

Design of an Autonomous Mobile Robot Prototype for Monitoring Indoor Environment

P. Anantha Raj¹, Dr. S. Sendhilkumar²

M. Tech IT Student, Department of Information Science and Technology, College of Engineering Guindy,

Anna University, Chennai, Tamil Nadu, India¹

Assistant Professor (Senior Grade), Department of Information Science and Technology, College of Engineering Guindy,

Anna University, Chennai, Tamil Nadu, India²

ABSTRACT: Autonomous mobile robot is a robot that can perform tasks and move around in their environment with high degree of autonomy without explicit control. The major challenges faced by autonomous mobile robots are handling dynamic environments, planning the obstacle free path, reducing power consumption and self-localization. This paper mainly deals with designing a mobile robot for monitoring indoor environment with autonomous path planning and dynamic environment handling facility. Robot uses two different planners namely global and local planner. Global planner plans the global path from the robot's current position to the target location using A* path planning algorithm. Local planner handles the dynamic environment using dynamic path changing algorithm and obstacle handling algorithm. This model of small size autonomous mobile robot can be used for monitoring purposes in indoor environment instead of fixed cameras.

KEYWORDS: Path planning; Autonomous mobile robot; Global planner; Local planner; Dynamic environment;

I. INTRODUCTION

Autonomous mobile robots are intelligent machines that can perform tasks in the real world and can move around in an environment by themselves. It is used in many fields like medical, military and industries to reduce the human effort and increase the accuracy of work. In some environments, usage of fixed camera will not be suitable for monitoring purposes. Instead, autonomous mobile robot embedded with path planning feature will be suitable for all kinds of environment. The goal of the autonomous mobile robot is to optimally plan the path and efficiently manage the energy while performing the tasks. Navigation can be efficiently done with the combination of the three functions namely path planning, self-localization and understanding map information.

The proposed robot uses path planning algorithm which computes a path to reach the destination. Path information is divided into discrete navigation functions like turning and moving particular direction in order to reach the destination. A motion planner takes the task location as input, increases the speed and sends turning commands to the robot's wheels. Mobile robot should follow the movement instruction to reach the destination by avoiding obstacles and dangerous situations like collisions and unsafe conditions. The major challenges of autonomous mobile robots are planning for obstacle free shortest path and handling dynamic environment. These challenges are handled by different planners named global and local planner. Global planner contains the terrain information and gets input as task location. It computes the global path from the current location to the task location and provides navigation information to the mobile robot. Local planner is invoked when there is an obstacle in the global path. In order to move further in the global path, local planner tries to avoid the obstacles using gap finding algorithm. If there is no possibility to find gap between obstacles, dynamic path changing algorithm is used to reach the task location. Dynamic path changing algorithm gets the current location of the robot, computes the new path from the current location to the next reachable position in global path, updates the obstacle information and sends new path plan to global planner. Global planner updates the obstacle in

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

terrain information and guides the mobile robot to reach target location by using new plan. After reaching the target location the mobile robot starts to monitor the target location.

The rest of the paper is organized as follows Section II deals with the Literature Survey, Section III explains about the System Architecture, Section IV describes about Methodology, Section V explains about the Results obtained and Section VI explains about Conclusion.

II. LITERATURE SURVEY

In recent days, research on mobile robots has been widely increased in various domains. In the near future, autonomous mobile robots will be used in all environments similar to the usage of computer to perform various tasks in various fields. Unified framework for robot planner [1] is proposed in this paper which makes efficient plan and it discusses analysis of path planning algorithms. Designing a wheeled robot using Raspberry Pi is described. Various path planning techniques for autonomous mobile robots are discussed [2] which provides the complete idea of different path planning techniques. Creating a grid based environment for mobile robot navigation [3] and applying algorithms on grid is demonstrated. Design and implementation of A* path planning algorithm for mobile robot [4] in a known dynamic environment is described. Global path planner, local path planner, integration of both global and local planner [5] are described. Design of a mobile robot [6] using Raspberry Pi as processor and ultrasonic sensor to detect obstacles has been explored. The task of the sensor system [7], sensors for collecting data from an environment, obstacle detection, avoidance and positioning are described. Usage of autonomous mobile robot for surveillance purpose [8] in indoor environment has also been explored.

