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Intelligent Mobile Robots

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Abstract

Background/Objectives: A new method is devised to build a collection of wheeled robots that are capable of communicating with each other and mapping a maze in a minimum amount of time by dividing the work between two or more robots. **Methods/Statistical analysis:** The design and implementation of multiple mapping robots are undertaken using Digital Magnetic Compass, Ultrasonic Sensor, and Arduino. The designed robots use a metric, world-centric approach for mapping algorithm. Robots follow the wall while continuously sending its co-ordinates to the base station. The base station or map monitor has PC with NRF module link connected with mobile robots, and the map is plotted on a GUI. The proposed approach is a low-cost robotic application to solve SLAM problem. **Findings**: The proposed work is an approach for mapping and exploration of mobile robots. Initially, each robot explores the environment by themselves, and later they communicate with other robots by exchanging sensor information. Magnetometer readings help the robot to estimate their relative location. The predictive models are updated by the robots based on their exploration of the environment. Based on the experiments done it is proved that mapping and map merging decisions made using multiple robots provided better performance than using some other technique which uses a single robot for exploration. The robots communicate with each other very often and verify their location to avoid false-acceptance map matches. In case the robots are about to meet at a point known as meeting point, these robots have prior information about their relative locations, and henceforth these robots can combine their data into a map named as shared map. SLAM technique is used to find out the uncertainty in the mapping of individual robots and merging the map provided by each robot. The coordination of robots and estimation of other robot's location is done using the shared map. The robots used their wireless network available with them for exchanging information with each other. In all official runs, all the robots successfully mapped, merged the maps and explored the environment. The maps produced by the robots during each run looked alike which indicates a high level of accuracy of the system. **Application/Improvements:** This concept can be implemented for exploration on planets or on rescue missions It can be made further into a SWARM system in which the robots has a very high level of intelligence..

Keywords: Digital Magnetic Compass, Mobile Robots, NRF, SLAM, Ultrasonic Sensor

1. Introduction

Programming just one mobile robot with artificial intelligence is hard. So adding more robots and having them exhibit a collective behaviour can increase the difficulty level exponentially. This makes such intelligence, a hot topic in the world of robotics today.

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Detecting the features robustly is one of the major problems of simultaneous localizing and map merging, i.e., SLAM of mobile robots. This feature detected is one of the key elements for construction of the feature map and localization of robot. If the robot acquires false information about the position of features (or) fails to do feature detection then the robot has to rely on odometry data, i.e., the data taken from motion sensors to estimate the changes in position of the robot. To successfully perform SLAM technique, feature detection has to provide feature information accurately.

Object detection and measuring object's relative position is done by using a sensing system. The object detected can be some other robot or an obstacle or even the target. Communication is very important between multiple robots only then the robots can send updates to other robots and order them[1–3]. Robots can also be used to generate a floor map of a building which is unknown[4]. Research is now being done in the area of different mapping techniques. Representing the geometry of the environment should have high accuracy[5]. A robust approach to mapping is determining environment's geometric properties. This representation is very useful, but is sensitive to noise. The other approach is the one that locates a region of interest and their relationship in the environment. The difference between World-centric and robot-centric mapping is that the former generates a map relative to a fixed coordinate system while the latter generates the map relative to the robot[2].

Major of the research work were on localization and mapping simultaneously. Robot path and map are both unknown. Many such works focussed on exploration of information in the environment[6–9]. An autonomous mobile robot has to locate its position and find its path in the environment where it is exploring. Digital magnetic compass and ultrasonic sensors were used by SLAM robots to explore the indoor environment. Multiple sensor techniques make use of an ultrasonic and infrared sensor, laser scanner, stereo camera, and an electronic compass to solve SLAM problem[10–13]. Robot needs to plan a motion path through the environment to navigate without colliding with obstacles. Data obtained by ultrasonic range measurements is used to detect and avoid obstacles in environment[14].

2. Materials and Methods

2.1 Hardware Design

Figure 1 shows the robot along with its various modules. Figure 2 shows the robot's architecture. Arduino Mega board is used as a central processor along with communication module and power supply. The Arduino MEGA board in the robot has ATmega2560 microcontroller and some other electronic components which are programmed using software. The Mega 2560 microcontroller board has 54 digital input/output pins, 16 analog inputs, 4 UARTs which are hardware serial ports, a crystal oscillator of 16MHZ. The robot has two kinds of sensors used for navigation. Digital Compass IC used is HMC5883L which has 3Axis. For easy interfacing, I^2C serial bus is used. This enables the digital compass for at least 2-degree heading accuracy. HC-SR04 is an ultrasonic module which has a working range of about 2 to 400 cm with 3mm accuracy. The sensor's output voltage is obtained by measuring the distance between the sensor and the object. 2 DC motors are used for controlling the motion of the robot. For the purpose of support, the front and back end of the robots are attached with 2 caster wheels. To move forward and backward and also to rotate clockwise and anti-clockwise, driving system is used. Communication between robot and PC is achieved using

Figure 1. Mapping robot: Actual assembly.

