PID orbit motion controller for indoor blimp robot

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Abstract

A blimp robot is attractive as an indoor robot because a blimp robot can float in the air by buoyancy and realize safe indoor flight with low energy. In our research, we focus on the indoor entertainment blimp robot because a blimp robot can be used the environment where children exist and offer a visual amusingness by combination with animated character-type balloon. Our blimp robot has a wireless camera as a sensor and moves by using the output device that has total of six propellers to produce thrusts for each axis in three dimensional coordinate system. In this paper, we report the circular, square, triangle motion controls of the blimp robot as fundamental motions for entertainment motions.

keywords : indoor blimp robot, entertainment, motion control, camera

1 Introduction

The research on a blimp robot is active area on the various research groups because a blimp robot freely moves in the environment without being influenced by the geographical features, realizes the long time flight by less energy and has high-security for a crash. A blimp robot can be applied to various tasks, e.g., monitoring, climate research, transportation and surveillance [1][2].

In our research, we focus on the indoor entertainment blimp robot such as a dancing blimp robot and an interactive blimp robot. Because a blimp robot can realize safe indoor flight in the environment where children exist and offer the visual amusingness by combination with an animated character-type balloon, a blimp robot is attractive and impressive as a new indoor-type amusement robot. As entertainment flights, a blimp robot can act a synchronized flying motion, a flying exploit, a communication with humans in a show and an event hold in an indoor plaza, gym and theater.

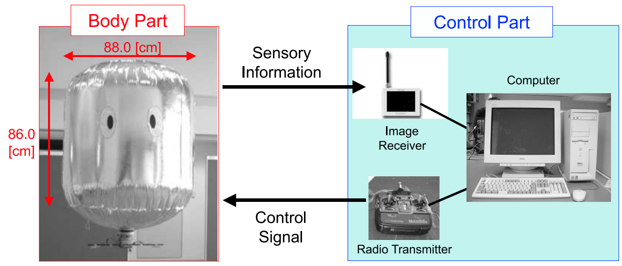

Figure 1: Control System of Our Blimp Robot

Although a blimp robot has various advantages, the control of a blimp robot is difficult compared to a two-dimensional mobile robot. A blimp robot needs the position control in three-dimensional space and the attitude control. Furthermore a blimp robot is influenced by slight air stream and subjected to inertia. In the research groups on a blimp robot, the control is one of the active topics in the problem for a blimp robot.

In this paper, we aim to achieve the circular, square and triangle motions as fundamental motions for a blimp robot. Because a circular motion includes the motion for a basic curve and square and triangle motions include the motions for a basic straight-line and twisting the corner, the realization of the motions can be applied to various motion controls.

2 Control system of our blimp robot

2.1 Pillar-type blimp robot

Figure 1 shows the outline of the control system for our blimp robot. The control system is divided into two parts: the body and the control part. The body

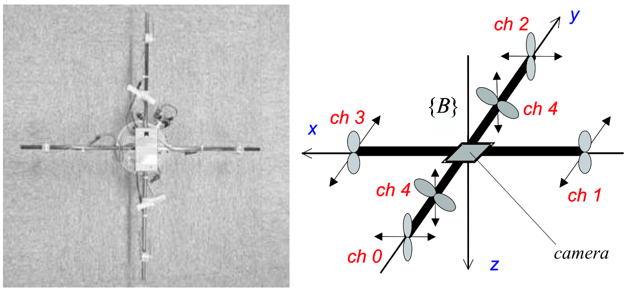

Figure 2: Output Device

part has a pillar-type balloon, an output device and a wireless camera. The control part placed outside has a computer, an image receiver and a radio transmitter.

The diameter of the balloon is 88[cm] and the height is 86.0[cm]. The pillar-type balloon carries a big payload because of the large volume. Furthermore, it realizes the fair air resistance in the horizontal plane.

The output device is attached to the bottom of the balloon. As shown in Figure 2, the output device has total of six propellers. The propellers produce thrusts for each axial direction independently in the coordinate system $\{B\}$ fixed at the blimp robot. The blimp robot moves in the horizontal plane with four propellers, $ch0$-$ch3$, positioned at the tips of a crisscross rod. The propellers $ch0$ and $ch2$ produce thrusts for x-axial movement. The propellers $ch1$ and $ch3$ produce thrusts for y-axial movement and for yaw angular movement. The propellers $ch4$ positioned on the central part of the crisscross rod produce thrusts for z-axial movement.

