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Two Dimensional Mapping by using Single Ultrasonic Sensor

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Abstract: An innovative and efficient approach to build a two-dimensional map of an indoor environment using an ultrasonic sensor has been described in this paper. A mobile robot (node) with an ultrasonic sensor has been used and map generation algorithm has been implemented using MATLAB software. This paper presents a simple map building algorithm to build a map using static obstacles present in the indoor environment. The mobile robot (node) uses a sub map merging mapping technique. The motive is to build a low cost mapping mobile robot to create the map of an unknown indoor environment. The mobile robot used has been built physically and the experimental results have been obtained from the presented indoor environment with different sets of obstacles. The mapping results prove the efficiency of the algorithm.

Keywords: Indoor, environment, Mapping, Mobile, robot, Sub, map, merging, Ultrasonic, sensor

I. INTRODUCTION

Robotics is an emerging and revolutionary field with a high scope of new innovations and technologies. Robotics and automation has covered almost every industrial field with several areas of application. Due to high efficiency and reliability, automated systems have reduced the human load and intervention to a great extent [1]. Mobile robotics finds its application in several areas including defence, medical, navigation, mapping, tracking, mobile transportation, unmanned vehicles, underwater exploration etc.

Mapping is a technique which constructs a potential map of an indoor environment thereby locating static obstacles in the defined area. Mapping is used to map non-GPS indoor environments where the area is unknown and cannot be mapped using satellites. Mapping in an indoor environment finds its applications in defence and rescue sectors. Intelligent sensor systems are used to gather data to identify the indoor environment and build the corresponding map [2]. The environment is unknown to the mobile node and the mobile node navigates through the environment for mapping it. This navigation can be done through several types of sensors. Various sensors that can be used are vision sensors, ultrasonic sensors, lasers or infrared range finders [3].

This paper uses a single ultrasonic sensor for obstacle detection and navigation of mobile robot in the unknown indoor environment. Ultrasonic sensor is one of the most commonly sensors used in mobile robots due to its low cost and simplicity of use [2, 3].

An ultrasonic sensor finds the range of an obstacle in front of it by sending a small burst of ultrasonic waves, and measuring the time taken for the echo to be received. [4]

The time-of-flight (TOF) of the echo pulse received from the obstacle within the ultrasonic range and speed of sound in air at standard temperature is used to measure the distance from the obstacle [3]. The range of ultrasonic sensor varies from few centimetres to a several metres.

In most of the mobile robots used for mapping, several ultrasonic sensors are deployed on the robot to cover all directions. But this technique is not very cost-effective, and also the problem of cross talk arises due to interference of sonar waves of many ultrasonic sensors [4].

So, in this work, a single ultrasonic sensor is used which sends the information horizontally and vertically and creates sub maps in both directions. A global map is obtained by merging the information gathered from the two sub maps.

The rest of the sections of the paper are as follows: A review of the related works is given in Section 2. In Section 3, the mapping algorithm and the robot model are explained. Section 4 shows the results of mapping and describes the performance of the proposed model. Section 5 deals with the conclusion of the work.

II. RELATED WORK

Literature Survey

The procedure of constructing a two dimensional map incorporates the information from the range sensors and recognizing the surroundings into a distinct information area [5, 6]. Numerous approaches have been used for building maps in indoor environments. These include Metric Approach, topological approach and hybrid approach given in [7- 9].

Each one of these methods proved advantageous in one or the other respects but had several limitations when compared on the basis of computational time and map resolution.

Kalman filters were also used for mapping indoors in [10]. They use probabilistic approach for finding landmarks in the indoor environment but they are only limited to non-Gaussian functions.

Advancements

Another method called the Occupancy grid mapping had been used widely due to its simplicity but its limitations were overcome by O.Cohen et.al.in [11]. They used sensor fusion structure for indoor mapping by using logical sensors and fuzzy based fusion algorithm.

But the main problem with this algorithm was that the sensor range uncertainties were not included and complexity was very high [12].

Other techniques include contour mapping in which data is obtained from selected nodes of network and a map is created at the sink [13-14].

But this method is not very cost-efficient as each mobile node needs to be modelled and programmed separately and also complexity increases due to presence of several moving nodes.