III. SYSTEM ARCHITECTURE

Details of the terrain with obstacles in grid view is given as input to the robot. A user interface is developed to show the map of the terrain to give the target location and view the live stream of target location. This communication is done using Wi-Fi connection. The path planner generates the path and contains information about the task to be done. The robot moves according to the path generated by the global path planner. When an obstacle is detected by the ultrasonic sensor, global path planner calls the local planner to handle the obstacle.

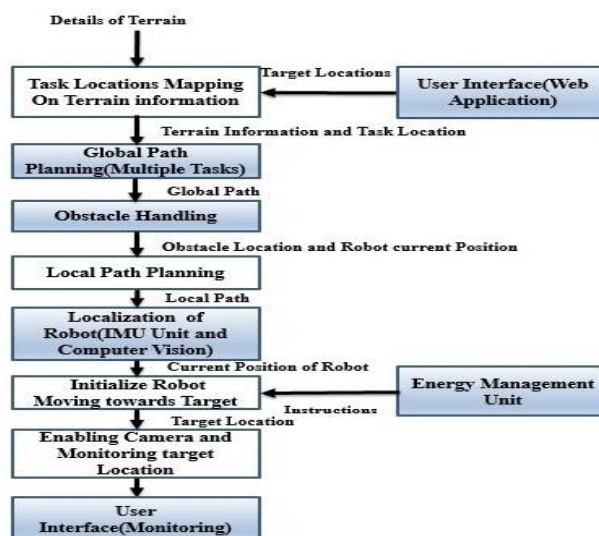


Figure1: System Architecture

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

Local planner generates the new path to reach the next reachable position in terrain by referring the global path. It then generates the new path to the target location from the current location and updates the obstacle location in the terrain information. After reaching the target location, planner updates the status and enables the Raspberry Pi camera to monitor the location. Lighttpd web server is configured in Raspberry Pi with static IP address, Raspberry Pi camera takes video of the target location and updates in the web server. Live video streaming of target location is shown in web application, user can view the web application for monitoring. The overall system architecture is depicted in Figure 1. Authenticated users are added in the same network of Raspberry Pi. They can monitor the terrain using the IP address of Raspberry Pi IP address. After the task completion, robot disables the camera module to reduce the power consumption, updates the task completion status in the web server and then goes back to the starting location.

IV. SOFTWARE SETUP

Raspberry Pi doesn't have inbuilt memory so external memory card with operating system is needed to use Raspberry Pi. Raspbian Jessie operating system is a free operating system based on debian optimized for the Raspberry Pi which comes with over 35,000 bundled with packages pre-compiled software. It is installed on memory card to run the Raspberry Pi hardware. VNC server is installed in Raspberry Pi so that Raspberry Pi desktop environment can be viewed remotely on any machine using internet. VNC viewer helps easy access to the Raspberry Pi easily. The purpose of VNC client and server setup is to view the Raspberry Pi files and modify them from another machine.

V. HARDWARE DESIGN

Raspberry Pi is a small size computer which has General Purpose Input Output (GPIO) pins which are all used to control different electronic devices such as motors and sensors. Raspberry Pi has many features like USB ports, GPIO pins, full HDMI port, Ethernet port, combined 3.5mm audio jack and composite video, Camera interface, Display interface (DSI), Micro SD card slot and video core IV 3D graphics core. Raspberry Pi's GPIO pin is connected with L293D driver.

