Sudan University of Science and Technology
College of Graduate Studies

Design and Implementation of a Robot for Road Pothole Detection Using GPS

تصميم و تنفيذ روبوت لرصد حفر الطرق بإستخدام نظام تحديد المواقع

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الآية

قال تعالي :

(امن الرسول بما انزل اليه من ربه والمؤمنون كل امن بالله وملائكته وكتبه ورسله لانفرق

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مولانا فانصرنا على القوم الكافرين (286)).

سورة البقرة

DEDICATION

I want to dedicate this work to my family and friends. It is through their support for me that I have been able to focus on my work. My parents taught me that value of learning early on, and have always been supportive to me on various decisions to continue my education.

ACKNOWLEDGEMENT

Thanks to Allah for giving me the strength that kept me standing, for hope which made me believe that this project will be presented in best form.

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Abstract

The highway system of a developed country contains thousands center line kilometers of streets. Such systems consist of asphalt, concrete or composite streets ranging in condition, in recent years, several road network monitoring and maintenance programs have been established in order to monitor the on-going performance of the road network, to predict future road conditions and assess long term needs, to support investment planning and decision making, and to identify rehabilitation and maintenance treatment. Here in Sudan there is a lack of monitoring for the road performance especially for the inspection of potholes that may lead to direct danger to not just the cars, but the driver of the car himself. There is a need for a technology to sort out this issue and this project is a proposed system that can detect the potholes of the road and determine its location through the longitude and latitude location of the embedded GPS system then sends this location to the database or the observer through GSM. This system is a robot that uses ultrasound sensors to detect the pothole and its depth then uses the GPS module to determine the location of the pothole detected and eventually a GSM to send the data to the observer.

المستخلص

نظام الطرق السريعة في الدول المتطورة يحتوي الاف الكيلومترات من الطرق. هذا النظام يتكون من الاسفلت والخرصانة او مزيج من الاثنين وتختلف حالات هذه الطرق. في الاونة الاخيرة تم ايجاد نظم متعددة لمراقبة وصيانة شبكة الطرق ولذلك لمراقبة اداء شبكة الطرق بصورة مستمرة، لتوقع حالة الطرق واحتياجاتها المستقبلية، للمساعدة في التخطيط واتخاذ القرار و لتحديد الحوجة للصيانة الشاملة.

في السودان: يوجد نقص في جانب متابعة الطرق خاصة رصد حفر الطرقات التي قد تمثل خطر مباشر ليس فقط للمركبات، ولكن لسائق المركبة كذلك. الحوجة ملحة لنظام يعالج هذه المشكلة، وهذا المشروع هو مقترح لنظام يقوم برصد حفر الطرقات وتحديد مواقعها عن طريق خطوط الطول والعرض لنظام تحديد المواقع الارضي ومن ثم ارسال موقع الحفر الى قاعدة البيانات او المراقب عن طريق النظام العالمي للاتصالات المحمولة. هذا النظام هو روبوت يعتمد على الموجات فوق الصوتية لتحديد الحفر وعمقها ومن ثم موقعها عن طريق نظام تحديد المواقع واخيرا ارسال الموقع عن طريق النظام العالمي للاتصالات المحمولة.

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LIST OF ABBREVIATIONS

DSP	Digital Signal Processor
FDN	Fixed Dialing Number
GPS	Global Positioning System
GSM	global system for mobile communication
IDE	Integrated Development Environment
IR	Infrared Sensor
ISO	International Organization for Standardization
ISDN	Integrated Services Digital Network
PIC	Peripheral Interface Controller
SMS	Short Message Service
USB	Universal Serial Bus

CHAPTER ONE

INTRODUCTION

1.1 Preface

Urban areas are witnessing rapid growth with the digital transformation and the growing demand for information and communication technologies among individuals, businessmen and governments, which is a driving force of social and economic transformation in various communities around the world. The issue of road development, initially to facilitate transportation and later to enhance road safety and to avoid accidents, has become a priority, prompting countries to launch the "Smart Way" project to facilitate access to information and develop data strategies and analysis to enhance safety for road users.

A pothole is a type of failure in an asphalt road, caused by the presence of water in the underlying soil structure and the presence of traffic passing over the affected area. Introduction of water to the underlying soil structure first weakens the supporting soil. Traffic then fatigues and breaks the poorly supported asphalt surface in the affected area. Continued traffic action ejects both asphalt and the underlying soil material to create a hole in the street. There are not many works that have been done until now, related to the pothole classification.

In one of the research of roads in Khartoum. They pointed out that some of the streets of the capital of Sudan lacked the required specifications on the asphalt side used. Roads are not compatible with a few flaws so far. They stressed the role of maintenance in prolonging the life of the road and maintenance of old forgotten things. Roads in Sudan are not subject to maintenance until it is too late. A study by Ahmed, a consultant for the roads and bridges, confirmed that there was a downfall in the internal roads and that there was some risk due to the obvious defects that cause traffic accidents. The drivers of the economic and financial vehicles suffered damages and tires and spills [1].

1.2 Problem Statement

Potholes presents a serious hazard on the road. Besides causing serious damage to the car (damaging shafts, tires and other parts of the car), most of the traffic accidents are caused by pothole on the roads. The impact of the cars in the pothole reduces the length of the default life of the car leaving the vehicle owner in a series of unavoidable mostly extremely expensive car maintenance sessions. While the frequent car maintenance can be so costly, the attempt to avoid a pothole can be even deadly. An attempt to skip a pothole can cause the driver to go out of track either falling out of road or hitting the cars on the other road lanes.

With thousands of kilometers of roads spread around, and the fact that a pothole is an event that all the causes of are usually available and couldn't be accounted for in a regular format, it becomes hard to detect a pothole whenever one is developed until an accident or another unfortunate event takes place. A detection system is required to allow regular maintenance for such causes of accidence and other road safety hazards.

1.3 Proposed Solution

The most obvious solution to the common event of road potholes (especially with the root cause being hard to treat due to the rain water escaping to the underlying soil of the road causing pothole with constant movement) the solution will be develop an effective method to detect a pothole as soon as one is developed before it come to present a serious hazard to the vehicles and their riders.

With the length of the roads and the relative inaccuracy of human inspection, the electronic technology provided being the pothole detection robot proposed in this project is the best alternative with the ability to program a default check interval and getting exact accurate measurements.

1.4 Aims and Objectives

The general aim of this project is to design a robot that detects pothole in wide road network, and obtains the coordinates of the pothole, its size and the time of detection then send these coordinates to the competent authorities.

Specific Objective

To develop a system that can access remote areas of the road network, can provide accurate measurements and excluded the human inaccuracy due to relevance of the pothole evaluation, to determine a preprogrammed inspection intervals and an effective reporting method. To contribute in the effective planning of the pothole addressing actions and to provide a base for strategic road maintenance planning.

1.5 Significance of the Study

With the aid of this study it could be easier to keep track of new potholes of the road and to identify if the pothole is dangerous or not and to detect its location to be fixed as soon as possible.

1.6 Methodology

The methodology of this project is to design the structure of robot to hold all the robot circuit components, and then the design of the movement of robot based on line following technique where IR sensors are used to detect the line at the side of the road. At the same time there are Ultrasound sensors that continuously sense the distance and pass its signal to the microcontroller and the microcontroller compares between the sensors readings to check if there is a pothole. If a pothole is detected the microcontroller will provide its depth and marks its location by using the GPS attached to the robot and the time and date when it is detected and sends the information to observer through an SMS by using the GSM module.

The project will also include building a robot model equipped with the components above and simulate the movement and detection system of the robot on a prepared road model.

1.6 Thesis Layout

This project consists of five chapters. Chapter one is an overview of the study and its significance. Chapter two discusses the project literature, project basics requirements and related work. Chapter three goes over the details of the project methodology while chapter four is dedicated to the results obtained from the simulation and study and to the discussion of these results. Chapter five goes over the conclusions and recommendations of the project. The thesis has two appendixes covering the design code and description of components.

CHAPTER TWO

LITERATURE REVIEW

This chapter presents a set of theories and concepts in the area of control system design, assembly and construction

2.1 Background

The earliest known industrial robot, conforming to the ISO definition was completed by "Bill" Griffith P. Taylor in 1937 and published in Meccano Magazine, March 1938 [2]. The crane-like device was built almost entirely using Meccano parts, and powered by a single electric motor. Five axes of movement were possible, including grab and grab rotation. Automation was achieved using punched paper tape to energize solenoids, which would facilitate the movement of the crane's control levers. The robot could stack wooden blocks in pre-programmed patterns. The number of motor revolutions required for each desired movement was first plotted on graph paper. This information was then transferred to the paper tape, which was also driven by the robot's single motor. Chris Shute built a complete replica of the robot in 1997 [3].

George Devol applied for the first robotics patents in 1954 (granted in 1961). The first company to produce a robot was Unimation, founded by Devol and Joseph F. Engelberger in 1956, and was based on Devol's original patents. Unimation robots were also called programmable transfer machines since their main use at first was to transfer objects from one point to another, less than a dozen feet or so apart. They used hydraulic actuators and were programmed in joint coordinates. Unimation later licensed their technology to Kawasaki

Heavy Industries and GKN, manufacturing Unimates in Japan and England respectively. For some time Unimation'sonly competitor was Cincinnati Milacron Inc. of Ohio. This changed radically in the late 1970s when several big Japanese conglomerates began producing similar industrial robots [4] .

In 1969 Victor Scheinman at Stanford University invented the Stanford arm, an all-electric, 6-axis articulated robot designed to permit an arm solution. This allowed it accurately to follow arbitrary paths in space and widened the potential use of the robot to more sophisticated applications such as assembly and welding. At the height of the robot boom in 1984, Unimation was acquired by Westinghouse Electric Corporation for 107 million U.S. dollars. Westinghouse sold Unimation to StäubliFaverges SCA of France in 1988, which is still making articulated robots for general industrial and clean room applications and even bought the robotic division of Bosch in late 2004.

2.1.1 Basics of Robotics

Robotics is the branch of technology that deals with the design, construction, operation, and application of robots, as well as computer systems for their control, sensory feedback, and information processing. These technologies deal with automated machines that can take the place of humans in dangerous environments or manufacturing processes, or resemble humans in appearance, behavior, and/or cognition. A robot is a machine capable of physical motion for interacting with the environment. Physical interactions include manipulation, locomotion, and any other tasks changing the state of the environment or the state of the robot relative to the environment. A robot has some form of mechanisms for performing a class of tasks. A rich variety of robot mechanisms has been developed in the last few decades. In this chapter, we will give an overview on the various types of mechanisms used for generating robotic motion.

2.2 Requirements and Components

The main require components for this project are:

Sensor

A sensor is a device that responds to any change in physical phenomena or environmental variables like heat, pressure, humidity, movement etc. This change affects the physical, chemical or electromagnetic properties of the sensors which is further processed to a more usable and readable form. Sensor is the heart of a measurement system. It is the first element that comes in contact with environmental variables to generate an output.

Types of Sensors

- Acoustic and sound sensors e.g. Microphone, Hydrophone.
- Automotive sensors e.g. Speedometer, Radar gun, Speedometer, fuel ratio meter.
- Chemical Sensors e.g. sensor, Sensors to detect presences of different gases or liquids.
- Electric and Magnetic Sensors e.g. Galvanometer, Hall sensor (measures flux density), Metal detector.

- Environmental Sensors e.g. Rain gauge, snow gauge, moisture sensor.
- Optical Sensors e.g. Photo diode, Photo transistor, Wave front sensor.
- Mechanical Sensors e.g. Strain Gauge, Potential meter (measures displacement).
- Thermal and Temperature sensors e.g. Calorimeter, Thermocouple, Thermostat, Garden gauge.

