Intelligent Escort Robot Moving together with Human – Methods for Human Position Recognition –

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Abstract

We consider in this research how mobile 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 order to escort a human, the robot needs to know the position of the person, first of all. In this paper, we consider the method to recognize position of human and report on our developed systems for detecting the human's position. We present three methods using a blinking LED device, an ultrasonic transponder and a combination of an omni-directional vision and a laser range finder, with some experimental results.

Key words: interaction and intelligence, autonomous mobile robot, escort robot, human position recognition.

1 Introduction

In recent years, mobile robots have become autonomous enough so that we have to think of their applications. While how robot can support human life has already been described in many researches[1-8], we consider in this research how mobile robots can render service by moving by themselves. In order to spread mobile robot use in human daily life, there is a need on researching in useful and impactful mobile robots' applications helping us in our day-to-day tasks. For this purpose, interaction with humans is a key function for a robot taking part actively in human life.

Our aim is to develop an INTELLIGENT ESCORT ROBOT moving along with people so that it can support them in everyday life by tightly interacting with humans. Several concrete supporting applications can be considered, such as indoor and outdoor guidance and information supplying, accompanying people or following humans while carrying heavy objects. The INTELLIGENT ESCORT ROBOT should be better than a guiding car-ride, an audio guide and a human's self-guide. It will be a substitute for human guide.

In order to escort a human, a mobile robot needs to know the position of the person, first of all. There can be many ways for a robot to understand the position of a person. In this paper, we present three our developed methods using a blinking LED device, an ultrasonic transponder and a combination of an omni-directional vision and a laser range finder. We also show some experimental results to examine their performance.

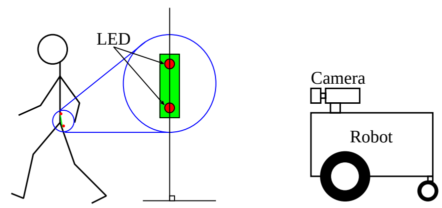

Figure 1: The robot detects the human having a light-emitting device by using a camera.

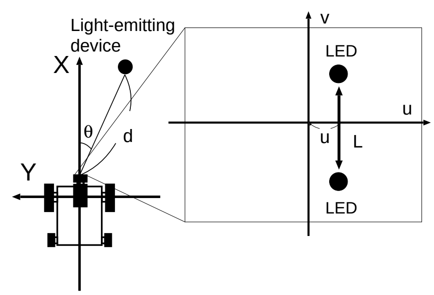

Figure 2: The schema of the image of LED obtained from camera mounted on the robot.

2 Human Position Recognition using Blinking LED

2.1 Method for human position detection

In order to realize a robust detection method, we equip the person with a light-emitting device and make the robot detect this device using a camera, first[9]. In order to appreciate the distance to the human, we use two LED fixed on a stick. The person carries this device perpendicular to the ground (Fig.1). By taking an image of this device, the

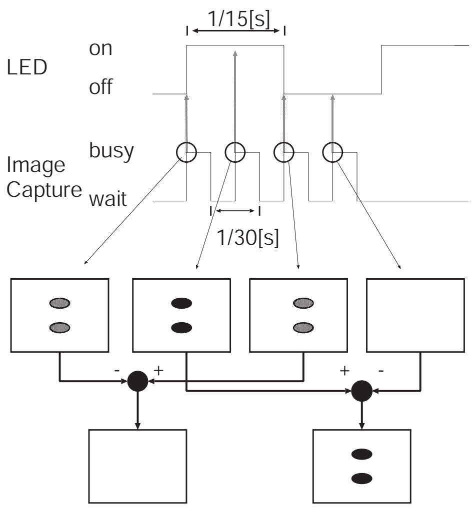

Figure 3: The timing of LED blinking and image capture. A good result is obtained when the second and fourth images are used in this case.

