Guidance of a person by scaling the image projected from a mobile robot

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Abstract: In this paper, we propose a new method to guide a person to an exhibition using a mobile robot with a projector. It has been reported that conventional guide robots cannot control the position of people around the robot; for example, when people gather around a robot, it becomes difficult to move. Robots had to explicitly instruct people to move by voice or display, saying, “Please make way.” or “Please move there.” However, repeated such explicit instructions are not comfortable for us. In this study, we propose a method to guide a person by scaling projected images using a mobile robot with a projector. Based on the tendency that we naturally move to the place where the projected explanation is easy to see, the proposed guiding behaviors can guide a person away from the robot or move the robot while keeping the person in the place. Preliminary experimental results showed that the person tends to be guided by the proposed method without explicit indication.

Keywords: guide robot, image scaling, implicit guidance, projection robot

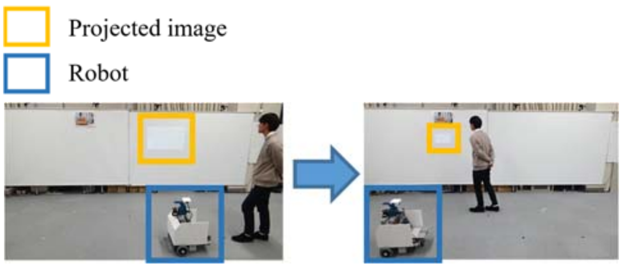
1. INTRODUCTION

Many mobile robots have been developed to support us in daily life. Among the tasks of robots that interact with us, guidance is considered to be one of the important tasks. So far, much research has been done on guide robots, such as in museums [1] [2] and at airports [3]. Guide robots are required to guide us in a sophisticated way.

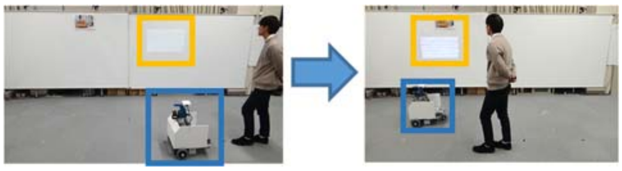
For example, when we guide people who came to our workplace, we explain the facilities and exhibitions on the way while guiding the person to a destination. At the time of guidance, we sometimes ask them to follow us or to stay. In previous research on guidance using robots, it is common to repeatedly instruct a person from a robot by integrating voices and gestures such as “Please come back here.” and “Please make way.” We feel bothersome when the instructions are repeated, and the people around us also feel noisy. In this way, the conventional guide robots asked us to move “explicitly” by using voice, gesture, and arrows on display devices.

In contrast, we often “implicitly” guide others with our behaviors and gestures. Recently, research on such natural guidance by robots has been proposed. In the task of evacuation guidance by robots, Jiang et al. [4] showed that the movement of a robot affected the behavior of evacuees and improved the efficiency of evacuation. In another example, Tamai et al. [5] proposed a method of guiding a person using a robot equipped with a projector, which utilizes the fact that human behavior is affected by both the robot's movement and projection behavior. However, the method in [5] guides a person only in the right and left direction toward the projected image by moving the projection. So the problem is that the method cannot guide the person in other necessary direction. In this paper, we propose a method to guide the person back and forth toward the projected image in an implicit manner using a mobile robot equipped with a projector.

So far, many studies on mobile robots using projectors have been proposed. Lee [6] proposed the concept of a mobile robot with a projector to present the necessary information to people in the environment and conducted an experiment to guide people by projecting an arrow. Matsumaru [7] projected information on the future moving speed and direction of a mobile robot so that people around the robot could understand the robot's future behavior. To realize walking rehabilitation using a mobile robot, Saegusa [8] used a projector to present the ground contact position of the legs. These studies have not investigated the influence of projections from mobile robots on human behavior.



