Advanced Science and Technology Letters
Vol.53 (ICM 2014), pp.249-254
http://dx.doi.org/10.14257/astl.2014.53.52

Landing Risk Assessment of Carrier-Based Aircraft Based on Fuzzy Multi-Attribute Group Decision Making

Hai-tao Jiang, Hui Li, Xiao-dong Su

School of Computer and Information Engineering, Harbin University of Commerce
Harbin 150001, Heilongjiang, China
{Hui Li, hrbcu_lh@163.com}

Abstract. In allusion to the special characteristic of longitudinal loop risk assessment in landing process of carrier-based aircraft, this paper extends the concept of decision-maker, and proposes a method of fuzzy multi-attribute decision making with normal fuzzy linguistic variables as decision-making information. Based on the establishment of carrier-based aircraft landing model, the expressions of risk evaluation indicators are ensured, and the relative attribute weight is calculated by the simulation of the safe flight area in landing process. The application of risk assessment is implemented by analogy between standard points and decision-maker. The analysis of numerical examples shows that the method is practical and the application in risk evaluation is reasonable. Multipoint decision information is complete and decision results accord with distributions of touchdown points. Comprehensive evaluation of flight safety with different pilots can be realized.

Keywords: Normal Fuzzy Number; Multi-Attribute Group Decision Making; Safe Flight Area; Relative Attribute Weight; Landing Risk Assessment

1 Introduction

Multi-attribute group decision making utilizes attribute information and attribute weights in advance to order and pick out the best one for a group limited alternatives [1-2]. As the complexity and fuzziness of objects in real, we always express decision information as linguistic variables or intervals [3]. Multi-attribute group decision making based on linguistic variables has been the research focus in decision making domain [4-8].

To solve the landing risk evaluation problem of carrier-based aircraft, we first present a brief problem description for risk assessment. The normal fuzzy linguistic variables is expressed for decision making, and a developed approach to solve multi-attribute decision making for landing risk is extended. An illustrative example is shown for proving the rationality of new decision method.

ISSN: 2287-1233 ASTL

2 Problem Description

During landing process, the flight status of carrier-based aircraft should be guided by Landing Signal Officer (LSO) [10]. LSO, pilot and aircraft constitute a whole landing control system, as shown in Fig.1. After catching cable, LSO describes light result from positions and gestures to evaluate operation capability [9, 11].

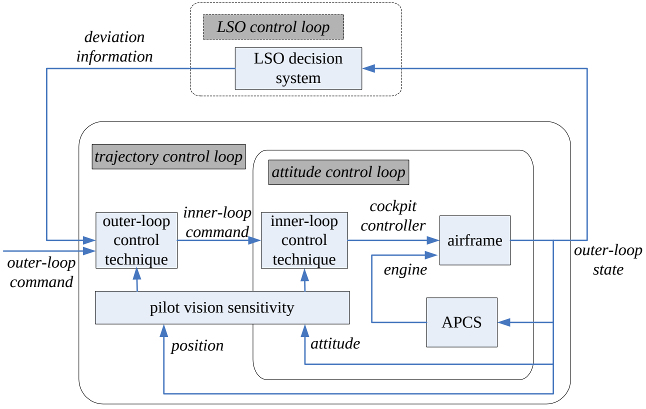

Fig. 1. LSO-pilot-aircraft guidance system

We know it is difficult to compare different pilots operation capabilities during the whole approach, and bring a convenience to comprehensive evaluation [12].

3 Normal Fuzzy Linguistic Variables

Definition 1. Let $\hat{s}_\theta = [x_\theta, \sigma_\theta]$ is normal fuzzy linguistic variable, as shown in Fig.2, where membership function $\mu_{\hat{s}_\theta}(x): R \to [0,1]$ is [13-15]

$$\mu_{\hat{s}_\theta}(x) = e^{-(\frac{x-x_\theta}{\sigma_\theta})} \quad (\sigma_\theta > 0). \tag{1}$$

Where $\hat{s}_\theta \in \hat{S}$, x_θ and σ_θ are the expect and variance of normal fuzzy linguistic variable respectively [16].

