A Paper on Active Sonar on Arduino/Adafruit

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Abstract— Sound is a longitudinal waveform existing in mediums such as air. The speed of sound at room temperature i.e., at 20 degrees centigrade is 343 m/s. Our project relies on sound to detect object distances and disturbances in 3D space. The inspiration for our project comes from animals who are able to use high-frequency tones to acquire information about their surroundings. For our project, we wanted to mimic the natural processes of bats in order to localize object distances, and to detect disturbances in 3D space. This project is built using VR which comes under high technology and is accessible to a great extent. The ability of sound to reflect off objects is also dependent on the material of the object. For our project, we intend to use SER to detect distances of hard objects, since the intensity of the reflection is higher for hard objects than for soft objects.

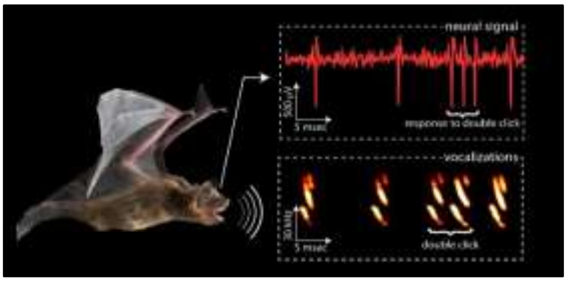
Keywords: Sonar, Arduino, Ultrasonic, Sonar Echolocation Ranger, Bats, Perturbations, Distance Measurement

I. INTRODUCTION

There are 2 types of Sonar – Active Sonar, Passive Sonar. Active sonar creates a sound (ping) and then waits to listen to the reflections (echoes) from the surrounding. Passive Sonar detects obstruction underwater at varying distances depending upon the use of sensors/transducers.

II. MOTIVATION AND BACKGROUND

The inspiration from our project comes from animals who are able to use high-frequency tones to acquire information about their surroundings. Some bat species are able to contract their larynx in order to produce ultrasonic clicks which get reflected off surrounding objects. Bats are amongst a few other mammals that can use sound to navigate- a trick called echolocation. Most bats produce echolocation sounds by contracting their larynx (vocal mechanism). Bats use the time delay to receive the echo as a measure of the distance an object of interest is (a nearby wall, insect, etc.). For our SER, we wanted to mimic the natural processes of bats in order to localize object distances and to detect disturbances in 3D space

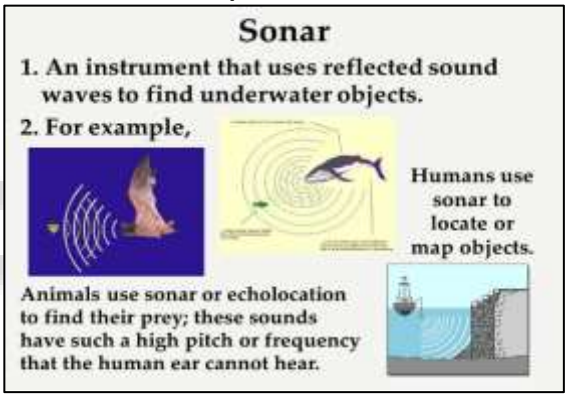


III. PROBLEM STATEMENT

One important property of sound waves is that the speed of sound is independent of the frequency of propagation, which means that echo times are independent of the frequency spectrum of the reflected sound. One of our regions of objectives is to focus on the design of motors and sensors. The purpose of the hardware component of our project is to house the electrical components, acoustically isolate the buzzer and motor, and concentrate the sound propagation into a narrow central lobe. The previous models which were built using Arduino/Adafruit couldn't capture or detect objects beyond 30-40 centimeters as the previous designs used a single transducer or sensor (depending upon Adafruit/Arduino). The error rate was quite high in previous models due to environment changes and precision rates of components.

IV. OBJECTIVES

The Sonar Echolocation Ranger (SER) is a biologically-inspired multimode echolocation system that can detect an object up to 1-1.5m away and compute object distances within ±2 cm of accuracy.



It displays a distance with a rudimentary LCD interface (distance mode) and can monitor a surface to detect and report any perturbations (perturbation mode). SER has possible applications in seismology, civil engineering, surveying, and robotics. The ability for sound to reflect off objects is also dependent on the material of the object.

