Model Identification of the Actuator Based on Image

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***Abstract*—Actuators are the important parts of an UAV, which control the flight. Obtaining the model of the actuator is a necessary step to design the controller of UAV. These days, the visual measurement technology has been widely applied in the field of industry. In our study, the video capture is applied to acquire the actuators' movement without changing the system's origin characteristics. This paper proposes a combination algorithm to identify the actuators' model which is accomplished on a hardware-in-loop simulation platform. The experimental results show the effectiveness of the algorithm. It also provides a strong theoretical basis for the design of the control system.**

***Index Terms*—video tracking, actuator, identification algorithm, control system**

I. Introduction

In general, UAV's flight is controlled by its aerodynamic force, while the aerodynamic force changes with the control power of the actuating mechanism. Otherwise, actuator is a very important part of the actuating mechanism, it will affect the performance of the UAV's guidance system, so it is very important to identify the actuators' model.[1]

Recently, many experts study varieties of methods for identifying model, such as least square method, genetic algorithm and so on. This paper proposes a combining algorithm that mixes the genetic algorithm and particle swarm optimization algorithm to identify a certain actuator's model.

Furthermore, the video capture is applied to catch the actuator's movement. We can observe the actuator's angle information directly. Then we can put all algorithms together in the experiment. The result shows the effectiveness of the algorithms.

II. Actuator

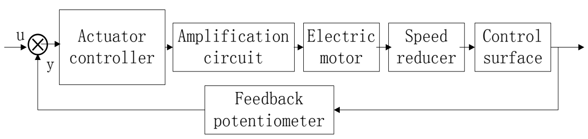

Figure 1. Components of actuator.

Actuator is not only an actuating mechanism but also a very important component in the guidance and control system. It is composed of actuator system controller and amplification circuit and electric motor and speed reducer and control surface and feedback potentiometer. The system diagram is shown in Fig. 1.

Actuator includes electric actuator and pneumatic actuator and hydraulic actuator.[2] Compared with the other two, the electric one is simplest in structure and lowest in cost. So this paper studies on the electric actuator, which is typically a two order system. The transfer function of the actuator can be described as formula (1).

$$G(s) = \frac{k}{T^2 s^2 + 2\xi T s + 1} \tag{1}$$

We can acquire difference equation by dispersing the transfer function and estimate model parameters by the difference equation. Its function is shown in formula (2).

$$\begin{aligned} & y(k) + a_1 y(k-1) + a_2 y(k-2) \\ & = b_0 u(k) + b_1 u(k-1) + b_2 u(k-2) \end{aligned} \tag{2}$$

III. Tracking Algorithm

Template matching algorithm can accurately track the moving object, it is also a common algorithm in tracking. So the algorithm is applied to this experiment to track the actuator's movement. The process of target tracking is shown in Fig. 2.

Figure 2. Process of template matching.

First of all, we are supposed to have selected a template. The selection of the template should keep characteristics of the target object as much as possible. In our experiment, the template of the actuator is shown in Fig. 3.

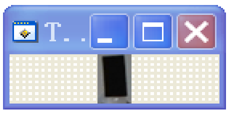

Figure 3. Template of the actuator.

The actuator was given a 20 degrees 1Hz sinusoidal control signal. The tracking of the actuator's movement are as follows:

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Figure 4. The first frame of actuator's movement.

Figure 5. The thirtieth frame of actuator's movement.

We can see the template algorithm can track the actuator's movement well from above. According to the information obtained from the tracking, we can calculate the angle of the actuator at any time.

In the process of acquisition, the environment always makes noise.In this experiment we have adopted many kinds of picture pretreatment to deal with it. Then we can calculate the rudder angle. The angle information is shown in Fig. 6.

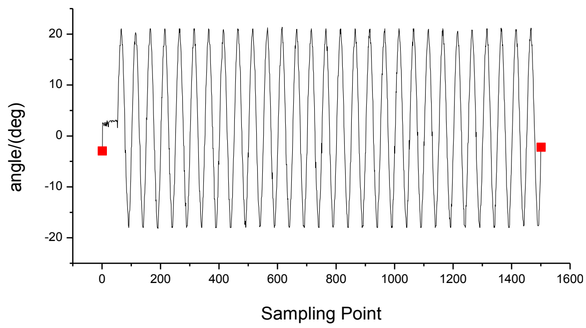

Figure 6. The angle of actuator

IV. Identification Algorithms

A. Genetic Algorithm

Genetic algorithm was proposed by professor Holland in 1957, [3] which is a globally optimizing algorithm that is simulating the evolution process of biological variation.

