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On Exploring Method and Software for Evaluating Effectiveness of Military Training Aircraft

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Abstract

The evaluation of training effectiveness (TE) of military training aircraft, though obviously very important, appears to have attracted much less attention than what it deserves in the open literature. This article aims to start from previous studies and explore further. First, TE of military training aircraft is discussed and our ideas for evaluating TE which are expressed mathematically are proposed. Then, using the presented mathematical models, software is developed that takes into consideration the influence of parameters of flight performance and quality on TE. The software's environment is Borland C++ and it sets up the parameters of trainer, training standard databases and training documents; it can analyze and then give the operational cost and cost-effectiveness ratio of military trainer. Finally, the software is utilized to compare the TEs of HAWK and MB339 with that of Chinese Air Force TF-6. The results of comparison show that the TE of TF-6 is the lowest.

Keywords: flight vehicle design; training aircraft; training effectiveness analysis; cost-effectiveness ratio; military aircraft; software design

1. Introduction

The main function of military training aircraft is very different from that of general fighter. As the main equipment for training the fresh airmen to be skillful pilots as soon as possible, military training aircraft rarely takes part in air combat directly or is in charge of air-to-ground attacking tasks[1]. Therefore, we cannot evaluate its training effectiveness (TE) by the methods which are used to evaluate the effectiveness of general fighter planes. Generally, air force expects the highest effectiveness during the process of training the pilots. Therefore it is necessary to bring forward a new concept of "training effectiveness". So far, there has been no explicit definition for it. In this article, we assume that the "training effectiveness" means the efficiency and capability of military training aircraft. Then, we can use this concept to evaluate the effectiveness in the training of pilots.

It is remarkable that in practice, the quality of a skillful pilot is also largely associated with other factors which include the training system, goal and facility of different countries, trainer's level, students' own quality, etc.[2]. It is common that the qualities of pilots from different countries trained by the same training aircraft differ greatly[3]. On the basis of Refs.[1]-[2], this article discusses a method for evaluating the effectiveness of military training aircraft and gives a more explicit mathematical description. To simplify the problem, the concept of TE here is limited to interior comparison in the same air force, ignoring the effect of some exterior factors mentioned above. We assume that those factors have the same effect on different kinds of compared training aircraft.

2. Mathematical Model for Evaluating Effectiveness of Military Training Aircraft

The so-called evaluation includes the following two steps: single criterion scoring and comprehensive scoring.

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2.1. Single criterion scoring

The mathematical formula of single criterion scoring is

$$\boldsymbol{S} = f(\boldsymbol{R}, \boldsymbol{T}, \boldsymbol{X}) \tag{1}$$

where $\boldsymbol{S}$ is the single criterion score matrix which contains scores of the n criteria, $n\times1$ dimension; $\boldsymbol{R}$ the requirement matrix which contains desired values of the n criteria, $n\times1$ dimension; $\boldsymbol{T}$ the sensitivity matrix which contains the upper bounds and the lower bounds of desired values of the criterion, $n\times2$ dimension; $\boldsymbol{X}$ the input matrix which contains actual values listed by criteria, $n\times1$ dimension; f the scoring function. If trainer data do not exceed the bounds that are set by desired values, i.e., upper bounds and lower bounds, score 8, 9 or 10 will be the function's linear result according to the magnitude of the error. Otherwise, the score will be decreased in the same way unless it is less than the lowest score 1. The algorithm is as follows:

$$s_i = \begin{cases} -2(x_i - r_i)/t_{i1} + 10 & 4.5t_{i1} + r_i \ge x_i \ge r_i \\ 2(x_i - r_i)/t_{i2} + 10 & -4.5t_{i2} + r_i \le x_i \le r_i \\ 1 & x_i < -4.5t_{i2} + r_i, x_i > 4.5t_{i1} + r_i \end{cases}$$
$$i = 1, 2, \cdots, n \tag{2}$$

where x_i, r_i, s_i are the ith row data of matrixes $\boldsymbol{X}$, $\boldsymbol{R}$ and $\boldsymbol{S}$ respectively; t_{i1}, t_{i2} are the ith row, 1st column data and the ith row, 2nd column data of matrix T respectively; t_{i1} and t_{i2} are the correlative upper bound and the lower bound of the error and are greater than zero here. Fig.1 illustrates the chart of this algorithm.

