Intelligent Hotel ROS-based Service Robot

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Abstract—With the advances of artificial intelligence (AI) technology, many studies and work have been carried out on how robots could replace human labor. In this paper, we present a ROS based intelligence hotel robot, which simplifies the check-in process. We use pioneer 3dx robot and considered different environment settings. The robot combined with Hokuyo Lidar and Kinect Xbox camera, can plan the routes accurately and reach rooms in different floors. In addition, we added an intelligent voice system which provides an assistant for the customers.

Keywords – Pioneer 3dx, ROS, logical control, robotic object detection, Navigation, G-mapping.

I. INTRODUCTION

The birth of modern robots marks the beginning of the realization of the human dream of intelligent machines [1]. At the present stage, grassroots work in the hotel industry is dull, because of the intensity of simple and repeated errand running tasks, coupled with the traditional concept of "the hotel is to serve" constraints. It is difficult to attract a new generation of labor, [2] coupled with the current wage level has been unable to let the hotel to recruit ideal staff. Therefore, in order to reduce the labor costs, reliable replacement is needed. According to the “2017 annual hotel turnover survey report” released by MTA, 20%-40% employees leave the hotel industry each year.

According to media reports, some customers have stayed an extra night in the hotel in order to experience the special hotel robot. The emergence of hotel robot is an application of the artificial intelligence (AI). AI is a hot area of research in which many theories, models and technologies are developed to simulate or expand the human intelligence.

Nowadays, with the development of the IoT (Internet of things) [3], various types of robots are applied to carry out different tasks and in different applications. Therefore, robots are used at hotels, shopping malls, hospitals and many others. [4, 5, 6]. In this paper, we will use the robot as a hotel guide. To transport to different floors, the robot can analyze the destination and plan the nearest route. [7] With the support of Hokuyo Lidar and Kinect camera, it is possible to understand the surrounding environment.

The proposed hotel robots have four functions. (i) When the guests arrive the setting region, the intelligent voice system will greet to them. Also voice system is used to remind guests in the following sections [8]. (ii) After check in, the G-mapping manager can plan the nearest route to the destination depending on the room number typed on the digital keyboard. (iii) Besides, the robot can lead the customer to the corresponding room. In the process of getting to the room, the robot will consider taking the elevator if necessary. Also, mechanical arm needed to press the button in the elevator and pick up food during the automatic food delivery. (iv) In addition, the robot also has transport service. When consumers purchase Hotel’s order, robots have the ability to complete the automatic delivery service.

II. THEORY AND APPROACHES

A. General Information

Using pioneer-3dx robot combined with Lidar, Kinect camera and speaker (as shown in figure 1), intelligent hotel robot is constructed. We developed the navigation and G-mapping, combining with the MATLAB, ROS and Eclipse.

The general idea of the traveling is divided into four sections: (i) Lead the robot out of the initial room. (ii) Keep the robot in the middle line of the corridor and come into the elevator. (iii) After reaching the necessary floor through elevator, the robot will lead customers to the room. (iv) The robot will return to the initial room.

The route setting is based on D* arithmetic algorithm. This algorithm is based on iteratively selecting a node from the open list. The node’s spreading (propagation) to neighboring nodes is evaluated and those nodes are placed in the open list [8]. D* starts by searching backwards from the goal node, from end to start, unlike the canonical A* [9], which starts the path from forward from start to finish. The iterative algorithm is finished when the start node is the node to be expanded next. Back pointers are used to find the path to the goal.

B. Pioneer 3-DX

Pioneer robots are smaller robots which have many capabilities. They can be used to simulate different systems and applications. Pioneer 3-DX with its onboard computer represent an intelligent autonomous mobile robot. It has the ability to scan and map the surrounding environment, avoid obstacles, and many other tasks [10].

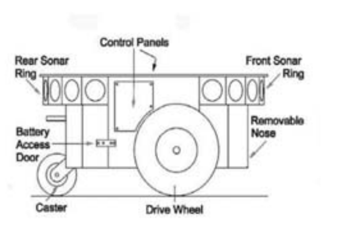

Fig. 1. Pioneer 3-DX   Fig. 2. Pioneer 3-DX Features [11]

For the Pioneer 3-DX, it provides various client-server connection options. Among these options is the use of user control panel serial port, a common “pass-through” serial cable or a radio ethernet connection (Figure 3).

