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Proposal for the Trajectory Control of Two Wheels Mobile Robot with Object Pushing and Self-position Estimation

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Abstract: Autonomous mobile robot has two wheels and travels while pushing object in the fixed arm. It is passing through a specified point by using the self-position estimation. We propose a method of orbit control to put object to the point of the target.

Keywords: Mobile Robot, Trajectory Control, Self-position Estimation, Spline Curve, Object Pushing

1. Introduction

The one of the ideal image of the Autonomous mobile robot is to recognize the environment in their own sensors and plan to move around freely.

The purpose of this study is to suggest a method of orbit control that passing through all of the points using the self-position estimation. In addition, as a point different from subject of path planning, it is autonomous mobile robot do some work at the same time. The contents of the work are to put object to the point of the target. We use autonomous mobile robot to be operate in the two left and right wheels, traveling while pushing objects in the arm which is fixed to the front.

If the autonomous mobile robot which use the self-position estimation has proceeded until it reaches the point of the target, it cannot put the object to the point of the target. Because the object which pushed by autonomous mobile robot is in front of the center of the left and right wheels, and that would pass the point of the target.

2. Self-position estimation

Self-position estimation is essential function for passing through the specified point. We will ask the two-dimensional coordinates from the rotation angle of the left and right wheels.

2. 1 Rotation angle of the left and right wheels

Put substitute R for diameter of wheel, and put substitute α for rotational angle of the wheel. The formula for the distance ΔL that traveled by wheel looks like this.

$$\Delta L = \frac{\alpha}{360}\pi R \tag{1}$$

This formula can be used to determine the amount of movement of the one wheels.

2. 2 Two-dimensional coordinates

Seek a two-dimensional coordinate from the rotation angle and the amount of movement of the left and right wheels.

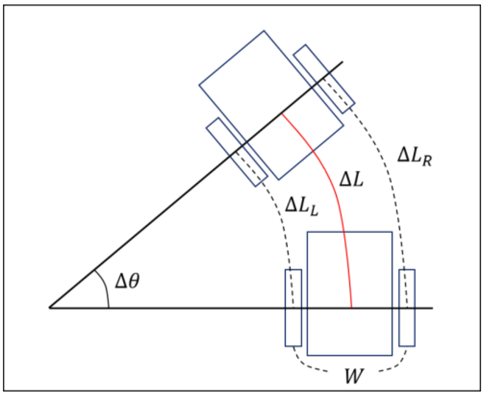

Figure 1: Relation between rotation angle and distance

Put substitute ΔL_L and α_L for left wheel, and put substitute ΔL_R and α_R for right wheel.

$$\Delta L_L = \frac{\alpha_L}{360}\pi R \tag{2}$$

$$\Delta L_R = \frac{\alpha_R}{360}\pi R \tag{3}$$

From an average of ΔL_L and ΔL_R, it can seek that amount of movement of the center of autonomous mobile robot.

$$\Delta L = \frac{\Delta L_L + \Delta L_R}{2} \tag{4}$$

By sought ΔL, expressed the angle of difference $\Delta\theta$ between the orientations of autonomous mobile robot. Put substitute W for the width of autonomous mobile robot.

$$\Delta\theta = \frac{\Delta L_L - \Delta L_R}{W} \tag{5}$$

Next, determine the direction of the current autonomous mobile robot. θ_{i+1} is the direction of the current autonomous mobile robot, and θ_i is the past direction.

$$\theta_{i+1} = \theta_i + \Delta\theta \tag{6}$$

From this formula, it can seek formula for the current x and y coordinates.

$$x_{i+1} = x_i + \Delta L \cos\left(\theta_i + \frac{\Delta\theta}{2}\right) \quad (7)$$

$$y_{i+1} = y_i + \Delta L \sin\left(\theta_i + \frac{\Delta\theta}{2}\right) \quad (8)$$

3. Trajectry desgin using the spline curve

We specified the following conditions when performing the trajectory design.