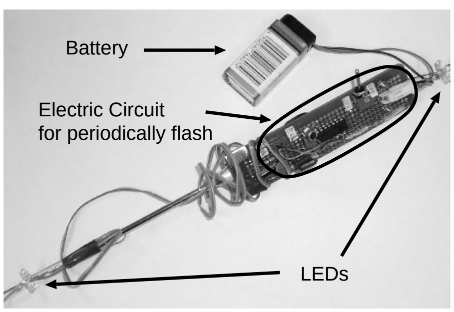

Figure 4: Light-emitting device used in the experiments.

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).

In order to detect robustly the LED in the images taken by the robot, we make them blink 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 LED have an intensity close to 0 and the location of the LED in the image can be obtained in a robust way. Yet, it is difficult to take successive images exactly when the LED are on and off. In order to cope with this issue, the blinking timing is set double to the frame rate of the camera which is 1/30 seconds. LED are on during 1/15 seconds and off during 1/15 seconds. Then four images are taken successively. By doing so, at least one image will contain the light-emitting device with the LED switched off, and at least one image will

Figure 5: A set of 4 LED for direction invariant emission.

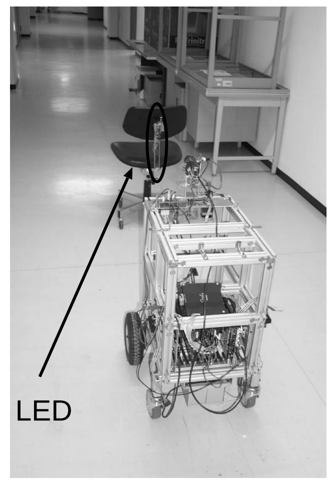

Figure 6: Experimental environment for use of LED.

contain the light-emitting device with the LED switched on. By using the first and third, or the second and fourth images, it is possible to detect correctly the LED. Fig.3 illustrates how the LED can be detected in spite of the non-synchronization of the image capture and the LED blinking frequency.

The experimental light-emitting device is shown in Fig.4. In this research, the distance between the robot and the human is supposed to be within 3 meters. The farther the human target gets from the person, an error of measured distance is increasing. Considering that, the device became length of approximately 24cm. We are using infrared LED in order to avoid disturbing people. A cut-off filter was installed on the camera mounted on the robot. In order to prevent the light intensity from decreasing when the orientation of the light-emitting device changes, 4 LED were grouped together on each extremity of the light-emitting device as shown in Fig.5.

Since the field of view of a sensor fixed on the robot is restricted, the human may go out of the robot's field of view when the vehicle changes its direction in order to perform human escorting. In order to keep the human in the field of view of the sensor, the sensor rotates so that the human is located in the center of the field. A sensor stage having one degree of freedom (pan) is installed on the top of the robot.

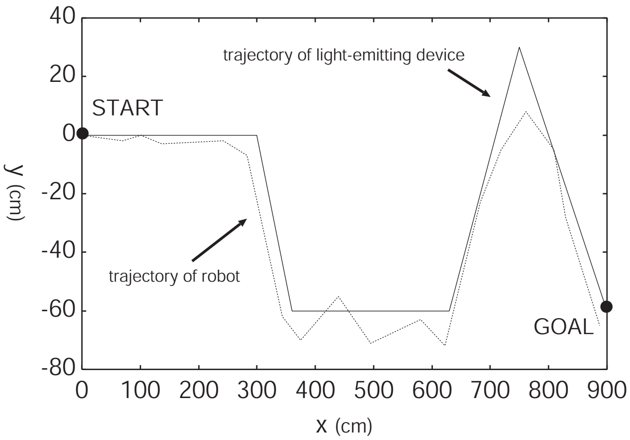

Figure 7: Experimental result of target following using the blinking LED.

2.2 Target following experiment using LED

Experiments based on the method described above were done in an indoor corridor. The light-emitting device was fixed on a wheeled chair which was moved according to a given path. The robot measured the position of the device and followed on the trajectory of the device. The experimental environment is shown in Fig.6, and experimental result is given in Fig.7. This result prove that the position of the device is correctly measured.