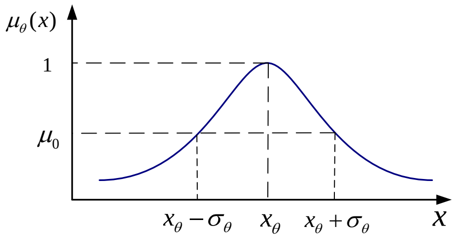

Fig. 2. Normal fuzzy linguistic variables

Definition 2. Let $\hat{s}_1=[x_{\theta_1},\sigma_{\theta_1}]$ and $\hat{s}_2=[x_{\theta_2},\sigma_{\theta_2}]$ are two normal fuzzy linguistic variable,, the possibility degree $p(\hat{s}_1 \geq \hat{s}_2)$ of normal fuzzy linguistic variable $\hat{s}_1 \geq \hat{s}_2$ by 3 σ law is

$$p(\hat{s}_1 \geq \hat{s}_2)=\max\{1-\max(\frac{\hat{s}_2^+-\hat{s}_1^-}{l_2+l_1},0),0\} \quad . \tag{2}$$

Where $\begin{cases} \hat{s}_i^+ = x_{\theta_i}+2.58\sigma_{\theta_i} \\ \hat{s}_i^- = x_{\theta_i}-2.58\sigma_{\theta_i} \\ l_i=\hat{s}_i^+-\hat{s}_i^- \end{cases}$ (i=1,2).

4 Landing Risk Evaluation Based on Fuzzy Multi-Attribute Group Decision Making

The step of landing risk evaluation based on fuzzy multi-attribute group decision making are:

(1) For one multi-attribute group decision making problem, let $\boldsymbol{X}=\{x_1,x_2,\ldots x_m\}$ be a discrete set of m feasible alternatives, $\boldsymbol{U}=\{u_1,u_2,\ldots u_n\}$ is a finite set of attributes, and $\boldsymbol{D}=\{d_1,d_2,\ldots d_k\}$ is a set of decision makers. Construct $\boldsymbol{R_k}=(r_{ij}^{(k)})_{m\times n}$ a decision matrix.

(2) Utilize the NFLWA operator to aggregate the attribute value $r_{ij}^{(1)}$ in the ith column of the decision matrix $\boldsymbol{R}_1$ into a overall attribute value of the alternative x_i (i=1,2,…,m):

$$r_i^{(k)}=\mathrm{NFLWA}_{\boldsymbol{\omega}^{(k)}}(r_{i1}^{(k)},\ldots,r_{in}^{(k)})=\omega_1^{(k)}r_{i1}^{(k)}+\ldots+\omega_n^{(k)}r_{in}^{(k)} \Big(i\in M \;, \; k=1,2,3,4\Big). \tag{3}$$

(3) Use the NFLWA operator to aggregate the attribute value $r_i^{(k)}(i \in M, k = 1,2,3,4)$ of the four standard positions into a overall attribute value of the alternative x_i (i=1,2,…,m):

$$r_i = \mathrm{NFLWA}_{\boldsymbol{\omega}}(r_i^{(1)},...,r_i^{(4)}) = \omega_1 r_i^{(1)} + ... + \omega_4 r_i^{(4)} \quad (i \in M). \tag{4}$$

(4) Compare each $r_i(i \in M)$ by using the possibility-degree formula(2), then construct the possibility-degree matrix $\boldsymbol{P}^{(1)} = (p_{ij}^{(1)})_{m \times m}$.

(5) The ordering vector $\boldsymbol{\omega}^{\boldsymbol{P}} = (\omega_1^P, \omega_2^P, ...\omega_m^P)^{\mathrm{T}}$

(6) Reorder r_i (i=1,2,…,m) in descending order in accordance with $\omega_i^P (i \in M)$. Then we can rank all the alternatives x_i and select the most desirable one in accordance with the value of r_i .

5 Simulation

Aircraft landing process is simulated for five times. The flight states of landing process are indicated in Fig.3-5, and final distributions of touchdown points are shown in Fig.6. Finally, the landing risk are evaluated.

