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DESIGNING OF LOW COST ARDUINO BASED ULTRASONIC SONAR SYSTEM

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ABSTRACT. *Sonar (Sound Navigation and Ranging) was covertly created by few countries during the reign of World War II. SONAR can be used to detect some moving object. It helps in the measurement of distance and angle from the observer. It works on the principle of Doppler shift. The designing of cheaper SONAR system for security purpose is the requirement of industry. In this research Paper, the designing and implementation of Arduino based SONAR system using ultrasonic sensor are presented. The device is able to detect the object, calculate its distance (up to 30cm) and can determine the elevation angle. It provides cheaper solution for security purposes.*

***Keywords**:* Arduino, Obstacle detection, Proximity sensors

1. **Introduction.** Sonar (Sound Navigation and Ranging) is a device which can be used for the detection of location of some moving objects. It utilizes ultrasonic waves to compute the angle of elevation, the distance, the speed of the moving objects and their bearing. Sonars are used by aviation authority for long range reconnaissance and early-cautioning purpose. Sonar is used for navigation and direction guidance in modern rockets. Ultrasonic sensor based Sonars are used for distinguishing the objects and separation of edge.

The cutting edge employments of SONAR are profoundly various, including airport regulation, radar cosmology, frameworks including altimetry and air traffic control, guided rocket objective finding, sea reconnaissance, air-safeguard and antimissile, radars operating for marine activities like the observation of ships and boats and the exploration of historic points, from the hostility of flying machines to the crash frameworks, space surveillance and meeting frameworks, meteorological precipitation checking and ground-entering radar for geographical perceptions. Innovative SONAR frameworks are installed for analyzing and computing helpful data from high commotion altitudes and are associated with advanced sign preparing.[1]

Army, Navy and the Air Force utilize the SONAR for obstacle detection. The SONAR is also used in self-stopping auto frameworks made by Mercedes, Benz, AUDI, FORD and many other companies. The SONARS will be used in future driverless autos made by Google like Prius and Lexus.

The present research work can be used as a low cost solution in a motor bike, a typical auto, or whatever else. The practice of using Arduino provides flexibility for the above said modules.

This research paper is subdivided in to three sections. Introduction is presented in section 1.Section provides the details of system overview. Section 2 explains the implementation details and section 3 presents the results and discussions.

2. Issues confronted. The electronic segments require some investigating to make the circuit to fulfill our requirements when used to frame any circuit. In present research work, the problem is that to present a SONAR which is cost effective and detect hurdle accurately. The device is able to detect the object, calculate its distance (up to 30cm) and can determine the elevation angle. It provides cheaper solution for security purposes.

3. System Overview. The experimental setup consists on the Arduino UNO R3 board, Ultrasonic Sensors and Servo motor. The detailed description of the hardware components is given below [2]

Arduino UNO R3. UNO, an Italian word, meaning ‘one’ is used to assign the Arduino software (1.0). The UNO R3 is grounded on the basis of ATmega328P and can be classified as microcontroller board.

It can be entirely used as a microcontroller; it merely requires its connection to the computer through USB port and some sort of power provided by AC-to-DC adapter or you can use battery to get started.

Table i. Technical specifications

Microcontroller	AT mega 328P
Operating Voltage	5V
Input Voltage (Recommended)	7-12V
Input Voltage (Limit)	6-20V
Digital I/O Pins	14
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current Per I/O Pins	20mA
DC Current for 3.3V Pins	50mA
Flash Memory	32Kb
SRAM	2KB
EEPROM	1KB
Clock Speed	16MHZ
Length	68.6mm
Width	53.4mm
Weight	25g

Power. The details of the power pins are as follows.

VIN. Input voltage to the UNO board. Mainly, it is utilized as an external power source (unlike a typical 5 volts source provided by USB connection or any other controlled power source).

5V. Due to the regulator installed in the board, this pin outputs a regulated 5volts. DC power jack (7 - 12V), the USB connector (5V), or the VIN pin can be used to supply power to the board. The board can be damaged if the voltage is supplied via the 5V or 3.3V pins because it avoid the regulator and can be destructive for board. That’s why it’s not advised to practice.