I. Through the specified point.
II. Specify the orientation of the robot at each point.

We perform a path planning using spline curves to satisfy the two conditions.

3. 1 Spline curve

How to do the trajectory design using a spline curve, it was in reference to paper [1] written by Mr. Komoriya and Mr. Tanie. This paper used B-spline curve. Spline curve is defined as the following formula in the paper.

$$P = \sum_{j=0}^{n} N_{j,m}(s) Q_j = P(s) \quad (9)$$

$$N_{j,1}(s) = \begin{cases} 0 & x_j \leq s < x_{j+1} \\ 1 & s < x_j, x_{j+1} \leq s \end{cases}$$
$$N_{j,m}(s) = \frac{(s - x_j) N_{j,m-1}(s)}{(x_{j+m-1} - x_j)} + \frac{(x_{j+m} - s) N_{j+1,m-1}(s)}{(x_{j+m} - x_{j+1})} \quad (10)$$

3. 2 Seek the ratio of the amount of operation from the curvature of the curve

In order to travel the designed spline curve, to determine the ratio of the amount of operation of the autonomous mobile robot from the curvature of the curve. The ratio is calculated by the following formula.

$$\frac{V_L}{V_R} = \frac{1 - \frac{l}{2\rho}}{1 + \frac{l}{2\rho}} \quad (11)$$

4. Put object to the point of target

The object which pushed by autonomous mobile robot is in front of the center of the left and right wheels, and that would pass the point of the target shown in Figure 2.

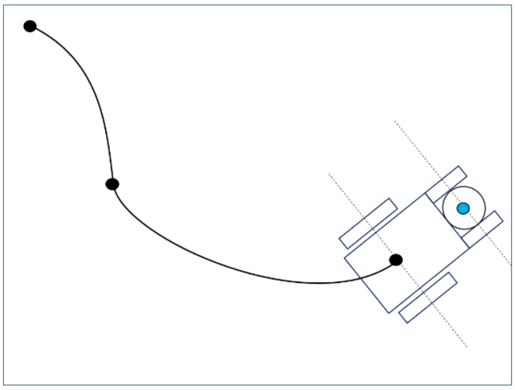

Figure 2: The object which pushed by autonomous mobile robot pass the point of the target

Therefore, at first, measure the distance between the center of object and the center of left and right wheels. Using that distance for radius, write a circle around the point of the target. The intersection of the circle and the spline curve, sets as a new point to autonomous mobile robot that should be stop shown in Figure 3.

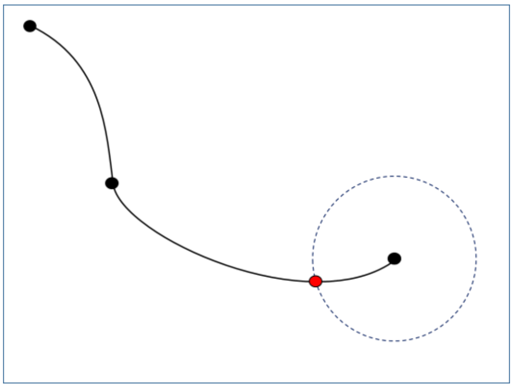

Figure 3: A new point to autonomous mobile robot that should be stop

However, posture vector on the new point is not directed to the point of the target. In other words, if autonomous mobile robot stops on the new point, it is not possible to put object to the point of the target. Accordingly, to set the posture vector of the new point, and then design a new spline curve. New point is located at the top of the circle whose center is the point of the target. Therefore, seek a vector towards the center of the circle from the new point.

Finally, the direction at the new point directed to point of target, design a spline curve until the new point shown in Figure 4.

