Remote and Autonomous Controlled Robotic Vehicle Based on Arduino with Real Time Obstacle Detection and Avoidance

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Abstract

Obstacle avoidance robotic vehicle using ultrasonic sensor and Bluetooth module is based on Arduino platform. This circuit is included one Arduino Nano board, one Ultrasonic sensor, one servo motor, two geared DC motors, Bluetooth module and other available components. The obstacle avoidance robotics is used for detecting obstacle and avoiding the collision. The ultrasonic sensor transmits the ultrasonic waves continuously from its sensor head. Whenever an obstacle appears ahead of it, the ultrasonic waves are reflected back from an object and that signal is passed to the Arduino's microcontroller. The microcontroller controls the motors left, right, back, front, based on ultrasonic signals. Bluetooth module and android RC application are applied to control the system remotely. The program is written in C-Language and uploaded to the microcontroller of Arduino Nano board through the Arduino IDE software. The operations of the whole circuit are controlled by the program.

Keywords: Arduino Nano board, Ultrasonic sensor, Bluetooth module, Arduino IDE window software,

Introduction

Arduino is an open-source electronics platform based on easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments. Arduino senses the environment by receiving inputs from many sensors, and affects its surroundings by controlling lights, motors, and other actuators. In simple terms, the Arduino is a tiny computer system that can be programmed with the instructions to interact with various forms of input and output. (Craft, 2013)

This research will demonstrate how to control the robotic vehicle using Arduino Nano board, Ultrasonic distance sensor and Bluetooth module. Ultrasound can be used to find the location of objects by means similar to the principle of radar works. High frequency acoustic waves reflect from objects. The distance to an object can be determined by measuring the delay between the transmission of an ultra-sound pulse and the return of the echo. This is the well-known means by which bats navigate in darkness. It is also believed to be used underwater by ocean divers such as dolphins and whales. Ultrasound can be used in sonar systems to determine the depth of the water in a location, to find schools of fish, to locate submarines, and to detect the presence of scuba-divers.

This circuit is designed to build an obstacle avoidance robotic vehicle using ultrasonic sensors. An Arduino Nano is used to achieve the desired operation. Robotics is generally a combination of computational intelligence and physical machines (motors). Computational intelligence involves the programmed instructions. This research proposes robotic vehicle that has an intelligence built in it such that it guides itself whenever an obstacle comes ahead of it. This robotic vehicle is built, using an Arduino Nano. An ultrasonic sensor is used to detect any obstacle ahead of it and sends a command to the Arduino. The block diagram of the whole system is shown in figure (1).

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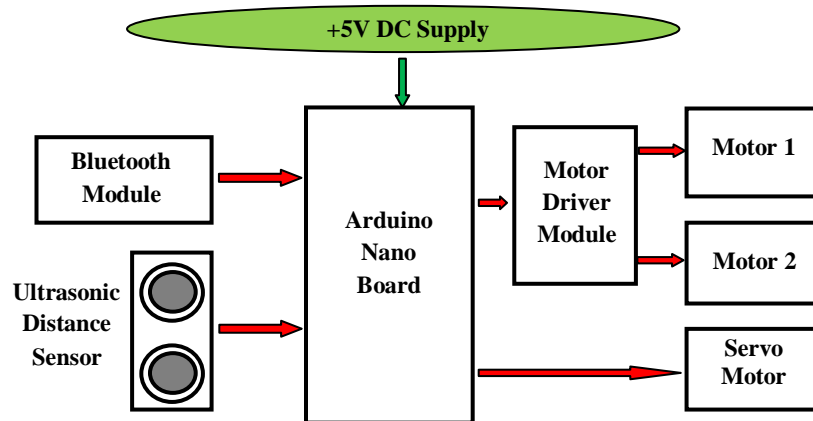[2] Professor & Head, Dr, Department of Physics, Hinthada University

Figure (1). Block diagram of the whole system

Introduction to Arduino Nano Board

Arduino Nano is a surface mount breadboard embedded version with integrated USB. It is a smallest, complete, and breadboard friendly. It has more analog input pins and onboard +5V AREF jumper. Physically, it is missing power jack. This new version 3.0 shown in figure (2) comes with ATMEGA328 which offer more programming and data memory space. (https://www.theengineeringprojects.com)