(a) Guiding behavor 1.
Guide the person closer by reducing the projected image



(b) Guiding behavor 2.
Only the robot approaches the wall. Keep the person in place by maintaining the size of the projected image

Fig.1 Guiding a person by scaling projected images

In this paper, we propose a method to guide a person back and forth toward the projected image by scaling the size of the image. The proposed method controls the size of the projected image and guides a person using the property that we naturally move to the position where the projected contents are easy to see. Based on the human

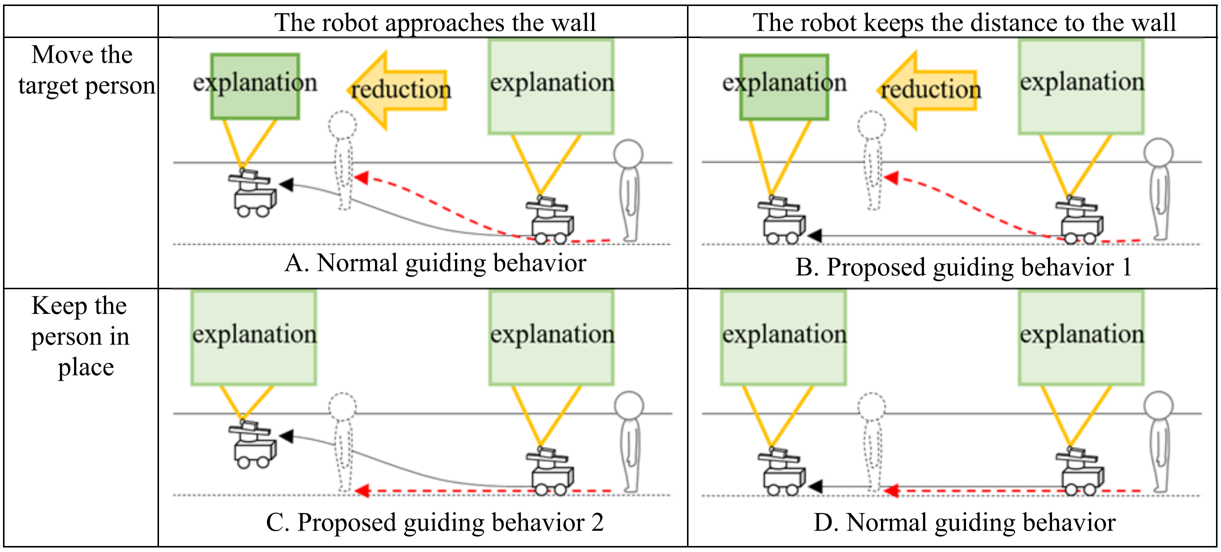


Fig.2 Proposed guiding behaviors and experiment conditions

position measurement, we confirm that the proposed guiding behaviors can guide a person away from the robot, or move the robot while keeping the person in the place.

2. GUIDING A PERSON BACK AND FORTH DIRECTION USING THE SCALING OF THE PROJECTION

2.1 Problem Definition

The purpose of a guide robot is to guide a person to a destination along a given route and to explain the exhibitions on the route. During the guidance, the task of the robot is to bring the person closer to a given route without explicitly instructing the person to move. Towards this goal, this paper proposes a method to guide a person in the back and forth direction by movement and projection behavior when the robot guides the human along the corridor.

2.2 The influence of movement and projection scaling on human behavior

Since conventional guide robots cannot control the position of surrounding people well, when people gather near the robot, robots have difficulty in moving and even self-localization based on measurements [9]. Also, it has been reported that too many people around the robot may cause annoyance to surrounding people [10]. To guide the people away from the robot, instead of repeating the explicit instruction using voice, we focus on the effect of robot movement and projection on the movement of people around the robot.

The guided people tend to move naturally to the position where the projection is easy to see. Using this property, Tamai et al. [5] proposed a method to guide a person to the right and left direction by moving an image projected on a wall. However, their method guides a person only in the right and left direction toward the projected image by moving the projection. In this study, we propose a method for guiding a person back and forth direction by combining the robot's movement and projection.