Genetic algorithm [4]-[5] is an algorithm which is inspired by nature. It doesn't need cumbersome steps like derivation. The problem is defined as chromosome in genetic algorithm, and the algorithm searches the optimal value by acting on the gene of the chromosome. There is no need to know the problem itself, the genes is updated by its fitness. The better the fitness is the bigger probability of survival the gene will get.

The flow chart of the genetic algorithm is shown in Fig. 7.

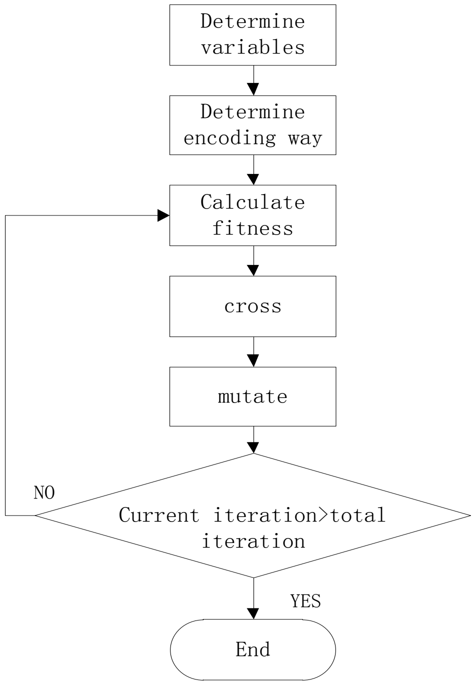

Figure 7. Flow chart of genetic algorithm

B. Particle Swarm Optimization

Particle swarm algorithm was first proposed by Dr. Eberhart and Dr. Kennedy in 1995. [6]It is inspired by the migration of birds and a kind of algorithm based on the foraging behavior of birds.

The algorithm is starting from a random solution to find the optimal value through iteration and to evaluate the quality of the values with the fitness. Each particle updates the velocity and position of its own and its colleagues. The flow chart of the particle swarm optimization is shown in Fig. 8.

C. A Combination Algorithm

Genetic algorithm and particle swarm optimization are all based on the interaction to find optimal value.

However, compared with the genetic algorithm, particle swarm is simpler, it doesn't need the crossover and mutation, while it is more easy to fall into local optimal value. The way to avoid the problem is to make the particle change. This paper proposes a combination algorithm, which applies the genetic manipulation to the particle swarm optimization to avoid falling into local optimal value. To be specific, generate random particles at first, calculate and sort the fitness of each particle, then divide the particles into two parts according to the optimal degree of fitness. The worst half should cross and mutation and then search the optimal values in the way of particle swarm optimization with the better half.

The flow chart of combination algorithm is shown in Fig. 9.

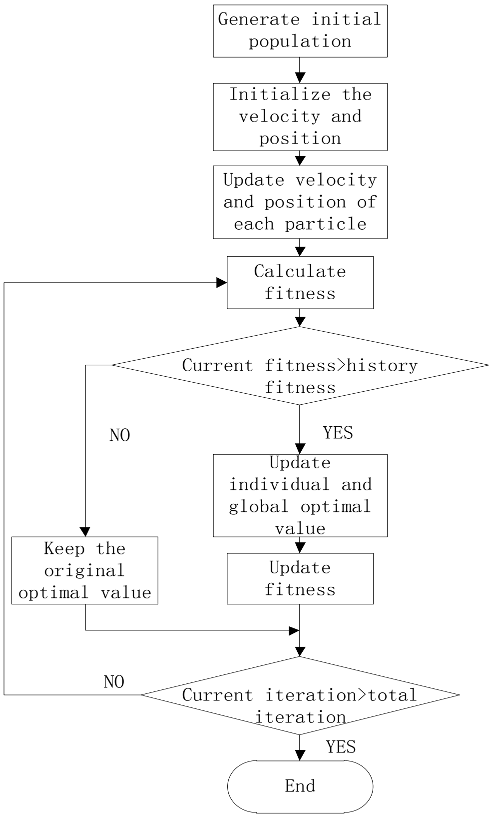

Figure 8. Flow chart of particle swarm optimization.