Ultrasonic sensor

An Ultrasonic sensor shown below in figure (4.1) is a device that can measure the distance to an object by using sound waves. It measures 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.

Figure (2.1): Ultrasonic Sensor

The Ultrasonic Sensor sends out a high-frequency sound pulse and then times how long it takes for the echo of the sound to reflect back. The sensor has 2 openings on its front. One opening transmits ultrasonic waves, (like a tiny speaker), the other receives them, (like a tiny microphone).The speed of sound is approximately 341 meters (1100 feet) per second in air. The ultrasonic sensor uses this information along with the time difference between sending and receiving the sound pulse to determine the distance to an object show in figure (2.1).

Microcontroller

A microcontroller is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals , microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications.

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. Some microcontrollers may use four-bit words and operate at clock rate frequencies as low as 4 kHz, for low power consumption (single-digit mill watts or microwatts). Other microcontrollers may serve performance-critical roles, where they may need to act more like a digital signal processor (DSP), with higher clock speeds and power consumption.

Microcontrollers are sometimes called Embedded Microcontrollers, which just means that they are part of a larger device or system unlike a general purpose computer, which also includes all of these components, a microcontroller is designed for a specific task to control a particular system. Microcontrollers are used in a wide number of electronic systems such as: control systems in industries; electronic measurement instruments; printers; mobile phones; security systems; hearing aids; TV; radio; and CD players Interrupts. Microcontrollers must provide real time (predictable, though not necessarily fast) response to events in the embedded system they are controlling.

PIC microcontroller

Peripheral Interface Controller (PIC) provided by micro-chip technology to categorise its solitary chip microcontrollers. These appliances have been extremely successful in 8bits microcontrollers. The foremost cause behind it is that micro-chip technology has been constantly upgrading the appliance architecture and included much require peripherals to the microcontroller to go well with clientele necessities.

AVR microcontroller

AVR also known as Advanced Virtual RISC is a customized Harvard architecture 8-bit RISC solitary chip micro-controller. It was invented in the year 1966 by Atmel. Harvard architecture signifies that program & data are amassed in different spaces and are used simultaneously. It was one of the foremost micro-controller families to employ on-chip flash memory basically for storing program, as contrasting to one-time programmable EPROM, EEPROM or ROM, utilized by other micro-controllers at the same time. Flash memory is a non-volatile (constant on power down) programmable memory.

The project is based on microcontroller board designs, produced by several vendors, using various microcontrollers. These systems provide sets of digital and analogue I/O pins that can interface to various expansion boards (termed shields) and other circuits.

The boards feature serial communication interfaces, including Universal Serial Bus (USB) on some models, for loading programs from personal computers. For programming the microcontrollers, the Arduino project provides an integrated development environment (IDE) based on a programming language named Processing, which also supports the languages, C and C++.

Manufacturers have often produced special versions of their microcontrollers in order to help the hardware and software development of the target system. Originally these other versions may be available where the ROM is accessed as an external device rather than as internal memory, however these are becoming increasingly rare due to the widespread availability of cheap microcontroller programmers.

Arduino microcontroller

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. (see figure (4.3) below), It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega 2560 board is compatible with most shields designed for the Uno and the former boards Duemilanove or Diecimila.

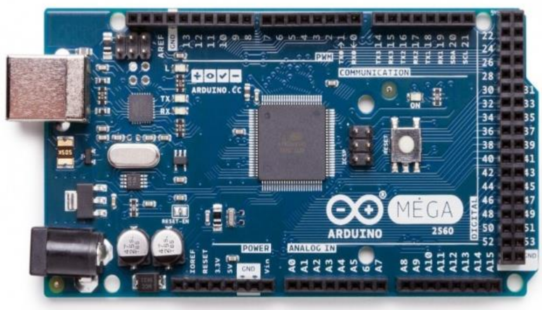

Figure (2.2): Arduino Mega

Microcontroller Applications include

Microcontrollers are intended for embedded devices, in comparison to the microprocessors which are used in PCs or other all-purpose devices. Microcontrollers are employed in automatically managed inventions and appliances like power tools, implantable medical devices, automobile engine control systems, office machines, remote controls appliances, toys and many more embedded systems. By dipping the size and expenditure in comparison to a design that make use of a different microprocessor, I/O devices and memory, microcontrollers formulate it inexpensive to digitally control more & more appliances and operations.

Mixed signal microcontrollers are general; putting together analog constituents required controlling non digital electronic structures.

Application of Microcontroller in Day to Day Life Devices:

- Light sensing & controlling devices
- Temperature sensing and controlling devices
- Fire detection & safety devices
- Industrial instrumentation devices
- Process control devices
- Application of microcontroller in Industrial Control Devices:
    i. Industrial instrumentation devices
    ii. Process control devices
- Application of microcontroller in Metering & Measurement Devices:
    i. Volt Meter
    ii. Measuring revolving objects
    iii. Current meter
    iv. Hand-held metering systems.

GSM module

Is a device which can be either a mobile phone or a modem device which can be used to make a computer or any other processor communicate over a network? A GSM modem requires a SIM card to be operated and operates over a network range subscribed by the network operator .It can be connected to a computer through serial, USB or Bluetooth connection.

A GSM modem can also be a standard GSM mobile phone with the appropriate cable and software driver to connect to a serial port or USB port on your computer. GSM modem is usually preferable to a GSM mobile phone. The GSM modem has wide range of applications in transaction terminals, supply chain management, security applications, weather stations and GPRS mode remote data logging.

Working of GSM Module

A GSM modem duly interfaced to the MC through the level shifter IC Max232. The SIM card mounted GSM modem upon receiving digit command by SMS from any cell phone send that data to the MC through serial communication. While the program is executed, the GSM modem receives command 'STOP' to develop an output at the MC, the contact point of which are used to disable the ignition switch. The command so sent by the user is based on an intimation received by him through the GSM modem 'ALERT' a programmed message only if the input is driven low.

Features of GSM Module

- Improved spectrum efficiency
- International roaming
- Compatibility with integrated services digital network (ISDN)
- Support for new services.
- SIM phonebook management
- Fixed dialling number (FDN)
- Real time clock with alarm management

- High-quality speech
- Uses encryption to make phone calls more secure
- Short message service (SMS)

The security strategies standardized for the GSM system make it the most secure telecommunications standard currently accessible. Although the confidentiality of a call and secrecy of the GSM subscriber is just ensured on the radio channel, this is a major step in achieving end-to- end security [7].

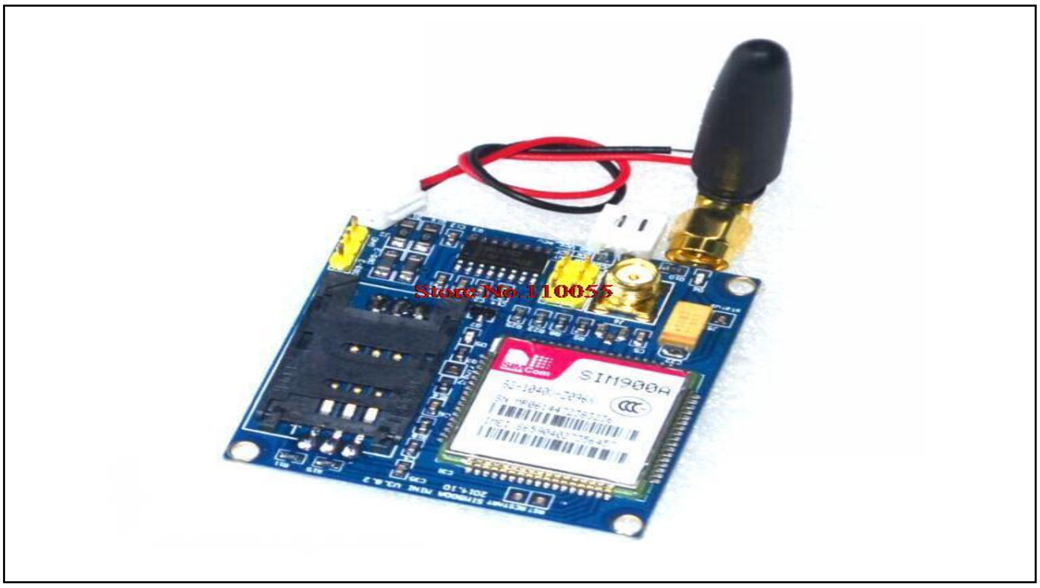

Figure (2.3): GSM Module

GPS

Figure (2.4): GPS Module

Specifications of the GPS

- Power Supply Range: 3 V to 5 V
- Model: GY-GPS6MV2
- Ceramic antenna
- EEPROM for saving the configuration data when powered off
- Backup battery
- LED signal indicator
- Antenna Size: 25 x 25 mm
- Module Size: 25 x 35 mm

- Mounting Hole Diameter: 3 mm
- Default Baud Rate: 9600 bps
-

2.3 Related Works

This part of the thesis outlines a set of theories, concepts and facts from both local and foreign authors, in the area of control system design, assembly and construction. These ideas served as guide in the development of the project. It synthesizes evidence from all the literatures reviewed to get an overall understanding of the state of knowledge of the project undertake.

1madhumathy P, Saurabh Singh, Shivam Shukla and Unni Krishnan, They discovered that most of the car accidents in India occur because of the pothole in the roads because of the lack of attention of the fisherman of the drilling, and used sensors to detect those pothole , and placed these devices in cars moving, and used a technique of gypsum to locate the pothole and put those coordinates to be a reference to be used later For the maintenance of those pothole The proposed system basically serves two purposes; it automatically detects the potholes and humps and sends the information regarding this to the vehicle Drivers, so that they can avoid accidents [5].

Sudarshan Rode, He proposed a design of ‘Pothole detection System’ which assists the driver in avoiding pot-holes on the roads, by giving him prior warnings. Warnings can be like buzzer if the driver is approaching a pothole, or driver may be warned in advanced regarding what road has how many potholes. This system is divided into three subsystems. First is sensing subsystem which senses the potholes encountered by it, about which it did not have the prior information. Then communication subsystem which transfers the information between Wi-Fi access point and mobile node. And finally the localization subsystem which reads the data given by Access points and warns the driver regarding the occurrence of pothole [6].

Chenumalla Harishankar and H.Raghupathi, Design project can conclude that when vehicle was enters into the critical the speed of the vehicle will automatically reduce and after the critical zone the vehicle moves with normal speed. With this project we can reduces the accidents at the critical zonesand we can reduces the speed of the vehicle from rash driving [4].

Nilam Kumbhar, Dipali Mhetre, Amarina Mujawar and S.T.Khot, They proposed system which will detect the potholes on the road and save the information in the server. Due to the rains and oil spills potholes are generated which will cause the accidents. The potholes are detected and its height, depth and size are measured using ultrasonic sensor. The GPS is used to find the location of pothole. All the information is saved in the database. This timely information can help to recover the road as fast as possible. Hence the system will help to avoid road accidents [7].

Mr.K.EdisonPrabhu, has Proposed a system which will detect the potholes on the road and save the information in the server and reduce the vehicle speed if needed. Due to the rains and oil spills potholes are generated which will cause the accidents. The potholes are detected and its height, depth and size are measured using ultrasonic sensor. The GPS is used to find the location of pothole. All the information is saved in the Database. This timely information can help to recover the road as fast as possible. By controlling the rate of fuel injection we can control the rotation of the drive shaft by means of an IR Non-contact tachometer. This helps to reduce the vehicle speed when pothole or hump is detected. Hence the system will help to avoid road accidents [8].

