Research on early warning mechanism of civil aviation accidents based on Grey Theory

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Abstract: The author, based on the grey prediction method, firstly combines the grey prediction model with support vector machine model to predict the civil aviation accident proneness, and establish the cascade grey support vector machine combination prediction model of civil aviation accident proneness. Based on the civil aviation accident proneness quantity in recent decade, this paper conducts prediction simulation by aid of Matlah software to check the grey prediction model, support vector model and grey support vector machine model, analyzes and compares the precision and features of three methods thus to verify the superiority of grey support vector machine model in civil aviation accident proneness prediction.

1. Introduction

The causes of civil aviation accident proneness include some certain factors (aircrew, maintenance, mechanical engineering, air traffic control, ground safeguard service) and uncontrollable factors (weather, bird attack), therefore, it is the grey dynamic system containing not only known intableeation but also unknown intableeation, which can not be analyzed and calculated reasonably through a simple mathematical model. The prediction methods of civil aviation accident proneness include regression analysis prediction, time sequence analysis prediction, variable weight combination prediction and saturation growth trend prediction. These traditional prediction methods all base on massive data to seek for potential statistical law in randomness, and the calculation errors in data operation process are easy to make the result appear with polarity error thus to transtable the positive correlation to negative correlation, mix the data correlation to be difficult in realizing the prediction purpose.

2. Grey correlation model description of civil aviation accident influencing factors

2.1 Analysis model of accident influencing factors

The existing aviation accident/incident analysis methods include CAAC regulation 396 accident/incident analysis model, primitive incident analysis method and EU United Airlines accident and accident proneness report system (ECCAIRS) analysis model. Among the three kinds of analysis models, CCAR3 9 6 accident analysis model lays particular stress on comprehensive investigation and classification of related accident intableeation but provides few selections for comprehensive cause analysis; the primitive incident analysis is richer than CCAR396 accident analysis model, one primitive incident correspond to several behaviors, each behavior corresponds to several reasons, and then precautions are raised; ECLAIRS analysis model is the most meticulous one, which selects the classic SHEI II model to analyze the relationships between human and environment, softwrae, hardware, system as well as between humans. This paper selects ECLAIRS analysis model and combines with the primitive incident analysis method to classify the influencing factors of civil aviation accident, owing to the limitation in the length, this paper only researches the first-level and second-level accident influencing factors, as is shown in table 1.

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Table 1 Civil aviation accident influencing factor classification

The first-level accident influencing factor	The second-level accident influencing factor
Personal factors (A)	Physiology/sense organ limitation
	Human physiology
	Psychological limitation
	Personal work management
	Knowledge and experience
Human-environment interface (B)	Natural environment
	Social psychological factor
	Company management, personnel assignment or supervision
	Operation task demand
Human-hardware/software interface (C)	Human-hardware interface
	Insufficient intableation/data material
	Human-software interface
	Automatic system
	Automatic prevention/warning
Human-system support (D)	Operation materials
	Human-machine interface-procedure
	Human-machine interface- training
	Others-system support problem
Human-human interface (E)	Exchange problem between humans
	Aircrew skills/resource management and training-human interaction
	Personnel related to supervision-human interface
	Personnel related to regulation activities-human interface
	Others-human interface

2.2 Correlation analysis of accident influencing factors

It conducts statistics on the aviation accident occurred in world civil aviation from 1991 to 2010, conducts detailed analysis on each accident, based on ECLAIRS classification standard and combined with the primitive incident analysis method, classifies the accident influencing factors, divides the accident causes into five levels, wherein, the lower factors are detailed descriptions on upper factors; secondly, it needs to determine the analysis time period before conducting quantitative statistics on influencing factors, it is needed to be pointed out that the data quantity is obviously insufficient owing to the limited accident intableation within one year, which further affects the scientificity and correctness of analysis result, it can be found throughout multiple calculations and verification that the analysis based on five-year period is more scientific and reasonable, therefore, it divides 20 years into four periods for statistics of accident influencing factors;

Finally, it conducts statistics on the appearance times of influencing factors in each analysis time period, and then the quantitative statistics table can be obtained, see table 2. In the table 2, X_0 refers to the sum of appearance times of the first-level accident influencing factors; X_A X_B refers to the times of personal factors in the accident; refers to the times of human-environment factors in the accident; X_C refers to the times of human-software/hardware interface factors in the accident; X_D refers to the times of human-system support factors in the accident; X_E refers to the times of human-human factors in the accident.

Table 2 Statistical table of civil aviation accident influencing factors from 1991 to 2010 (times)

Time period	X_0	X_A	X_B	X_C	X_D	X_E
1991-1995	67	6	12	22	14	13
1996-2000	88	5	5	53	11	14
2001-2005	60	3	5	18	18	16
2006-2010	52	3	10	19	7	13

3. Grey multiitem SVM kernel AR-SVM model

3.1 Grey pre-processing

Grey pre-processing is the sample processing algorithm based on historical data construction, wherein, $GM\left(1,1\right)$ is the commonly-used grey model,which contains univariate differential equation[13].