V. RELATED WORKS

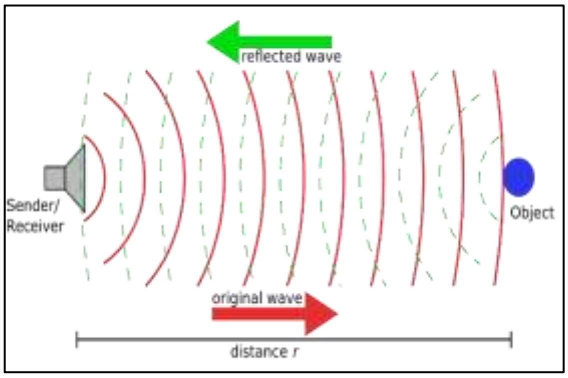
Literature reviews corresponding to the active sonar construction using either Arduino or Adafruit were controlled. The target was to understand the strength of the model constructed to determine the range covered by the same to detect perturbations in the ecosystem. It has been noted that the majority of researchers, scholars, and consultants have been active in the field of earthquakes, geography, the importance of seismic analysis, medical, surveying, and so on which are the major sector for applications of Active Sonar.

1) [Centre for Communication System Research, George Mason University et.al (2019)] designed and analysed a design of Echolocation Ranger using Solid works and Adafruit which gave the insight to object detection.

2) [Hossein Peyvandi, Mehdi et. Al (2018)] studied in detail about SERs and published a paper on Sonar: Classic and Modern Approach, including certain legal procedures and precautions to be taken whilst designing a Sonar.
3) [Alberto Baldacci et.al (2018)] studied "Detection performance enhancement obtained through an environmentally adapted scheme" involving the future scope of Sonar using Signal Processing.
4) [Nelson J. K et.al (2016)] researched to find out about the existing systems in use and gave us ideas on how to make the sonar more effective and advanced in their paper "Active Sonar: Through the Ages."
5) [Bar-Shalomet. al (2013)] studied the detection of human obstacles.

VI. METHODOLOGY AND IMPLEMENTATION

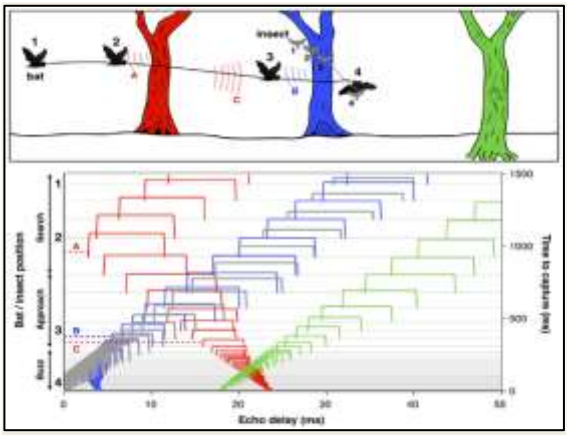
– The first step is to install mechanical equipment that would be capable to handle the hardware design effectively.
– Next, connect the components to the PCB/Breadboard according to the circuit (Advised to test it beforehand on a breadboard or Simulation-based software for e.g., LTSpice, Proteus, Eagle, etc).
– For the software part, set the code in IDE if using Arduino or in Adafruit Model 1480 if using Adafruit.
– Place the LED Stand at extreme ends of the mechanical set-up so if the object is detected to be coming from the east direction, the right LED Stand would glow to red/white and the other LED Stand would remain low or turned off. Nothing is done manually here for the LEDs to turn on or turn off.
– Now, set a motor/motors at equidistance from the sensor so that the sensor rotates whenever perturbation in the system is detected followed by the glowing LED Stand.
– When an object is detected, the distance will be displayed on the LCD Screen (more like Virtual Reality) along with the angle of the object from ground level.
– In order to generate concentrated bursts of ultrasound in a specific direction, we had to study different transducer and sensor properties.
– One important finding of our research was that equidistant phased-array transmission, wherein each sound source is separated by a wavelength, optimizes the amplitude of the central sound lobe (as well as minimizes its width).
– When the wavelength of sound greatly exceeds the size of an incident object, the echo wave is small in amplitude and difficult to detect from a distance.
– This is because the whole waveform, due to its large length, is not able to get completely reflected off the object. However, when the wavelength is much smaller than the size of an object, the whole waveform is able to get reflected off an object. The equation $V=f\lambda$ encapsulates the relationship between sound speed, frequency, and wavelength (v is the speed of sound, f is the frequency, and λ is the wavelength).