Ascertain whether potholes can be auto-detected using acceleration data collected from vehicle-mounted wireless sensor motes. In this preliminary stage, we investigate only the effects of vertical component (Y) of the recorded acceleration. We established that it is indeed possible to identify the potholes, with a very high degree of accuracy, by analyzing only the vertical acceleration readings. Although the technique we used was very simple, the results we obtained were very encouraging [9].

CHAPTER THREE

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SYSTEM DESIGN

This chapter is discussing the process of conducting the project design and shows the block diagram of the project and how each component is positioned in the system.

3.1 System Design

The study employed the engineering design method. It is a systematic and practical use of investigative findings and theories or technical nature, toward the design, development, testing, evaluation or improvement of useful products to meet specific performance requirements.

Robot structure and movement:

In this design the first step is designing a structure of a robot to hold all the components needed for the robot and the circuit of the robot, then the design of the robot's movement which is based on Line Following technique where an IR sensor is used to detect the line at the side of the road and it gives a signal according to the color that it receives, the robot is designed to make use of the lines already drawn to indicate the end of the rood hence make this design easy to adopt in application. The signal generated is then fed to the microcontroller to analyze it and then produce an action in the form of motors movements to follow the line.

The design includes 2 IR sensors those read the darker side of the road. When the robot deviates from its track and one of the sensors detects the lighter color of the road, it automatically signals the micro controller to adjust the movement directions. The robot is also equipped with obstacles detection function which consists of an ultrasonic sensor fixed to the front of the robot, whenever the sensor detects an object in front of the robot, it signals the robot to stop movement.

Pothole detection:

At the same time of the robot movement, there are Ultrasound sensors that continuously sense the distance from the sensors to the floor and pass their signal to the microcontroller and the microcontroller compares between the sensors readings to check if there is a pothole. If a pothole is detected the microcontroller will provide its depth and marks it location by using the GPS attached to the robot and the time and date when it is detected and send these information to the database through an SMS by using the GSM module.

The robot will be equipped with 3 ultrasonic sensors attached at a fixed distance from the floor with that distance being the robot zero point. All sensors readings are compared at regular bases. The robot detects potholes whenever readings on the sensors vary or exceed the predetermined robot zero point.

The robot will be programmed to identify three levels of pothole based on the depth of each pothole. The message sent by the GSM will include information regarding pothole classification based on the preprogrammed range, the exact reading of the pothole depth and the coordinates using GPS.

3.2 Block Diagram

The block diagram contains blocks connected together by lines to show the relationship of the blocks, each block of them describes the circuit components used in the research. The following block diagram shown below in figure (3.1) is the block diagram used in the design.

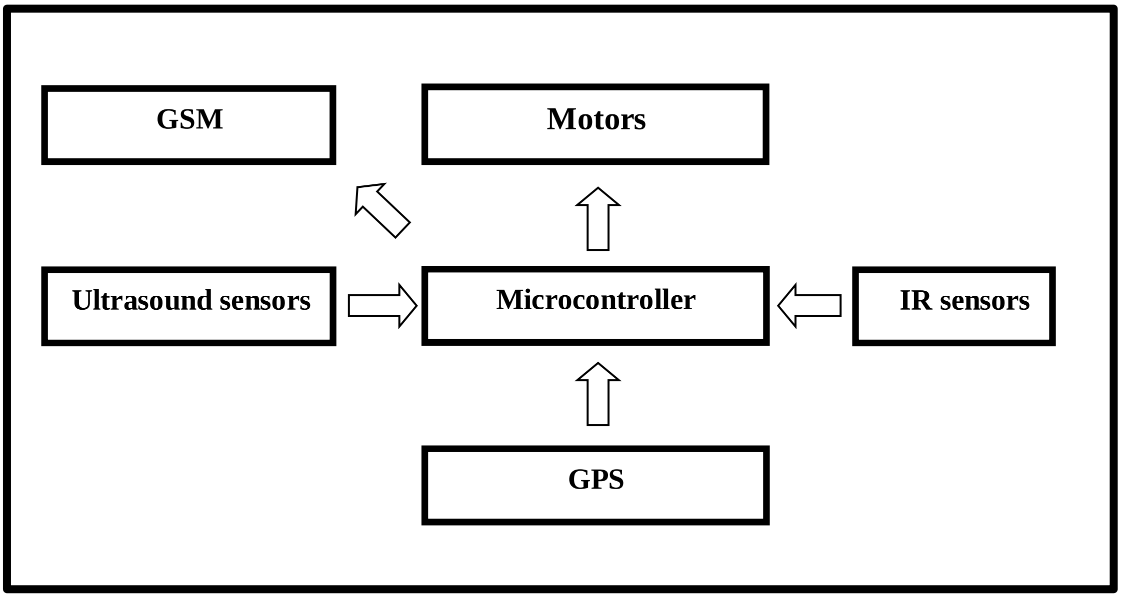
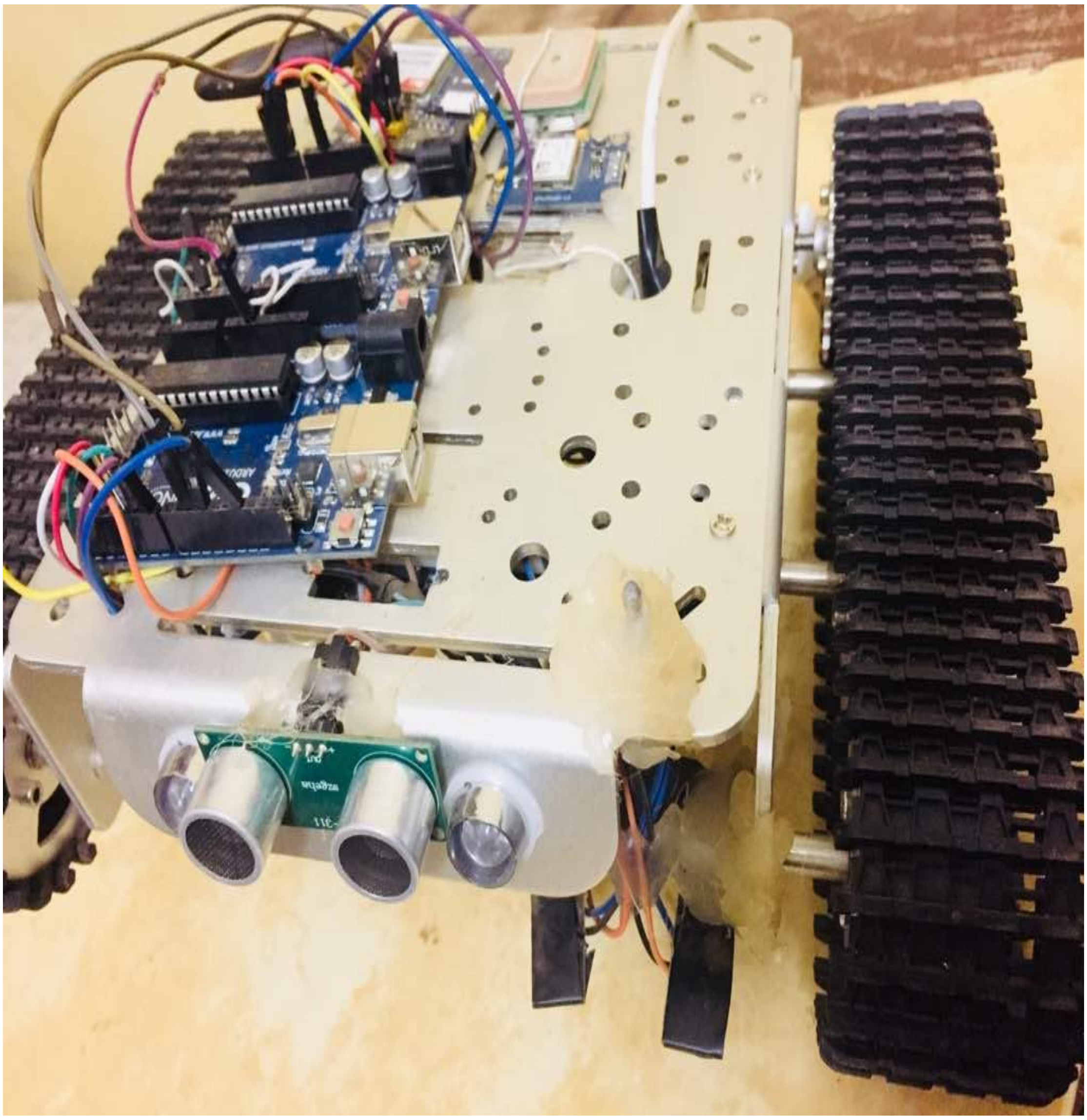


Figure (3.1): Block Diagram of Project

In this block diagram first there are the IR sensors to control the movement of the robot and continuously feed its signal to the microcontroller when the robot is moving to guide the robot to follow the line, second there are three Ultrasound sensors that are used as a distance measuring sensors to detect the pothole and its depth and also continuously feed the signal to the microcontroller to process it. Then if a pothole is detected, the GPS gives its location and sends the location and pass it to the microcontroller and the microcontroller will pass the information to the GSM in order to send that location of the pothole.

3.3 Implementation

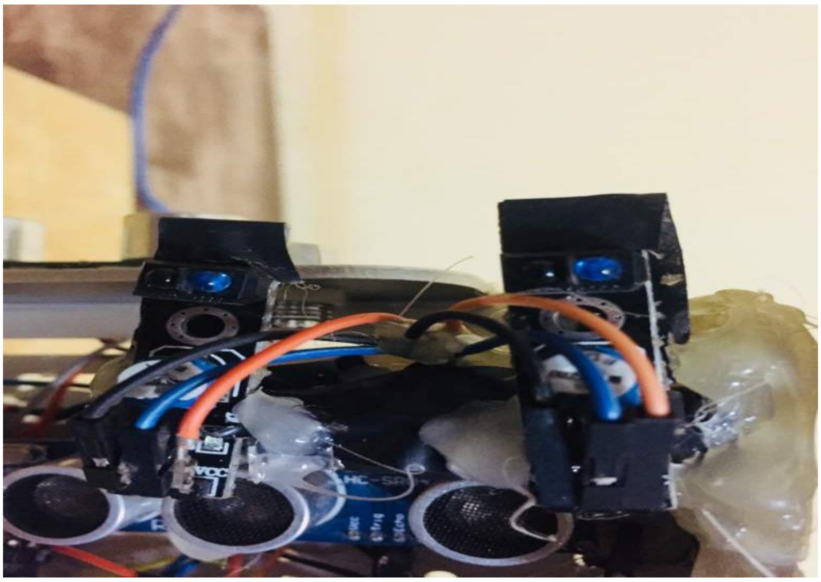
The implementation of the device made by the local resources and from the available market with ease, then the development of the robot prototype structure is done with reasonable cost due to the availability of all the component of the frame and the electronic component. An image of the robot is shown below in Fig. 3.2 where it shows the structure of the robot and the electronic component that the device is consisting of.