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Proposed Work

In this work, we have proposed a low-cost, simple and effective solution to map-building problem in indoor environments. A mobile robot with a single ultrasonic sensor has been used that navigates along the boundaries of the indoor environment in horizontal and vertical directions to create sub maps and these sub maps are merged to create a global two dimensional map of the indoor environment using the MATLAB software.

III. INDOOR MAPPING ALGORITHM

Mobile Robot (Node)

An ATMEGA8 microprocessor is used for the main control. An L293D motor driver IC is used to interface the two motors with the microprocessor. The robot uses HC-SR04 ultrasonic sensor and this sensor has a working frequency for 40 Hz. The working voltage is 5V and the working current is 15mA. The maximum range of this sensor is 5m and the minimum range is 2cm. A picture of the mobile robot (node) is shown in the figure 1.

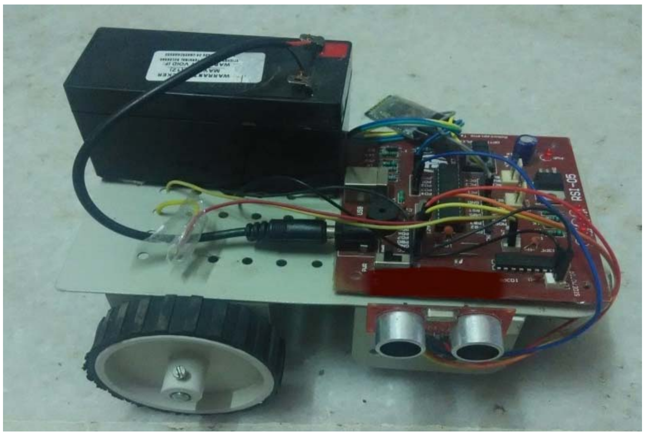

Figure1. Mobile robot (node)

The components of the mobile robot node are labeled in fig 2. It shows the mobile robot base, the ATMEGA8 microprocessor, 12V battery and the ultrasonic sensor mounted on the left side of the mobile robot and a bluetooth.
The ultrasonic sensor is mounted on left side as the robot moves in the indoor environment along only the vertical and horizontal sides covering the environment in an L-shape.
The Bluetooth is used to set up serial communication between the mobile robot and the MATLAB software.

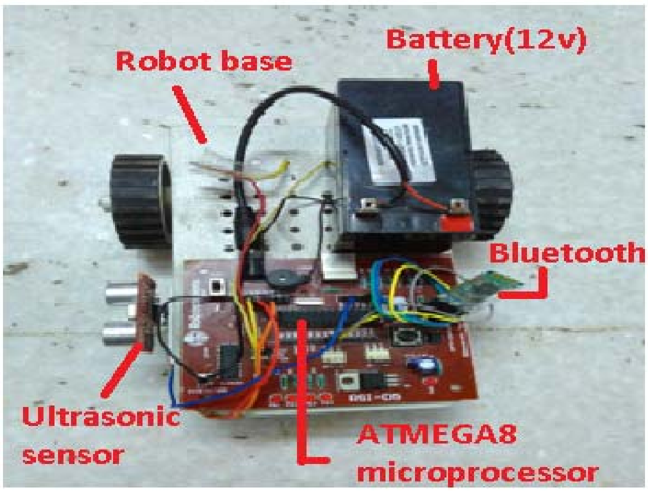

Figure2. Mobile robot components

Mapping Algorithm using MATLAB

The Mapping is done using MATLAB simulation software. A serial communication is established between the robot and the software. The software uses the data obtained from the mobile robot to generate map. The robot is controlled by using Graphical User Interface (GUI) in MATLAB.
The figure 3 shows the GUI module used to operate the mobile robot. Forward, Backward, Left and Right soft controls are given for controlling the movement of the mobile robot. The GETDATA key is used to load the ultrasonic range data into MATLAB. Serial open and close are used to communicate with Bluetooth of mobile robot to start and close the serial communication.

