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Maximizing Range Using Ultrasonic Sensor and Arduino

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ABSTRACT: This paper explains how to optimize the ultrasonic sensor's work in detecting and measuring distance and obstacle characteristics underwater using a microcontroller Arduino. One of the most significant challenges of underwater studies is the difficulty for operators to navigate remotely operated vehicles (ROVs) in surroundings where visibility is partially or entirely obstructed. As a solution, a video camera is attached in front of the vehicle and stream the video real-time using a computer operated monitor on the surface. However, set-up and installation may be very complicated and expensive. Instead, we explore the use of a more straightforward and less costly way for visual feedback: the ultrasonic sensor or Sonar (sound navigation and ranging). A single transducer was used to communicate and supply the power needed by the ultrasonic sensor. The sensing procedure is based on the measurement of ultrasonic pulse's travel time from the target object submerged under water. The sonar was waterproofed before sinking in the water to achieve the desired output. Any hindrances to maximize the desired result were eliminated. The result shows that the sensor delivered significant information about the relative proximity of the obstacles against the ROV when all the testing requirements were met.

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I. INTRODUCTION

In exploring and taking measurements underwater, researchers most likely use remotely operated vehicles (ROVs) to achieve their objective. Most maintenance and inspection events of gas plants and sub-sea oil are initiated by hiring divers and deploying submersible devices like the remotely operated vehicles (ROVs).Marine surveys traditionally use towed instruments and sonars for data collection (Nolan &Toal, 2014). Traveling underwater can result in a wide variety of situations. Areas like ponds, lakes, and deeper water levels make visibility even harder and severely limited. The operator may find it difficult to see the vehicle's exact location as well as determine its safe path while traversing the waters. However, individual devices are specifically designed for this purpose – the Ultrasonic sensors or Sonar sensors.

Ultrasonic or Sonar sense is perhaps one of the best methods to detect and sense the proximity of a particular object of many forms. Sonar navigation and ranging make use of ultrasonic sound waves that travel to a public medium such as water to calculate the distance (McArthur,2009) to a target being detected and vibrates at a frequency far more than the range of human hearing. Although sonars are used commercially for many years, not all can be affordable especially for underwater sonar systems. There are criteria in choosing the right sensor: accuracy, resolution, range, type of sensor, environmental condition, control interface, resolution, and calibration (Into robotics, 2013).

Most ultrasonic sensors are applied for automotive industry garnering global sales of $1.84 billion in 2016 and are expected to increase in 2022 forecasting $3.2 billion (Statistical, 2017). One market report shows a complete breakdown of the global ultrasonic sensors market based on authenticated facts, data, and insights. The report identified the significant manufacturers of ultrasonic sensors: Honeywell International, Baumer, Siemens, OMRON, and SensComp (PRNewswire, 2017).

Two types of sonar are identified: active sonar and passive sonar (All about circuits). Active sonar comprises detector and emitter which features its capacity to both detect the distance of an object and its orientation. It can sense the signal strength to determine the amount of time it took to be picked up by the receiver. Active sonar uses one or more transducers to deliver sound wave reflection from possible underwater obstacles Passive sonar, on the other hand, picks up signals from marine life such as whales and vessels such as a submarine. Since passive sonar doesn't have emitters, they merely receive sound waves towards them. Passive sensors are primarily presented as microphones that only detect the noise present under certain conditions.

Primarily, sonar's use is to see and navigate underwater through sound propagations. Since sound waves travel farther in water than air, sonar became the most preferred sensors apart from other sensor types like radar (All About Circuits).

Although sonars are preferred for underwater detection, it can still be used in an air medium. However, a researcher must anticipate little chance of interference, which may display on the monitor while measuring the distance.

A periodic electrical signal drives the transducer to emit packet of sound waves known as pingand reflects off from the object back to the sensor where vibration is converted back to measure the distance to an object (McArthur,2009). Its transducer or in general terms described as its microphone sends and receives ultrasonic pulses to relay the information back about the object's proximity. Through the high-frequency sound waves that the sensor emits, the waves reflect from boundaries producing variations of echo patterns. Through the echo patterns, the detector identifies the distance to the target by recording the time lapses between the sending and receiving process of the sonar pulse. Because of this ability, sonar sensors have distinct benefits over optical, mechanical and radar technologies.

This paper explores how to maximize the ultrasonic sensor's work is optimized as a detector underwater using a transducer called Arduino. The concept will be explained from applying a simple, compact sonar system that uses inexpensive materials. Such operation will be described usingdifferent applications, and mainly ROV concept and how it works to determine distance and characteristics of nearby objects. All the data and demonstrations in this paper will be based on relevant studieswhile resources are being cited.

II. ULTRASONIC SENSOR AND ITS CONCEPT

Ultrasonic is a sound above average human hearing range, which is at a maximum frequency of 20 KHz (Coulton). The sensor uses a contactless principle to measure levels for both liquid and solid objects in different industries. In most cases, it is suitable for corrosive, hot, and boiling liquids and ranges from 40 KHz to 200 KHz. The ultrasonic sensor works a similar way as the radar but uses a sound wave instead of radio waves. It is comparable with how the Bats use the method to measure the distance while they are traveling. Additionally, this sensor uses a level measurement to discover fish positions in the ocean, view of the scuba diver in the sea, and locate submarines water level.