A wireless camera is attached facing downward on the output device. The blimp robot recognizes the environment and own state about the position and the attitude by using the camera. The image signal is transmitted to the image receiver in the control part, and then it is loaded into the computer through a video capture board. The computer processes the image to decide the operations for each propeller, and then the decisions of the operations for each propeller are transmitted to body part as a control signal through the radio transmitter.

2.2 Positioning system

In the tasks for a monitoring and a surveillance, a blimp robot normally needs to move in the environment by recognizing each local location. However an entertainment blimp robot just recognizes the artificial environment put the prepared landmarks regardless of the locations, e.g., plaza, gym and theater, because the operating environments are comparatively free for an entertainment robots such as RoboCup including an amusing factor.

In our previous work [3], we have developed the simple positioning system in viewpoint of a facile introduction to various places. In the positioning system, M red circles are placed on a gridiron on the floor as shown in Figure 3. Each circle has an identification number $ID_l(l = 1, \ldots, M)$ and two coordinate values P_l and $p_l(t)$. P_l is the value in the absolute coordinate system fixed at the environment $\{U\}$ and $p_l(t)$ is the value in the blimp coordinate system fixed at the blimp robot $\{B\}$. The blimp robot get the own position P_b in $\{U\}$ by recognizing the circles in the image processing and calculating ID_l, P_l and $p_l(t)$ [3].

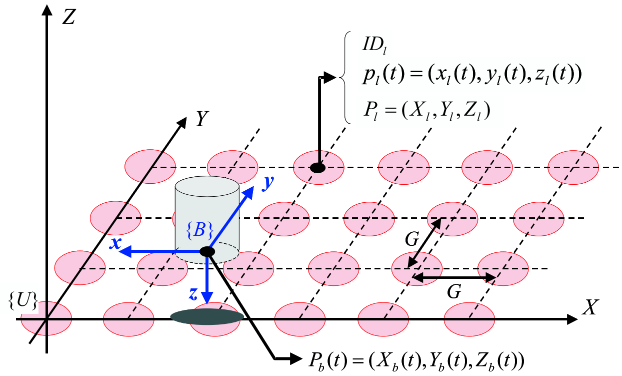

Figure 3: Outline of Positioning System

We can apply the positioning system to various places with facility because we just scatters the landmarks such as red circles in the environment and the blimp robot just recognizes the prepared environment.

2.3 Controller

A blimp robot has complex dynamics because a blimp robot has several nonlinear characteristics, e.g., an inertial influence at a movement, a change of thrusts by burning a battery power and a strain of a balloon form. Therefore PID-controller is applied to the control architecture in the research groups [1][2], because it is difficult to decide the analytical controller for a blimp robot. In PID-controller, we can regulate the controllable parameters with relatively little effort by repeated trial and error.

In our PID-controller, the manipulated variable $m(t)$ is given as the ratio of the rotation time for each propeller in sampling time ΔT. The manipulated variables $m_x(t)$ and $m_z(t)$ corresponding to $ch0$, $ch2$ and $ch4$ are decided by the relative distance from the blimp robot to the target point defined as follow.

$$m_x(t) = K_{px}\left(e_x(t) + \frac{1}{T_{Ix}}\int e_x(t)dt + T_{Dx}\frac{de_x(t)}{dt}\right)$$

$$m_z(t) = K_{pz}\left(e_z(t) + \frac{1}{T_{Iz}}\int e_z(t)dt + T_{Dz}\frac{de_z(t)}{dt}\right)$$

The propellers, $ch1$ and $ch3$, are used to control both the pulsion for y-axis and the attitude for yaw angle

