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INFORMATION TECHNOLOGY SECURITY AIRCRAFT FLIGHT IN DIFFICULT CONDITIONS BASED MULTIFACTORIAL FUZZY MODELS

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Abstract. *The proposed method is designed for situations where the original information that characterizes the state of the aircraft, clearly defined and numerical variables and the so-called "linguistic variables" This simple relationship between the variables are described by means of fuzzy statements, and the complex relationship between the concepts with fuzzy algorithms.*

Keywords: aircraft; catastrophic situation; complexity of the flight conditions; difficult situation; emergency; flight accident; fuzzy algorithm; linguistic variables; membership functions; normal situation.

1. Introduction

In all aviation safety documents is defined as complex characteristics of air transport and aerial work, which determines the ability to carry out missions without endangering the life and health [Zubkov, Minaev 1987; Federal…]. Because of this, level of flight safety of modern manned Aircraft (AC) and effectiveness of solutions to problems in accordance with their intended use strict specifications. Therefore, key objective of the present stage of development of aviation is to develop methods and technologies using the latest technology, including artificial intelligence to improve safety in all situations.

For modern aircraft hazard is typically not single factor, complex effect of the complex interaction of several factors which have an unpredictable effect on the external force acting on the aircraft, the activity of operator, the work of automatic control, the behavior of the whole system, and this leads AC goes into an abnormal area of irreversible movement, the chances of safe release of which are very small. The situation is complicated by the inability, and sometimes significant measurement error of these factors, the presence of different kinds of uncertainties. A description of these uncertainties with the use of the mathematical apparatus of fuzzy sets to create a highly effective system for forecasting and monitoring of such special situations and coordinate the decisions taken at each level of the system and obtain a clear solution [Burdun 1998; Burdun, Parfentyev 1999].

2. Statement of the problem

To develop methods for the identification of Flight Accidents (FA) in difficult conditions on the basis of fuzzy logic classification of these situations need.

In continuous operation of equipment, and electronic parts due to changes in the technical and technological parameters of AC, as well as adverse weather conditions and is likely to pilot error may disrupt normal flight mode. The reaction of the aircraft on the impact of these changes is ambiguous and not always accompanied by a breach. Clearly, in most cases, some form of these changes is practically impossible to establish. Therefore, the classification of the FA on the basis of these changes, which create these or other hardware failure, you should use the changes are most severe in its effects and lead to more complicated flight conditions. To eliminate the effects of malfunctions aircraft to find a place of their display or to assess their impact on the operation. Note that even if no flight mode, these issues have not been studied [Burdun 1998; Burdun, Parfentyev 1999].

To construct model of identification of the situation during the flight AC taking following classification [Federal…]:

- normal situation,
- complexity of the flight conditions,
- difficult situation,
- emergency,
- catastrophic situation.

Typically, the separation classification of situation during take-off, flight and landing provides well-defined character line change flight parameters. Each class contains some of the indicators, the values, of which can judge the nature of incident. For example, the complexity of flight conditions is defined as special situation, characterized by slight performance degradation, or a slight increase in crew workload, for example, a change in the flight plan route.

An emergency is defined as a particular situation, involving a significant deterioration in performance and achievement (excess) limit restrictions or physical fatigue or crew workload, which can no longer rely on the fact that it will fulfill its tasks accurately or completely [Federal…].

We denote situation of the vector X with fuzzy elements, which indicates the ratio of given situation to one of the above classes of situations:

NS – normal situation;

UUP – increasing complexity of flight conditions;

CS – complex situation;

AS – emergency;

KS – catastrophic situation.

Then the situation is represented as a vector X (NC, ICFC, ComS, E, CS). The vector element of situation in general depends on the possible causes of situations [Anodina et al. 1992; Federal…]:

– failure or malfunction individual elements of Functions and Systems (FS);

– Exposure to adverse Environmental Conditions (EEC);

– Deficiencies in Ground Support Mission (DGSM);

– errors and improper use of functional systems and piloting (ERR);

– Manifestation of Adverse Features (MAF).