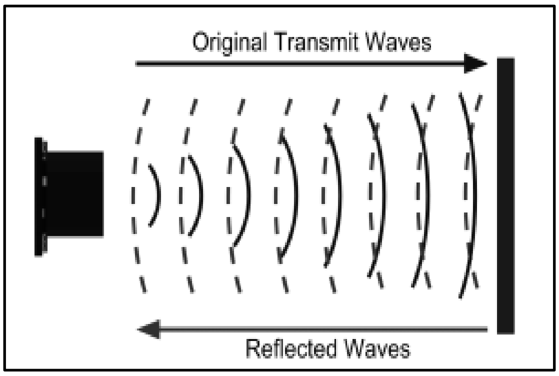


Figure1. Ultrasonic sensor transmitting and receiving sound waves (MaxBotix)

Ultrasonic sensors or transducers belong to a type of acoustic sensor that comprises three broad categories: the transmitter, the receiver, and the transceiver. The transmitter's role is to convert electrical signals into ultrasonic sound waves. Receivers convert this sound into electrical signals, and transceivers transmit and receive the sound waves. Unlike optical sensor which uses transmitter and receiver, the ultrasonic transducer uses a single element to do the emission and reception (Sensor Basics).

Based on a reflective model of ultrasonic sensor, only a single oscillator emits and receives the ultrasonic waves consecutively. In the same way, radar and sonar operate, ultrasonic transducers are often used in systems that evaluate objects by understanding the reflected signals. Ultrasonic probes and baths apply the energy formed to activate particles in a wide range of materials. For instance, by measuring the time lapse between sending the signal and receiving the reflection in the form of echo, the distance is calculated.

1.1 Ultrasonic Applications

Migatron Corporation, a company that specializes In ultrasonic sensors, made with piezoelectric crystals identified two uses of ultrasonic sensors: for proximity detection and ranging measurement. Proximity detection refers to sensing of an object passing at a certain range and generating an output signal through a detection point that is independent of the materials and target size. Ranging measurement measures the precise distance of an object moving to and from the sensor measured based on time intervals between the transmitted and reflected ultrasonic sound. They also illustratedtypical applications of ultrasonic sensors: liquid level sensors, distance measurement, and product line sensors.

Ultrasonic sensors have manyapplications such as the following:

1. Distance Detection

After the ultrasonic wave is transmitted and received via a transducer, it generates waves which spread out according to its beam pattern. As the wave travels through air and reaches an object, the signal goes back to the transducer. A small analog signal is generated, amplified, and filtered before processing the signal occurs.

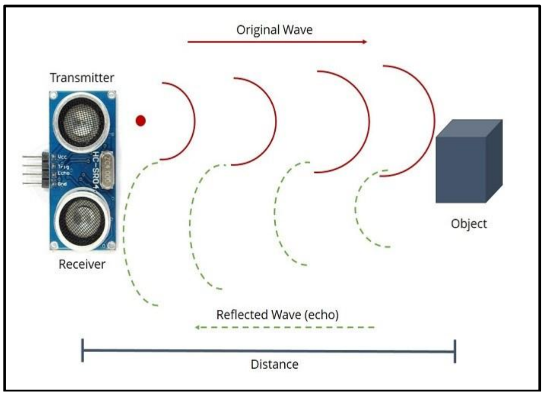


Figure2. Illustration of ultrasonic sensor HC-SR04 using Arduino to measure distance (randomnerd tutorials)

2. Liquid level control

Ultrasonic sensors are widely used in underwater to measure the distance and the characteristics of an obstacle. In water industries, it is essential that measure the water level in applications like tanks, basins, wells, and cooling towers. During operations, the sensor is mounted over the water to determine the distance (Massa, 2016). This sensor is reliable and cost-effective for this application.

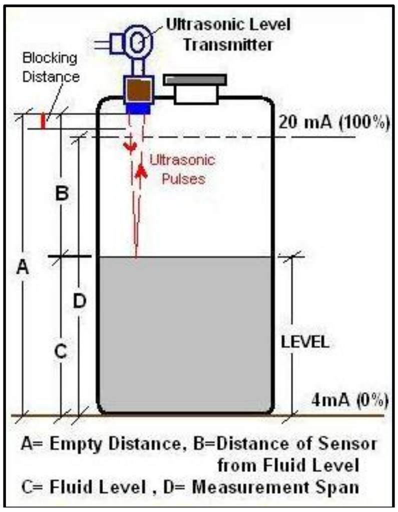


Figure3. A water tank set-up with an ultrasonic sensor (Coulton)

3. Loop control

Similar to how a Bat transmits ultrasonic sound, the target material's density affects how much sound signal is reflected. Traditional suppressing materials disperse echo instead of revealing it. Thus the poor quality of sound waves goes back for sensing. Foams lack the density to scatter such reflections as sound passes through them.

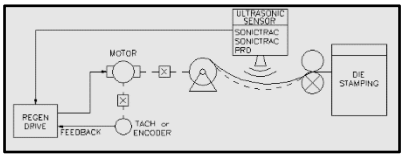


Figure4. Loop Controlled Center Driven Feeder (Carotron)

This slow speed application allows direct control of the material loop through an ultrasonic sensor, which is set-up to provide +/- DC reference signal to a regenerative drive. This drive has an output direction that is controlled by the reference polarity. Its capability is also needed to handle high inertia of the material roll.

4. Robotic sensing

In automotive applications, ultrasonic sensors are used in advanced driver assistance systems (Soehren, 2014). ADAS are modules that drive ultrasonic signals performing all forms of signal processing.

