

Research on the Crucial Technology in Virtual Training System of Engineering Equipment

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Abstract

The virtual training system involves a large number of technical problems which affect the promotion and application in our country. In this work, several key techniques for the development of engineering equipment virtual training system are addressed. Firstly, the reconstruction method for three views of machine parts is proposed based on rapid 3D surface fitting as well as NURBS composite surface. Then, the interactive control techniques for the 3D visualization interactive assembly are studied in detail. The key technology of collision detection is also illuminated in the last part. The entire engineering equipment support training system, that includes structure expressing, principle demonstration, panoramic roaming, disassembly training as well as maintenance and repair training, is developed. This facilitates the trainees in learning the support training procedures step by step, and quickly improves their technical skills.

Keywords: virtual training, engineering equipment, three-dimensional reconstruction, collision detection, NURBS fitting.

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1. Introduction

Engineering equipment support virtual training system was first proposed by the United States in 1990s. Since its arrival, the virtual training system has attracted high attention from the scientific institution, military administration, some universities and business communities. It is treated as an effective method to guarantee the support of large advanced products. U.S. NASA, military and some colleges, research institutions and large companies have commenced more popularly to carry out research in this area, and have achieved significant achievements. Nowadays virtual training and support system is generally conducted in maintenance training, maintenance design, supportability design and etc.

Because of the complexity and variety of engineering equipment's structure, working principle and appearance, there are many technical problems and complicated algorithms in the development of virtual training system. The 3D modeling reconstruction is important for the complex machine parts, for example hydraulic oil components, working attachment, braking system and swing support, especially for the operating action of these components in virtual training scene. In order to solve the collision detection and interference issues between the movement of engineering equipment models and its movement, models and virtual scene as well as virtual human and virtual maintenance tools, together with enhancement of the precision and realistic sense of virtual training scene, the collision and interference techniques are demonstrated. The above key technologies are expounded in detail.

2. 3D Reconstruction Techniques of Modeling

Rapid Fitting 3D Reconstruction Method for Three Views of Machine Part. The rapid model construction of part is implemented by means of rapid fitting of simple three projective views relation. With this method, rapid construction of 3D basic shape of machine part is performed by identifying the simple two-dimensional graphics of three positive projection direction as well as three axial fitting constraints of the machine part [2, 3]. Consequently, the 3D model satisfied with the corresponding requirements is obtained based on modification and

processing of mathematical transform and Boolean calculation to basic part shapes. Three views rapid fitting reconstruction program are illustrated in Figure 1.