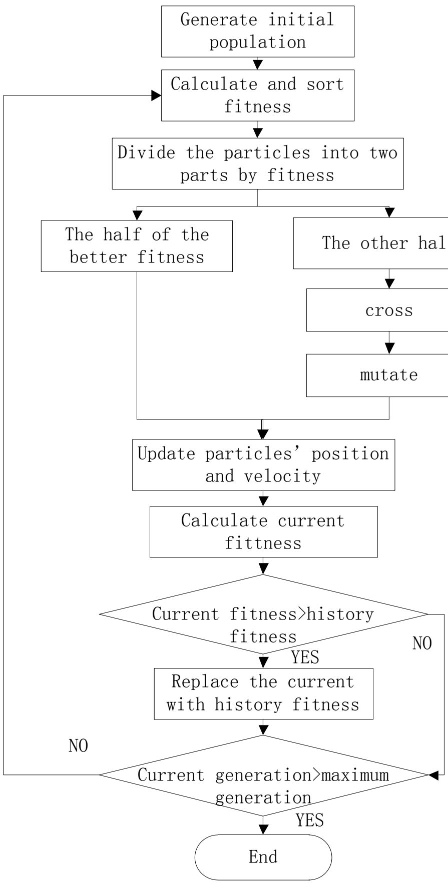

Figure 9. Flow chart of combination algorithm.

In general, Genetic algorithm and particle swarm optimization algorithm and the combination algorithm transform the identification problems into optimization problems. So it is very important to compare their optimal performance.

D. Performance Comparison

Now, these three algorithms are tested by Rosenbrock function, which has one global minimum. However, it is easy to fall into local optimum. The graph of Rosenbrock function is shown in Fig. 10.

Table I shows the convergence probability and average evolution generation of the three algorithms, we can see the combination algorithm's global search ability is strongest.

However, what matters most is the identification accuracy of the three algorithms. So these three algorithms are tested to identify a given model. The difference equation of the given model can be described as formula (3).

$$y(k)=y(k-1)-0.4y(k-2)+1.5u(k-1)+0.2u(k-2)+v(k) \quad (3)$$

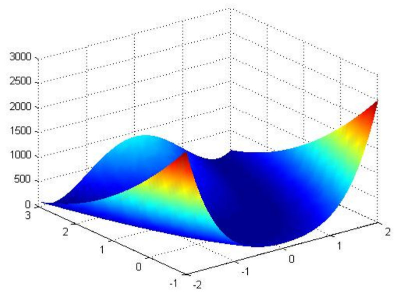

Figure 10. Optimization performance test function- Rosenbrock.

TABLE I. CONVERGENCE PROBABILITY AND AVERAGE EVOLUTION GENERATION

algorithm	Convergence probability	Average evolution generation
Genetic algorithm	13%	78
particle swarm optimization	53%	25
combination algorithm	96%	15

The identification parameters and identification error of each algorithm are shown from Fig. 11 to Fig. 16.

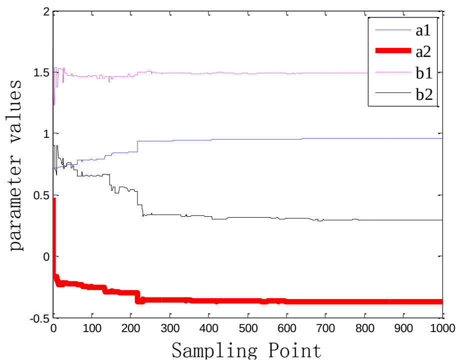

Figure 11. Identification parameters of genetic algorithm.

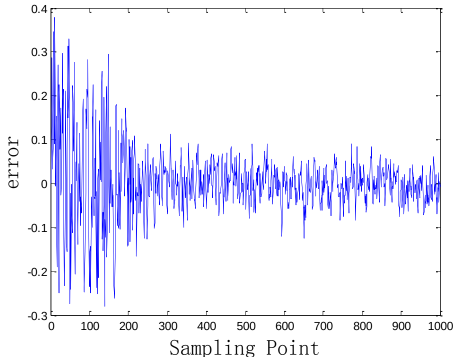

Figure 12. Error of genetic algorithm.