5-Vehicular detection for automotive assembly

Carullo and Parvis (2001) used the ultrasonic sensor to measure distance in an automotive application, wherein their primary objective is to obtain distance value from selected points of the ground of a motor vehicle. Here, they studied the concept of smart cars that require high-technology using a constrained optimization technique to obtain the reflected pulses detectable by threshold comparator.

Other uses of ultrasonic sensor are box-sorting using multi-transducer, profiling, counting detection, inkwell level detection, irregularity detection, breakage, tension control, stacking height control, and beam detection.

When using ultrasonic sensors, there are a variety of applications that make it very beneficial. Its uses for measuring wind speed and direction, tank or water levels, airspeed, and water speed are just among the most common. In measuring direction or speed, the device uses multiple detectors to measure relative distances to objects in the water or air. When it comes to tank or sea water level, the sensor measures the ranging distance to the surface of the water as well as the objects behavior and character. Other applications of ultrasonic sensors include sonar, burglar alarms, wireless charging, and humidifiers.

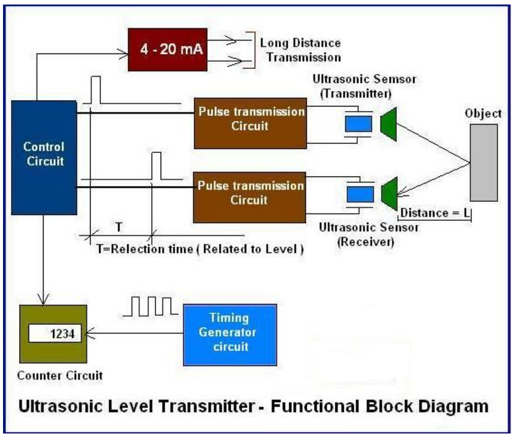


Figure5. Ultrasonic Level Transmitter Block Diagram (Coulton)

Ultrasonic systems typically generate pulses through a transducer above a frequency 18KHz by turning the electrical energy into sound waves. As these waves are emitted, it goes back through a reflection wherein the same electrical power is measured and displayed. The technology applies to limited shapes of surfaces and the consistency of the material. The softer the surface is, the more distortion on the surface level readings is expected (TesTex). Also, this technology can detect objects that are approaching as well as track their positions. Ultrasonic testing may be used through different mediums. Even though it copes with surface conditions well compared to other strategies, good contact between the transducer and the material being tested must be keenly observed. High level of surface roughness can decrease the transmitted energy, which results in the loss of received amplitude and reduction in detection capacity. Generally, surface coatings like thin foams are transparent to ultrasonic, but thick foams may cause surface reflections, the reason why it should be removed before testing.

1.1.1 Ultrasonic Distance Measurement

The hindrances on expensive sensors are saved by the creation of the sensor called HC-SR04. Distance Measurement using Arduino is a straightforward project for detection purposes. However, it is essential that before starting with the design, in-depth knowledge must be achieved. As it has been discussed from the earlier pages, the ultrasonic sensor uses a distance measuring concept similar to Bats, wherein a soundwave is emitted and reflected for value.

1.1.2 Ultrasonic Sensors for Water Level Detections

A typical sensor used in detecting the water level in a reservoir is through an infrared optical sensor (Sing & Ker, 2015). However, the most efficient and contactless means of water level detection is through ultrasonic sensors because it possesses high accuracy ranging from 2cm to 500cm to and from the object while delivering a resolution of 0.3cm (Bello et al., 2018). Mostly, researchers use the HC-SR04 rangefinder because of its capacity to transmit short but high-frequency pulses on regular intervals propagating at a sound velocity.

1.1.3 Ultrasonic Obstacle Detection

Underwater obstacle detection uses transducers that are designed for the mentioned purpose. One of the autonomous flight tasks with drones (aerial vehicles) is the obstacle detection within its aerial environment (Gibbs et al., 2017). However, current laser technology appears to be the most commonly used in aiding maintenance repairs and operations because of its capacity to provide high resolution in the long range.

1.1.4 Functions of Ultrasonic Sensor

Generally, the sensor's role is quite sophisticated because of the way it measures different characteristics of an object. It measures physical quantity like pressure and speed which are converted into signals. Since sensors depend on its working principle and the categories of measurement programmed when it is designed, almost all of its types emit signals and measure reflections to come up with an absolute value or dimension. One of the most common sensors ever invented is the ultrasonic sensor.

Even though there are many types of sensors for measuring water depth, the ultrasonic sensor application is widely known to be the most convenient. Using this type of sensor calculates water depth by finding the distance between the water surface and transceiver. The sensor transmits a short ultrasonic pulse and delivers it back when it strikes the surface. As the pulse travels back, the traverse time is measured. Then, the measured distance is deducted from the total depth of the tank to determine the depth.

Research conducted by Bello et al. (2018) featured an automated non-intrusive sensing control system to monitor the water level of the reservoir tank base on the wave reflection property. It consists of two ultrasonic transceivers that generate pulses to be used for determining the depth of the water surface. A microcontroller ATMEGA328 was programmed to control the water level and read the sensors. It was also used to display the volume of water on

LCD. The result shows that the system is stable both at laminar flows and turbulence.

Liquid level sensors are essential to the control process and inventory management within the industries. Both the analog type (continuous level) and digital type (point level) sensors are applicable based on the system requirements and the liquid level measurement process. Digital sensors are used to detect a single liquid height at a predetermined level and are ideal for high or low alarms that flag either overfill conditions or indications of levels below the desired threshold. Analog sensors, on the other hand, provide level monitoring for the whole system and measures liquid level in range instead of a single point, drawing analog signal that correlates to the liquid level inside the vessel or tank.