3 Human Position Recognition using Ultrasonic Transponder

3.1 Method for human position detection

If we consider how a mobile robot could estimate the position of a specific person by using ultrasonic sensors, it is possible to find the distance to the object thanks to the pulse echo method. The use of a sensor consisting of multiple receivers enables to determine the inclination angle of the object[10]. Since three receivers are used in our method, a set of three angles to the target are obtained by the following equation.

$$\sin\theta = \frac{\Delta l_1}{d_1} = \frac{\Delta l_2}{d_2} = \frac{\Delta l_1 + \Delta l_2}{d_1 + d_2} \quad (1)$$

By checking the consistency of those three angles, the system can overcome the problem which is so called "one wave length error[11]". The distance Δl_1 and Δl_2 are obtained from the difference of time of flight at pairs of receivers whose interval are d_1 and d_2 as shown in Fig.8.

However it is not possible with this method to recognize a specific person among several ones. We considered that it would be possible to differentiate a specific person if the ultrasonic wave emitted by the robot performing measurements can be separated from the ones emitted by a transponder carried by the person whose position is to be detected[12]. The robot transmits an ultrasonic pulse A and the transponder held by the person transmits another ultrasonic pulse B after detecting pulse A while the pulse A is returned by the reflection at obstacles (see Fig.9). In order to differentiate the ultrasonic pulse transmitted by the transponder from it from the obstacles, we use double pulse coding method[13]. The two pulses are transmitted from the transmitter with a pre-determined short interval (Fig.10). If the transponder transmits a double pulse with a different interval, the double pulse can be differentiated from others.

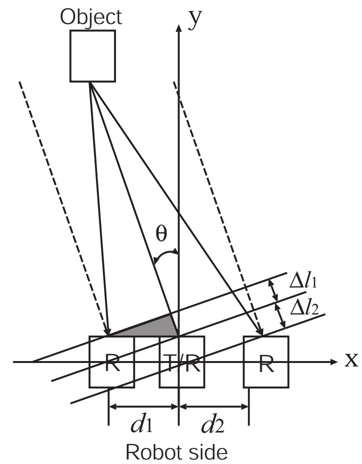

Figure 8: Principles of angle measurement using multiple receivers.

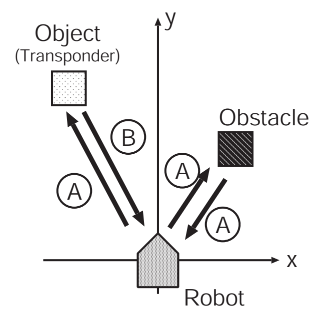

Figure 9: Position detection of a specific target using an ultrasonic transponder.

3.2 Target tracking experiment 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.11. The transponder is moved by hand on an circle in front of the robot as shown in Fig.12. The result of the target position tracking is shown in Fig.13. The calculated locations of the transponder are plotted in the graph. It can be seen that the system is able to measure the position of the target well.

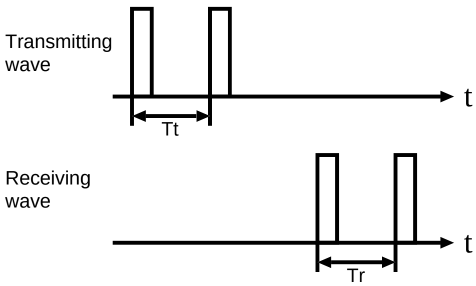

Figure 10: The timing of transmission and reception of the pulses in the double pulse coding.

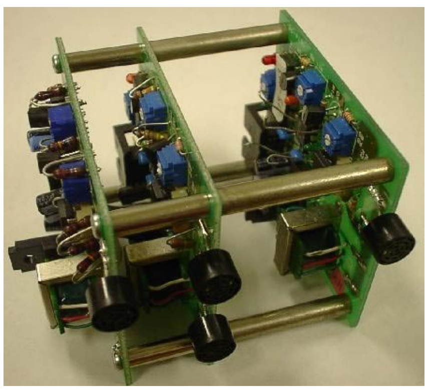

Figure 11: Ultrasonic sensor on the robot.

