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Development of Human Following Mobile Robot System Using Laser Range Scanner

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Abstract

This paper discussed a human following mobile robot system using laser range scanner. The laser range scanner is very useful device for getting the environmental information around the robot. We developed the human detecting algorithm that the laser range scanner to detect the shins of the target person. When the laser range scanner scans the person's shin, the shape of the section of the shin shows parabola shape of the convex below. The mobile robot can detect and follow the target person based on the positions of both shins. Since the laser range scanner detects the obstacles, the system has the collision avoidance functions. The effectiveness of our system is demonstrated by several performance tests.

*Keywords:*Laser Range Scanner; Human Detection and Following; Mobile Robot; Human Robot Interaction

1. Introduction

The development of robots has been important to industrial production, including that in factories. Intelligent robots are expected to work cooperatively with people in daily life and in medical treatment and welfare. It is necessary for the intelligent mobile robot to detect and follow the parson to support human works. For example, an intelligent cargo transportation robot carries the luggage in place of a porter at the airport. The mobile cleaning robot to track the sound source using the three microphones has been developed [1]. The mobile robot system for tracking and following moving people using an omnidirectional camera and a laser was developed [2]. A human tracking system for an autonomous mobile robot using neural-based motion detectors has been proposed [3]. This system uses motion sensors based on the motion sensitive neurons found in the medial temporal area of the primate brain. The target tracking system for a mobile robot under varying illumination using stereo camera has been proposed [4]. The people tracking and localization for social robot using an infrastructure of sensors embedded in the environment has been presented [5]. The localization of mobile robot using images by distributed intelligent networked devices has been proposed [6]. This method is used the Kalman filtering scheme to estimate the location of moving robot. The mobile robot system that has functions of human following and returning to the starting location autonomously while avoiding obstacles using LRF(Laser Range Finder) and camera was developed [7]. The human detection method that uses only a single laser range scanner to detect the waist of the target person was developed [8].

This paper presented a human following mobile robot system using laser range scanner. The laser range scanner is very useful device for getting the environmental information around the robot. We developed the human detecting algorithm that the laser range scanner to detect the shins of the target person. The mobile robot can detect and follow the target person based on the positions of both shins. Moreover, the mobile robot system has a collision avoidance function using the LRS. The goal of our system is that the mobile robot can follow the walking person in the narrow space. The effectiveness of our system is demonstrated by several performance tests.

2. Human following mobile robot system

We developed a human following mobile robot system using laser range scanner. The outline of the human following robot system is shown in Fig.1. This mobile robot detects the position of person's shins based on the data of laser range scanner and

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follows the target person. The human following mobile robot system is composed of the manufactured wheel type mobile robot (Kobuki, Yujin Robot), laser range scanner (LRS: UST-20LX, Hokuyo Ltd.)[9], web camera (HD Pro Webcam C920, Logtech) and control PC(XPS12, Dell) (see Fig.2)). The web camera is used only for recording the robot situation. We use the ROS (Robot Operation System) [10] for the implementation of the system.

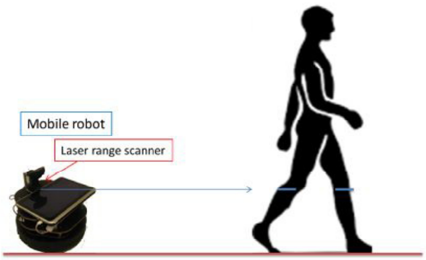


Fig. 1 The outline of human following mobile robot system

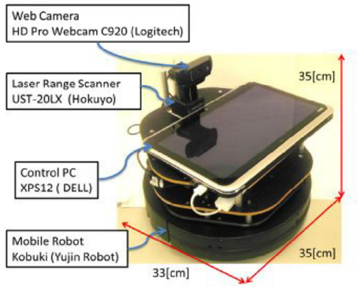


Fig.2 Human following mobile robot system

The LRS is mounted on the mobile robot in order to detect a person. The specification and the appearance of the LRS are shown in Table.1 and Fig.3 respectively.

Table 1. Specification of the laser range scanner

Light source	Semiconductor laser diode, class 1
Measuring area	60 to 20000 [mm], 270°
Accuracy	±40 [mm]
Angular resolution	0.25° , 1081 steps
Scanning time	25 [ms/scan]
Interface	Ethernet 100BASE-TX
Weight	130 [g]
Size(W×D×H)	50[mm]×50[mm]×70[mm]

Fig.3 Laser range scanner

The LRS detects collision-free spaces around the mobile robot. The measuring distance of the LRS is from 60[mm] to 2000[mm] and the measuring angle of it is 270° (see Fig.4). The LRS gets the 1081 data (steps) at the one scanning. Fig.5 shows the example of the display of the LRS data. The collision-free space is shown in Fig.5.