Figure6. Photo of Tank Level Sensor System (Migatron Corp)

Researchers use ultrasonic sensors to measure the depth of water targeting the ground, as well as detect the object underneath. Although many sensors may be used for this application, the ultrasonic transducer is one of the common types of sensing. In robotics, it is essential to optimize the purpose of the machine, as well as comply with its specified requirements. Given this, selecting the right sensor can be crucial but is not a strict process as long as the conditions are met. Sometimes, one may need several hours to sort what sensors are ideal in terms of tracking and detecting an object. Another feature that makes ultrasonic special is its ability to measure without touching the target or the sensor itself, making it last longer and only require less maintenance.

The application of ultrasonic rangefinders underwater is mainly to detect and manage incidents of the collision. They are instrumental as proximity sensors (non-contact) to detect position, level, distance, and presence. Ultrasonic sensors are far better and more reliable than infrared sensors because they are independent of smoke, dust, light, color, and materials of hard surfaces. This means that the soft materials that do not reflect sonar waves may cause operational issues. However, ultrasonic sensors are widely used in various applications and diverse industrial and non-industrial settings, especially now that different advances in the development of innovative ultrasonic sensors are diversifying the models. This diversification includes aspects that affect its application: characterization, remote sensing, complex environments, ultrasonic visualization and imaging, biomedical and medical use, non-linear acoustics, and industrial applications (Sinha &Pantea, 2018).

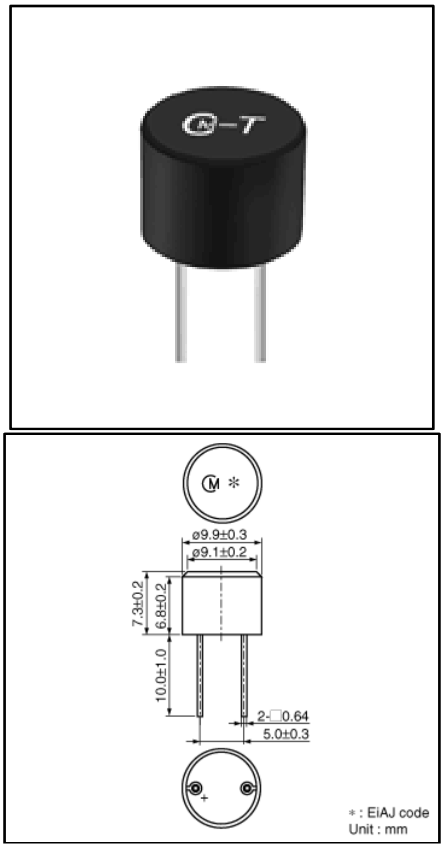
In many cases of measuring and detecting objects underwater, the ultrasonic sensor is submerged in water. However, not all types of ultrasonic transducers are designed for underwater use. Other ultrasonic sensors like MaxSonar-WR (weather resistant) are IP67 rated and are purposely designed for a specific submersion range that only reaches a maximum of the 1-meter level (Gillespie, 2017). Moreover, different ultrasonic sensors are not intended to function for underwater use. Because of this, it is essential that users are aware of the sensor's function before using it; otherwise, the manufacturer's warranty will be voided.

Selecting the best sensor type from various manufacturers is not an easy task especially when a beginner is trying to build a simple machine or robot. In other words, a sensor has to be chosen based on the required shape, size, and range – the three main features that should have to coordinate within the robot's specifications. It is essential to choose a sensor that would deliver consistent performance and precision, which are dependent on many factors.

1.1.5 Ultrasonic sensor for Product Line Sensors

Another typical application of ultrasonic transducers is its use to the manufacturing process for automated control on factory grounds while acting as an indispensable tool for companies. The system is used to maximize its efficiency by ensuring precise measurement and control. Sustained development of the unique piezoelectric technology also allows many companies to commercialize a line-up of high performing aerial sensors. Sensing a multi-feeding of paper sheets, for example, requires certain precision levels and narrow directivity. With frequencies above 17 KHz, conventional oscillators cannot deliver such required characteristics.

Piezoelectric ceramic is used to match the acoustic impedance with that of the air (Murata). Applying piezoelectric ceramic prevents the large gap between the acoustic impedance of the sky and the ceramics. These gaps create a significant loss in the oscillating radiation from the ceramics. A special material called acoustic matching layer is attached to the ceramics to match the impedance with the air, leading to allowable production of ultrasonic sensors up to 100 KHz (Murata). Figure 3 shows a high-frequency ultrasonic sensor model MA300D1-1 and its specifications.



Operating Temperature range	neg 20 to 70 degrees celcius
Construction	High-frequency type
Center Frequency	300kHz
Overall Sensitivity	1.5~4.0Vp-p
Directivity	5deg.(Reference Value)
Capacitance	1300pF
Capacitance Tolerance	±20%
Max. Input Voltage	50Vp-p Drive wave number:5 cycles, Drive cycle:300Hz

Figure7. A High-Frequency Ultrasonic Sensor MA300D1-1and its specifications (Murata)

Figure8. Product Line Sensors in the automotive manufacturing process (Migatron Corp.)

1.2 Ultrasonic Sensor and Arduino for Detection

Measuring distance without actual contact requires ultrasonic sensors. They are an excellent tool for several usages like water level and distance measurement. Mainly, ultrasonic systems are efficient ways to calculate precise small distances. A circuit project made by Saddam (2015) used an ultrasonic sensor to determine the obstacle's distance to and from the sensor. Because the basic principle of ultrasonic transducers is highly dependent on the sound reflections (echo), the researcher made distance calculations based on the traveling time of both the outgoing and reflecting sound waves to origin after striking on the obstacle. Arduino is used to helping calculate the distance for his research.

