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## ULTRASONIC SENSOR BASED 3D MAPPING AND LOCALIZATION

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**Abstract:** Autonomous robotic mapping has led us to places well beyond our reach, places where human expeditions are too dangerous, technically challenging, or too expensive. The robot collects data from its surroundings and also builds a 3D map, which it will use in real-time to move around thus making it autonomous. The user in real-time will also receive the data retrieved by the robot. The HCSR-04 ultrasonic sensor connected to the Arduino board is controlled and a pulse of the ultrasonic wave is sent. The sensor then listens for any reflected wave that might come back from an obstacle. The Arduino notes this time interval between pulse sent an echo received and calculates and stores this data. It also stores at what angle this data was recorded and then commands. The board makes the servo increment of 1 degree from 0 to 180 and back to 0 continuously in a loop while simultaneously recording ultrasonic data in centimeters. This data is sent over to the serial port and is picked up by the processor software and after further processing, it plots and updates the RADAR plot. the servo to move to the next position. The data is retrieved from the system using the Arduino software and relayed to MATLAB to make the plotting. Real-time data is shown as a moving graph on Processing IDE, which is linked with the Arduino Uno.

**Keywords - Ultrasonic, Radar, MATLAB, Arduino, Mapping, 3D, Sensor.**

### I. INTRODUCTION

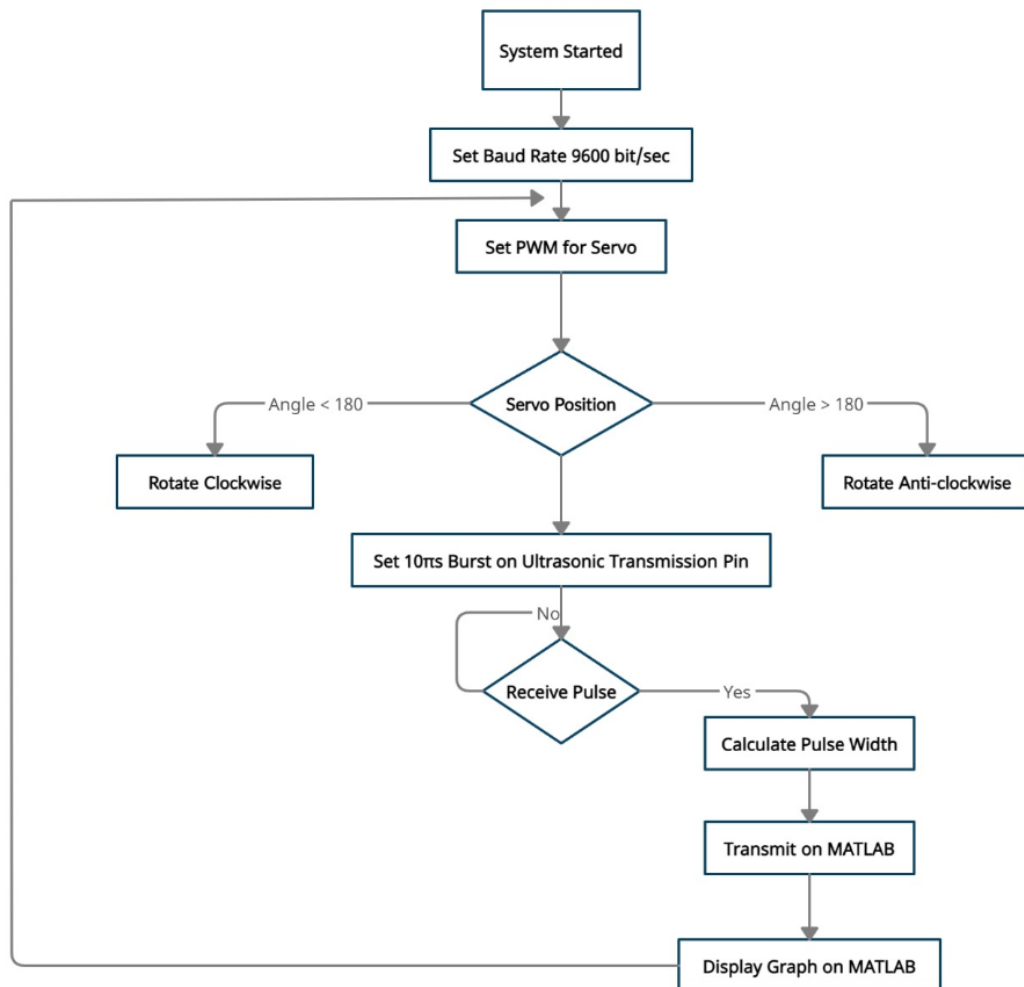
Robots are quickly advancing from sci-fi motion pictures and books into our regular day to day existences. They can be found anyplace and wherever beginning from your neighborhood clinic to your home, and surprisingly the nearby coffeehouse. These exceptional upgrades in the field of advanced mechanics have opened up new freedoms for making new revelations and achieving errands which were recently considered to be incomprehensible. The significant fields of study that are adding to mechanical technology are electrical and mechanical designing close by with software engineering. While electrical and mechanical designing arrangements with the plan, development, and use of robots, PC frameworks manage their control, tangible criticism and data handling. Furthermore, with these three fields of study as one mechanical technology has swayed forward towards a more promising time to come. You would now be able to see robot arms acting in medical clinics, processing plants and so on as they limit the edge for mistakes. They are additionally found in homes, shops and cafeterias where they do every day errands which were once done by people, so fundamentally robots can achieve undertakings both which people can and can't do.