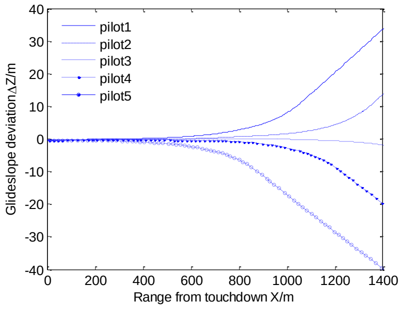

Fig. 3. Glideslope deviations curves

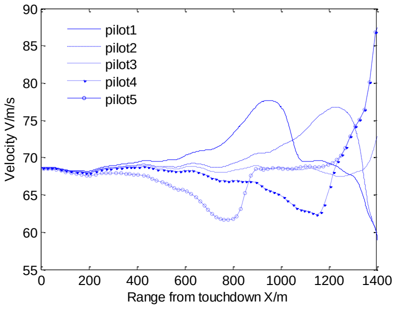

Fig. 4. Speed curves

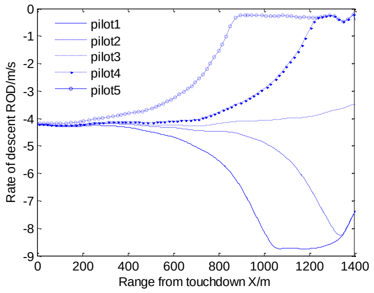

Fig. 5. ROD family of curves

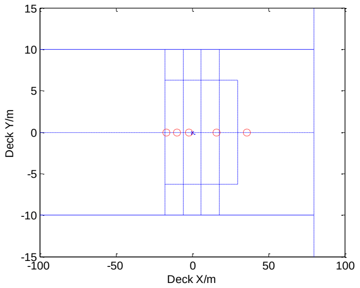

Fig. 6. Distributions of touchdown points

Ordering vector:

$$\omega^{P} = (0.166405, 0.23374, 0.28477, 0.18145, 0.133635)^{\mathrm{T}}$$

Rank all the alternatives r_i in accordance with the values of ω^{P}. We can see that the ranking order is:

$$r_3 > r_2 > r_4 > r_1 > r_5$$

The decision result shows that the landing risk of group 3 is the least. Comparing with Figure 6, correspondingly the touchdown point locates between the second cable and the third one, and it is closest to the desired touchdown, however, other voyages points distributions are far from the desired one, and the decision risk is increased. The decision result equates with the distributions of touchdown points, and it proves the practicality of this decision method.

6 Conclusion

This paper has presented possibility-degree algorithm of normal fuzzy variable, and introduced an improved multi-attribute group decision making approach. After establishing LSO-pilot-carrier-based aircraft model, it has built Safe Flight Area, and get relative attribute weighted vector. At last normal fuzzy multi-attribute group decision making has an application in landing risk evaluation of carrier-based aircraft. Simulation results show that the reasonable and application of the new algorithm.

References

1. Thomas Rudowsky, Stephen Cook, Marshall Hynes, etal. Review of the carrier approach criteria for carrier-based aircraft. Techinical report NAWCADPAX/TR-2002/71, (2002).
2. Xu Zeshui, Da Qingli. Multi-attribute decision making based on fuzzy linguistic assessments. Journal of Southeast University (Natural Science Edition), 32(4): 1-3, (2002)
3. Han Zuosheng, Liu Peide. Multiple attribute decision making method based on trapezoid fuzzy linguistic variables. Fuzzy Systems and Mathematics, 25(3): 119-126. (2011)
4. Herrera F, Martinez L. An approach for combing numerical and linguistic information based on the 2-tuple fuzzy linguistic representation model in decision making. International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, 8:539-562. (2000)
5. Li D F, Yang J B. Fuzzy liner programming technique for multi-attribute group decision making in fuzzy environments. Information Sciences, 158: 263-275. (2004)
6. Xu Z. Group decision making with triangular fuzzy linguistic variables //IDEAL 2007, LNCS, 4881:17-26. (2007)
7. Liang Xuechun, Chen Senfa. Multiple attribute decision making method based on trapezoid fuzzy linguistic variables. Journal of Southeast University(English Edition), 24(4),478-481. (2008)
8. Liu P, Yu s. The extended TOPSIS based on trapezoid fuzzy linguistic variables. Journal of Convergence Information Technology, 5(4):38-53. (2010)
9. Robert K. Heffley. Outer-loop control factor for carrier aircraft.USA. (1990)

10. R A Hess. Simplified Approach for modeling pilot pursuit control behaviour in multi-loop flight control taks[J]. Institution of mechanical engineer, 220(2):85-102. (2006)
11. NAVAIR 00-80T-104. NATOPS Landing signal officer manual.US. (2001)
12. Qu Xiangju, Cui Hailiang. Variable strategy pilot model of carrier landing approach. Journal of Beijing University of Aeronautics and Astronautics, 29(11): 993-997. (2003)
13. Xu Zeshui. Study on methods for multiple attribute decision making under some situations. School of Economics & Management, Southeast University, (2002)
14. Liu Lin, Chen Yunxiang, Ge Zhihao. Approach to the multi-attribute linguistic decision making and its' application. System Engineering and Electronics, 31(1): 113-115, 207 (2009)
15. Zhang Yingxin, Analysis on mine coal dust explosion dangree base on normal fuzzy function. Coal Engineering, 7: 72-74 (2009)
16. Lv Zehua, Chen Chuanbo, Qin Peiyu. Normal distribution fuzzy sets-A new extension of fuzzy sets. Computer Science, 2006, 33(11): 1-14, 173. (2006)