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High-speed laser localization for restaurant service mobile robot

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Abstract: Nowadays, service robots are very popular in robot family. The objective of this paper is to develop a restaurant service mobile robot. This service mobile robot can transfer dishes in the restaurant. It also can show the customers to the unoccupied table. The service efficiency of the restaurant service can be increased with this service robot. This service mobile robot is equipped with "Laser positioning system" The laser positioning system is used for rapid and precise positioning and guidance of the mobile robot.

Keywords: restaurant service mobile robot, Laser positioning system, mobile robot.

I. INTRODUCTION

There are many types of service robots, such as cleaning and house keeping robots, surveillance robots, edutainment robots, rehabilitation robots and so on [1-8]. It is hard to find the autonomous service robots to be used in a restaurant. L. Acosta et al. [9] a highly specialized autonomous robot. The task of the robot is the setting and clearing of tables in a controlled environment. The "Robot Kitchen" restaurant in Hong Kong is conducting a two week feasibility test featuring three robotic employees including a large robot that is equipped to take customer orders, transmit them to the kitchen, and deliver the meals to the customer's table [10]. Another Canadian robo-waiter developed for the 2001 Robo-Cup hosted by the American Association for Artificial Intelligence, Jose, is shown below serving a muffin to Minister of Industry Brian Tobin [11].

The restaurant service robots can help the waiters or waitresses to do many jobs, such as guiding customers, ordering dishes, and delivering meals. The restaurant service robots not only can assist the humanity to finish some jobs, but also they can dance or sing songs to amuse the customers. The service robots can play an important role in a "Robot" restaurant.

In this research, we have developed a restaurant service robot which is equipped with laser positioning system. The target or the motion path of the service robot can be easily changed.

II. HARDWARE STRUCTURE OF THE RESTAURANT SERVICE ROBOT

The restaurant service robot is equipped with laser positioning system. The target or the motion path of the service robot can be easily changed. The subsystems will be explained as the following contents. The structure and the photo of the second generation restaurant service robot is shown in Fig. 1.

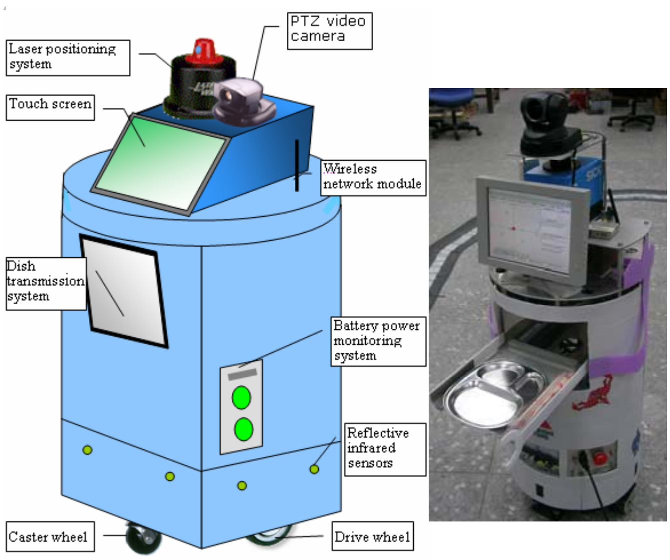


Fig 1. Structure of the second generation restaurant service robot

2.1 Design of the robot mechanism

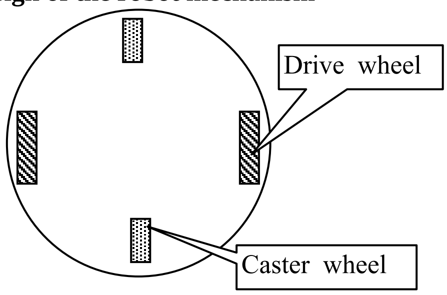


Fig 2. The differential drive system

The main body of the service robot is consisted with five layers of 40 cm circular aluminum alloy board. As shown in Fig. 2, the differential drive system is used in the robot platform. The drive wheels are placed on each side of the robot platform. Two DC servo motors with internal gear reduction are connected to the driving wheels. The caster wheels (non-driven wheels) with spring damper are placed in front and rear sides of the robot platform.

2.2 Five layers structure of the service robot

(1) First layer (Bottom layer)

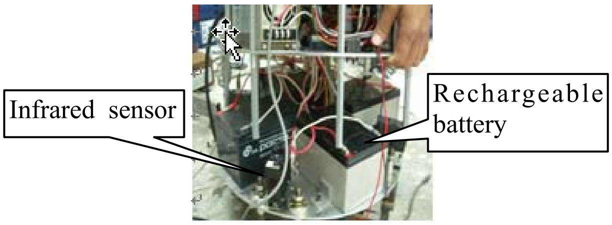


Fig 3. Layout of the bottom layer

Layout of the bottom layer is shown in Fig. 3. Four rechargeable batteries are placed on top of the bottom layer. Eight reflective type infrared sensors are attached around the bottom layer for obstacle avoidance.