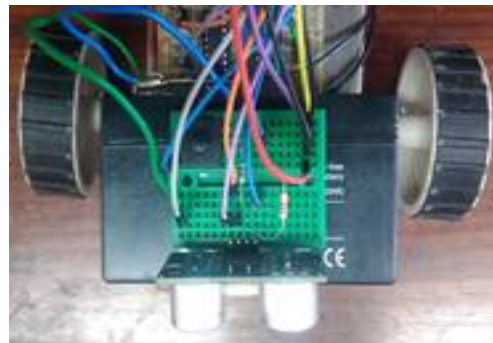


Figure2: Circuit connection of Raspberry Pi and L293D Figure3: Circuit Connection of Ultrasonic Sensor

Figure2 shows the circuit connection of Raspberry Pi and two L293D motor drivers. Single L293D can control two different motors at a time in both directions. It is a 16 pin integrated circuit which includes an Vcc, a ground pin, an enable pin, two inputs corresponding to two outputs. Raspberry Pi sends the signal to L293D input enable pins. Basic mobile robot navigation functions such as moving forward and turning 90 degree are developed to verify the circuit connections. HC-SR04 is a sensor which is used to identify the objects in front of the robot. It has three major parts oscillator, echo and trigger. Sometimes Echo pin may receive more voltage which damages the processor so voltage divider circuit is needed to maintain the input voltage level below 3.3V. Figure3 shows the circuit connection of ultrasonic sensor. Voltage divider consist of Resisters 1 kilo ohm and 2 kilo ohm. Echo pin is connected between two

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

resisters. Trigger pin is directly connected to GPIO pin. Oscillator generates sound, trigger sends the sound and Echo receives the sound. Distance is calculated based on time difference between sending and receiving of sound.

Figure4 shows the entire circuit connection of all parts of an autonomous mobile robot. 12v Rechargeable lithium polymer battery is used to provide power supply to four DC motors. Lithium polymer battery is directly connected to L293D motor driver and the driver supplies power to the DC motors. The Raspberry Pi camera module is used to take video of the target location. Camera module is connected with Raspberry Pi using serial interface.

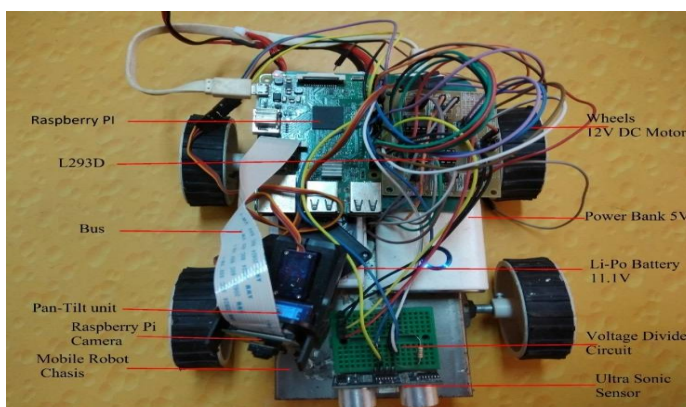


Figure4: Parts of an autonomous mobile robot

Raspberry has inbuilt Wi-Fi module which is enabled to connect with other network devices. Wireless network is created using Wi-Fi connection to make communication between user and robot. Pan-Tilt hardware is used to hold Raspberry Pi camera module which rotates camera in all directions such as up, down, left and right. Pan-Tilt unit has two servo motors, one is used to control pan and another one is used to control tilt.

VI. METHODOLOGY

Basic navigation functions are moving forward, reverse direction, turning left and right side. Table1 describes all navigation functions. These functions are executed by sending control signals to DC motors separately using L293D motor driver. DC motor has two pins (A, B), one pin should be high and another one should be low to move in one direction. For instance if the robot wants to move in forward direction, enable pin should be high, motor 1A motor 2A should be high and motor 1B, motor 2B should be low.

