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Control of RC-Helicopter by Using Fuzzy Sliding Mode Controller

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Abstract

Radio-Controlled helicopter has superior movement abilities like as hovering or backward move. So it has been used as a sprinkler of agricultural medicines or an observer of dangerous area such as a volcano, etc. But its operation is not simple because it has many control factors and they interfere with each other. Therefore the helicopter is not controlled by simple theory in the case of automatic operation. Then fuzzy sliding mode control, which has fastness, fineness and robustness, is thought to be suitable to satisfy various requirements of the helicopter operation. In this work, the fuzzy sliding mode control was applied to the flying of RC helicopter. As the result, it was controlled with good performance.

1. Introduction

Helicopters have superior movement abilities like as hovering or backward move. So Radio-Controlled (RC) helicopter has been used as a sprinkler of agricultural medicines or an observer of dangerous area such as a volcano, etc. But its operating is not simple because of small self-stability and its small size. And it has four control factors (up-down, yawing, pitching and rolling) and they interfere with each other. So they should be controlled fast and finely with robustness in order to realize various movements. Thus professional operator is necessary for the flying.

Under this situation, flying assist systems for the operator or auto pilot systems have been studied[1],[6]. Modern control based on mathematical model is thought to have good performance, but the construction of the mathematical model of the helicopter is difficult. From the point of views of simplicity and control ability, sliding mode control[2] is suitable to control the helicopter. And calculation time can be short because of its simple system. However control chattering is caused in some cases. Fuzzy control[3] also has high performances. But it is necessary to construct fine and many rules. And calculation time is long because of many if-then rules. On the other hand, fuzzy sliding mode (FSM) control has been proposed[4]-[6]. This method has fastness, fineness and robustness, and may have ability to compensate both the lacks of the fuzzy control and the sliding mode control. Though the design of the controller is not so simple, it can be performed relatively by using the fuzzy model.

The RC helicopter must be operated fast for drastic movements and finely for stable movement and stable hovering especially. And robustness is also necessary for various condition changes. Therefore we thought the FSM control is suitable to the operation. In this paper we report the results of the application of the FSM control to the flight of the RC helicopter.

2. Design of Fuzzy Sliding Mode Controller

The method of the design of the FSM controller has been proposed elsewhere[5],[6]. The controller is to be constructed for the fuzzy model of RC helicopter and then used to control real RC helicopter. The simple explanation of the construction is as follows. (1) The input and output data is observed from real flight of the RC helicopter operated by professional person. (2) Fuzzy model of the helicopter is made from the input-output data by using Fuzzy Neural Network. (3) FSM controller is constructed for the fuzzy model. In the process (3), control parameters are decided from the fuzzy model by using genetic algorithm[7]. Controlling scheme is shown on phase plane in Fig.1. In the figure, e and Δe are the deviation (between object position and real one) and its time deviation respectively. The phase plane is divided two types of control regions. First is hitting region where the body (state variable) is hit toward the hyperplane by hitting low. Second is fuzzy region where it is moved, along the hyperplane, toward zero point by fuzzy control low. This setting situation has been confirmed to have good performance without control chattering and steady-state deviation by the simulation experiments[5],[6].

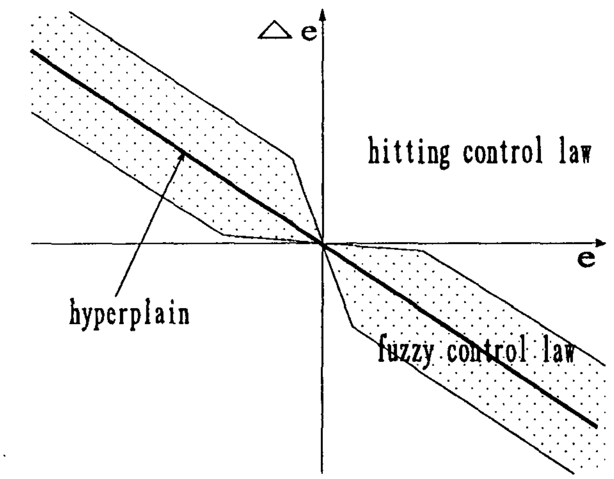


Fig.1 Outline of Fuzzy Sliding Mode control

3. Experiment

3.1 Experimental system

The helicopter is model one for 10 (cc) engine and is remodeled for 1500 (W) DC motor. Its body is supported by an apparatus not to fly out of experimental room but to be able to move free directions (up-down, yawing, pitching and rolling). Block diagram of RC helicopter controlling system is shown in Fig.2. Four sensors (ultrasonic distance sensor for height messier, magnetic direction sensor for yaw angle measure, and two gravity acceleration slope sensors for pitch angle measure and roll angle measure) are placed on the body. Four measured values detected from four sensors are sent to micro computer by radio. On the other hand, four object values are also sent to the computer from a transmitter by radio. And four control values are sent to the helicopter body from the computer by radio. The control algorithm of this system is as follows. The object value of the movement factor for the flight are given (flight schedule is set up) and then the movement factor of the body is controlled as that the deviation between the object value and measured value is to be zero using the FSM controller.

