Learning landing control of indoor blimp robot for autonomous energy recharging

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Abstract

We report on learning landing control of autonomous energy recharging for indoor blimp robots. Indoor blimp robots have potential applications in monitoring, surveillance, and entertainment. It might be necessary for long term flight to achieve these applications,. Since blimp robots cannot load a heavy battery, it is difficult for long time flight. We focused on autonomous energy recharging to solve this problem, especially moving to the charging station, we call it landing control. We make use of learning control for landing control because of its satisfactory accuracy. The results of experiments demonstrated that learning control is effective for landing control.

key words - indoor blimp robot, autonomous energy recharging, landing, controller

1 introduction

Indoor blimp robots have the features of using buoyancy to move three dimensional movements, moving less energy, and safety in crashed compared to small air-crafts or helicopters. For these features, indoor blimp robots have enormous potential for applications such as entertainment movement, monitoring activity at high attitudes.

However they have difficulties to control because of nonlinear thrust, balloon imbalance, and air resistance, so many researches focus on control design for indoor blimp robots, such as maintaing a fixed position[1], and circular or triangle motion[3]. These control design are based on achieving applications of ahead, also it might be necessary for long periods movement. Because of payload restrict, indoor blimp robots cannot load batteries for long periods movement. For long periods movement, we describe autonomous energy recharging system, especially landing control to charge battery.

2 Indoor Blimp Robot

We use columned blimp robot. Compared to ellipsoidal typed balloon, columned type balloon have the advantages of uniform air resistance for directions, moving precisely in the desired direction directly without rotation. These features might be necessary to achieve the applications for indoor blimp robots.

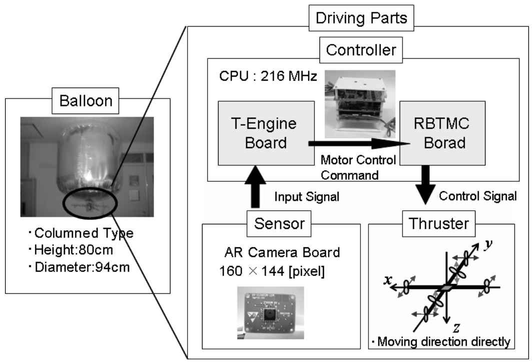


Figure 1: Overview of indoor blimp robot: balloon and control system.

Figure 1 shows a columned blimp robot and control system overview. Blimp robot consists of a balloon for enabling to float and a driving parts for moving. Driving parts consist of the controller, thrusters, and sensor.

In design of balloon, we decided on diameter as $0.94[m]$ and height as $0.8[m]$ to enable the blimp to float by buoyancy.

The controller consists of a T-Engine board and $RBTMC$ board. Image processing calculations and decisions on outputs to control the blimp are run on the T-Engine board and sent to the $RBTMC$ board as control commands for propellers on thrusters. Based on control commands, the $RBTMC$ board controls motors that drive propellers at a sampling time $\Delta T = 0.3[s]$, which is based on consumption time for image process and control decision.

The blimp recognizes positional information and environmental conditions through camera sensor,AR camera, which sends image data to the controller via an internal bus and is fitted on thder T-Engine board.. The image resolution is 160×144 pixels, and color information is composed of 16bit data in RGB color space.

The blimp robot has six propellers, $ch0$ and $ch2$ for x-axial movement, $ch1$ and $ch3$ for y-axial movement, and $ch4$ and $ch5$ for z-axial movement. Propeller thrust is adjusted by controlling motor rotation due to hardware constraints. We attempt to adjust thrust by switching On/Off signals controlling motor rotation.

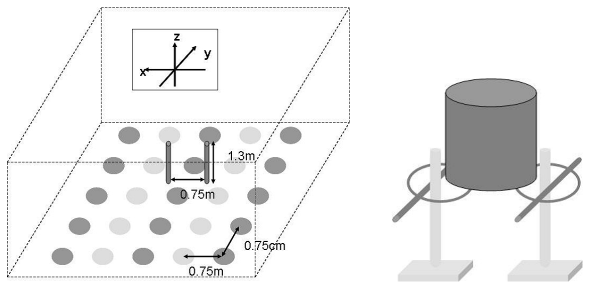
3 Autonomous energy recharging

Autonomous recharging is the key of long periods movement and activities for mobile robots. In the research activity of 2D mobile robots, autonomous recharging are proposed[4],[5]. Many researches focus on 1)making the charging station including environment , and 2)control design to the station. In the field of 3D mobile robots, indoor or outdoor robots, these functions are required.

3.1 Environment

The left figure of Figure 2 shows the environment and charging station for indoor blimp robots. The blimp recognizes its position information from landmarks placed on ground and moves based on position information, see as [3]. The blimp moves to the two $130[cm]$ height poles, which set $75[cm]$ apart, for autonomous energy recharging, which movement called as landing control for indoor blimp robots.

