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Design of Virtual Assembly Operation Evaluation System Based on EON Platform

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Abstract – Based on the technology of desktop type virtual reality, the structure and interactive control principle of virtual assembly training evaluation system is researched. Human-computer interaction environment of virtual assembly is constructed. Virtual assembly process planning is completed, and virtual assembly process of assembly modeling is realized, which based on EON platform. By the use of the well expansibility of EON, the information of operations are recognized and recorded through the programming of combine the EON platform and database. The evaluation of operation sequence is realized through constructs the rule-bases which based on expert knowledge. The function of virtual training system is consummated, the method and idea of design has good application value.

Keywords – EON platform; Virtual Assembly; Training evaluation; Design of System

Introduction

Assembly of parts is an important part of the manufacturing and maintenance process. The proficiency and skill levels of the operators have a significant impact on product performance. The training of the operators need a lot of time and cost. The emergence and progress of virtual reality technology has brought a new way to solve the problem of assembly training. In recent years, virtual assembly training system is widely used in various types of complex product assembly training because of its good characteristics, such as: excellent immersion, time-effective, and economical ([1], [2]).

Training evaluation is an effective way to test the training effect of trainees, but the method is rarely used for operation of the virtual training assessment. In this paper, a training evaluation system is developed. The system not only takes the assembly sequence of the trainees as evaluation objects, but also takes the standard of the assembly operations process into account. The structure and key technology of the system are introduced.

1. System components

Because of the characteristics such as lower cost and better immersion, the desktop virtual reality technology is widely used in the less immersion demanding occasions. The desktop type assembly training evaluation system contains hardware devices and software platform. Hardware devices include input devices and output devices for interactive control, graphics and image processing equipment, audio frequency simulation equipment and memory etc. The software platform is composed of the operating system and application software. Fig.1 shows the components and structure of the virtual assembly training evaluation system.

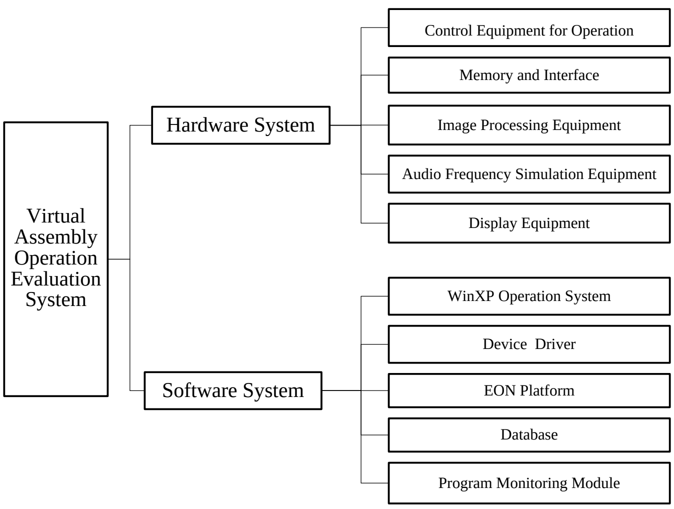


Figure 1. The components and structure of virtual assembly training evaluation system

2. The design of interactive control based on the EON platform

2.1. Interactive control mechanism of the EON

Interactive control is the basis of contacting with trainees and virtual environment, the interactive control of the system can be divided into two kinds: external control and internal response. External control is sent instructions to the virtual scene from the trainee by using mouse, handle, data gloves, and some other input devices. The instructions, which are sent from the trainee, are feedback from the monitors and other output devices. Internal response is the process that the monitor program calling the EON function module from the database, the function module respond to a variety of instructions by triggering events, and then achieve the operation of the model such as selecting, moving, rotating, etc. EON virtual interactive software platform can support most of the input device which can be found in the market. EON has a visual programming interface, and provides variety package program module nodes. For interaction, we must first establish the mapping between input control device and the virtual environment by using sensor node, and then select the appropriate function node according to the design intent. These nodes receive and transmit information by setting their property of the field through the router. The information would be processed by the program encapsulated within the nodes, at last the effect of the implementation feedback to the trainee by the output device ([1], [3]). The principle of interaction is shown in Fig. 2.