The vector element accept the situation to normalize. In addition, for each phase of flight accept your situation vector.

Thus, the problem boils down to definition of vector of situation, the elements of which are given vague and interdependent.

Designed on the basis of this method to identify the FA will be different particularly flexible and be able to analyze both normal and special circumstances of the operation, to investigate the process of flying in different types of one or more types of faults. Each fault has its own characteristics and requires specific methods of their records in the developed model.

3. Method of solution

For more detailed description of proposed methodology and to facilitate the identification process, the entire set of parameters divide into groups, respectively, with the causes of occurrence of situation (see Table).

The threshold value is entered via the class definition of the situation, using criteria such as the deterioration of flight performance, increased workload, etc. It should be noted that a similar table can be created for vector situation.

As can be seen from Table, some signs of the values entered, and some of them are expressed in terms "extreme rare", "moderately rare", "rare". It should be noted that the proposed set of indicators of the state of the aircraft is not a full and complete and may be changed by the information of different nature, such as an indicator of the reliability of power devices, provide information about level of resources, etc. However, this does not affect the essence of the proposed technique, and only increases the reliability of decision similar table can be constructed for the following phases of flight

To describe the fuzzy parameter values T_{life} and U_L we choose the method of constructing the membership function of odd numbers close to the interval estimates. In this interval, we have expert judgment "X is approximately in the range of m to n". During this time of the membership function is equal to one, and beyond to the left of the interval "X is approximately equal to m", and the right of the range "X is approximately equal to n". To construct the membership function number approximately equal to some number *m* using an exponential function supplies a limited range of values as [Borisov et al. 1990]:

$$\mu(x) = \exp\left[-k(m-x)^2\right], \qquad (1)$$

$$k = -\frac{4\ln(0.5)}{(\beta)^2},$$

where β – distance between points *a* and *b*, for which the function $\mu(x)$ is set to 0.5.

Thus, the task of building for a number reduces to finding the parameters *a* and *b* can then be determined and the parameter *k*. To determine the membership function, double-use (1). In addition, in determining the numerical values of the indicators, experts point interval corresponding to the degree of uncertainty [Borisov et al. 1990]. For example, the life of an expert is formulated like this: "It takes a value between *A* year prior to the year".

If the index is expressed in fuzzy terms with linguistic meaning, then to construct the membership function is used "parametric approach to the construction of identity" [Borisov et al. 1990, p. 19]. The need to use this method is due to vague statement expert in evaluating indicator.

Main features of AC parameters for classification FS takeoff

Indices	Designations	Thresholds				
		Normal	Complicated	Complex	Emergency	Catastrophic
Block FS						
Life time	T_{life}	T_{life}^{n}	T_{life}^{com}	T_{life}^{c}	T_{life}^{e}	T_{life}^{ca}
Loading	U_L	U_L^{n}	U_L^{com}	U_L^{c}	U_L^{e}	U_L^{ca}
Mechanical failures	Mf	Extremely rare	Moderately rare	Rare	Not rare	Frequent
Errors in the data and the logic of on-board subsystems	BS	Extremely rare	Moderately rare	Rare	Not rare	Frequent
Block EEC						
Windactions	W	Rated	Perceptible	Minimum	Not strong	Strong
Atmospheric turbulence	T	Not perceptible	Perceptible	Minimum	Not strong	Strong
The effect on the aerodynamics of the AC and sensors	A	Not perceptible	Perceptible	Minimum	Not strong	Strong
Icing bearing surfaces and control surfaces	Ice	Rated	Perceptible	Minimum	Not strong	Strong
Adverse atmospheric conditions	Aac	Recommended	Perceptible	Minimum	Limit	Extreme limit
Block ERR						
Variations of mass, moments of inertia and center of gravity;	Vm	Recommended	Perceptible	Minimum	Limit	Extreme limit
Changing aerodynamic configuration	Ac	Recommended	Perceptible	Satisfactory	Limit	High
Changes profile of the flight and the control script	Pf	Recommended	Perceptible	Satisfactory	Limit	High
Distance for takeoff and climb	Dc	Recommended	Not recommended	Inadequate	Very inadequate	As insufficient
Block DGSM						
The state of the runway	Rw	Recommended	Not recommended	Poor	Very poor	Extreme poor
Artificial and natural barriers located on the earth's surface along the trajectory of the AC	Anb	Recommended	Not recommended	Poor	Very poor	Extreme poor
Balancing	B	Recommended	Not recommended	Inadequate	Very inadequate	Maximum inadequate
Block MAF						
Performance of engine	Pe	Recommended	Not recommended	Inadequate	Very inadequate	Maximum inadequate
Gear State	Gs	Recommended	Not recommended	Poor	Very poor	Extremely ill