The right figure of Figure 2 shows landing overview. Indoor blimp robot must move to the two-poles from the upper space. Landing control is necessary to descend straight. As landing control accurately, 1)putting plane coordinates, 2)slowing horizontal velocity, and 3)retrying docking to the station apart from



Experimental enviornment Landing overview.

Figure 2: Experimental environment and charging station

the station, are required. The control design of the blimp robots satisfies these requirements.

3.2 Control design

It is difficult to design an analytical controller based on a dynamic model because a blimp has such nonlinear characteristics as air resistance, and inertia during movement.

Researchers have experimented with PID [3],fuzzy [6],and learning [2] controllers for blimp robots because they do not need the complex analysis required for dynamic model. We use a PID controller for movements, such as circular and triangle, and learning controller for landing control. PID controller for the blimp robot might be difficult for landing control with satisfactory accuracy in the related work [3]. Learning control has the advantages compared with PID control, such as parameters are a little and it reflects on an inertia, air resistance and temperature.

3.2.1 PID control

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 $m_x(t)$, $m_y(t)$, $m_z(t)$ are decided by the relative velocity from the blimp robot to the target point. The manipulated variable $m_\theta(t)$ is calculated by the relative angular. These manipulated variables are defined as follows.

$$m_x(t) = K_{Px}e_x(t) + K_{Ix}\Sigma e_x(t)\Delta T + K_{Dx}\frac{De_x}{\Delta T}$$

$$m_y(t) = K_{Py}e_y(t) + K_{Iy}\Sigma e_y(t)\Delta T + K_{Dy}\frac{De_y}{\Delta T}$$

$$m_z(t) = K_{Pz}e_z(t) + K_{Iz}\Sigma e_z(t)\Delta T + K_{Dz}\frac{De_z}{\Delta T}$$

$$m_\theta(t) = K_{P\theta} e_\theta(t) + K_{I\theta} \Sigma e_\theta(t) \Delta T + K_{D\theta} \frac{De_\theta(t)}{\Delta T}$$

where K_P is proportional gain, K_I is integral gain and K_D is derivative gain, and $De(t) = e(t) - e(t - \Delta T)$. Thrusts $M_0(t)$,...,$M_5(t)$ generated for propellers $ch0$,...,$ch5$ are determined by using $m_x(t)$,$m_y(t)$,$m_z(t)$,$m_\theta(t)$ as follows.

$M_0(t) = m_y(t) + m_\theta(t)$, $M_1(t) = m_x(t) + m_\theta(t)$, $M_2(t) = m_y(t) - m_\theta(t)$, $M_3(t) = m_x(t) - m_\theta(t)$, $M_4(t), M_5(t) = m_z(t)$.

3.2.2 Learning control

Learning control is realized by updating the learning table, its horizontal axis is the relative distance and vertical axis is the relative velocity. The blimp robot becomes the preferable condition using learning control after updating the learning table. Figure 3 shows the overview of the learning control,where 0 is the positive rotation and 1 is the negative rotation. When the relative distance do not reach to the zero of the horizontal axis and the relative velocity gets across the zero of the vertical axis, the learning table is updated with inversion of each element. There is the possibility to update the learning table in movements to adjust the environment condition.

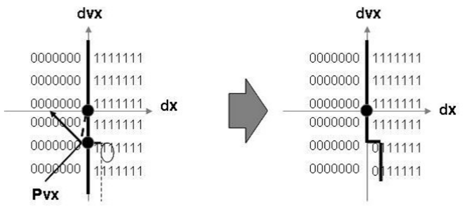


Figure 3: Overview of learning control

3.2.3 Landing area

We divide the movement area of the blimp robot into three for landing achieving with satisfactory accuracy. We consider that it is possible to land by this area division even if the blimp robot misses the desired orbit to the station. First area is that the blimp robot get near to the charging station. In this area, we make use of PID control. Second area is near the charging station, but the precision cannot be satisfied. In the second area, the blimp robot move to the upper space of the charging station by learning control to satisfy the accuracy of the landing. Third area is that the blimp robot descend to the charging station. In this area, the blimp robot is controlled by its velocity with learning control not to break the charging station and blimp itself. If the blimp robot moves from the third area to the second area, the blimp robot moves up and retries landing.

