Run control of the mobile robot using visual information

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Abstract

This research aims at capturing a mobile robot the environment information of based on the picture obtained from the CCD camera carried in the mobile robot, and carrying out the stable autonomous run. This paper considers the technique of image processing with the CCD camera for an autonomous run, and the basic experiment of a run.

1.Intoroduction

In the recent years, the introduction of robot was bean considered in various fields. Various functions were bean required and the robot use was expanded. One of the functions requires environmental recognition and avoidance of an obstacle. In order to develop such robot, this laboratory, for some time, has mainly respond to the field of welfare and nursing. A mobile recognition robot has been researched and developed [1][2][3].

This research is aimed at capturing the surrounding each environment information of mobile robot based on the pictures obtained from the CCD camera carried in the mobile robot, and carrying out the stable autonomous run. This paper considers the technique of image processing with the CCD camera for an autonomous run, and the basic experiment of a run.

2. Experiment System

The robot which is being used in this research was manufactured by incorporated company DENKEN in 2000. The figure is shown in Fig.1. It consists of 2 drive 2 caster (2DC2W) systems. The mobile robot is equipped on the right and left with the driving wheel, auxiliary caster rings at the front and back, a driving wheel on either side rotates by DC motor. Equipped with the rotary encoder of resolution 80 (Pulse Per Resolution) beside the driving wheel, and counting the number of pulses, the right-and-left independence can be achieved and a wheel can be controlled. The difference in the rotation speed of a right-and-left driving wheel performs a steering function. The CCD camera (EVI-G20: Sony) is carried by the height of about 130 [mm] at 55 degrees of perpendicular directions at the head. The picture obtained from the camera is taken in by the memory on an image-processing board (FDM-PCI3: FOTORON).

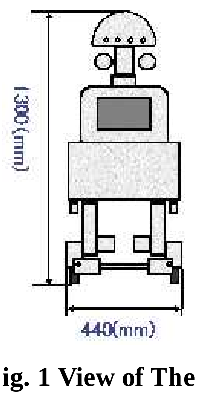


Fig. 1 View of The Mobile robot

3. Model of mobile robot

The mobile robot figure used in this research is shown in Fig.2.[2][4]。 The mobile robot is a system, which drives a driving wheel on either side by another actuator, and is an independent driving wheel type and PWS (Powered Wheel Steering).

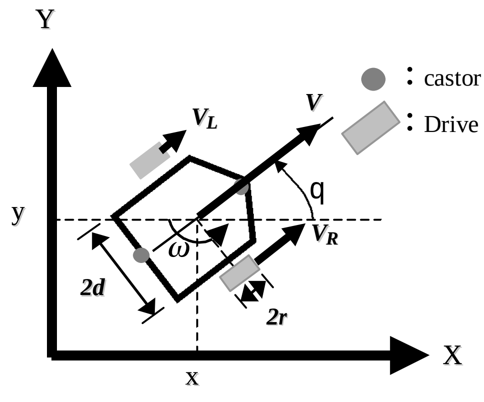


Fig. 2 Model of mobile robot

If the thickness of a wheel is disregarded and sets the distance from a body center to a wheel is d, and the radius of a wheel r, and the grounding speed of a wheel V_R, V_L, and a rotation angle of a wheel ϕ_R, ϕ_L, it can write.

$$\phi_{R,L} = 2 * PI * count_{R,L} / Encoder\_Slots \quad (1)$$

$$V_R = r\dot{\phi}_R \quad (2)$$

$$V_L = r\dot{\phi}_L \quad (3)$$

Moreover, if the actuator which drives a wheel regards it as the control input of this system as (V,ω) ($\dot{\phi}_R$, $\dot{\phi}_L$)that by which speed control is carried out, it can express a relation with generalization coordinates in the following forms.

$$\begin{pmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{pmatrix} = \begin{pmatrix} \cos\theta & 0 \\ \sin\theta & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} V \\ \omega \end{pmatrix} = \frac{r}{2} \begin{pmatrix} \cos\theta & \cos\theta \\ \sin\theta & \sin\theta \\ \frac{1}{d} & -\frac{1}{d} \end{pmatrix} \begin{pmatrix} \dot{\phi}_R \\ \dot{\phi}_L \end{pmatrix} \quad (4)$$

