A SPATIAL MEASUREMENT AND RECOGNITION SYSTEM USING AUTONOMOUS MOBILE ROBOT

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ABSTRACT

In this paper, an autonomous mobile robot (AMR) is designed to determine the lateral dimensions of an arbitrary enclosed space and to predict its area and shape. The robot operates in two modes, navigation and measurement modes. It uses the ultrasonic sensor to guide around obstacles in the navigation mode and also to calculate the area, in measurement mode, by determining the x-y dimensions. Communication with the robot is achieved by means of a Bluetooth connection to an android mobile phone. Extracted information from measurement times are found to be useful in tracking the path of the autonomous mobile robot.

Keywords: Autonomous mobile robot, Autonomous control, Obstacle avoidance, Area estimation

INTRODUCTION

Autonomous robot systems have successfully been applied in manufacturing, health, transportation, military (security) and recently in agriculture. An autonomous robot (AMR) system is a system with an independent power source that can autonomously navigate, perceive the environment and perform functions without any human intervention. In some applications, such as in habitat monitoring, especially in hard-to-reach areas, autonomous robots working in a sensor network, could potentially assist in exploring and characterizing the habitat of some species, for example the cave dwelling bat (Martinkova N et al, 2020). Vital information such as the dimensions and to some extent the area of an enclosed space could be used to determine the population density. For such applications, simultaneous localization and mapping becomes difficult due to the absence of a GPS signal and landmarks.

A number of related studies have proposed autonomous robots for operation in indoor environments, outdoor environments and for construction sites (Chaoqun W et al, 2017, Sasaki et al, 2017 and Kim P et al, 2018). In Chaoqun W et al (2017), the developed robot builds a three-dimensional (3D) map of an uneven and unstructured indoor environment and then generates a traversable map for efficient autonomous navigation. The cost, physical size and the computational requirements of this design resulting in a huge power consumption limits the application of this design to only indoor spaces for humans. Similar approaches utilizing a 3-D map generation have been used for the design of autonomous robots capable of navigating in construction environments (Kim P et al, 2018).

While distance measurements via ultrasonic sensors and lasers depend on the environment, natural light, and the surface reflectivity of the object under measurement, alternative approaches to measuring distance, which are image based methods, are usually expensive and unsuitable for real-time measurements due to their reduced processing speeds (Shukla N. et al, Cano-Garcia, A. et al 2007 and Carullo et al, 2001).

In this work, a wheel type autonomous driving robot is proposed for area measurements and habitat monitoring. The steering pivot point is centered at the middle such that the motions of the steering and drive actuators of motors are mechanically coupled. There are two rear active steerable wheels and a front steering wheel. The proposed robot is capable of independent navigation from one location to another guided by an ultrasonic sensor. The system is controlled by an Arduino Nano board which interfaces to an HSR04 ultrasonic sensor (a transceiver device), servo motor micro SG90 and direct current (DC) motors. The information from the ultrasonic sensor is used for collision avoidance and for the calculation of the area (length and breadth) of a room in meter square. The system is interfaced to a mobile device by means of a Bluetooth HC05 Bluetooth sensor and extracted information from the robot is displayed on a paired android mobile phone.

METHODOLOGY

Fig. 1 presents a block diagram of the proposed AMR. The microcontroller on the Arduino Nano board is used for system control, the board controls the ultrasonic sensors, Bluetooth module, servo motor, buzzer and DC motors. The ultrasonic sensor is a transceiver component, its detects the distance to the object using the fact that sound travels at a speed of around 340 m/s. The architecture design of the AMR is simple, flexible and can be actualized in different ways to suite different purposes with minimum design changes.