ACTION	MOTOR1A	MOTOR1B	MOTOR2A	MOTOR2B	Enable pin
Forward	High	Low	High	Low	High
Reverse	Low	High	Low	High	High
Turn Left	High	High	High	Low	High
Turn Right	High	Low	Low	Low	High
Pivot Left	High	Low	Low	High	High
Pivot Right	Low	High	High	Low	High
Stop	High	High	High	High	Low

Table 1: Truth table of all navigation functions

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

Terrain information is given as two dimensional grid view with obstacle locations. Obstacles are denoted in different symbols so that path planner differentiate waypoints and obstacles. Web based user interface is developed to mark the target location. After target location is received, robot sends the acknowledgement to the user. Planner gets the current location and target location of the robot. A* algorithm generates the obstacle free shortest path. The following algorithm describes the steps involved in the process of dynamic path changing when the obstacle is found in the global path.

PSEUDOCODE FOR DYNAMIC PATH CHANGING

- Step 1: Detect the obstacle.
- Step 2: Avoid obstacle and move forward. Else: Call local planner.
- Step 3: Get the current position and next reachable point.
- Step 4: Initialize start and end position.
- Step 5: Compute the new path.
- Step 6: Execute robot movements with new path.
- Step 7: Stop.

The generated path is converted into discrete movement instruction and it calls the corresponding navigation function. Global path planner does not deal with small and dynamic obstacles. Robot starts to move according to the path generated by the global planner. If the robot finds any obstacle in the global path, global planner calls local planner to handle the situation. Local planner is created to handle the dynamic environment. Obstacles are identified using ultrasonic sensor which is also called as distance sensor. Distance sensor has two main parts to identify the obstacle. Trigger pin is used to send sounds and echo pin is used to receive the signal from distance sensor. If echo pin receives the signal then it indicates that there is an obstacle in the path. If any obstacle is found in the path, it observes the obstacle using distance sensor information, tries to find the gap between obstacles by intelligent gap finding algorithm and simultaneously updates the obstacle information in the terrain information. It plans new path from the current location of the robot to the next reachable path of global path to avoid the obstacle. This path changing mechanism is done by dynamic path changing algorithm.

Local planner updates the information about the obstacle location and the global planner changes the terrain information. Then the local planner sends the new path information to the global planner. Enabling camera in Raspberry Pi, configuring webserver and MJPEG streamer on Raspberry Pi monitors the target location. MJPEG-Motion JPEG is a video format in which each video frame is compressed as a JPEG image. MJPEG streamer takes JPGs and streams them as MJPEG via http to web browsers. Camera module is connected in the Raspberry Pi Camera Serial Interface (CSI) slot. Lightltd webserver is installed in Raspberry Pi, static IP address is assigned and user device is connected in the same network. Video of target location is captured using Raspberry Pi camera and viewed in user interface. MJPEG streamer application is enabled in web server and this streams the video and photo of the target location. Web application with video player is needed to stream target location and web application has to be configured with IP address of Raspberry Pi and to stream video. Pan-Tilt unit has SG90 servo motor which needs 5V power supply. It can be given directly from Raspberry Pi physical pin and ground. Servo motor has three pins namely Vcc (red wire), ground (black wire), Pulse (yellow). The servos position is controlled by the pulse width of the signal. Duty cycle values are calculated using pulse width and period. By having different duty cycle values, servo motor can be rotated in different directions.

VII. RESULTS

A. Path planning algorithm

The terrain information is given as two dimensional grid with obstacles. Planner stores this information as terrain and gets the target location from the user to compute the path. Planner does not take the grid cell which has the value x while computing path, since it is referred as obstacle. Figure 5 shows the design of terrain in real time. It has six

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

rows and six columns. Robot will be placed in starting point and gets the target location from the user. Robot will move from starting grid to destination by traversing the waypoints of path given by the planner. Robot takes 1 second to move in forward direction from one grid to another grid, 0.9 second for left and right turn and 1.8 seconds for U turn. Figure6 shows path generated by global path planner. Starting point is (0, 0) and ending point is (5, 5). It shows all waypoints in between (0, 0) to (5, 5) and robot discrete movements.



Figure5: Design of Terrain in Real Time.