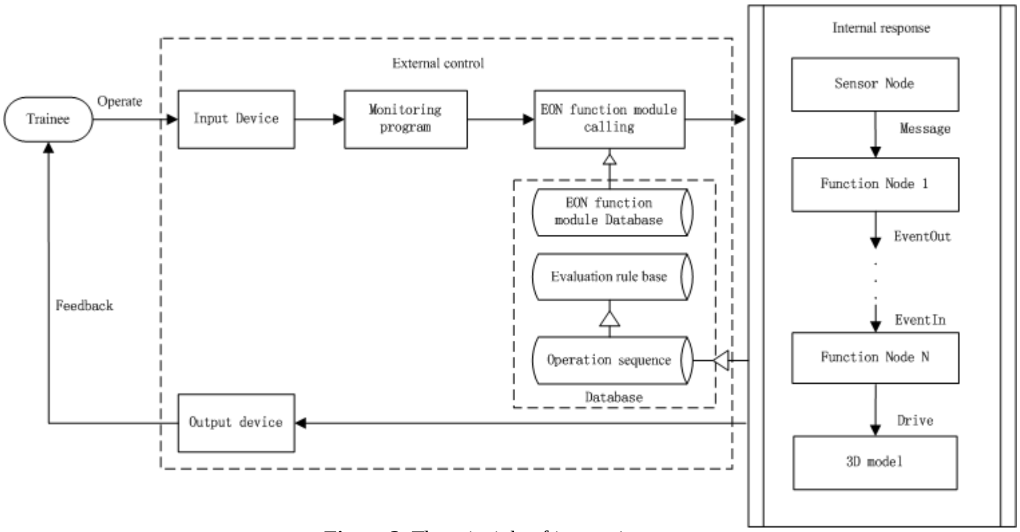


Figure 2. The principle of interaction route

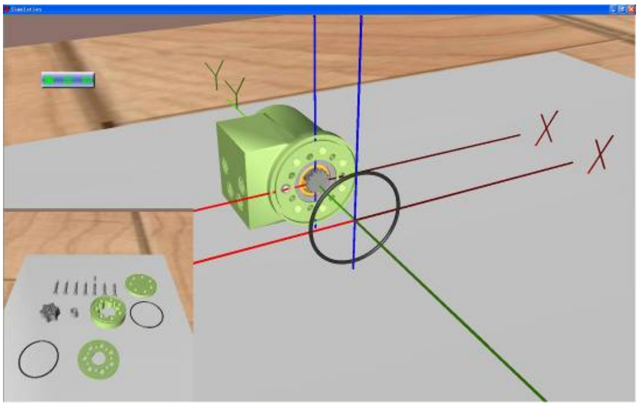
2.2. EON-based assembly process planning