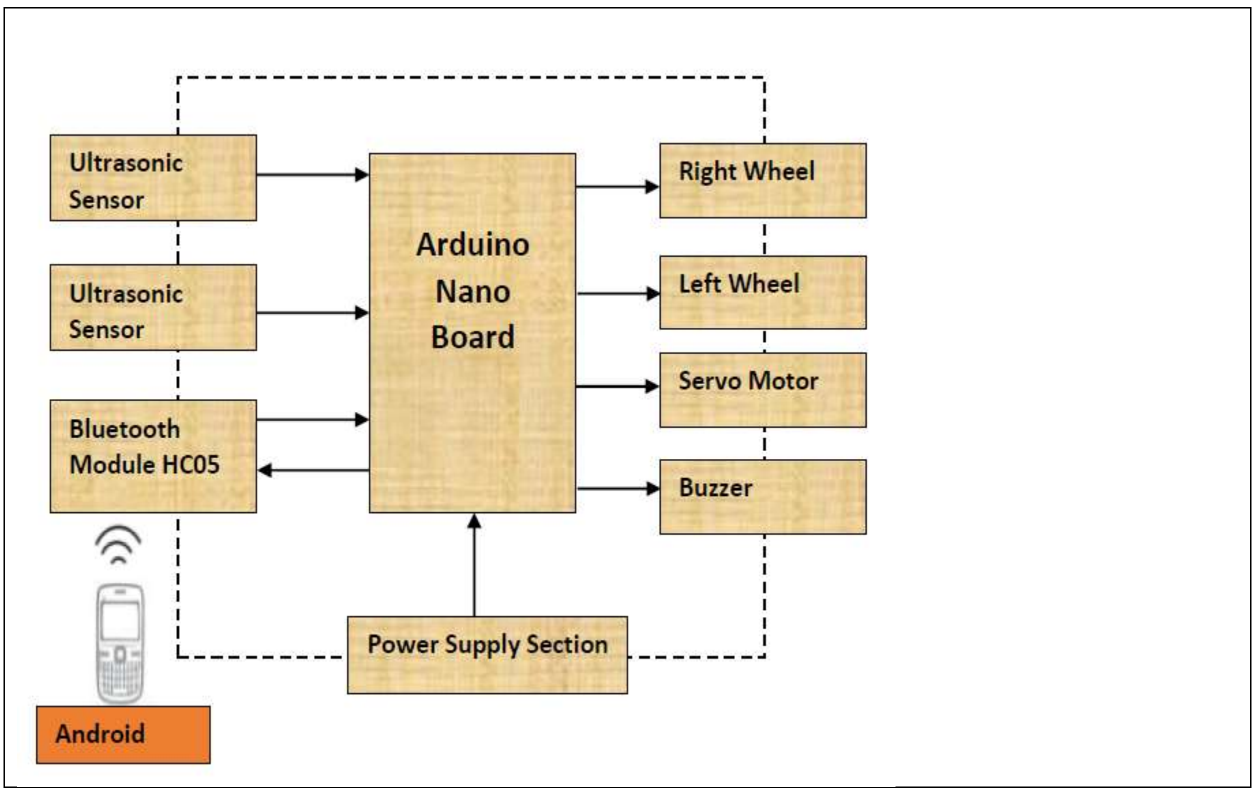

Fig. 1: Block diagram of the proposed AMR

The ultrasonic sensor transmits eight 40 kHz pulses and determines the time that the echo is received in order to calculate the distance. Two ultrasonic sensors are used for this design. The ultrasonic range finder mounted in front of the system detects the obstacles and provides information to the controller to guide around the obstacle. The ultrasonic range finder mounted on the servo motor performs two measurements of distance in opposite directions. After a measurement is made at 0 degree, the servo motor is rotated to 180 degrees to enable the ultrasonic sensor perform the second measurement. These two sensors provide distance information to the controller as the two wheeled DC motor moves the robot remotely and autonomously.

The AMR is powered from a 4.2V, 1800mA supply inputs from a Lithium battery. The DC motors are powered through the power supply circuit connected to the battery which serves a dual purpose as the circuit is also used for the charging of the battery. The microprocessor, the brain for the AMR, is mounted on the Arduino Nano. The controller sends pulse width modulation (PWM) signals to the DC motor in order to move the AMR autonomously and also away from an obstacle on its path. The Arduino microcontroller coordinates and executes the algorithm for the system. The layout diagram of the AMR is shown in Fig 2.