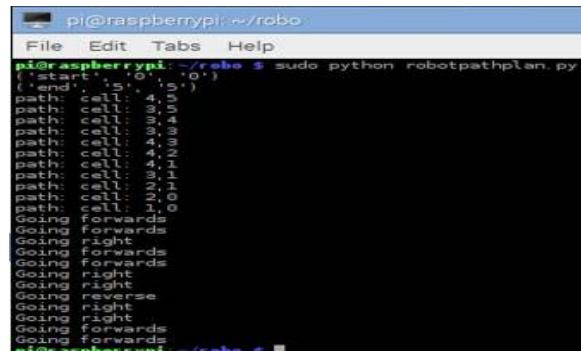


Figure6: Path from starting point to destination.

The generated path is obstacle free and shortest path. Terrain is designed as 6*6 grid view on white sheet. The height and width of each grid is 22 cm. There are 36 grids in the terrain in which 11 grids are marked as obstacle and 25 grids are obstacle free.

B. Obstacle detection and dynamic path changing

Once the path planner receives the target location using A* algorithm, the path information is converted into discrete movement instructions and the planner executes the instruction. If any dynamic obstacle is found in the path, robot does some actions to handle the obstacle. Ultrasonic sensor continuously sends the sound to find whether there is any obstacle in the path. If the distance between obstacle and the robot is less than 50 cm, then the planner sends the instruction to stop the robot.

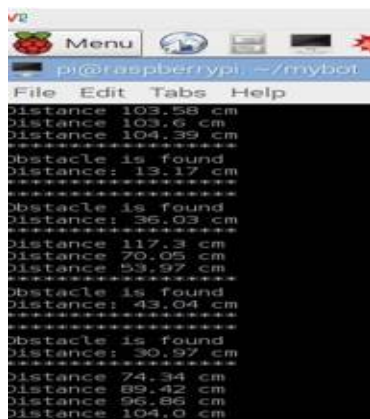


Figure 7: Obstacle Detection.

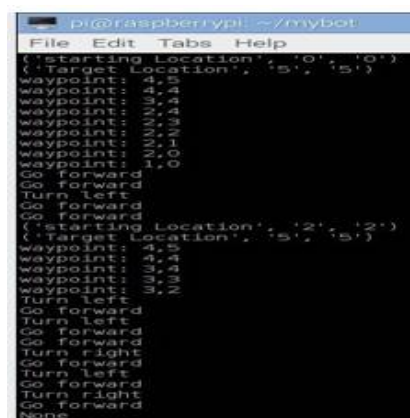


Figure 8: Dynamic Path Changing mechanism

Figure7 shows the distances between various obstacles in the path and robot. It mentions the obstacle only if the distance between object and robot is less than 50 cm. Robot stops its movement when the obstacle is detected for 5

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

seconds and then the planner plans the new path to avoid the obstacle. It finds the current location and gets the target location from the previous plan detail and starts to move in the new path. This obstacle avoiding and planning new path mechanism is dynamic path changing mechanism. Figure 8 shows the path information from the current location to target location. Starting location is (0, 0) and target location is set as (5, 5). In this case, the obstacle is found in location (2, 3) so the robot stops the movement in location (2, 2). Then the new path is generated from (2, 2) to target location (5, 5).

C. Autonomous Mobile Robot

Autonomous mobile robot does tasks autonomously such as obstacle detection, obstacle avoidance, planning the obstacle free shortest path, reaching the target location and monitoring the target location by having the effective planner which controls all actions of the mobile robot.