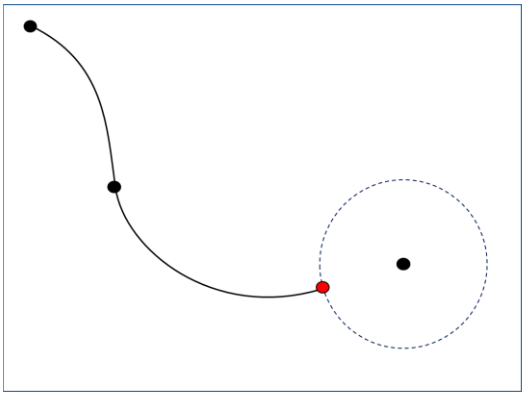

Figure 4: A new spline curve

By driving the new spline curve, autonomous mobile robot can put object on the point of the target shown in Figure 5.

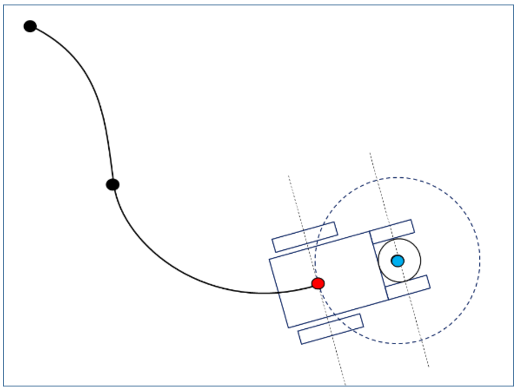

Figure 5: Spline curve can put an object at the point of target

5. Verification

We were conducted test using an autonomous mobile robot. In order to verification which can put object on the point of the target along the spline curve that is designed by the above method.

Autonomous mobile robot was produced by using the LEGO Mindstorms EV3 shown in figure 6.

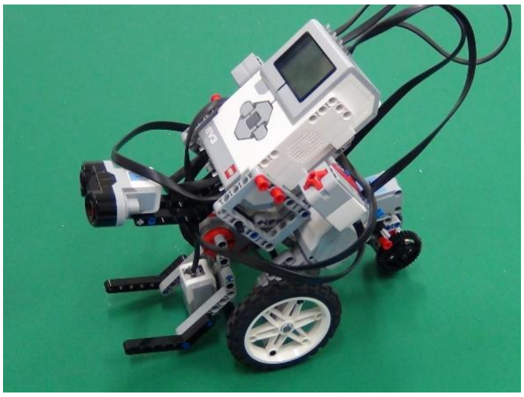

Figure 6: Autonomous mobile robot

It has two drive wheels, and one caster for maintain the posture. Rotation of the wheels can be detected by a sensor built into the motor. Drive control of the wheel is performed by *PI* control using the rotation angle calculated from the sensor.

P control is a proposal control. It is intended to control the control input as the primary function of the deviation of the control amount and the target value. if large deviation between the target value, the control input is increase. Conversely, if small deviation between the target value, the control input is reducing. The control input can be calculated by the following formula.

$$\begin{aligned} &Control\ input \\ &= Proportionality\ constant * deviation \end{aligned} \tag{12}$$

I control is the integral control. It is used to correct small deviations that *P* control cannot cope. From the accumulated value of the deviation, it is possible to determine the manipulated variable by the following formula.

$$\begin{aligned} &Cumulative\ value\ of\ the\ deviation \\ &+= (Previous\ deviation \\ &\qquad + Current\ deviation) \end{aligned} \tag{13}$$

$$\begin{aligned} &Control\ input \\ &= Integral\ constant \\ &* Cumulative\ value\ of\ the\ deviation \end{aligned} \tag{14}$$

By adding the control input each other that calculated by the above formula, to determine the final manipulated variable. The source code is as follows.

```
pre_diff = current_diff;
pid_pre_motor = pid_current_motor;
pid_current_motor = (mWheel.getCount() * -1);
current_diff =
          target - (pid_current_motor - pid_pre_motor);

p = KP * current_diff;

sum_I += (current_diff + pre_diff) / 2;
i = KI * sum_I;

power = p + i;
```

To running after we specify the rotation angle of the the target to 60 ° shown in figure 7. Early rotational speed is increased faster, because the deviation to the target is large. If the deviation to the target is small, and maintain the rotational speed by fine-tuning.