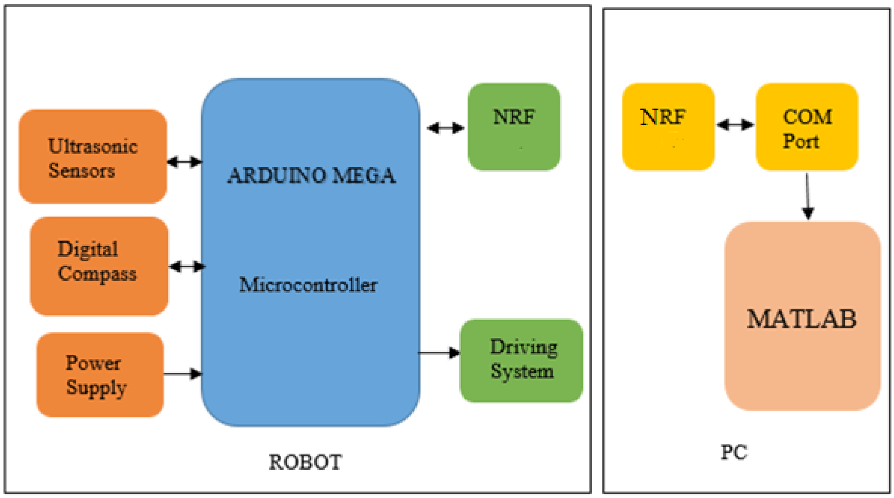

Figure 2. Mapping robot block diagram.

NRF.NRF module is a module designed for transparent wireless serial connection setup. This robot has 7.4 Volts battery for powering of driving system and Arduino. The base station has PC with NRF link connected with mobile robot. PC has MATLAB software with Arduino driver to communicate with PC's COM port. Live coordinates send by mobile robot receives by PC and map is plotted on MATLAB's graph.

2.2 Obstacle Avoider

A basic obstacle avoider was created to understand and check the primary working and functions of the ultrasonic sensor, servo and motor driver. The robot can travel around without any collision shown in Figure 3.

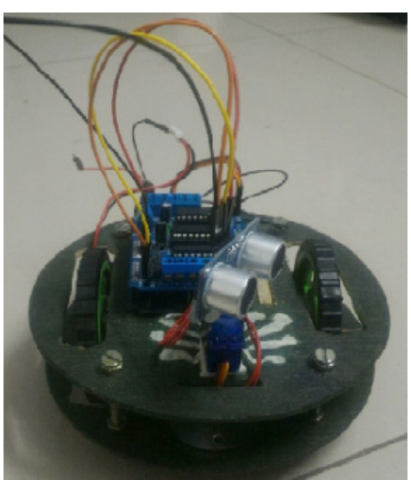

Figure 3. Obstacle avoider.

2.3 Remote Controlled Robot

The functioning of the RF module is tested and range and usage determined by converting the obstacle avoider into a remote controlled robot directly through the PC shown in Figure 4.

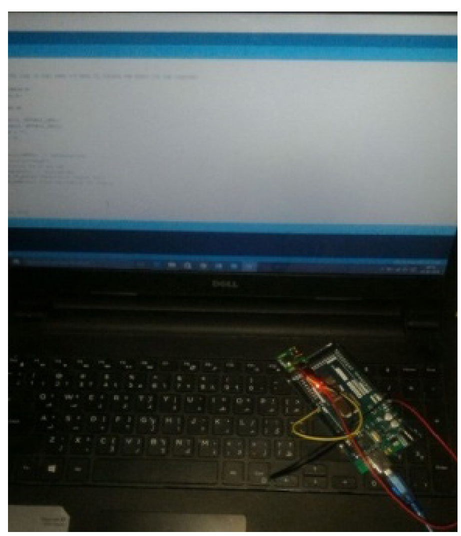

Figure 4. Receiver communication with PC.

2.4 Sonar

The capability of ultrasonic sensor to map an area is determined by making a sonar as shown in Figure 5.

