A virtual examination evaluation system design and implementation of equipment maintenance

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Abstract. This paper presents a design method of assessment system for equipment virtual maintenance training, introduces the framework of the system, the components of each module and the scoring basis of the assessment link, and puts forward the scoring weight ratio according to the characteristics of equipment. Finally, taking the equipment as an example, the virtual assessment system is implemented.

1. Design of assessment system framework
The virtual assessment system for a certain type of equipment maintenance mainly consists of three parts: input, maintenance assessment simulation and output, as shown in figure 1.

![Virtual assessment system framework](image_url)

**Figure 1. Virtual assessment system framework.**
1.1. Input part
It mainly deals with the command information issued by the examiners to the virtual maintenance simulation environment through the mouse keyboard and gamepad to control various events in the virtual maintenance environment.

1.2. Output part
Through the display, the information in the virtual environment such as disassembly, repair, maintenance and the operation process of examination and evaluation is fed back to the examiner, and the introduction of the whole machine and parts and the maintenance process information are provided for the personnel. The information of the examination process is output in the form of files, which is convenient for the personnel to analyze the virtual maintenance training process and effect.

1.3. Virtual assessment simulation part
This part is the core of the system, including the construction of virtual scene, assessment process planning and the realization of simulation interactive function. The establishment of 3d model and maintenance information database is the foundation of the whole system. The specific functions of each module of the system are as follows.

1.3.1. 3D modeling and maintenance information database establishment. The construction of 3d model is the foundation and key of virtual assessment system. Because the model usually USES precise mathematical form to express geometric information, which will make the calculation amount of virtual scene become large, so the model should be optimized in the process of model transformation. Through the establishment of virtual maintenance information database, various information about component structure, common faults and maintenance information can be stored to facilitate the study of personnel.

1.3.2. Construction of simulation scenarios. The construction of simulation scene is the basic work of virtual maintenance assessment simulation, which determines the sense of reality and immersion of the system. The construction of simulation scenario requires the following work: model loading, working environment setting, initial state of scenario model, etc.

1.3.3. Simulated interactive control. The setting of interactive functions of the virtual assessment system is a very important module of the whole software system. It mainly inputs information and instructions to the virtual maintenance environment through the mouse, keyboard and other components, and changes the state of various objects in the environment, such as the picking up of parts, perspective conversion and movement of parts.

1.3.4. Maintenance process planning. Maintenance process planning mainly includes virtual maintenance disassembly sequence planning, disassembly path planning, fault diagnosis and maintenance process simulation. In the process of component maintenance, the time of component disassembly occupies a large proportion in the whole maintenance operation. Obtaining the optimal disassembly sequence can greatly shorten the maintenance time.

2. Design of equipment examination system
In the assessment mode, the thinking assessment and assessment model of this project takes the error operand, fault type and other parameter information output by the maintenance assessment simulation module as input, and obtains the assessment results, so as to provide a basis for the comprehensive assessment of the training process. The specific method is as follows.

2.1. Determine evaluation object
The evaluation object is the maintenance training operation level of trainees.
2.2. Determine evaluation indicators
Considering the integrity of maintenance operations, the mastery and proficiency of maintenance procedures, the design evaluation indexes are: misoperation coefficient, troubleshooting coefficient, test time coefficient and difficulty level of fault types.

2.3. Determine individual performance indicators
According to each evaluation index, the corresponding training performance is given and a single evaluation index is obtained.

2.3.1. Misoperation coefficient
Wrong operation coefficient with $\eta_1$, said the number of wrong operation for $f$, allows for the greatest number of wrong operation for $f_{\text{max}}$.

$$\eta_1 = \begin{cases} 
1 - \frac{0.5f}{f_{\text{max}}}, & f \leq f_{\text{max}} \\
0, & f > f_{\text{max}} 
\end{cases}$$

This score is $S_1 = \lambda_1 \eta_1$. $\lambda_1$ is the weight of the malfunctioning index.

2.3.2. Troubleshooting coefficient
The troubleshooting coefficient is denoted by $R$

$$R = \begin{cases} 
1, & \text{Fault cleared} \\
0, & \text{Failure not eliminated} 
\end{cases}$$

This score is $S_2 = \lambda_2 R$. $\lambda_2$ is the weight of the troubleshooting index.

