IEICE The Institute of Electronics, Information and Communication Engineers

IEICE Proceeding Series

Movement Continuation Based Prediction of Target Logarithmic Trajectory at Corner for Human Following Robot Losing Target

Masahito Ota, Hiroshi Takemura, Hiroshi Mizoguchi

Vol. 1 pp. 187-190
Publication Date: 2014/03/17
Online ISSN: 2188-5079

2012 International Symposium on Nonlinear Theory and its Applications
NOLTA2012, Palma, Majorca, Spain, October 22-26, 2012

Movement Continuation Based Prediction of Target Logarithmic Trajectory at Corner for Human Following Robot Losing Target

Masahito Ota, Hiroshi Takemura, and Hiroshi Mizoguchi

Department of Mechanical Engineering, Tokyo University of Science
2641 Yamazaki, Noda-shi, Chiba, 278-8510 Japan
Email: masahito.ota.tus@gmail.com

Abstract—This paper presents a human following robot that can continue to follow even when it loses sight of the target human at corner. To realize such robot, the authors propose a human trajectory model of turning the corner. Using the proposed model, the robot can predict trajectory of the target human when he or she turns the corner and disappear from the robot's view. Based upon our observation and intuition of human motion at the corner, we find that the trajectory can be modeled as logarithmic function. In order to confirm effectiveness of the proposed model and the following robot using it, the authors conduct experiment. Experimental result proves the effectiveness and supports our idea successfully.

1. Introduction

In recent years, human following robots are often developed. The human following robot follows a particular person as a target. The human following robot can provide some services to the target with recognizing the target positions every time. However, even though many reports about the human following robot are conducted [1] [2], few reports about provision of the robot losing a target are conducted. Figure 1 shows that a human following robot lost a target in the robot's view at a corner. Especially, the robot is lost the target at a corner and many corners exist in daily life. In that situation, the robot needs to find a target trajectory and move on the trajectory.

Thus, this study aims to make a robot move based prediction of a target trajectory at a corner when the robot lost the target. In this paper, we propose a method to predict target positions. We find out human's trajectory at the corner. And we conduct an experiment to assess effectiveness of our proposed method. As a provision when the robot lost the target, we propose two steps to take the target in the robot's view again. First step is prediction of the target trajectory. Second step is the robot's movement with prediction.

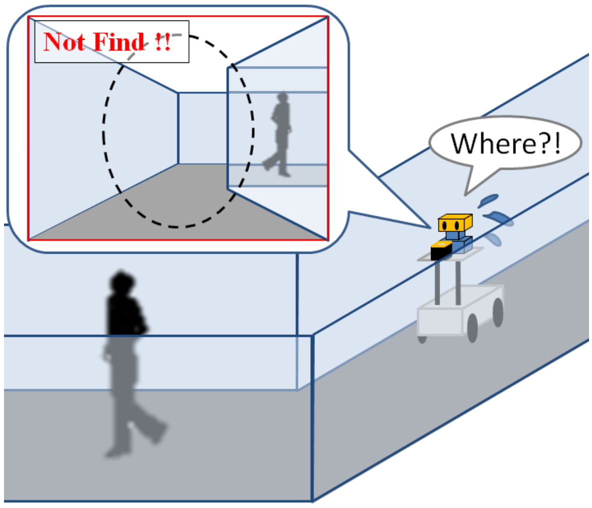


Figure 1. Robot lost a target human

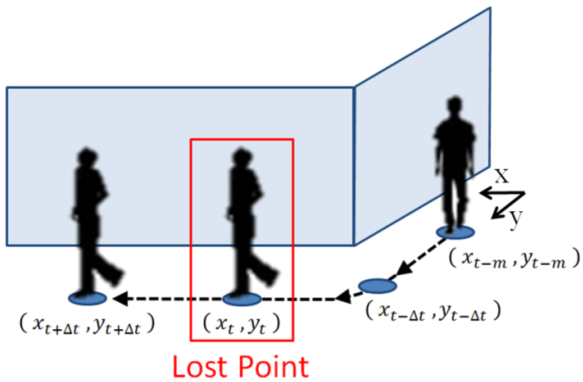


Figure 2. Detection of human trajectory

2. Movement Prediction of The Target

2.1. Prediction of The Target Trajectory

Figure 2 is shown a human trajectory when human turns a corner. We conducted experiments for detecting a trajectory when human moves at a corner. We define two functions such as equation (1) and equation (2) with unknown parameter p1, p2, p3, p4, p5.

$$f(x_t) = p_1 \, log(p_2 x_t + p_3) + p_4 \quad (1)$$

$$f(x_t) = p_1 x^4 + p_2 x^3 + p_3 x^2 + p_4 x + p_5 \quad (2)$$

Equation (1) is a logarithmic function. Equation (2) is a quartic function. These parameters are computed with a few human positions when human turns a corner. This method uses Least Minimum Method. Example of these functions shows in Figure 3. “Logarithmic” is line of equation (1). “Quartic” is line of equation (2). “Human Trajectory” is trajectory of human. We compute error average of all positions between each computed equations and human trajectory. This result shows in Figure 4. “Quartic” is error average of equation (2). “Logarithmic” is error average of equation (1). Error average of function (1) is less than that of function (2). Therefore, human moves a logarithmic function’s trajectory at a corner.