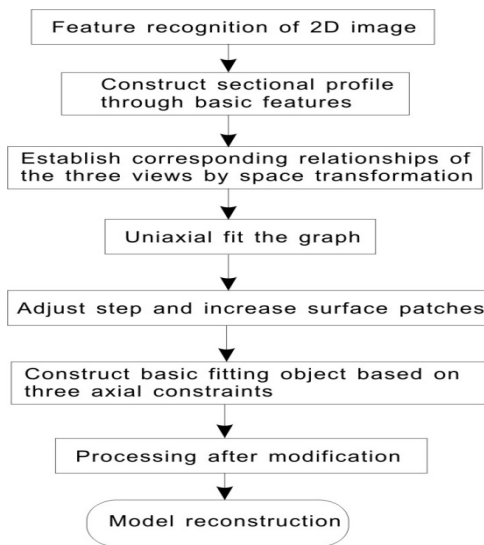


Figure 1. Rapid Fitting Reconstruction Steps for Three Views of Parts

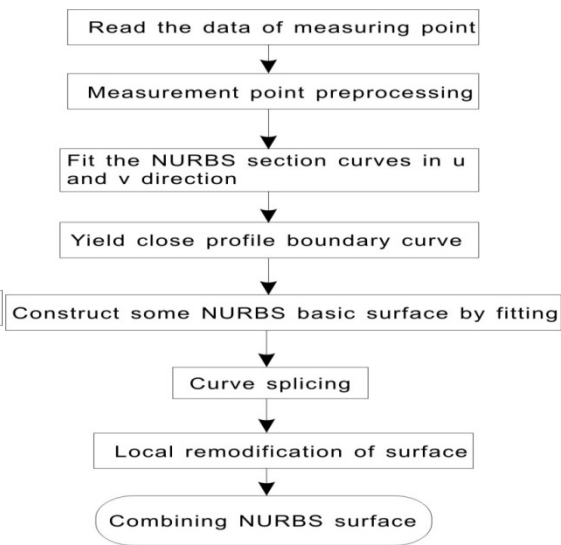


Figure 2. NURBS Surface Reconstruction Schematic

NURBS Composite Surface Reconstruction. In this work, free-form surface modeling is carried out on the basis of triangular Bezier surface construction and NURBS parametric surface fitting methods [4]. Accordingly, it could construct complex and precise component model featured with precision, fine and trueness. So it provides vivid training object. The mathematical model of NURBS surface is expressed as Equation 1.

$$P(u, v) = \frac{\sum_{i=0}^m \sum_{j=0}^n w_{i,j} d_{i,j} N_{i,k}(u) N_{j,l}(v)}{\sum_{i=0}^m \sum_{j=0}^n w_{i,j} N_{i,k}(u) N_{j,l}(v)} \quad (1)$$

The geometric shape of the part is classified into two categories: one is elementary analytic surfaces, such as planar, cylindrical, conical surfaces together with torus and etc. Most of the part shapes belong to it. The other is the surfaces and curves that are formed by free transform of complex ways, namely, composed of free-formed curves and surfaces, other than constructed with elementary analytic surfaces. Most of covering parts, for example, combustion room of the engine, intake and exhaust manifolds, exhaust pipe and so on. are of this classification. The free-formed surface construction can accurately represent the standard analytic shape, such as conic curve and rotation surface, by utilizing NURBS curves, surfaces and its corresponding operations. When there exists free surface, analytic curves and surfaces simultaneously in the geometry object, it is most effective to construct the model with NURBS operation.

The part model construction of engineering machinery is implemented by using combination of stitching and re-modifying of NURBS surface fitting method. The basic process is: firstly, carry out the preprocessing for data filtering, sorting, reducing and segmenting of measurement point, then create several cross section NURBS curves in u and v directions, construct curve network that represents the basic shape of reconstruction surface; secondly, according to boundary point coordination on contours of parts in u and v directions, the closed reconstruction surface boundary contours are fitted so as to define the reconstructing surface

region that guarantees the continuity and closeness; lastly, through technical processing of stitching, transition, extending, cutting and smoothing for the blocked surface, together with remodification by means of feature-based modeling, such as surface stretching, Boolean calculation, surface chamfering and stitching of CAD system, and achieve suitable composite surface. The surface processing flow is described in Figure 2. The control vertices of NURBS surface are described on Figure 3.