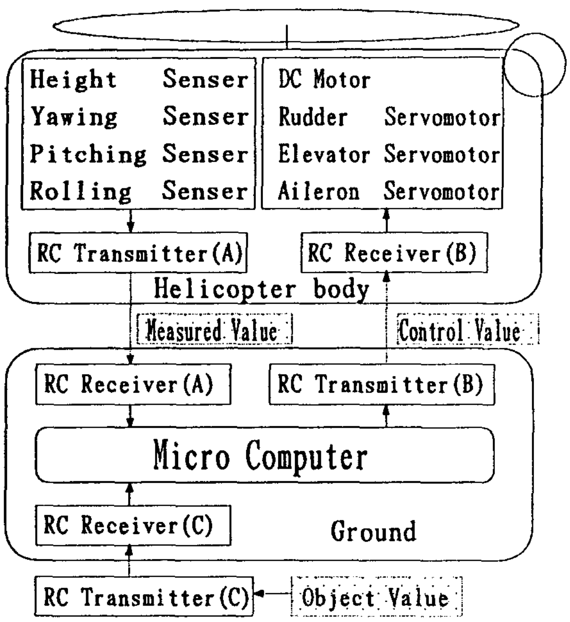


Fig.2 RC helicopter control system

3.2. Results and discussion

Figure 3 shows the state trajectory on the phase plane detected from the step response of the yawing movement. The slanting line in the figure indicates the hyperplane of the FSM control. It can be confirmed that the body is controlled by the FSM controller from the motion of the plot in the figure. Similar results are also observed for the other movement factors.

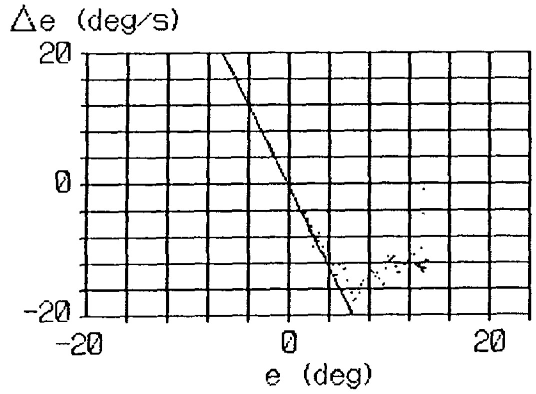


Fig.3 State trajectory detected for yawing control

The results of the flight experiments were evaluated about following points.

(1) The stability and the deviation under steady-state condition.
(2) The response and the stability when the object value is changed.
(3) The stability when the perturbation like as the wind is caused.
(4) The stability when a certain movement is controlled and then the other movements are caused by its interference.

We thought the controlling performance was good when these evaluations were suitable to general use of the RC helicopter.

First we pay attention to yawing movement (YM). When the RC helicopter is operated by manual, the YM can be hardly operated without a gyro system that contributes to generate anti movement for undesirable movement. The cause is as follows. The rotation moment of the YM is small and the YM is fastest among all the movements. The controls of the other movements interfere with the YM, and the height control especially does with the YM by antitorque. Then hunting motion is easily happened. So the control of the YM is said to be more difficult than the other control. It is important to be controlled with exceptional fastness and fineness.

Figure 4 shows the result under steady-state condition for the YM. The horizontal and longitudinal scales indicate the time and the yawing angle respectively. The object value is set as zero. The yawing angle is stable, and timely or steady-state deviations are suppressed between ± 1(deg). It is said to be very good performance.

When step like operation of the object value for the YM is done, the result as shown in Fig.5 is observed. The yawing angle is moved fast to the changed object value, and there exists no overshoot and the deviations are so small.