Based on the accumulative calculation on the original data of extreme preference risk in the market, the data sequence model with index growth feature can be obtained, and the differential model of extreme preference risk in the market based on the sequence can be obtained as well as its time response data, and the grey pre-processing model of extreme preference risk in the market based on the accumulative reduction mode can be obtained[14]:

$$\begin{aligned}\hat{x}^{(0)}(k+1) &= \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k) \\ &= (1-e^{\hat{a}})(x^{(0)}(1) - \frac{\hat{u}}{\hat{a}})e^{-\hat{a}k}\end{aligned} \tag{1}$$

In the tableula, $k = 0,1,2,\cdots$, $x^{(0)}$ is the original prediction value; $\hat{x}^{(1)}$ is accumulative sequence sample predicted value; $\hat{a}$ and $\hat{u}$ are the first-order indicator of differential model. If there exists with large data disperse situation in the prediction process, the grey processing precision will be low, and the pre-processing of $GM\left(1,1\right)$ should be improved. In order to reduce the non-smoothness of extreme preference risk in the market and enhance the grey prediction precision of original sequence, enhance the model fitting degree. The original model sequence is recorded as $\{x^0(t)\}, t = 1,2,\cdots,n$, and then the smoothness tableula can be obtained:

$$x'^{(0)}(t) = \frac{x^0(t-1) + 2x^0(t) + x^0(t+1)}{4} \tag{2}$$

Aiming at 2-end situation, the calculation table is:

$$\begin{cases} x'^0(1) = \dfrac{3x^0(1) + x^0(2)}{4} \\ x'^0(n) = \dfrac{x^0(n-1) + 3x^0(n)}{4} \end{cases} \tag{3}$$

In the tableula: x'^0 is the smoothness mean of extreme preference sequence in the market; x^0 is the original sequence of extreme preference in the market. x^0 can realize data weight increasing after the smoothness mean is solved, can reduce the fluctuation of data and obtain better data fitting effect.

3.2 Self-regression model order determination (AR)

When conducting order determination on AP model, it is needed to calculate the auto-covariance of extreme preference in the market, the table is:

$$\hat{\gamma}_k = \frac{1}{n}\sum_{j=1}^{n-k}(X_i - \overline{X})(X_{i+k} - \overline{X}) \quad (4)$$

And then the correlation parameter table of extreme preference sample in the market can be obtained:

$$\hat{\rho}_{\mathrm{k}} = \frac{\hat{\gamma}_{\mathrm{k}}}{\hat{\gamma}_0} \quad (5)$$

And the partial correlation parameter table is:

$$\hat{\phi}_{kk} = \frac{\hat{D}_k}{\hat{D}}, \forall 0 < k < n \quad (6)$$

In the tableula, the correlation parameters:

$$\overline{X} = \frac{1}{n}\sum_{i=1}^{n} y_i \quad (7)$$

$$\hat{D}_k = \begin{vmatrix} 1 & \hat{\rho}_1 & \cdots & \hat{\rho}_{k-1} \\ \hat{\rho}_1 & 1 & \cdots & \hat{\rho}_{k-2} \\ \vdots & \vdots & \ddots & \vdots \\ \hat{\rho}_{k-1} & \hat{\rho}_{k-2} & \cdots & 1 \end{vmatrix} \quad (8)$$

$$\hat{D} = \begin{vmatrix} 1 & \hat{\rho}_1 & \cdots & \hat{\rho}_1 \\ \hat{\rho}_1 & 1 & \cdots & \hat{\rho}_2 \\ \vdots & \vdots & \ddots & \vdots \\ \hat{\rho}_{k-1} & \hat{\rho}_{k-2} & \cdots & \hat{\rho}_k \end{vmatrix} \quad (9)$$

In accordance with the existing knowledge: in the asymptotic distribution on $\hat{\rho}_k$ and $\hat{\phi}_{kk}$, compare the situations of $\left|\hat{\rho}_k\right|$ and $\left|\hat{\phi}_{kk}\right|$ and $\sqrt{\frac{1}{n}} \times 2$ only. Assume m_{ar} and m_{ma} satisfy the following relationships:

$$\begin{cases} |\hat{\rho}_k| \le \sqrt{\frac{1}{n}} \times 2, \forall m_{ma} \le k \le n \\ |\hat{\phi}_{kk}| \le \sqrt{\frac{1}{n}} \times 2, \forall m_{ar} \le k \le n \end{cases} \quad (10)$$

Find out m_{ar} contableing to the above constraint, the order of self-regression SVM risk prediction model can be obtained.

4. Conclusion

This paper provides a new evaluation idea for quantitative analysis on civil aviation accident influencing factors, aims at providing suggestions on civil aviation safety management work. In the future civil aviation safety management work, it should focus on researching the prevention of key influencing factors, only in this way can the safety management level of civil aviation be enhanced.

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