3V3. the supply of 3.3 volt generated by the regulator on-board. A maximum of 50 mA current can be extracted from it.

GND. Ground pins.

IOREF. The microcontroller operates on the voltage reference provided by this pin on the UNO board. IOREF pin voltage can be read by an appropriately configured shield and this pin can further choose the most favorable power source. Or it may permit voltage translators to work with the 5V or 3.3V which are on the outputs.

Communication. The UNO has capability to communicate with another sister UNO Board, with any computer device or various types of microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 Receiver (RX) and 1 transmitter (TX). The ATmega16U2 provide the facility of sequential communication over USB and to software on computer, it performs as a virtual com port. The typical standardized USB COM drivers can be used for 16U2 firmware, and thus it requires no external driver. Keeping in mind that if the OS is Windows it requires an extension file. The Arduino Software (IDE) can send simple textual data to and from the board by means of a serial monitor. If the data is transferred by the USB-to-serial chip and USB connection to the computer, the RX and TX LEDs on the board will flash; keeping in consideration that the discussed method cannot be applied for serial communication on UNO’s digital pins. In the case of serial communication, a Software Serial library is installed which permits such kind of communication on any of the UNO's digital pins like 0 and 1[2]

SPI communication and I2C (TWI) are also supported by the ATmega328. SPI communication is made possible with the help of SPI library while the usage I2C bus is made possible a Wire library included in the Arduino Software (IDE).

Ultrasonic sensor. Ultrasonic Sensors are a classified in the group of transducers which can work at a considerable amount of range. Just like Sonar or Radar, these sensors work on the principle which involves the evaluation of the traits of target by interpreting the sound waves or echoes respectively. This ultrasonic range (>20KHz) of sound waves is typically generated by using transducers of the sensors. The sensors convert electrical energy into sound, and then convert the sound waves converts to electrical energy upon receiving, which can be measured and demonstrated.

Servo Motor. A servomotor allows the precise control of velocity, acceleration and angular position serving as a rotary actuator. For position and location feedback, a suitable motor is coupled to its sensor. A relatively sophisticated and well refined controller which is a module, designed specifically for use with the servomotors. To attain closed loop command with a standard open loop motor, it uses a particular servomechanism. Servomotors have a wide use in automation, robotics, and automatic machines manufacturing.

4. Practical implementation. First of all, the servo motor was connected to Arduino board. In this project servo SG-90 motor was used for angular movement of ultrasonic sensors

Connections of Servo Motor. An ordinary servo motor has three terminals:

i Red for VCC

ii Brown for GND

iii Yellow for signal

A servo motor works typically at 4.8 to 6 volts. By associating it to the Ground of the Arduino, GND can be given quite conveniently. Red and black wires are used for VCC and GND respectively. These wires were connected to the 5V VCC and GND pin on Arduino. The yellow cable is used to communicate with Arduino which is brain of our setup. Arduino control servo motor's angular position. The accumulated period for the signal of servo motor is 20ms. To move from 0^o edge to 180^o, 2ms signal is connected while for 0^o itself, it utilizes 1ms. So after a short calculation, it can be realized that a pulse time of 1.5ms must be connected to move the hub of servo motor to the inside. For this purpose, the Arduino is connected with the beat wire of the servo motor that gives the computerized signal to signal width adjustment of the signal. Consequently, by programming for a specific signal interim the servo motor can be controlled effortlessly. As in Figure 3.

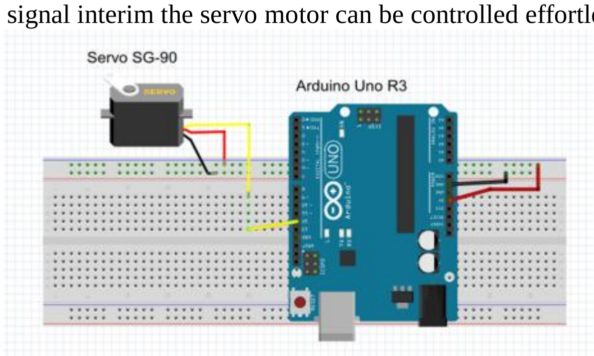

Fig. 1 Connect servo to Arduino

Connection of Ultrasonic Sensor. A standard Ultrasonic Sensor contains of the following three wires:

i. For VCC.
ii. For GND.
iii. For heartbeat signal.

