INTELLIGENT ESCORT ROBOT MOVING TOGETHER WITH HUMAN –HUMAN FOLLOWING BEHAVIOR–

Akihisa Ohya, Yousuke Nagumo and Motoki Takahata

PRESTO, JST / University of Tsukuba, Japan

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 following people and report on the realization of a mobile robot capable of following 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 follow his target. We consider two methods using a light-emitting device and an ultrasonic transponder. In order to prevent collision with obstacles, the robot should track the route followed by its target. We present the effectiveness of our approaches by showing the experimental result using a real mobile robot.

1. INTRODUCTION

In recent years, mobile robots have become autonomous enough so that we have to 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 following people and report on the realization of a mobile robot capable of following a person.

2. METHOD USED TO DETECT HUMAN POSITION

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 follow his target. There are several ways for a robot to understand the position of a person. In this research, we consider two methods using a light-emitting device and an ultrasonic transponder.

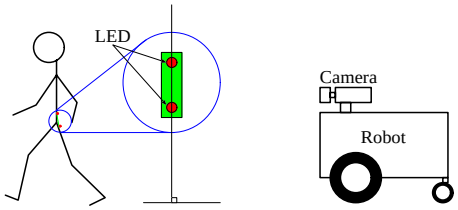

Fig.1 The robot follows the human using a camera.

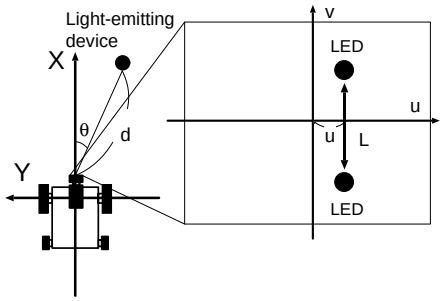

Fig.2 The schema of the image of LEDs obtained from camera mounted on the robot.

2.1. Human Detection Using LED

First, we equip the person with a light-emitting device and make the robot detect this device using a camera. In order to appreciate the distance to the human, we use two LEDs fixed on a stick. The person carries this device perpendicular to the ground (Fig.1). By taking an image of this device, the robot is able to know the distance to the human thanks to the interval between the two lights in the image. 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 (Fig.2).

2.2. Human Detection Using Ultrasonic Transponder

If we consider how a mobile robot could estimate the position of a specific object by using ultrasonic sensors, it

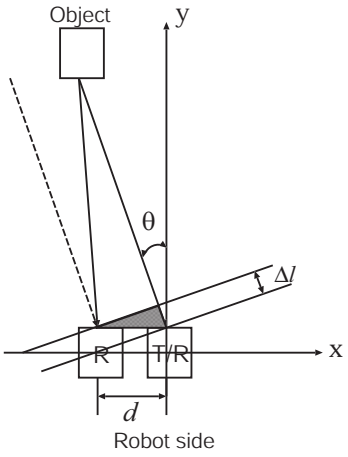

Fig.3 Principles of angle measurement using two ultrasonic receivers.

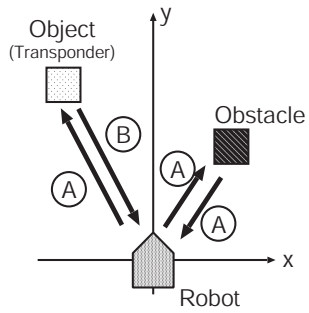

Fig.4 Position detection of a specific object using the ultrasonic transponder.

is possible to find the distance to the object thanks to the pulse echo method. The use of a sensor consisting of several receivers enables to determine the inclination angle of the object[6]. The distance Δl is obtained from the difference of time of flight at two receivers whose interval is d as shown in Fig.3. The angle θ can be calculated by the following equation.

$$\sin\theta = \frac{\Delta l}{d} \qquad (1)$$

However it is not possible with this method to recognize a specific object among several ones. We considered that it would be possible to differentiate a specific object if the ultrasonic wave emitted by the robot performing measurements can be separated from the ones emitted by a transponder carried by the object whose position is to be detected. The robot transmits an ultrasonic pulse A and the object which has an transponder transmits another ultrasonic pulse B after detecting pulse A while the pulse A is returned by the reflection at an obstacle (see Fig.4).

