Intelligent Escort Robot Moving together with Human -Interaction in Accompanying Behavior-

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Abstract: We consider in this research how robots can render service by moving by themselves. Our aim is to develop an intelligent escort robot moving along with people so that it can support them in everyday life by interacting with humans. In this paper, we consider the pattern to be used for accompanying people and report on the realization of a mobile robot capable of accompanying a person. In order to escort a human, a mobile robot needs to know the position of the person and must be able to determine its own path in order to accompany his target. We construct an algorithm to realize the human accompanying behavior. We also consider about obstacle avoiding behavior while the robot is accompanying the person. We present the effectiveness of our approaches by showing the experimental results using real mobile robots.

Keywords: Interaction and Intelligence, Intelligent Escort Robot, Accompanying Behavior, Mobile Robot

1. Introduction

In recent years, mobile robots have become autonomous enough so that we can think of their applications. We consider in this research how robots can render service by moving by themselves. Our aim is to develop an intelligent escort robot moving along with people so that it can support them in everyday life by interacting with humans.

How robot can support human life has already been described in many researches[1-5], including welfare. Several concrete supporting applications can be considered, such as indoor and outdoor guidance and information supplying, accompanying or escorting people, or following humans while carrying heavy objects. In this paper, we consider the pattern to be used for accompanying people and report on the realization of a mobile robot capable of accompanying a person.

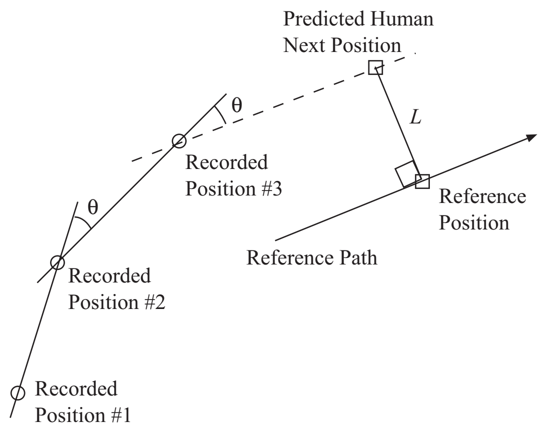

Fig. 1. Prediction of the human next position and calculation of the reference position and the reference path for the accompanying behavior.

2. Algorithm for human following behavior

2.1. Estimation of human future position

In order to accompany a person, the robot has to know the position of the target person. The robot should also estimate the next position of the person in order to move without delay. A method for estimating the human next position is considered first. The robot predicts the next position and speed of the person based on the history of her/his position with time recorded every constant distance. The robot calculates the distance between the human's actual and previous recorded positions. If the distance the human moved is greater than a value decided in advance, the position of the human is recorded in a list. Assuming that the human will move with the same acceleration and the same angular velocity, the next human position can be calculated by linear approximation (Fig.1).

2.2. Definition of path and speed

After predicting the next human position, the robot calculates the reference path and position where the robot should be in the next moment. The path is parallel to the predicted human's trajectory with a constant distance *L* (Fig.1). The speed of the robot should be set so that the robot can reach the reference position on the next moment. The robot can run side by side with human by repeating these processes.

2.3. Obstacle avoidance behavior

In order to prevent collision with obstacles, the robot should have an obstacle avoidance behavior. When the robot finds an obstacle on its path, it starts decreasing the distance between itself and the human. If the human perceives this action and changes its path, the obstacle avoidance behavior may succeed fortunately. However, if the human doesn't change its path, the robot has to stop once and follow the human until the obstacle is completely avoided.

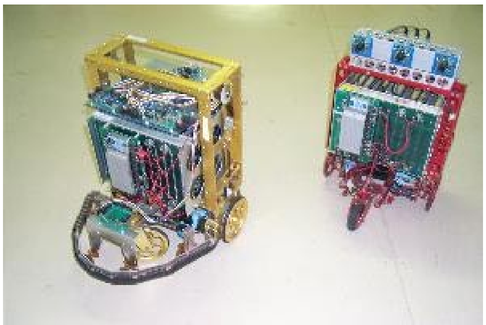

Fig. 2. Two mobile robots used in the fundamental experiment.

