Development of Virtual disassembly and assembly platform for marine air compressor

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Abstract: The use of virtual reality technology to assist equipment maintenance and skills training has a broad application prospect, but the existing systems are often lack of sense of reality, over-simplified because it’s difficult to establish the disassembly process model, the lack of 3D interaction design, etc. Taking marine air compressor as an example, this paper analyzes the functional requirements of the virtual disassembly and assembly platform, studies the key technologies of multi-source data integration, 3d modeling with high sense of reality and high complexity disassembly process modeling, uses Maya/Unity3D and other software to realize relevant technologies and functions, and gives the development process of the system. The developed system has been applied in many maritime institutions in China. It has been demonstrated with reference value and application prospect.

1. Introduction

In seafarer education and training, the existing practical skills assessment method has the shortcomings of high investment cost of equipment and high safety risks. With the development of computer technology, there have been many successful cases of using virtual reality technology to assist teaching in vocational education and training [1-6]. It has become a trend to build virtual marine engine equipment in the computer and practical skills assessment by three-dimensional means. This assessment method can provide a virtual learning environment for students to avoid the safety risks and failures caused by physical operations. Virtual disassembly and assembly training helps to improve the understanding of the appearance and procedures of complex mechanical mechanisms in real ship operations. It can repeatedly simulate complex maintenance operations that are difficult to drill. It has the features of low cost and high performance. Internationally, the marine engine room simulators produced by Kongsberg, Wartsila and other companies have been at the world-leading level, but no application related to virtual disassembly has been reported. MAN B&W and Wartsila, the world's leading ship equipment manufacturers, just filmed real videos to guide overhaul. The virtual disassembly method has not been used yet. In China, thus a large seafarer country, relevant maritime colleges and research institutions have also invested many research and development efforts in virtual practical training[7]. However, the existing results are mostly with insufficient picture quality, poor reality in operation, and limited interactivity. In this paper, taking the development of virtual disassembly and assembly platform for the air compressor as an example, we study the use of virtual reality to demonstrate the structure and assembly relationship of ship machinery parts and realize the training of maintenance skills such as disassembly, measurement and overhaul.
2. System Design

The design of the virtual disassembly and assembly platform for marine air compressors is based on the needs of three aspects: auxiliary maintenance of actual ships, practical teaching of navigation, and evaluation of seafarers' competence. The main air compressor of vessel "AHTS 681" is used as the prototype to realize the maintenance process of equipment, three-dimensional demonstration, virtual training and evaluation.

The disassembly system needs to have functions such as demonstration, practice, examination, and interactive manual. In the demonstration mode, it needs to be able to pause and adjust the observation perspective; in the practice mode, it needs to be able to realize the functions of parts picking, step return, step fast forward, special tool and general tool selection and discrimination, operation record, help tips, etc.; in the examination mode, it needs to realize all the functions of the practice mode and realize the process evaluation.

3. Key Technologies

The virtual disassembly and assembly platform for marine air compressors uses Maya and Unity3D development platforms. First, establish a three-dimensional model of the air compressor in Maya, render and optimize it, and use tools such as Zbrush and Photoshop to assist in making textures. Then import the model and texture into the Unity3D development platform, and realize the virtual disassembly and assembly function through programming [8-11]. The entire development process can be divided into
four stages: multi-source data integration, three-dimensional model construction, disassembly process modeling, program integration and optimization. The whole development process is shown in Figure 2.

3.1 Multi-source data integration
The main work of this stage is to collect, extract, integrate and manage data. The data mainly includes the three-dimensional size, structure, assembly relationship, material and other information of equipment, parts and environment. Data sources mainly include equipment maintenance manuals, manufacturer's atlas, installation instructions, actual ship appearance photos, actual ship maintenance photos, laboratory photos, teaching materials, etc. In the process of data integration, the size information of each view is particularly important and needs to be consistent with the actual object. If the dimensional accuracy is low, all kinds of interference and conflicts will be generated when animation production and other part modeling are carried out later, which requires constant modification and rework, which will bring unnecessary workload. The photos help to make high-realistic model materials.

3.2 3D model construction
In this paper, from the three aspects of high-precision parts and real ship scene modeling, high-definition mapping and material production, offline baking and real-time lighting, methods to improve the realism of the 3D model are given.