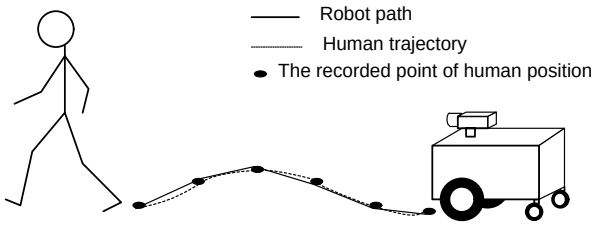

Fig.5 Determination of the path for human following. The position of the human is recorded at a moderate interval.

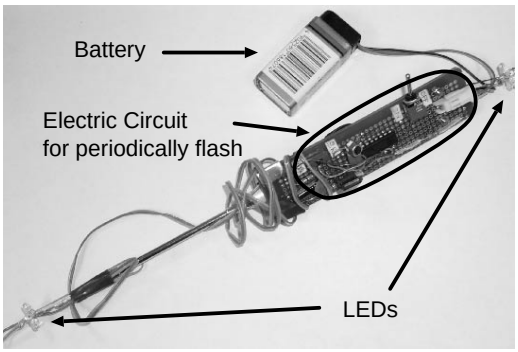

Fig.6 Light-emitting device used in the experiment.

3. HUMAN FOLLOWING BEHAVIOR

In order to prevent collision with obstacles, the robot should track the route followed by its target[5]. The robot calculates the distance between the actual position of the human and the previous location of the human. If the distance the human moved is greater than a value decided in advance, the position of the human is recorded in a list. The robot reads each position recorded in the list successively and makes the appropriate movements to reach point (Fig.5).

In order to estimate its position, the vehicle uses odometry and computes the location of the human relatively to the position of the vehicle. The location of the human is recorded by the robot in a global referential. The robot can adjust its speed according to the number of points recorded in the list that exist between the actual pose of the robot and the location of the human. By doing so, the robot can track the path followed by its target.

4. EXPERIMENTAL SYSTEM

4.1. System for Human Following Using LED

The experimental light-emitting device is shown in Fig.6. We are using infrared LEDs in order to avoid disturbing people. In order to prevent the light intensity from decreasing when the orientation of the light-emitting device changes, four LEDs were grouped together on each extremity of the light-emitting device.

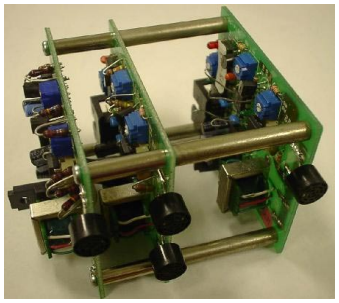

Fig.7 Ultrasonic sensor on the robot.

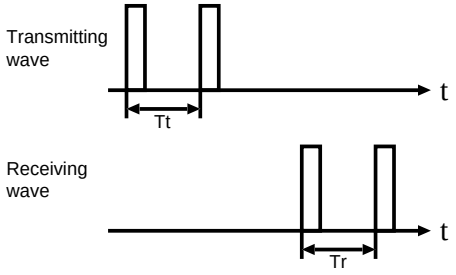

Fig.8 The timing of transmission and reception of the pulses in the double pulse coding.

Since infrared LEDs are used, a cut-off filter was installed on the camera mounted on the robot. In order to increase the precision of distance estimation, the camera was mounted on its side on the robot so that the captured image is 240 pixels width and 768 pixels height.

In order to detect robustly the LEDs in the images taken by the robot, we make them turn on and off and take images of the light-emitting device when the lights are on and off. Then the difference of the two images is computed. As a result, pixels that don't correspond to the blinking LEDs have an intensity close to 0 and the location of the LEDs in the image can be obtained in a robust way.

4.2. System for Human Following Using Ultrasonic Transponder

The ultrasonic sensor on the robot has one transmitter and three receivers. It is constructed from three electric boards as shown in Fig.7. Since three receivers are used in this system, a set of three angles to the target are obtained. By checking the consistency of those three angles, the system can overcome the problem which is so called "one wave length error [7]."

In order to differentiate the ultrasonic pulse transmitted by the transponder from it from the obstacles, we use double pulse coding method[8]. The two pulses are transmitted from the transmitter with a pre-determined short interval (Fig.8). If the transponder transmits a double pulse with a different interval, these double pulses can be differentiated from each other.