4 Experiment

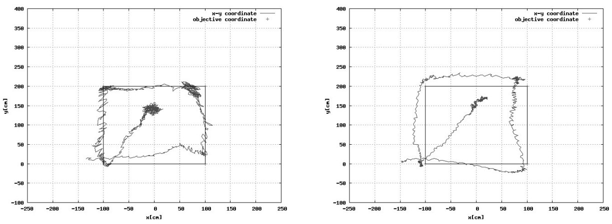
4.1 Experimental setup

In the experiment, we confirm the achievement of the landing control using learning control and the complicated motion for applications. The blimp robot moves for the square and rotational motion. After the square and rotation, the blimp robot tries the landing motion. The square motion includes basic motions for straight-line and twisting a corner. These motion can be applied to various movements for indoor blimp robot. In the square motion, the blimp robot is controlled to pass apexes on the square, $200[cm]$ on a side in XY-plane. The blimp robot is controlled to move $150[cm]$ and $250[cm]$ high for Z coordinate alternately on each apex. Before the rotational motion, the blimp robot moves to the target point for the landing motion. In the rotational motion, the blimp robot rotate from $\pi/2[rad]$ to $-\pi/2[rad]$. The rotational motion can be applied to the autopilot and monitoring. In the landing motion, the blimp robot tries to descend to the target point its 3D coordinate $P_s = (0, 150, 120)$. Landing to the station is required accuracy , X and Y coordinate within $10[cm]$ from the center of the station, and yaw angular within $\pi/16[rad]$.

The blimp robot change its control from PID control to learning control after rotational motion. The experimental environment is the space in the building of University as shown Figure 2. The controllable parameters are manually set by repeated trial and error in preliminary experiments.

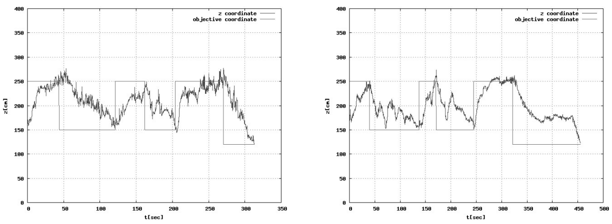
4.2 Result

Figure 4, 5, and 6 shows the whole motion of the blimp robot. In the square motion, the blimp robot has moved approximately along the objective orbit in XY-plane. Z coordinate movement of the blimp robot has also moved approximately, a little unstable because of the difficulty of the neutral buoyancy. In the rotational motion, the blimp robot has rotated approximately to the objective angular. In the landing motion, the blimp robot has descended to the target point P_s instantly. Also, X, Y coordinates and yaw angular are within the required precision. In another experiment, the blimp robot cannot descend to the target point P_s instantly because of unsatisfying precision to the station. In this case, the learning control is more effective compared to instant movement because of updating its table repeatedly. We conclude that learning control is effective for landing motion from the experimental result.



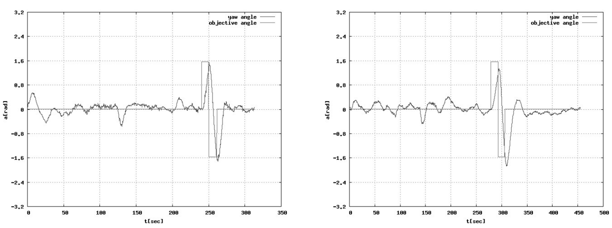
Exp1 Exp2

Figure 4: X-Y coordinate trajectory of the blimp robot



Exp1 Exp2

Figure 5: Z coordinate transition of the blimp robot



Exp1 Exp2

Figure 6: Yaw angle transition of the blimp robot

5 Conclusion

In this paper, we reported the learning landing control of autonomous energy recharging for indoor blimp robot. In the experiment, we showed the motion combination of the square, rotational and landing motion. We could achieve the reliable accuracy for the landing with learning control.

In the future works, we need to configure the electrical device to charge the battery. Also, we need to achieve a less time consumption for movements to save the battery. In these functions, the blimp robot act the performances, entertainment movements, and monitoring for the long time.

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References

[1] S.Zwaan, A.Bernardino, J.Santos-Vitrol, "Visual station keeping for floating robots in unstructured environments"," *Robotics and Autonomous Systems*,Vol. 39, pp. 145-155, 2002.

[2] K.Motoyama et.al. , "Development of Autonomous Blimp Robot with Intelligent Control",*Entertainment Computing - Technologies and Applications*, pp. 191-198, Kluwer Academic Publishers, 2003.

[3] H.Kawamura et.al., "Motion Design for Indoor Blimp Robot with PID Controller", Journal of Robotics and Mechatronics, Vol.17, No5, pp. 500-508, 2005.

[4] S.Oh, A.Zenlinsky, K.Taylor, "Autonomous Battery Recharging for Indoor Mobile Robot", Proceedings of Austrlian Conference on Robotics and Automation, 2000.

[5] M.C.Silverman et.al., "Staying Alive: A Docking Station for Autonomous Robot Recharging", IEEE International Conference on Robotics and Automation, 2002.

[6] M.Sugisaka et.al., "Development of the Fuzzy Control for a GPS-located Airship", Proceedings of the Tenth International Symposium on Artificial Life and Robotics, 2005.