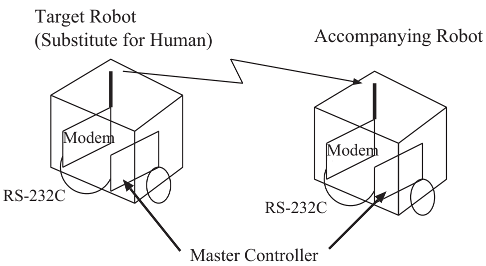

Fig. 3. Inter-robot communication using wireless modems.

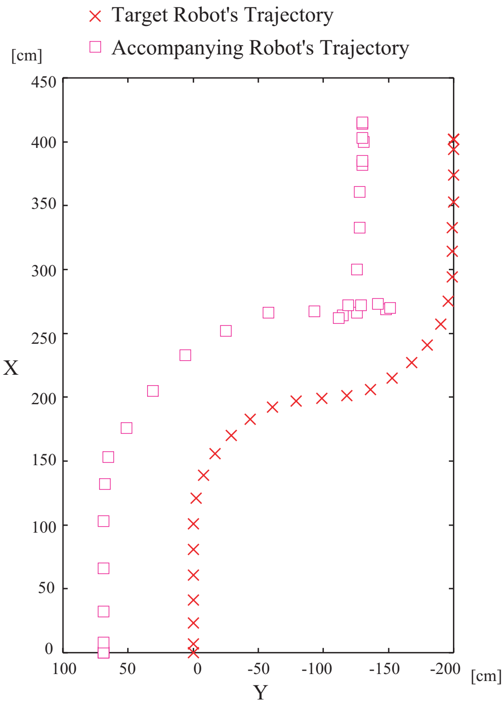

Fig. 4. Experimental result for accompanying behavior using two mobile robots. The trajectories of the robots recorded at a fixed time interval are plotted. The accompanying robot moved on the right side of the target robot which is the substitute for human.

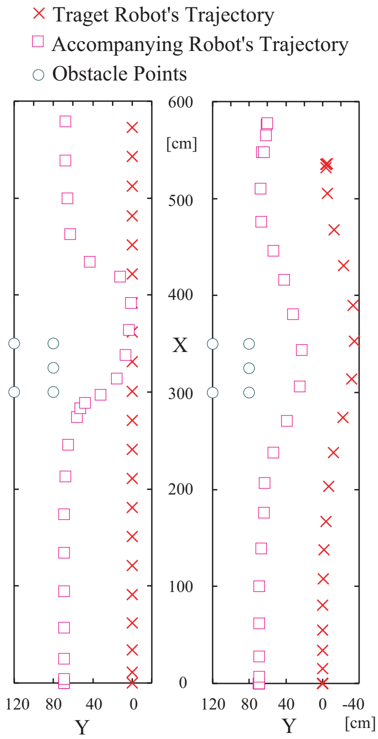

Fig. 5. Experimental result with obstacle avoidance. An obstacle existed in front of the accompanying robot. The left figure shows the case the target robot didn't change its path, while the right figure shows the case the target robot changed the path according to the approach of the accompanying robot.

3. Experiments

The validity of the proposed algorithm is verified through experiments.

3.1. Fundamental experiments using two mobile robots

As the first step, an accompany task is realized using two robots (Fig.2). In order to estimate the position of the robot to accompany, the target robot sends its position to the accompanying robot by a wireless modem (Fig.3). The accompanying robot then predicts the next position and speed of the target and computes the reference path and position at next moment.

The robot successfully accompanied the target robot which moved on various path patterns. An example of the experimental result is shown in Fig.4. The target robot run on the path having 'S' character shape. The accompanying robot could move together with the target without delay. It run fast at the right curve so that it could keep the accompanying position. It stopped once at the left curve since it leaved the target behind.

