CONTROL ALLOCATION OF FLYING-WING WITH MULTI-EFFECTORS BASED ON T-S FUZZY MODEL

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ABSTRACT
A flying vehicle with unconventional layout usually has better pneumatic and stealth performance compared with the traditional one. In this paper, we achieve the construction of a T-S fuzzy model for modeling the dynamics of flying-wing, and a fuzzy controller is designed to realize the flight control. An index is proposed to describe the deflection of the multiple-control surface composition to the desired virtual control. Finally, the effectiveness and real-time quality of the method is verified by the simulation.
KEY WORDS
Flying-wing; T-S fuzzy model; control allocation; estimated distribution algorithms

1 INTRODUCTION

Flying-wings flight aerodynamic configuration has only one pair of wing with the design of integration of wing and fuselage, this kind of design greatly reduces the resistance of aircraft and RCS and can increase the range and the viability of aircraft in the battlefield at the same time.

Lots of research results on control allocation have been made by Chinese and foreign researchers, the specific can be summarized into two categories: optimization-based allocation and the non-optimal allocation method. Optimization-based methods include the generalized inverse method [1-3], the direct allocation based on linear programming method [4,5], and the dynamic allocation based on quadratic programming method; non-optimal control methods include Daisy chain control allocation method [6,7].

Estimated Distribution Algorithm (EDA) is based on Mathematic Programming methods, the control allocation problem can be calculated as an optimizing problem with multi-objective. In this paper, we firstly construct the T-S fuzzy model for flying-wings. Then we set a serious of optimize indexes based on the flight vehicle. At last we will give a conclusion and further works.

2. FLYING-WING T-S FUZZY MODEL

Fuzzy modeling approach can solve the problem of nonlinear system modeling. The nonlinear system can be transferred into a combination of a number of the linear models; the resulting fuzzy model can approximate the complex nonlinear system. The point is a nonlinear dynamic model of the multiple local linear models as a fuzzy approximation, and the nonlinear control system is composed by several local linear fuzzy control systems in synthetic form. The flying-wing longitudinal nonlinear model simulation block is shown in figure 2.

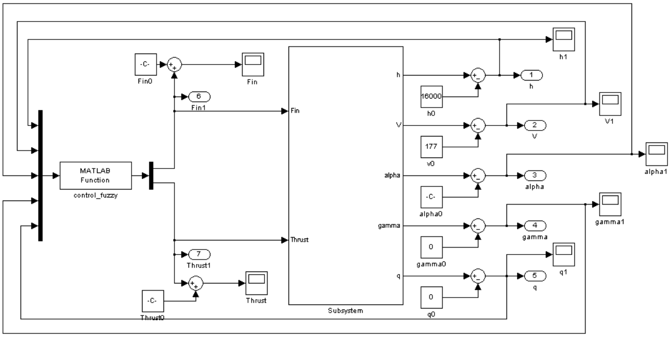

Figure 1. Longitudinal nonlinear model simulation block of flying-wings

T-S fuzzy vertical model is as follows:

$$\dot{\boldsymbol{x}}(t)=\sum_{i=1}^{r}\mu_i(\xi(t))\{\boldsymbol{A}_i\boldsymbol{x}(t)+\boldsymbol{B}_i\boldsymbol{u}(t)\} \tag{1}$$

The control input $\boldsymbol{u}(t)$ is

$$\boldsymbol{u}(t)=\sum_{j=1}^{r}\mu_j(\xi(t))\boldsymbol{K}_j\boldsymbol{x}(t) \tag{2}$$

Take (2) into (1), the close loop system is derived.

$$\dot{\boldsymbol{x}}(t)=\sum_{i=1}^{r}\sum_{j=1}^{r}\mu_j(\xi(t))\mu_j(\xi(t))(\boldsymbol{A}_i+\boldsymbol{B}_i\boldsymbol{K}_j)\boldsymbol{x}(t) \tag{3}$$

We design $\boldsymbol{K}_j$ based on the pole placement method, set a control subsystem for each pole placement in $[-2\pm 2i,-0.5\pm 0.5i,-1.5]$, by $\boldsymbol{A}_i$ and $\boldsymbol{B}_i$ we can get $\boldsymbol{K}_i$.

In this section we design the T-S fuzzy control model for flying-wing, which can achieve for the control of nonlinear model. Based on the TS mdoel, We design the fuzzy control system through the full state feedback method based on pole placement method.

3 CONTROL ALLOCATION MODEL FOR FLYING-WING

The shape of flying-wing aircraft is an inverted W. All the control effectors are set down in the posterior margin of inverted W. Figure 3 and Table 1 shows the model of the flight vehicle and its control effectors.

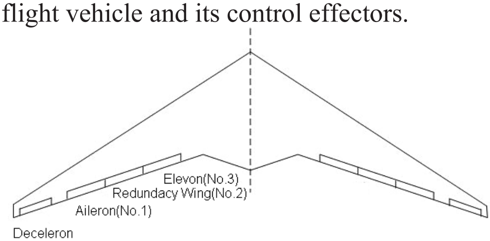

Figure 2. control effectors model of flying-wing

The flying-wing aircraft has multiple control surfaces, through the proper configuration of the deflection of the comprehensive utilization of various control effectors; we can achieve the total aerodynamic control surface deflection minimum while the control effect unchanged. It is necessary to use the control allocation to improve the flying-wing control system performance.

As we can see from the above analysis, the control allocation problem is a multiple variables, multiple objective optimization problem, and the following optimization algorithm will be established based on the mathematical model of flying wing control allocation multiple surfaces control.