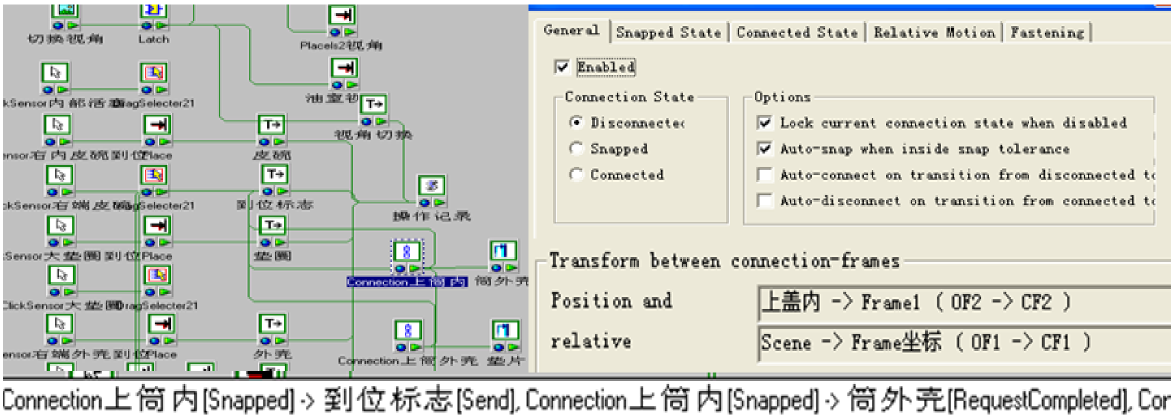
2.2.1. The assembly path planning

In order to reduce the time of changing views when choose parts, the multi-window way is taken to represent the virtual scene. The trainee selects the appropriate parts or tools in the“parts put area”by clicking the mouse, then the selected object moves to the position in the assembly area according to a preset path. Through the integrated using of ClickSensor node and DragSelect node, the assembly process is accomplished. The range of movement and velocity is constrained by setting its motion degrees of freedom (DOF). During the process of draging and dropping operation, the constraint relations between the parts are limited by setting of the collision detection and collision response manner of the relevant parts. The purpose of the collision detection is to scan collision parts and to report the position information. The correct collision response can simulate the real operation process, when the collision occurr. The collision object makes the right response according to different purposes. In this system, collision detection for interference only needed to stop traverse phenomenon. EON virtual interaction platform has many collision detection nodes and collision-related component group, such as CollisionGeometryType node, CollisionObject node, Collision Manager node, CollisionBoxes component, CollisionEventSelector component, and so on. The CollisionGeometryType node is mainly used to set the type of bounding box of the parts which participate in the collision detection. Collision- GeometryType node contains six geometry types bounding box for user to choose CollisionObject node mainly used to set the objects and response types of the collision, CollisionManager node is used to manage multiple CollisionObject node. The real-time collision detection can be carried out by integrated using of these nodes. ([2], [3])

2.2.2. The method be used to determine when the parts assembly in place

Whether the parts are assembled in place related to the quality of assembly directly. And the identification of when the parts assembled in place is important for assembly evaluation. The assembly relationship between the assembly parts can be broadly divided into surface contact fit, interference fit, clearance fit, and fastening connections. At present, the collision detection is the most commonly method to examine whether the parts assembled in place in the virtual scene. But this method is not suitable for the case of interference fit and fastening connections obviously. The coordinate system not only contains the information of axes direction, but also contains the information that the location of the origin of coordinates. So attaching a hidden reference coordinate system to each of the parts, the parts can be taken as assembled in place when the reference coordinate system of parts is overlap. Fig. 3(a) shows the display status of the reference coordinate system. This method overcomes the lack of recognizing collision detection in place. It is accurate in judgment of the assembly in place, and the trigger mode is prompt and brief. In the EON platform, the 3Dpoint reference coordinate system node is added to the frame of parts, set a fixed point in scene or the parts which contains the most constraint relation as the benchmark reference coordinate system. Set the parameters and properties of the Connection node, so the two parts can connect automatically and send the information when their reference coordinate system within a certain range distance. Set the connection strength of the assembly parts to reflect the difficulty of its demolition, the connection strength of interference fit is bigger when the connection strength of clearance fit is smaller. Fig. 3(b) shows the routing connections and the set of node property.





(a) The display status of the reference coordinate system (b) The routing connections and the set of node property

Figure 3. The method of identify the parts assembly in place

2.2.3. Identify of constraint release between multi-dimensional constraints parts

During the assembly process, some error operation may need to dismantle the parts which have been assembled. The dismountability of the parts is due to the constraints and the force effect. Because of the mechanical effect is difficult to performance in virtual environment and the collision detection is not precise enough, constraint release of some multi-dimensional constraints parts is difficult to identify, such as the cover restricted by the bolts. If the time of taking the cover away is not suitable, it will result in the phenomenon that is contrary to the reality. In this case, the cumulate triggered of events method is adopted to recognize situation of constraints. By using Timesensor node and Counter node, the time of event detection is set and constraint release event of the parts is cumulated. The mission planning node will be touched off when the total number of trigger achieves the default value, then the parts can be dismantled. The set of the node property and routing connection are shown in Fig. 4.