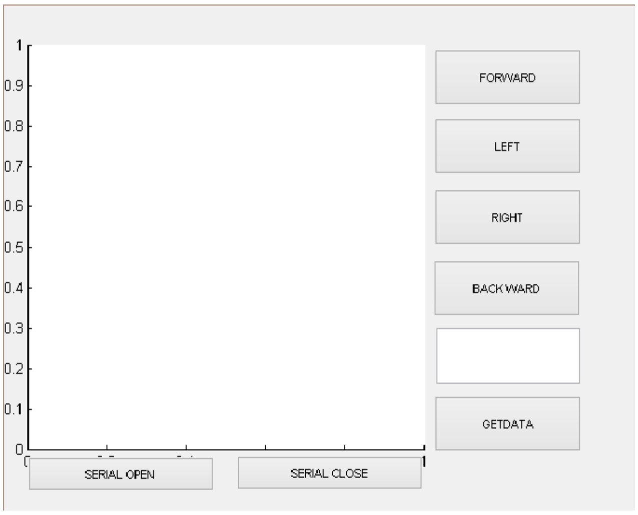

Figure3. GUI module for soft handling of mobile robot

The robot assumes that the walls of the indoor environment are at an angle of 90 degree. This robot uses ATMEGA8 microprocessor and uses AVR program loader software to interface the ultrasonic sensor with the microprocessor and AVR –ISP programming is used to load the program in controller. ATMEL STUDIO 6 is used for embedded programming using C.

For the working of the ultrasonic sensor a short 10us trigger input signal is fed from the processor to the sensor. On receiving this signal the ultrasonic sensor sends out pulses at 40 Hz and receives the echo from the obstacles. The pulse width of the echo signal varies according to the size of the object.
The mobile robot moves alongside the walls of the indoor environment in L-shape. The ultrasonic sensor is mounted upon the left side the mobile node.
While the robot moves vertically along the side 1, the ultrasonic sensor sends a beam of ultrasonic waves horizontally in the environment to detect obstacles within its range. The sensor is calibrated to detect an obstacle within a range of one and a half metres of range.

The discrete sonar data is collected in steps of 10 and the data matrix is sent serially to MATLAB software. As the robot completes its motion along the side 1, a sub map 1 is generated. Similarly, when the robot moves along the side 2 horizontally, the ultrasonic waves are sent vertically and vertical data is fetched.

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A sub map 2 is generated for the side 2 data. A global two-dimensional map of the indoor environment is created by merging the two sub maps using MATLAB.

The snapshots of the indoor environments with two different obstacle arrangements are shown in the figures 4 and 5.

Figure4. Indoor environment with 1st set of obstacle arrangement

Figure5. Indoor environment with 2nd set of obstacle arrangement

IV. RESULTS AND DISCUSSIONS

An indoor environment of 1.5m x 1.5m has been considered for the movement of the mobile robot. As the robot moves vertically, horizontal data of the environment is fetched by the ultrasonic sensor.

When the robot completes its motion along the vertical side, the data matrix is sent to MATLAB. Similarly, when the robot moves horizontally along the side 2, the vertical data is collected by the ultrasonic sensor and communicated to the software. The environment is separated as grids in the MATLAB software. The elements in the grid are the range values obtained by the ultrasonic sensor.

The images of 200 x 400 pixels are used to show sub map1 and sub map 2 constructed for the 1st and 2nd sides respectively. The side 1 map is shown in fig.6 and the side 2 map is shown in fig.7. Different colours have been used to show the potential object areas. The blue vertical line is the robot step line which is constructed as the robot moves along the first side.

The red colour shows the area in which the obstacles are present in near vicinity the robot i.e. the distance between the robot and obstacle is within 0-100 centimeters for side 1 and 0-120 cm for side 2.

The yellow colour area shows the moderate possibility of finding an obstacle. It determines the potential areas where an object could be found in the range 100-300 centimetres for side 1 and 120-400 cm for side 2.

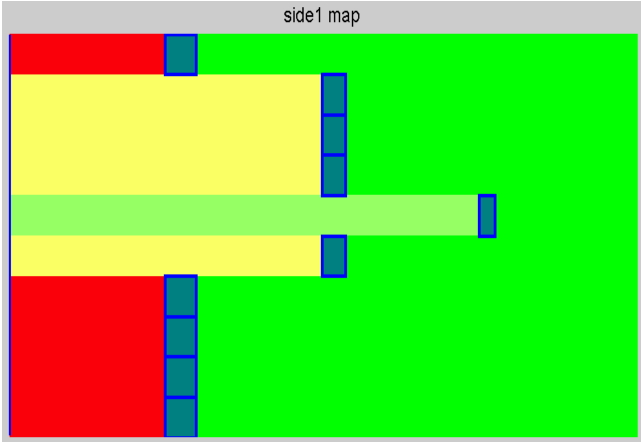

Figure6. Sub map 1 created for the first side of the indoor environment

The light green area shows the possibility of having objects at a very far distance from the mobile robot. It determines the obstacles present at range beyond 300 cm for side 1 and more than 400 cm for side 2.