As can be seen from Table, the indicators are expressed in terms of linguistic values, have five levels. In the construction of the corresponding membership functions shall be based on the threshold a "difficult situation".

Membership function "complicated", "difficult" and "emergency" situation, take in a triangular shape (see Figure, *b*), and a "normal situation" (see Figure, *a*), and the "catastrophic situation" (see Figure, *c*), S-shaped

To build these features expert offers a 100%-s three-point scale to indicate from which the two extreme points in its opinion do not belong to the described linguistic value, the other definitely belongs to this term. In evaluating indicator expert instead of the linguistic meaning can use terms such as "more", "less than" or "not very", etc. In this case, one of the terms is a modification of the other. The problem is that, using the parameters of the basic terms to describe the transition to the ground term does not belong in a structured relationship "very", "extreme".

As shown in [Borisov et al. 1990, p. 19–24] to solve this problem, a unit of automorphic functions:

$$y \to \frac{\alpha x + \beta}{\gamma x + \delta}. \qquad (2)$$

The unknown coefficients $\alpha, \beta, \gamma, \delta$ are determined, if we know the three basic values (z_1, z_2, z_3) and the modified values (w_1, w_2, w_3):

$$\begin{aligned}
&\alpha = z_1 z_2 (w_1 - w_2) + z_1 z_3 (w_3 - w_1) + z_3 z_2 (w_2 - w_3);\\
&\beta = w_1 w_2 z_3 (z_1 - z_2) + w_1 w_3 z_2 (z_3 - z_1) + w_3 w_2 z_1 (z_2 - z_3);\\
&\gamma = z_2 (w_1 - w_3) + z_1 (w_3 - w_2) + z_3 (w_2 - w_1);\\
&\delta = w_1 w_2 (z_1 - z_2) + w_1 w_3 (z_3 - z_1) + w_3 w_2 (z_2 - z_3).
\end{aligned} \qquad (3)$$

Using these coefficients can be determined reverse transition from the main to the modified term:

$$x \to \frac{-\delta z + \beta}{\gamma z - \alpha}. \qquad (4)$$

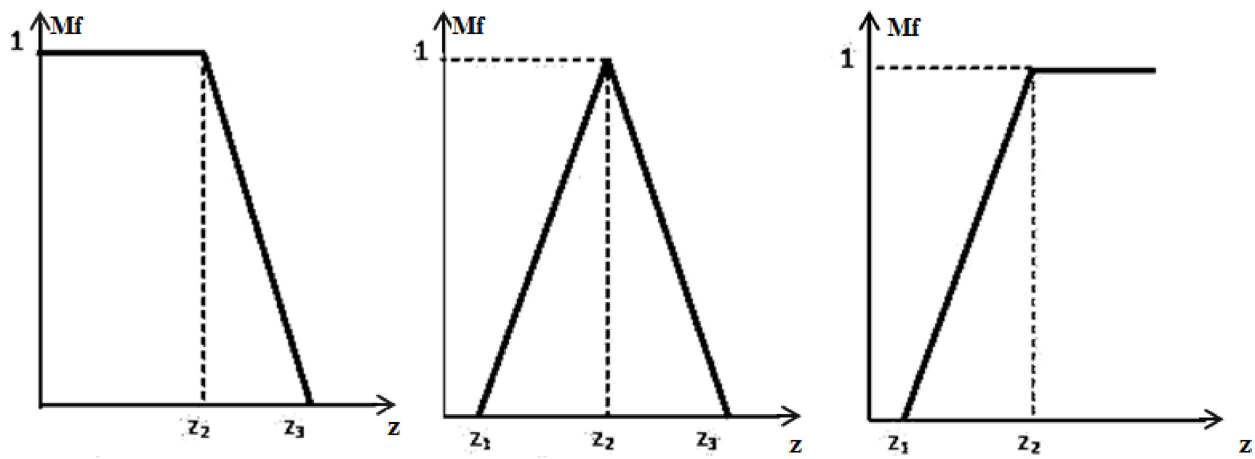
In the transition from the triangular shape of the term to the term S-shaped function using the following formulas for determine the unknown coefficients $\alpha, \beta, \gamma, \delta$ in the case of Figure, *a*:

