Vision based control for line following blimp robot

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Abstract

We report on following the line based on camera image for indoor blimp robot. Indoor blimp robot can be moved to the altitude and the place with differences in the building. There are applications of the guide and the round in the building by using those features. It is generable target orbit to put the one that becomes a landmark on the moved place. Therefore, we put the line as a landmark. The line is showing flat information in the target orbit, and information on height can be obtained according to the width of the line. In this paper, we report the extraction method of the line, and how to follow the line.

key words - indoor blimp robot, following line, autonomous robot

1 Introduction

The blimp robot can be moved to the altitude and the place with differences in the building, it is an advantage for blimp robot that the place to which the robot of a humanoid type is not moved easily can be moved. Moreover, it is possible to move safely in the building compared with a small airplane and the helicopter, etc. and use to the applications like the guide in the building, the round and the watch are thought by using of such a feature.[1] There is a problem of enlarging the balloon to obtain big buoyancy, so it is difficult to use a lot of sensors. Moreover, the control is difficult because the influence of inertia is large, and it sensitively reacts to turbulence by movement of air-conditioning and the person on an environmental inside.

It is needed to make it follow to the generation of the target orbit and the orbit to achieve such an application. It is moved to the target point recognizing a three-dimensional position of an environmental inside by using the landmark in a research up to now. However, the target orbits on the plane can be given by closely arranging the landmark in the moving place in the application that moves only a specific indoor place. Then, it aims to move to the target point to assume the landmark to be a line, to give the target orbits, and to make on the orbits follow in research. The line is an easy landmark that expresses the target orbits, and the height of the target orbits is recognized from the width of the line. Because the calculation cost of this is lower than the method such as putting the sign on the line, it is thought the control way is effective in the place where the turbulence that rotates by 180 degrees momentarily does not occur.

In this paper, the composition of the balloon robot used, the extraction method of the line, and how to decide to thrust are described as follows.

2 Blimp robot

Blimp robot has an elliptical body to reduce air resistance. These airships are generated by high-speed movement. However, it is not necessary important for indoor blimp robots to generate high-speed movement. So we designed a columned blimp robot.[1][2][3] This design can make air resistance in the direction of movement equal. And the column type can greatly take the volume. And, it is preferable the airframe's without turning when thinking a narrow indoor space is moved to be able to move directly. This blimp robot has three propulsion units.Ch4 is enabled vertical movement, and ch0, ch1, ch2 and ch3 are enabled dimensional horizontal plane movement.

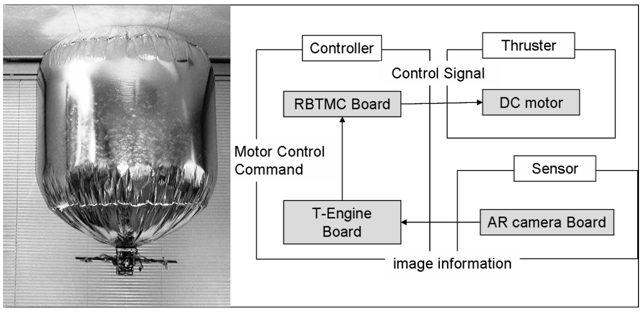

Figure 1: blimp robot and overview

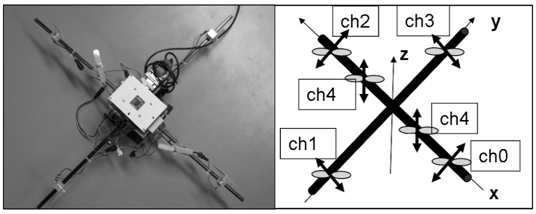

Figure 2: propeller unit

We decided on diameter D[m] and height H[m] to determine balloon size. Total weight of blimp robot W[g] is calculated as follow calculation.

$$W = \pi\rho_{he}H(\frac{D}{2})^2 + \pi cD(H + \frac{D}{2}) + U \qquad (1)$$

ρ_{he} = 178.5[g/m^3] is helium density and, c[g/m^2] is the unit weight of balloon material. Balloon material is aluminum film, whose unit weight c is 30.0[g/m^2]. U is the weight of the propeller unit consisted of the six propellers, the camera sensor, and the controller. Weight U is about 480[g]. And, B_u is the buoyant force.

$$B_u = \pi\rho_{air}H(\frac{D}{2})^2 \qquad (2)$$

ρ_{air}=1226.0[g/m^3] at 0 ℃,1atm. B_u must be larger than W. We set diameter D to 0.94[m], and height H to 0.8[m].