A servo motor may have an ultrasonic sensor mounted on it which is further with the Arduino board. The basic principle for the operation of ultrasonic sensor is the reflection principle. A pulse signal is propagated through the Arduino to the ultrasonic sensor and an ultrasonic wave is directed through the sensor. As a result, if there is any obstacle, any mirror in front or any distinguished barrier, the waves which are acquired by the ultrasonic sensor, are mirrored by it. Otherwise the signal will be referred to the Arduino in any other unlikely situation. This signal was sent to the PC/tablet for the handling through programming. The results demonstrated the distance of the obstacle from the system. The results were demonstrated on SONAR screen which showed the separation and the point at which it was recognized. Figure 2 represented the full circuit diagram.

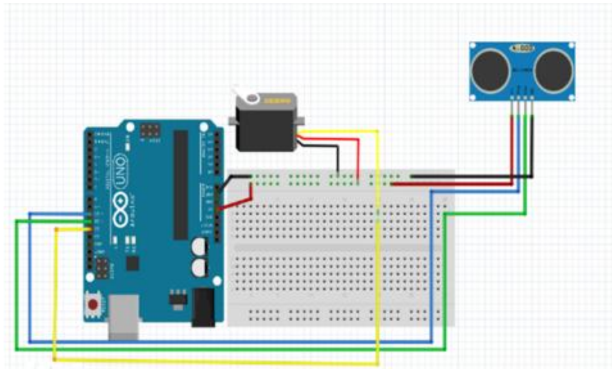

Fig. 2 Connecting ultrasonic sensor and Arduino

Preparation of Arduino.

Integrated development environment (IDE). The Arduino integrated development environment (IDE) is a Java based cross-stage application. For the Processing programming dialect and the wiring ventures, it acquired from the IDE. For the purpose of familiarizing programming with specialists and amateur programmers, IDE is often intended. It integrates elements with a code editorial manager, for instance, sentence structure highlighting, support coordinating and programmed space. It is also equipped for organizing the projects and conveying them to the board with a solitary snap. A code, more likely a system, generated for Arduino is known as a "sketch".

Arduino projects are generated and compiled in the most basic and simplest languages like C or C++. For making various I/O operations much simpler and reliable, the IDE accompanies a product called wiring from the first wiring project.

i Setup() Run once at the start of the program

ii Loop()More than once until the board powers off

To select the board, open the software for Arduino IDE. Selection of board is:

i Go to tools

ii Selection of board

iii Select the port at which Arduino board is selected

Compose the code in the space give and tap on aggregate. As soon as the order for code is confirmed, tick on transfer to allocate the description to the Arduino board.[5]

Processing Software. Processing software is an open source programming language. With the aim to educate the essentials of PC programming in a visual and graphical setting and to aid in launching the electronic sketchbooks, IDE operates for different visual alignment and configuration groups, electronic terminologies, new media craftsmanship. This undertaking was signed by the personnel of Esthetics at MIT Media Lab, Casey Reas and Benjamin Fry, in 2001. The dialect expands on the Java dialect, however utilizes a streamlined linguistic structure and represent programming model. [4]

Communication between Arduino and Computer. Another significant issue identified with the Arduino board was the correspondence between Arduino and PC. There was a communication between RS-232 and TTL circuits. Different strategies were adopted to manage this problem [5]

i Firstly, MAX-232 IC was utilized to communicate with the Arduino. Due to high voltage drop and jumble in the velocity, it was neglected to impart.

ii Next, AVR was used as USB to Serial converter in the Arduino board. This technique was failed and data transmission was not possible in our working.

iii Finally FTDI FT-232R chip was used for USB to Serial data transfer.

Programming the Arduino to show the result screen. The main task was to show the results on SONAR screen. For this purpose, VB. NET was used to shape the SONAR screen. It was a difficult task to establish the interface with the Arduino information. This task was completed with the help of Processing programming (Version 2.0) [6]

5. WORKING PRINCIPLE. A specific sound pulse is emitted by the Ultrasonic sensors that redirects of the objects penetrating the wave field. The sensor then receives this reflected pulse, or “echo”. An output signal is generated upon the detection of the sound which can be using a computer, a typical controller or by an actuator. The output signal can be analog or digital[3]. Figure 3 shows sensor working.