$$\begin{aligned}
&\alpha = z_2 (w_2 - w_1) + z_3 (w_1 - w_3);\\
&\beta = w_2 z_3 (w_3 - w_1) + w_3 z_2 (w_1 - w_2);\\
&\gamma = w_2 - w_3;\\
&\delta = w_1 (w_3 - w_1);
\end{aligned} \qquad (5)$$

in the case of Figure, *b*:

$$\begin{aligned}
&\alpha = z_1 (w_1 - w_3) + z_2 (w_3 - w_2);\\
&\beta = w_1 z_2 (w_2 - w_3) + w_2 z_1 (w_3 - w_1);\\
&\gamma = w_1 - w_2;\\
&\delta = w_3 (w_2 - w_1).
\end{aligned} \qquad (6)$$

Using the above formula (2, 4, 5, 6) we construct a membership function for the measure "the state of the runway". During the initial term of the term accept "bad", and modified-term "very bad".



a *b* *c*

Membership function(Mf) for situations FA:
a – normal situation;
b – complexity of the flight conditions, difficult situation, emergency;
c – catastrophic situation

Let the expert points out three values interest: In relation to the index of "bad": with respect to the index of "very bad".

Let the expert points out three values

$z_1 = 40,\ z_2 = 50,\ z_3 = 60.$

In relation to the index of "bad" and in relation to the index of "very poor"

$w_1 = 60,\ w_2 = 70,\ w_3 = 80.$

According to the formula (3) determine the coefficients to describe the transition:

$\alpha = -2000,\ \beta = 40000,\ \gamma = 0,\ \delta = -2000.$

Using found conversion pass from the term "very poor" – to the term "very very bad" – "extreme poor":

$w_1 = 80,\ w_2 = 90,\ w_3 = 100.$

Similarly, with the help of the basic term "bad" and the modified term "not bad (or not recommended)":

$w_1 = 20,\ w_2 = 30,\ w_3 = 40$

you can define the term "not advised (or recommended)":

$w_1 = 0,\ w_2 = 10,\ w_3 = 20.$

To recognize the situation you need to create a knowledge base that contains a set of utterances used, logical operations and regulations [Borisov et al. 1990]. At the initial stage of building the knowledge base used by general theoretical information and opinions of experts on the AC considered as a description of the classes. In this case, the classes are described by experts such statements as: "If A and B, and .... THAT is a class C". In this recording the A and B-condition imposed on the values of the parameters from the class name.

To create a knowledge base using Table. As mentioned above, each parameter in the block is formulated using thresholds. According to the above classification to define the class introduce the following rules:

– if the values of all the parameters of a complicated condition better, the situation is accepted normal;

– if at least one parameter is significantly impairs their performance or a slight increase in crew workload, the situation is complicated accepted;

– if at least one parameter significantly affects its performance or unnoticed beyond the operating limits, but without reaching the limit restrictions or a significant increase in crew workload, the situation is complicated accepted;

– if at least one parameter significantly affects its performance or operational limitations beyond the achievement of limit restrictions or a strong increase in crew workload, the situation has taken an emergency;

– if multiple parameters are outside the operational constraints to the achievement of the limiting constraints, and there is considerable discomfort to the crew, the situation is catastrophic accepted.

