Simultaneous Control of Translational and Rotational Motion for Autonomous Omnidirectional Mobile Robot

2nd Report: Robot Model Considering Moving Parts and Evaluation of Movable Area by Heights

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Abstract: This paper presents a real time collision avoidance method for an autonomous omnidirectional mobile robot considering shape of the robot and movable area by heights based on simultaneous control of translational and rotational motion. Service robots which have been developed in recent years have arms to work and execute tasks. In these robots, the size of width is sometimes not equal to that of length by heights. In order to avoid obstacles considering safety and mobility for the robots, it is necessary to evaluate shape of the robot and movable area by heights. To evaluate them, the robot model is defined in heights of each moving part. Evaluating of the robot model and the movable area for each height, if the robot is unable to move keeping a safe distance from the obstacles, the robot determines the suitable orientation angle considering the minimum length from the center of the robot model to that outer shape. In this paper, the novel control method based on the Fuzzy Potential Method is presented. To verify the effectiveness of the proposed method, several numerical simulations are carried out.

1 INTRODUCTION

Recently, autonomous mobile robots work in human living space have been studied and developed. Some cases of these robots installation to public facilities have been reported (Tiejun et al., 2005). These robots sometimes have two arms so these robots can be used for manipulation and human-robot interaction (Kuindersma et al., 1999), (Mehling et al., 2007). In these robots, the size of width is not equal to that of depth by heights. In order to avoid obstacles considering safety and mobility, it is necessary to consider moving parts and evaluate shape of the robot and movable area by heights.

Various obstacle avoidance methods and their availabilities for mobile robots have described (Borenstein and Koren, 1991), (Minguez and Montano, 2004). Most of these studies regard the robots as points or circles and control methods of the translational movements in two-dimensional plane are discussed. However, depending on the shape of the robot, this approach reduces and wastes available free space and can decrease the possibility that the robot reaches the goal. To enable wide robots to avoid obstacles safely and efficiently, it is necessary to control not only a translational motion but also a rotational motion. Several studies have focused on the orientation angle of the robot (Kavraki, 1995), (Wang and Chirikjian, 2000). However, these methods require an environmental map and the studies have not shown the effectiveness for avoidance of unknown obstacles by autonomous mobile robots. Therefore, in our current research, to avoid unknown obstacles reactively for wide robots, simultaneous translational and rotational motion control method is presented (Suzuki and Takahashi, 2011). In addition, there are obstacles of various heights in the human living space and the relation between the robot and the surrounding environment

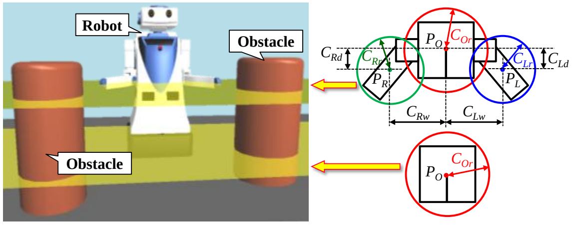

Figure 1: Proposed robot model considering moving parts.

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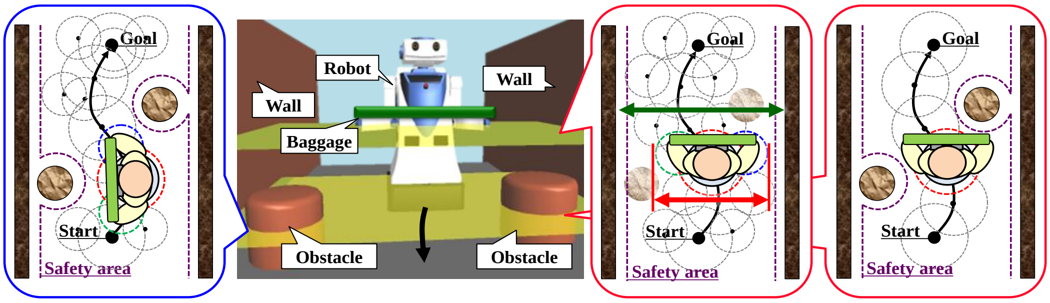


Figure 2: Trajectory of the robot with two motion control method: (*left*) considering footprint at the height of wheeled platform, (*right*) evaluating shape of the robot and movable area by heights with robot model considering moving parts.

changes depending on shape of the robot. Therefore, in order to avoid obstacles more safely and efficiently, it is necessary to evaluate shape of the robot and movable area by heights. Moreover, the relation between the robot and the surrounding environment is changed depending on the shape of the robot by moving parts. Consequently, this study proposes the following two points.

- Robot model considering moving parts.
- Simultaneous control of translational and rotational motion considering shape of the robot and movable area by heights.

