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Evaluation for Parachute Operator Reliability Based on Fuzzy CREAM

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***Abstract*—It is important to evaluate the reliability of parachute operators before implementing the airborne mission to improve the mission completion rate and ensure the safety of personnel. This paper draws on the cognitive reliability and error analysis method (CREAM), and establishes a quantitative model of human reliability based on fuzzy CREAM for the CREAM model in which the common performance condition (CPC) describes the horizontal boundary is not obvious and the error probability interval is wide. Firstly, the CPCs of the CREAM model are modified according to the characteristics of the airborne operation, and the threshold of the performance evaluation index is clarified. Secondly, the common performance evaluation index is quantified based on the Gaussian function, and the weight of the index is assigned; Third, defuzzify the probability of error and calculate the probability of human error. The analysis of the example shows that the method considers the individual, equipment, mission, environment, organization and other factors, and has certain objectivity. It can be used for the reliability assessment of parachute operators before the mission, reducing the incidence of human error. It can also be used for reliability analysis of personnel operations in parachute system reliability assessment.**

Keywords—parachute; human reliability analysis; cognitive reliability and error analysis method; fuzzy theory; common performance condition

I. INTRODUCTION

Any weapon system is a typical human-machine system, and the operator reliability is an important part of the reliability of the weapon system. According to historical data, about 60% of airborne accidents are related to human error. Therefore, it is important to evaluate the reliability of parachute operators before implementing the airborne mission to improve the mission completion rate and ensure the safety of operators. Cognitive Reliability and Error Analysis Method (CREAM) is one of the most representative methods of second-generation human factor reliability analysis proposed by HOLLNAGEL in 1998 [1-3]. It emphasizes that human behavior is not an isolated random behavior, but rather an environment in which the mission is completed. The CREAM model determines the expected effect of each CPC on performance reliability by quantifying the environment in which people are located, and then analyzes the control mode of people in this environment. Finally, the prediction of human reliability is realized.

This paper draws on the cognitive reliability and error analysis method (CREAM), and establishes a quantitative analysis model for the human factor reliability of parachute operators based on fuzzy CREAM model in view of that CREAM model has no obvious horizontal boundary and large error probability interval. The method comprehensively considers a number of factors such as individual, equipment, mission, environment, organization, etc., and has certain objectivity. It can be used for reliability assessment of parachute operators before the mission, reducing the incidence of human error. It can also be used for reliability analysis of personnel operations in parachute system reliability assessment.

II. CREAM MODEL AND COMMON PERFORMANCE CONDITIONS

Common performance condition(CPC) refers to the environment and working conditions when people complete tasks in CREAM model. It is summarized into 9 items [4,5]: organizational integrity, working conditions, man-machine interface and operational support, and planning availability. Simultaneous target number, available time, working time zone (physiological rhythm), full training and experience, and the quality of team members' cooperation. However, the CREAM model only provides a simple qualitative description of the CPC, and does not provide specific evaluation criteria. The actual operation is subjective; and the CREAM method is originally used in the nuclear industry. Different application environments have different CPC requirements. In order to describe the characteristics of the airborne operation accurately, we have adjusted the CPC.

From the perspective of man-machine interaction process, airborne operators usually need to operate the system to complete the corresponding missions in a certain organizational atmosphere and physical environment. In this process, individuals, equipment, missions, environment, organization effects on each other. Based on the historical data, we summarized the airborne operation CPC. To simplify the model, the threshold range of the CPC evaluation index is taken as (0,100), see Table I, and the CPC is divided into satisfactory, lower satisfactory, acceptable, and dissatisfied, used to reflect the expected effect of reliability, see Table II.

III. CREAM MODEL FUZZY IMPROVEMENT

A. Fuzzy Membership Function

In [6], by comparing the effects of triangle, normal and trapezoidal distribution on the results of human reliability analysis, it is considered that the normal distribution can more accurately reflect the actual situation. Therefore, the Gaussian membership function is used for fuzzification:

$$f(x)=\exp(-\frac{(x-\mu)^2}{2\sigma^2}) \tag{1}$$

where, μ is the mean, σ is the std.