Moreover, the equation below a equation (4) is obtained and this means the Nonholonomic restraint that a wheel does not sideslip [4].

$$\dot{x}\sin\theta - \dot{y}\cos\theta = 0 \quad (5)$$

4. Image Processing

The picture is taken in from a CCD camera, it is a picture expressed with a total of 24 bits of 8 bits each of RGB. It is very hard to treat RGB for correlation to be strong in each and acquire the feature from a picture. Then, in order to treat the feature from a picture independently as much as possible, the following equation performs LHS conversion of lightness, hue, and the saturation.

$$L = 0.299R + 0.587G + 0.144B \quad (6)$$

$$H = \tan^{-1}\left\{\frac{R-L}{B-L}\right\} = \tan\left\{\frac{0.701R - 0.587G - 0.144B}{-0.299R - 0.587G + 0.856B}\right\} \quad (7)$$

$$\begin{aligned} S &= \sqrt{(R-L)^2 + (B-L)^2} \\ &= \sqrt{(0.701R - 0.587G - 0.144B)^2 + (-0.299R - 0.587G + 0.856B)^2} \end{aligned} \quad (8)$$

Also in this, L picture serves as a numerical value mostly proportional to the strength of the brightness which man's eyes feel, and used only this picture also for improvement in the speed of processing.

Edge detection was performed in order to ask the luminosity picture like the point for an objective boundary and an objective outline. First, the difference the operator is using and it asked for the strength of the edge between each pixel. Next, if smaller than the value L with the difference of the strength of edge altogether and it was white and except it, the figure was displayed as Edge Image as black. It turns out that an objective boundary and an objective outline are called for to some extent.

(a) Original Image

(b) Monochrome Image

(c) Edge Image

Fig.3 Image Processing

5. Driving Experiment

In order to run at the rate of following a course linearly and a target, the experiment run on a mobile robot was conducted the following condition.

- Target number of rotations：8（pulse/0.1s）In order to carry out a wheel one revolution in 1 second
- Run a mobile robot only by Proportional control. This is because it is shown that number of rotations reaches to a target value only in Proportional control by research of the past mobile robot [3].

The number of rotations of an actual wheel is shown in Fig4.The equation of speed control of the wheel at this time has become like (11) equation, 0 has become the maximum and 255 has become the minimum. Moreover, the value to which applied the deviation by (9) equation and which applied the proportionality parameter to the deviation by (10) equation is expressed as an amount of operations.

$$er = r\_set - rightcount$$
$$el = l\_set - leftcount \quad (9)$$

$$r\_ope = r\_ope + r\_K_p \times er$$
$$l\_ope = l\_ope + l\_K_p \times el \quad (10)$$

$$rightspeed = 235 - 12.3 \times r\_ope$$
$$leftspeed = 235 - 12.3 \times l\_ope \quad (11)$$

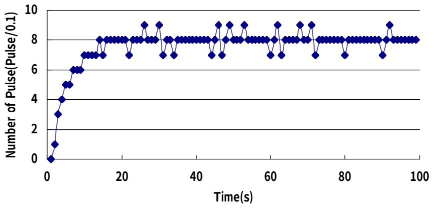
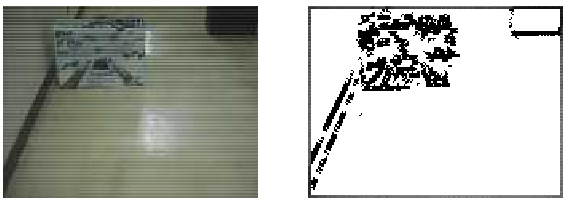


Fig. 4 Right Wheel Rotation Number

Although the value of target number of rotations was mostly detectable, it has checked carrying out amplitude slightly. Therefore, it is necessary to examine the optimal parameter using PI, PID control, and still newer control.

6. Obstacle Avoidance Experiment

The obstacle avoidance experiment was actually conducted in the environment, which is said to the method of the forward left as the 1st obstacle, and is said to the method of the forward right as the 2nd obstacle. At this time, target speed in case there is no obstacle was set to 15.7 [cm/s].



