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UNDERWATER GROUND MAPPING FOR FLOOD DISASTER USING ULTRASONIC SENSOR

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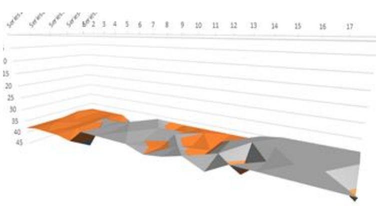
Graphical abstract



Abstract

Search and Rescue (SAR) team used dip stick to measure the water depth and identify the badly eroded area and a guide line will be placed to assist them. However, ground erosion is unpredictable coupled with unknown sizes make the SAR task more difficult thus posing grave danger to SAR team in action. Therefore, this current method is no longer reliable because the flood current will swipe it away and rendered the guide line to be unfeasible over time consuming. A system proposed in this study was developed using ultrasonic sensor array to reconstruct the ground map in flood area. It consists of several sensor arrays to collect the underwater depth information and convert them into mapping data before relaying them to ground station. The results then will help the SAR team to identify the safe path to reach for the flood victims. The factor to focus on is the depth of the flood, the current flow and the medium that the wave will go through. The current flow will be the main threat because the sensor needs to be on the right angle to get the accurate reading. The data then will be transfer to excel to start the mapping for underwater ground. Based on the result from the prototype testing conducted using water tank, sensors can be installed to get wider map view and mapping can be improved by using multi-angle shapes for it to be more accurate in flood disaster.

Keywords: Underwater ground mapping, flood disaster, ultrasonic sensor, current, depth

1.0 INTRODUCTION

Ultrasound or sonar propagation in waters is greatly influenced by the interaction with both the water surface and the bottom surface. This interaction can be used as a tool for detecting small targets on or beneath the seabed or for examining the physical properties of the surface [1].

Visualization of acoustic wave fronts started to be the object of intensive research in the 1960s. The understanding of acoustic wave fronts and their interaction with objects is important for optimizing both the performance of acoustic sources and detectors and for the generation of structures, surfaces and materials with particular acoustic absorption and scattering characteristics [2]. Moreover, the visualization of acoustic wave fronts represents a reliable test for transducer design or periodic control, i.e., to check if the properties of the generated sound beam still persist over a long-term period [3].

Multiple-element ultrasonic arrays can be used to provide improved spatial resolution and additional degrees of measurement freedom. By exploiting the additional degrees of freedom, it may be possible to measure and interpret the distorted ultrasonic field emerging from a complex material, effectively converting the "noise" into "signal" for more complete quantitative nondestructive evaluation (NDE) of the material [4]. That is, an individual element of an array are able to sense smaller regions of a spatially varying field rather than averaging over the "footprint" of the array as does a single element receiver of the same total aperture size. True two dimensional arrays are not readily available. As an alternative, a common yet time-consuming approach to sampling an ultrasonic field is to scan a small-aperture hydrophone across a plane, yielding what is sometimes referred to as a pseudo-array [5].

The increasing use of ultrasonic phased arrays in the inspection and testing of composite materials brings with it the importance of developing ultrasonic signal processing techniques that will achieve better imaging and inspection performances by maximizing efficiencies or minimizing computational requirements [6]. The velocity of ultrasonic waves varies in water, oil, and different composition of water and oil. The composition of water and oil can be determined from the measurement of this propagation time [7].

The speed which sound travels depends on the medium which it passes through. Ultrasonic sensors are often called transducers. The function of the transducers is to convert electrical energy into mechanical energy which directly corresponds to ultrasonic vibration, and vice versa. The most common way of generating and detecting ultrasonic waves utilizes the piezoelectric effect of a certain crystalline material such as quartz. Since the piezoelectric effect is reciprocal, it produces a deformation (a mechanical stress) in a piezoelectric material when an electrical voltage is applied across the material, and conversely, it produces an electrical voltage when a deformation (a mechanical stress) is applied to the material. Thus, the piezoelectric materials can be used for generating and detecting ultrasonic waves that are related to the mechanical stresses [1]. The method utilized in this study is similar to the method used in tomography whereby the transmitter current passes the water and through the receiver. It could also goes through any small dimension object depends on the frequency used [8]–[12].

$$\lambda = c/f$$

Where;
λ – Lamda
c – Speed of sound in water
f - Frequency

The normal occurring flood water in Malaysia is atypically muddy and full of debris. It is not as clear as normal water. It comprised of sand, mud and many other floating and submerged materials which will hinder the soundwave to not bounce back to the receiver. Other than the flood water condition, the flood current, temperature of the water and the distance of flood-bed are other factors affecting the ultrasonic speed. The stronger the occurring flood current, more noises recorded ultrasonically which will affect the reading. In term of temperature, ultra wave can move smoother if the temperature is warmer. The higher the temperature, better waveform will go through. Lastly, the flood-bed will affect the reading if it comprised of soft sedimentation such as moss or mud, the wave would probably not bounce back.