Fig. 3 Sensor working principle

Ultrasonic Sensor Construction. There are some fundamental components of an ultrasonic sensor:

i Comparator
ii Detector circuit
iii Transducer/receiver
iv Solid-state output

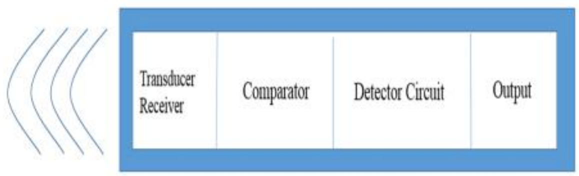

Fig. 4 Components of Ultrasonic sensor

Comparator and Detector Circuit. The distance is calculated by the comparator by comparing the speed of the sound to emit-to-receive timeframes, as soon as the sensor collected the reflected echo.

Transducer/Receiver. The ultrasonic pulses are responsible for, sending sound waves outward from the face of the sensor. The echoes of those sound waves when reflected off by an object are also received by transducer.

Solid-State Output Switching Device (SSO). An electrical signal is generated by the SSO which is then illuminated by an interface device like a programmable logic controller (PLC). The existence of an object is specified by the signal from digital sensors in the sensing field, while the distance of that object is indicated by the analog sensors.

Sensing Frequency. Usually, commercial sensors work in the range of 25 kHz and 500 kHz. However, ultrasound units used mainly for medical purposes operate at 5 MHz or more. A 30 kHz sound wave may work up to 20 m (66 ft.) or more approx., while a 200 kHz sound wave is limited to a range of about 1 m (3 ft.) which shows that sensing frequencies and sensing distances are inversely proportional to each other.

Sensing Range and Effective Beam. The total area between the maximum sensing limit and the minimum sensing limit is termed as sensing range of an ultrasonic sensor. As in Figure 5

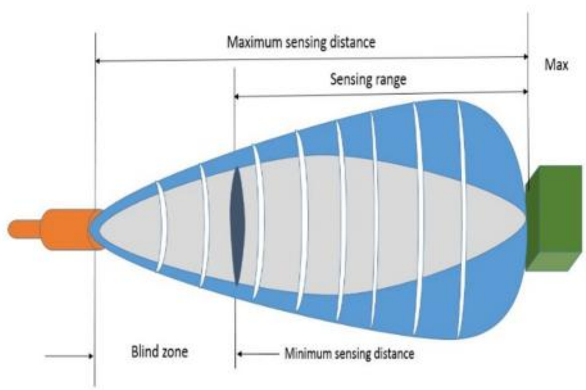

Fig. 5 Ultrasonic sensing distance

Minimum Sensing Distance. The sensor is incapable of receiving the sound wave or echo accurately if the

ultrasonic beam after striking the target returns to the sensor before the sensor has completed its communication. This incapability is due to the reason that ultrasonic sensors have a little unusable region near the face of the sensor and this impractical region is known as the blind zone.
The minimum distance which is ignored or misread by the sensor after the echoes return from an object is the outer boundary of the blind zone. [7]

Maximum Sensing Distance. The maximum distance which can be detected by a sensor depends upon the target magnitude and substance. The maximum sensing distance would be the least, if the object is hardest to detect.

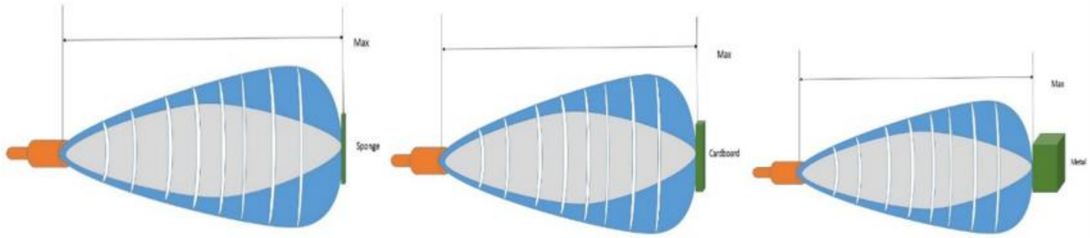

Fig. 6 Sensing range sensitivity

Materials having the capability to absorb sound like cotton, fabric, foam etc. are harder to detect than glass, steel or plastic etc. which are acoustically reflective materials. However, these spongy materials would limit the maximum sensing distance if detected somehow. Figure 6 shows sensitivity of different materials.