We define b_1 , b_2 and b_3 as the deflection coefficient of flying-wing effectors: Elevon, Redundacy, Aileron. We choose the optimization objective as follows:

$$J = a_1 J_1 + a_2 J_2 + a_3 J_3 \tag{4}$$

Where a_1 , a_2 and a_3 are the weighting coefficient of the optimization objective.

Define J_1 as the effect of multiple surfaces coordination control mostly close to the effect of a single control surface in the performance. Hence J_1 can be defined as:

$$J_1 = \left| c_1 b_1 + c_2 b_2 + b_3 - 1 \right| \tag{5}$$

Define J_2 as the limitaion of surfaces deflection, avoiding excessive deflection of a control surface:

$$J_2 = \max(b_1, b_2, b_3) - \min(b_1, b_2, b_3) \tag{6}$$

Define J_3 as the total deflection of multiple control surfaces, avoiding excessive deflection of all the control surfaces:

$$J_3 = b_1 + b_2 + b_3 \tag{7}$$

Considering all the optimization indexes above, the control allocation mathematical optimization model of flying-wing multiple control surfaces is:

$$\min \ J = a_1 J_1 + a_2 J_2 + a_3 J_3 \tag{8}$$

where $b_1 \in [0,1]$, $b_2 \in [0,1]$, $b_3 \in [0,1]$.

4. CONTROL ALLOCATOIN BASED ON EDA

The control allocation problem has been transformed into an optimizing problem with multi-objective and multi-extreme value. In this section we will calculate the control allocation results based on the EDA, then use Matlab Simulink to make the simulation.

4.1 PROCESS OF ESTIMATION DISTRIBUTION ALGORITHM

Estimation Distribution Algorithm (EDA) is a adaptive optimization algorithm with generality and global optimization compared to traditional optimization algorithm. The process of EDA is shown as follows:

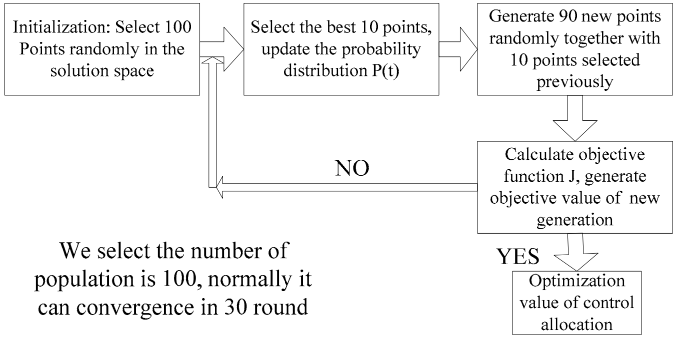

Figure 3. the process of Estimation Distribution Algorithm

From the results we learn that the evaluation function eventually converge to the optimal solution. Based on the evaluation results for each effecter, we will simulate the response curve in the next section.

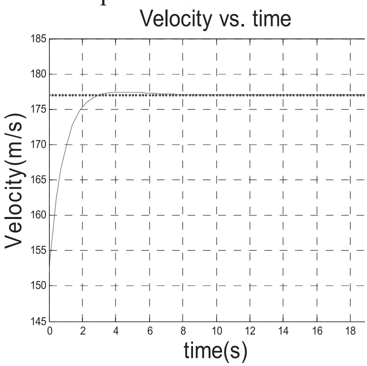

Figure 4. velocity response curve with multi-effecters

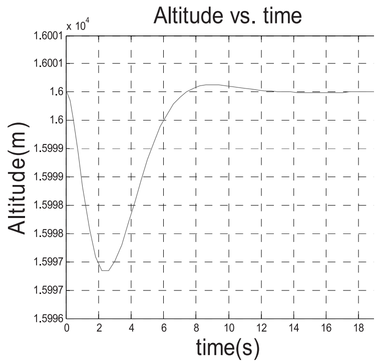

Figure 5. altitude response curve with multi-effecters

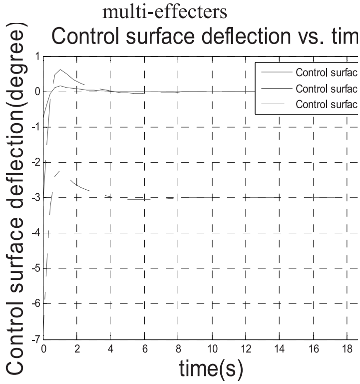

Figure 6. control surface deflection response curve with multi-effecters

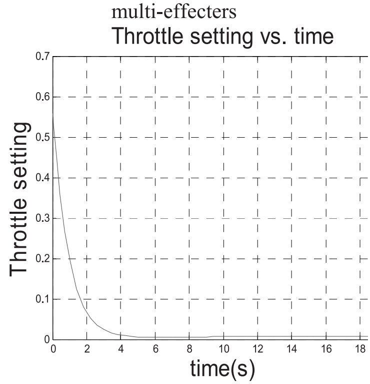

Figure 7. throttle setting response curve with multi-effecters

5. SUMMARIES

In this paper,. A T-S fuzzy model is constructed for modeling the dynamics of flying-wing flight vehicles, and fuzzy controller is designed to realize their nonlinear flight control. We use EDA to calculate the control allocation for flying-wing with multi-effecters. Based on the evolution results, we simulate the flight control state in velocity, altitude, attack angle, pitch angle, control surfaces deflection and throttle, as a result all these state eventually converge to zero, which demonstrates the stability of the *longitudinal model of the flying-wing aircraft*

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