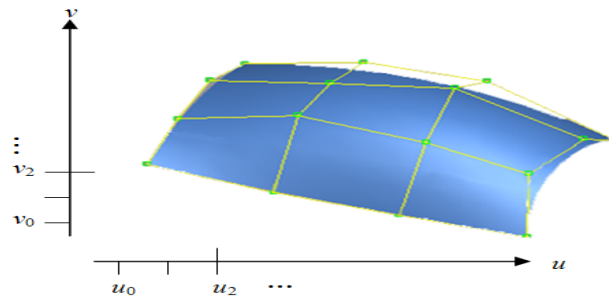


Figure 3. Schematic Description of NURBS Surface Control Vertices

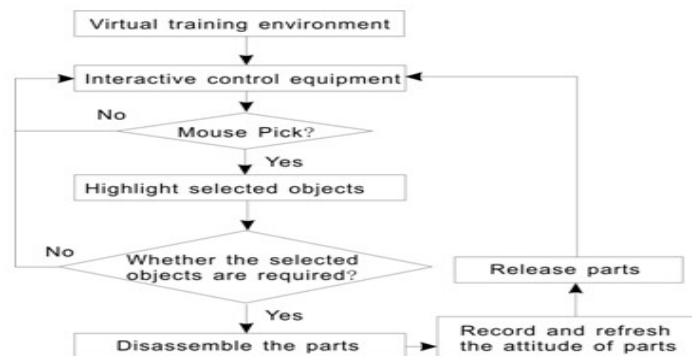


Figure 4. Mouse Picking Procedure in Virtual Training Environment

3. Interactive Simulation and Control Techniques in Training Procedure

Mouse Picking of Machine Parts. In the process of real-time interactive 3D visualization assembly in virtual environment, mouse picking of image is often carried out, in which the realization mechanism is based on mouse picking algorithm. When the component is picked up, the selected object would be highlighted to visually prompt user the current selectable objects so as to upgrade the picking efficiency. The picking flow chart is presented in Figure 4. When user selects the objects for drop and drag with mouse in virtual environment, the system manipulates the coordinate change of the selected objects by acquisition of the position data/instructions of mouse. Thus the position of the objects can follow the variation of mouse coordinate.

Virtual Hand Operation of Parts. Conventionally, it is very hard to guarantee the movement precision and accuracy in virtual scene on account of the visual perspective effect for mouse picking. By means of adding virtual hand into the virtual repair training scene, users can interact with the objects in virtual scene by manipulation of the virtual hand. The model of virtual hand can be constructed with geometric modeling tools. Various attitude model of virtual hands can be established according to functional requirements. Thus users move the virtual hand in the scene of virtual maintenance, and let it collide with the manipulated objects. When collision occurs the link property would be enabled. The virtual hand is accordingly combined with the objects. Thereby the following operation of virtual hand is the manipulation of selected object as to carry out specific disassembly/assembly tasks. The kinetic flexibility and accessibility for

virtual hand in virtual maintenance scene determine its applied scope. Two manipulation modes are supplied as follows.

The section headings are in boldface capital and lowercase letters. Second level headings are typed as

Manipulation of Mouse and Keyboard. Because the mouse cursor movement on computer display is two-dimensional, thereby it should be transformed to three-dimensional movement by calculation. The plane motion of the mouse is mapped to the XOZ and XOY plane of world coordinate system in virtual maintenance scene respectively via the control of push button on keyboard.

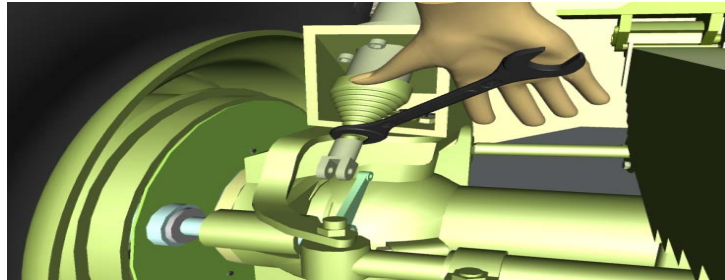


Figure 5. Virtual Hand Fixes Stewing Nut

Manipulation of Joystick and Keyboard. Virtual hand roam in virtual maintenance scene can also be achieved by utilizing the scheme of camera roaming. By means of add KeyMove node to virtual hand, users can move the virtual hand by cooperation of up and down arrow keys as well as letter keys. The other method of keyboard manipulation is to use WalkAbout node that is like driving skills. The WalkAbout node is inserted into the virtual hand object, and users can obtain the free manipulating techniques by setting its properties. Joystick manipulation is realized by adding Joystick node to the virtual hand, and connecting joystick to computer as well as setting the flexibility properties and motion scope so to implement joystick control. Because most of the current joystick has only two axial freedom degrees, its implementation of three-dimensional movement is restricted to some extent. Therefore it is of less use. But as a good manipulation tool, the keyboard control can be simulated as joystick control through third-party software, the flexibility and simplification degree will be raised greatly.