Effective Beam. Ultrasonic pulses are emitted when a transducer vibrates which cause cone-shaped beam propagation. However, using a potentiometer, this cone can be adjusted, to widen or extend the sensing range. As in figure 7.

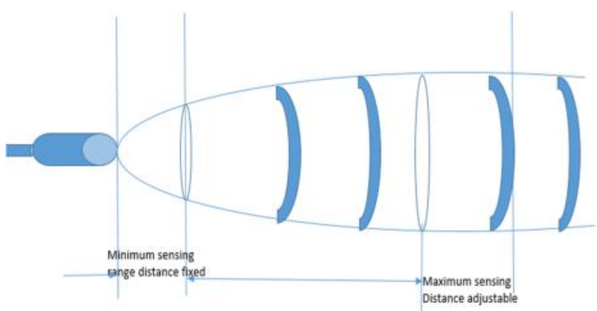

Fig. 7 Effective beam

Manufacturers provide instructions for the sensitivity attributes of their sensors. Some trial is required to determine the sensing range in any given environment.

Distance Formula. As discussed already, ultrasonic high frequency waves are emitted by the transmitter part of ultrasonic module, in the form of pulses. These waves are then detected by the microphone after colliding with any object. The distance from any object is measured by computing the duration by these signals to travel from transmitter to receiver. From the broad range of ultrasonic sensor modules available in market, HC-SR04 will be used for the discussed research. The ultrasonic module is start off with pulse of 10us. From Figure 8 distance formula can be easily understood. [9]
The distance from all is determined by means of following formula;

Distance = speed x time

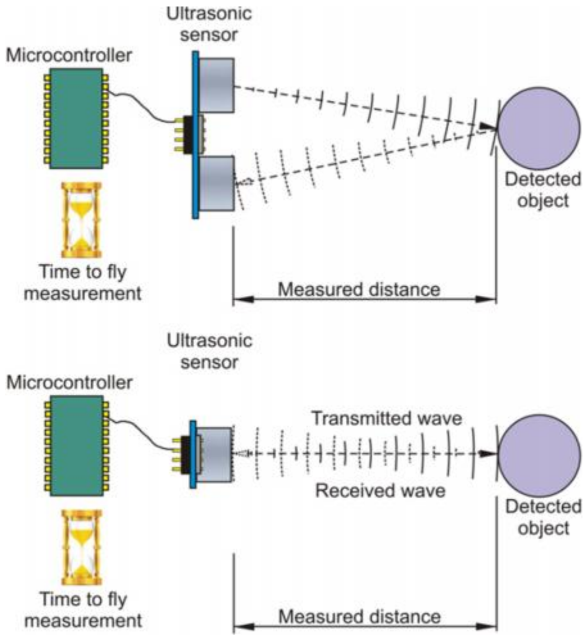

Fig. 8 Distance measurement

As we identify that the speed of sound in air is 20C which is equivalent to 344 meter per second. The time stated in beyond equation should also be divided by two.[8] According to the theory, ultrasonic waves travel from TX and then return to the RX by travelling same distance. So the formula to calculate distance develops;

Distance = 344 x time / 2 meter

6. Results discussions. Army, Navy or Air Force are the big users of SONAR. Even modern automated cars, driverless vehicles, self-stopping frameworks are utilizing the SONAR. These systems are normally very costly. It is necessary to design low cost SONAR.

Designing an Ultrasonic low cost SONAR was a difficult task. This task was completed using Arduino and ultrasonic sensor. The use of Arduino board provides the adaptability and low cost for the user. The device can fulfill the technical requirements of the user. In Figure 9 and Figure 10 the system is in working condition.