TABLE I. CPCS OF PARACHUTE OPERATORS

No	CPC	Indicator	Description	Fuzzy
1	Individual	Psych.	Indiv. stress , etc.	(0,100)
2		Physi.	Physi. fitness, strength, endurance, etc.	(0,100)
3		Percep. ability	Auditory, visual, sensory, etc.	(0,100)
4		Skill quality	Work experience, skills and qualities	(0,100)
5		Emer. capab.	Response to emergencies, processing capacity	(0,100)
6	Equipment	Man-machine design	Are there any defects in the design of human-machines that affect safe operation?	(0,100)
7		Tech. status	Is the technical status good?	(0,100)
8		Folding standard	Is the folding strict?	(0,100)
9		Safety signs	Is the equipment safety logo complete and clear?	(0,100)
10	Mission	Ample time	Adequacy of available time	(0,100)
11		Difficulty	Operational complexity	(0,100)
12		Staffing	Guarantee the rationality of personnel arrangements	(0,100)
13	Environment	Natural environment	Bad weather such as rain and snow	(0,100)
14		Working condition	The favorable level of the two environmental conditions	(0,100)
15		live situation	Are the two configuration elements complete?	(0,100)
16		Team cooper.	Whether the team cooperation is close	(0,100)
17	Organization	Institu. requirements	Whether the relevant plans are perfect and implemented	(0,100)
18		safe education	Safety education and training, risk assessment	(0,100)
19		Safety concept	Safety culture	(0,100)
20		Job management	Whether the work process complies	(0,100)

TABLE II. RELATIONSHIP BETWEEN CPCS AND RELIABILITY OF PARACHUTE OPERATORS

CPC	Reliability
satisfaction	Optimal
Low satisfied	Not obvious
Acceptable	Not obvious
Not satisfied	lower

According to formula (1) and Table I, the parameters of the parameters μ and σ are determined by fitting, and the membership function of each CPC evaluation index is obtained. Taking "technical status" as an example, the fuzzy set of "technical status" is divided into four by Gaussian membership function, which are satisfactory, satisfactory, acceptable and unsatisfactory:

$$\begin{cases} f_1(x)=\exp\left(-\dfrac{(x-0)^2}{2\times 18^2}\right) & x\in[0,30] \\ f_2(x)=\exp\left(-\dfrac{(x-40)^2}{2\times 18^2}\right) & x\in[10,70] \\ f_3(x)=\exp\left(-\dfrac{(x-60)^2}{2\times 18^2}\right) & x\in[30,90] \\ f_4(x)=\exp\left(-\dfrac{(x-100)^2}{2\times 18^2}\right) & x\in[70,100] \end{cases} \tag{2}$$

Where, f_1, f_2, f_3, f_4 are the 4 types of technical status membership degrees, and x is the "technical status" evaluation value.

CREAM is a complete cognitive model that depends on how human control his behavior in a particular environment. This level of control can be divided into 4 control modes, namely, strategic, tactical, opportunistic and chaotic [7]. At the same time, each type of control mode corresponds to a human error probability interval, as shown in Table III.

TABLE III. CONTROL MODEL AND HUMAN ERROR PROBABILITY

Control Model	human error probability
Strategic	$(5\times10^{-5},1\times10^{-2})$
Tactical	$(1\times10^{-3},1\times10^{-1})$
Opportunity	$(1\times10^{-2},0.5)$
Chaotic	$(1\times10^{-1},1)$

In order to solve the problem of overlapping in probability of the adjacent control mode, the logarithm of the error probability of the control mode is taken.

$$\begin{cases} Z_1(p)=\exp\left(-\dfrac{(p-0.5)^2}{2\times 0.3^2}\right) & p\in[-1.0,0] \\ Z_2(p)=\exp\left(-\dfrac{(x-(-1.15))^2}{2\times 0.51^2}\right) & p\in[-2.0,-0.3] \\ Z_3(p)=\exp\left(-\dfrac{(p-(-2.0))^2}{2\times 0.6^2}\right) & p\in[-3.0,-1.0] \\ Z_4(p)=\exp\left(-\dfrac{(p-(-3.5))^2}{2\times 0.9^2}\right) & p\in[-5.0,-2.0] \end{cases} \tag{3}$$