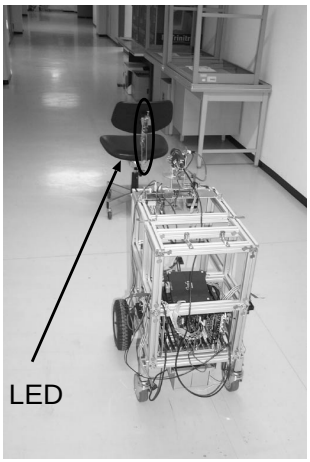

Fig.9 Experimental environment for use of LED.

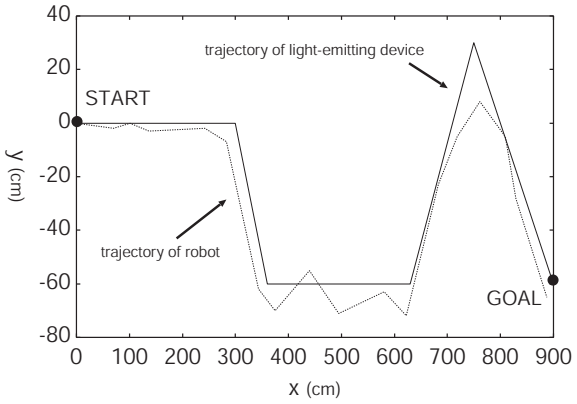

Fig.10 Experimental result of target following using LED.

5. TARGET FOLLOWING EXPERIMENT

5.1. Experiments using LED

In a first step, the light-emitting device was fixed on a wheeled chair which was moved according to a given path. The path followed by the light-emitting device was compared to the points the device passed recorded by the robot. The experimental environment is shown in Fig.9, and experimental results are given in Fig.10. This result prove that basic following movement is realizable.

In a second step, the light-emitting device was carried by a person and the robot had to follow it. The robot could track the path followed by the human target. Figure 11 represents different steps of this experiment.

5.2. Experiments Using Ultrasonic Transponder

The transponder is moved by hand on an circle in front of the robot as shown in Fig.12. The calculated locations of the transponder are plotted in Fig.13. It can be seen that the system is able to measure the position of the target well.

Fig.11 Human following behavior by using LED.

6. CONCLUSION

In this paper, we presented a method to achieve human following behavior as a first step toward the development of an intelligent escort robot moving along with a person. We showed two methods to realize the human following behavior using LED and ultrasonic transponder. As a future work, it should be done to verified how robust these methods are and to cope with situations when the robot can not detect human. We are also planning to make experiments using sound generation to inform the status of the robot to the human in order to realize more smooth interaction of the behavior. Furthermore, we are trying to add an accompanying behavior with human. Once the stage of building a clever robot capable of moving along with humans will have been achieved, we will consider lastly the relation between human and intelligent robot interaction.

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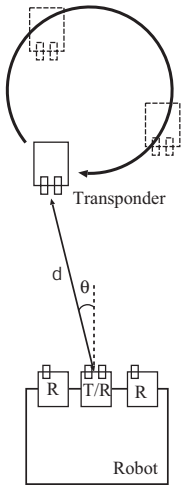

Fig.12 Experimental setup for the target position tracking using the ultrasonic transponder.

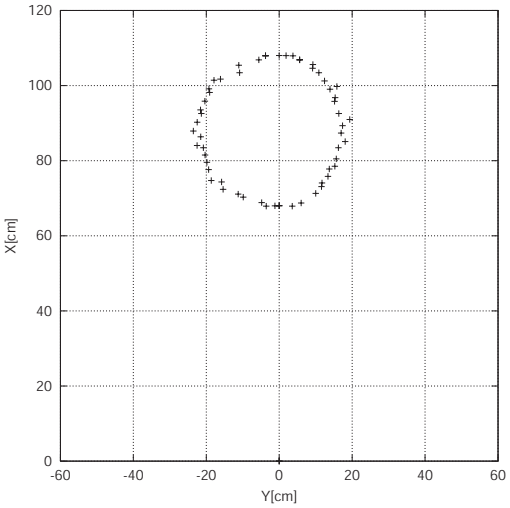

Fig.13 Result of the target position tracking using the ultrasonic transponder.

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