(2) Second layer

The following subsystems (Fig. 4) are placed in the second layer:

- Switching power: transfer DC 24V(battery) to DC 5V, 12V
- Sensors signal transfer board: transfer the sensors output (DC 24V) to TTL signal level (DC 5V)
- Panel of the I/O card
- Voltage and current meter: monitoring the batteries power consumption
- DC servo motor drivers
- Emergency STOP button

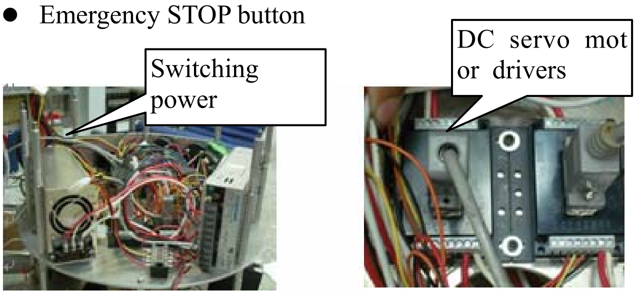


Fig 4. Layout of the second layer

(3)Third layer

The following subsystems (Fig. 5) were placed in the second layer:

- PC based robot controller
- Sensors data acquisition card (I/O card)
- USB to RS232 converter

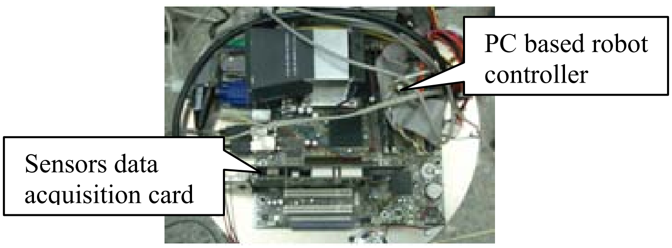


Fig 5. Layout of the third layer

(4) Fourth layer

The dish transmission system is put on the fourth layer. The dish transmission system consists of geared DC motor, chain, linear guides, limit switches, and dish plate. The dish plate is mounted on the linear guides. With the chain mechanism, the geared DC motor can move the dish plate forward and backward until it touches the limit switches.

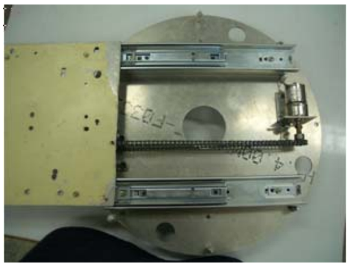


Fig 6. The dish transmission system (fourth layer)

(5)Fifth layer (Top layer)

The following subsystems (Fig. 7) were placed in the second layer:

- Touch screen
- Wireless network module
- Pan/Tilt/Zoom (PTZ) video camera
- Speaker
- Laser positioning system

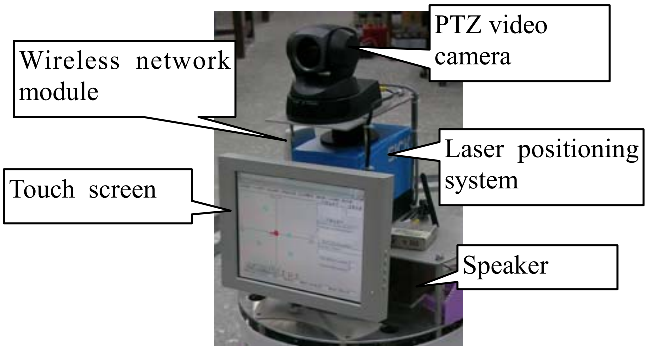


Fig 7. Layout of the top layer

2.3 Web based video monitoring system

Through the web based video monitoring system, the live image of the PTZ CCD camera on the robot can be transferred to the video server. As shown in Fig. 8, the staff on the counter can see the live image before the robot. Additional CCD cameras around the restaurant also can be integrated in this system for monitoring the robot or restaurant.

Fig 8. Web based video monitoring system

2.4 Obstacle avoidance system

As shown in Fig. 9, eight reflective infrared sensors are placed around the robot on the bottom layer for obstacle avoidance. Eight infrared sensors are numbered from 1 to 8 in a clockwise direction. If the obstacle is in front of the robot or on the left hand side, it will turn right. If the obstacle is on the right hand side, it will turn left.