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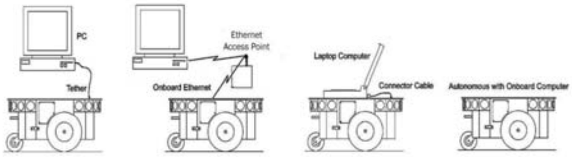

Fig. 3. Client-server connection options [11]

Pioneer 3-DX robot supports up to four sonar arrays. Each one comes with eight transducers that can be used for object detection, obstacle avoidance and navigation. The sonar positions in all Pioneer 3-DX are fixed and placed to enable better scanning for the surrounding environment (Figure 4).

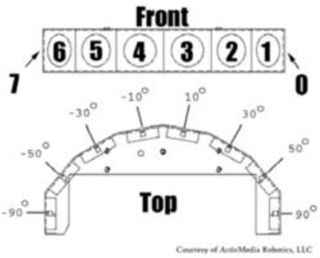

Fig. 4. Sonar Array [11]

C. Lidar

Hotel robots need Lidar (Light Detection and Ranging) [12] to scan and record a defined floor map while avoiding obstacles. It is an on-board laser scanning using GPS (Global Position System) and IMU (Inertial Measurement Unit). The sensor releases a laser signal that travels through the air. When the laser signal hits the object it reflects. The reflected energy is received by the sonar and used to calculate the distance between the object and the robot.

Fig. 5. HOKUYO Lidar

If the time of transmission and the time of reception are accurately recorded, the distance (R) of the laser to the ground or the surface of the object can be calculated by the following formula:

$$R = \frac{ct}{2}$$

Where (c) is speed of light and (t) is difference between the time of transmission and the time of acceptance.

Lidar is used to scan the surrounding environment when the robot avoids obstacles. It can measure the return time of each ray at one moment to get the distance of the obstacle from the robot. When multiple consecutive rays return for a long time or do not return, then there is no obstacle in that direction. Therefore, Lidar mainly scans out the surrounding environment in the function of avoiding obstacles.

D. G-mapping and Navigation

Our fundamental purpose is based on navigation. The theory of navigation is D* arithmetic. The robot plans a reasonable route to the destination through the navigation system. Navigation; a two-dimensional function package in ROS; is simply based on the information flow of the sensor such as the input odometer and the global position of the robot. Then, the safe and reliable robot speed control command is calculated through the navigation algorithm (refer to figure 6). By the path cost of a node we come from the previous node to the goal. This value is calculayed by

$$g(s) = \min_{s' \in nbrs(s)} (c(s, s') + g(s')),$$

where nbrs (s) are the neighboring nodes of s, c (s, s′) is the cost of traversing the edge between s and s′, and g(s′) is the path cost of node s′.

We plan to travel the route in Global frame: the overall path planning according to a given target destination. In the navigation of ROS, the global route of the robot to the target location is first calculated through global path planning. This feature is implemented by the "navfn" package. Navfn calculates the minimum cost path on the costmap through the Dijkstra optimal path algorithm as the global route of the robot. In the future, the VFH algorithm or others should be added to the algorithm.

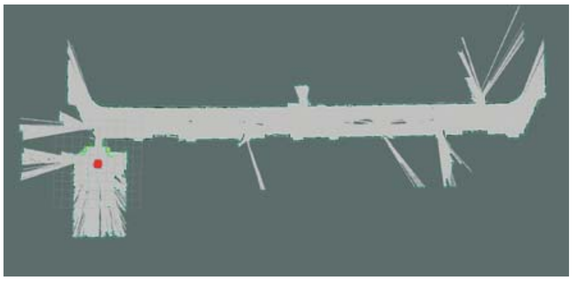
Fig. 6. RVIZ

E. Speaker and voice library

To make our service more interactive, we added a speaker to communicate with the customers. We record the voice and add it into the library.

F. KINECT XBOX ONE

At the end, we installed a camera on the robot to determine whether the elevator door is open by judging the distance of the robot itself to the target position, which is a good way to increase the accuracy (Figure 7). The digital camera converts the analog video signal generated by the video capture device into a digital signal and stores it in a computer. The digital camera captures the image directly and transmits it to the computer via a serial, parallel or USB interface.