(a)Original Image **(b)Edge Image**

Fig.5 Obstacle Image

Giving imagination repulsive potential between the edge portion of a picture, and a robot's center performs the obstacle avoidance.

Since the picture is using only the left-hand side of the camera carried in the robot, it turns out that the center of a picture and a robot's center have shifted. When the size of a picture serves as width 160 [pixel] and length 120 [pixel], a horizontal axis is set to i and a vertical axis is set to j by making the upper left into the starting point, a robot's center will be located in the position which is i= 93 pixels.

The equation, which gave repulsive potential so that it might become so large that a robot's center and edge portion are near, is shown in (12). At this time repulsive potential in i=93-160[pixel] is made into Uo_r and repulsive potential in i=1-93[pixel] is made into Uo_l.

$$Uo\_r = Uo\_r + 1/\sqrt{(93-i)^2 + 0.5j^2}$$
$$Uo\_l = Uo\_l + 1/\sqrt{(93-i)^2 + 0.5j^2} \quad (12)$$

Since an actual distance in the portion of the bottom of a picture is 240 [cm] at this time, an actual distance in the portions of 126 [cm] and the top is rectifying the horizontal axis using (13) and (14) equation.

$$calibration = 1 + 0.0075 * (120 - j) \quad (13)$$

$$\begin{aligned} &if \quad i > 80 \\ &\quad new\_i = 80 + (i - 80) * calibration \\ &if \quad i < 80 \\ &\quad new\_i = 80 - (80 - i) * calibration \end{aligned} \quad (14)$$

When Uo_r is larger than Uo_l and an obstacle exists in right-hand side, load is given to left_speed, and the left is revolved. Conversely, when Uo_l is larger than Uo_r and an obstacle exists in left-hand side, load is given to right_speed, and the left is revolved. The equation at this time is shown in (16).

$$\begin{aligned} &if \quad Uo\_r < Uo\_l \quad Uo = Uo\_l - Uo\_r \\ &if \quad Uo\_l < Uo\_r \quad Uo = Uo\_r - Uo\_l \end{aligned} \quad (15)$$

$$rightspeed = 235 - 12.3 \times r\_ope + kUo$$
$$leftspeed = 235 - 12.3 \times l\_ope + kUo \quad (16)$$

Thus, change of the number of counts of the encoder when carrying out speed control has become like Fig.6. In about 8 - 13 seconds, it turns out that the left number of counts is larger than the right number of counts, it circled on the right, and the 1st obstacle is avoided. Next, it turns out that the right number of counts became larger than the left number of counts in about 18 - 22 seconds, it circled on the left, and the 2nd obstacle is avoided. Since an obstacle does not exist in a screen, by 4 [pulse / 0.1s], it is stabilized after 23 second and it is carrying out the going-straight run.

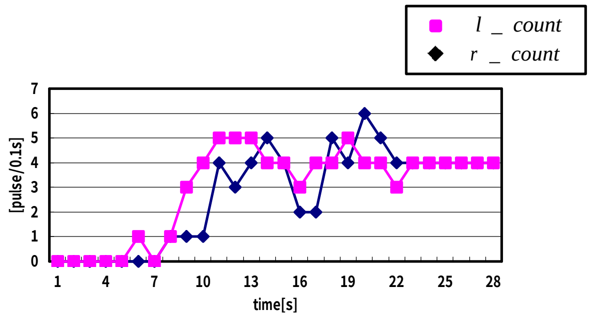


Fig.6 Wheel Rotation Number

7. Conclusions

Imagination repulsive potential was given to the speed of a wheel using the edge information on the picture obtained from the CCD camera, and carrying out speed change performed the obstacle avoidance run on a smooth orbit.

As a problem, after avoiding an obstacle, it will go straight on with an angle as it is. Imagination repulsive potential will receive influence not only in distance and a size with an obstacle but in the pattern and.

I decide a target point from now on, and think that the run stabilized by taking in not only imagination repulsive potential, but also imagination attraction can be performed.

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