2.3 Human guidance in the anteroposterior direction by scaling projected images

To guide a person appropriately according to the situation, it is sometimes necessary to guide a person back and forth direction toward the projected image. For this problem, we focus on the fact that when the size of the projected image is scaled, we naturally move to positions where the projected explanation is easy to see. Specifically, if the contents of the projected image are greatly enlarged, we can see sufficiently even if we are far away from the projection. Based on this property, we believe it is possible to guide the position of a guided person back and forth direction toward the projected image and guide the person away from the robot.

In the following, we propose two guiding behaviors that guide a person back and forth direction independently of the movement of the robot by combining the movement of the robot and the scaling of the projection.

Guiding behavior 1: Guides the person closer to the projection while the robot moves straight along the wall.

To avoid collision with other pedestrians, or to guide a person to the direction of the next guide route in advance, it is necessary to move the person away from the robot and close to the projected wall. It is necessary for the robot to independently guide the person near the projection while moving along the wall.

By reducing the size of the projected image and adjusting it to a size that is easy to see at the more close positions, the person is expected to approach the projected image (Fig. 2(B)). In contrast, when the robot keeps the size of the projected image, the person is expected to follow the robot (Fig. 2(D)). In the case of guiding away from the wall, it can be realized by enlarging the size of the projected image.

Guiding behavior 2: Guide the person straight along the wall while the robot moves away from the person.

The robot sometimes needs to adjust its position, such as avoiding obstacles and securing a route for the next movement. In such a case, it is necessary that the robot does not stop the human observing the exhibition and make the robot follow, but only the robot moves by keeping the human in the place.

By making use of the fact that the person keeps positions that the projection is easy to see, the robot moves away from the wall while adjusting the size of the projected image to be maintained. The person is expected to move along the wall keeping the present distance in which the projection is easy to see, and the robot can move in the anteroposterior direction (Fig. 2(C)). In contrast, when the size of the projected image naturally decreases, the person is expected to follow the robot (Fig. 2(A)). When the robot moves away from the wall, the person is expected to keep the distance to the wall by maintaining the size of the projected image.

3. EXPERIMENT SETUP

In this section, we explain the experimental environment.

3.1 Robot

Figure 3 shows the mobile robot used in the experiment. A pan-tilt actuator (TRACKLabs BiclopsPT) is mounted on a mobile robot (T-frog Project Robot Frame i-Cart mini), and a projector (Aigo Projector Cloud PT6316L) is placed on the pan-tilt actuator. The robot has the function of turning the projector in vertical and lateral directions. A LiDAR (UTM-30LX) is mounted at a position 46 cm from the ground and localizes its position by matching the observation with the grid map of the environment acquired in advance based on a particle filter [11]. The robot moves autonomously on the selected route.

Concerning the moving speed of the robot, in previous studies, the speed is set to a slightly slower than our average walking speed (about 1.1 m / s). In Pacchierotti et al., the speed of the robot is set to 0.6 m / s [12]. According to conventional research, the maximum speed of the robot was set to 0.5 m / s.

3.2 Projection position control and image processing

The image with the description of an exhibit was always projected onto the right side of the robot regardless of its orientation (Fig. 4). The center position of the projected image was 120 cm in height on the wall surface. The direction of the projector is determined from the center of the projected image and the robot's estimated position. Then the pan-tilt actuator is controlled so that the image is projected to the calculated position.

We prepared the images in which the descriptions of the exhibitions were written. Then we expanded and reduced them by image processing. Based on the relation between the posture of the robot and the projection plane, we applied the deformation to the projected image and realized the projection without distortion. Fig. 4 shows an example of the robot explaining an exhibit using a projector.