The Figure (3.2): Structure of the System

3.3.1 The Line Following Sensors

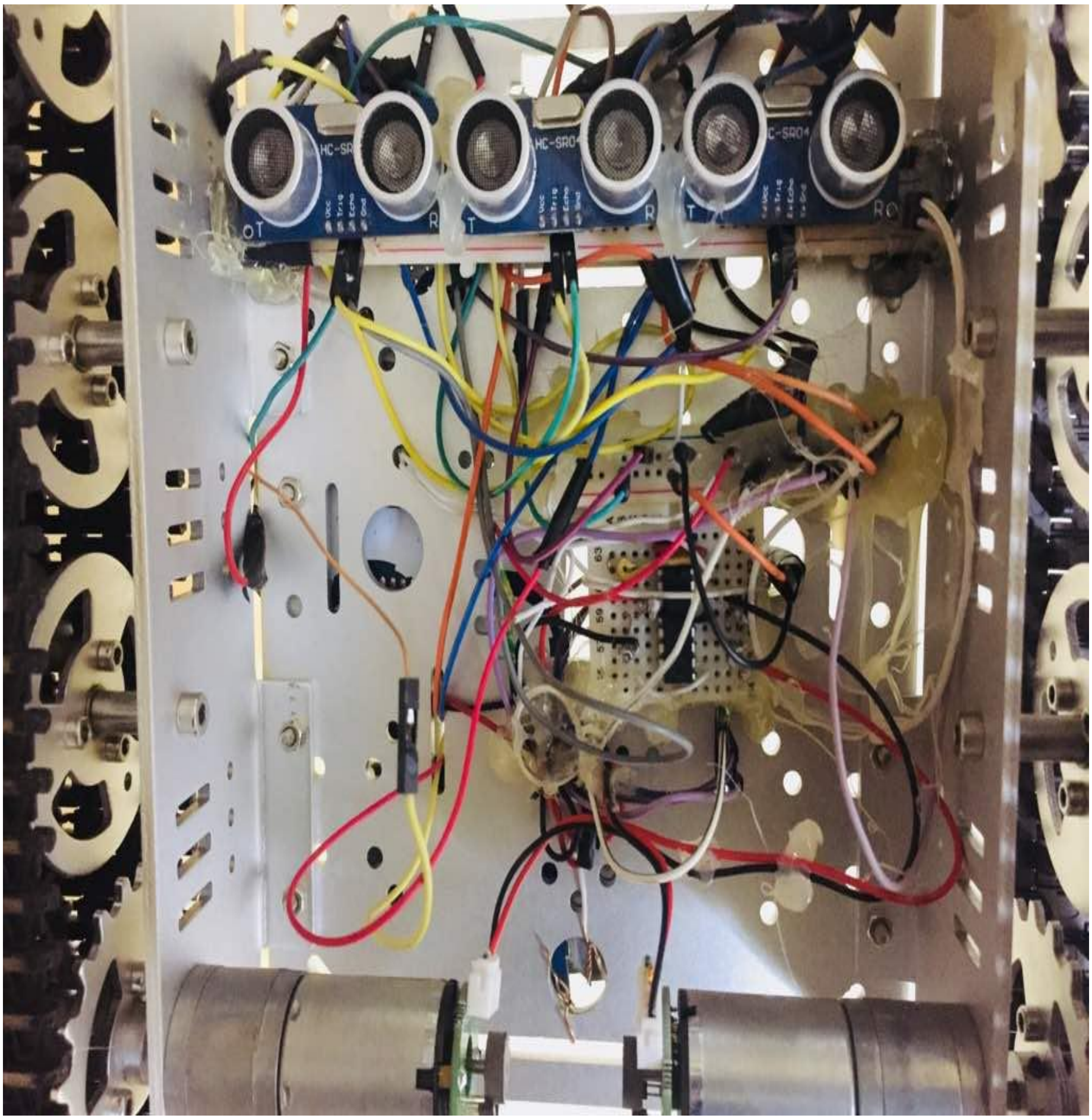
The line following sensor shown below in Fig. 3.3 is composed of two IR sensor where this senor has the ability to differentiate between the colors according to the amount of the IR received by the IR receiver build in the sensor, the distance between the two sensor is the width of the yellow line of the road which mean that the line is placed between the sensor. When the robot is moving the IR sensor continuously send its reading to the microcontroller which analyses the reading to guide the robot based on this readings. When the amount of the IR received is low than the threshold set in the code that means the sensor is on the yellow line and the microcontroller activate the opposite turn through the motor to set the robot on the track again. The other state when the sensor on the black which is the asphalt of the road the IR sensor output is high and the microcontroller will activate the move forward when both the sensor reading is high "asphalt".



The Figure (3.3): IR sensors

3.3.2 The Ultrasound Sensor

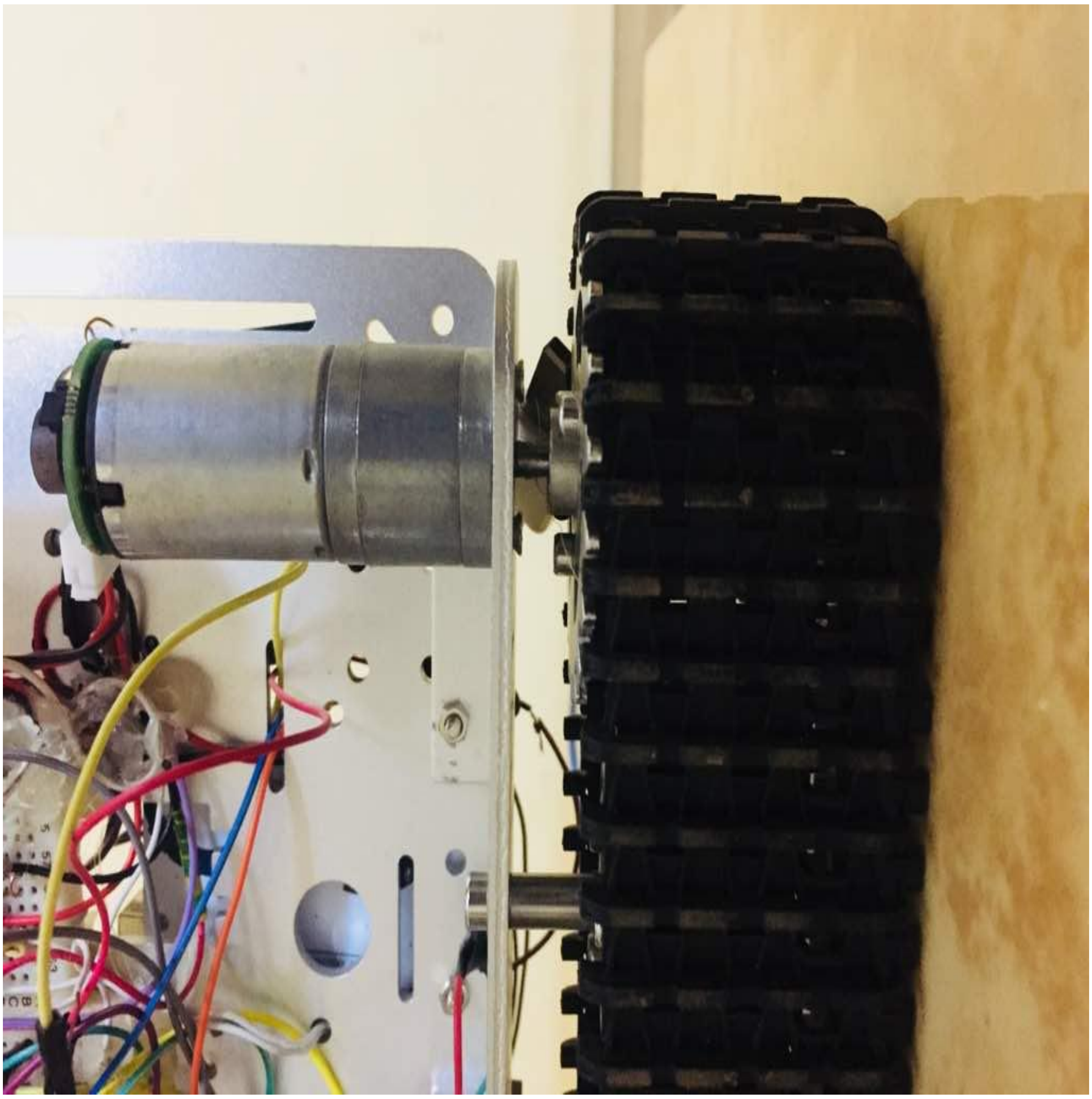
The ultrasound sensors shown below Fig. 3.4 are used to check the distance from the structure of the robot to the ground which is the asphalt of the road. The ultrasound sensor fed a signal with the distance to the microcontroller in which the microcontroller analysis the distances from the three ultrasound and compare the reading to find out if there is a hole in the ground by which if the difference between two of the sensors reading is high.



The Figure (3.4): Ultrasonic Sensor of Robot

3.3.3 The Motors

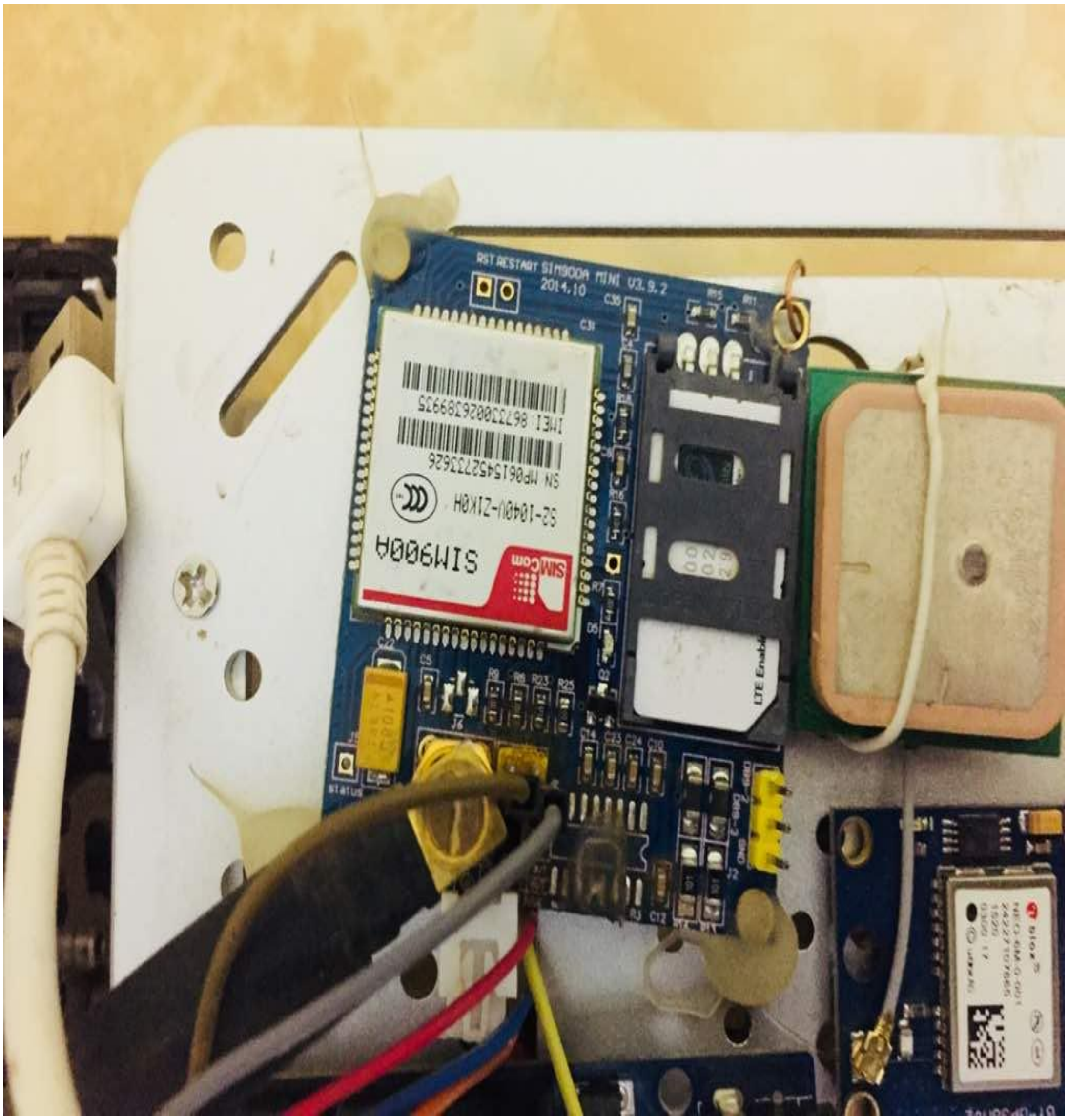
The motor shown below in Fig. 3.5 is a geared DC motor which is used to give a motion to the robot structure. The motor found at left and the right side of the structure receive a signal to operate from the microcontroller in which the microcontroller give a signal based of the IR sensor reading to activate the left motor in case of the need of a right turn or the right motor in case of a need of a left turn or both of the motors in case of the need of a forward movement.