2.3.3. Test time coefficient
Test time coefficient using "$\eta_2$", said the system set the inspection time for "$T_{\text{specify}}$", actual time spent in the process of the assessment for "$T_{\text{actual}}$",

$$\eta_2 = \begin{cases} 
0, & T_{\text{actual}} > T_{\text{specify}} \\
1 - \frac{0.5T_{\text{actual}}}{T_{\text{specify}}}, & T_{\text{actual}} \leq T_{\text{specify}} 
\end{cases}$$

This score is $S_3 = \lambda_3 \eta_2$. $\lambda_3$ is the weight of the time indicator.

2.3.4. Difficulty level of fault type
The difficulty of fault type level with "$\eta_3$", said shall be formulated by the maintenance manuals. The higher the level, the higher the coefficient should be set.

This score is $S_4 = \lambda_4 \eta_3$. $\lambda_4$ is the weight of the failure type difficulty index.

2.4. Determine the weight
After determining the performance of a single assessment indicator, usually, not all assessment indicators are equally important to the assessment results. Therefore, it is also necessary to determine the weight of each indicator, which can be given by experts. This project adopts the three-scale method to estimate the weight of each evaluation index according to the idea of importance degree, that is, to estimate the relative importance of each index to reflect the importance degree of different indexes to the evaluation results. Three-scale method refers to pairwise comparison of index importance, and the mathematical description is as follows.

Step1: Establish the judgment matrix $C$

$$C_{ij} = \begin{cases} 
1, & \text{i index is more important than j index} \\
0, & \text{i index and j index are equally important} \\
-1, & \text{i is not as important as j} 
\end{cases} \quad \forall i, j$$

Step2: The optimal transfer matrix is obtained by calculating the judgment matrix
\[ d_{ij} = \frac{1}{M} \sum_{k=1}^{m} (c_{ik} + c_{jk}) \quad \forall i,j \text{ is the order of } C \]

Step 3: Find consistency matrix \( Q \)
\[ q_{ij} = \exp(d_{ij}) \quad \forall i,j \]

Step 4: The eigenvector corresponding to the maximum eigenvalue of \( Q \) is calculated, and then the eigenvector is normalized, and each component obtained is taken as the relative weight of each index. In the research topic, according to the pairwise comparison of the importance of evaluation indexes, the judgment matrix \( C \) is firstly obtained.

\[
C = \begin{bmatrix}
0 & -1 & 1 & 0 \\
1 & 0 & 1 & -1 \\
-1 & -1 & 0 & -1 \\
0 & 1 & 1 & 0
\end{bmatrix}
\]

\( Q \) is calculated successively.

\[
Q = \begin{bmatrix}
1 & e^{-0.25} & e^{0.75} & e^{-0.5} \\
e^{0.25} & 1 & e & e^{-0.25} \\
e^{-0.25} & e^{-1} & 1 & e^{-1.25} \\
e^{0.5} & e^{0.25} & e^{1.25} & 1
\end{bmatrix}
\]

Therefore, the weight is calculated as \( A = [0.1975, 0.1905, 0.2935, 0.3185] \), get \( \lambda_1 = 0.1975, \lambda_2 = 0.1905, \lambda_3 = 0.2935, \lambda_4 = 0.3185 \).

2.5. Determination of overall achievement
The comprehensive evaluation results are determined by weighting the results of a single evaluation index. \( S = S_1 + S_2 + S_3 + S_4 \)

3. Implementation of equipment assessment system
Taking a certain type of equipment as an example, the system conducts experiments on the operation, maintenance and other subjects of the personnel's equipment. The system effect is shown in figure 2.

![Image of equipment assessment system](image)

Figure 2. Implementation of virtual maintenance assessment system.

4. Conclusion
Through the design of equipment maintenance virtual assessment system, we solve the problem of personnel assessment standardization in virtual maintenance training. Equipment assessment personnel can complete the evaluation of training effect through the virtual simulation system, which greatly saves the loss of equipment and improves the efficiency of assessment.
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