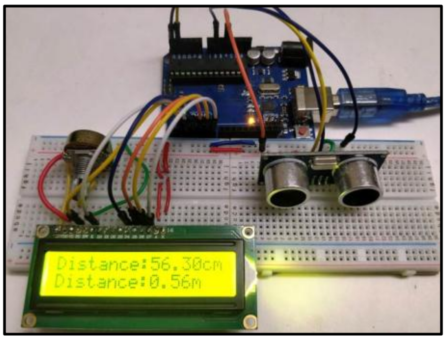


Figure9. Distance Measurement using Ultrasonic sensor and Arduino (Saddam, 2015)

The design uses ultrasonic sensor HC-SR04 to measure distance range of 2cm to 400cm, with an accuracy of 3mm. Its module comprises an ultrasonic transmitter, a receiver, and a control circuit. The working principles of an ultrasonic sensor (HC-SR04) are:

1. Using trigger, a high-level signal is driven for 10 microseconds.

2. Eight 40 KHz signals are sent automatically while detecting the ultrasonic pulses.
3. Once the signal is received, it is considered a high level. (Saddam, 2015)

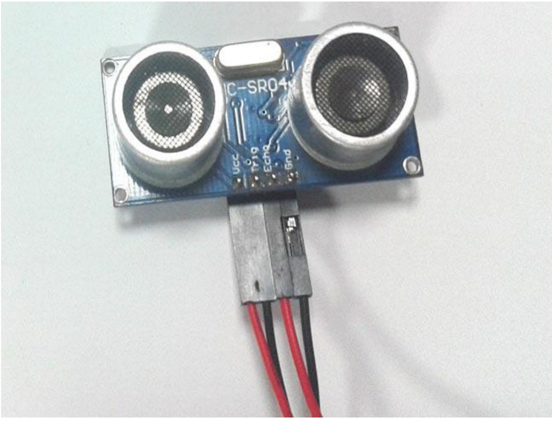


Figure10. Actual photo of HC-SR04 module (Circuit Digest)

To explain its process, as ultrasonic sensors work on a natural state of echo, a pulse is sent for about 10 microseconds to trigger the module. When the pulse is detected, the module automatically sends out eight sound cycles of 40 KHz signal and identifies its echo. After striking with the obstacle, the wave reflects and is captured by the receiver.

Distance is calculated through the following formula:

D = (t*s(344m/s))/ 2

The product of time and speed is divided into two because the signal traveled twice (from and to) back to the sensor. This means that the travel time to reach the obstacle is half of the total time taken.

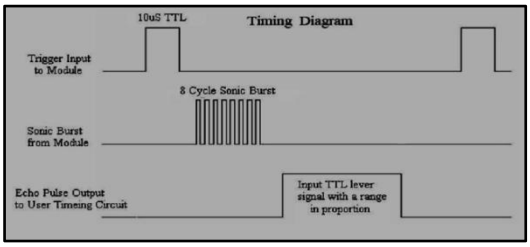


Figure11. Pulse illustration of HC-SR04 (Circuit Digest)

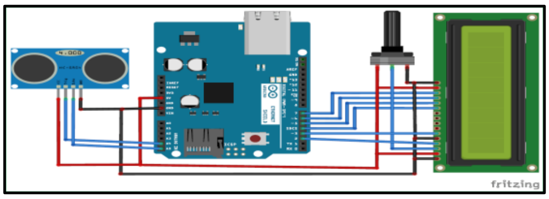


Figure12. Circuit diagram of the ultrasonic sensor and Arduino (replicated: Saddam, 2015)

Theabove figure shows the circuit diagram for the ultrasonic sensor and Arduino. To elaborate, the connection of the ultrasonic sensor's trigger and echo pins are directly connected to the A4 (18) and A5 (19) pins of Arduino. The 4-bit mode Arduino is connected to a 16x2 LCD, and the RS control pin, En, and RW are connected to the Arduino pin 2, 3, and GND. Data pins D4-D7 are connected to 4, 5, 6, 7 of the Arduino. To achieve the goal, a trigger must be initiated from the ultrasonic sensor module to emit signals using Arduino and wait for the echo to reflect. Arduino does its job by reading the signal's travel time from the moment it was issued to the time the echo reflected was received. Given the speed of sound (344m/s), the distance is calculated using the formula mentioned above. A sensor code is generated to perform calculations and display results by using appropriate functions.

```
#include <LiquidCrystal.h>

#define trigger 18
#define echo 19

LiquidCrystal lcd(2,3,4,5,6,7);

float time=0,distance=0;

void setup()
{
 lcd.begin(16,2);
 pinMode(trigger,OUTPUT);
 pinMode(echo,INPUT);
 lcd.print(" Ultra sonic");
 lcd.setCursor(0,1);
 lcd.print("Distance Meter");
 delay(2000);
 lcd.clear();
 lcd.print(" Circuit Digest");
 delay(2000);
}

void loop()
{
 lcd.clear();
 digitalWrite(trigger,LOW);
 delayMicroseconds(2);
 digitalWrite(trigger,HIGH);
 delayMicroseconds(10);
 digitalWrite(trigger,LOW);
 delayMicroseconds(2);
 time=pulseIn(echo,HIGH);|
 distance=time*340/20000;
 lcd.clear();
 lcd.print("Distance:");
 lcd.print(distance);
 lcd.print("cm");
 lcd.setCursor(0,1);
 lcd.print("Distance:");
 lcd.print(distance/100);
 lcd.print("m");
 delay(1000);
}
```

Figure13. Code to calculate the distance (Saddam, 2015)

Comparably, a motion sensor Arduino was designed by Zakariye (2013). The project aimed to create an alarm for individuals and businesses in keeping their homes and companies safe from intruders. The device uses light, vibrations, and other methods that detect changes in the environment such as various forms of movement and light obstacles. However, the design uses a PIR sensor and not an ultrasonic transducer.