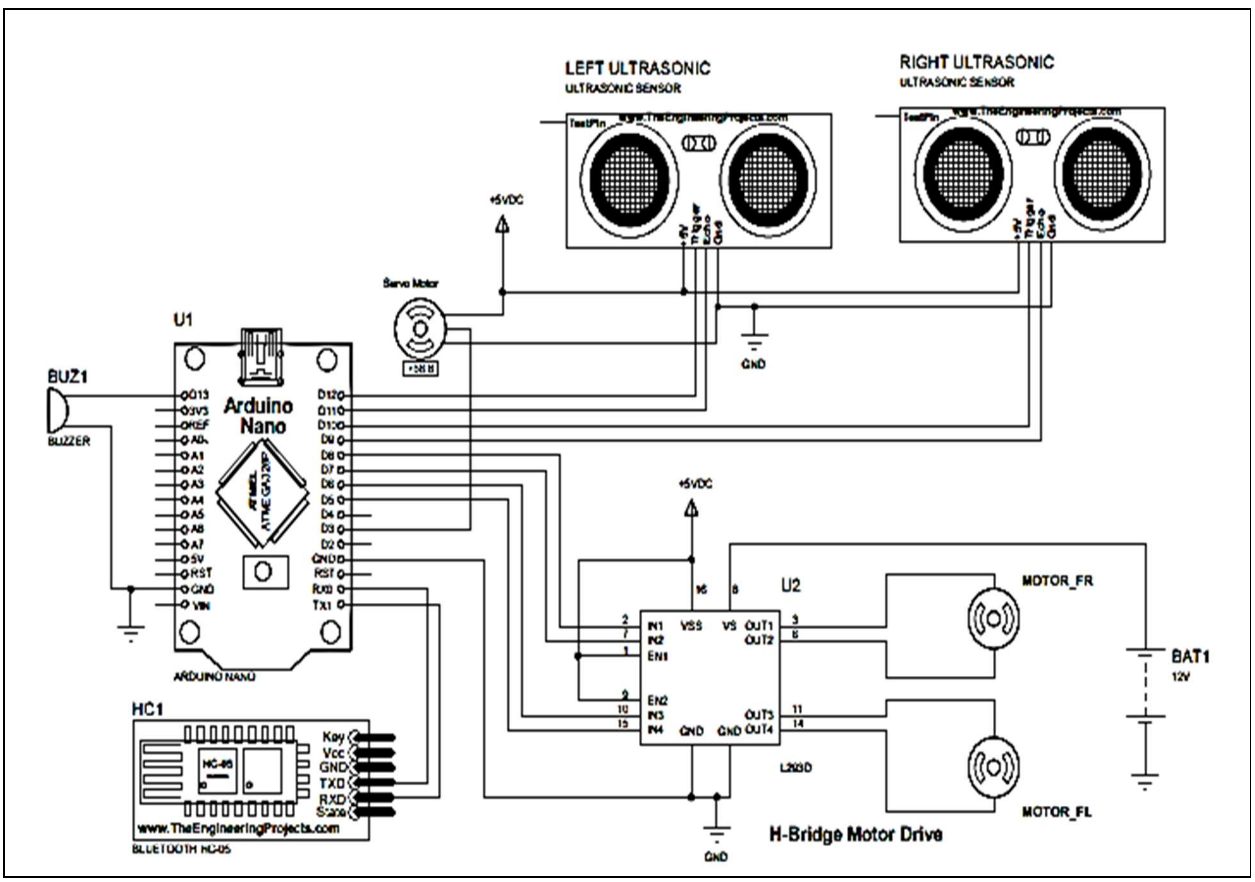

Fig. 2: Layout diagram of the AMR

In the navigation mode, the AMR is configured to continuously read distances of objects to itself. If the distance from the object to the range finder is less than 10 cm, the robot will see the object as an obstacle and then avoids and adjusts its position to focus on target.

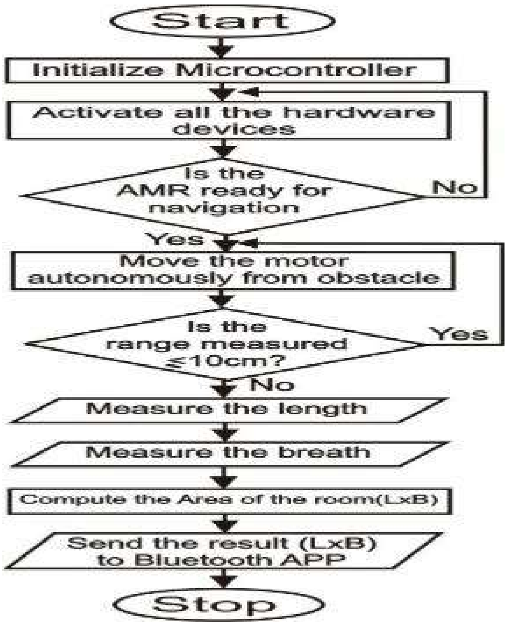

Fig. 3: The Flow chart of the AMR

On the other hand, if the distance is greater than 10 cm, the robot will measure the length and breadth of the space, calculate the area and transmit the result wirelessly to an android paired phone. The algorithm for the AMR is represented in the flowchart of Fig. 3.

In measuring the area, for example for a rectangular space, the length of the plate carrying the ultrasonic sensors is factored in the calculation. Therefore, the area is calculated as $A = (l + k) \times (b + k)\ (m^2)$, where $k = 5 \times 10^{-2} m$ is the length of the plate carrying the sensors measure.

RESULTS

Fig. 4 shows the developed AMR system. Fig 5 shows a sample screenshot of the data received on a Bluetooth-enabled android mobile phone from the AMR for two different environments. The calculated area for the sample spaces are 5.69 m^2 and 13.21 m^2 respectively. The robot makes repeated measurements at different orientations with respect to time and the average of the measurements is taken and transmitted wirelessly to a paired android phone. As measured dimensions differ but with nearly the same calculated area, the extracted information on the measurement times are used to determine the robot's trajectory in space.