3.2.1 Geometric modeling.
The degree of detail performance of the part model and the scene model is the most important factor affecting the realism of the virtual disassembly system. This requires a high degree of restoration of the part details, assembly relationships (such as hierarchical structure, assembly constraints), and real ship scenes in the modeling. Before modeling, the overall model construction and layout of the equipment and environment are carried out, the parts are decomposed and modeled, and the proportions are agreed to ensure that the parts of the collaborators are consistent. At the same time, it is necessary to analyze the details of the disassembly and assembly business steps and determine the granularity of the modeling in order to obtain a better balance between complexity and precision. In large-scale equipment disassembly systems such as large two-stroke diesel engines, multi-level detailed models of different precisions can also be made for the equipment, and parts models of different complexity can be dynamically called according to the viewing angle and distance to increase the system frame rate. Figure 3 shows the three-dimensional model of the air compressor built in Maya modeling software.
3.2.2 Material production.
You need to split the UV for the finished model, and use the material editor in the modeling software to add materials to the object. Set the object's color, gloss and other properties by adjusting the material properties to achieve the desired smooth, rough and other effects.

This article uses Substance Painter/Photoshop/Maya and other software to edit and produce the required textures. Among them, Substance Painter is responsible for drawing the color, texture, texture, and gloss of the texture, and Photoshop is responsible for the color ID and correction errors. Maya is responsible for rendering the normal map.

3.2.3 Lighting simulation.
The shading effect of the model during rendering is also an important factor affecting the sense of reality. Baking is a method of rendering lighting information into textures and pasting the baked textures back into the scene. It renders the original texture information, lighting information and shadow effects of the object into a texture and stores it, and then loads the baked texture to show the shading effect of the model surface when the scene is rendered in real time.

In order to improve the sense of reality and real-time rendering efficiency, this paper uses the combination of offline lighting and online lighting to simulate the shading effect. Using the Mental Ray renderer in Maya, offline baking generates baking textures with static shading effects. Further, the real-time online lighting calculation using the shader in the three-dimensional program can simulate the dynamic highlight effect formed by the change of the observer's viewpoint. A shader is a program that runs on the graphics card GPU. Real-time lighting algorithms can be controlled through shader programming. Compared with the engine's built-in lighting calculation function, this method can get more flexible special effects and does not occupy CPU resources. This paper studies the dynamic lighting algorithm, the principle of specular reflection map sampling, uses the HLSL language to write the shader, and program the vertex shader and pixel shader code segment in the ShaderLab editor of Unity3D to simulate the dynamic highlight formed by the observer's viewpoint change and other effects.
reflection and other special effects, effectively improve the rendering efficiency of the graphics engine, and enhance the real-time performance of the virtual disassembly system.

Finally, after organizing the model in Maya and clearing the unreferenced resources, export the scene as a .FBX format file for import into Unity, as shown in Figure 6.

3.3 Modeling of the disassembly and assembly process
The complexity of the virtual disassembly process directly determines the degree of conformity between the virtual disassembly and the actual disassembly, and is a decisive factor that affects the reality of the virtual system's behavior. Existing systems are affected by factors such as technical difficulty, development cost, etc., simplifying the actual maintenance process more, often using sequential disassembly and assembly procedures, and insufficient restoration of the actual maintenance process.

In order to support parallel disassembly, tool selection judgment, disassembly step control, disassembly process evaluation, etc., this article subdivides each disassembly, measurement, and debugging process into several element operations, and establishes a relationship model between the element operations, namely, disassembly Installation process model.

The disassembly process model includes two parts: disassembly meta-operation information and meta-operation relationship. Meta-operation information refers to information such as the number of animation start and end frames, tools used, evaluation weights, page numbers in the operation manual, etc.; meta-operation relations refer to the front and rear meta-operation IDs, disassembly sequence, disassembly and assembly relations between parts, and disassembly and assembly processes (Including data) and so on.

3.3.1 Establishment of disassembly and assembly process model.
At present, the modeling related to the assembly process of industrial products often adopts the strategy of combining the association relationship model and the hierarchical relationship model. The relevant theories are relatively complete, but this model does not consider the characteristics of actual maintenance and disassembly activities. In the process of ship equipment maintenance, the disassembly sequence of "assembly → component → component → part" implied by the hierarchical model is often not strictly followed, but related parts are grouped into a group, and the component is first disassembled or the parts are disassembled as a whole, and then the component parts are disassembled. [12]