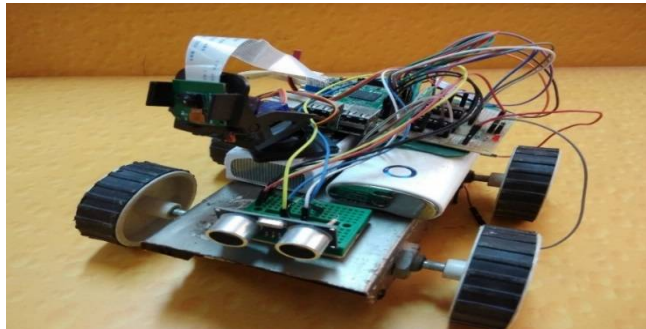


Figure 9: Autonomous Mobile Robot for a known Terrain

Figure 9 shows the complete design of an autonomous mobile robot for monitoring indoor environment which has robot chassis with four wheels, Raspberry Pi as processor, two L293D motor driver to control 4 different DC motors, ultrasonic sensor to detect obstacle, Raspberry Pi camera to take video of target location, Pan Tilt unit to change position of Raspberry Pi camera, 12V lithium polymer battery to provide power supply to four DC motors, 5V power supply to provide power supply to Raspberry Pi, mini bread board and some wires (male-male, female-female, male-female, female-male).

D. MJPG video streaming

Motion JPEG is a video compression format in which each video frame or interlaced field of a digital video sequence is compressed separately as a JPEG image. Autonomous mobile robot sends the video of the target location in MJPG format to the webserver of user. Figure 10 shows the screenshot of monitoring the target location.



Figure 10: Screenshot of monitoring Target Location

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

Mobile robot sends the video stream of the target location to the client web server. Communication between mobile robot and remote user system is done using Wi-Fi connection. Remote user can watch the live stream of the target location from different location. User can change the position of pan-tilt unit to see different view of target location, at maximum a user can view 180 degree without changing the robot position but only by controlling the pan tilt unit.

VIII. CONCLUSION

An autonomous mobile robot has been designed for planning shortest and obstacle free path from the current location to the destination location. Remote user can monitor the particular location from his/her place using web stream of target location send by the mobile robot. This kind of mobile robots can be used in large industries to monitor the site especially for critical situations like machine failure and explosions where human cannot reach that particular location. It can also be used as assistant of humans to monitor inside any organization and college. It can be also used by remote user from different location using Virtual Private Networks (VPN). The future work of this paper deals with designing the robot to do some tasks based on the situation by embedding the robot with extra hardware like robot arm.

REFERENCES

- [1] Pablo Munoz., Maria D. R. Moreno., and David F. Barrero., "Unified Framework for Path-Planning and Task-Planning for Autonomous Robots", *Journal of Robotics and Autonomous Systems*, Vol.82, pp.1-14, 2016.
- [2] Leena, N., and Saju, K. K., "A Survey on Path Planning Techniques for Autonomous Mobile Robots", *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, Vol.8, pp.76-79, 2014.
- [3] Gehlod. L., Jain. V., Dutta, M., and Lal, D. K., "A Grid Based Robot Navigation by Using Priority Algorithm", *International Journal of Advanced Research in Computer and Communication Engineering*, Vol.2, Issue.8, pp.3009-3014, 2013.
- [4] Sharma, R., "Design and Implementation of Path Planning Algorithm for Wheeled Mobile Robot in a Known Dynamic Environment", *International Journal of Research Engineering and Technology*, 2:06, pp.967-970, 2013.
- [5] Imran, M., and Kunwar, F., "A Hybrid Path Planning Technique Developed by Integrating Global and Local Path Planner", *International Conference on Intelligent Systems Engineering (ICISE)*, pp.118-122, 2016.
- [6] Narayan Pandharinath Pawar., and Minakshee M. Patil., "Driver Assistance System based on Raspberry Pi", *International Journal of computer Applications*, Vol.99, No.16, pp.36-39, 2014.
- [7] Kucsera, P. E. T. E. R., "Sensors for mobile robot systems", *Academic and Applied Research in Military Science*, Vol.5, No.4, pp.645-658, 2006.
- [8] Di Paola, D., Milella, A., Cicirelli, G., & Distanto, A., "An autonomous mobile robotic system for surveillance of indoor environments", *International Journal of Advanced Robotic Systems*, Vol. 7, No.1, pp.19-26, 2010.