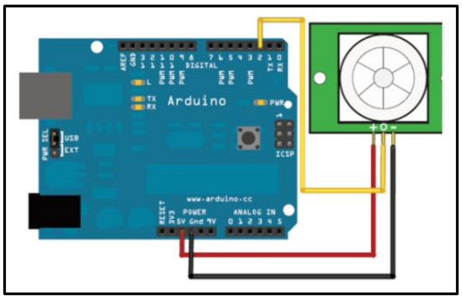


Figure14. Circuit diagram for motion sensor Arduino (Zakariye, 2013)

1.3 Sonar Sensing for Underwater ROVs

A study conducted by Nolan &Toal (2014)described the ultrasonic sensor for integrationon the unmanned underwater vehicle (UUV). Through a wide-angle transmission pattern, short minimum detection range, high range resolution, and fast response time, the sensor was characterized. The UUVs proximity operation to marine platforms like hazards and seafloor, sensors that range below 2-meter minimum detection ranges to some few centimeters are needed because commercial sensors with this capability are not yet available, the sensor they presented was designed to provide coverage at close range while augmenting data from using conventional sonar and vision sensors in targets like docking, station keeping, and avoidance from the collision.

Figure15. An ROV equipped with a modern technology lighting system and video camera (Marine Technology)

Primarily, maintenance and inspections of gas plant and sub-sea oil are initiated by hiring divers and ROVs. Sonars and towing instruments were used as a traditional method of data collection. Essential cost-savings are available through the use of vehicles that do not have to rely on specialist support vessels and whose tasks are not limited by weather conditions (Danson, 2002).

1.3.1 Vision and Camera Sensors

Figure13. Vision and Camera Sensors (Edmund Optics)

Underwater visual systems are an essential part of most, ROV platforms. Camera structures are a vital tool for the pilot because it allows him to visualize the vehicle's working environment, as well as to initiate remote vehicle navigation and possible positioning in a close-premisereview or intervention setup. However, vision sensors are sometimes unreliable in many water conditions:

• Vision sensor can be significantly affected by water turbidity and translucency.

• Suspended particulates in the water column, e.g., clouds of sandthat are accidentallyinterrupted by a vehicle movement, may render a vision system

• In shallow waters, the tide and depth alter the light gradient of the baseline background image which leads into the more significant challenge of object classification.

Another high design that uses Arduino is the model created by McArthur (2009), which uses a transducer MB7062, a MaxBotix waterproof sensor. MB7062 uses a single transducer having a center frequency of 42KHz and PVC housing with IP67 protection rating. Because of its house, it can be submerged underwater level up to one meter in 30 minutes (Bloch, 2009).The transducer was connected with the Arduino, and the submersible sensor was tested through a swimming pool using three pieces of 5 ft. PVC pipe connected by slip by slip couplers. PVC of 6 inches length was attached perpendicular to the base pipe end so that the sensor would point directly at eh edge of the pool.

Several LEDs with colors green, red, and yellow light up alternately as the ROV approaches an obstacle underwater. It signals the operator if there is an indication of obstacles or collision providing the operator enough to respond to notice the object. Threshold distances that determine the LED color to turn on for any reported distance were included in the data that Arduino code collects. Distance or more than 10 feet was programmed to trigger green LED, while between 6 and 10 feet would trigger the yellow LED, less than 6 feet would trigger a red LED. The output on the Arduino serial port is the distances measured by sonar sensor and is captured using the built-in serial monitor in the Arduino IDE.

Sometimes structural components like the small pipe are positioned in the acoustic path between the water and the ultrasonic sensor. These components reflect a portion of the sound, a false echo that interferes with the capability of the sensor to correctly detect the echo from the water surface. However, some advanced ultrasonic transducers can be accustomed to ignoring the false echoes, enabling them to provide accurate liquid level measurements (Massa, 2016).

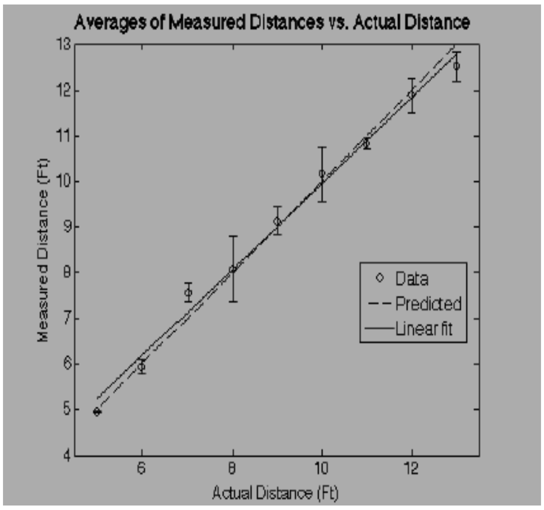


Figure16. Distance reported by MB7062 against the predicted distances (McArthur, 2009)

The above figure creates an equation for the linear regression displayed by the sensor, where x is the actual distance to the object; such equation is:

Y=0.945x + 0.5057 in (ft.)