With the proposed method, if the robot is unable to move keeping a safe distance from the obstacles, the robot determines the suitable orientation angle considering the minimum length from the center of the robot to that outer shape in real time. To verify the effectiveness of the proposed method, several simulations are carried out.

2 CONCEPT

For the robot which the size of width is not equal to that of depth by heights according to moving parts, in order to achieve obstacle avoidance considering safety and mobility, it is necessary to evaluate shape of the robot and movable area by heights.

2.1 Robot Model

To consider the changes of the shape of the robot by moving parts, a new robot model with multi-circle shown in Figure 1 is proposed. The modeling method is as follows.

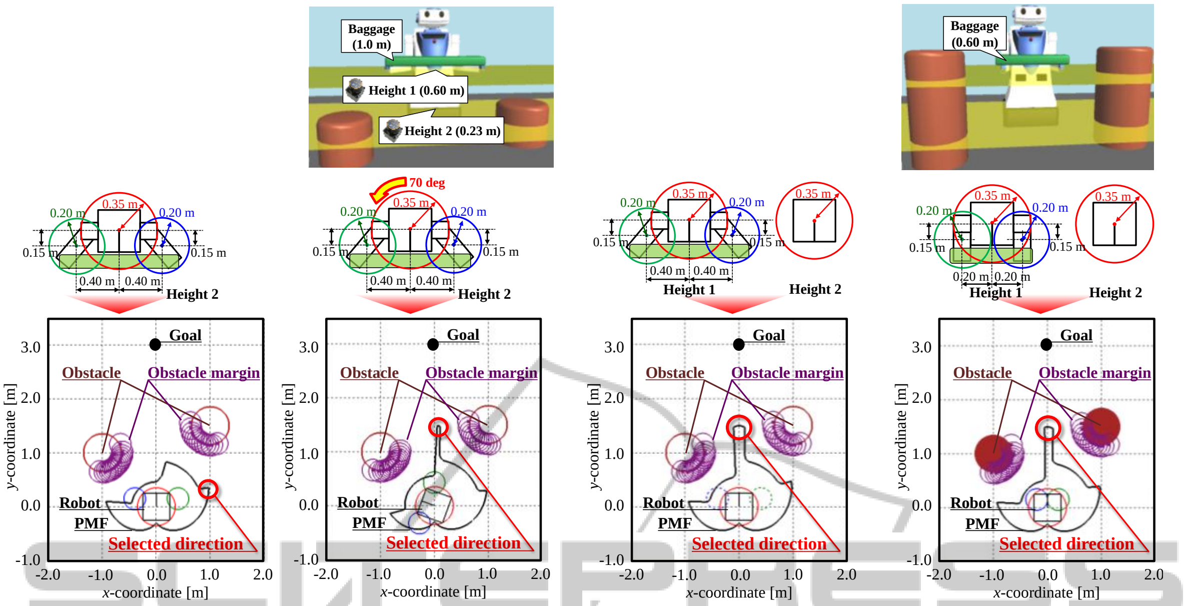
- The model is defined at the heights that the occupied area of each moving part is maximum.
- The robot body is enclosed by a circle.
- The moving parts are enclosed in each circle.

With proposed robot model, changing the position of the moving parts, the relation between the robot and the environment is changed. Thus, performing the motion control considering that point, as well as translational and rotational motion control, the robot can respond flexibly to various situations.

2.2 Motion Control Considering Shape of the Robot and Movable Area by Heights

Evaluating of the shape of the robot and the movable area by heights, if the robot is unable to move keeping a safe distance from the obstacles, the robot determines the suitable orientation angle considering the minimum length from the center of the robot to that outer shape. Then, evaluation of the shape of the robot and the movable area is used the width of the robot model and the movable area measured with range sensor like Laser Range Finder (LRF) by heights. Considering the orientation angle in real time based on the evaluation of the shape of the robot and the movable area by heights, the robot can move smoothly without unnecessary rotational motion keeping a safe distance from obstacles like Figure 2 (*right*).

In this study, the novel control method based on the fuzzy potential method (FPM) (Tsuzaki and Yoshida, 2003) is proposed. In the FPM, element actions are represented as potential membership functions (PMFs). The vertical axis of PMF indicates the grade for the direction of the robot. The PMFs for translational and rotational motion are respectively designed by evaluating the shape of the robot and movable area by heights. Finally, translational and rotational velocity commands, which are calculated by defuzzification of PMFs, are realized by an omnidirectional drive system. (Suzuki and Takahashi, 2011).