The Figure (3.5): Geared DC Motor the robot

3.3.4 GPS and GSM of the System

The Fig. 3.6 shown below shows the GPS module of the system which is continuously monitor the location of the robot, and when a pothole is detected by the ultrasound sensors the GPS module fed a signal to the microcontroller with the location of the robot and the microcontroller send this location to the observer through the GSM module.

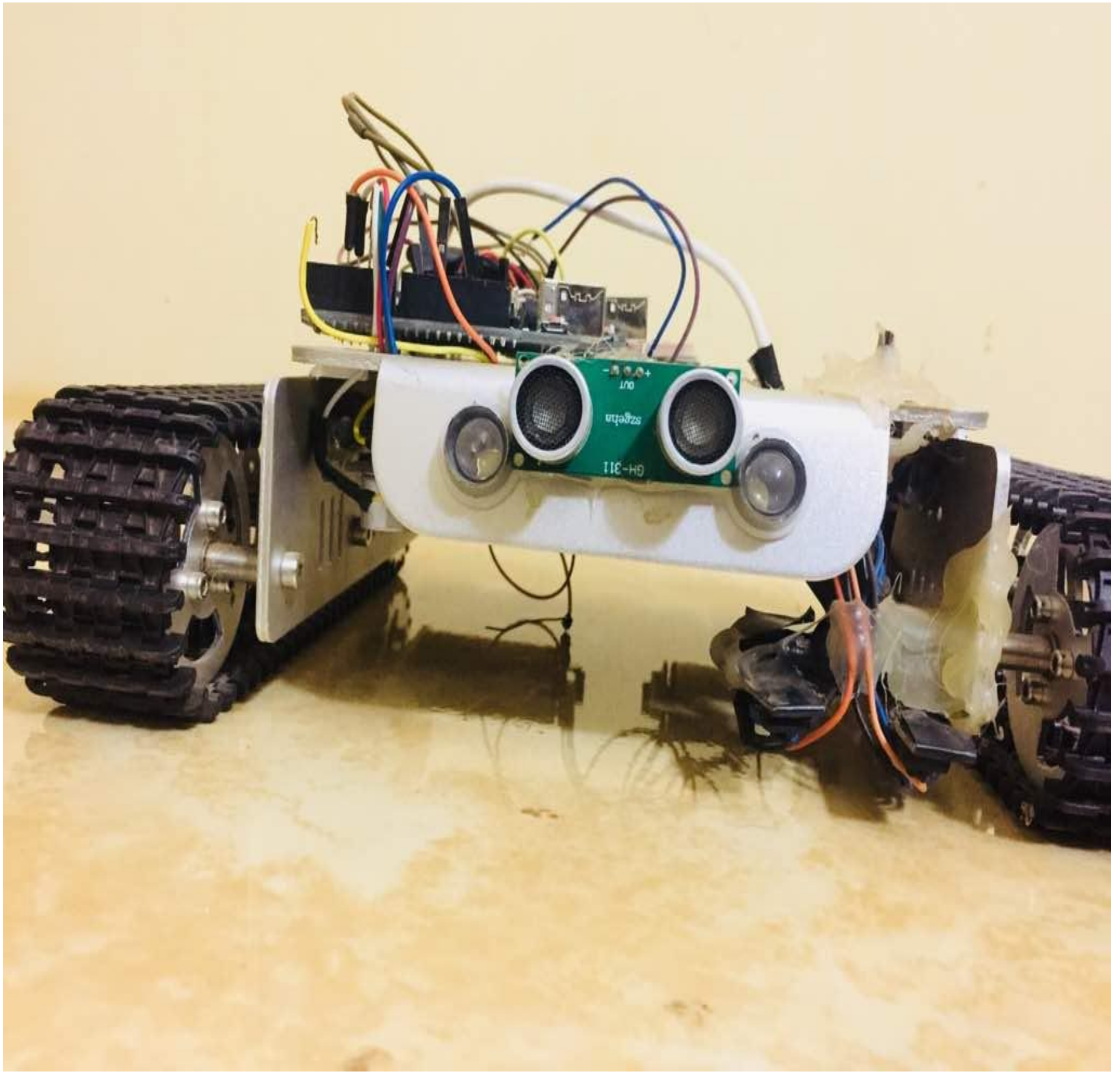


The Figure (3.6): GPS and GSM of system

3.3.5 Object Detection and Lighting

The Fig 3.7 shown below shows an ultrasound sensor placed at the front of the robot and it is used to monitor the front of the robot when the robot moves forward and it is used to stop the robot if there is any object in the robot way.

The lighting are used to alert when there is object inform of the robot and it is also used on the night to make the robot seen by the other cars since the robot can be operate at night.



The Figure (3.7): Object Detection and Lighting

The modified model has two controllers:

Controller one includes the IR sensors, one ultrasonic sensor for obstacle detection and the movement motor. The other controller includes the three pothole detection ultrasonic sensors, the GPS and the GSM. A flow chart for the final model is down below.

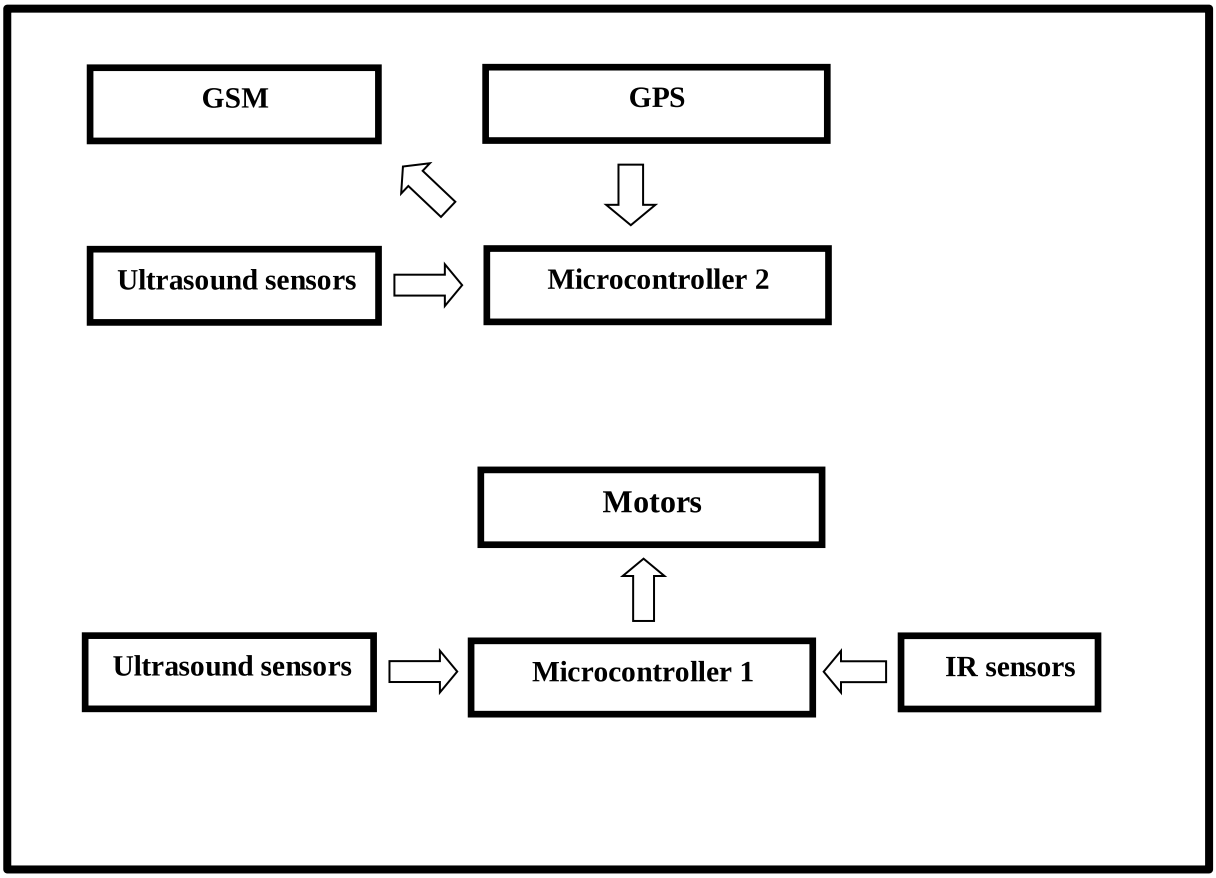


Figure (3.8): Modified Block Diagram of Project

CHAPTER FOUR

RESULTS AND DISCUSSION

In this chapter the design and simulation of robot is included, and also include the simulation software hardware and the simulation steps.

4.1 Design of Hardware

The following is the circuit diagram of the robot where it shows all of the components connected together and work as a one device where the Arduino is the brain of the device and it controls all of the inputs and outputs. Here in figure (4.1) the inputs are coming from the Ultrasound sensor to detect the pothole and its depth and the GSM and GPS are connected to the Arduino to send and detect the location respectively. Then figure (4.2) shows the connection of the IR sensors that are used to guide the movement of the robot and also shows the connection of the motors that are used in the wheels of the robot.