Obstacle avoidance behavior is also accomplished with very smooth movement by the method mentioned in the previous section. Fig.5 and 6 show the trajectories of the robots and the several scenes of obstacle avoidance behavior respectively in case an obstacle existed in front of the accompanying robot. In case the target robot didn't change its path in spite of the approach by the accompanying robot, the accompanying robot

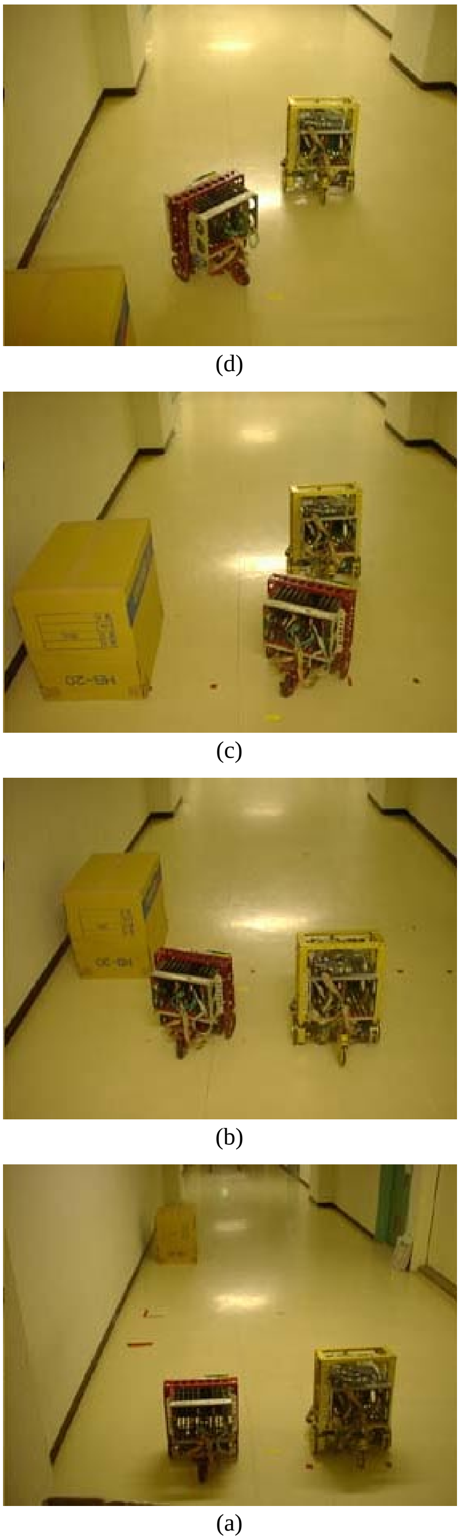

Fig. 6. The scenes of the experiment for obstacle avoidance. The left robot is the target (substitute for human) and the right is the accompanying robot. (a) An obstacle exists in front of the accompanying robot. (b) The accompanying robot approaches to the target robot. (c) The accompanying robot follows the target. (d) The accompanying robot goes back to the accompanying position.