The propellers are positioned independently axial direction fixed to the blimp. Because the motors for propellers are driven by ON/OFF signal, it is difficult to generate certain amount of thrust. So 10 switching points set at sampling time ΔT=0.3[s]. Blimp robot is equipped AR camera as a sensor. The image resolution is 160×144 pixels. And, Color information is sent by 16 bits RGB color space. The image information obtained with the camera is sent to T-Engine board, and thrust that processes the image there is decided. The motor control command is sent from T-Engine board to RBTMC board and the motor is rotated.

3 Line extraction

To follow the line, width and the centerline of the line are acquired from the image. The purpose of the width of the line is to request the height of the blimp robot, and it is followed to the centerline of the line to take both sides of the line in the image. To calculate them, the edge point of the line is searched out. The edge point is a verge of the color of the line and the color of the floor. The distinction of the color of the color of the line or the floor is judged from a color near the threshold by the YUV space. It is difficult in

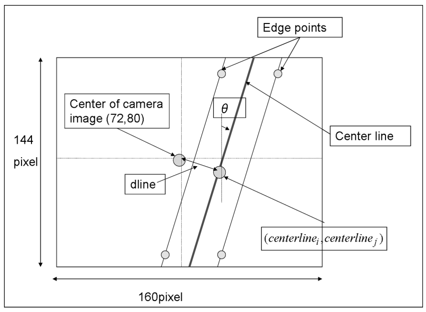

Figure 3: Information on line in camera image

the point of the calculation time to judge whether it is an edge point of all pixels of the camera image. So, we search edge points from the pixel of the image of a round. And, it searches for the pixel of the image in putting several points and it looks for an internal point of the seeing line. An internal point is a point judged that four pixels in surroundings are the colors of the line. When ,every one point, it is searched for to the edge of the image from the internal point, and it is judged an internal point, the edge point, and the color of floor, the edge point is judged as an edge point of the line.

When the line is taken in the camera image, it might have the edge point in four points. Two straight lines of the edge line are calculated from the edge point in four points. The centerline of the line is calculated by averaging expressions two straight lines.

The method of calculating the width of the line calculates the distance with another edge line from one edge point.

$$linewidth = \frac{\mid j - Ai - B \mid}{\sqrt{1 + A^2}} \quad (3)$$

J and i are shown the pixel position in the camera image of one edge point. A and B are shown the gradient and the cut in the camera image of another edge line from the edge point. And, the value of the width of the line changes by the position of the calculated point because the edge lines are not parallel when calculating only in one point. Therefore, the width of the line is calculated with each edge point in two points on the same edge line, and the average value is used as width of the line at that time.

Next, the distance of the blimp and the line is calculated. The standard of the distance is a centerline of the line. The distance of the center of the camera image and the centerline of the line are calculated because it is made in the composition of this balloon robot so that the position of the camera may come to the center of the airframe. Because the size of the camera is 160 × 144 now, a center pixel of the camera becomes point (72, 80). The point that distances shorten most in the centerline of the line for this point is calculated. These points are $centerline_i$ and $centerline_j$. Because the distance of these points is a unit of the pixel, the number of pixels for the actual width of a line and the width of the line acquired from the image is used for an actual distance to change.

$$dline = \sqrt{(centerline_i - 72)^2 + (centerline_j - 80)^2} \times \frac{line}{linewidth} \quad (4)$$

The line is actual width of the line, and linewidth is calculated width of line. And, the angle to the line with centerline is calculated. This angle is calculated by trigonometric function as follows.

$$\theta = Cos^{-1}(\frac{1}{\sqrt{1 + A_{center}^2}}) \quad (5)$$

A_{center} is gradient of centerline.

4 Control method

It is described how to decide to thrust in this section. Because it is possible to be thought about the direction of Z of the propeller independently, we think about the control by the X-Y plane. It is necessary to control to approach the centerline in X-Y plane. The blimp robot is made to follow to the line by keeping producing thrust in the direction and adjusting the angle hand like the robot of the car type[4] and the mouse type. Then, it keeps putting out constant thrust in two of four propellers of the X-Y plane, and the angle is adjusted by other two. Constant thrust is generated with ch0 and ch2 of Figure 2, and the angle is ch1 and ch3 of Figure 2. To adjust the angle to be suitable for the direction of the centerline of the line, the angle of the target is set. The angle of the target makes it can be influenced by deflection with the line though it grows and set greatly.

$$\theta_{target} = Cos^{-1}(\frac{dline}{\sqrt{FORWARD^2 + dline^2}}) \quad (6)$$

