows:

According to the VRML standard, the value of the vector field optimized the contour shape of the object. And the object's position is determined by the rotation and translation fields of the node "Transform". Therefore, the scene animation realized according to the following method: According to the rule of "index face set" geometric node construction, the top-down idea, traverse the domain to be transformed from the root node to the target node, modify the domain value, and realize the geometric node and the position in the scene space changes. Then, the position of the geometric node continuously changes to realize the animation display of VRML by further combining the "routing" and "time sensor" nodes. The steps to capture the target domain value are as follows:

1. To capture the model object, use the GetRoot Nodes method to search from the root node through the search engine, or use the GetNodes method to search from all nodes named DEF, or directly use the mouse click event to search by the GetTouchNodes method. These three methods can obtain a NodesCollection, which includes the Transform node.
2. Through the attributes of the target node, such as the name "Assembly", find the corresponding node object (NodeObject) that is the transform node. And then obtain the transform node fieldset (FieldsCollection), including "rotation", "translation", etc. Finally, the specific domain name (such as translation) captures the target domain value.

5. Conclusion

Assembly simulation can vividly and intuitively display and improve the assembly ability of products. The assembly simulation system proposed in this paper can effectively integrate information such as assembly operations, assembly process, and equipment for the assembly process, realize the organic combination of assembly environment and different assembly levels. Simulation and this system fully consider the current digital situation of aviation companies in product design and manufacturing. It is built on the company's existing software platform. Also, it uses the company's existing product models and process information. So, it is more practical and can meet the company's needs. The demand for visualization of the aircraft assembly process is significant for shortening the product design cycle, improving product assembly quality, and improving assembly efficiency. It also has recommended value for the assembly of other mechanical products.

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