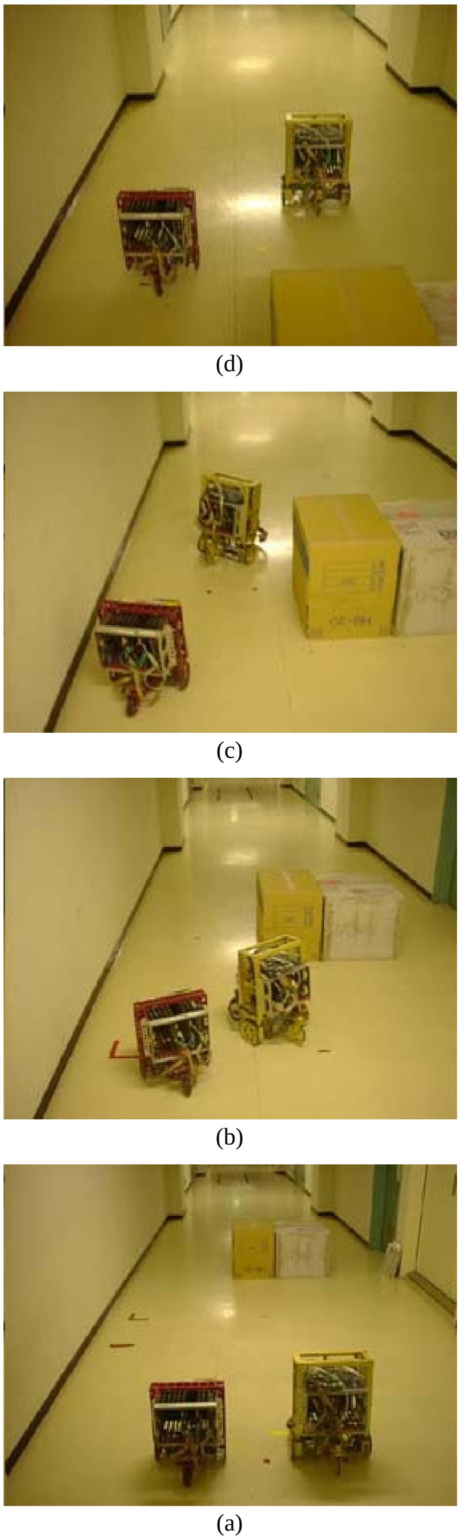

Fig. 7. The scenes of the experiment for obstacle avoidance. The left robot is the target (substitute for human) and the right is the accompanying robot. (a) An obstacle exists in front of the target robot. (b) The target robot approaches to the accompanying robot. (c) The accompanying robot follows the target. (d) The accompanying robot goes back to the accompanying position.

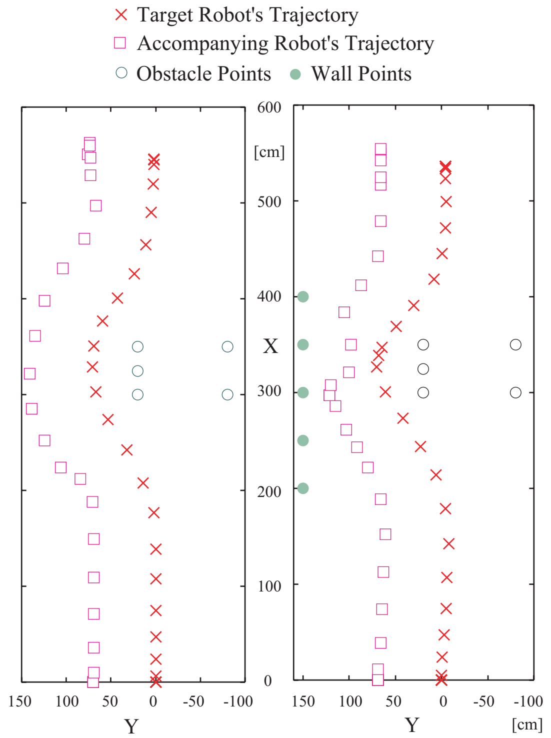

Fig. 8. Experimental result with obstacle avoidance. An obstacle exists in front of the target robot. The right figure shows the case there is a wall which prevents the accompanying behavior while no wall exists in the case of left figure.

once stopped, followed the target and went back to the accompanying position after avoiding the obstacle (left side of Fig.5). In case the target robot changed the path according to the approach, the obstacle could be avoided while keeping the accompanying behavior (right of Fig.5).

Fig.7 and 8 show the scenes and the trajectories of obstacle avoidance behavior in case an obstacle existed in front of the target robot. In case no wall exists, the accompanying robot could keep the accompanying position while the target avoided the obstacle (right side of Fig.8). In case there exists a wall, the accompanying robot's behavior was prevented by the wall (left of Fig.8). The accompanying robot once stopped, followed the target and went back to the accompanying position after avoiding the obstacle.