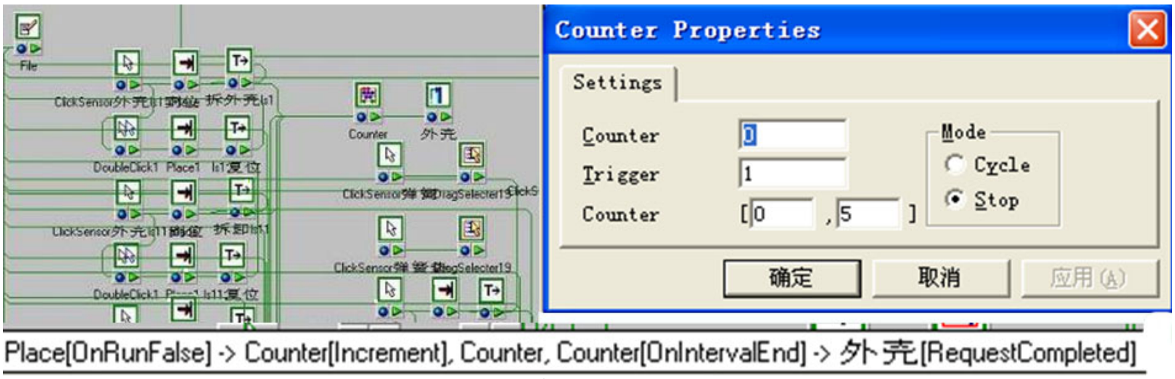


Figure 4. The set of connection routing and the property

2.3. The expression of technology standard in the assembly process

The assembly technology is related to the assembly quality directly, which is an important aspect in the assembly process. The assembly technology includes the selection of tools and equipments, testing methods, and the standard of tolerance matching ([4], [5], [6]). For example, the gap adjustment during assembly, which needs a reasonable choice for the detection adjustment tool to determine the gap adjustment range. Considering the characteristics of the desktop virtual maintenance, the method of using equipment is expressed by button options. The trainees confirm the method of using equipment by choosing the button, then the preset operation process simulation will be executed. The numerical range which the equipment should show, adopted the way of the image options，this method both image and ease of operation records and judge. Fig.5 shows the choices of spring scale review of active spiral bevel gear assembly for a certain type of vehicle.