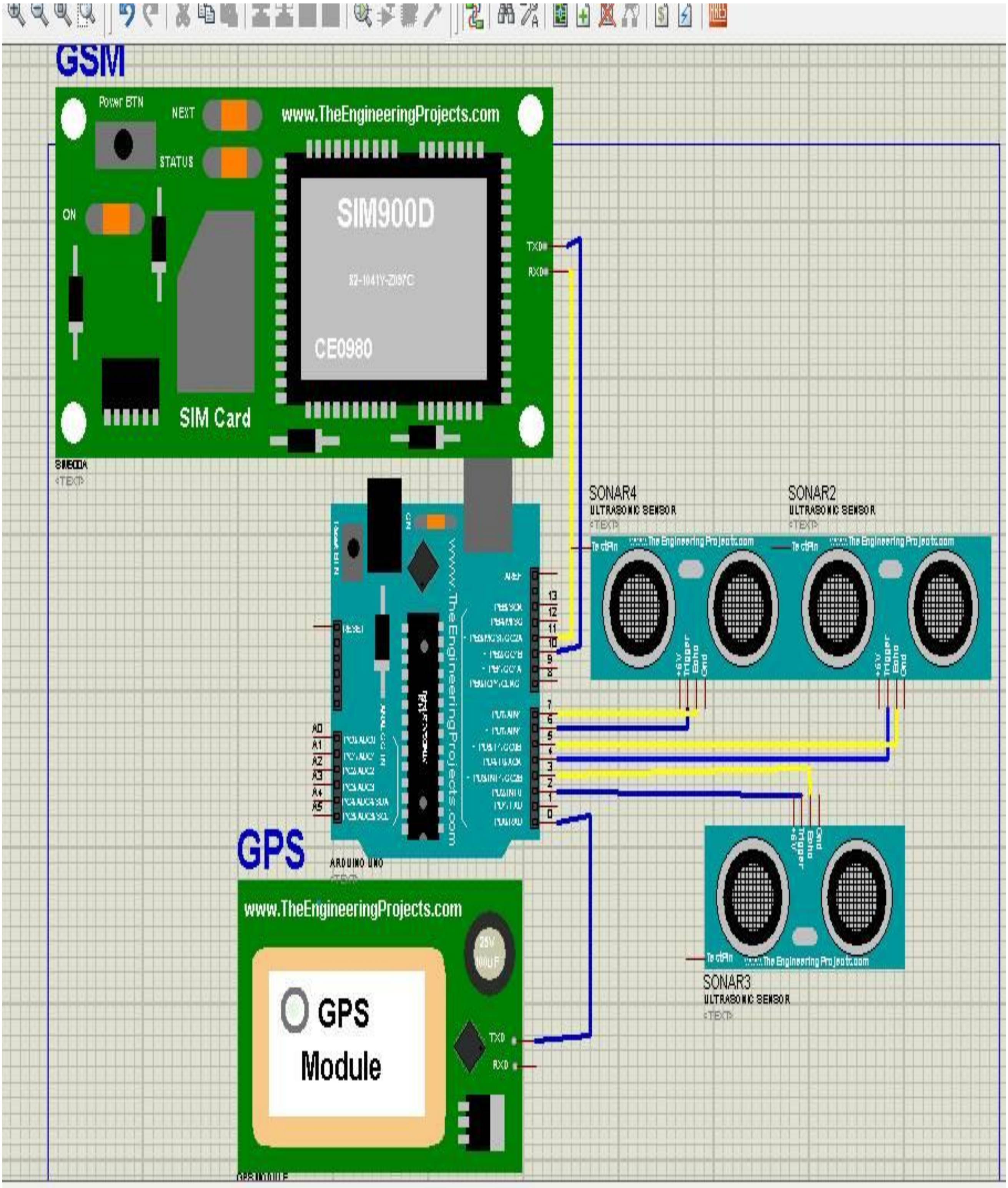


Figure (4.1): GSM, GPS and Ultrasound Circuit

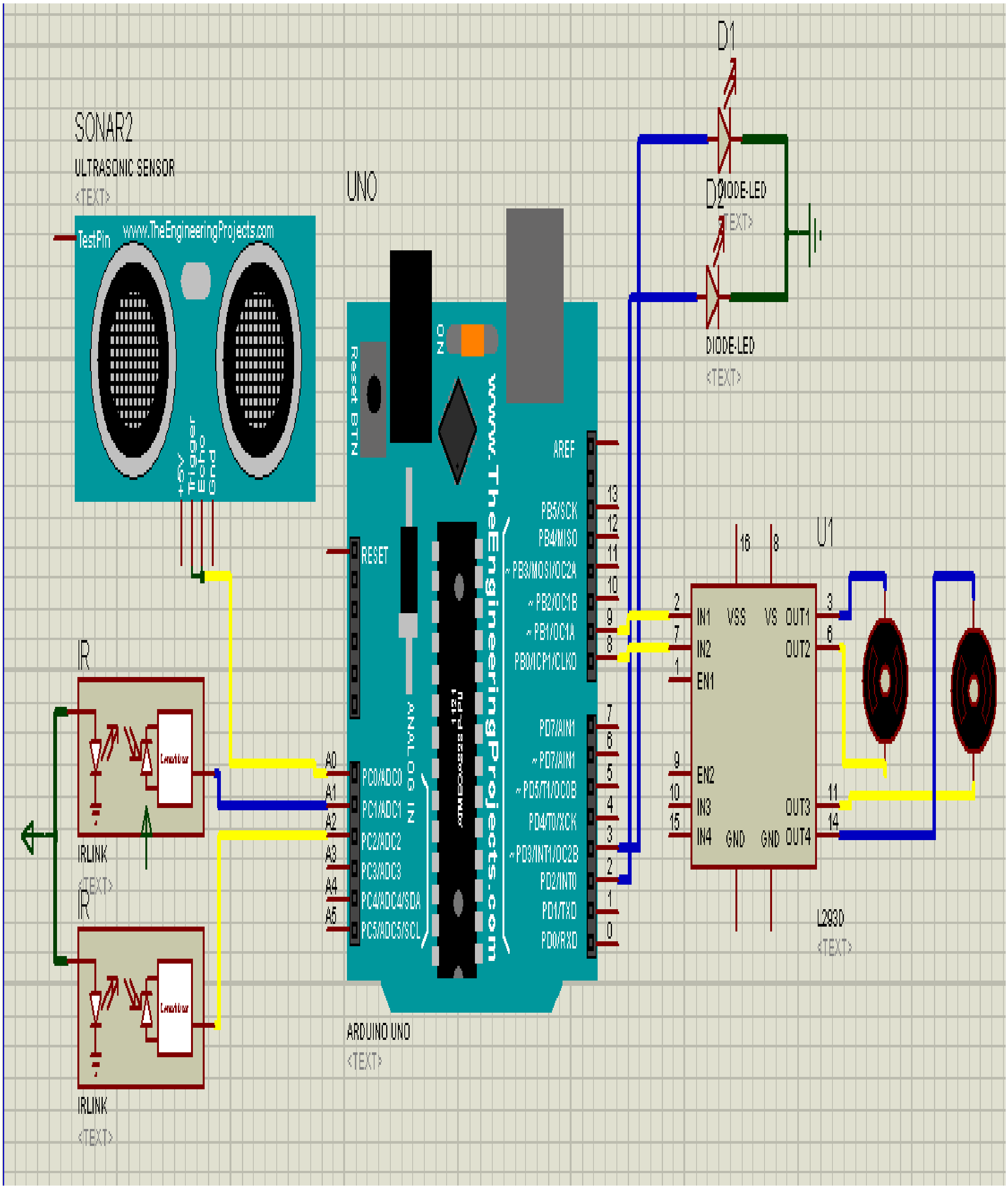


Figure (4.2): IR and Motors Circuit

4.2 Design of Software

The software of the device is code by the Arduino application which allows the user to write sketch for the code and upload it to the device. The software design by a modified language from the C or the C++, a copy of the source code is provided at the appendix A.

4.3 Simulation of robot movement and pothole detection:

4.3.1 Simulation set-up:

This experiment has been set to simulate the pothole detector robot both movement and detection technique to insure the optimum performance of the system when put to large scale application.

4.3.1.1 Robot movement set-up:

The experiment model was sat on an approximately 1.5 meters long triangular wooden board. The board was painted black to simulate an asphalt road with two parallel white lines those simulate the end of the road line and the middle line. The lines are drawn at a distance equivalent to that of the two IR sensors hence the robot will be occupying on path of the rood at each designed movement path and will cover half the rood at each direction which will eventually means full coverage of the street.

4.3.1.2 Potholes detection set-up:

Robot was designed to report potholes with three different classifications (small, medium and large). The small pothole is detected on a height of five centimetres from the sensors. Given that the height of the sensors from ground level is three centimetres and one more centimetre is allowed for road finishing in order to avowing the creation of false results, hence it means that only distance over 4 centimetres will be reported. On this programming; the depth of the small pothole is one centimetre. Medium potholes are detected on a distance of 6 centimetres equivalent to a depth of 2 centimetres and the large potholes is reported on any distance more than 6 centimetres. Pothole depth is reported by the distance from the sensors while the width of the pothole is evaluated by the number of sensors the pothole was detected by meaning a pothole of a small width will be detected by one sensor. One extended will be detected by two sensors and if three sensors has detected a pothole in the same location, it means the pothole is extended to the full width of the road path.

On the simulation wooden board, seven holes were made with different positions and depths: Three holes (H1, H2, H3) of one centimetre each with a width detectable by one sensor, one hole (H4) of a two centimetre depth detectable by two sensors, two holes (H5, H6) of three centimetres depth detectable by one sensor each and one hole (H7) of three centimetres depth detectable by three sensors.

4.3.2 Simulation output:

Holes H1, H2, H3: H1 was detected by sensor number 1, H2 by sensor number 2 and H3 by sensor number 3. Each hole was reported as a small pothole with a distance of 5 centimetres from the sensors. See screen capture below.

Figure (4.3): System Report of H1

Figure (4.4): system report of H2

Figure (4.5): system report of H3

Hole H4 was detected by sensor number 1 and sensor number 2. The hole was reported as a medium pothole with a distance of 6 centimetres from the sensors. See screen capture below.

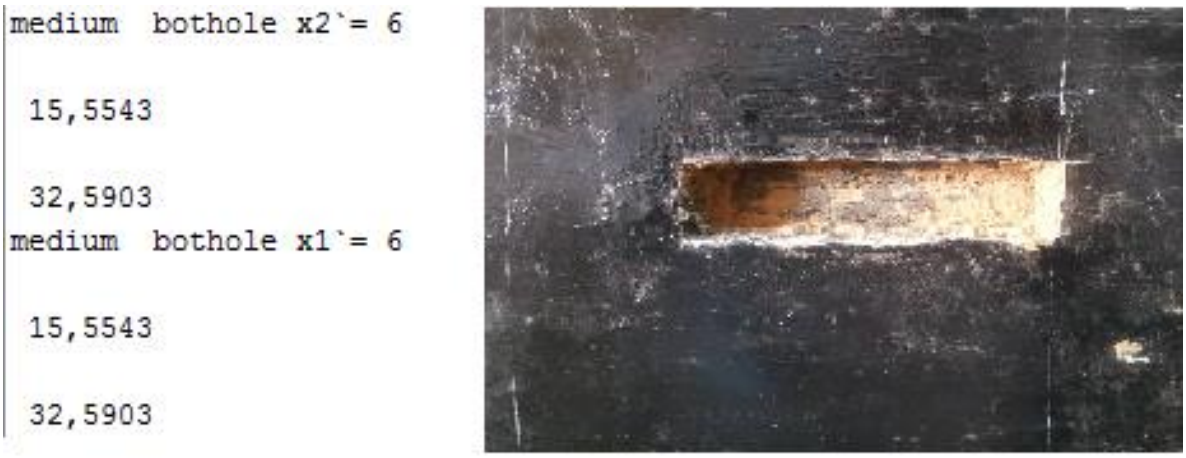


Figure (4.6): system report of H4

Holes H5, H6: H5 was detected by sensor number 2 and H6 by sensor number 3. Each hole was reported as a large pothole. See screen capture below.

Figure (4.7): system report of H5

Figure (4.8): system report of H6

Hole H7 was detected by sensor number 1, sensor number 2 and sensor number 3. The hole was reported as a large pothole. See screen capture below.

```
large  bothole x1`= 74

 15,5543

 32,5903
large  bothole x3`= 72

 15,5543

 32,5903
large  bothole x2`= 72

 15,5543

 32,5903
```

Figure (4.9): system report of H7

4.4 Results and Discussion

System was consisting of 2 IR sensors for movement control, 3 ultrasonic sensors for pothole detection and one ultrasonic sensor for obstacles detection. The system included 1 micro controller, GPS and a GSM.

After connecting the system, the robot movement and detection system was tested using a simulation of the road by painting a piece of wood to look like and asphalt street and contains holes with three sizes (1 cm, 2 cm and 3 cm). The device showed that it is able to move and follow the line by using the IR sensors built on the structure of the robot which are placed on the left and right sides of the yellow line of the road. Robot was able to detect pothole by using the ultrasound sensors that are used to measure the depth of the pothole (built in sensors can detect different depth ranging from 0.01 cm to even 50 cm with a precision of 0.01 cm) and was able to send an SMS by using the GSM with the location of the pothole by using the GPS module.