In these experiments, the robot is given in advance the information about the position of obstacles because it is not equipped with a high sensing performance sensor.

3.2. Experiments of accompanying behavior with human

There are several ways for a robot to understand the position of a person. In this study, we use a method using a light-emitting device which we developed[6].

We equip the person with a light-emitting device and make the robot detect this device using a camera (Fig.9). In order to appreciate the distance to the human, we use two LEDs fixed on a stick (Fig.10). The person carries this device perpendicular to the ground. By taking an image of this device, the robot

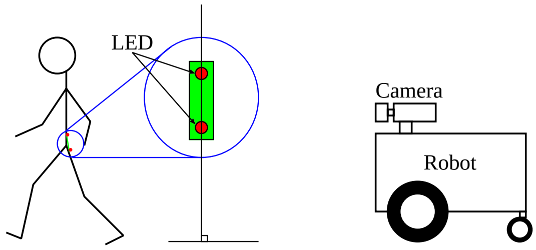

Fig. 9. The robot detects the human having a device by using a camera.

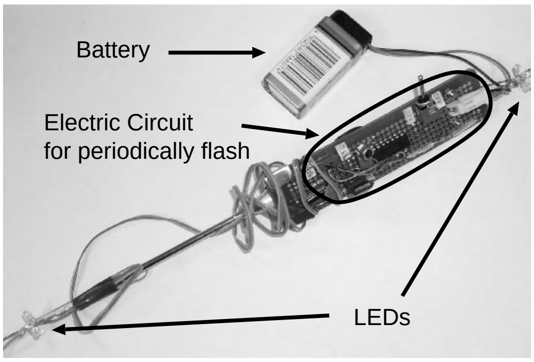

Fig. 10. Light-emitting device used in this experiment.

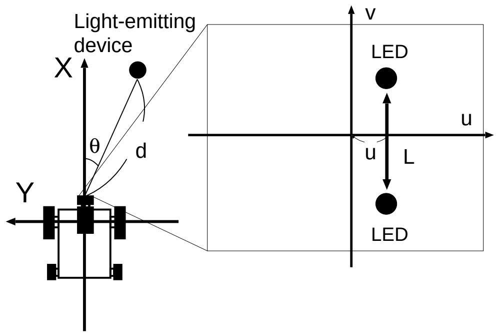

Fig. 11. The schema of the image of LEDs obtained from camera mounted on the robot.

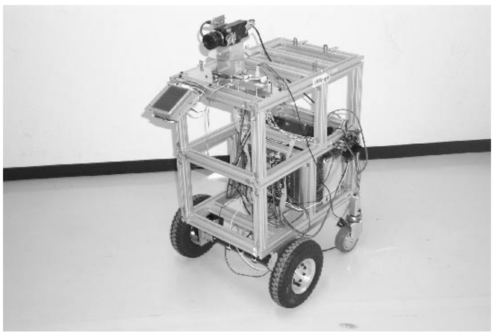

Fig. 12. The mobile robot developed for this research.

is able to know the distance to the human thanks to the interval between the two lights in the image (Fig.11). It can also appreciate the direction taken by the device by determining the distance between the lights and the central vertical axis of the image. A sensor stage having one degree of freedom (pan) is installed on the top of the robot (Fig.12).

Experiments based on the method described above were done in an indoor room. The robot could accompany the person who carried the device while he walked on a 'S' shaped path (Fig.13).

4. Conclusion

In this paper, we presented a method to achieve human accompanying behavior as a step toward the development of an intelligent escort robot moving along with a person. We proposed an algorithm to realize the human accompanying behavior including the obstacle avoidance and verified its validity through experiments. As a future work, the robustness of this method should also be verified. We are also trying to sum up the accompanying, guiding and following behaviors. Once the stage of building a clever robot capable of moving along with humans will have been achieved, we will consider lastly the interaction between human and intelligent robot.

Fig. 13. Experiment of accompanying behavior with human.

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