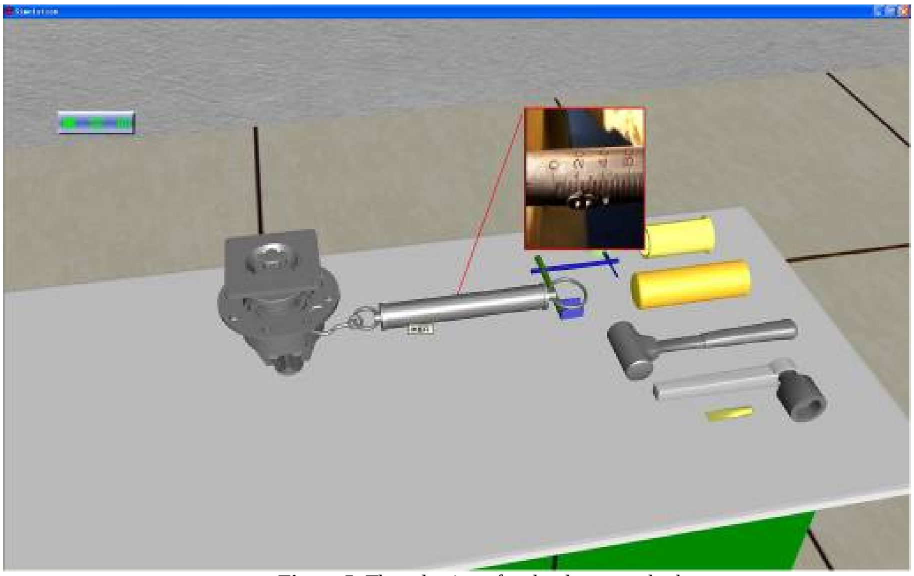


Figure 5. The selection of technology standards

3. Identification and recording of operating process

The record of the operating steps in a virtual environment is the basis to achieve training evaluation. The process of record-keeping includes catch trigger, identify the style of event, output the contents of event, read and store into the database. The principle of realization process is shown in Fig.6. Take the importance of different operating information into account, it is easy to identify and record the operation. On the one hand, only key events trigger of the interactive control is recorded. The key events include selecting the parts and tools, the choice of buttons and images, superposition of relative coordinate system. On the other hand, restrict the triggered style of the various operations, such as all of the selection operation using right click, draging parts and other persistent operating using left click, restoration of parts and tools using double right click. The message of operation will be sent to the TextSender node through the route when the key event is triggered. Then the TextSender node send a text which is pre-existed in node through TextOut domain. Create EON communication link with the external environment through program with the JScript scripting, then store the text into a preset Notepad ([5], [8], [9]). For the good compatible operational between the Delphi language and database, using the Delphi programming to partition the text string and store into the database. The form and content of the memory location is shown in Table.1.

Table 1. The storage format of operation

Coding of steps	Information of Operation object		Event Type	Time of occurrence
Step n	Name	Coding	Select / restoration / in place / redirection	Minutes: Seconds