This task manages self-ruling robots which use sensors (for this situation ultrasonic sensors) to make a 3D guide of their environmental factors. Independent robot frameworks rely profoundly upon their capacity to recuperate strong spatial model of their environmental factors from tactile data and use it in robot arranging and control. Every one of these capacities empower the robot to settle on its own brief choices dependent on the information gathered by the sensor. The information got from the sensors can be utilized to make a 2D/3D model for later use in various exploration projects and studies. At first the sensors will be utilized for get-together information that will create a 2D picture of its environmental factors. The robot can be utilized for planning referred to just as obscure indoor or open-air areas dependent on its need.

### II. LITERATURE SURVEY

Obstacle detecting techniques are majorly used in automobiles to enable a collision free and driver assisted technology for users. Ultrasonic sensor transmits the 40 kHz ultrasonic waves from its sensor head and again receives the 40 kHz ultrasonic waves reflected from an object, to determine its distance from the sensor. The calculated data from the US sensor needs to be sent to OpenCV or to

MATLAB for which a communication with Arduino board from MATLAB or OpenCV has to be established. Many new designs and techniques have become popular in unmanned aerial vehicle (UAV) research.



### III. Hardware and Software components

#### 3.1 Arduino Uno

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output pins that may be interfaced to various expansion boards and other circuits

The board has 14 digital input/output pins, 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. The Uno is the medium through which the sensor sends its readings back and forth and controls everything else that goes on inside the bot. In simpler words it controls the Bots actions.



Fig. 1: Arduino Uno

#### 3.2 Ultrasonic Sensor HC-SR04

The HC-SR04 Ultrasonic Distance Sensor is a sensor utilized for recognizing the distance to an item utilizing sonar. The HC-SR04 utilizes non-contact ultrasound sonar to measure the distance to an object and comprises two ultrasonic transmitters (essentially speakers), a receiver, and a control circuit.

The sensor HC-SR04 is basically what guides the bot and takes all the readings. It emits ultrasonic waves which hits an obstacle and reflects back to the sensor after which it calculates the distance between the bot and the obstacle. There are four pins on the sensor, VCC, TRIG, ECHO and GND. Each of these pins are connected to the Arduino board via jumper wires. The VCC pin is connected to the 5V supply, the TRIG and ECHO pins are connected to output and input pins respectively on the Arduino board and the GND to one of the three ground connection pins on the board.