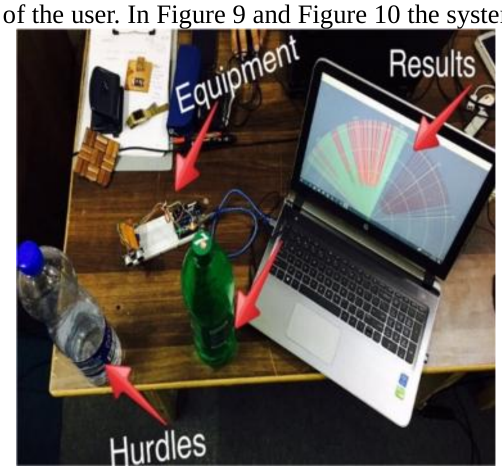

Fig. 9 System in working condition

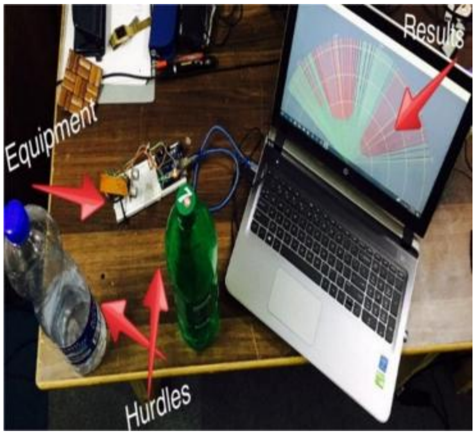

Fig. 10 System in working condition

Results. Red lines in the SONAR screen shows hurdles. And the overall 180^o is the coverage area of Sonar. It can be less than 180^o but we assume it equal to 180^o. You can see in Figure 11, Figure 12 and Figure 13.

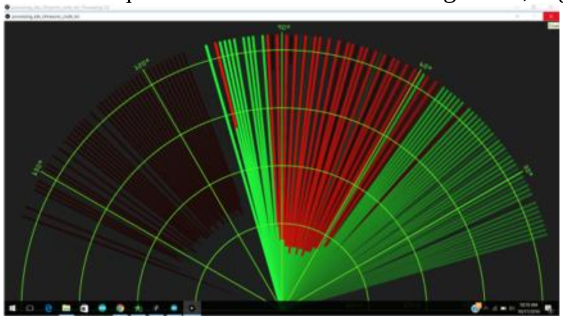
Fig. 11 Detecting 1 hurdle

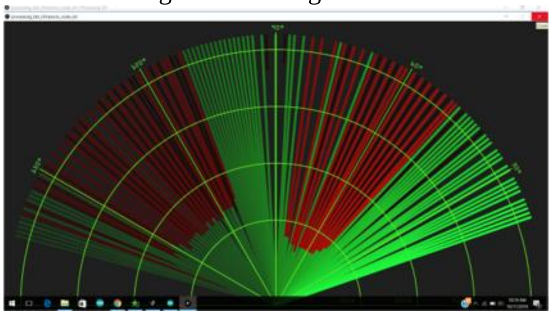
Fig. 12 Detecting 2 hurdles

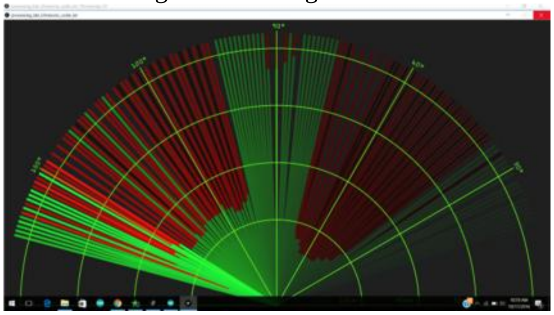
Fig.13 Results

Conclusion. In the present research project, an Ultrasonic sensor based SONAR system was prepared. It provides a cheaper, low cost, low power solution for security purposes. The solution was designed and developed in University of Management and Technology (UMT) Labs. The path and distance of the object was accurately calculated and were shown on the screen. The range of the device was small due to unavailability of long range sensors in local Hall road market. Further research work is required to differentiate the objects and to increase the range of the device.

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