A FUZZY DYNAMIC ANALYSIS METHOD FOR AEROMAINTENANCE SYSTEM

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Abstract

In this paper the authors first propose the approach of a fuzzy system dynamic modeling for a large system by applying the technique of the fuzzy optimum estimation on the basis of traditional system dynamic and the fuzzy mathematical and control theory. The method of modeling is more convenient quantum to analysis the interaction with many factors on aeromaintenance system which has been verified through the stimulating the special aeromaintenance system there fore the new way has been opened up for realizing the system optimum running.

Keyword: system dynamic, fuzzy mathematic, mathematic model, aeromaintenance

1. Introduction

Aeromaintenance system can be considered as a large system, in which many factors for example the quality of maintenance people and maintenance cost or maintenance management and maintenance providing and so on, are included. In order to make the system optimum running it is urgent need to search the method by analyzing the mechanism of system running in aeromaintenance field. With developing of control engineering and fuzzy mathematics and system dynamic in recent years a new way may be provided for quantum analyzing aeromaintenance system by synthesizing the fuzzy mathematics theory and states space theory or system dynamic method. The method of fuzzy system dynamic modeling can be presented in this paper, then the traditional system dynamic is developed forwards a large step.

2. Basic Principle

The thought of fuzzy system dynamic is described as firstly, the dynamic equation of system to be analyzed is set up by using the method of traditional system dynamic, then the experiment of the stimulation is carried out based on historical data and input information secondly, based on output information of the stimulation of system dynamic, the fuzzy state equation of system is set up by using some proper fuzzy transform and the relation analysis. Thirdly, the fuzzy state equation of system is linearized and optimum decoupled, at last, for the fuzzy state equation of system which has been simplified the matrix of weighted modification coefficient which can be obtained by analyzing and calculating with the weighted matrix, is used to modify the system dynamic equation so F.S.D.E (the fuzzy system dynamic equation) can be obtained then the analysis for aeromaintenance system can be carried out by using F.S.D.E. The system principle is shown in the block diagram of Fig 1.

Figure 1. The block diagram of the system principle

The map of system causality and system flow diagram are given out respectively in Figure 2. and Figure 3.

Figure 2. System causality map

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let \( \rho_{ij} = \sum_{k=1}^{i,j} \rho_k \)

where \( \rho_{ij} \) is subordinated to fuzzy normal distribution therefore the congnate matrix \( T \) is defined as

\[
T = (T_{ij})_{m \times n} = \frac{1}{\sqrt{\rho_{ij}}} 
\]

(5)

Similarly, the coupling evaluation matrix of other variable in subsystem can be get as below

\[
V_{ij} = \frac{1}{m} \sum_{k=1}^{n} \sum_{l \neq j} Q_{jk} Y_{ikl} 
\]

(6)

so

\[
V = (V_{ij})_{m \times n} 
\]

(7)

where \( Y_{jk} \) is the fuzzy functional of weighten between the \( i \) variable and \( j \) variable on nondication of the thinking of \( k \) target, \( Q_{jk} \) is the fuzzy relation coefficient between the \( i \) variable and the \( j \) variable, it can be caried out in the same way as Equ. (3) and (4).

3.2 Lineareal the fuzzy state equations

Let the fuzzy transform matrix be 

as below respectively

\[
P_{1m\times n} = T' \cdot (\bar{A}_1, \bar{P}_1) \cdot T 
\]

(8)

\[
P_{2m\times n} = V' \cdot (\bar{A}_2, \bar{P}_2) \cdot V \cdot r(P_1) 
\]

(9)

then let

\[
\dot{x}_1 = \bar{\omega}_1 P_1, \quad \dot{x}_2 = \bar{\omega}_2 \cdot P_2 
\]

(10)

Taking Equ.(10) into Equ.(1) and Equ.(2) we can get:

\[
\dot{\bar{X}}_1 = \bar{A}_1, \dot{\bar{x}}_1 + \bar{B}_1 \bar{U}_1 
\]

\[
\dot{\bar{X}}_2 = \bar{A}_2, \dot{\bar{x}}_2 + \bar{B}_2 \bar{U}_2 
\]

(11)