To calculate the zero-order uncertainty of the MB7062 sensor, the following equation is used:

U_0 = +/- (1/2) * resolution (95%),

wherein**U_0** was determined to be +/-0.85 inches (equivalent to +/- 0.071 feet) based on the smallest rise between the reported distances over all tests. Looking at the figure, it appears that the distances followed a certain trend that validates measurements declared by the sensor. Additionally, a slope of 0.945 linear fits close to 1 is reasonable.

Meanwhile, the instrument uncertainty of +/-0.66 feet shows large enough to merit concerns about the reliability of the sensor. However, the calculated error like interference caused by swimmers during the test should be taken into consideration because it causes disturbances in the water. Because of this, the measuring devices slightly moved during the testing process.

Figure 17below shows the propagation of sound waves to and from the transducer. The time that lapses between the transducer and the echo is related to the distance to an object through this given equation:

$2d = {}_{sound} * t$

Where, d is the object's distance, $v_{sound}$for the water velocity, and t for the elapsed time; t represents the sound wave's travel time from and to the object.

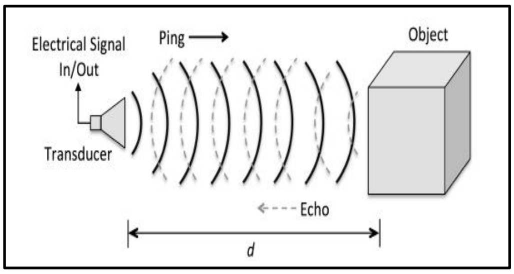


Figure17. Propagation of ultrasonic sound waves emitted by the transducer and reflected off the object with location d from the sensor.

In designing a robust sonar system, several considerations and difficulties like the physics of sonar may be expected: temperature gradients, sound wave attenuations, instrument sensitivity, and noise (McArthur, 2009). Thus, extra care should take place to ensure that the resonant frequency of the transmitting and receiving transducer has sufficient travel distance for its sound waves while maintaining its condition under minimal susceptibility to interference from the noise sources.

1.4 Pros of an Ultrasonic Sensor

Because the ultrasonic sensor has no moving parts, it can independently function without any physical contact with the object. That's why it is most suitable for measuring tank levels with corrosive, hazardous, and boiling liquids. Given this, the reading accuracy remains unaffected even though the chemical compositions are changed as well as the dielectric material consistency in the fluid process. Furthermore, below are the other benefits of using ultrasonic sensors:

1. High Frequency, sensitivity, and penetrating power

This feature of the ultrasonic transducer allows the system to detect external and deep target location quickly. While it's true that some sensors come with a pre-configured capacity to work optimally, others are programmable to accommodate individual needs based on its application.

2. Easy interfacing
Ultrasonic sensors can be easilyinterfaced with almost all types of controllers. In this paper, we cited the use of the HC-SR04 ultrasonic sensor and interfaced it with Arduino.

3. Greater accuracy
The measurement procedure produces an accurate and precise depth of the surface and thickness of the material. Ultrasonic sensors like HC-SR04 uses sonar as Bats do. It offers excellent non-contact detection on ranges with high accuracy and readings.

4. Sensitivity to nature
Its sensitivity to the natural environment and orientation of the object makes it easy for detection.

5. Convenient to use
The ultrasonic sensor is independent of black material or sunlight, so it is widely used even at very high temperatures and light variations.

1.5 Cons of an Ultrasonic Sensor

Even though ultrasonic level transmitters are the best devices for measuring fluid levels and the reflected sound waves are of acceptable quality, there is a possibility that it may not be convenient if the depth of the tank is high or if the echo is dispersed or absorbed. With the presence of smoke or high-density moisture, the sensor may not deliver its function well.
The definitions and concepts of ultrasonic sensor appear to have honest and genuine details about its operation. However, in practice, various technical complexities must be noted to manage the correct level reading. Some factors are considered:

1. Variation of air temperature
Sound velocity changes according to the air temperature. In installing an ultrasonic sensor, it is suggested that an integrated temperature sensor is also set-up to compensate for the changes of velocity.

2. Irregular Shapes
Welded joints and irregular shapes developed by the edges interfere the echo reflected from the object. This empty distance and measurement span must be anticipated correctly to include in the calibration of the transmitter.

3. Transient characteristics
Transient characteristics of the sensor cause blocking distances. The measurement span should be controlled for it not to extend to the blocking distance.

In addition to the cons of ultrasonic sensor mentioned above, it is also prone to interference when viewed in the soft surface like foam and cloth. These sensors work best with the high-density surface to reflect good quality sound waves for detection. Ultrasonic sensors are also ineffective in delivering good responses with loud noises such as air hoses as they may provide false information. Also, they have response time with a less fraction compared to other types of sensors. Lastly, the ultrasonic transducer delivers minimal sensing distance depending on the type of sensor chosen; environmental factors like humidity and pressure may affect its responses.