A robot takes time-series positions of the target during human following. The target turns a corner (that time is t-m) and disappears of the robot’s sight (that time is t). The robot computes parameters of equation (1) with the target time-series positions between (x_{t-m}, y_{t-m}) and (x_{t-1}, y_{t-1}).

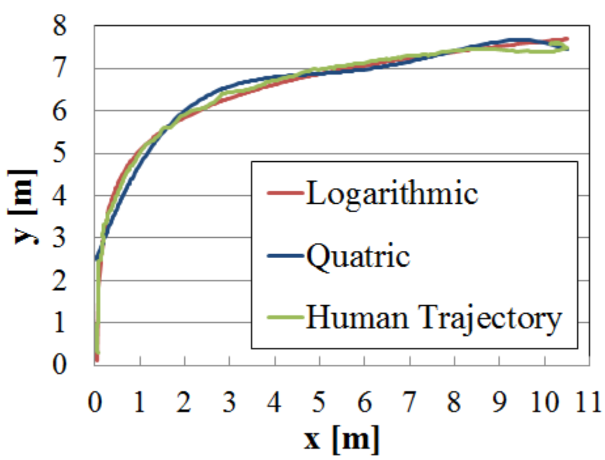


Figure 3. Each function and trajectory of human

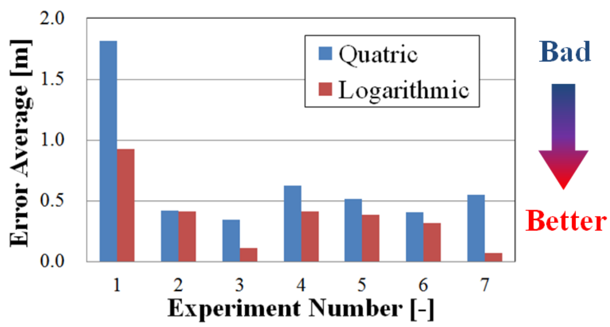


Figure 4. Error average

2.2. Robot’s Movement to Fit in Prediction

Next, we predict that where the target is. We define that target moves at a constant speed at a corner. We calculate the target movement distance “lt” between the target time-series positions $(x_{t-\Delta t}, y_{t-\Delta t})$ and (x_t, y_t). We calculate the target movement velocity. The target positions after a few seconds are predicted with the target movement distance, movement velocity, equation (3), and equation (4).

$$l_t = \int_{x_t}^{x_{t+\Delta t}} \sqrt{1 + \left(\frac{df}{dx}\right)^2} \, dx \quad (3)$$

$$y_{t+\Delta t} = f(x_{t+\Delta t}) \quad (4)$$

If the robot moves on the target trajectory, prediction needs until the robot turns a corner. Therefore, we predict the target positions for five seconds. Five seconds is sufficient that the robot turns a corner. We predict five points after the robot lost the target. First point is after one second when the robot lost the target. Second point is after two seconds. Third point is after three seconds. Fourth point is after four seconds. Fifth point is after five seconds. If the robot loses the target, the robot moves first point. If the robot arrives first point, the robot moves second point. Thus the robot moves to five points in sequence.

3. Experiment

3.1. Experiment Method

We conducted an experiment to assess our proposed method’s effectiveness. Experimental steps show in Figure 5 and below.

(a) A robot gets time-series positions of a target human with human following.

(b) The target turns a corner. And the robot loses the target. Then the robot detects the target trajectory, and predicts five points.

(c) The robot moves to first point. If the robot arrives at first point, the robot moves second point. Thus the robot moves five points in sequence. We looks see whether the robot can take the target in the robot’s sight again.

In the experiment, we measure the target positions with a fixed sensor at left bottom in Figure 5. These target positions are named measure position. And five points the robot predicted are named predict position. We assess effectiveness with distance errors between measure position and predict position at the same time.