We use the camera for two purposes: to judge the switch on the elevator door and let the information in the camera's field of view be transmitted to the robot. After that, you need to analyze the image, which requires OpenCV software.

OpenCV is a computer vision library. It has many built-in functions and routines to be used in image processing and computer vision area. It also can be interfaced with other languages such as MATLAB, Python and Ruby.

Fig. 7. KINECT XBOX ONE camera.

III. EXPERIMENTS

We conducted two experiments using Pioneer and HOKUYO Lidar both in the engineering building during the weekdays. (i) The first one is leading the customers to the room within the same floor; (ii) the second is leading them to different floors. In addition, during the running of the robot, there were some people in the corridors, which are considered as obstacles. Taking that in to consideration, we set the experiments during the weekdays and keep the initial point to be in the same position. Our aim is to measure the accuracy and efficiency of the robot to finish the leading. Our data include the points setting in the middle of the journey and the travel time.

Room Number	Times	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
238	Travel 1	(4.58,-0.48,0)	(3.27,-4.64,0)	(4.56,-4.56,0)	(4.29,-0.0458,0)	(0,0,0)	/	/
	Travel 2	(4.58,-0.48,0)	(4.56,-4.56,0)	(3.27,-4.64,0)	(4.56,-4.56,0)	(4.29,-0.0458,0)	(0,0,0)	/
	Travel 3	(4.58,-0.48,0)	(4.29,-0.046,0)	(4.56,-4.56,0)	(3.27,-4.64,0)	(4.56,-4.56,0)	(4.29,-0.0458,0)	(0,0,0)
236	Travel 1	(4.58,-0.48,0)	(4.4,-10.8,0)	(3.34,-10.7,0)	(4.29,-0.0458,0)	(0,0,0)	/	/
	Travel 2	(4.58,-0.48,0)	(4.4,-10.8,0)	(3.34,10.7,0)	(4.4,-10.8,0)	(4.9,0.00614,0)	(0,0,0)	/
	Travel 3	(4.58,-0.48,0)	(4.89,-5.48,0)	(4.4,-10.8,0)	(3.34,-10.7,0)	(4.4,-10.8,0)	(4.9,0.00614,0)	(0,0,0)
234	Travel 1	(4.58,-0.48,0)	(3.54,17.1,0)	(4.79,-17.3,0)	(4.29,-0.0458,0)	(0,0,0)	/	/
	Travel 2	(4.58,-0.48,0)	(4.79,-13.3,0)	(3.54,-17.1,0)	(4.79,-17.3,0)	(4.29,-0.0458,0)	(0,0,0)	/
	Travel 3	(4.58,-0.48,0)	(5.15,-7.56,0)	(4.79,-17.3,0)	(3.54,-17.1,0)	(4.79,-17.3,0)	(4.29,-0.0458,0)	(0,0,0)
230	Travel 1	(4.58,-0.48,0)	(4.74,-23,0)	(5.14,-23.4,0)	(4.29,-0.0458,0)	(0,0,0)	/	/
	Travel 2	(4.58,-0.48,0)	(5.14,-23.4,0)	(4.74,-23,0)	(5.14,-23.4,0)	(4.29,-0.0458,0)	(0,0,0)	/
	Travel 3	(4.58,-0.48,0)	(5.27,-13.7,0)	(5.14,-23.4,0)	(4.74,-23,0)	(5.14,-23.4,0)	(4.29,-0.0458,0)	(0,0,0)

The engineering building has three floors as shown in figure 8, 9 and 10. The robot will lead to the room in any floors after you input a room number on the keyboard.