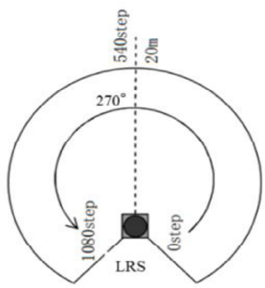


Fig.4 Measuring area of LRS

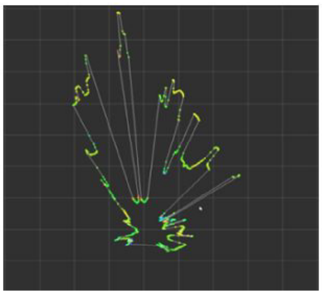


Fig.5 Display of the LRS

3. Human detection and following using LRS

3.1 Human detection using LRS

The LRS is mounted on the mobile robot at the 25[cm] from the floor. When the person stands to 30[cm] in front of the mobile robot, the height position (25[cm]) of LRS is the position of the person's shins. As shown in Fig.6, the LRS scanning data of person's shins shows two parabola shapes of the convex below whether the person changes the standing position. In Fig.6, the dotted circle shows the search area of the person and two parabola shapes of the convex below are the sections of the person's both shins. The mobile robot can detect the person's position based on the geometric characteristics of both shins.

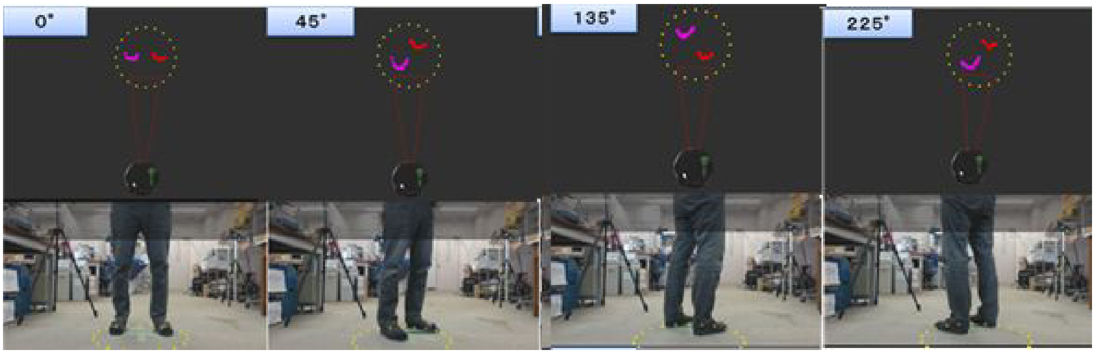
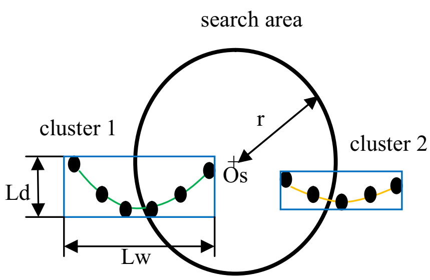


Fig.6 LRS scanning data of the person's shins

At first, the points of LRS data are gathered up the domain of the group (cluster) in consideration of the distance between the scanning points. The threshold distance value between two scanning points is determined based on the distance from the LRS to scanning position. As shown in Fig.7, the cluster becomes the circumscription rectangle of LRS data. The candidate of the person's shin (shin cluster) is the cluster which overlapped the search circle area of the person's shin. The center of the search circle is the center position of the target person and the radius of it is 25[cm] in consideration of the person's step. The mobile robot system follows the person by means of renewal of the position of the person's shins in the search circle area. The position of the target person is estimated by the center positions of two shin's clusters which are obtained at the previous phase. We determined the conditions of shin cluster which are shown in Fig.7. These conditions are determined in consideration of the depth and width of cluster and step number of scan data. The minimum steps STmin and the maximum steps STmax are depended on the distance from LRS to the center of the search circle area. If the candidates of shin cluster are over three, the system selects the two clusters which are the nearest positions of the center of the search area.