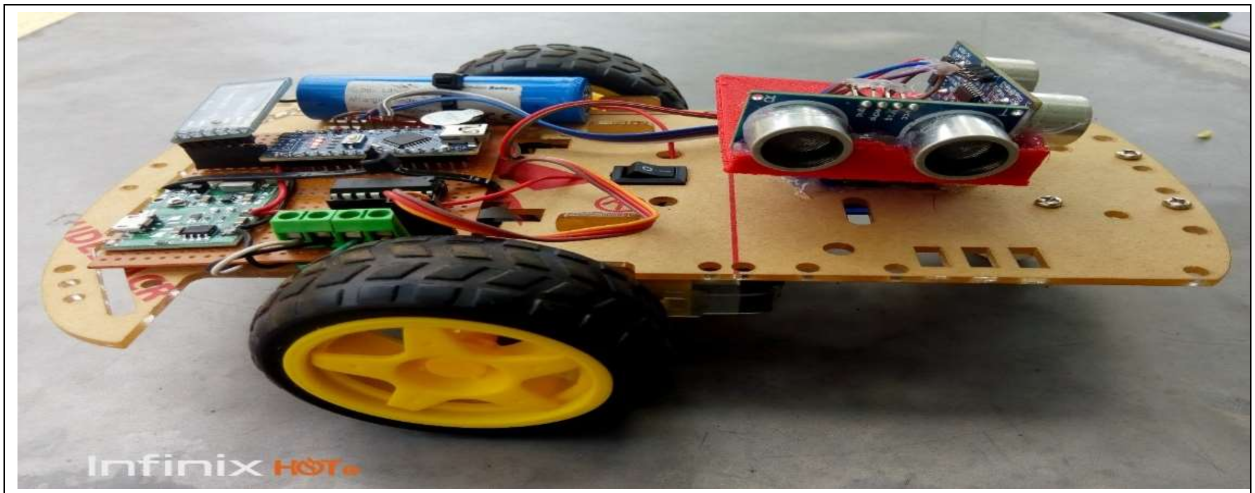

Fig. 4: The developed autonomous mobile robot including on-board ultrasonic sensors

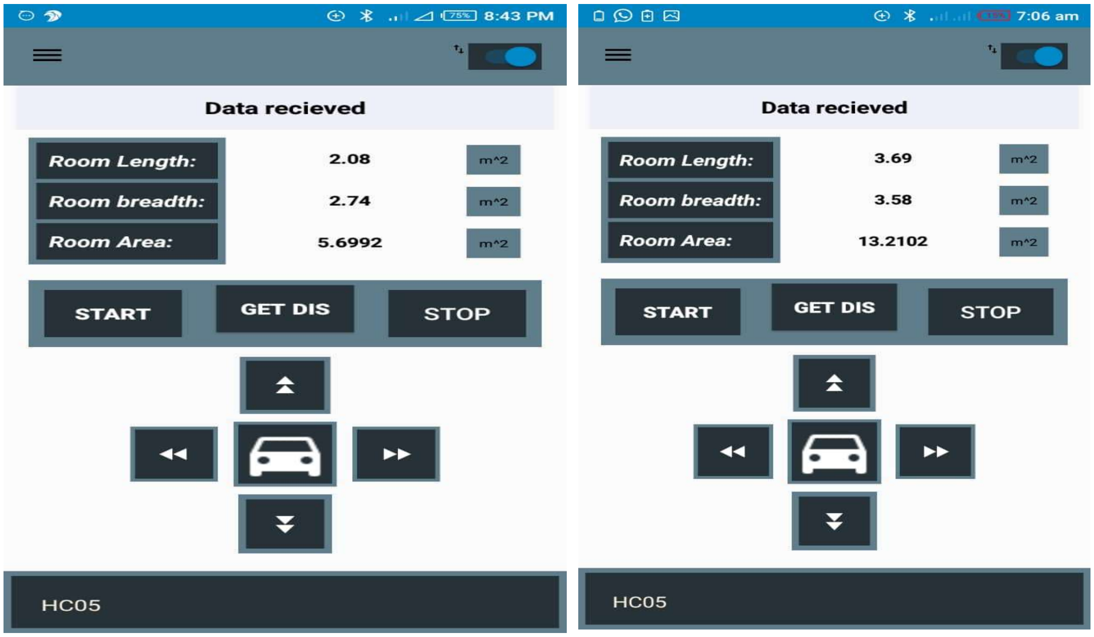

Fig. 5: Screenshot of data received on the android mobile phone application from the AMR for two different environments.

CONCLUSION

The developed ultrasonic range finder is a low-cost, energy-efficient, AMR distance measurement device that is suitable for indoor area measurements without the need for pre-installed fixed landmarks. It uses the inputs from the ultrasonic sensor for both obstacle avoidance and range and area calculation. The data obtained from the robot is transmitted wirelessly to an android mobile device through a Bluetooth connection. The developed device is suitable for remote population density estimation in enclosed spaces such as in habitat monitoring and if a thermal sensor is co-integrated, it can be used for rescue operations in hard to reach areas.

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