Path prediction and acceleration algorithm using the direction of stone's motion

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Abstract: This study creates the path of the sweeper robot based on the data of Curling stone 's anticipated strategic throw path. The gradient was used as a coordinate estimation method for path prediction. The error rate is calculated by comparing the path with the path of the stone in real time after the path prediction. Regenerates an optimal path for returning the path in the direction of minimizing the error. Based on this technology development, we propose a forming method suitable for sweeping by the position of the sweeper robot to follow the stone later.

Keywords: Path Prediction, Sweeping strategy, inclination, Error rate

1. Introduction

When playing with a human being with a conventional throwing robot, the throwing robot without a sweeper is insufficient for throwing the stone to the correct position to the target coordinates. There is a limit depending on the situation due to the change in ice quality due to the difference in the stone and the influence of the temperature change. Between these variable elements, a sweeper strategy is needed to increase the accuracy with which the stone reaches the target point. The main purpose of this experiment is to add a sweeper robot to increase the accuracy of the shot of the robot.

This study predicts the direction of curling stone and generates path of sweeper robot. The first path of the sweeper robot is created using the expected path of the stone. Then check the position of the stone in real time. If the path of the stone deviates primarily from the path generated, the path of the stone is regenerated by tracing and predicting a path that is out of the expected path of the stone. In addition, sweeping is performed based on this path, and the stone is returned to the primary path again.

We propose a method to estimate the error of the stone beyond the expected path and to predict the path of the changed stone. Prediction is required through a comparator of the expected path and the real-time path. The error caused by the comparison is finally reduced by using one of PID control, root finding, and curvature calculation. Through the comparison of the three methods, we propose a method to predict the real - time path in the fastest time.

2. Path Prediction

2.1 Estimated Path and Coordinate Estimation Using Slope

To create the expected path of the stone, use the slope to move to the current path. It is possible to estimate the slope up to the next path and then estimate the next expected from the slope. This method can be regarded as a method considering only the moving direction and speed of the curling stone.

The slope is obtained in the same way as (1).

$$\frac{x_i - x_{i-1}}{y_i - y_{i-1}} = m_i \tag{1}$$

Ⅰ) m_3 should be predicted. If m_1, $m_2 > 0$ and $m_1 \geq m_2$, the equation (2) can be obtained.

$$m_3 = m_2 - (m_1 - m_2) = 2m_2 - m_1 \tag{2}$$

If $m_1 \leq m_2$, we can see that equation (2) is obtained.

Ⅱ) When the slope of the progress direction of the stone is m_1, m_2, $m_3 < 0$ and $|m_1| \geq |m_2|$ (3) can be obtained.

$$|m_3| = |m_2| - (|m_1| - |m_2|) = 2|m_2| - |m_1| \tag{3}$$

$|m_1| - |m_2|$ (3) is obtained. (2) and (3) are found to be the same when absolute values are used. If the variability of m_1 and m_2 is large, a suitable algorithm can be found by changing the weights of m_1 and m_2.

(4) Of x_3 and y_3 corresponding to the predicted coordinates can be obtained by using the equations (2) and (3). The current stone passes through the point of x_2, y_2, and since this coordinate value is known, there are two unknowns (x_3, y_3) and one equation.

$$\frac{x_3 - x_2}{y_3 - y_2} = m_3 \tag{4}$$

(5) can be obtained by expanding equation (4).

$$x_3 - m_3 y_3 = x_2 - m_3 y_2 \tag{5}$$

To find the exact value of two unknowns, create another expression. Another relationship of x_3 and y_3 can be obtained through the current stone's velocity. Therefore, by inferring the x-coordinate by reflecting the current coordinates of y, a more accurate future x value can be obtained. The equation is as shown in (6).

$$\frac{y_3 - y_2}{t_3 - t_2} = v_{y3} \tag{6}$$

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(7) is obtained through the expansion of equation (6).

$$y_3 = y_2 - v_{y3}f \quad (7)$$

f: Minimum cycle of reading coordinates, $t_3 - t_2$.

$v_{y3}f$ in equation (7) can be obtained from equation (8).

$$v_{y3} = v_y cos\,\theta \quad (8)$$

θ: The angle that the previous path makes with the y axis.