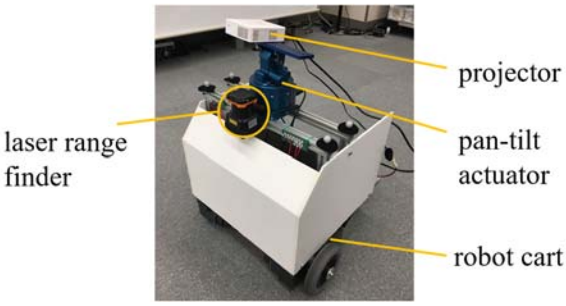


Fig.3 Mobile robot with projection function used in experiments

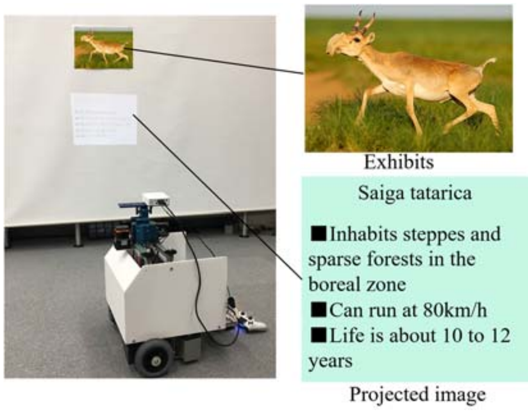


Fig.4 Example of a projecting exhibit description

3.3 Person position measurement system

We installed three LiDARs (Hokuyo automatic UTM-30LX) to measure the position of a pedestrian surrounding the experiment environment. To stably measure the position of the pedestrian's center of gravity, we put the sensors at 120 cm, which is about the height of a person's shoulder and is higher than the height of the robot. We assumed that there was only one pedestrian in the measurement area.

The measurement consists of two steps: pedestrian detection and tracking. In the detection step, it extracts the pedestrian candidates by the background subtraction and clustering. Then it detects an entity that fits a person's size and computes the center of gravity. In the tracking step, it applies a particle filter to estimate the trajectory of the pedestrian. The tracking system computed the smoothed position at a rate of ten times per second.

4. EXPERIMENTS

To confirm the effect of the guiding behaviors proposed in Section 3, we measured the behavior of guided participants when the robot performed the guiding behaviors. We compared the conditions in which the robot performs the proposed guiding behaviors with the conditions in which the robot does not deliberately adjust the size of the projected images.

4.1 Conditions

Fig. 2 shows the experimental conditions. We compared the condition B that the proposed method reduces the size of the projected image while keeping the distance from the wall with the condition D that the robot just keeps the distance from the wall while projecting. We also compared the condition A that the robot approaches the wall while projecting image and the condition C that the robot maintains the size of the projected image while approaching the wall. The robot moved on two types of paths. In the guidance behaviors A and C, the robot approached the wall 0.9 m closer, while in the guidance behaviors B and D, the robot went straight. The movement routes of the robot are shown in Fig. 5. In the guidance behavior A and B, the size of the projected images after the guiding action became 0.4 times larger.

4.2 Hypothesis and Prediction

In the conventional guidance using mobile robots, it has been reported that the guided person follows the robot and tends to gather around the robot. We believe that the proposed method can realize the guidance to the direction away from the robot by scaling the projected image.

First, we believe that the person naturally moves in the front-back direction by scaling the size of the projected image, when the robot goes straight along a wall. Based on these considerations, we made the following hypotheses:

Prediction 1: When the guide robot moves by keeping the distance from the projection plane while reducing the size of the projected image on the projection plane (condition B), the guided person tends to approach the projected image than when performing the same movement without changing the projected image (condition D).

In addition, we believe that it is possible to move the robot away from the person while maintaining the distance of the person to the projection plane by keeping the size of the projected image.

Prediction 2: When the guide robot approaches the projection plane while keeping the size of the projected image on the projection plane (condition C), the guided person is less likely to follow the robot than when the projected image size naturally decreases when approaching (condition A).

4.3 Measurements

We measured the distance between a guide person and the projected image using the human tracking system and computed the moving distance before and after the guided behavior. We measured the travel distance from the time when the robot started guiding behavior (Fig. 6 (2)) to the time when all participants finished moving (14 seconds later.).