The Specifications of Arduino Nano Board

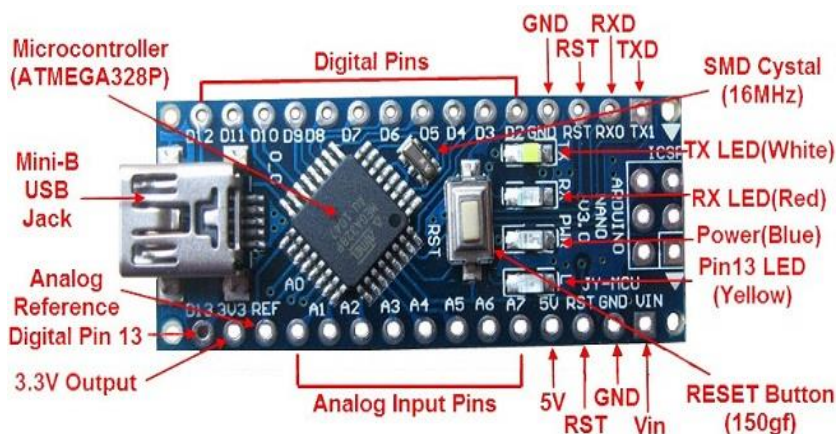|	
Microcontroller	Atmel ATmega168 or ATmega328
Operating Voltage (logic level)	5 V
Input Voltage (recommended)	7-12 V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	8
DC Current per I/O Pin	40 mA
Flash Memory	16kB (ATmega168) or 32 kB (ATmega328)
SRAM	1 KB (ATmega168) or 2 KB (ATmega328)
EEPROM	512bytes(ATmega168)or 1kB (ATmega328)
Clock Speed	16 MHz

Figure (2). The most important components of Arduino Nano board

The Basic Ultrasonic Sensor Operation

An Ultrasonic sensor is a device that can measure the distance of an object by using sound waves. It is used to measure the distance by sending out a sound wave at a specific frequency and listening for that sound wave to bounce back. By recording the elapsed time between the sound wave being generated and the sound wave bouncing back, it is possible to calculate the distance between the sonar sensor and the object. The sensor can take the time for the sound wave to return and multiply it by 344 meters (or 1129 feet) to find the total round-trip distance of the sound wave. Round-trip means that the sound wave traveled 2 times the distance to the object before it was detected by the sensor; it includes the 'trip' from the sonar sensor to the object and the 'trip' from the object to the Ultrasonic sensor. The object distance can simply be calculated as the round-trip distance in half. The diagram of basic ultrasonic sensor operation diagram is shown in figure (3). (McRoberts, 2010)
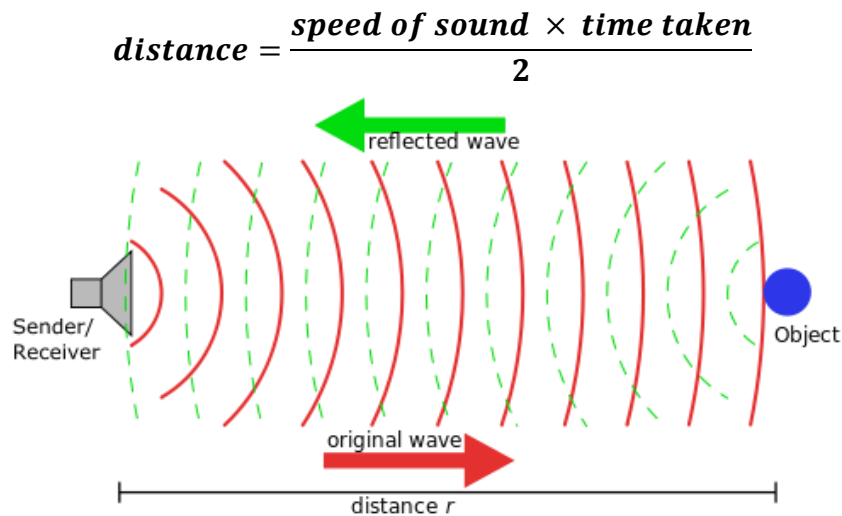
$$distance = \frac{speed\ of\ sound\ \times\ time\ taken}{2}$$

Figure (3). Diagram of the basic ultrasonic sensor operation

Ultrasonic Ranging Module HC - SR04

The HC-SR04 module interfaced to Arduino Nano board as shown in figure (4) is used in this research work. The HC-SR04 module includes ultrasonic transmitters, receiver and control circuit. It provides 2cm - 500cm non-contact measurement function, the ranging accuracy can reach to 3mm. The basic principle of work:

1. Using I/O trigger for at least $10\mu s$ high level signal,

2. The module automatically sends eight 40 kHz and detect whether there is a pulse signal back.

3. If the signal back, through high level, time of high output I/O duration is the time from sending ultrasonic to returning. (Boxall, 2013)

Figure (4). HC-SR04 ultrasonic distance sensor

HC-05 Bluetooth Module

HC Serial Bluetooth product consists of Bluetooth serial interface module and Bluetooth adapter. Bluetooth serial module is used for converting serial port to Bluetooth. It setup a transparent wireless serial connection. The default baud rate on the HC-05 is 9600. That's slow for high-speed transmission. The HC-05 is a 3.3V system but the breakout board offers current limiting resistors for some protection. The HC-05 Bluetooth module is shown in figure (5). The following pins are available on the module: (http://www.martyncurrey.com)

1. **V_{CC}** : 5V should be connected here to power the module.

2. **GND:** 0V or Ground should be connected here.

3. **TXD:** Transmit Data - connect the TX/TXD pin of your microcontroller to this pin.

4. **RXD:** Receive Data - connect the RX/RXD pin of your microcontroller to this pin.

5. **KEY:** this pin is used to change the mode of the Bluetooth module.

6. **LED:** this pin shows the working mode of the module.

Figure (5). HC-05 Bluetooth module

L9110 2-Channel Motor Driver

The L9110S 2-Channel motor driver module is a compact board shown in figure (6) that can be used to drive small robots. This module has two independent motor driver chips which can each drive up 800mA of continuous current. The boards can be operated from 2.5V to 12V enabling this module to be used with both 3.3V and 5V microcontrollers. A set of female header pins is used to connect this module to a microcontroller. The motors are attached via two sets of screw terminals. A PWM Pulse Width Modulation signal is used to control the speed of a motor and a digital output is used to change its direction. Four holes make this board easy to mount onto the robot or other project. (http://www.instructables.com)
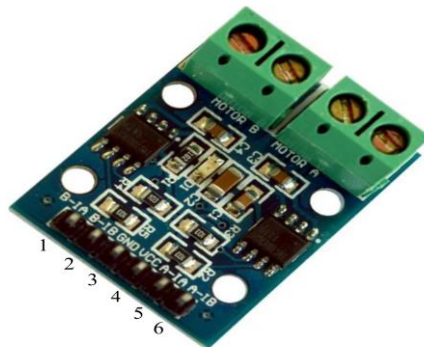

Figure (6). L9110S 2-channel motor driver module

DC Gear Motor

The gear motors are utilized in the magician classis and RedBot Kit and offer a cheap and easy to use setup to the wheels turning. This motor can run at approximately 340 rpm when drive by dual Li-Ion cell battery. It is most suitable for light weight robot running on small voltage. Out of its two shafts one shaft can be connected to wheel, other can be connected to the position encoder. figure (7) shows the dual shaft BO gear motor. (http://www.efxkits.com)

Figure (7). Dual shaft BO gear motor

SG90 Micro Servo Motor

The servo used in this research is SG90 Micro Servo weighing about 9g as shown in figure (8). A servo motor allows a precise control of the angular position, velocity, and acceleration. Servo motors have three wires: power, ground, and signal. The power wire is typically red, and should be connected to the 5V pin on the Arduino board. The ground wire is typically black or brown and should be connected to a ground pin on the Arduino board. The signal pin is typically yellow, orange or white and should be connected to a digital pin on the Arduino board. (http://www.efxkits.com/)