III. CONCLUSION

Ultrasonic sensors are widely used for many purposes, and one of them is for the use of detection and sensing underwater obstacles, including measurements of liquid level and distance range from objects. There were different types of sensors, and each of them has their essential purposes. This paper mainly discussed the key features and characteristic of the Ultrasonic sensors including its applications and functions to different industries. Ultrasonic sensors emit sound waves that are reflected to determine and measure the distance from the target object. The use of ultrasonic transducers is emphasized through its system applications like liquid levels and object proximities.
Because of the complexity of sonar systems, buying a ready-made device can be very expensive because the sensors themselves account for only a little portion of the total cost, which means the majority of the expenses may likely go the development support that comprises demanding electrical circuits. The primary thing to perform successfully on such designs all matter from the signal produced by the transducer. Here, an Arduino is used as the transducer. Despite the sensor system's complication, a student or researcher may be able to create a simple and inexpensive design, but it may require in-depth knowledge of different engineering fields such as electrical and electronics. Other devices such as oscilloscopes and other electrical and electronic equipment are required.
Pros and Cons of an ultrasonic sensor were demonstrated too. We have found out that these sensors have strengths and weaknesses, just like other sensors such as radar. Three applications of underwater ultrasonic sensors were explained: distance measurement, liquid level detections, and obstacle detection. We presented a sample of a modest ultrasonic transducer mounted in front of an ROV to measure and determine the distance to

nearby obstacles underwater from the formula given.

A low-cost ultrasonic sensor delivering a good range of resolution with wide-directivity was presented in this paper. The transducers introduced in this paper wereMB7062 and HC-SR04 interfaced with Arduino for small size low-power consumption that is ideal for ROVs. The system demonstrated was designed purposely for the use of collision avoidance and stabilization application on remotely operated underwater vehicles wherein it delivers the same capabilities as commercial sonars.

The initial part of the paper discusses the uses of the general sensor such as radars and shows the vast possibilities of ultrasonic sensors, particularly in the use of underwater measurements and detections. McArthur's design was purposely created to test the transducer's capacity to respond and report to the ROV operator the distances being measured to and from the objects (how far and how closes). For this reason, uncertainties are expected to occur because of the nature of the water medium while doing the test. In the case where lesser risk and higher resolution is desired, a multiple-transducer may perform better compared to Arduino.

Because sensors are typically designed purposely with its corresponding range, maximizing the distance between the transducer and target can be possible by eliminating the factors that affect the signals, in this case, are the soft surfaces where sound waves are being reflected. Soft surfaces such as foams absorb sound waves and do not deliver good quality echo back to the transducer, eventually resulting in various errors. Thus, the distance can be optimized not through the sensor system itself but with the type of surface and environment of the cover: very less uncertainty or error results in accuracy and precise measurement .

IV. References

[1]. Digikey. How to use a sonar sensor or an Arduino to measure distance. Retrieved on February 28, 2019.
[2]. Bloch, H. P. (2009). Ingress Protection code explained. World Pumps. 11:26. Print.
[3]. Buchler, J. (2002). Applications of Ultrasonic Testing using improved signal processing methods. Vol. 7 No. 10. Retrieved on February 27, 2019.
[4]. Burnett, R. (2018). Understanding how ultrasonic sensors work. Retrieved onFebruary 23, 2019.
[5]. Carotron. Non-contact Loop Control. Retrieved on February 28, 2019.
[6]. Circuit Digest. 27 June 2015. Ultrasonic Sensor Module. Retrieved on February 28, 2019.
[7]. Coulton. Beginner's guide to the ultrasonic level transmitter. Retrieved on February 28, 2019.
[8]. Danson E. 2002. The Economics of Scale: Using Autonomous Underwater Vehicles (AUVs) For Wide-Area Hydrographic Survey and Ocean Data Acquisition. International Federation of Surveyors FIG 2002 XXII Conference. Washington, D.C.
[9]. Edmund Optics. Imaging Electronics 101: Understanding camera sensors for machine vision applications. Retrieved on February 28, 2019.
[10]. Gillespie, K. (201). Using an ultrasonic water depth sensor. Maxbotix. Retrieved on February 25, 2019.
[11]. Intorobotics. (2013). Types of sensors for target det. and tracking. Retrieved on February 28, 2019.
[12]. Massa, D. (2016). Ultrasonic Sensors for Water Level Measurement. Retrieved on February 28, 2019.
[13]

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University, Utah. P. 1-8.
[14]. Migatron Corp. Applications of Ultrasonic Sensors. Retrieved on February 28, 2019.
[15]. Murata. High-Frequency Ultrasonic Sensors. Retrieved on February 28, 2019.
[16]. Parkar, S. et al. (2018). Obstacle detection using the ultrasonic sensor for amphibious
[17]. surveillance robot. Vol. 4, pp. 28-33. IOSR Journal for Engineering. India.
[18]. PRNewswire. 14 August 2017. Ultrasonic Sensors Industry – Global Market
[19]. Analysis, Size, Share, Growth, Trends, and Forecast 2017-2022. Retrieved on February 28, 2019.
[20]. Random Ner Tutorials. Complete Guide for Ultrasonic Sensor HC-SR04 with Arduino.Retrieved on February 28, 2019.
[21]. Saddam.(2015). Arduino and Ultrasonic sensor based distance measurement. Retrieved on February 28, 2019.
[22]. Sing, L. Y. & Ker, P. J. (2015). A microcontroller-based system for liquid level detection using infrared sensing. IEEE Student Conf. Res. Dev. Pp. 294-295.
[23]. Sinha, D. &Pantea, C. (2018). Ultrasonic Sensors 2018. Los Alamos, New Mexico. Retrieved on February 27, 2019.
[24]. Statistica. (2017). Global Automotive Industry ultrasonic sensor sales in 2016 and 2022. Retrieved on February 27, 2019.
[25]. TesTex. Preparation. Retrieved on February 28, 2019.
[26]. Zakariye, A. 2013. Motion Sensor Arduino. Retrieved on February 28, 2019.