Constant Positional Control by GA of an Airship-type Robot Propelled by Pectoral Fin Movement

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We report herein the constant positional control by GA of an airship-type robot propelled by pectoral fin movement.

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1. Introduction

We have developed an airship-type robot that hovers in the air and has a propulsions mechanism that resembles a fish swimming through the air. We considered pectoral fins as the propulsion mechanism for an airship-type robot. The pectoral fins are chiefly used in operation and in stabilization of the body. Using pectoral fin movement as the propulsion mechanism of the airship-type robot, we have developed a robust constant position control system. We use a genetic algorithm (GA) for position control and attempted an autonomous search to determine the best pectoral fin movement pattern. However, when the GA is applied to an actual robot, a problem exists in that the time required to search for an optimum answer is significant. Therefore, we attempted to improve the settling performance of the GA by performing the actual operation and the simulation in parallel.

2. Specifications of Airship Type Robot

Figure 1 shows the structure of the robot. The robot is has a buoyancy of approximately 200 g, which is provided by a balloon filled with helium. The pectoral fin mechanism, which consists of two servo motors (GWS PICO BB) and two fins constructed of sheets of polystyrene foam, a sensor unit containing three ultrasonic sensors (BestTechnology BTE054) and one yaw sensor (MicroStone MGQ1-01B), and an H8 microcomputer (AKI-H8/3048F) are installed in the frame that supports the balloon⁽¹⁾. Figure 2 shows the control system. The x , y , and z axes are defined as shown in Fig.2. The x , y , and z coordinates of the robot are measured using three ultrasonic sensors, and the yaw angle θ of the robot is measured using a yaw sensor. Data is sent and received by the H8 microcomputer through an RS232C cable connected to a PC. The power supply is an external supply.

3. Constant Positional Control by GA

Figure 3 shows the control flow chart. The GA searches for the best pectoral fin movement pattern by which to move the robot to the goal position. The

Fig. 1. Structure of the robot

Fig. 2. Control system

Fig. 3. Control flow chart

initial position is assumed to be $P_0 = (x_0, y_0, z_0, \theta_0)$, and the goal position is assumed to be $P_g = (x_g, y_g, z_g, \theta_g)$. When the robot is made to move from position P_0 for time t using a certain movement pattern, the position of robot is assumed to be $P_k = (x_k, y_k, z_k, \theta_k)$. The evaluation function F is used to evaluate the movement pattern and determine the error margins of P_g and P_k . The evaluation function F is given by the following equation:

$$F = \frac{a}{1 + g_x(x_g - x_k) + g_y(y_g - y_k) + g_z(z_g - z_k) + g_\theta(\theta_g - \theta_k) + \dots} \quad (1)$$

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where a is an arbitrary constant and g_x, g_y, g_z and g_θ are the weight functions of each parameter. The individual having the highest evaluation in the final generation is considered to be the optimal solution. The best movement pattern is decided by reading the genetic information of this individual. To improve the settling performance of the GA, we used a compound GA that combines actual operation and the simulation. The GA in actual operation is assumed to be GA_O , and the evaluation function of GA_O is assumed to be F_O . The GA in the simulation is assumed to be GA_S , and the evaluation function of GA_S is assumed to be F_S . Moreover, the GA that brings F_S close to F_O is assumed to be GA_F , and the evaluation function F_F is given by the following equation:

$$F_F = \frac{b}{1 + |F_O - F_S|} \dots\dots\dots (2)$$

where b is an arbitrary constant. The result of GA_S can be reflected directly in GA_O by bringing F_S close to F_O . Because the time required to actually make the robot function can be omitted, the optimization time can be greatly reduced.

4. Constant Position Control Experiment

In the following, we consider the z direction. The position is adjusted to a relative position. Here, $z_0 = 0$ cm, $z_g = 100$ cm, $t = 5$ s, and F_O is given by the following equation:

$$F_O = \frac{1000}{1 + |z_g - z_k|} \dots\dots\dots (3)$$

In the present study, we examined the case of using only GA_O and the case of using only the compound GA, respectively. The case of GA_O is denoted as case A. In case A, the robot is actually made to function by GA_O until the tenth generation. The cases in which only the compound GA is used are denoted as cases B, C and D. The robot is actually made to function by GA_O until the 1st generation in case B, until the 5th generation in case C, and until the 9th generation in case D. The optimization of 200th generation is performed by GA_S using the F_S obtained by GA_F . Afterward, the optimal solution obtained by GA_S is reflected in GA_O . In each condition, we measured the change in the $z_k - z_g$ distance, and the experiment was conducted five times. Next, for the cases of $z_g = 0$ cm, 25 cm, 50 cm, 75 cm, and 100 cm, the simulation of the 200th generation in GA_S was performed using F_S obtained by D. The result is reflected in GA_O by the compound GA, and we measured the $z_k - z_g$ distance. The experiment was conducted five times for each z_g .

5. Experimental Results

Figure 4 shows the change in the $z_k - z_g$ distance for each case. The marker is the average of five measurements, and the error bar is the standard deviation σ . The minimum distance was 40 cm in the tenth generation in D, the optimization of which required 30 min. Figure 5 shows the distance of the optimal solution for GA_S and the distance when the optimal solution is reflected in actual operation using the compound GA. The

Fig. 4. Change in the distance to the goal

Fig. 5. Distance comparison

values are the average of five measurements, and the error bar is the standard deviation σ . The optimization for each z_g required 5 sec. In Fig.4, compared to case A, case C approaches z_g in fewer generations, and the number of generations is same in cases A and D. However, among all cases, case D most closely approaches z_g . Therefore, a better pectoral fin movement pattern can be achieved in a short time by using the compound GA. In addition, the settling performance of the GA can be improved. In Fig.5, the result of the simulation by GA_S and the result of actual operation by the compound GA are in approximate agreement. Therefore, by using the compound GA and studying F_S beforehand, the pectoral fin movement pattern can be optimized in only 5 sec for an arbitrary height.

6. Conclusions

In the present report, we developed an airship-type robot propelled by pectoral fin movement, and a constant position control system by GA. Moreover, in a constant position control experiment using the compound GA, the optimization of the 200th generation, which requires eight hours using GA_O , was able to be achieved in only 5 sec. In addition, the settling performance of the GA was able to be improved. Areas for future research include power supply installation, wireless communication, and three-dimensional position control.

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References

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