The interactive control techniques of virtual maintenance assembly/disassembly in large and complex maintenance scene is performed with the above technical basis together with sequence assembly/disassembly planning and assembly relation of hierarchical constraint, real-time collision detection as well as distance detection and etc. The complex scene must pay attention to simplicity and repeatability of the operating process, responding speed of system and operating accuracy. The system can also provide certain helpful information so as to accomplish the good training effects. Figure 5 illustrates the operation of virtual fixing nut.

4. Collision Detection Techniques

Configuration of Collision Detection in EON Studio. Eon Studio supplies three nodes for collision detection: CollisionGeometryType, CollisionObject and CollisionManager. The CollisionGeometryType Node is used to specify the type of bounding box for collision objects. Currently six types of bounding volumes are provided for the user selection, they are TBoundingspheres, Boundingsphere, Boundingboxes, Boundingbox, Convexhull, Convexhull s and Geometryaxis. The CollisionObiect node holds properties and report collisions for individual collision objects. These nodes are linked to a Frame node by adding a frame reference in the ObjectFrame field or by placing it below a Frame node and thereby identify the Frame as collision object in the simulation. The CollisionManager node holds global properties for a set of collision objects between which collisions should be tested.

Because EON Studio uses hierarchical bounding box to implement collision detection and collision response, the system is highly real-time.

The Collision Detection between Model and Scene. The virtual workplace node OfficeRoom3 in EON studio can not be directly used for collision detection. That is to say, when the assembly machine parts drop, or move to and fro as well as up and down, it may penetrate the ground or wall and like too distorted. Therefore the 3D wall should be added into the outer wall of hexahedral surface of OfficeRoom3 node. Consequently the objects penetration is resolved by this method. It is presented in Figure 6.

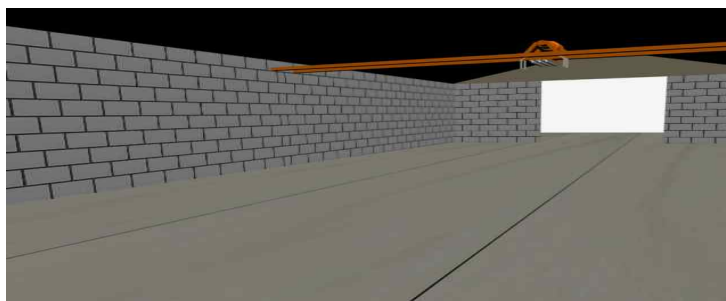


Figure 6. Adding 3D outer walls to solve penetration problem

Thus the interactive collision detection and response detection between equipment parts, tools, work stand and workplace can be realized by adding CollisionObject node and RigidBody node below subtree of parts model frame node, workstand frame node and wall frame node, along with the insertion of CollisionManage node and DynamicsManager node at any position below Scene subtree as well as relevant configuration. The immersion and reality sensor may be further enhanced.

4. Conclusion

In this paper, the key techniques of constructing 3D model and virtual maintenance training scene have been studied for the application on the process engineering equipment maintenance training. The main contributions of this work could be briefly summarized as follows.

- 1) The 3D parts modeling of engineering equipment is illustrated in detail. The model construction steps are presented.
- 2) The interactive control techniques between engineering equipment parts, workplace, work stand, tools and others are studied. It resolved the problem of parts assembly/disassembly and demonstration of work principle and maintenance guidance.
- 3) The collision detection and response detection of object in virtual scene are described. The penetration of machine parts is implemented effectively.

References

- [1] Naval Facilities Engineering Command. *Management of Civil Engineering Support Equipment*. 2003.
- [2] Bin Liu, Zhitang Li, Zhanchun Li. An Image Hiding Algorithm Based on Bit Plane. *Computational Intelligence and Security*. 2005; 3802: 611-616.
- [3] Ran-Zan Wang, Chi-Fang Lin, Ja-Chen Lin. Image Hiding by Optimal LSB Substitution and Genetic Algorithm. *Pattern Recognition*. 2001; 34(3): 671-683.
- [4] Zou Xiao-fan, Hung Jin-ying. Research on NURBS Surface Modeling and Machining System. *Journal of Jiamusi University (Natural science edition)*. 2007; 25(2): 120-128.