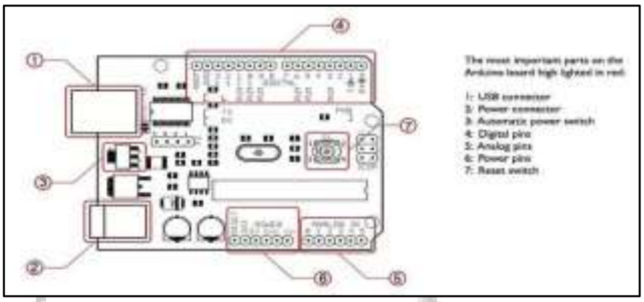
– Thus, in order to produce small-wavelength waves, it is necessary to increase the frequency of the sound.
– Ultrasonic sound waves have become popular in echolocation because of the high-frequency waves' ability to reflect off objects and are a reason why ultrasonic waves are used in our project.
– The number of LEDs and sensors to use for our project also has important theoretical consequences. If we were to use one sensor and one LED, the distance detected would be smaller since the range covered by one sensor would be quite small. In other words, if the point that reflects the sound were to move, a single sensor would be able to detect this movement.
– However, one sensor would be insufficient for detecting if a face of an object were to change orientation. This is because the pointwise distance between a speaker and a single point on an object's face can stay constant even though the object's face is being rotated.
– Since it is necessary to detect perturbations even for longer distances, we use multiple LEDs (LED stand) and 3 sensors along with the basic requirements. This gives us improved robustness in perturbation detection, as well as improved accuracy in distance measurement.

VII. SCHEMATIC ILLUSTRATION

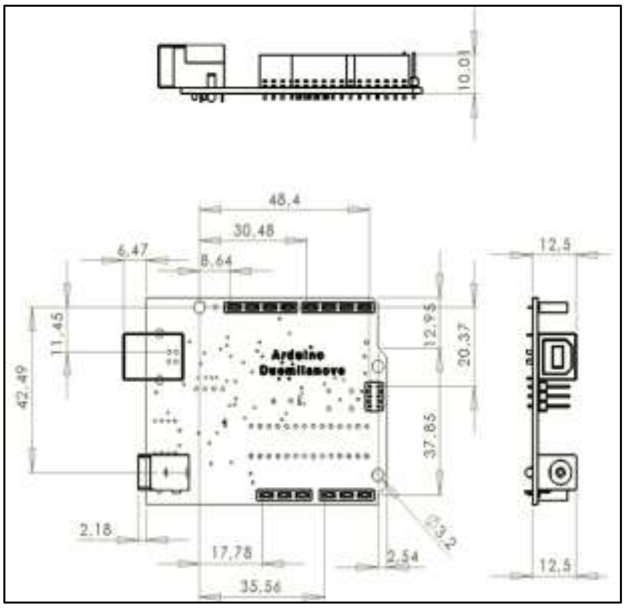
This illustration shows how echoes from different objects or disturbances in the path of the bat's sonar beam form acoustic streams with changing delays over time. Upper panel: The figure shows a bat pursuing an insect in the vicinity of three trees at varying distances. The numbers set, indicate the positions of the bat and insect at corresponding points in time. Color-coded arcs illustrate an echo coming from the red tree at position 1 (A) and echoes from the blue and red trees at position 3 (B and C). Lower panel: Echoes coming from the insect (thick Gray lines) and each of the trees (red, blue, and green) arrive at changing delays (x-axis) over time (right y-axis) as the bat flies in pursuit of its prey. Each sonar vocalization (it is not shown) results in a cascade of echoes from objects in the path of the sound beam, which arrives at different delays relative to vocalization onset.



VIII. DIAGRAM OF ARDUINO UNO



- Arduino Uno is a microcontroller board based upon the 8-bit ATMega328P microcontroller.
- To support the microcontroller there are other specific components such as crystal oscillator, serial communication (Arduino UNO can communicate with a computer, another Arduino board, or with a microcontroller board), voltage regulator, etc.
- This board consists of 14 digital input/output pins (out of which 6 can be used as PWM outputs), 6 analog input pins, a USB connection, a power barrel jack, an ICSP header, and a reset button.
- We have used Arduino Uno as it is effectively executing the expected results with an error rate at minimum value.
- Amongst other reasons, Arduino Uno Kit is cost-effective and the model can be modified for futuristic scopes without changing the kit.
- The below shown figure is Arduino Uno 2D Model



IX. CONCLUSION

The entire hardware design, including the circuit, setup designed for effective results is entirely proprietary and therefore will be subject to patent opportunities in the future. This way we have built an Active Sonar with the help and motivation from various animals or insects and study on necessary topics. The perturbation detection system is evaluated by inspecting the number of false-positive and true positives. When we tested our system under various conditions such as larger and smaller object detection, we found that when the Active Sonar was stationary, it was able to effectively detect small disturbances in the position/orientation of object faces. However, if this thresholding system was used while the Sonar was being held, the system registered values with an error of 1.5 cm. Therefore, we can choose to judge the effectiveness of the perturbation system when the threshold is properly set for the application. When the thresholds will be set appropriately, we can achieve great success in detecting disturbances.

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