Figure 6 shows the result when the fluctuation like as the wind is applied to the body and then is cut. After the

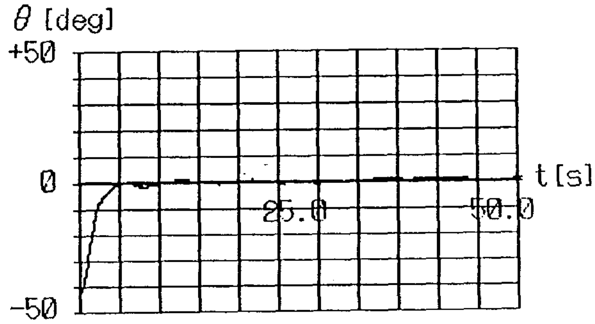


Fig.4 Yawing under steady-state condition

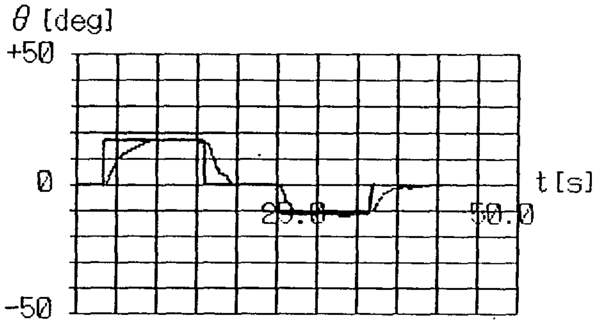


Fig.5 Yawing response for object value change

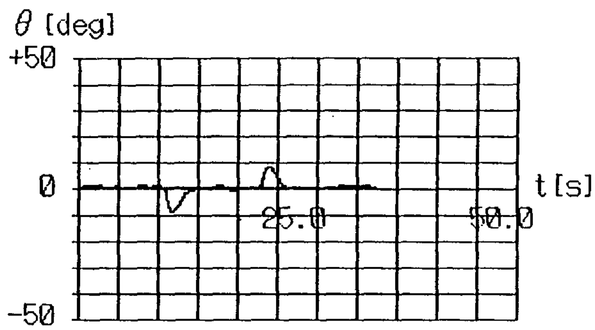


Fig.6 Yawing response for perturbation

change of yawing angle to the fluctuation direction, it is moved back to the object value (zero value) fast with the cut and the resultant deviations are so small.

These results indicate proposed system has enough ability to control the YM of the RC helicopter.

The results observed for the height, the pitching and the rolling controls showed, respectively, good performances similar to the above-mentioned results for the yawing. Only the results for the step like operation are shown in Figs 7-9.