Ultrasonic sensors were installed at a height of 3 cm programmed as the detector zero point. When the robot detected the 1 cm hole (4 cm distance from the sensors) the robot reported small sized pothole and in the same way medium size with 2 cm deep hole and large with 3 cm deep. When one of the sensors gets a different reading than the others the system reports a pothole and if a robot tires falls into a hole and it makes the body of robot go of balance hence different readings of height are read by the sensors the root will also report a pothole which means the robot can detect different sizes of potholes.

The report sent by the system included the pothole classification (small, medium or large), the depth of the pothole and the location using the GPS coordinates with the date and time of the reading.

It was noted through the simulation the ultrasonic sensors took much time to process and affected the robot movement. The robot will stop until the ultrasonic sensors reading have been processed, hence the potholes detection system was separated and placed on a different controller than the movement system in order to speed up the data processing without affecting either function (detection or movement).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This project presented a device that can help in improving the infrastructure of the cities by detecting the locations of potholes to be fixed. The device is simple in structure and uses the road lines already available as movement system which makes the device easier to adopt in regular operation. And also works as a solution to prevent damage to cars and risks to humans who are in the cars and people in the roads.

The detection system and the movement system should be placed on different microcontrollers so no function would affect the efficiency of the other and the robot movement and potholes detection function could run smoothly.

The reporting system could be designed to report different classification of potholes alongside the depth to the potholes which is of benefit to the observer because each class can have a different action.

The robot can detect potholes outside the range of the sensors up to the length of the robot body.

5.2 Recommendations

It is recommended to use more powerful motor to be able to use bigger robot structure to detect bigger size pothole where this design as a prototype and is small and also to add more options to the robot to be more user interface friendly and to add cameras to take pictures of the pothole. And also it can be added a camera to be as a guide for the robot movement which can give more flexible movement for the robot. And also it is recommended to add more part to the robot to be able to fix the pothole whenever it is detected. Ultrasonic sensor on a higher altitude can be used to detect potholes in the middle of the street.

References

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APPENDIX A

Source Code of the Project

1. Ultrasound and Motor Code

```
void setup() {
pinMode(A0, INPUT); // ULTRSONE  SENSOR 0
pinMode(A1, INPUT); // IR SENSOR 1
pinMode(A2, INPUT);// IR SENSOR
pinMode(8, OUTPUT);// MOTOR 1
pinMode(9, OUTPUT);// MOTOR 2
pinMode(2, OUTPUT);// LED 1
pinMode(3, OUTPUT);// LED 2
  // put your setup code here, to run once:
}
void loop() {
if(digitalRead(A0)==LOW)
  {
if(digitalRead(A1)==LOW&&digitalRead(A2)==LOW)
  {
digitalWrite(8, LOW);
digitalWrite(9, LOW);
}
if(digitalRead(A1)==HIGH&&digitalRead(A2)==LOW)
{
digitalWrite(8, HIGH);
digitalWrite(9, LOW); }

if(digitalRead(A1)==LOW&&digitalRead(A2)==HIGH)
  {
digitalWrite(9, HIGH);
```

```
digitalWrite(8, LOW);
}
if(digitalRead(A1)==HIGH&&digitalRead(A2)==HIGH)
    {
digitalWrite(8, HIGH);
digitalWrite(9, HIGH);
 }
 }
if(digitalRead(A0)==HIGH)
    {
digitalWrite(8, LOW);
digitalWrite(9, LOW);
digitalWrite(2, HIGH);
digitalWrite(3, HIGH);
delay(100);
digitalWrite(2, LOW);
digitalWrite(3, LOW);
delay(100);    }
    }
```

2. System Code

```
#include <TinyGPS++.h>
#include <SoftwareSerialh>
SoftwareSerialmySerial( 10, 11 );
TinyGPSPlusgps;
#define trigPin 2
#define echoPin 3
#define trigPin1 4
#define echoPin1 5
#define trigPin2 6
```

```
#define echoPin2 7

void setup()

{

Serial.begin(9600);

mySerial.begin(9600);

pinMode(trigPin, OUTPUT);

pinMode(echoPin, INPUT);
pinMode(trigPin1, OUTPUT);

pinMode(echoPin1, INPUT);

pinMode(trigPin2, OUTPUT);

pinMode(echoPin2, INPUT);

}

void loop()

{

long duration,  distance;

long duration1,distance1;

long duration2,distance2;

 //////////////////////////////////////////////

digitalWrite(trigPin, LOW);  // Added this line

delayMicroseconds(2); // Added this line

digitalWrite(trigPin, HIGH);

//  delayMicroseconds(1000); - Removed this line

delayMicroseconds(10); // Added this line

digitalWrite(trigPin, LOW);

duration = pulseIn(echoPin, HIGH);

distance = (duration/2) / 29.1;

delayMicroseconds(500);

////////////

digitalWrite(trigPin1, LOW);  // Added this line
```

```
delayMicroseconds(2); // Added this line
digitalWrite(trigPin1, HIGH);
//  delayMicroseconds(1000); - Removed this line
delayMicroseconds(10); // Added this line
digitalWrite(trigPin1, LOW);
  duration1 = pulseIn(echoPin1, HIGH);
  distance1 = (duration1/2) / 29.1;
delayMicroseconds(500);
/////////////
digitalWrite(trigPin2, LOW);  // Added this line
delayMicroseconds(2); // Added this line
digitalWrite(trigPin2, HIGH);
//  delayMicroseconds(1000); - Removed this line
delayMicroseconds(10); // Added this line
digitalWrite(trigPin2, LOW);
  duration2 = pulseIn(echoPin2, HIGH);
  distance2 = (duration2/2) / 29.1;
delayMicroseconds(500);
////////////////////////////////////////
int x1 = distance;  //ULTRSONE  SENSOR 1
int x2 = distance1; //ULTRSONE  SENSOR 2
int x3 = distance2; //ULTRSONE  SENSOR 3
if (x1 > 4 )   //loop of ULTRSONE  SENSOR 1
{
if( x1 == 5 )
  {
mySerial.available();
Serial.write(mySerial.read());
mySerial.println("AT+CMGF=1");    //Sets the GSM Module in Text Mode
```

```
delay(1000);  // Delay of 1000 milli seconds or 1 second

mySerial.println("AT+CMGS=\"+249961797368\"\r");  // Replace x with mobile number

delay(1000);

mySerial.print("smalbothole ");

mySerial.print("x1`= ");

mySerial.println(x1);

mySerial.println(gps.location.lng(), 6);

mySerial.println(gps.location.lat(), 6);

mySerial.println((char)26);// ASCII code of CTRL+Z

delay(1000);

  }

if( x1 == 6 )

  {

mySerial.available();

Serial.write(mySerial.read());

mySerial.println("AT+CMGF=1");    //Sets the GSM Module in Text Mode

delay(1000);  // Delay of 1000 milli seconds or 1 second

mySerial.println("AT+CMGS=\"+249902888399\"\r");  // Replace x with mobile number

delay(1000);

mySerial.print("medium  bothole ");

mySerial.print("x1`= ");

mySerial.println(x1);


mySerial.println(gps.location.lng(), 6);

mySerial.println(gps.location.lat(), 6);

mySerial.println((char)26);// ASCII code of CTRL+Z

delay(1000);

  }
```

```
if( x1 > 6 )
  {
mySerial.available();
Serial.write(mySerial.read());
mySerial.println("AT+CMGF=1");    //Sets the GSM Module in Text Mode
delay(1000);  // Delay of 1000 milli seconds or 1 second
mySerial.println("AT+CMGS=\"+249902888399\"\r");  //  Replace  x  with  mobile
number
delay(1000);
mySerial.print("large  bothole ");
mySerial.print("x1`= ");
mySerial.println(x1);
mySerial.println(gps.location.lng(), 6);
mySerial.println(gps.location.lat(), 6);
mySerial.println((char)26);// ASCII code of CTRL+Z
delay(1000);
  }
}
///////
if (x3 > 4 )  ////loop of ULTRSONE  SENSOR 3
{
if( x3 == 5 )

  {

mySerial.available();
Serial.write(mySerial.read());
mySerial.println("AT+CMGF=1");    //Sets the GSM Module in Text Mode
delay(1000);  // Delay of 1000 milli seconds or 1 second
mySerial.println("AT+CMGS=\"+249902888399\"\r");  //  Replace  x  with  mobile
number
```

```
delay(1000);
mySerial.print("smalbothole ");
mySerial.print("x3`= ");
mySerial.println(x3);
mySerial.println(gps.location.lng(), 6);
mySerial.println(gps.location.lat(), 6);
mySerial.println((char)26);// ASCII code of CTRL+Z
delay(1000);
  }
if( x3 == 6 )
  {
mySerial.available();
Serial.write(mySerial.read());
mySerial.println("AT+CMGF=1");    //Sets the GSM Module in Text Mode
delay(1000);  // Delay of 1000 milli seconds or 1 second
mySerial.println("AT+CMGS=\"+249902888399\"\r");  //  Replace  x  with  mobile
number
delay(1000);
mySerial.print("medium  bothole ");
mySerial.print("x3`= ");
mySerial.println(x3);
mySerial.println(gps.location.lng(), 6);

mySerial.println(gps.location.lat(), 6);
mySerial.println((char)26);// ASCII code of CTRL+Z
delay(1000);
  }
if( x3 > 6 )
  {
mySerial.available();
```