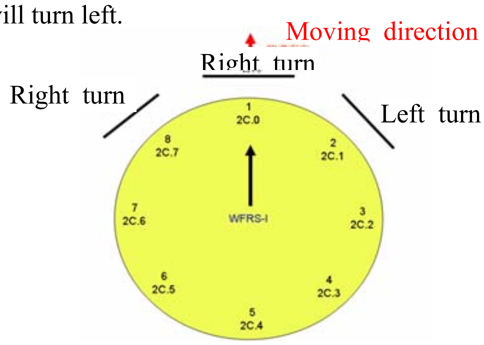


Fig 9. Eight reflective infrared sensors are placed around the robot on the bottom layer

If the robot moving forward, only part of the infrared sensors (No. 1, 2, 3, 7, 8) in front the robot are used to detect the obstacle. The other infrared sensors (No. 4, 5, 6) are used to detect free space behind the robot. The obstacle avoidance algorithm is shown in Fig. 10. In this figure, number "1" represents the infrared sensor detecting an obstacle. If all this five infrared sensors (No. 1, 2, 3, 7, 8) detect obstacles and the other infrared sensors (No. 4, 5, 6) do not detect any obstacle

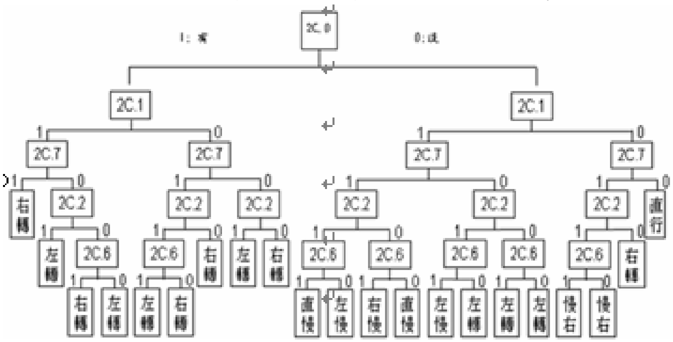


Fig 10. Obstacle Avoidance algorithm

2.5 Laser positioning system

As shown in Fig. 11, the laser positioning system is a component of a navigation system. It continuously supplies current positional data to the robot's computer, which makes course corrections based on this positional data. It scans its surroundings two-dimensionally through 360 by means of its rotational movement and detects fixed, defined, reflector marks. The system has a serial interface for connecting to the computer of the service robot.

The laser positioning system's position and orientation is continuously calculated on the basis of the reflector positions known to the positioning system in an absolute "world co-ordinate system", and prepared for transfer. The movement of the positioning system itself is taken into account by continuous application of the speed vector, i.e. the system provides position and orientation data extrapolated to the point in time when the data was requested.

Fig 11. Laser positioning system

The laser positioning system operates like optical radar that has the task of detecting fixed reflectors within the surrounding area. The detection of three reflectors is sufficient to determine its position. Within this co-ordinate system, the laser positioning system determines its current absolute position in the x- and y-directions, including its angular position in the co-ordinate system (orientation).

Fig. 12 shows the relationship between the absolute and the local coordinate systems. The axes labeled Xl and Yl show the sensor's "local co-ordinate system" that moves around with it. The sensor zero point is at the rotational axis of the scanning head. The local coordinate system of the laser positioning system moves within a world co-ordinate system defined by the user:

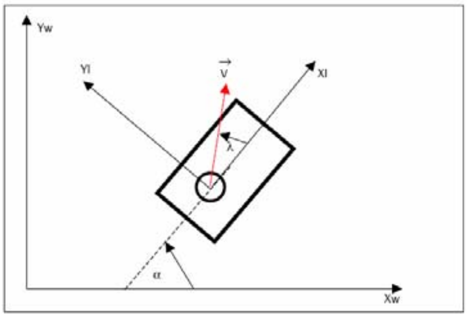


Fig. 12. Coordinate system of the laser positioning system

where:

(Xw, Yw) – World coordinate system

(Xl,Yl) – Local co-ordinate system of the laser positioning system

α= direction in the world co-ordinate system

V= speed vector

For example:

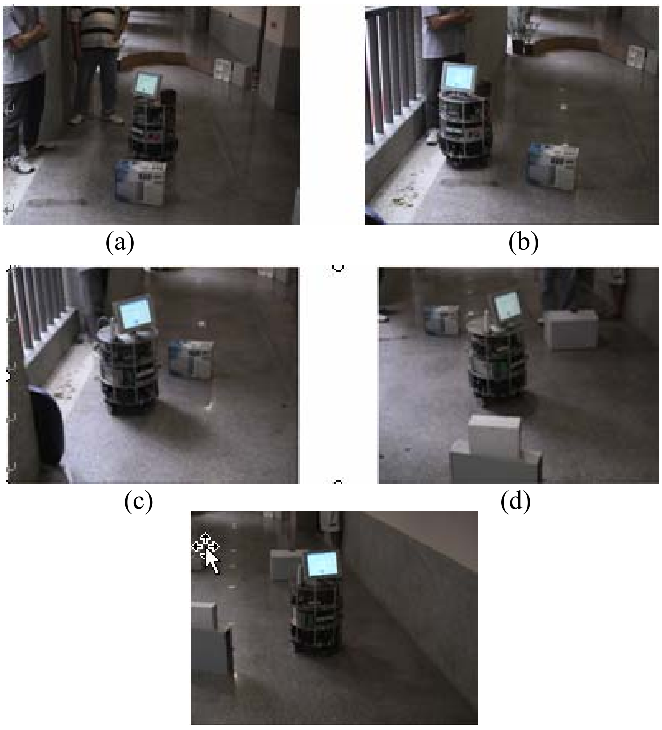
Transformation of the speed vector from local co-ordinate system in the world co-ordinate system:

$$
\begin{aligned}
Vx &= Vxl \times \cos\alpha - Vyl \times \sin\alpha \\
Vy &= Vxl \times \sin\alpha + Vyl \times \cos\alpha
\end{aligned} \qquad (1)
$$

III. EXPERIMENTAL RESULTS

3.1 Wander with obstacle avoidance

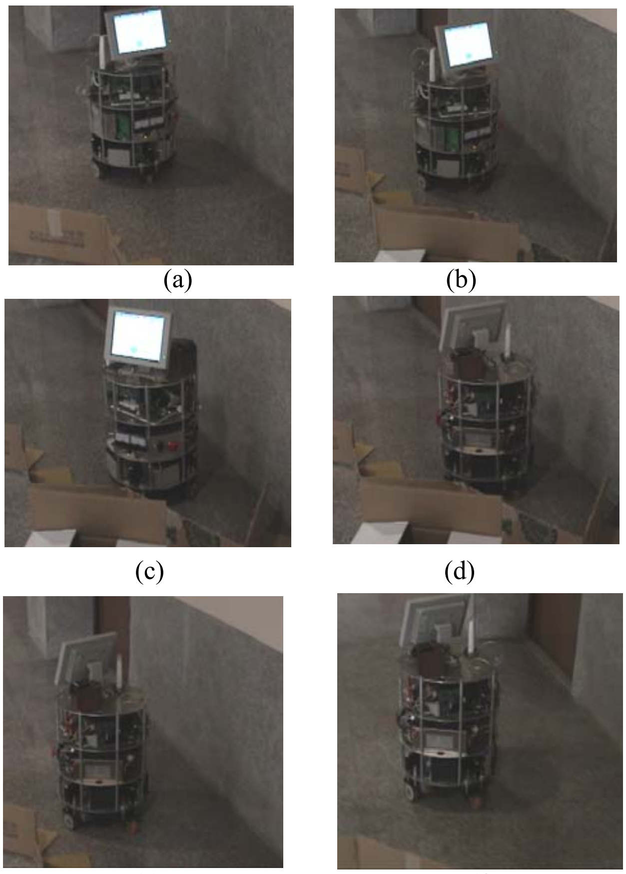
As shown in Fig.13 (a) - Fig.13 (e), the robot wanders with obstacle avoidance using the infrared sensors. From the experimental results, the robot can detect the static or dynamic obstacle. The robot dodges the obstacles without collision.



(a) (b) (c) (d) (e)

Fig 13. Wander with obstacle avoidance

3.2 Escape from dead-end zone



(a) (b) (c) (d) (e) (f)

Fig 14. Escape from dead-end zone

In this experiment, we will test the robot using obstacle avoidance algorithm to escape from dead-end zone. If all this five infrared sensors (No. 1, 2, 3, 7, 8) detect obstacles and the other infrared sensors (No. 4, 5, 6) do not detect any obstacle behind the robot, robot will make an 180° turn and then move straight. As shown in Fig. 14, the robot can escape from dead-end zone successfully.

IV. CONCLUSION

Service robots assist human beings, typically by performing a job that is dirty, dull, distant, dangerous or repetitive. Integration of robots with service industry is an important trend for now and the future. In this research, we have developed a restaurant service robot which is equipped with laser positioning system. The target or the motion path of the service robot can be easily changed.

The proposed restaurant service robot can transfer dishes in the restaurant. It also can show the customers to the unoccupied table. The service efficiency of the restaurant service can be increased with this service robot. This service mobile robot is equipped with "Laser positioning system". The laser positioning system is used for rapid and precise positioning and guidance of the mobile robot.

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