Figure (8). TowerPro SG90 servo motor

Installing the Arduino IDE on Windows

The Arduino IDE runs on all the latest versions of Microsoft Windows, such as Windows XP, Windows Vista, and Windows 7. The Arduino software for Windows, Mac, and Linux can be downloaded from http://arduino.cc/en/Main/Software. The IDE enables to write and edit code and convert this code into instructions that Arduino hardware understands. The IDE also transfers those instructions to the Arduino board. The Arduino IDE software window is shown in figure (9). (http://arduino.cc/en/)
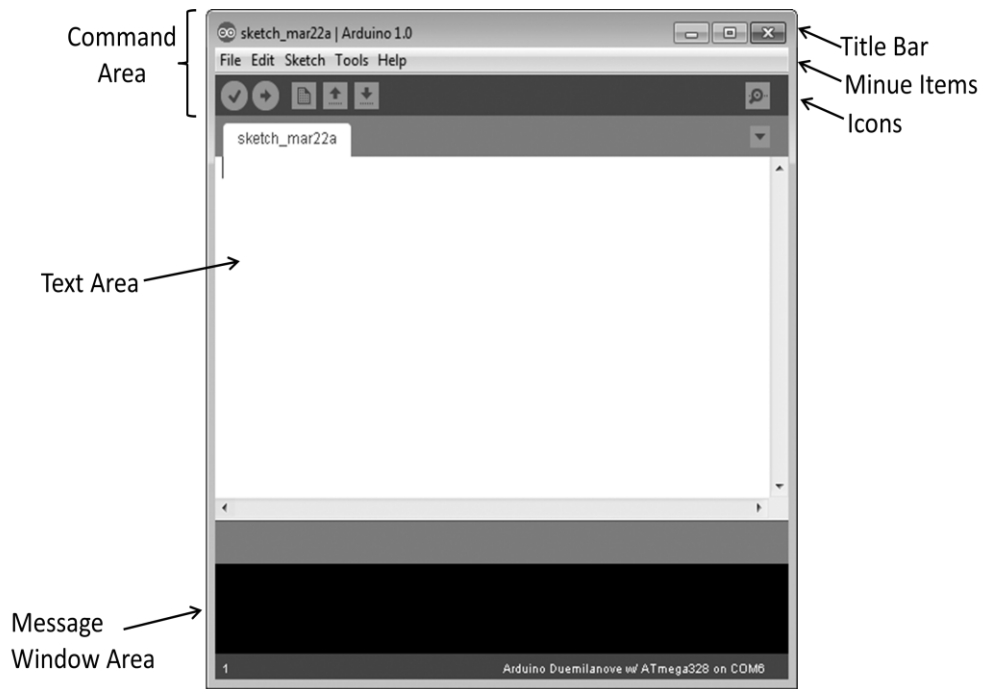
Figure (9). The Arduino IDE main window

The Android Application

The remote control in this research is an Android smart phone. The commands are sent from the smart phone by android application. The application is designed to enable the Bluetooth features of the device and make the connection with the Bluetooth module attached to the robot. This application is called Bluetooth Remote Controller. After downloading this application from Google, open it, scan for Bluetooth devices, enter the PIN number and make the connection between smart phone and robot. It is set up the application to send commands likes "F" to move forward, "B" to move backward, "L" to move left, and "R" to move the robot to the right. The main window of this application is shown in figure (10).
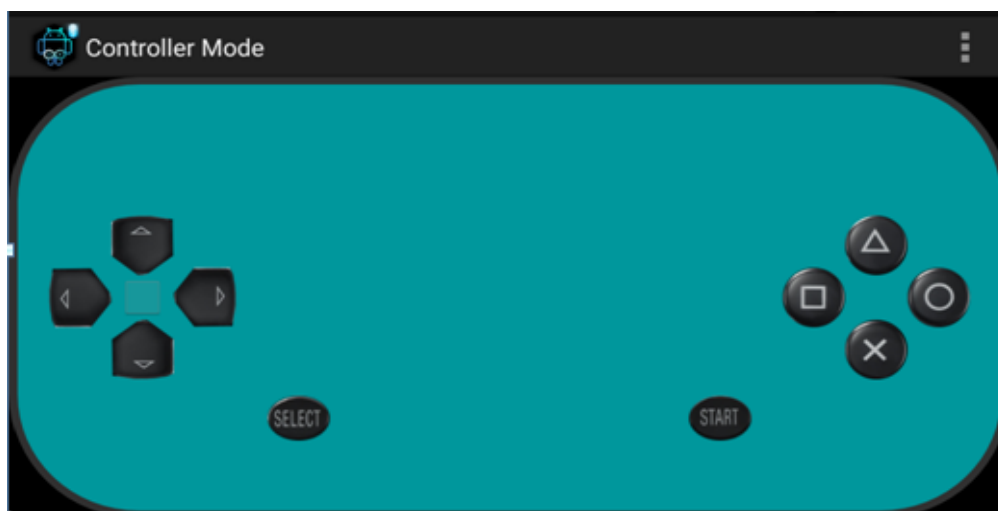