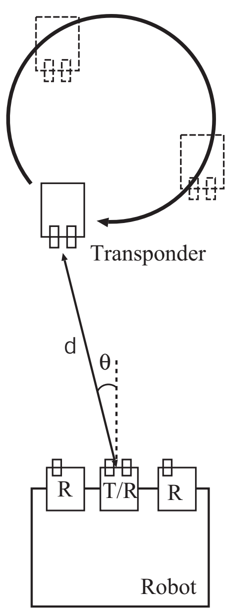

Figure 12: Experimental setup for the target position tracking using the ultrasonic transponder.

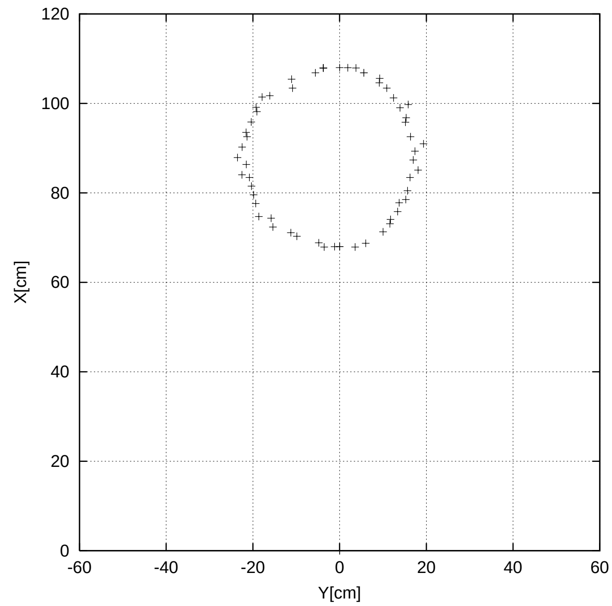

Figure 13: Result of the target position tracking using the ultrasonic transponder.

4 Human Position Recognition using Omni-directional Vision and Laser Range Finder

4.1 Method for human position detection

We also developed another method to detect human's position by a passive way. We use an omni-directional vision sensor and a laser range finder. Fig.14 shows a robot equipped with those sensors. The omni-directional vision can easily obtain a whole 360 degrees image of its surroundings. On the other hand, the laser range finder such as SICK laser scanner can measure the distance for each angle(direction) very accurately. We took a strategy that the omni-directional image is used for detecting a human basically and the scanned laser readings are used to measure the position of the human. The sensing can be more robust by fusing the data obtained from these sensors.

An example of the image obtained from the omni-directional vision sensor is shown in Fig.15. A person is standing in front of the robot. (The image is reverted in the horizontal axis because of the configuration of the omni-directional mirror.) Fig.16 shows the detected edges obtained by differentiating Fig.15. As the other source of the environmental information, the laser range finder can generate a schematic map of the environment as shown in Fig.17. In order to fuse these sensor information, the obtained data is formed into like Fig.18. In this figure, the upper graph represents a histogram of edge pixel shown in Fig.16. The lower graph shows distance measured by the laser range finder. The horizontal axis expresses the directional angle from the robot. As we can see, there are peaks

Figure 14: The robot equipped with an omni-directional vision sensor and a laser range finder.

Figure 15: An example of the image obtained from the omni-directional vision sensor.

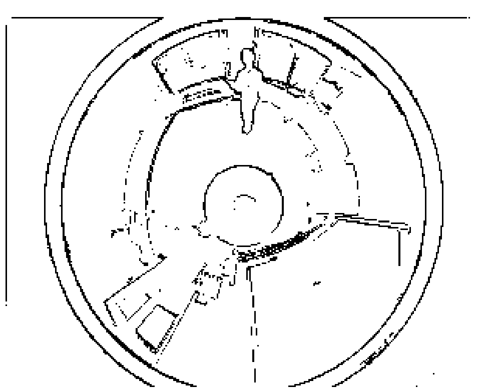

Figure 16: Edges detected by differentiating Fig.15.