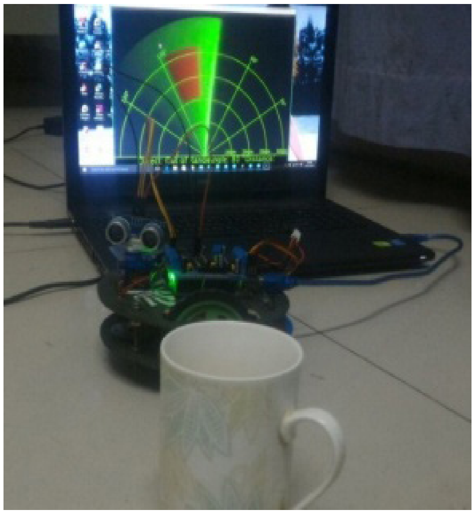

Figure 5. Sonar.

2.5 Real-time Plotting of a Stationary Robot

A real-time map around a stationary robot is plotted with an ultrasonic sensor and servo motor as shown in Figure 6.

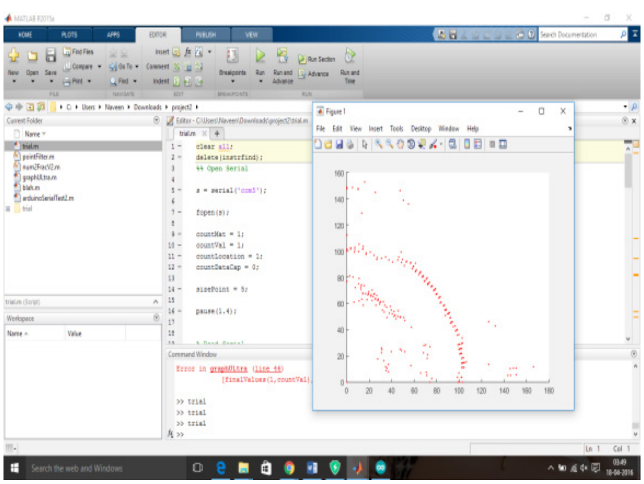

Figure 6. Real time map.

2.6 Communication

The algorithm for each robot is different so that they follow different paths. The first robot runs on basic obstacle avoidance, second on the left wall following and third on the right wall following shown in Figure 7. Communication between the robot and the PC is set up and the robot is placed into the map to map the entire maze up to its capability. The time taken to plot the entire maze is recorded. Later on, it was decided to plot the compass values only during turns so that the compass readings do not interfere with NRF module and to get straight lines between each turns shown in Figure 8.

Figure 7. SLAM.

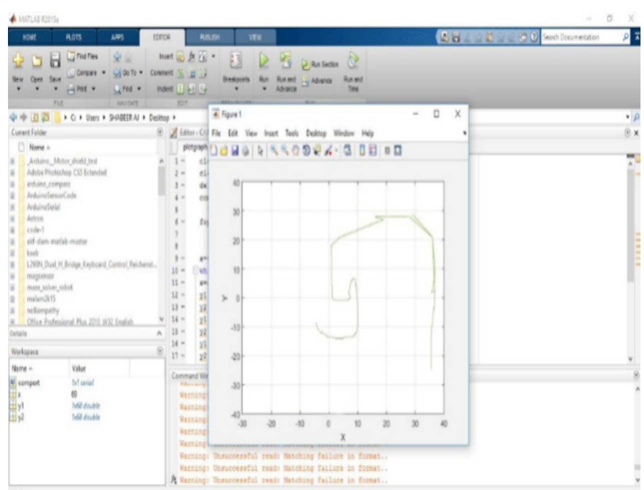

Figure 8. Map.

3. Algorithm

Robot navigation and mapping algorithm is implemented with a minimum level intelligence on maximum cost reduced robots. Motion path of a robot is planed through the environment to navigate without colliding with obstacles. We used the concept of world-centric approach for mapping along with a modified wall following algorithm for navigation.

When robot turns on first, it read value of its heading degree using digital compass. Then it looks for front and side obstacle distance using ultrasonic sensors. Designed robot follows wall to navigate through environment. Robot moves forward when there is no obstacle or wall at front and a side wall is present. As robot turns, it sends its co-ordinates to base station. Co-ordinates are updated using compass value.

If front wall is detected then, robot 1 takes right turn, when left and right walls are not detected robot takes right turn, if left wall alone is not detected it takes a left turn and if walls are present on all three sides, the robot turns back. If front wall is detected then, robot 2 takes left turn, when left and right walls are not detected robot takes left turn, if right wall alone is not detected it takes a right turn and if walls are present on all three sides, the robot turns back. Robot 3 follows a random obstacle avoidance path.

