Comprehensive Fuzzy Evaluation for Simulated Training of Aerial Mechanist

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Abstract. Performance evaluation is an important part of simulated training, and also a challenging project in the development of simulators for aerial mechanist training. In this paper, the evaluation method is explained in detail, and then the evaluation model is put forward, and finally the application of comprehensive fuzzy evaluation is discussed in this paper.

Keywords: Fuzzy evaluation, Simulated training, Mechanical engineering.

1. Introduction
Simulated training is an important way to improve the operational skills of aerial mechanists. The accuracy of evaluation directly affects trainees’ trust and enthusiasm for the simulator. Therefore, performance evaluation is very important, but it is also difficult because of its wide range and comprehensiveness. In addition, some evaluation points have multi-factorial, and multi-variate with fuzzy boundaries. Consequently, quantitative analysis won’t work. Based on the fuzzy mathematics, the simulated mathematical model of performance evaluation is established for the simulated training of aerial mechanists. This model has already been applied to the evaluation subsystem of X type aircraft training simulator and the evaluation result is reasonable and objective.

2. Basic Principle
Fuzzy evaluation based on fuzzy mathematics theory simulates the way the human brain processes fuzzy information, and employs the scientific cognitive method of “analysis-synthesis”, in which the evaluated object is decomposed into several evaluation factors, and then these factors are evaluated separately, after that a fuzzy evaluation vector is obtained for the factor, and finally, the comprehensive evaluation value is obtained by fuzzy transformation. The main process of fuzzy evaluation is:

(1) Evaluation factor set $U = \{u_1, u_2, \ldots, u_n\}$, where $u_i$ is the evaluation factor, and $n$ represents the number of individual factors on the same level, which constitutes the evaluation framework.

(2) Judgment set $V = \{v_1, v_2, \cdots, v_m\}$, where $v_j$ is the judgment scale, $m$ is the number of elements, that is, the grades or level of comments. This set defines the selection range of judgment in the evaluation. The elements $v_j$ can be either qualitative comments or quantitative scores.
(3) Judgment matrix \( R = \left( r_{ijr} \right)_{nm} \), where \( r_{ijr} \) is the membership degree of factor \( u_i \) to grade \( v_j \), and \( i = 1,2,\cdots,n \), \( j = 1,2,\cdots,m \). The row number of \( R \) is the number of evaluation factors, and its column number is the element number in the judgment set.

(4) Weight vector \( A = (a_1, a_2, \cdots, a_n) \), where \( a_i \) represents the importance of the factor \( u_i \) that is, the weight assigned, satisfying \( a_i > 0 \), \( a_1 + a_2 + \cdots + a_n = 1 \).

The combination of the weight vector \( A \) and the judgment matrix \( R \) is the result of the comprehensive evaluation of factors, namely the model:

\[
B = A \circ R = (b_1, b_2, \cdots, b_n)
\]

where \( b_j = \bigoplus_{k=1}^{n} (a_k \cdot r_{jk}) \), \( j = 1,2,\cdots,m \), here \( a \oplus b = \min \{a+b,1\} \).

The element in the vector is the result of the comprehensive evaluation of an object. The comparison among multiple objects can be realized by the maximum membership degree method or the comprehensive scoring method.

3. Establishment of Performance Evaluation Index System

3.1. Selecting Judging Factor Set

During the simulated training, the key performance indexes reflecting the operation level of trainees include operations in strict accordance with the operational procedures without accidents, handling emergencies correctly, skilled operations with high efficiency. What’s more, the trainees’ operation action, mental state and their sensitivity to environment are also in the evaluation categories. Therefore, three major evaluating factors are set up in the evaluation system, that is, operation quality, operation efficiency and teachers’ evaluation.