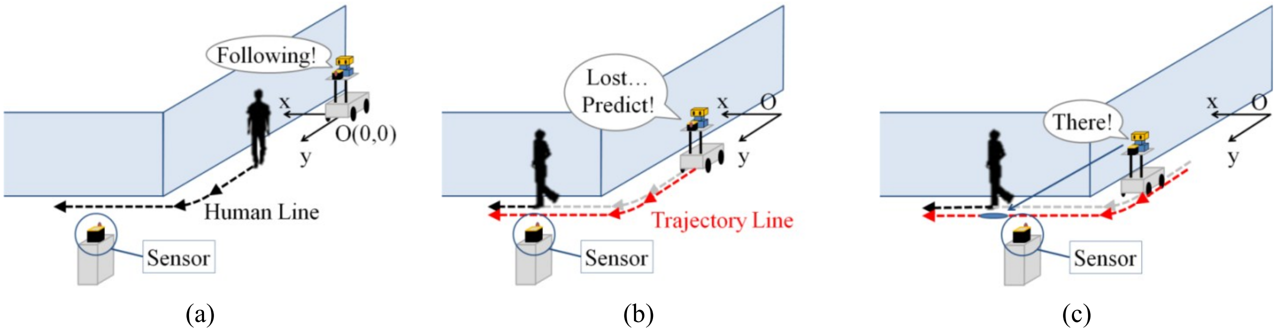


Figure 5. Situation of experiment

Situation of the experiment shows Figure 6. The robot puts 12[m] away from a fixed sensor. This position is the robot's default position. As a fixed sensor, we used Laser Range Finder "UTM-30LX" made by HOKUYO AUTOMATIC CO.LTD. This sensor measures to an accuracy of ±30[mm]. The robot has two sensors. One is Stereo Camera "Bumblebee2" made by Point Gray CO.LTD. Another is "UTM-30LX". We used a human tracking system made by Nemoto et al [3]. These sensors have 40[frame/sec]. The target movement shows red line in Figure 6. This movement's distance is 3[m]. The target moves 1.2[m/s]. Therefore, the robot predicts the target positions with 100 frames.

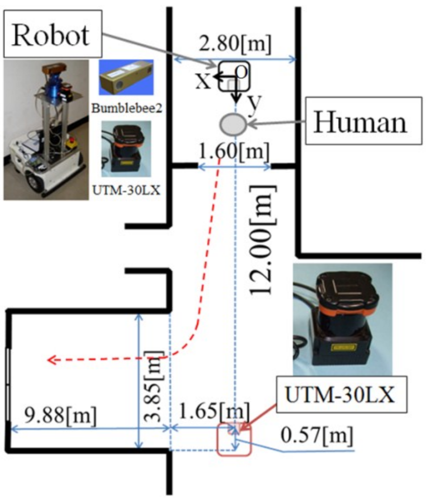


Figure 6. Experimental area

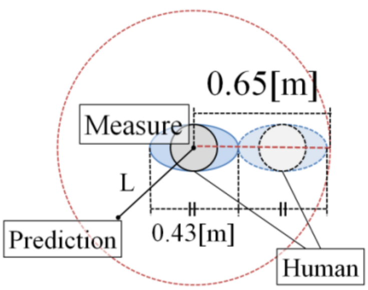


Figure 7. Acceptable area

3.2. Evaluation Standard

If distance errors between predict position and measure position is far, a robot can't take the target in the robot's sight again. Thus we define "Lmax" as max distance error. Prediction is success if distance error is less than Lmax. Figure 7 is shown predict position and measure position. At this time, distance error "L" is computed with equation (5)

$$L = \|M - P\| \tag{5}$$

Acceptable area needs to be within a circle in diameter of sum of three people shoulders. Shoulders average of human is about 0.43[m]. Thus Lmax defined 0.65[m].

3.3. Result and Consideration

Figure 8 is shown time-series camera images on the robot. Green frame in Figure 8 shows that camera finds the target human. By illuminance, camera lost the target at $t = 2[s]$. However human tracking continue by laser range finder. Though the robot lost the target in the robot's sight between $t = 6[s]$ and $t = 8[s]$, the robot could turn a corner, and moved behind the target with prediction. As a result, the robot could take the target in the robot's sight again at $t = 10[s]$.

Figure 9 (a) is shown a result of a target trajectory and a robot's trajectory in the experiment. A target trajectory is "Human Line" and a robot's trajectory is "Robot Line". The robot lost the target at red point. Each axis's origin is the robot's default position. In Figure 9 (a), the robot moves as if human following after red point. Figure 9 (b) is shown predict position and measure position. Starting from left, each position is first, second, third, fourth, and fifth point.

Figure 10 is shown distance errors at each position. In process of time, distance error is more increase. However distance errors are less than max distance error at all time. Therefore, we achieved effectiveness of our proposed method to predict human position.