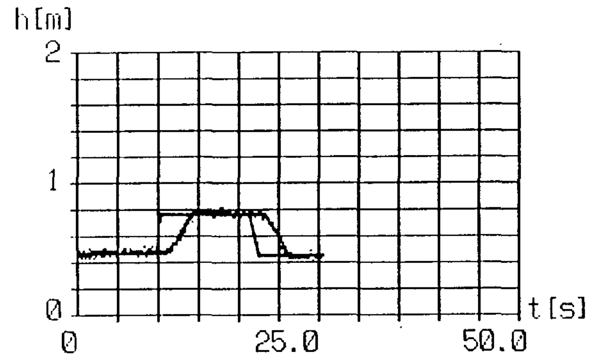


Fig.7 Height response for object value change

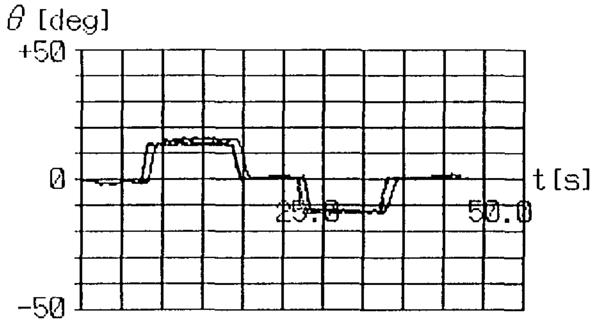


Fig.8 Pitching response for object value change

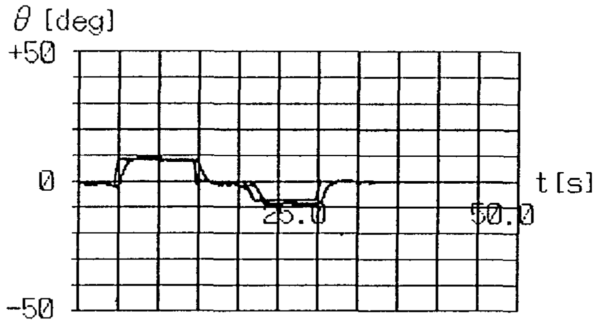
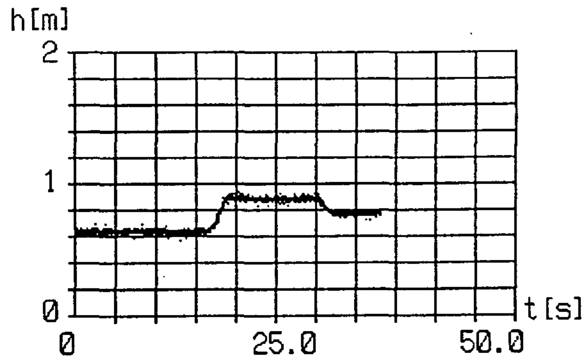
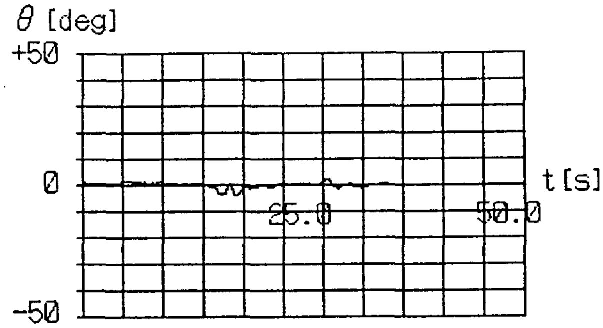


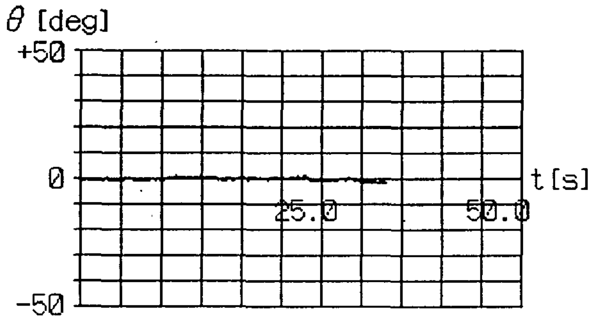
Fig.9 Rolling response for object value change



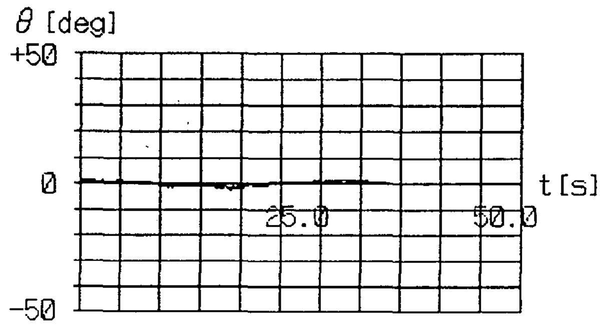
(a) Height



(b) Yawing



(c) Pitching



(d) Rolling

Fig.10 Simultaneous control of four factors

The height is controlled with good performance as shown in Fig. 7.

The pitching and rolling angles are also controlled smoothly though some small deviations are seen as shown in Figs 8 and 9.

The interference among four movements is caused by some reasons. The height control interferes with the yawing motion by the antitorque. In contrast with it, the yawing control does with the height by the power change derived from the pitch control of tail rotor. Pitching and rolling do with each other by the gyro-precession effect and some mechanical linkage gaps, and unstable spin motion is happened. And the slide or the chattering of neutral point of the mechanical linkages causes various interference of a certain movement with the other movements. From the point of view of the interference, simultaneous control was examined.

The results, when four movements are controlled simultaneously and the height is control, are shown in Figs 10(a)-(d). The yawing angle (Fig. (b)) is affected a little when the motor power is up and down for the height control (Fig.(a)), but is cooled down fast to the steady-state condition. The interference is suppressed effectively. The pitching angle (Fig.(c)) and rolling angle (Fig.(d)) are hardly changed though it is not clear if no interference or the interference is absorbed.

The other direction interference was examined and similar controlling performances were got. In every case, the performances satisfy the general use of the RC helicopter.

4. Conclusion

The RC helicopter was controlled using the fuzzy sliding mode controller based on the fuzzy model. As the results, fast control, small overshoot, small deviation from the object value, and calm-down effect on the interference among four movement factors were observed. Such performances were concluded to be sufficiently useful for the general flight of the RC helicopter.

5.References

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