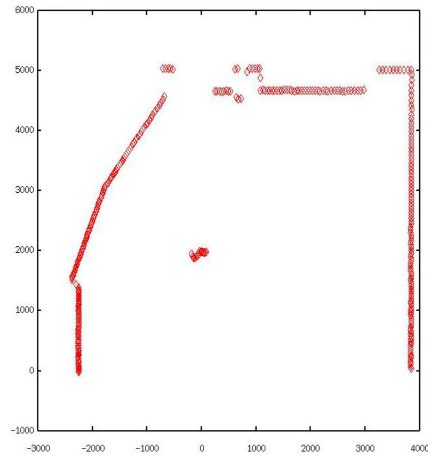

Figure 17: An example of the 2D plot of the scanned laser readings in the same situation as shown in Fig.15.

in the edge histogram together with big sudden changes in the laser range data, at 87 and 95 degrees. Indeed those angles coincide with the directional angle to the both side of the person. After searching such feature points, the position of the person can easily calculated using distance measured by the laser. The distance between two calculated position will be checked in order to verify whether the measured object is a human.

4.2 Target tracking experiment using an omni-directional vision and a laser range finder

The experiment of the target person tracking was performed using developed robot system. The measurement of target position was repeated at several different target position. The result is shown in Fig.19. Measured positions of the person is connected by grey lines while real positions by black lines. The target position could be measured with an accuracy of around 15cm even in the farther case.

5 Conclusion

In this paper, we presented methods to recognize human's position as a first step toward the development of the INTELLIGENT ESCORT ROBOT moving along with a person. We showed three our developed methods using a blinking LED, an ultrasonic transponder and a combination of an omni- directional vision and a laser range finder. The effectiveness of the methods was verified by showing experimental results.

As a future work, we want to realize escorting behavior of the INTELLIGENT ESCORT ROBOT using the methods of human's position recognition presented in this paper. After accomplishing the realization of the robot, we will consider lastly the relation between "interaction" with human and "intelligence" of the robot.

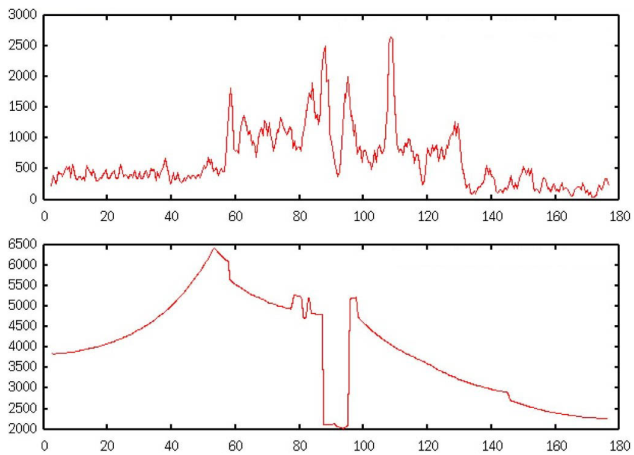

Figure 18: Upper graph represents the histogram of edge pixel shown in Fig.16. Lower graph shows distance measured by the laser range finder. The horizontal axis expresses the directional angle from the robot.

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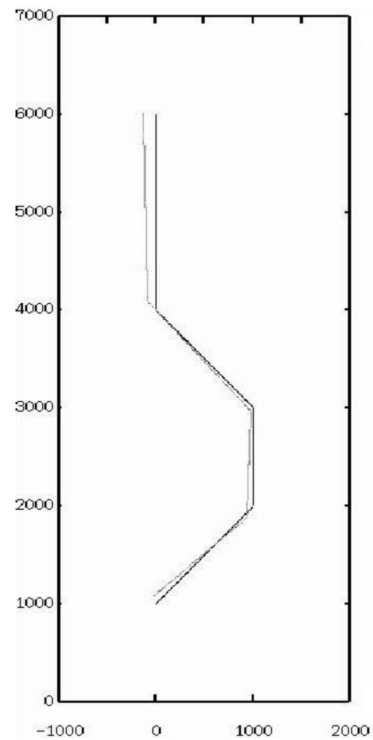

Figure 19: Experimental result of the target position tracking. Measured positions of a person is connected by grey lines while real positions by black lines. (Unit [mm])

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