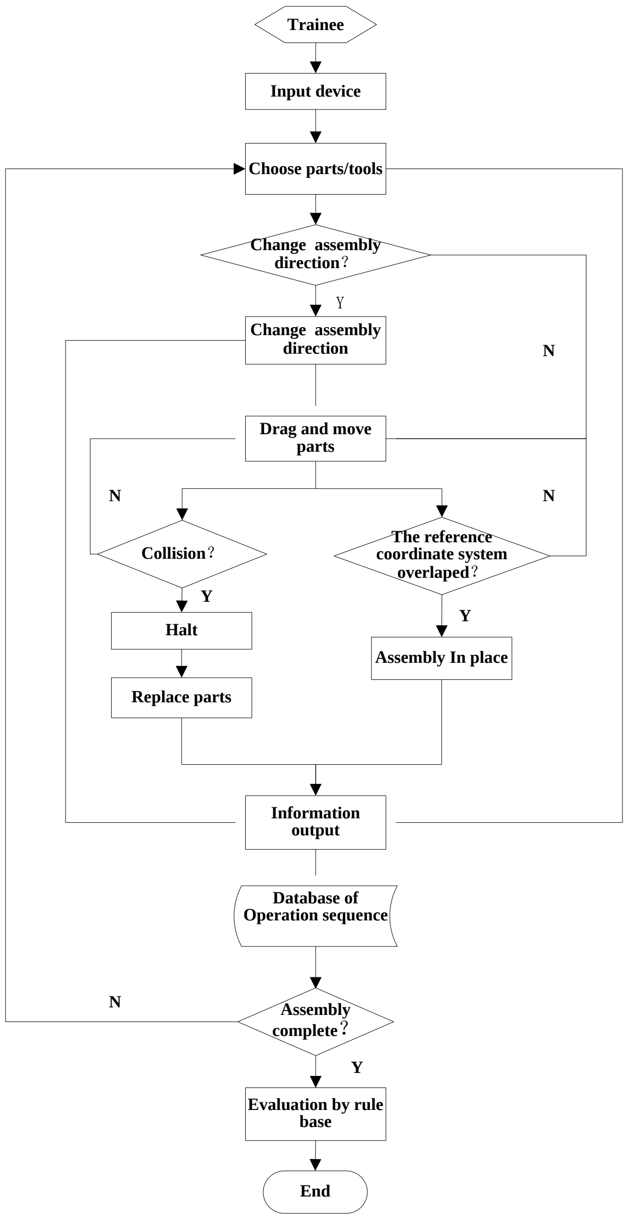


Figure 6. The principle of evaluation process

4. Database of the evaluation rules design based on expert knowledge

4.1. Infeasible assembly sequence recognition

Feasible assembly sequence showed exponential growth with the increase of the number of parts, it is difficult to enumerate, while infeasible assembly sequence can be described, therefore, we can judge the infeasible of operation by recognizing the infeasible assembly sequence. The most infeasible assembly sequence can be excluded by using collision detection and no coincide of the reference coordinate system. But the method may make mistakes in judgment of some adjacent assembly. So constraints adjacency matrix of parts is established as formula (1). For auxiliary judgment, when $a_i a_j$ =-1, the assembly sequence is infeasible. ([5], [6], [7])

$$
\begin{array}{c} \\ a_1 \\ a_2 \\ a_3 \\ \vdots \\ a_j \end{array}
\begin{array}{c}
\begin{array}{ccccc} a_1 & a_2 & a_3 & \cdots & a_i \end{array} \\
\begin{bmatrix}
0 & 1 & 1 & \cdots & 0 \\
-1 & 0 & 1 & \cdots & 0 \\
-1 & -1 & 0 & \cdots & -1 \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
0 & 0 & 1 & \cdots & 0
\end{bmatrix}
\end{array}
\qquad (1);
$$

$$
a_i a_j = \begin{cases}
1 & a_i \text{ adjacent to } a_j \text{, and } a_i \text{ should assembled before } a_j; \\
0 & a_i \text{ isn't adjacent to } a_j; \\
-1 & a_i \text{ adjacent to } a_j \text{, and } a_i \text{ should assembled after } a_j;
\end{cases}
$$

In order to improve the general-utility of evaluation methods and the normative of the rule base. The parts and pictures are numbered and classified as Table.2.

Table 2. The classification of parts

Classification	Description
A	The parts and technology standard which aren't important to the performance of the assembly parts
B	All the parts and technology standard other than ***A***
C	The parts which contains the most constraint relationships in the assembly unit (including sub-assembly)
$D_1 \ldots D_n$	The interchangeable parts which have the same function.
$E_1 \ldots E_n$	Sub-assembly unit

4.2 Design of evaluation rules

First, the quality of the assembly is the basic standard for operation evaluation, which reflects the technology level of assembly personnel directly. There are some factors affecting the assembly quality, such as whether the parts are assembled in place, the choice of assembly technology is right or wrong, etc. In the virtual environment, we also need to consider that whether the sequence of operations meet the constraints and mechanical reality. Second, the efficiency of assembly is also an important index of technical proficiency of trainees. Whether tools selection is reasonable, the change of assembly direction and type, all of these are important factors which affect the assembly efficiency. In consideration of all influencing factors, the rules of evaluation system are designed from five aspects, they are physical integrity of assembly, the assembly sequence of feasibility, the correctness of assembly technology, the redundancy of operation steps and time. The Table.3 shows that the common mistakes and their influence of assembly quality which is statistical researched from a number of experts.

Table 3. The Questionnaire about Assembly Situation

Classification of situation	Probability of occurrence	Degree of influence
Important parts haven't assembly in place	3	9
Unimportant parts haven't assembly in place	9	3
Parts mistakenly assembled	3	9
Assembly technology error	7	7
Tools or equipments selection error	5	5
Assembly steps and time redundancy	9	1

Description: 9: Prodigiouss; 7: Biggish; 5: Commonly; 3: Lesser; 1: Pimping.

The default total score of system is 100, and the results of the evaluation are divided into four types as follow: Skilled, *Score* ∈ [85,100]. Eligible, *Score* ∈ [65,85). Disqualification, *Score* ∈ [50, 65). Failed, *Score* ∈ [-∞, 50). According to the survey results from experts, the evaluation rules are as follows: ([4],[5], [10])

(1) If parts $a_i \in \{\boldsymbol{A}\}$, and a_i is not assembled in place at last, then *Score* = *Score*-10;

(2) If parts $a_i \in \{\boldsymbol{B}\}$, and a_i is not assembled in place at last, then *Score* = *Score* -40;