θ_{target} is the angle of target, and FORWARD is a constant number to decide the angle of the target. Blimp robot is difficult to decide the analytical controller.[3] Because the parameter can be decided by the trial and error, the PID control is used for the control of the direction of height. However, it is made to control by the PD control because it is thought that the influence of the paragraph of I effective after time passes doesn't come out in the adjustment of the angle.

$$m_z(t) = K_{zP}e_z(t) + K_{zI}\int e_z(t)dt + K_{zD}\frac{de_z(t)}{dt} \quad (7)$$

$$m_\theta(t) = K_{\theta P}e_\theta(t) + K_{\theta D}\frac{de_\theta(t)}{dt} \quad (8)$$

K_{zP} and $K_{\theta P}$ are proportional gain, K_{zI} is integral gain, and K_{zD} and $K_{\theta D}$ are derivative gain. $e(t)$ is deflection with velocity of target, and $de(t) = (e(t) - e(t - \Delta T))$. m_z is thrust in propeller ch4, and m_θ is thrust in propeller ch1 and ch3. And, number of propellers ch0 and ch2 are propeller for generating constant thrust.

5 Experiment

5.1 Experimental setting

In this experiment, the line is drawn at the straight line and blimp robot moves on that. The line puts red paper with length of 5[m] on the floor. And, the width of the line is set by 0.1[m]. If the width of the line is 0.1m, it sees it by 32 pixels when the position of the camera of the blimp is 0.5[m], and 16 pixel when 1[m]. The interval that searches for the edge point is made four pixels. And, the constant to decide the angle of the target to control the angle is set as 100. Moreover, the target position of height is assumed to be 1[m]. This is because of thinking the blimp robot moves in the building. The camera has equipped the under the airframe of the robot and the top part of the robot is about 2.3[m] at 1[m] in the height of camera.

5.2 Result

Fig.4, Fig.5 and Fig.6 show with the target value when blimp robot is made to follow the line. Even if each graph is seen, the part where the value changes greatly is seen. This is caused from the large difference from the previous value when the width of the line is calculated. Fig7 is the one that the number of extracted edge points was shown. It is showed when it is a number of edge points less than it though the width of the edge calculates correctly if the edge point is gotten by four points. Moreover, because height and the distance with the line are calculated based on the value of the width of the line, this value is personally effective in the control. And, power toward direction that came off might be larger than power to face the line by the turbulence such as the winds. It is not possible to control by disappearing the line in the camera image. The angle is an error margin of about 0.1[rad] against the angle of the target.

In this experiment, it mostly went off from the line around 3[m] of the line, and it was possible to move by 5m because it advances straight when the influence of the deflection of the angle and the wind is little. Every experiment, the erratic value was seen in the graph of height.

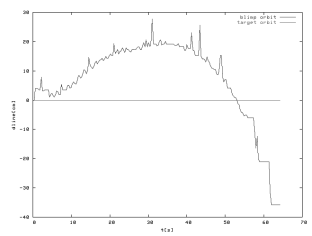

Figure 4: Deflection with line

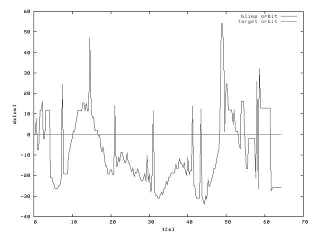

Figure 5: Deflection with height of target

6 Conclusion

In this paper, we reported the following to the line for indoor blimp robot. It needs to be improved in the extraction accuracy of the line because graph of height actual has resulted greatly the vibration. Moreover, it was often thrown away form the line by the power of the disturbance such as the winds.

In the future work, it is necessary that blimp robot is moved by guessing actual height whether to improve the extraction accuracy of the width of the line. In addition, the line is not made easy to lose sight by installing the fish-eye lens in the camera to get wider view. We want to move blimp robot in not only the straight line but also the curve.

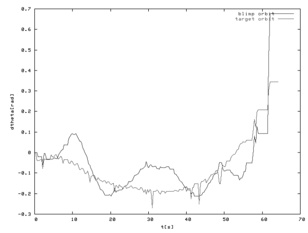

Figure 6: Deflection with angle of target

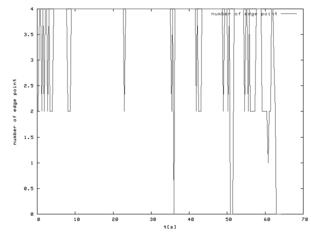

Figure 7: Number of the edge points

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