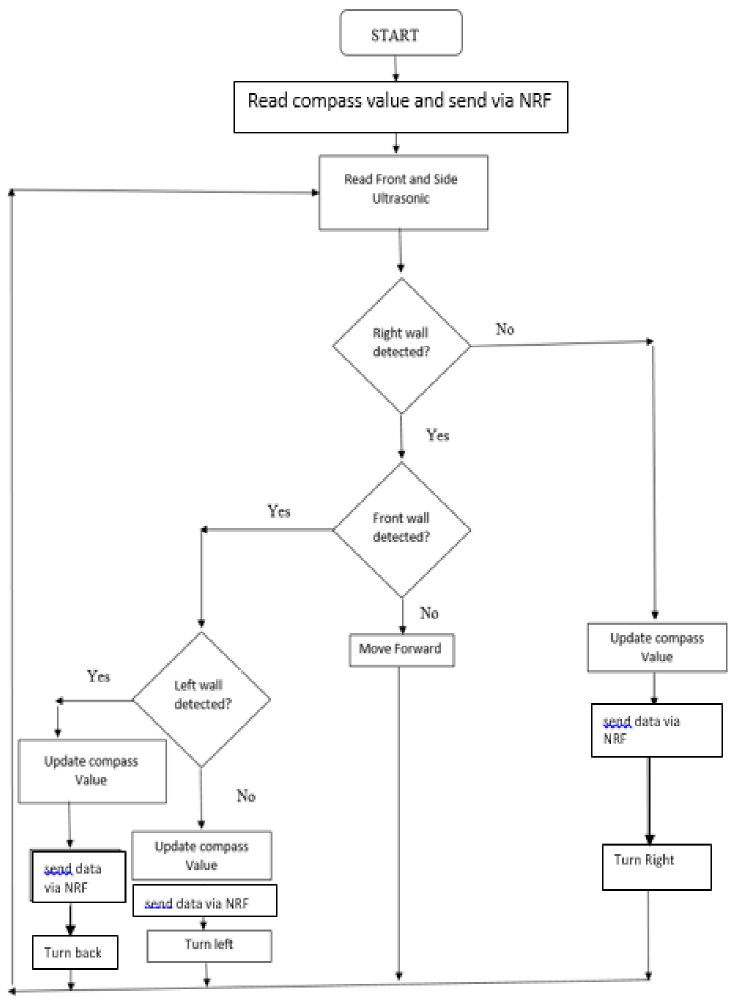

Figure 9. General flowchart.

While in turning process robot uses speed control to make turn. After robot completes its 90-degree turn it stops and again read for both ultrasonic values. The compass value is updated to the computer just before making the turns. When robot turns on it assumes itself to pointing towards north with heading degree of 0. At each corner, it takes turn of 90 degrees. At each forward movement, robot points towards one of the four directions. The user needs to select appropriate COM port of the PC and baud rate. Baud rate of 9600 is set at robot transmitter end and at base station receiver end. Data received by NRF receiver appears at PC's COM port. Then using MATLAB the compass values are plotted onto a graph. Robot sends co-ordinates in the form of x, y, x, y… and is thus continuously updated. X-Y graph is plotted on MATLAB front panel. The general flowchart is shown in Figure 9.

3.1 Algorithm for NRF24l01 Communication (Transmitter)

1. Start;
2. Define all the necessary header files and structures and variables;
3. Begin the radio;
4. Set the number of nodes or addresses required for radio communication for both transmitter and receiver;
5. Set the radio data speed and frequency that does not interfere with any other frequency around;
6. Set the MISO (Master In Slave Out) PIN of nrf24l01 as LOW initially;
7. Open the radio for writing or sending the data;
8. Obtain the data to be send to the receiver;
9. Set the MISO PIN as HIGH;
10. Send the data to the receiver using defined receiver address;
11. Set the MISO PIN back to LOW;
12. Stop.

3.2 IAlgorithm for NRF24l01 Communication (Receiver)

1. Start;
2. Define all the necessary header files and structures and variables;
3. Begin the radio;
4. Set the number of nodes or addresses required for radio communication with both transmitter and receiver;
5. Set the radio data speed and frequency that does not interfere with any other frequency around;
6. Set the MISO (Master In Slave Out) PIN of nrf24l01 as LOW initially;
7. Set the radio to stop transmission mode and set as receiver mode;
8. Open the radio for reading the transmitted data;
9. Obtain the data send to the receiver using the unique addresses defined for different transmitters by delaying for each transmitter;
10. Print the obtained data to MATLAB;
11. Stop.