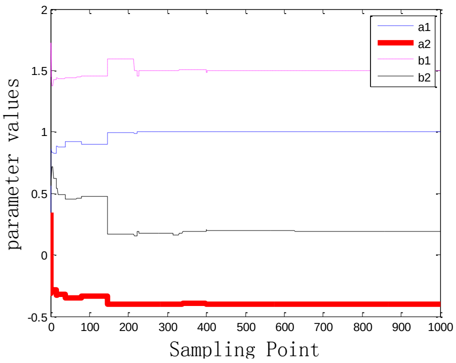

Figure 13. Identification parameters of particle swarm optimization algorithm .

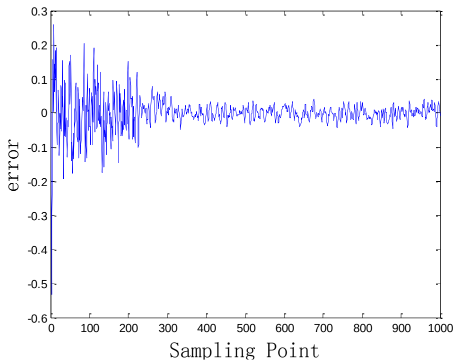

Figure 14. Error of particle swarm optimization algorithm .

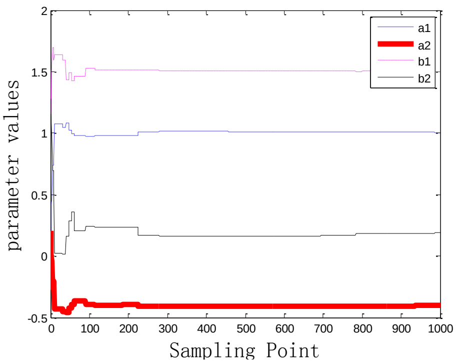

Figure 15. Identification parameters of combination algorithm.

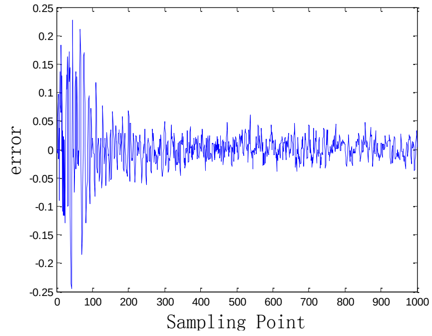

Figure 16. Error of combination algorithm.

The simulation results show that the proposed combination algorithm has better global convergence and higher identification accuracy. Therefore, it is used as the identification algorithm for actuator.

E. Identification of Actuator's Model

The input signal and output signal are regarded as the experimental data to identify the model parameters of the actuator through the proposed algorithm.

At last, parameters of the actuator are obtained by identification with the results of dynamic analysis.

The parameters are:

$a_1 = -0.56$, $a_2 = 0.33$, $b_0 = 0.198$, $b_1 = 0.34$, $b_2 = 0.198$

Then we can get the parameters of transfer function: T=0.0078, ξ=0.55, $k = 1.027$.

The error of estimated output and the actual output is shown in Fig. 17.

It is clear to see that the output of the estimated model can go after the true output. Simulation results have verified effectiveness of the identification algorithm.

V. SUMMARY

This paper takes template matching algorithm as the tracking algorithm to track and acquire the actuator's movement. Then the data of images can be transferred to the computer and be saved by the video collection card. Plus, this paper proposes a combination algorithm to identify the model of actuator, which has a two typical second-order systems.

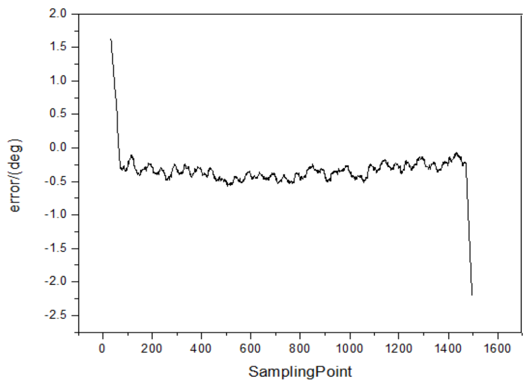

Figure 17. Error of actual model and estimated model.

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