B. Membership Quantization and Weight Assignment

Quantify the various CPC evaluation indicators, and obtain the membership matrix of CPC evaluation indicators.

$$(\lambda_{ij})_{m\times n} = \begin{bmatrix} \lambda_{11} & \lambda_{12} & \lambda_{13} & \cdots & \lambda_{1n} \\ \lambda_{21} & \lambda_{22} & \lambda_{23} & \cdots & \lambda_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \lambda_{m1} & \lambda_{m2} & \lambda_{m3} & \cdots & \lambda_{mn} \end{bmatrix} \tag{4}$$

Where λ_{ij} is the degree, $i = 1,2,\cdots,m$, $j = 1,2,\cdots,n$

Using the relevant theory, calculate the weight of each CPC index in the membership matrix[8]:

$$e_i = 1 + \frac{1}{\ln n}\sum_{j=1}^{n}\lambda_{ij}\ln\lambda_{ij} \tag{5}$$

$$w_i = e_i \Big/ \sum_{i=1}^{m} e_i \tag{6}$$

Where e_i is the entropy of the i item of CPC evaluation indicators, and w_i is the weight of the i item of CPC evaluation indicators.

C. Defuzzification Error Probability

In order to accurately calculate the probability of human error, the degree of membership of the 4 control modes obtained in B is defuzzified. Considering the case of less membership, the center of gravity method is used [9]:

$$P = \frac{\int Z(p)pdp}{\int Z(p)dp} \tag{7}$$

IV. CASE ANALYSIS

In order to evaluate the reliability of operator A's human factors, the scores of the CPC evaluation indicators of Table I are brought into equation (2), and the membership degree of each CPC index is calculated, as shown in Table IV.

TABLE IV. CPCS OF PARACHUTE OPERATOR A

CPCs	*f1*	*f2*	*f3*	*f4*
A1	0.0000	0.0000	0.1258	0.8742
A2	0.0000	0.0000	0.0000	1.0000
A3	0.0000	0.0000	0.2894	0.7106
A4	0.0000	0.0000	0.3589	0.6411
A5	0.0000	0.0000	0.8201	0.1799
A6	0.0000	0.0000	0.2115	0.7885

TABLE IV CONTINUE

A7	0.0000	0.0000	0.3011	0.6989
A8	0.0000	0.0000	0.7586	0.2414
A9	0.0000	0.0000	0.3247	0.6753
A10	0.0000	0.0000	0.5881	0.4119
A11	0.0000	0.0000	0.6875	0.3125
A12	0.0000	0.0000	0.4103	0.5897
A13	0.0000	0.0000	0.5142	0.4858
A14	0.0000	0.0000	0.7201	0.2799
A15	0.0000	0.0000	0.3430	0.6570
A16	0.0000	0.0000	0.1887	0.8113
A17	0.0000	0.0000	0.4625	0.5375
A18	0.0000	0.0000	0.5531	0.4469
A19	0.0000	0.0000	0.2855	0.7145
A20	0.0000	0.0000	0.4652	0.5348

According to formula (3)-(6), the degrees are quantified, and the weights of the 4 control modes are calculated. According to formula (7), the probability of human error due to A airborne operation is calculated as P=0.0013. Therefore, the reliability of A is 98.77%.

V. CONCLUSION

In order to evaluate the reliability of parachute operators, this paper builds a fuzzy analysis model based on fuzzy CREAM model for humane reliability based on cognitive reliability and error analysis (CREAM). Firstly, the CPCs of the CREAM model are modified according to the characteristics of the airborne operation, and the threshold of the performance evaluation index is clarified. Secondly, the common performance evaluation index is quantified based on the Gaussian function, and the weight of the index is assigned; Third, defuzzify the probability of error and calculate the probability of human error. Through the analysis of the probability of operator A's human error, the probability of human error due to airborne operation is calculated as P=0.0013, that is, the reliability of human factors is 99.87%. The method comprehensively considers a number of factors such as individual, equipment, mission, environment, organization, etc.. The research results can be used for the reliability assessment of parachute operators before the mission to reduce the incidence of human error. It can also be used for reliability analysis of personnel operations in parachute system reliability assessment.

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