In response to the above problems, this article has improved the assembly process model to form a disassembly process model in a virtual disassembly scenario, as shown in Figure 5. The matching constraint relationship between components at the same level in the model is represented by an association relationship model. The association relationship model is based on a directed graph, and introduces the concepts of virtual constraints and undirected constraints as an improvement and supplement to the model [13-15]
In the actual disassembly and assembly process, first determine whether its parent node is the root node. If so, call the target disassembly algorithm according to the association relationship model corresponding to the first-level disassembly reference layer in the hierarchical relationship model to plan the target component disassembly; if not, search for the disassembly path according to the hierarchical relationship model and determine whether each node on the searched disassembly path has a skip disassembly path. If so, the disassembly path of the target disassembly part after the skip disassembly path is given, and the middle of the disassembly path will be skipped. Node restoration obtains the restored disassembly and assembly structure model. At this time, according to the sequence of the nodes on the searched disassembly path, the target disassembly algorithm is called according to the correlation model corresponding to the level of each node, and the disassembly and assembly unit corresponding to each node Carry out target disassembly planning to obtain the disassembly sequence of the target components; if not, call the target disassembly algorithm according to the order of the nodes on the path of the hierarchical relationship model, and call the target disassembly algorithm according to the correlation model corresponding to the level of each node. Install the unit to plan the target disassembly. The disassembly process model is implemented in XML Scripts.

3.3.2 Optimization of disassembly and assembly process model.
The disassembly and assembly focuses on the actual expression of the disassembly and assembly sequence and usage method of the physical object, so requirements for the scene reality and the simulation of the disassembly and assembly process flow are high. Among them, the interference check and path planning in the virtual assembly are passed through the advance Generate disassembly animation to avoid. The accuracy of meta-operation animation performance directly determines the degree of agreement between virtual training and physical training. The disassembly and assembly process not only needs to meet the actual situation of the actual ship inspection and repair, but also consider the characteristics of computer operations, which requires a balance between complexity and operability in the division of element operations. Based on the above considerations, this article
3.4 Virtual disassembly program implementation

The system’s main technical implementation scheme is shown in Figure 6. This paper describes the program design and implementation scheme in terms of training mode design, function design, human-machine interface design, and performance index.

3.4.1 Training mode design. The training evaluation system provides three training modes: demonstration, practice, and examination.

Under the demonstration function, the system can demonstrate the whole process of disassembly, test, and debugging in a three-dimensional virtual environment. It can be played automatically or manually. Manual playback can be a node in a single step. Under the practice function, students can operate input and output devices to disassemble, adjust, and experiment in a three-dimensional virtual environment. The operation steps are prompted, and the practitioner can also take notes for each operation step. Under the test function, there should be a corresponding client, select an appropriate database, and realize communication. The tester can set the test content, time, and whether there are reminders, etc.

3.4.2 Function Design. The functions that should be implemented in each disassembly scenario include

1) Exploded view and group view
2) Step timing, pedometry, scoring
3) Parts pickup
4) The part information display, such as name, weight, process parameters, etc.
5) The disassembly guidance function, including text guidance, three-dimensional visual guidance.
6) Disassembly error message
7) Tool selection, use of special tools

3.4.3 Human-machine interface design. The training evaluation system should have a user-friendly and operable human-machine interface with the following main design functions.
1) Create a start screen for 3D panoramic display of the equipment, and then enter the disassembly and assembly selection menu for the main components
2) The software is capable of full-screen adaption to typical monitor resolutions and can also manually set the screen resolution
3) User settings such as language, resolution, shortcut keys, etc. can be modified and saved
4) Support keyboard and mouse, touch, HTC-VIVE and other human-computer interaction
5) Interface, scene using hierarchical menu navigation, navigation buttons using the corresponding parts of the 3D rendering production

3.4.4 Mobile scene optimization. Based on unity's virtual reality, we make full use of a large number of original scripts provided by unity to program and control the 3D model of the cabin equipment to realize the disassembly and assembly of the model. Use the various function nodes and custom script nodes provided by Unity to control the disassembly and assembly of the model, the key actions of the cabin equipment, and the animation demonstration.

3.4.5 Performance Index. Using various optimization means to optimize the scenes, on a computer with I7 CPU, 8G RAM, and 4G video memory, the scenes were opened with the standard resolution of 1920*1080. The loading and switching operation of any one scene don't exceed 5 seconds. The complete test is conducted at three screen resolutions of 3840×2160, 1920*1080 and 1280*1024 without any error or misalignment. The frame rate of the scene screen is not less than 30fps, no frame skipping situation, the frame rate difference ±2fps. It ensures that users use the software for more than 2 hours without dizziness, nausea and other conditions.

4. Conclusion
In this paper, with the help of virtual reality technology, the Virtual disassembly and assembly platform for marine air compressor is designed. The key technologies are studied and realized from 3 aspects: construction of 3D model of parts, construction of disassembly process model, and virtual disassembly and assembly procedures, which effectively realize the high realistic disassembly and assembly training of ship engine room equipment in computer 3D environment and provide a low-cost learning path for trainees.

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