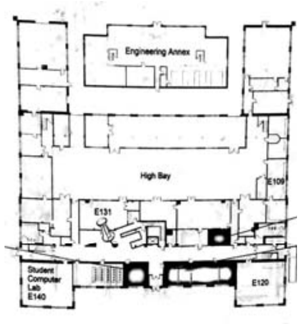

Fig. 8. First floor

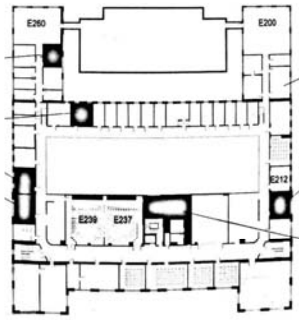

Fig. 9. Second floor

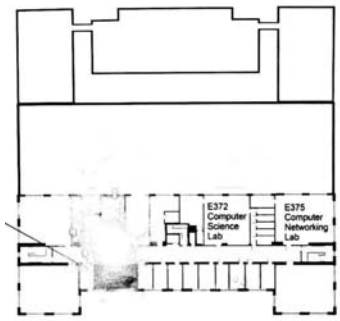

Fig. 10. Third floor

In the first experiment, we set the initial point at the E240 in the engineering building. And we tested three points in the second floor: E234, E236, E238 and E230. In the second experiment, we set two rooms on the third floor: E320, E315. We recorded the traveling time, the success rate and the Lidar information for each time.

IV. RESULTS

In the first experiment, we assume the destination is on the same floor. So, the robot does not need to lead customers to the elevator. We assume four rooms on the second floor: 238, 236, 234, 230 (refer to figure 11). The points that were set in the middle of the starting and destination are shown in figure 11. We used these points to drive the robot to reach the destination. The robot passes these points one by one and records the time it needs to arrive everyone. We can find that the average success rate is more than 80%. On the other hand, with the increasing of the journey, the accuracy rate dropped dramatically. This can be related to the long-distance navigation that brings some errors to the wheel odometry. Also, we found that the accuracy rate increases with the increase of the points in the middle of the journey. Furthermore, the traveling time decreases with the increase of the points at most of time as shown in figure 12.

Fig. 11. Second Floor Test Point Data

Room Number	Times	Time 1	Time 2	Time 3	Time 4
238	Travel 1	01:52.0	02:31.0	02:58.0	02:47.0
	Travel 2	01:55.0	02:11.0	02:08.6	02:11.1
	Travel 3	01:58.7	02:06.3	02:44.0	02:24.7
236	Travel 1	03:41.2	02:59.7	03:31.3	03:18.5
	Travel 2	02:51.5	02:58.6	03:34.3	03:33.1
	Travel 3	03:12.3	03:27.7	02:49.9	03:04.6
234	Travel 1	03:25.2	03:59.6	04:08.7	03:48.6
	Travel 2	04:10.5	04:08.4	03:56.3	03:53.9
	Travel 3	04:06.6	03:55.7	03:59.3	04:01.7
230	Travel 1	04:46.5	05:13.5	05:08.6	05:05.9
	Travel 2	05:10.5	05:02.4	04:58.4	05:12.6
	Travel 3	05:09.6	04:49.6	05:13.7	04:57.6

Fig. 12. Second Floor Traveling Time Data

In the second experiment, we set the destination to the third floor. We found that the robot is away from the setting point with the increase of the route. The practical position of the robot has a 0.5-1 meter gap as the value of the odometry. As shown in figure 13 and 14, these two tests are starting at the same initial point and the surrounding environments are nearly the same. But the first test is obvious away from the setting point in front of the elevator. However, the robot also can travel to the correct destinations on the third floor.

Fig. 13. Elevator Test 1

Fig. 14. Elevator Test 2

V.DISCUSSION

During the test process, we found that the error on the wheel odometry have a big influence on the total journey. There are two possible solutions to deal with this problem. (i) First, we unify the sensors to scan the map and navigation. Because we are using Pioneer 3dx sonar arrays for scanning the map of the Engineering and Lidar for leading the way, there is an error during switching/communicating between the sensors. (ii) Second, use additional sensors to coordinate with the Lidar to decrease the error.

VI. CONCLUSION AND FUTURE WORK

In this study, we tested the robot's ability of leading customers to different locations. The proposed system gives the customer an interactive experience in which the robot can interact with the customer. The proposed robot can greet the customer at the check-in and once arrived at the room.

In the future, service robots are people-oriented, so they must be a combination of intelligent-based and human-based services. Thus, we list three aspects that need to be improved: (i) It is necessary to expand the D* arithmetic. Based on the D* arithmetic, sometimes robot cannot find the way in a short time. We plan to try the A* and VFH arithmetic [13] to find the best way. (ii) We plan to add a robotic arm to open the elevator or press the correct floor number inside the elevator as needed. (iii) to improve the intelligent and at the same time reduce the human labor, we will provide a method to send orders by robot through the QR code.

VII. ACKNOWLEDGEMENTS

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