【Conditions of shin cluster】

$$\begin{cases} 0.02[\mathrm{m}] \le Lw \le 0.30[\mathrm{m}] \\ 0.02[\mathrm{m}] \le Ld \le 0.30[\mathrm{m}] \\ 0.10[\mathrm{m}] \le Lw + Ld \le 0.40[\mathrm{m}] \\ ST\ min \le LST \le ST\ max \end{cases}$$

Where
LST : Step number ofscan data
ST min, ST max : depend on the disance from LRS to the origin Os

Fig.7 clustering of LRS scanning data and the condition of shin cluster

3.2 Estimation of the shin position

The position of the target person is estimated by the both shin positions. However, when the person stands at the position of the right angle for the mobile robot, one leg is hidden by the other leg. As shown in Fig.8, the system detects only one shin cluster. This situation is called the occlusion. At the case of the occlusion, the system estimates the position of the hidden shin position based on the collection value. The collection value of the hidden shin is determined the 0.115[m] in consideration of the person's step. We supposed that the same shin cluster exists behind the one shin cluster. Fig.9 shows the comparison of the two situations which are no estimation case and estimation case. As shown in Fig.9(b), hidden shin is estimated and center position of the person is obtained correctly.

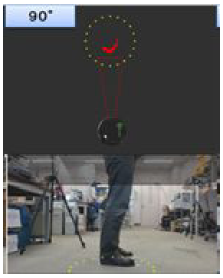
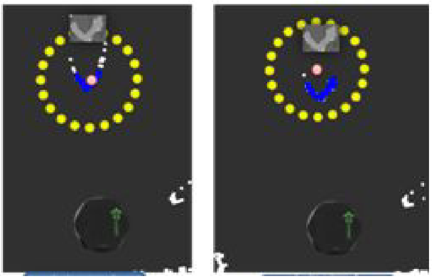


Fig.8 The case of the occlusion



(a) no estimation (b) estimation of hidden shin

Fig.9 The comparison of two cases

3.3 Direction and speed for human following

The target speed and the direction of the mobile robot are obtained based on the center position of the person. As shown in Fig.10, the center position of the person (Pi) is calculated based on the center positions of both shins. The mobile robot moves to the direction of the target person. The goal position of the mobile robot is determined based on the person's position and the offset distance (Fig.11). We set the offset distance 0.6[m] in consideration of the width of the mobile robot because the mobile robot doesn't collide with the person's legs. The target speed of the mobile robot is calculated based on the target distance Td and the speed gain Kg. We determine the speed gain Kg is 1.5 based on the experimental results. Since we assume that the person walks at the constant and ordinary speed, the system estimates the person's position when the person is hidden by the objects. The person's walking speed is estimated based on the ten times of the mean of the speed variation of the person. If the target person was hidden by the object, system estimates the position of the person by the previous walking speed. For less than three seconds, the system can follow the hidden person.

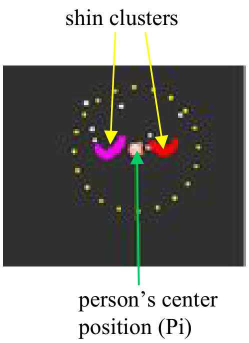


Fig.10 The center position of the person

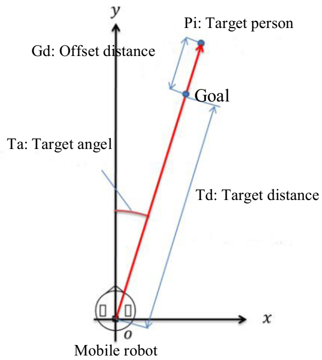


Fig.11 The target distance and direction of mobile robot

4. Collision avoidance using LRS

The mobile robot system has a collision avoidance function using the LRS. As shown in Fig.12, the collision detection area which is the rectangle is created between the mobile robot and the target person. The width of this rectangle is 0.8[m]. If the obstacles exist in the collision detection area, the system detects the end position of the obstacle which is the nearest position from the center line of the rectangle. The system creates the collision avoidance area which is the circle. The center of the circle is the end point of the obstacle and the radius of it is 0.4[m] in consideration of the radius of the mobile robot. The system calculates the collision avoidance vector which is the tangent of this circle. The mobile robot forwards to the direction of the collision avoidance vector.

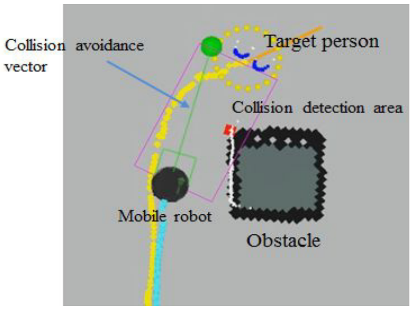


Fig.12 The situation of the collision avoidance

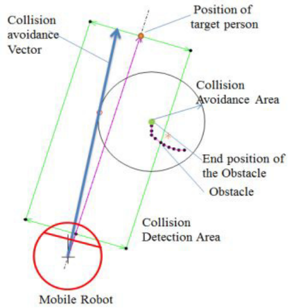


Fig.13 The collision avoidance vector

5. Experimental Results

We conducted two performance tests to clarify the effectiveness of our system.