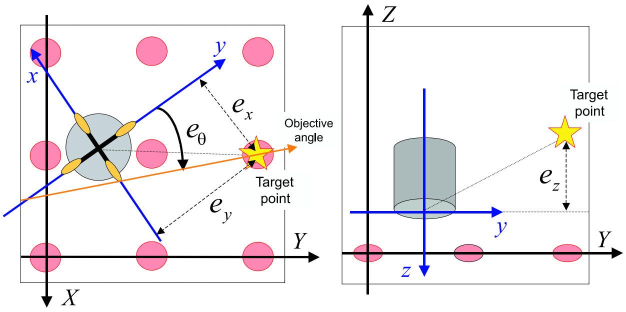

Figure 4: Deviation from the Blimp Robot to the Target Point

as shown in Figure 4. Therefore the manipulated variables $m_{y\_r}(t)$ for $ch1$ and $m_{y\_l}(t)$ for $ch3$ are decided by both the relative distance and the relative angular from the attitude of the blimp robot to the objective attitude defined as follow:

$$m_{y\_r}(t) = m_{y\_d}(t) + m_\theta(t)$$

$$m_{y\_l}(t) = m_{y\_d}(t) - m_\theta(t)$$

where $m_{y\_d}(t)$ is the term of the relative distance for y-axis and $m_\theta(t)$ is the term of the relative angular defined as follow.

$$m_{y\_d}(t) = K_{py}\left(e_y(t) + \frac{1}{T_{Iy}}\int e_y(t)dt + T_{Dy}\frac{de_y(t)}{dt}\right)$$

$$m_\theta(t) = K_{p\theta}\left(e_\theta(t) + \frac{1}{T_{I\theta}}\int e_\theta(t)dt + T_{D\theta}\frac{de_\theta(t)}{dt}\right)$$

3 Experiment

3.1 Experimental setup

In the experiment, we experiment on the control of the blimp robot for circular, square and triangle motions. Because the circular, square and triangle motions includes basic motions for a curve, straight-line and twisting a corner, the achievements of these motions can be applied to various movements. In the circular motion, the blimp robot is controlled to pass 10 target points on the circle with radius 150[cm] in XY-plane. In the square and the triangle motions, the blimp robot is controlled to pass apexes on the square and triangle 250[cm] on a side in XY-plane. The blimp robot is controlled to keep 200[cm] high for Z-axis in all motions. For the attitude control, the blimp robot is controlled to parallelize the line connecting the previous target point and the current target point.

The experimental environment is the space in the building of University as shown in Figure 5. The

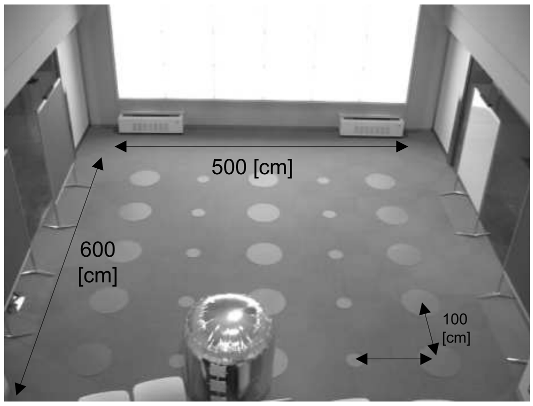

Figure 5: Experimental Environment

width, depth and height are 600, 500 and 500[cm]. 25 red circles are placed on a gridiron on the floor, and the interval is 100[cm]. The controllable parameters K_p, T_I and T_D are manually set by repeated trial and error in the preliminary experiments.

3.2 Result

Figure 6, 7 and 8 show the experimental results for the circular, square and triangle motions. In each figure, the left and right side is the motional orbit in XY-plane and YZ-plane. The solid line shows the motional orbit of the blimp robot and the dashed line shows the objective orbit connecting the target points in turn.

In the circular and square motions, the blimp robot has moved approximately along the objective orbit in XY-plane. In the triangle motion, the blimp robot has got away from the objective orbit after turning the corner compared with the circular and square motions, because the twisting angle for the triangle motion is larger than the angles for the other motions. Moreover, because the blimp robot has turned the corner going in the direction to next target point, the blimp robot has turned the corner without passing over the target points for the corner. However the blimp robot could have modified the own position by the arrival at next target point.

The unstable motional orbits have been caused for Z-axis in all experiments, because the realization of the neutral buoyancy is difficult and the thrusts for x and y-axes in $\{B\}$ have influenced for Z-axial motion by the rocking vibration of the body. The rocking vibration causes the vibrational orbits in Figure 6, 7 and 8, because the motional orbits are measured by the camera attached on the blimp robot. Because the rocking vibration is caused by the high position of the center of the gravity, we consider that we use the horizontally long body as one of the solutions for the rocking vibration.