Most data by mapping robots are via sonar sensors, laser beams and cameras. Even though sonar technology is quite developed there a few fields where it is actually applied. Some of the traditional place's sonar is used are marine applications, camera autofocus and a few robotic applications that rely on sonar data to achieve their goals. Ultrasound sensors are used in medical appliances one such example is ultra-sonogram, which helps create the image of an unborn baby.

#### Working principle:

The ultrasonic sensor (or transducer) works on the same principles as a radar system. An ultrasonic sensor can convert electrical energy into acoustic waves and vice versa. The acoustic wave signal is an ultrasonic wave traveling at a frequency above 18kHz. The famous HC SR04 ultrasonic sensor generates ultrasonic waves at 40kHz frequency.

Typically, a microcontroller is used for communication with an ultrasonic sensor. To begin measuring the distance, the microcontroller sends a trigger signal to the ultrasonic sensor. The duty cycle of this trigger signal is 10 $\mu$ S for the HC-SR04 ultrasonic sensor. When triggered, the ultrasonic sensor generates eight acoustic (ultrasonic) wave bursts and initiates a time counter. As soon as the reflected (echo) signal is received, the timer stops. The output of the ultrasonic sensor is a high pulse with the same duration as the time difference between transmitted ultrasonic bursts and the received echo signal.

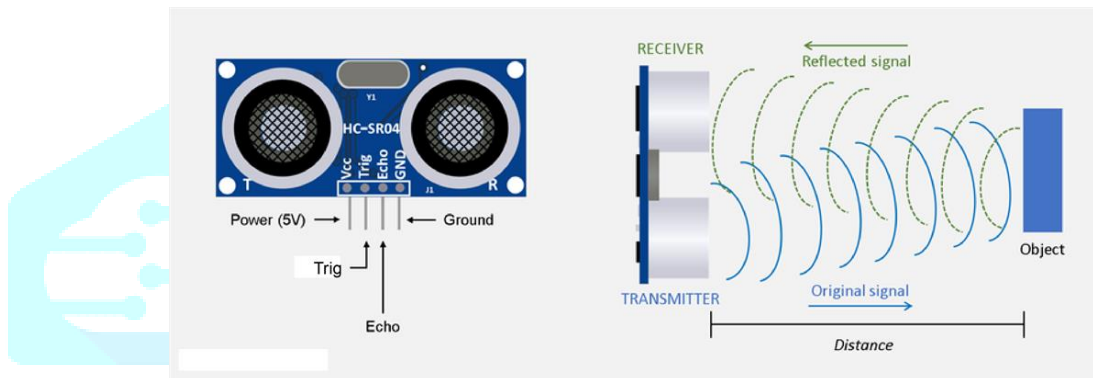


Fig. 2: Ultrasonic sensor and its working

### 3.3 Servo motor

A servomotor is a closed-loop servomechanism that uses position feedback to control its motion and final position. The input to its control is a signal (either analogue or digital) representing the position commanded for the output shaft.

The motor is paired with some type of position encoder to provide position and speed feedback. In the simplest case, only the position is measured. The measured position of the output is compared to the command position, the external input to the controller. If the output position differs from that required, an error signal is generated which then causes the motor to rotate in either direction, as needed to bring the output shaft to the appropriate position. As the positions approach, the error signal reduces to zero and the motor stops.

#### Working principle:

Servo Motor consists of a DC Motor, a Gear system, a position sensor, and a control circuit. The DC motors get powered from a battery and run at high speed and low torque. The Gear and shaft assembly connected to the DC motors lower this speed into sufficient speed and higher torque. The position sensor senses the position of the shaft from its definite position and feeds the information to the control circuit. The control circuit accordingly decodes the signals from the position sensor and compares the actual position of the motors with the desired position and accordingly controls the direction of rotation of the DC motor to get the required position. Servo Motor generally requires a DC supply of 4.8V to 6 V.