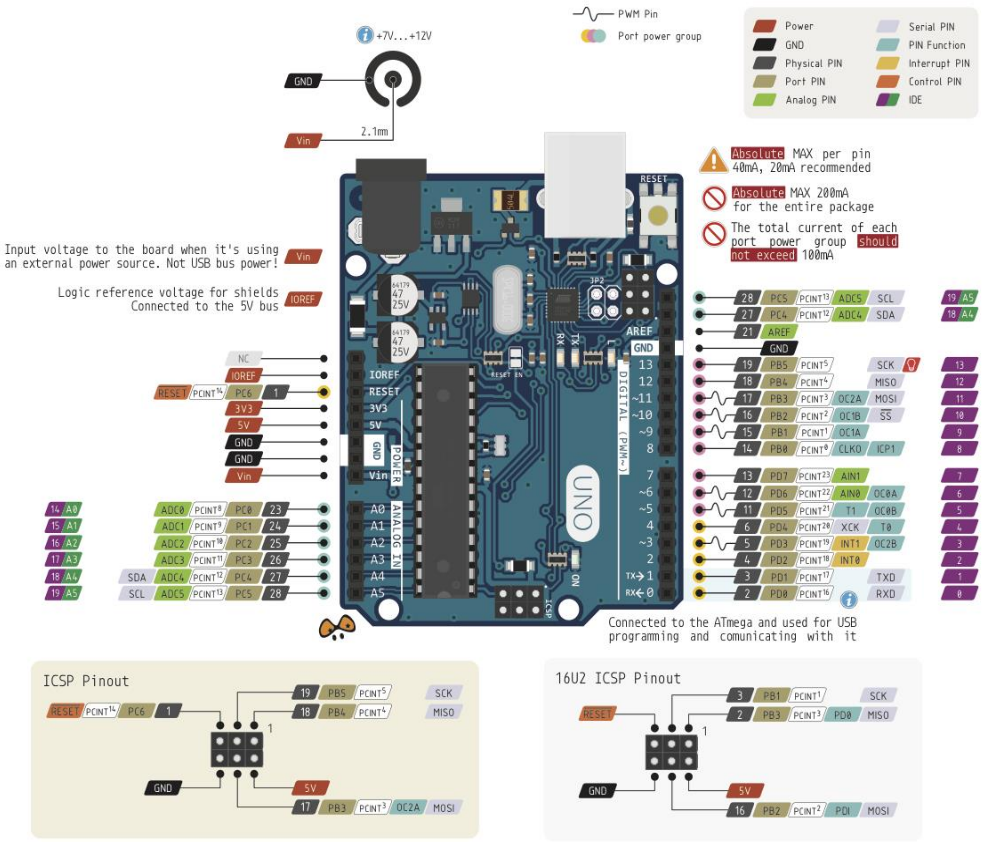
```
Serial.write(mySerial.read());
mySerial.println("AT+CMGF=1");    //Sets the GSM Module in Text Mode
delay(1000);  // Delay of 1000 milli seconds or 1 second
mySerial.println("AT+CMGS=\"+249902888399\"\r"); // Replace x with mobile
number
delay(1000);
mySerial.print("large  bothole ");
mySerial.print("x3`= ");
mySerial.println(x3);
mySerial.println(gps.location.lng(), 6);
mySerial.println(gps.location.lat(), 6);
mySerial.println((char)26);// ASCII code of CTRL+Z
delay(1000);
  }
}
//////
if (x2 > 4 )  ////loop of ULTRSONE  SENSOR 2
{
if( x2 == 5 )
  {
mySerial.available();
Serial.write(mySerial.read());
mySerial.println("AT+CMGF=1");    //Sets the GSM Module in Text Mode
delay(1000);  // Delay of 1000 milli seconds or 1 second
mySerial.println("AT+CMGS=\"+249902888399\"\r"); // Replace x with mobile
number
delay(1000);
mySerial.print("smalbothole ");
mySerial.print("x2`= ");
mySerial.println(x2);
```

```
mySerial.println(gps.location.lng(), 6);

mySerial.println(gps.location.lat(), 6);

mySerial.println((char)26);// ASCII code of CTRL+Z

delay(1000);

  }

if( x2 == 6 )

  {

mySerial.available();

Serial.write(mySerial.read());

mySerial.println("AT+CMGF=1");    //Sets the GSM Module in Text Mode

delay(1000);  // Delay of 1000 milli seconds or 1 second

mySerial.println("AT+CMGS=\"+249902888399\"\r"); // Replace x with mobile number

delay(1000);

mySerial.print("medium  bothole ");

mySerial.print("x2`= ");

mySerial.println(x2);

mySerial.println(gps.location.lng(), 6);

mySerial.println(gps.location.lat(), 6);

mySerial.println((char)26);// ASCII code of CTRL+Z

delay(1000);


  }
if( x2 > 6 )

  {
mySerial.available();

Serial.write(mySerial.read());

mySerial.println("AT+CMGF=1");    //Sets the GSM Module in Text Mode

delay(1000);  // Delay of 1000 milli seconds or 1 second

mySerial.println("AT+CMGS=\"+249902888399\"\r"); // Replace x with mobile number
```

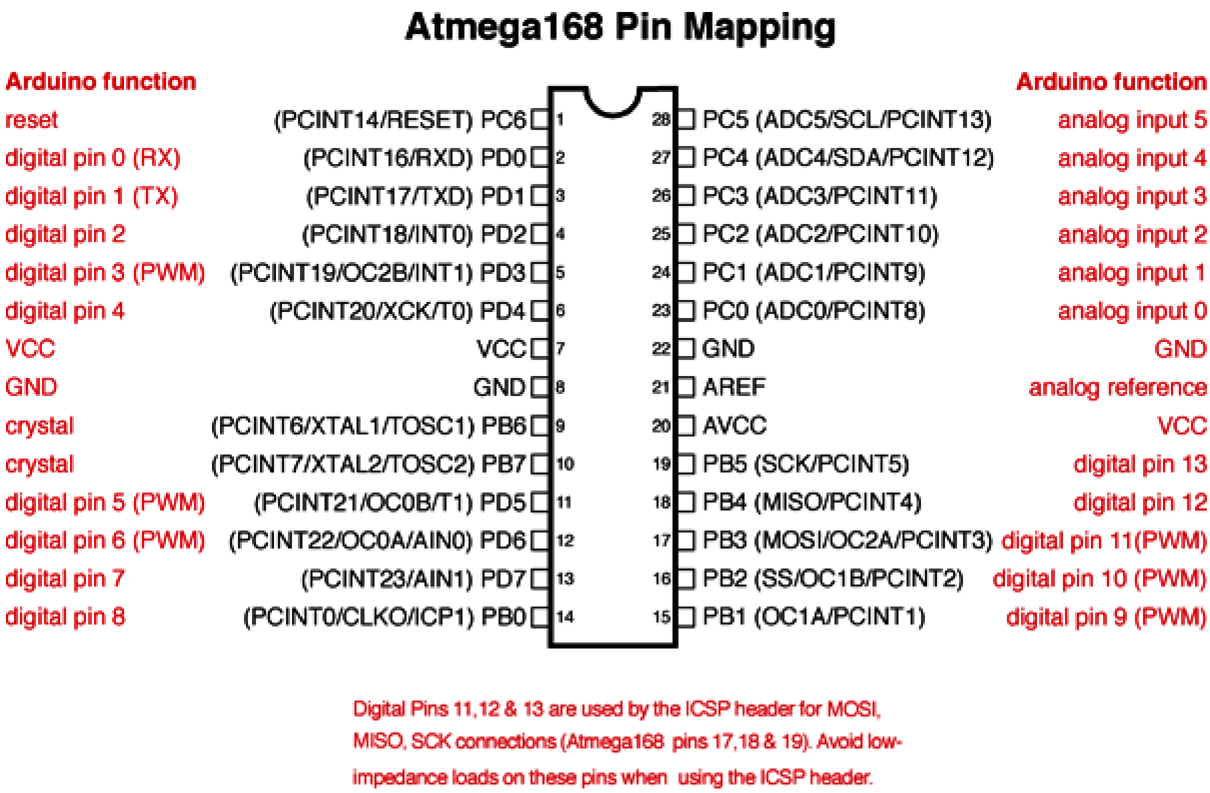
```
delay(1000);

mySerial.print("large  bothole ");

mySerial.print("x2`= ");

mySerial.println(x2);

mySerial.println(gps.location.lng(), 6);

mySerial.println(gps.location.lat(), 6);

mySerial.println((char)26);// ASCII code of CTRL+Z

delay(1000);

  }
}}
```

APPENDIX B

Arduino Uno:



Arduino is an open source computer hardware and software company, project, and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices and interactive objects that can sense and control objects in the physical and digital world. The project's products are distributed as open-source hardware and software, which are licensed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL), permitting the manufacture of Arduino boards and software distribution by anyone. Arduino boards are available commercially in preassembled form, or as do-it-yourself (DIY) kits.



IR sensor (Pulse Oximeter)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
POWER SUPPLY						
Power-Supply Voltage	V_{DD}	Guaranteed by RED and IR count tolerance	1.7	1.8	2.0	V
LED Supply Voltage R_LED+ or IR_LED+ to PGND	V_{LED+}	Guaranteed by PSRR of LED driver (R_LED+ and IR_LED+ only)	3.1	3.3	5.25	V
Supply Current	I_{DD}	SpO_2 and HR mode, PW = 215µs, 50sps		600	1200	µA
		IR only mode, PW = 215µS, 50sps		600	1200	
Supply Current in Shutdown	I_{SHDN}	T_A = +25°C, MODE = 0x80		0.7	10	µA
PULSE OXIMETRY/HEART-RATE SENSOR CHARACTERISTICS						
ADC Resolution				18		bits
Red ADC Count (Note 3)	REDC	RED_PA = 0x0C, LED_PW = 0x01, SPO2_SR = 0x05, ADC_RGE = 0x00, T_A = +25°C	55536	65536	75536	Counts
IR ADC Count (Note 3)	IRC	IR_PA = 0x0C, LED_PW = 0x01, SPO2_SR = 0x05 ADC_RGE = 0x00, T_A = +25°C	55536	65536	75536	Counts

COVER GLASS CHARACTERISTICS (Note 4)						
Hydrolytic Resistance Class		Per DIN ISO 719		HGB 1		
IR LED CHARACTERISTICS (Note 4)						
LED Peak Wavelength	λ_P	I_{LED} = 20mA, T_A = +25°C	870	880	900	nm
Full Width at Half Max	$\Delta\lambda$	I_{LED} = 20mA, T_A = +25°C		30		nm
Forward Voltage	V_F	I_{LED} = 20mA, T_A = +25°C		1.4		V
Radiant Power	P_O	I_{LED} = 20mA, T_A = +25°C		6.5		mW

Ultrasonic Ranging Module HC - SR04

☐ Product features:

Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The modules includes ultrasonic transmitters, receiver and control circuit. The basic principle of work:

(1) Using IO trigger for at least 10us 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 IO duration is the time from sending ultrasonic to returning.

Test distance = (high level time velocity of sound (340M/S) / 2,

☐ Wire connecting direct as following:

5V Supply
Trigger Pulse Input
Echo Pulse Output
0V Ground

Electric Parameter

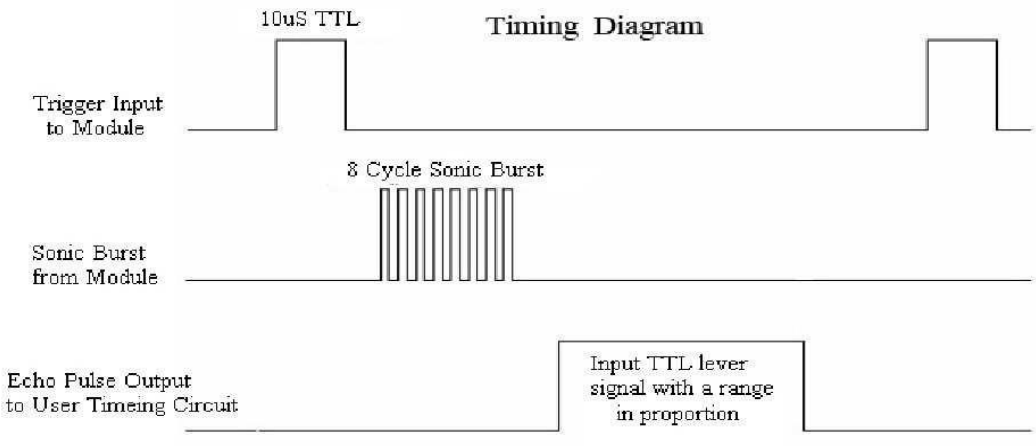
Working Voltage	**DC 5 V**
Working Current	**15mA**
Working Frequency	**40Hz**
Max Range	**4m**
Min Range	**2cm**
MeasuringAngle	**15 degree**
Trigger Input Signal	**10uS TTL pulse**

Echo Output Signal	**Input TTL lever signal and the range in proportion**
Dimension	**45*20*15mm**

Vcc Trig Echo GND

Timing diagram

The Timing diagram is shown below. You only need to supply a short 10uS pulse to the trigger input to start the ranging, and then the module will send out an 8 cycle burst of ultrasound at 40 kHz and raise its echo. The Echo is a distance object that is pulse width and the range in proportion .You can calculate the range through the time interval between sending trigger signal and receiving echo signal. Formula: uS / 58 = centimeters prevent trigger signal to the echo or uS / 148 =inch; or: the range = high level time * velocity (340M/S) / 2; we suggest to use over 60ms measurement cycle, in order to signal.



□ Attention:

□The module is not suggested to connect directly to electric, if connected electric, the GND terminal should be connected the module first, otherwise, it will affect the normal work of the module.

□ When tested objects, the range of area is not less than 0.5 square meters and the plane requests as smooth as possible, otherwise ,it will affect the results of measuring.

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