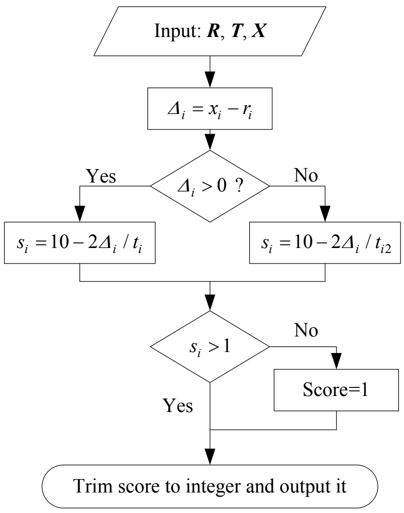

Fig.1 Chart of single criteria scoring.

2.2. Comprehensive scoring

The mathematical formula of comprehensive scoring is

$$T_{\mathrm{EV}} = (\boldsymbol{S} \times \boldsymbol{W}) \times \boldsymbol{F} \tag{3}$$

where T_{EV} is the TE value, $\boldsymbol{W}$ the weighting matrix of $n\times m$ dimensions which contains the weighting values showing the importance of the selected criteria in different training tasks, $\boldsymbol{F}$ the frequency matrix which contains the training task frequency in a certain training phase. It is noticeable that comparison of TE values of trainers can only be made with the same criteria and training plan, and the TE value does not have any practical meaning unless a comparison is made[4-6].

Fig.2 below illustrates the evaluating process of TE.

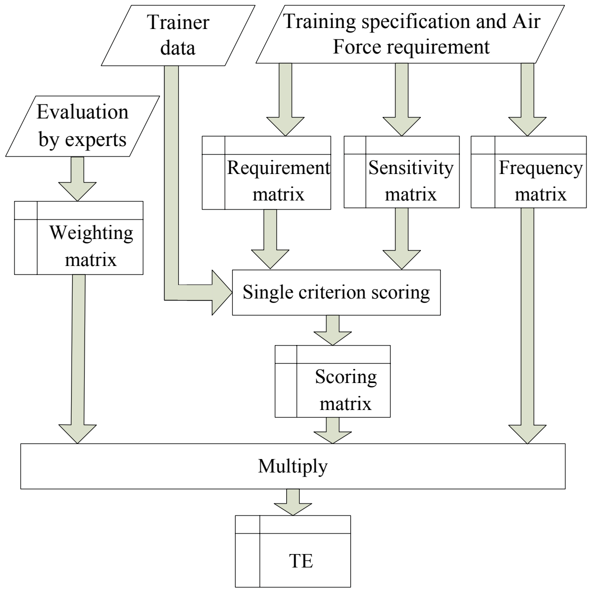

Fig.2 TE evaluating process.

3. Illustrations of Evaluating Method in Practice

The key idea of this evaluating method is that users choose the important flight parameters or factors of trainer as the criteria, and then set ideal requirement values (matrix $\boldsymbol{R}$) and the bound of error (matrix $\boldsymbol{T}$) according to actual cases and experience. Every single criterion's score varies from 1 to 10 as shown in Eqs.(1)-(2). Users set appropriate weighting factors (0-3) for flight parameters according to the importance of the selected criteria during each certain training phase and task with experts' advice. The sum of weighted scores shown by $\boldsymbol{S}\times\boldsymbol{W}$ in Eq.(3) is the comprehensive score of the trainer in certain training task. As the training task frequency differs in training phases, users can get the final score by multiplying the scores of every training task with their frequencies (as $\boldsymbol{F}$ in Eq.(3)) of training respectively.

In addition, we should understand exactly the meaning of the following matrixes of factors and the TE value during the evaluating process.

3.1. Requirement matrix R

$\boldsymbol{R}$ contains desired values of every criterion closely