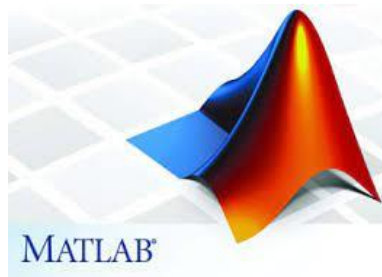
Fig. 3: Servo motor

### 3.4 MATLAB

MATLAB is a programming platform designed specifically for engineers and scientists to analyze and design systems and products that transform our world. The heart of MATLAB is the MATLAB language, a matrix-based language allowing the most natural expression of computational mathematics.

MATLAB can be used to:

- Analyze data
- Develop algorithms
- Create models and applications



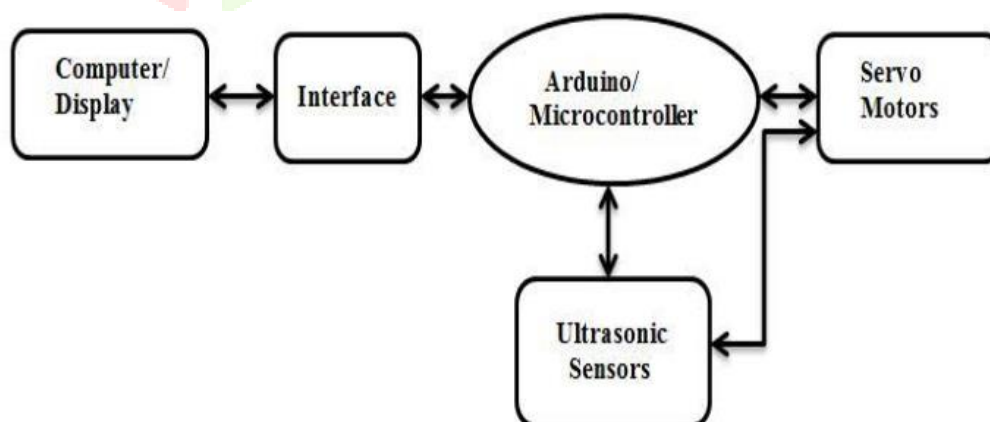
### 3.5 Processing 3

Processing is a flexible software sketchbook and a language for learning how to code within the context of the visual arts. Since 2001, Processing has promoted software literacy within the visual arts and visual literacy within technology. There are tens of thousands of students, artists, designers, researchers, and hobbyists who use Processing for learning and prototyping.