The operation quality score is mainly given on the occurrences of trainees’ mis-operations. Based on the particularity of simulated training for aerial mechanists and specific requirements, possible wrong operations occurred during the simulated training are further classified and simply processed according to “X Airplane Flight Manual”, “X Plane Special Situation Disposal Manual for Aerial Mechanist” and “X Aircraft Aerial Mechanist Training and Evaluation Outline”. The classifications are as follows:

1. Serious mis-operation. There are some mandatory rules in “Flight Manual” and “Special Situation Disposal Manual”. The operations stipulated by these rules are directly related to flight safety. When the operations are not carried out in accordance with the rules, it will inevitably lead to serious accidents.

2. Sub-serious mis-operation. It refers to the mis-operations that may cause damage to aircraft engine parts and other sub-serious accidents, although it will not lead to serious accidents in terms of flight safety.

3. Non-standard operation. It refers to the trainees are not skilled in operation. The trainees’ actions are slow and not standard.

4. General mis-operation. This kind of mis-operations generally won’t cause great damage to the relevant equipment or system, but it will cause certain impact, such as reducing the service life span of the equipment, and the control quality of related parameters. In the actual simulated training process, most of the error operations belong to this type.

5. Auxiliary operating error. During flight, such mis-operations will not cause great damage to related equipment and system, or even have no impact, but the operation sequence is not standard or there are redundant operations. The operation in the flight process should be standardized and perfect, and should be carried out in strict accordance with established relevant regulations. As long as there is any wrong operation, it will distract the attention of the crew and affect the confidence of the operators, thus reducing the operation level of the operators and increasing the probability of other wrong operations.
The operational efficiency score is mainly based on the time that trainees spend on completing the simulated training program. The standard time, as the benchmark, is determined according to the statistical experiment or experience. The evaluation value of the operation time is obtained after the actual operation time is compared with the standard time, and then the score of operation efficiency is achieved.

The former two items can be obtained from the operation record data and automatically evaluated, but the actual operation is also affected by such unmeasurable and undetectable factors as physical status, mental outlook and experience, therefore teachers’ evaluation is specially involved in the scoring system. The teachers’ evaluation is the score given by the teacher according to the trainees’ reaction to the event, the sensitivity to the status of the equipment, the reaction process, the proficiency of the operation, and the trainees’ tension and mental outlook in the whole process.

3.2. Determine Evaluation Index and Membership

The evaluation set is a description of each evaluation factor. This description forms a fuzzy mapping with the evaluation factors, divides the evaluation of each evaluation factor into several grades according to certain rules, and establishes the evaluation set. In the evaluation of this system, each index is determined to be four grades as excellent, good, qualified and unqualified. That is:

$$V = \{v_1, v_2, \ldots, v_n\} = \{\text{excellent, good, qualified, unqualified}\}$$ (2)

There are many methods to determine the degree of membership, for example statistical method, comparative average method, relative comparison method, priority relationship ordering method, tripartite method. Tripartite method is employed to determine the membership considering the characteristics of these methods and the convenience of their implementation. Firstly, the maximum value and minimum value (upper limit and lower limit) of the evaluation factor indexes in the simulated training are determined, and then each index system belonging to the range of excellent, good, qualified and unqualified is determined respectively by the tripartite method. On the basis of ensuring the accuracy, the interval division is carried out by using the triangular distribution principle of fuzzy distribution.

3.3. Establishment of Weight Set

It is necessary to assign certain weight to each factor in order to reflect influence of each factor index on training. The weight will exert a great influence on the final evaluation result during comprehensive evaluation. Different weights sometimes lead to completely different conclusions.

Considering the particularity of aerial mechanist training, some operational errors are subversive. Hence Delphi method (expert estimation method) is employed to determine the weight coefficient of each factor. According to the requirements of “Aerial Mechanist Training Program” for the aircraft, the expert reasonably determine the sequence of the weight coefficient for each index, which highlights the importance and rationality of the index coefficient.