Finally, we can infer two remaining unknowns using Equation. (5) and (7).

2.2 Estimation of Estimated Paths and Coordinates Using Errors

For estimating the following path coordinates, a comparison of the current path and the expected path should be accompanied. The difference resulting from the comparison can be assumed to be an error value. There are following methods to reduce this error value.

(Ⅰ) PID Control

$$\mathrm{MV(t)} = K_p \mathrm{e(t)} + K_i \int_0^t e(r)dr + K_d \frac{de}{dt} \quad (9)$$

(Ⅱ) Root finding

$$a_n = \frac{1}{2}\left(a_{n-1} + \frac{k}{a_{n-1}}\right) \quad (10)$$

(Ⅲ) curvature

$$\text{curvature} = \frac{1}{r} = \frac{|\dot{x}\ddot{y} - \dot{y}\ddot{x}|}{(\dot{x}^2 + \dot{y}^2)^{3/2}} \quad (11)$$

Using the above three methods, we predict the next path of the stone and estimate the coordinates.

In the above procedure, the estimated path and coordinates are estimated by using the slope (Section 2.1) and the error (Section 2.2), and the path of the sweeper robot is regenerated based on the estimated coordinates. The algorithm of Equation (9), (10), and (11) is an algorithm applied when the expected path of stone is deviated.

The slope algorithm alone can estimate the next position of the stone, but the stone progresses to the curvature. For this reason, we introduced the 2.2 algorithm in order to apply these characteristics.

3. Experiment

The experiment was conducted in a simulation and in a Matlab environment. The simulator creates a path for the robot based on the path of the stone. Add noise to the stone information to show the robot's path changes as the stone path changes. The robot's path of travel calculates the expected path of the next stone, predicting and moving the next robot path in advance. This was used to compare errors with stones that actually moved to the next path.

Table 1. Stone and Robot trajectory

	x_stone	y_stone	x_robot1	y_robot1	x_robot2	y_robot2
1	-20	15970	5530.71	18451	-10135	20491
2	0	15860	5550.71	18341	-10115	20381
3	10	15750	5560.71	18231	-10105	20271
4	20	15260	5570.71	17741	-10095	19781
5	40	14970	5590.71	17451	-10075	19491
6	50	14630	5600.71	17111	-10065	19151

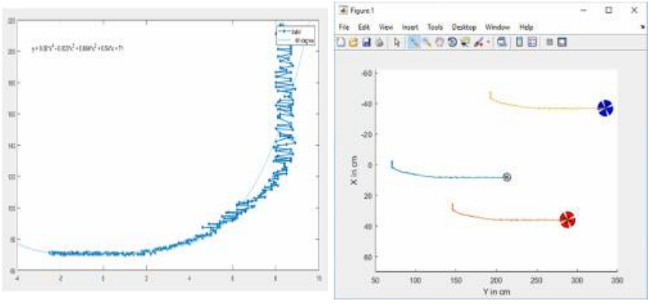

Figure 1. Robot path prediction and formation

Using the above information, the trajectory as shown in Table 1 was extracted and the simulation results as shown in Fig. 1 were obtained. At this time, the range of coordinates on the y-axis is reduced by 100 times, and the experimental results are extracted.

4. Concluding Remarks

In the above experiment, the estimated path of the stone is estimated, and the path of the sweeper robot is regenerated according to the changed path by estimating the changed stone path. Based on these researches, we will formulate swifter robot's formation and sweeping point in the future. These two are the basis of estimating the expected path and coordinates described above and are the development center for judging sweeping point of sweeper robot.

In this paper, we predicted and traced the following path using two methods: slope method and error method. The method using the gradient is a method of estimating the next expected coordinate using the slope to the next path, the method using the error is an error caused by the comparison between the current path and the predicted path in case the accurate coordinate value can’t be extracted by the estimated coordinates using the gradient. By comparing the extracted coordinates with the extracted coordinates using the gradient, two algorithms have been developed to extract the coordinates.

This development will not only help me to understand curling in the future, but I think curling robots will also improve their curling abilities. In addition, the path tracking on the ice sheet will be useful for many studies even if it is not for the purpose of tracking the stone.

References

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