## IV. METHODOLOGY

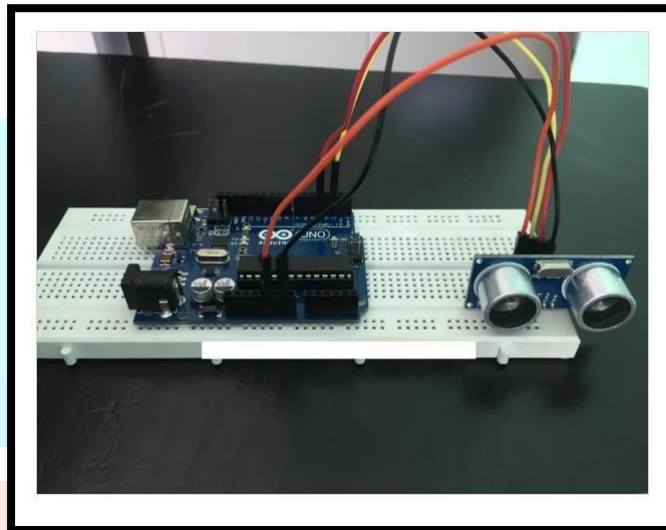
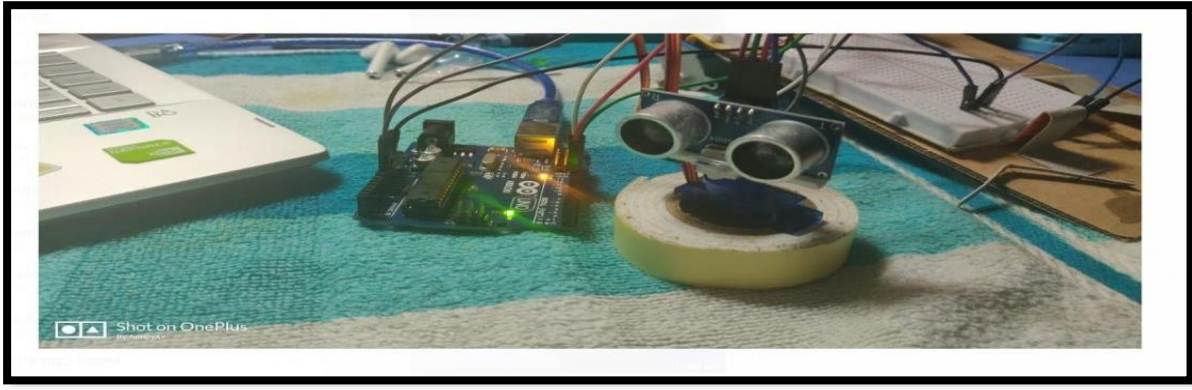
- First the ultrasonic sensor connected to the Arduino board is controlled and a pulse of ultrasonic wave is sent. The sensor then checks for any reflected wave that might come back from an obstacle.
- Arduino notes this time interval between pulse sent and echo received and calculates and stores this data. It also stores at what
- angle this data was recorded and then commands the servo to move to the next position.
- The board makes the servo increment 1 degree from 0 to 180 and back to 0 continuously in a loop while simultaneously recording ultrasonic data in centimeters.
- This data is sent over to the serial port and is picked up by the processor software and after further processing, it plots and updates the RADAR plot.





## V. RESULTS

### 5.1 Circuit Images



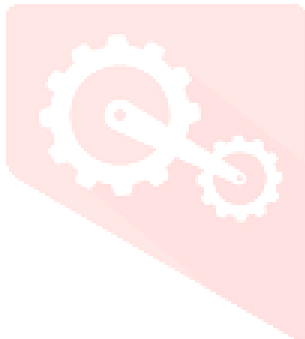
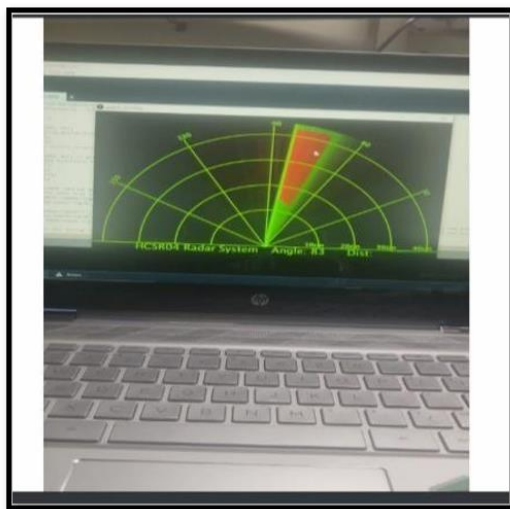
### 5.2 Processing 3 based