4. Comprehensive Assessment of Performance Evaluation

According to the requirements of the training program and the actual situation of the simulated training, the simulated training of aerial mechanists is divided into three modules: airline flight, traffic pattern flight, and special situation (fault) identification and disposal training, which covers most of the specific training contents. For a specific subject training, its operation is multi-level, multi-faceted. Therefore, the evaluation should also start from the basic index at the bottom level, and then evaluation is carried out step by step, and finally the comprehensive evaluation of the whole simulated training process is fulfilled. Take traffic pattern flight evaluation module as an example to illustrate the performance evaluation.
During the training, the operation items are provided by the typical operation expert knowledge base stored in the Host, and the training simulator records the operation time and operating steps of the operators. For a single operation, the length of operation time, the number of operation errors and error types can be recorded. Statistics of flight training for a traffic pattern is shown in table 1.

Table 1. Statistics of Traffic Pattern Flight Training

| Operation Type                        | Number |
|--------------------------------------|--------|
| Number of serious mis-operation      | 0      |
| Number of sub-serious mis-operation  | 0      |
| Number of non-standard operation     | 2      |
| Number of general mis-operation      | 1      |
| Number of auxiliary operating errors | 2      |

4 teachers’ evaluation good; excellent; good; qualified

For the evaluation of “operation quality”, the evaluation matrix is as follows:

\[
R_1 = \begin{bmatrix}
0.20 & 0.50 & 0.30 & 0 \\
0.31 & 0.44 & 0.25 & 0 \\
0.19 & 0.38 & 0.42 & 0.01 \\
0.25 & 0.45 & 0.30 & 0 \\
0.22 & 0.59 & 0.19 & 0
\end{bmatrix}
\]

(3)

According to the expert scoring method, the weight relation of each factor is founded as follows:

\[
F_1 = [0.5, 0.3, 0.1, 0.08, 0.02]
\]

(4)

Fuzzy operator \( M(\cdot, \oplus) \) is employed to conduct the comprehensive evaluation for the operation quality in order to comprehensively consider the influence of various factors and comprehensively reflect the operation situation in the operation process. The normalized result is as follows:
The operation time is compared with the standard time to obtain the evaluation result. Standard time is defined for each specific operation item, and the evaluation result is automatically given by the system as follows:

\[ B_1 = F_1^* R_1 = \begin{bmatrix} 0.23 & 0.49 & 0.28 & 0 \end{bmatrix} \]  

(5)

For the teachers’ evaluation, the results obtained by the fuzzy statistics are as follows:

\[ B_2 = \begin{bmatrix} 0 & 0.25 & 0.5 & 0.25 \end{bmatrix} \]  

(6)

The evaluation matrix obtained is as follows:

\[ R_2 = \begin{bmatrix} 0.23 & 0.49 & 0.28 & 0 \\ 0 & 0.25 & 0.5 & 0.25 \\ 0.2 & 0.6 & 0.2 & 0 \end{bmatrix} \]  

(8)

For the comprehensive evaluation of the whole traffic pattern flight training, the importance degree of evaluation elements can be divided according to the evaluation of expert knowledge base as follows: the operation quality is very important, the teachers’ impression is important, and the control efficiency is general. Hence the weight coefficient matrix is obtained:

\[ F_2 = \begin{bmatrix} 0.5 & 0.3 & 0.2 \end{bmatrix} \]  

(9)

The comprehensive evaluation of operation quality is made by using fuzzy operator, and the normalized result is as follows:

\[ B = F_2^* R_2 = \begin{bmatrix} 0.16 & 0.44 & 0.33 & 0.07 \end{bmatrix} \]  

(10)

According to the principle of maximum membership, the final evaluation result of this subject training can be judged to be good.

5. Conclusion

Two times of fuzzy evaluation are adopted to evaluate the operation quality and the final result respectively, which can highlight the importance of operational elements. Training result of the subject can be obtained. Also, the quality level of the operators at the same grade can be given according to the distribution of membership degree. This method has been employed to evaluate the simulated training of more than 40 aerial mechanists for more than 120 times, and evaluation results are recognized by trainees and instructors. It has proved that the evaluation method is in line with the actual situation, and can improve the training level of trainers. In a word it has a good application value.

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