(12)

where \( \bar{\omega} \) is the fuzzy operator

\[
\bar{A}_1 = \text{diag}(\bar{a}_{11}, \bar{a}_{12}, ..., \bar{a}_{1m}) 
\]

\[
\bar{A}_2 = \text{diag}(\bar{a}_{21}, \bar{a}_{22}, ..., \bar{a}_{2n}) 
\]

(13)

(14)

Because of some parameters of the matrix \( \bar{A}_1 \) and \( \bar{A}_2 \), being unknown, we must estimate these parameters by using the method of optimum estimation based on the stimulation output information of S.D.E thus two vectors of unknown parameters \( \hat{\theta}_1, \hat{\theta}_2 \) can be estimated according to the below formulation

\[
\hat{\theta}_1 = (\bar{P}_1 \cdot \bar{F}_1, \bar{F}_1, \bar{P}_1, \bar{F}_1, \bar{F}_1, \bar{F}_1) \cdot \bar{y} 
\]

\[
\hat{\theta}_2 = (\bar{P}_2 \cdot \bar{F}_2, \bar{F}_2, \bar{P}_2, \bar{F}_2, \bar{F}_2, \bar{F}_2) \cdot \bar{y} 
\]

(15)

(16)

3.3 Determining the optimum modified Weighten matrix

Firstly, determining the weighten matrix of information on system architecture, when taking \( \hat{\theta}_1 \) and \( \hat{\theta}_2 \) into Equ.(15) and (16), we get two equations as below

\[
\hat{\theta}_1 = \bar{A}_1, \hat{X}_1 + \bar{B}_1, \bar{U}_1 
\]

\[
\hat{\theta}_2 = \bar{A}_2, \hat{X}_2 + \bar{B}_2, \bar{U}_2 
\]

(17)

(18)
Let characteristic equation of above two equation be as below respectively
\[ |S1 - \hat{A}_1| = 0 \] \hspace{1cm} (19)
\[ |S1 - \hat{A}_2| = 0 \] \hspace{1cm} (20)

Sloving the two equation (19) and (20) we can obtained some characteristic roots as \( S_i, \ldots S_m \) or \( \lambda_1, \ldots \lambda_j \), where \( m \geq 1 \) or \( m \geq 2 \), \( j \geq 1 \), \( j \geq 2 \), thus the weighten matrix of information of system construction can be defined as below
\[ \bar{W}_i = \{1/S_i, \ldots 1/S_m\}_{i \times 1} \] \hspace{1cm} (21)
\[ \bar{W}_s = \{e^{-\lambda_1}, \ldots e^{-\lambda_j}\}_{i \times 1} \] \hspace{1cm} (22)

Secondly, Determining the optimum targets.
The optimum targets can be defined as below
\[ J_1 = \min \{C_1^T \bar{z}^1 \} \] (23)
\[ J_2 = \min \{C_2^T \bar{z}^2 \} \] (24)

where \( \bar{z}^1, \bar{z}^2 \) are the output of stimulation of S.D.E, \( C_1 \) and \( C_2 \) can be computed from Eqn (17) and (18), \( \Delta(t) \) is fuzzy operator, \( P(w_i), P(w_j) \) is the synthetic fuzzy function respectively, however \( P(w_i) \) and \( P(w_j) \) are defined as below
\[ F(\bar{w}_i) = \sum_{i=1}^{S} u(\bar{w}, i) \] (25)
\[ F(\bar{w}_s) = \sum_{i=1}^{S} u(\bar{w}, s) \] (26)

where \( u(\bar{w}, i) \) is the satisfying fuzzy function of \( i \) flow-variable, \( u(\bar{w}, s) \) is the satisfying fuzzy function of \( s \) other-variable. Note: different variable obey unlike the fuzzy distribution for example, maintenance cost or investment variable and so on obey the distribution as below
\[ u(\bar{w}, i) = \begin{cases} 1 & 0 \leq w_i \leq 0, \\ 1 - \frac{w_i - \theta_i}{\theta_i - \theta_1} & 0_1 \leq w_i < 0_2, \\ 1 & w_i \geq 0_2, \end{cases} \] (27)

however the variable of the construction of knowledge or degree and age or experience of aeromaintenance people obey the distribution as below
\[ u(\bar{w}, s) = \begin{cases} 0 & 0 \leq w_s \leq 0, \\ 1 - \frac{w_s - \theta_s}{\theta_s - \theta_1} & 0 \leq w_s < 0_2, \\ 1 & 0_2 \leq w_s < 0_3, \\ 0 & w_s \geq 0_3. \end{cases} \] (28)