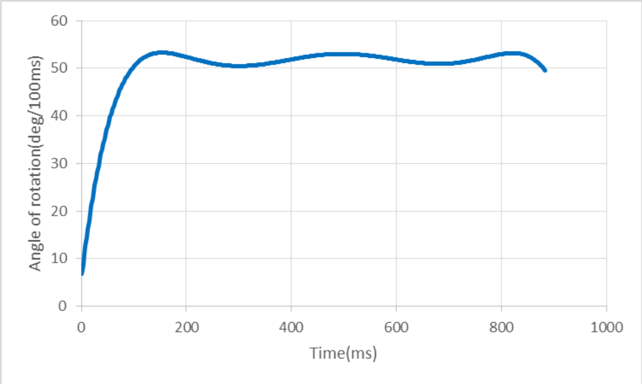

Figure 7: The rotational speed of the drive wheel

To reduce error, we verified at a low speed in this time.

5. 1 Self-position estimation

In order to ascertain whether Self-position estimation formula (7) (8) is correct, it was verified by using a course of ETrobocon. The resulting coordinates are superimposed on the course shown in Figure 8.

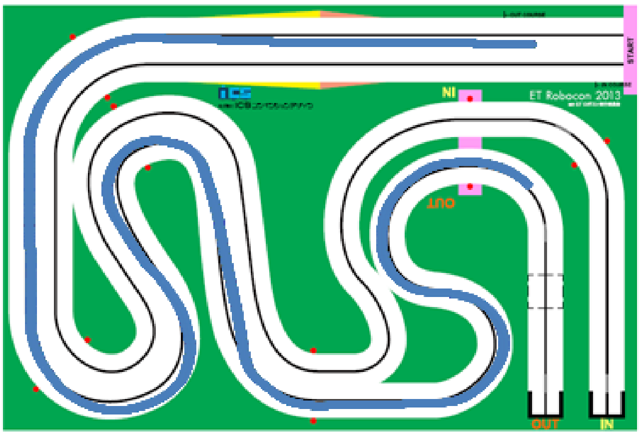

Figure 8: The results obtained coordinates

From the fact that nearly overlaps with the line on the course, the formula can be said to be correct.

5. 2 Ratio of the control input

In order to determine whether the ratio of the amount of operation formula (11) is correct, it drew a circle of curvature 30cm. And move the autonomous mobile robot which get position by self-position estimation, after we insert the curvature into that formula. As a result, graph that shown in figure 9 showing the position of the autonomous robot is correct because it draws a circle with a radius of 30 cm.

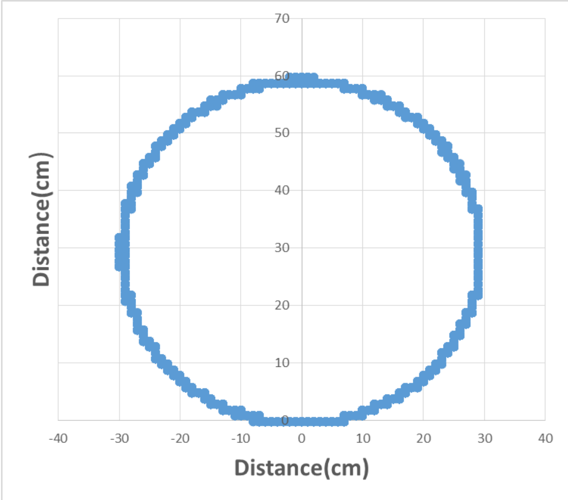

Figure 9: Coordinates obtained by self-position estimation

6. Conclusion

We proposed for the Trajectory Control of Two Wheels Mobile Robot with Object Pushing and Self-position Estimation.

There is a problem that the object which pushed by autonomous mobile robot to put the point of target. In this study was described how to solve them.

7. Future Works

For accurate localization, it is required to correct of variations of current coordinates. We expect that some obstacles or lines drawn on the ground contribute to correction.

References

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