The green colour in the image shows the path where the mobile robot can move freely in the environment i.e. this area shows the part of environment where the obstacles are not present or the empty floor area of the indoor environment.

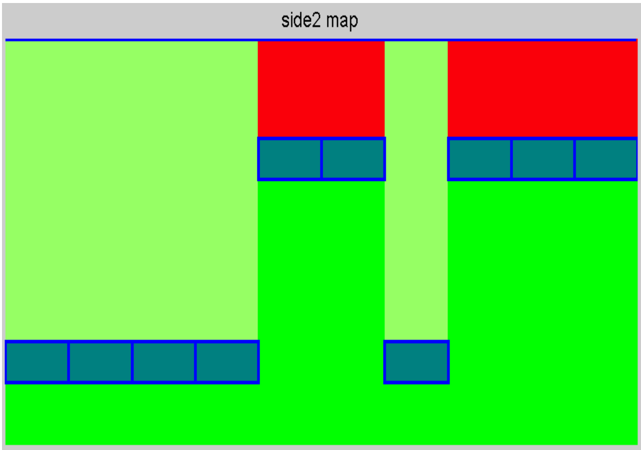

Figure7. Sub map 2 created for side 2 of the indoor environment

A final map or global map of the indoor environment is obtained by merging the sub maps 1& 2. A new image is obtained by adding the two sub maps and this is the final map of the environment as shown in fig.8.

In the final map, the white portion shows the area where the possibility of finding obstacles near the robot is maximum or within the range of 100 cm.

The light yellow and yellow areas highlight the obstacle areas where there is possibility of finding objects within the range 100-300 cm.

The light green areas show areas with objects at far distance from the mobile node and the green area depicts the path where the robot can move freely or area where no obstacles are present.

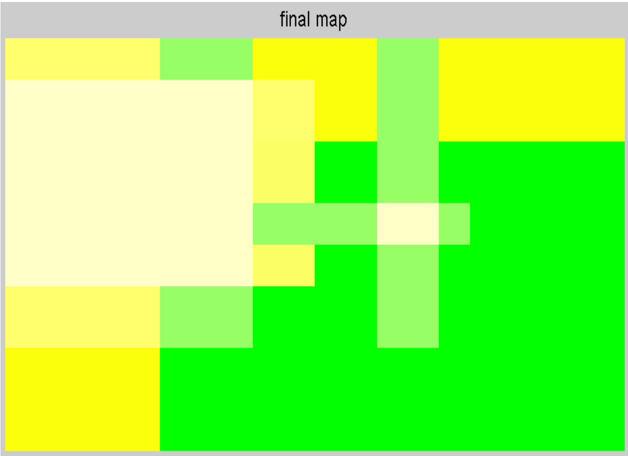

Figure8. Final map of the indoor environment

V. Conclusion

This robot has been experimented in different sets of obstacle arrangements within the given indoor environment. The mobile node has been able to navigate successfully along the sides of the environment and effective map of the environment has been developed.

The map so created is efficient in terms of determining the potential areas where the obstacles could be found in the indoor environment.

Also, the map describes the free paths where the robot can move freely. The colour combinations used in the map image depict the areas of finding the obstacles in the defined ranges. Using the result of the experiments, the efficiency and constraints of the robot have been determined.

We conclude that there is a possibility for further improvement in the accuracy and flexibility of the robot.

Moreover, the robot can detect only static obstacles and the dimensions of the obstacle will not be known from the map built. Also, the curvature of the obstacle cannot be identified and the obstacle should be plane with no sharp edges.

To determine the object shape and its classification could be a work of future research. Moreover, 3-D mapping can be further used to enhance the resolution of the indoor map.

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