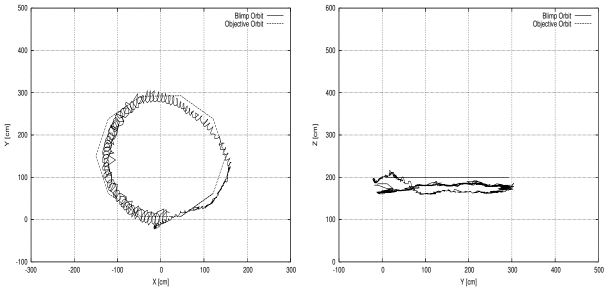

Figure 6: Orbit for Circular Motion

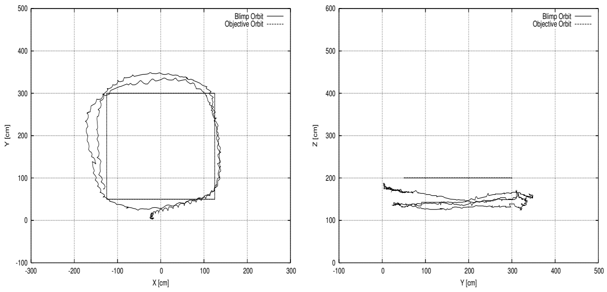

Figure 7: Orbit for Square Motion

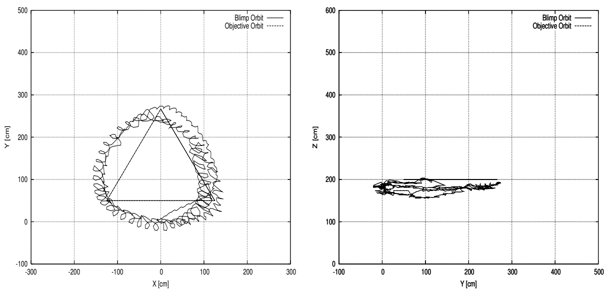

Figure 8: Orbit for Triangle Motion

The attitudinal transition of the blimp for each experiment is shown in Figure 9. Slight over rotation have been caused in the square and triangle motions, because the twisting angles are acute angle. However the blimp robot could have control the attitudes to the objective attitudes in short time.

4 Conclusion

In this paper, we reported the fundamental motion controls of our pillar-type blimp robot for application to an entertainment. In the experiments, we pick up the circular, square and triangle motions as the fundamental motions, because the orbits for the motions have the motions for a basic curving line, straight line and curving a corner. Although we could achieve the fundamental motions to move approximately along the orbits, we need to enhance the control accuracy.

In the future works, we need to achieve the more complex and amusing motions by combination with various motions, e.g., curve line, straight line, twisting

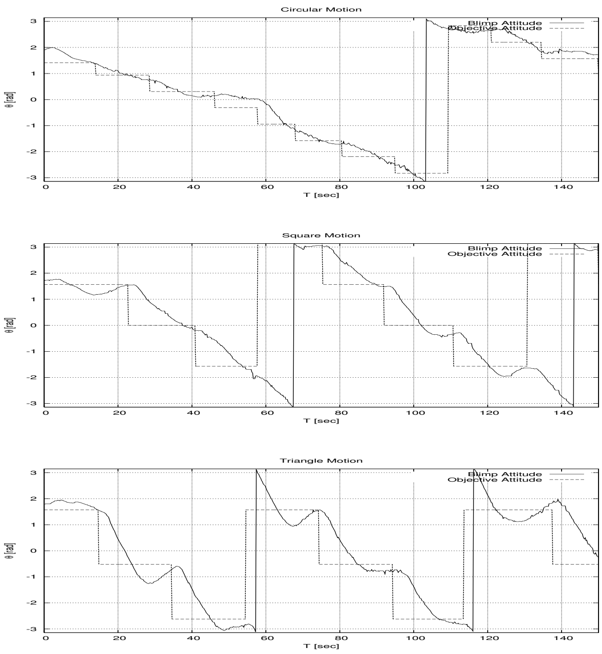

Figure 9: Attitudinal Transition

the corner, rotation on the spot and change of a height. If the blimp robot can execute the sequence of motions given by combinations with the above motions, the blimp robots act the performances and synchronized flight motions as dancing entertainment blimp robots.

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