(3) If parts $a_i \in \{\boldsymbol{C}\}$, $a_i \in \{\boldsymbol{E_n}\}$, a_i *is assembled after* $\{\overline{E}_n\}$,then *Score*=*Score*-10;

(4) If *Step n*=a_i, *Step n*+*m*=a_j, $a_i a_j$=-1, then *Score*=*Score*-20;

(5) *Step n* is the choice of assembly technology standard, and the technology standard∈{***A***},if the choice is wrong, then *Score*=*Score*-15;

(6) *Step n* is the choice of assembly technology standard, and the technology standard∈{***B***}, if the choice is wrong, then *Score*=*Score*-30;

(7) If the choice of tool is wrong, then *Score*=*Score*-10;

(8) If the total number of standard operation steps are S_1, and practical operation steps of trainees are S_2, then *Score*=*Score*-$|S_2-S_1|/(0.02S_1)$;

(9) If the total length of standard operation time is T_1 *sec.*, and the total length of practical operation time of trainees is T_2 *sec.*, then *Score*= *Score*- $(T_2-T_1)/(0.04T_1)$;

When the sign of the last parts is assembled in place being sent out, system extract the record of operations from database, then send the record to the rule base for evaluating, and output the results at last. For the convenience of the trainees to review operations procedure real-time, in non-full screen mode, the steps are real-time displayed in the left list box. The interface of assembly evaluation system for a certain type of vehicle steering is shown in Fig. 7.

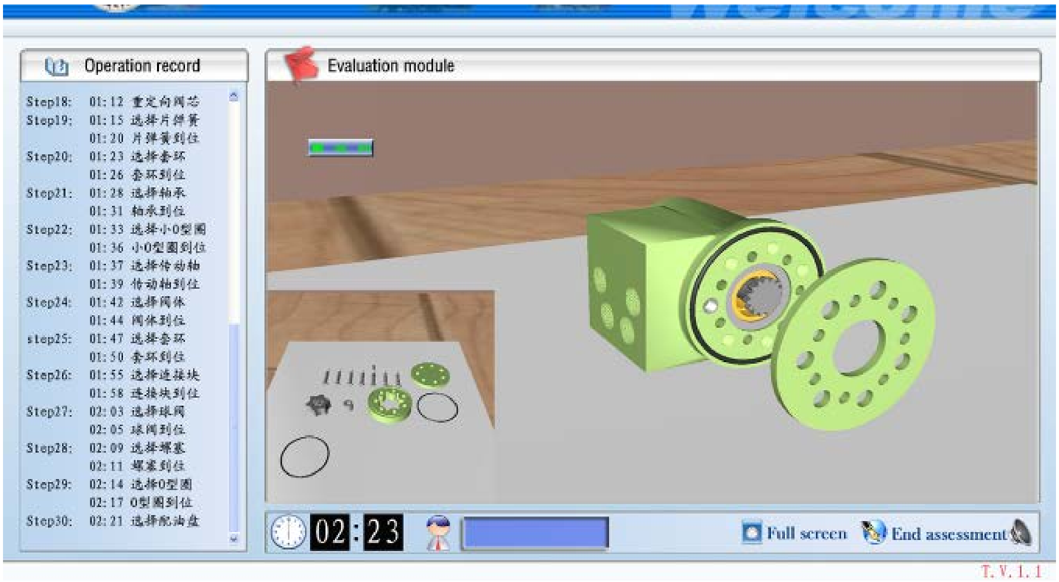


Figure 7. The interface of assembly evaluation system

5. Conclusion

On the basis of the virtual training system which is widely used, a virtual assembly operations evaluation system is designed. This system can realize the interaction between virtual assembly environment and trainees, and identify the operation of trainees by scanning the event trigger in virtual environment. The sequence of operations are recorded into database, and then sent to rules base which is constructed on expert knowledge, the evaluation process is realized after the output of results. The function of virtual assembly training system is further improved. Through applying to a mechanical vehicle virtual maintenance training system, whose efficiency is proved.

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