4.4 Environments

Fig. 5 shows the environment in which the guidance experiment was conducted. The experiment was carried out in the indoor corridor environment of 10 m × 2.5 m.

4.5 Participants

Eight participants (eight males, whose average ages were 21.5 and SD is 0.50) participated in our experiment. All procedures used in this research were approved by the Ethical Committee of Hiroshima City University.

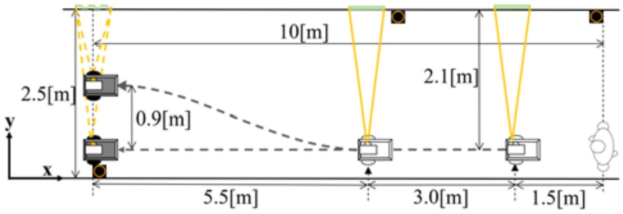


Fig.5 The movement routes of the guide robot. The robot approached the wall in guiding behavior A and C.

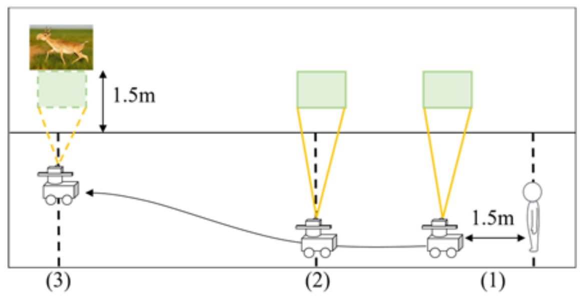


Fig.6 Procedure. (1) initial position of the robot and participant. (2) start position of the guiding behaviors. (3) in front of an exhibit where the robot stopped

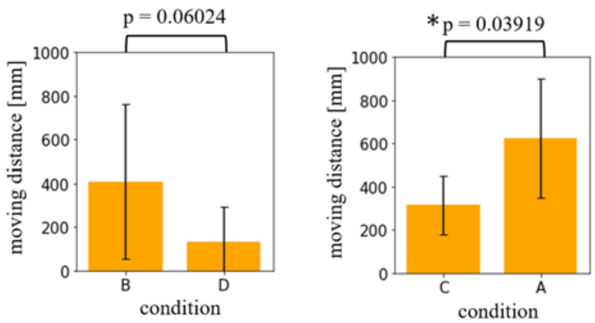
4.6 Procedure

Before the experiment, participants were given a brief description of the outline of the experimental procedure and agreed to participate in the experiment. Participants were instructed that the robot would guide and explain one of the exhibits and that we would then ask to fill out a questionnaire about the exhibition contents. To get used to the guidance by the robot, the participants observed that the guide robot moved alone and projected the description of an exhibition. Participants were instructed to "Please let the robot guide you." and experienced four types of guidance shown in Fig. 2. The guiding behaviors were presented in a pseudo-randomized order. When the participants were guided, they moved to the designated initial position (Fig. 6 (1)), and the experimenter gave the participants a start signal and then started the robot guidance. The robot projected an explanatory message, "I will start guiding you." immediately after the start of guidance. Then, the robot went straight along the corridor and carried out a guiding behavior from the point (Fig. 6 (2)). When it reached the exhibition, the robot stopped and continued projection (Fig. 6 (3)). We used different exhibits and descriptions for each guiding behavior. Participants returned to the starting position when they felt that they had seen the exhibition sufficiently.

5. RESULTS

In the conditions A and D, where the projected image was not intentionally scaled, most participants followed the robot. In contrast, in conditions B and C, in which the projection image was scaled, many participants behaved to increase their distance from the robot. Fig. 7 shows the distance that the participants moved toward the projection image before and after each guiding behavior.

We evaluated the differences in the mean values of the moved distance between conditions B and D, and between conditions C and A. Paired-samples t-tests were conducted to determine the effect of the proposed guiding behavior. There was a significant difference between conditions C and A ($t(7) = -2.5808, p = 0.03919$). On the comparison of conditions B and D, the participants tended to approach the wall in condition B, but there was no significant difference ($t(7) = -2.2381, p = 0.06024$).