Figure (10). The main window of the Bluetooth remote controller

Circuit construction

In this work, an Arduino Nano board was used as the heart of the control system. Arduino is the main processing unit of the robot. Out of the 11 available digital I/O pins, 6 pins are used in this project design. The ultrasonic sensor has 4 pins: Vcc, Trig, Echo and Gnd. Vcc and GND are connected to the supply pins of the Arduino. Trig is connected to the pin 12 and Echo is connected to pin 11 of the Arduino. The L9110S 2-Channel motor driver module is a 6 pins IC. Pins 3 and pin 4 are V_{CC} and GND pins. Pins 1 and pin 2 are control inputs from microcontroller for first motor. They are connected to pins 5 and pin 6 of Arduino respectively. Similarly, pin 5 and pin 6 are control inputs from microcontroller for second motor. They are connected to pins 9 and 10 of Arduino. Left motor (consider this as the motor for left wheel) is connected to motor B potion of driver board. The right motor, which acts as the right wheel motor, is connected to motor A portion of driver board. The RX pin of the Bluetooth module is connected to TX pin of Arduino and TX pin of module to RX of Arduino. In this research, a 5V supply is used which is connected to L9110S motor driver module, Arduino Nano board and servo motor. The complete circuit diagram and the practical construction of this system are shown in figures (11) and (12).
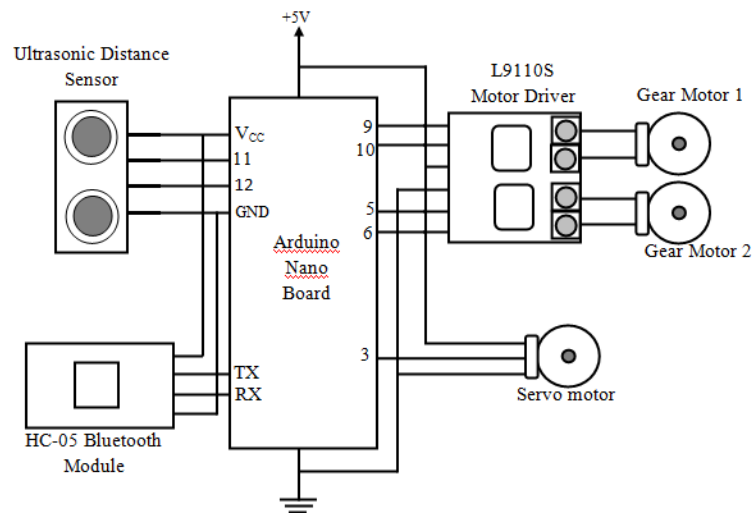

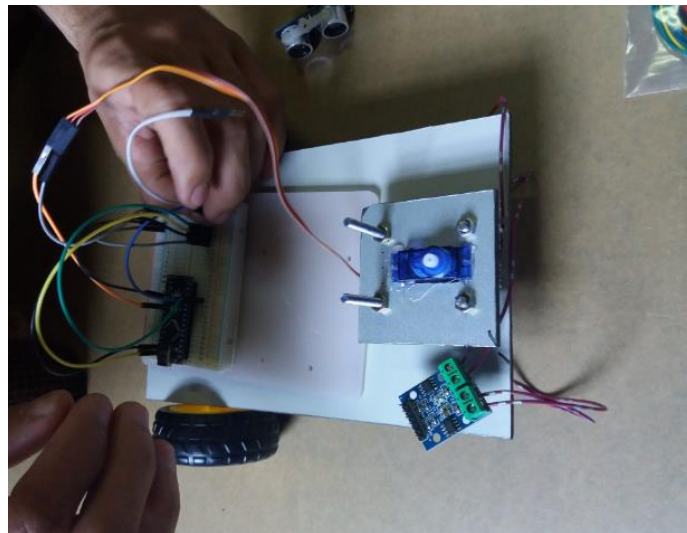Figure (11). Complete circuit diagram of whole system

Figure (12). The practical construction of the whole system

Operation of the Whole System

The operation of this work is divided into two main parts. First is automatic controlled driving mode by ultrasonic distance sensor and second is remote controlled driving mode by Bluetooth application from android Smartphone. Firstly the data from the android app is sent as an input to the Bluetooth module which further gives it to the Arduino Nano. Arduino selects the operation mode according to the receiving signal.

In the automatic controlled driving mode, the Trig pin on ultrasonic sensor is made logic high for at least 10µs. A sonic burst is sent from the transmitter module. This consists of 8 pulses of 40KHz. The signals return back after hitting a surface of object and the receiver detects this signal. The Echo pin is high from the time of sending the signal and receiving it. This time can be converted to distance by software program. When the robot is powered on, both the motors of the robot will run normally and the robot moves forward. During this time, the ultrasonic sensor continuously calculates the distance between the robot and the reflective surface.