Statements can be formulated with the use of linguistic variables, fuzzy values, fuzzy relations and fuzzy logical relationships. For the description of a class can be used by several such statements, which are connected by a bunch of logical "AND" and "OR". It uses the rules of operation of union and intersection of fuzzy sets, respectively [Borisov et al. 1990]:

– for a disjunction "AND"

$\mu(x) = \min[\mu_1(x), \mu_2(x)],$

– for a disjunction "OR"

$\mu(x) = \max[\mu_1(x), \mu_2(x)],$

where $\mu_1(x),\ \mu_2(x)$ – membership functions of the conditions imposed on the parameters.

If the description of the classes is formulated in the form of a plurality of combinations of statements by all parameters, any situation can be attributed to a particular class. For this purpose, to recognize the presented situation, we introduce a degree of membership of the situation to a particular class. To do this, in all respects and for all classes define the membership function. In addition, we define the membership function for each statement. In this case, using the above rule operations with fuzzy parameters. Degree the situation in a particular class is determined from the following formula [Borisov et al. 1990, p. 38–44]:

$$\pi_k = \max_i \left\{ \min_j \left[\sup_{x \in X_j} \left(\min\left(\mu_j(x), \mu_{kij}(x) \right) \right) \right] \right\}, \quad (7)$$

where π_k – degree the situation with class number k;

k – class number;

i – number of statements;

j – number of parameter;

X_j – the range of j-th parameter;

$\mu_j(x)$ – membership function of j-th parameter;

$\mu_{kij}(x)$ – membership function of the i-th utterance of i-th parameter in the k-th class.

In order to determine the degree of membership of the situation to a class according to formula (7) is necessary:

– to define the intersection of the membership function of each parameter and the statement;

– determine the upper bounds of intersections of the membership function in all areas of the parameter values;

– determine the minimum value of the least upper bound on the parameters;

– determine the maximum value of the least upper bound of all the statements in this class.

When the diagnosis is necessary to take into account the value of membership degrees of the situation in all classes.

4. Conclusions

Advantage of this method compared to other methods is that it does not require a more rigorous study of threshold values, and can be applied in the absence of accurate information about the values of the parameters. The proposed method does not require information about a specific object, so it can be applied not only to the AC taken separately, but also to any brand of AC.

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Н.Б. Агаєв, Дж.А. Агамалієва. Метод ідентифікації авіаційних подій сучасного літального апарата на основі нечітких моделей

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Запропоновано методику ідентифікації авіаційних подій. Розглянуто ситуації, коли вихідна інформація, яка характеризує стан літального апарата, задається нечітко на числові та лінгвістичні змінні. Прості відносини між змінними описано за допомогою нечітких висловлювань, а складні відносини між поняттями з нечіткими алгоритмами.

Ключові слова: авіаційна подія; катастрофічна ситуація; лінгвістичні змінні; літак; надзвичайна ситуація; нечіткий алгоритм; нормальна ситуація; складна ситуація; ускладнення умов польоту; функція належності.

Н.Б. Агаев, Дж.А. Агамалиева. Метод идентификации авиационных происшествий современного летательного аппарата на основе нечетких моделей

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Предложена методика идентификации авиационных происшествий. Рассмотрены ситуации, когда исходная информация, характеризующая состояние летательного аппарата, задается нечетко на числовые и лингвистические переменные. Простые отношения между переменными описаны с помощью нечетких высказываний, а сложные отношения между понятиями с нечеткими алгоритмами.

Ключевые слова: аварийная ситуация; авиационное происшествие; летательный аппарат; катастрофическая ситуация; лингвистические переменные; нечеткий алгоритм; нормальная ситуация; сложная ситуация; усложнение условий полёта; функция принадлежности.

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