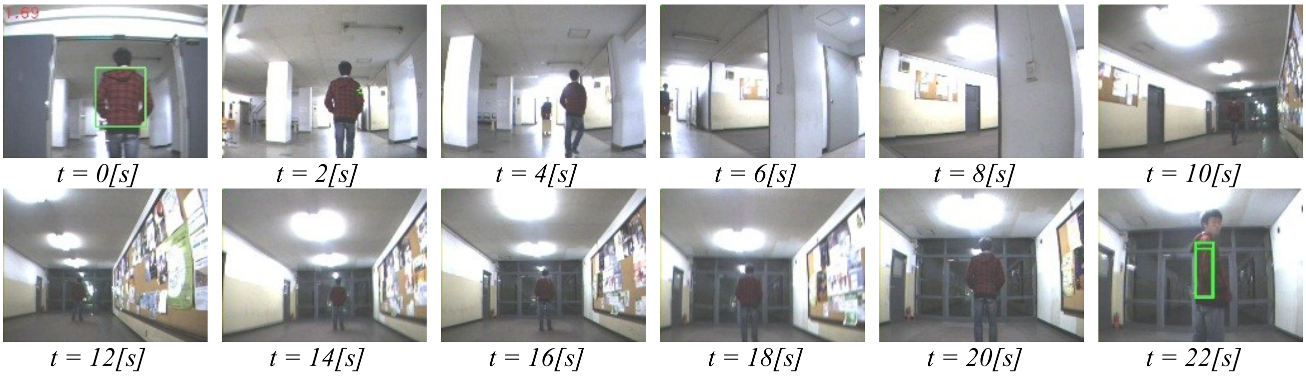
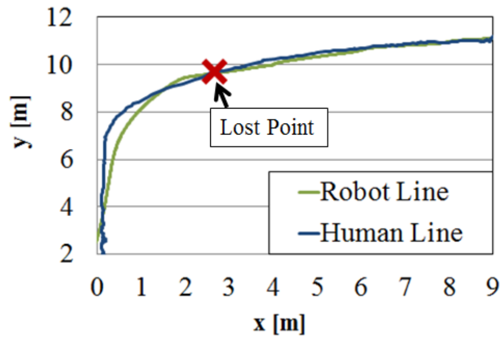
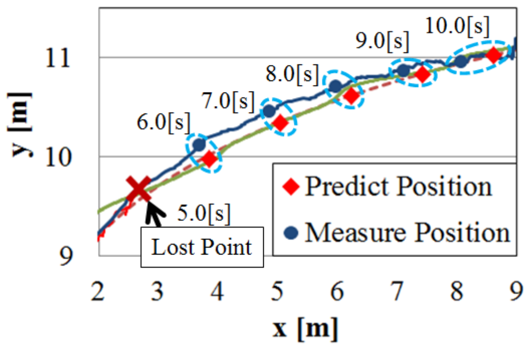


Fig.8 Robot's view



(a) Robot line And human line



(b) Predict and measure position

Figure 9. Experimental result

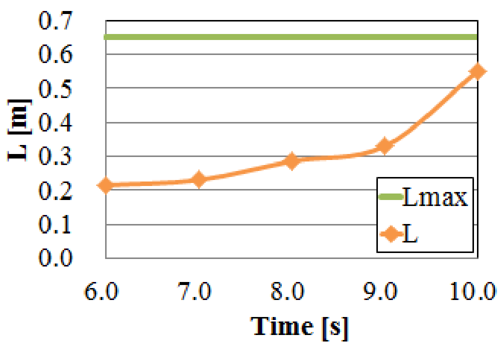


Fig.10 Distance between predict and measure position

4. Conclusion

This paper presented a human following robot that can continue to follow even when it loses sight of the target human at corner. To realize such robot, the authors proposed a human trajectory model and a prediction method of losing human at corner. We found that the trajectory can be modeled as logarithmic function. In order to confirm effectiveness of the proposed model and the following robot using it, the authors conducted experiments. As experimental result, robot can continue to follow the target human even when it loses sight of the target human at corner. And each distance error between predict position and measure position was less than 0.65[m]. Thus, we achieved our idea successfully.

References

[1] M. Kobilarov, G. Sukhatme, J. Hyams, and P. Batavia, "People tracking and following with mobile robot using an omnidirectional camera and a laser," *Proceedings of the IEEE International Conference on Robotics and Automation*, Orlando, Florida, pp. 557-562, 2006.

[2] A. Milella, C. Dimiccoli, G. Cicirelli, and A. Distante, "Laser-Based People-Following for Human-Augmented Mapping of Indoor Environments," *Proceedings of the 25th IASTED International Multi-Conference on Artificial Intelligence and Applications. Innsbruck*, Austria, pp. 151-155, 2007.

[3] H. Takemura, N. Zentaro, H. Mizoguchi, "Development of Vision Based Person Following Module for Mobile Robots In/Out Door Environment," *Proceedings of the 2009 IEEE International Conference on Robotics and Biomimetics (ROBIO2009)*, pp.1675-pp.1680, 2009.