This information is processed by the Arduino. If the distance between the robot and the obstacle is less than 25cm, the robot will stop for 0.3s and the ultrasonic sensor will check the left direction distance and right direction distance by servo motor. If the left direction distance is greater than the right distance the robot will move to the left direction. Similarly, right distance is greater than the left distance, the robot will move to the right direction.

In the remote controlled driving mode, when we press "UP ARROW" of android application, it sends the data "F" to Bluetooth module and microcontroller detects "F" and the robot car moves FORWORD. When we press "DOWN ARROW", it sends the data "B" to Bluetooth module and microcontroller detects "B" and the robot car moves REVERSE. Similarly, "LEFT ARROW" for left direction turning and "RIGHT ARROW" for right direction. If any buttons on the android window don't touch, no data (signal) receive the Bluetooth module and the robot vehicle will stop (Fig. 13).
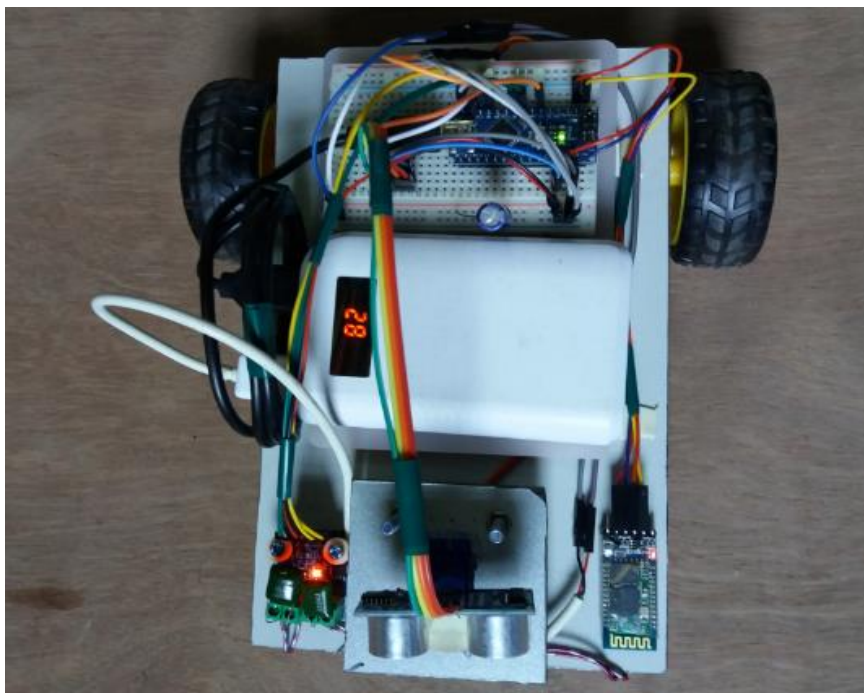

Figure (13). The practical operation of the obstacle avoidance robotic vehicle

Discussion and Conclusion

Nowadays many industries are using robots due to their high level of performance and reliability and which is a great help for human beings. The obstacle avoidance robotics is used for detecting obstacle and avoiding the collision. This is an autonomous robot. The design of obstacle avoidance robot requires the integration of many sensors according to their task. The obstacle detection is primary requirement of this autonomous robot. The robot gets the information from surrounding area through mounted sensors on the robot. Some sensing devices are used for obstacle detection like bump sensor, infrared sensor, ultrasonic sensor etc. Ultrasonic sensor is most suitable for obstacle detection and it is low cost and high ranging capability.

Arduino robot can be controlled by an android mobile or tablet, with the help of an android application that can be downloaded from Google Play store. The android application gets connected to the Bluetooth module and sends desired commands. This application controlled robot is capable to move in any direction. The driving mode can be changed by pressing the buttons (Select and Start) on the android application window. The start button can be used for remote controlled driving mode and the select button for automatic driving mode.

As this research is based on Arduino, the programming is very easy and can be easily modified. It doesn't require the Arduino motor shield. When using a 9V battery, at least 2 such batteries are needed to power the robot. It is better to use 3-9V batteries (one for Arduino and ultrasonic sensor, one for L9110S and other for motors). The ultrasonic sensor should not be connected directly to power supply as it might affect the normal performance. A servo motor can be fixed to the ultrasonic sensor and only ultrasonic sensor rotates according to the servo. Based on the distance, the entire robot rotates. Instead of ultrasonic sensor, an IR transmitter-receiver pair can also be used. Obstacle avoiding robots can be used in almost all mobile robot navigation systems.

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