4. Results and Discussions - Summing up of All the Process

All the given concepts must be integrated into a single program to perform the required task. The SLAM alone itself is a high-end program for the Arduino to handle hence most of the processing is undertaken within the

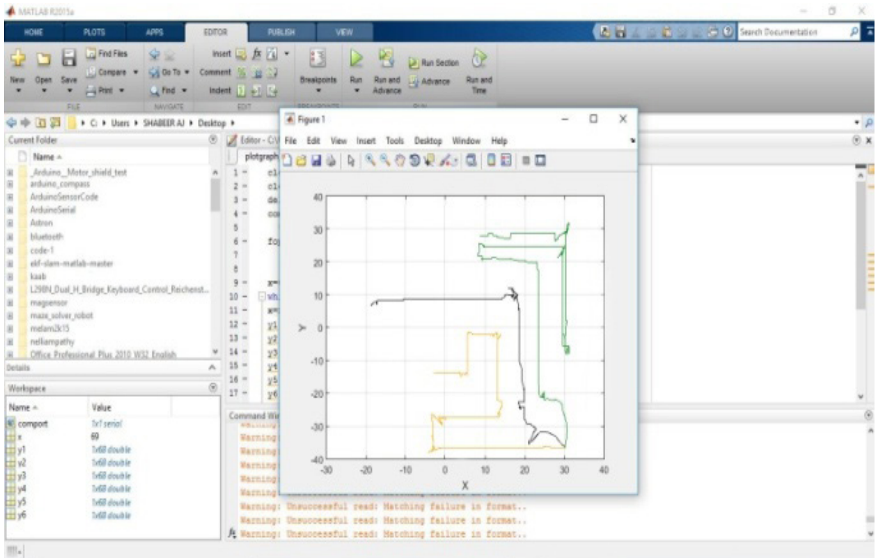

Figure 10. Final map.

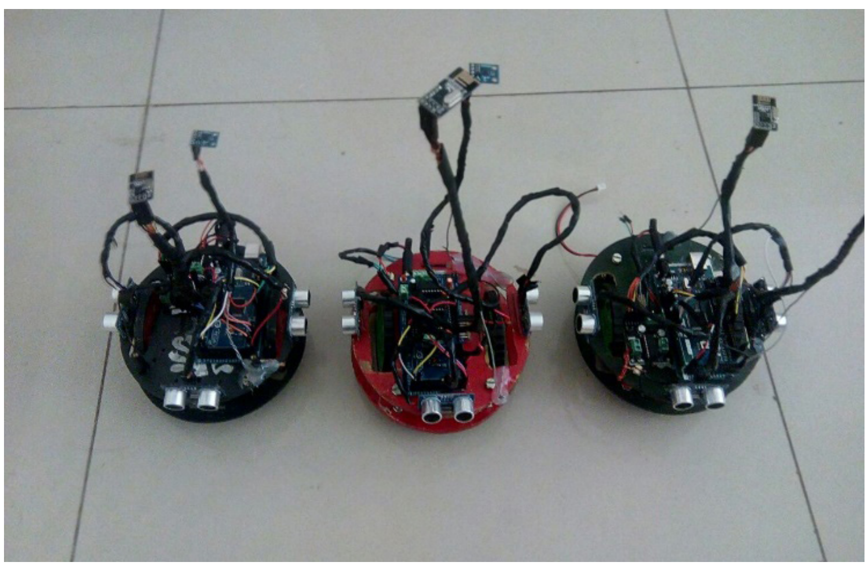

Figure 11. Final robots.

computer while only the required type of signal is taken from the Arduino. For further accurate and advanced outputs, a high-end board such as the Raspberry Pi is required along with better sensor inputs through LIDAR, Kinect or camera. The final map is shown in Figure 10. The final robots are shown in Figure 11, and multi-robot assembly is shown in Figure 12.

Figure 12. Multi-robot mapping.

3. Conclusion and Future Work

The work presented is a novel approach for mapping and exploration of an unknown environment using robots. A group of robots was used to do this task of exploration. The robots initially map and explores by themselves and later they interact with each other for sharing their pose information to other robots. Their relative position is generated from the readings of magnetometer. The experiments done revealed that the technique used makes decisions better than other techniques using single robot to explore the information about the environment The robots were made to communicate with each other frequently in order to avoid false maps. The robot used wireless network for sharing information. When the robots meet each other, they share their data into a shared map. The shared map helps for robot coordination and poses estimation of other robots. This technique on mapping and exploring was evaluated in real-world environment. During evaluation of all runs, the robots successfully mapped and explored the environment. All maps created by the robot at all runs looked identical indicating robustness of the system.

Future work may also include addition of higher processing power; better sensors and camera execute complete SLAM. It can be made further into a SWARM system in which the robots have a very high level of intelligence.

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