(a) Comparison of guide behavior B and D

(b) Comparison of guide behavior C and A

Fig.7 Comparison of the distance that the participants moved in the back and forth direction during guide behaviors

5.1 Effects of Guiding Behavior 1 (condition B)

In the condition that the size of the projected image is reduced while the robot goes straight, the guided person tends to approach the projection and move to the place where the projection is easy to see. Fig. 8 shows an example of a typical movement trajectory. The red-filled squares represent the positions when the robot starts a guiding behavior, and the black-filled circles represent the positions where they finally stopped. This graph shows that a person approached the wall, even though the robot goes straight without changing the distance to the wall. The results suggest that the robot can guide the person in the direction away from the robot while keeping the current position.

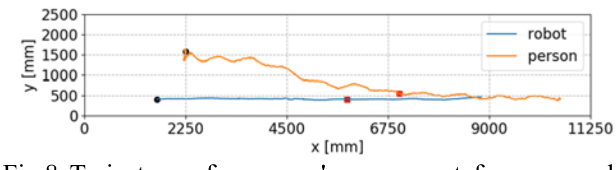


Fig.8 Trajectory of a person's movement for proposed guiding behavior 1

5.2 Effects of Guiding Behavior 2 (condition C)

In the condition that the robot moves in the anteroposterior direction while keeping the same size in the projected image, the guided person does not follow the movement of the robot and tends to keep the distance from the wall. Fig. 9 shows an example of a typical movement trajectory. This graph shows that only the robot can approach the wall while keeping the person's distance from the wall. The results suggest that only the robot can move back and forth direction without the guided person moving in the same direction.

6. DISCUSSION AND CONCLUSION

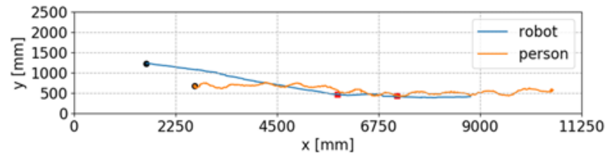


Fig.9 Trajectory of a person's movement for proposed guiding behavior 2

The contribution of this paper is to propose a method to guide a person back and forth direction toward the projected image independently from the movement of a robot by scaling the size of the explanation image projected on the wall. We proposed two guiding behaviors combining robot movement and quantitatively showed the effect of guided person movement based on human position measurement. Our limitation is the size of our participant group. With only eight participants completing the study, it is difficult to claim that proposed guiding behaviors affect the movement of participants from movement and projection from a mobile robot.

In guiding behavior 1, the robot reduced the projected image while keeping the distance from the wall in the guidance. In general, when a mobile robot guides a person, the person tends to follow the robot when the robot approaches the wall. At the same time, when the robot uses the projection, it seems that the guided person tends to maintain the position where the projection image is easy to see. The guided person may decide the moving direction as a result of the integration of the two influences. We considered that a person has both a tendency to follow a robot and to move to a position where it is easy to see the projected image. In this condition, the tendency to move to the position where the projection was easy to see was remarkable.

In guiding behavior 2, the robot started to approach the wall while keeping the size of the projected image. As in guiding behavior 1, we considered that only a few people approached the wall because many participants paid attention to the projected image.

We believe the results of our preliminary experiments showed the possibility of the new guidance method by mobile robots. As a point which we do not consider in this paper, the effect on the movement of the guided person may differ according to the situation of the guidance. If the human pays attention to the robot and looks at it, the effect of scaling the projection may be relatively small. In order to carry out the intended guidance, different strategies are required according to the object which the person is watching and the target which the person is interested in. The proposed method does not carry out guiding based on human position and attitude. Our future work is to realize a guide robot that selects a guiding behavior combining appropriate movement and projection depending on the situation of guidance.

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