(a) Situation A (b) Situation B (c) Situation C (d) Situation D

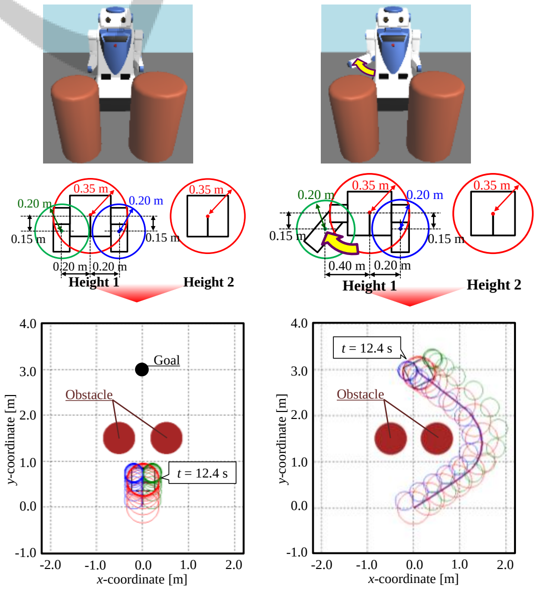
Figure 3: Aspects of the translational PMF and the traveling direction depending on the robot model and rotational motion.

3 SIMULATION

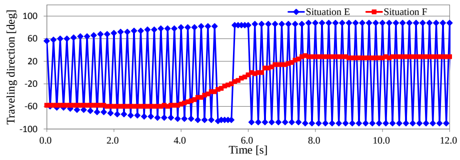
The robot has an omnidirectional drive system, and can measure 4.0 m in ±120 deg range at 0.23 m height of the wheel platform and 0.60 m height of arms with two LRFs. A safe distance for obstacles is 0.20 m. In situations A-D, the positions of two obstacles that radius is 0.35 m were immobilized at each point (-1.0 m, 1.0 m) and (1.0 m, 1.5 m) and the robot transports baggage with arms, as shown in Figure 3. On the other hand, in situations E and F, the obstacles were immobilized (-0.5 m, 1.5 m) and (0.5 m, 1.5 m) and the robot can open the forearms at the height 2, as shown in Figure 4.

3.1 Effectiveness of Evaluation Shape of the Robot and Movable Area by Heights

In situations A-C, the height of obstacles is lower than the robot arms. In situation A shown in Figure (a), the robot cannot go through between the obstacles keeping the safe distance from the obstacles. As the result, the robot selected the traveling direction toward the outside of the obstacles to the goal. In situation B shown in Figure 3 (b), the rotational motion of the robot changes the relation between the robot and the environment from situation A. As the result, the robot can select the traveling direction to go through between the obstacles keeping the safe distance from the obstacles. In situation C shown in Figure 3(c),



(a) Situation E (b) Situation F



(c) Time history of the traveling direction.

Figure 4: Verification of the effectiveness of the proposed robot model in a symmetrical environment.

evaluating the shape of the robot and the movable area by heights, the robot can select the traveling direction to go through between the obstacles keeping the safe distance from the obstacles without unnecessary rotational motion like situation B. In situation D shown in Figure 3(d), the height of obstacles is higher than that of the robot arms. If the shape of the robot at the height 1 is horizontally long according to the baggage, the robot can go through between the obstacles by rotational motion as well as situation B. By contrast, in situation D that the robot closes arms according to the size of the baggage, the robot can select the traveling direction to go through between the obstacles without unnecessary rotational motion keeping the safe distance from obstacles by evaluating the shape of the robot by heights.

These results showed that it is possible for the robot to select the traveling direction that makes a short route to the goal keeping the safe distance from obstacles by the evaluation of the shape of the robot and the movable area by heights.

3.2 Effectiveness of Consideration of Moving Parts

In situation E shown in Figures 4(a) and 4(c), the robot cannot get to the goal because it is difficult to determine the traveling direction uniquely only using reactive motion control method in situation that the surrounding environment of the robot is completely symmetrical. By contrast, in situation F, the robot changed the position of the moving part. As shown in Figures 4(b) and 4(c), the robot can deal with this problem by changing the relation between the robot and the surrounding environment depending on the position of the moving parts.

These results show that the robot becomes possible to respond flexibly to various situations by the proposed robot model because the choices of method for motion control to change the relation between the robot and the environment increase.

4 CONCLUSIONS

In this paper, toward the realization of motion control for autonomous mobile robots that can be flexible in various situations, the robot model considering moving parts has been proposed. In addition to translational and rotational motion, using this robot model, it was verified that the changes of the moving parts can change the relation between the robot and the environment. Furthermore, the real time collision avoidance method based on the fuzzy potential method considering the shape of the robot and the movable area by heights has been proposed. Evaluating of the robot and the movable area for each height, if the robot is unable to move keeping a safe distance from the obstacles, the robot determines the suitable orientation angle considering the minimum length from the center of the robot model to that outer shape. The effectiveness has been verified by numerical simulations. It has been shown that the robot becomes possible to respond flexibly to various situations by proposed robot model and control method.

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