Thirdly determining the optimum modified weighten matrix.
let \( R_i = \sum_{j=1}^{S} \bar{U}_{ij} \bar{U}_{ji} = \{R_{ij}\}_{S \times S} \) \hspace{1cm} (30)
\[ \bar{z}_1 = \bar{x}^1 \otimes R, \] (31)
\[ \tilde{z}_2 = \bar{x} \otimes R_s \] (32)

where \( R_i, R_s \) is the optimum modified weighten matrix, \( \otimes \) is the special fuzzy operator it is defined as below
\[ x \otimes R = \{\tilde{x}_1, \ldots \tilde{x}_n\} \]

where
\[ \tilde{x}_i = \begin{cases} 0 & \left| \frac{z_i(t)}{z_i(t + \Delta t) - z_i(t)} \right| < \sum_{j=1}^{m} R_{ij} \\ \frac{z_i(t)}{z_i(t + \Delta t) - z_i(t)} & \sum_{j=1}^{m} R_{ij} \end{cases} \] (33)

2.4 Fuzzy system Dynamic equations

Based on above the equations, the fuzzy system dynamic equations can be determined as below
\[ \dot{x}_1(k+1) = \bar{P}(k) + \bar{A}(k) \bar{x}_1(k) \] (34)
\[ \dot{x}_2(k+1) = \bar{x}_2(k) + \bar{C}(k) \bar{x}_1(k) \] (35)

where \( x_1, x_2 \) are the output state variable vector of fuzzy system dynamic equations the whole process of computing in detile referred to the scheme of F.S.D.E in Figure 4.

![Diagram](image-url)

**Figure 4.** the scheme of F.S.D.E modeling
4. Example

Taking the aeromaintenance system of the special equipment which are mounted on the same type of aircraft as an example to verify the F.S.D.E. In the process of modeling the aeromaintenance system of special equipment, six flow-level variable are selected, including the quality of aeromaintenance people and unrepaired equipment or the ability of maintenance's supplying and the cost of maintenance and so on, the number of other variable selected is 102.

F.S.D.E has been stimulated by using the method of Adams estimate correction let the interruption of stimulations $\Delta t = 1$ unit, the results of the system running have been stimulated during thirty years. Under the condition of the investment with constraint and the degree of useful equipment being 95%, the analysis of simulation can be done therefore it is achieved that the optimum number of maintenance people and the optimum rate of construction of academic attainments or knowledge or ability and the optimum of stock of equipment and the optimum quality of stock of equipment and the optimum period of maintenance, however we have discussed other problems that these factors affected the performance of aeromaintenance system in this paper for example the maintenance people adjusting and replacement of generation of test device of new type and the renewal of special equipment and the change of environtment of aeromaintenance and so on. The whole process of computing and the analysis in detail is not given out because of the paper space limitations, but the results states that it is key to the efficiency of aeromaintenance system that the quality of aeromaintenance people and maintenance regime or the finance of maintenance and so on.

5. Conclusion

In this paper the traditional system dynamic have been developed a large step by applying the fuzzy mathematics and morder control theory. The method of fuzzy system dynamic modeling which has been presented is convenient to consider the indefinite complexity influence of factors on the large system, particularly the thought of modeling proposed is very adaptable to set up the mathematic model of large system which includes the man or management or socty and so on. This model has three advantage the one is to analyze the dynamic property of aeromaintenance system and the interation relationship with many factors of aeromaintenance system easily, the second is convenient to determine the rate of main element which consists of aeromaintenance system, the another is convenient to search the optimum scheme of aeromaintenance system running.

This research proved that the fuzzy transform is effective for dealing with the problem of nonliner in the dynamic state equations of large system. The applicability and advantages of this method have been verified through the simulating the maintenance system of the special aero-equipment.

The result states that the quantum mathematics models of aeromaintenance system can be set up by using this method easily therefore. In order to realize the scientific aeromaintenance and management, the new way has been presented this paper.

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