Output

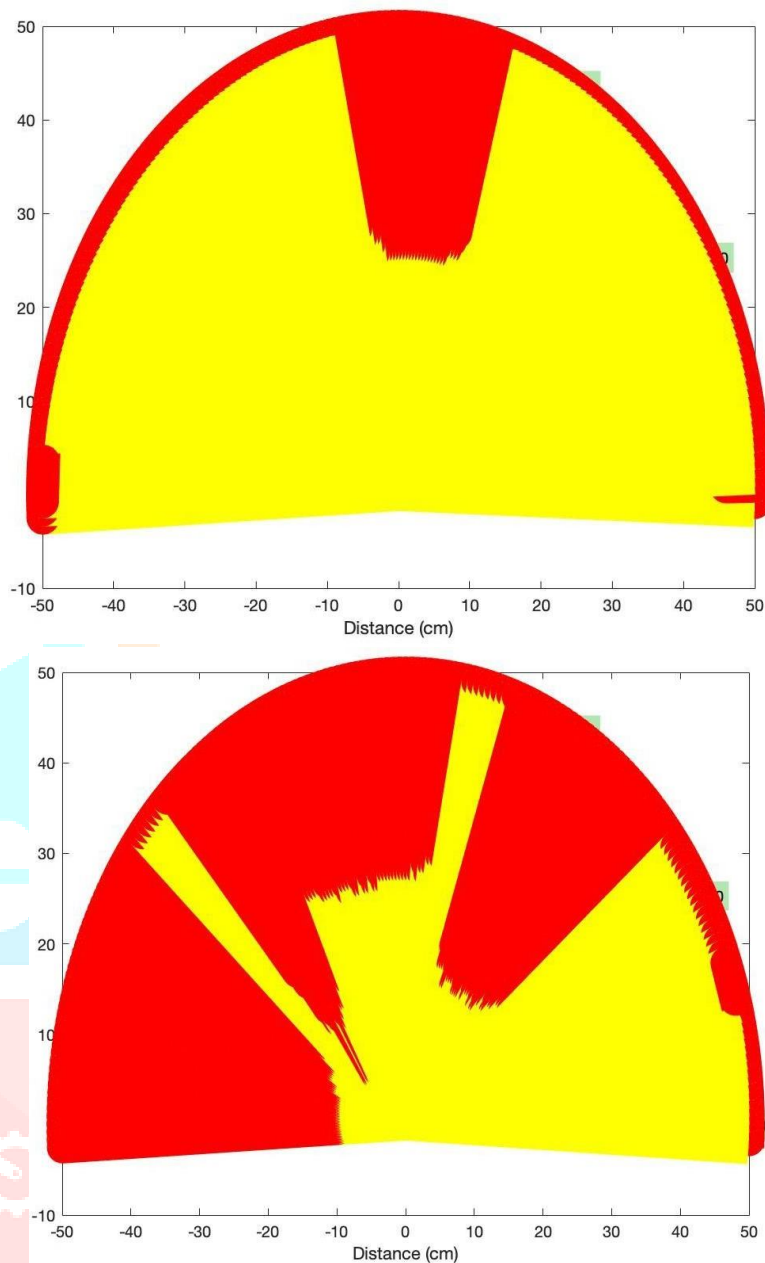


**Red color:** indicates obstacle in vicinity.  
**Green color:** indicates absence of any obstacle (clear path).

Here, the large patch of red area shows a large obstacle, at a distance of 4 cm from the device. The small green line in-between shows a possible perforation in the object, that was successfully penetrated by the ultrasonic waves.



### 5.3 MATLAB based Output



The graph shows the two shaded regions i.e., yellow and red regions.

Here, the yellow part shows that there is no object and the red part shows that there is an object in that particular region. Through this process we can also trace the position and angle of that object.

### VI. CONCLUSION

In this work, an ultrasonic radar system was designed and executed tentatively for distance estimations purposes to be utilized in different applications. An Arduino Uno was utilized as a regulator in the design alongside different components, for example, servomotor, ultrasonic sensor and PC for distance computation of articles or hindrances set at various points (from 0 to 180 degrees) inside the reach up to 5 meters.

For more than over a decade there has been numerous researchers from various reputed institutions have conducted studies regarding 3D mapping and localization using ultrasonic sensors and autonomous robots. Since then, the concerned field has seen immense development, numerous robot units have been developed and tested in the field successfully. Even though we have only completed the 2-dimensional mapping phase of the project we intend to complete the 3-dimensional phase soon enough. The processing unit of the robot currently only takes horizontal readings, which allows us to create the 2D image of the environment however as soon as we develop the mount for the vertical readings, we will be able to create 3D images. Soon enough the first prototype will be completed and will be able to operate in real-life instances. This project is simply documenting the initial phase of the research, as further progress is made more documentation can be done.

## VII. ACKNOWLEDGMENT

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