5.1 Performance test 1

The mobile robot follows the target person who walks the rectangular course of 1.8m in width and 2.5m in depth. Four subjects (three men and one woman) participated in the experiment. The each subject was tested 3 times in test 1. The example of the detection of the person's shin is shown in Fig.14. The Fig15 shows the example of the trajectories of the mobile robot at the performance test 1. As shown in Fig.15, mobile robot moves the rectangular course according to the motion of the walking person. The success rate of the performance test 1 is 83%. The reason of the failure was that the mobile robot didn't follow the person at the corner of the test route.

Fig.14 Detection of the person's shin

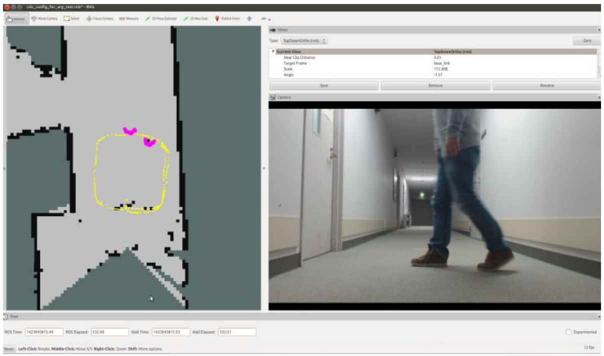


Fig.15 Experimental result of performance test 1

5.2 Performance test 2

The mobile robot follows the target person who walks along the test course in the room. The test course is shown in Fig.16. The test course of performance test 2 is more complicated than one of the test 1. Three subjects (all men) participated in the test 2. The each subject was tested 3 times in the test 2. As shown in Fig.17, mobile robot follows the target person to move through the narrow space in the room. The success rate of the performance test 2 is 66%. The reason of the failure was that the mobile robot misrecognized the leg of the desk to the person's shin.

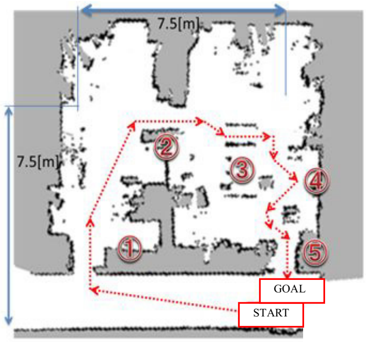


Fig.16 Test course of performance test 2

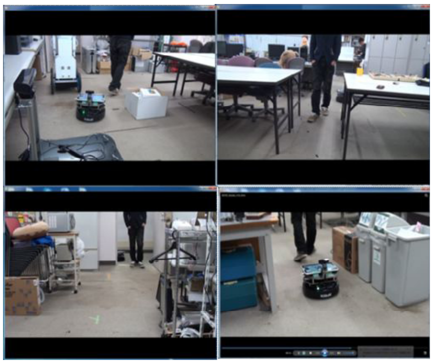


Fig.17 Experimental result of performance test 2

5. Conclusions

In this paper, we developed a human following mobile robot system using laser range scanner. In order to detect a person we use a laser range scanner which is very useful device for getting the environmental information around the robot. We developed the human detecting algorithm that the laser range scanner to detect the shins of the target person. The mobile robot can detect and follow the target person based on the positions of both shins. The scanning data of person's shins shows two parabola shapes of the convex below whether the person changes the standing position. We determined the conditions of the shin cluster based on the geometrical characteristics of the person's shin. The mobile robot moves to the direction of the target person. The position of the target person is obtained by means of renewal of the position of person's shins. The speed of the mobile robot is calculated based on the target distance and the speed gain. Moreover, the mobile robot system has a collision avoidance function using the LRS. We conducted performance tests to clarify the effectiveness of the system using the LRS. The success rate of the performance test2 in the complex environment was 66%. The mobile robot follows the target person to move through the narrow space. The reason of the failure was that the mobile robot misrecognized the leg of the desk to the person's shin. In our future work, we intend to explore further the practicality of the system by various experimental scenarios. We expect that this human following mobile robot system apply to the intelligent cargo transportation robot.

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