A conventional transducer suffers high-pressure resistance, low resolution, less sensitivity and the performance curve is no longer understandable. Output data need to be reanalyzed, fine-tuned and consumes double wattage rating. Target detection, object classification, platform localization, control and position marking, sub-bottom geological mapping, ocean topography and profiling, bathy-velocimeter, acoustic holography, seismic measurement, biological noise measurement, current measurement, underwater telemetry and sensors network are some applications that require marine transducers. Micro transducer represents new approach for detection and generation that can overcome the shortcomings of conventional transducers [13].

Ultrasonic signals suffer less scattering in turbid waters; therefore, a high resolution underwater acoustic imaging system can be used for imaging under this condition. A high resolution underwater acoustic imaging system was designed to be used on remote operating vehicles. This system is an active, coherent, imaging system that uses a wide-beam transmitter to illuminate the target. The transmitter sends out a pulse or a chirped signal, and a sparse, two-dimensional array is used to receive the reflected signals from the target [14].

A. Bellettini and M. Pinto [15] says that the principle of a synthetic aperture is to displace a normal waveform through the medium and to integrate multiple successive transmissions to create a longer waveform. The ratio of the effective length of the longer waveform to that of the normal waveform is a measure of the gain of the technique.

Underwater sensor can realize real-time unmanned monitoring of the deep water areas, target discovery, location, identification, and local control of actuators. Typically, the underwater acoustic sensor consists of three parts: the underwater sensor nodes, buoys set as gateway node and remote server. Underwater acoustic sensor typically use location-based routing protocol for network data transmission, and deep-water sensor nodes cannot use radio equipment for locating only a very small number of nodes in the network carry the GPS device (usually the gateway node), so underwater sensor nodes can only be indirectly located by calculating their relative positions to the beacon nodes [16].

In this study, a prototype is tested using 5 ultrasonic sensors connected to a computer to transmit pulse and receive soundwave reading. From the reading, the data will be processed and transferred to Microsoft Excel to plot 3D mapping.

2.0 EXPERIMENTAL

The model uses 5 ultrasonic sensors, 12v power supply, amplifier circuit on each sensors and Visual Basic software for data collection.

2.1 Sensor Selection

The ultrasonic used in this model is MCUSD25P200B10.7RS-30C Underwater Ultrasonic Sensor. It is capable to transmit and receive using one sensor. It can be used underwater without damaging the sensor. It can go from 30cm until 3m depend on the power source. The minimum distance must be more than 30cm for the sensor to function properly.

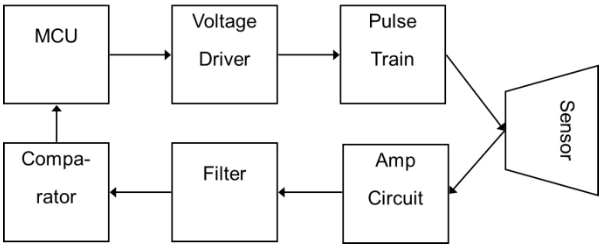


Figure 1 Prototype block diagram

2.2 Data Acquisition System

A system is made to control the pulse for the ultrasonic sensor and receive the data from the sensor. To create a software system, a visual basic is use to create a controlling device. The prototype is connected to the computer by usb device. By determine the port used by the prototype, visual basic can identify the prototype using the programming. The prototype can work in two ways, by push button which will take single result or by time interval where we can set the time to transmit and receive.

2.2.1 Visual Basic 6

Visual Basic 6 is used to produce software which can control the prototype. It can be done with the computer system. Computer system falls into two classes, the software system and the hardware system. The software is the collection of programs or instructions that control the operations of computer hardware [17]. Visual basic program use c++ language. Every command can easily be program for main and sub command the programming have combined and become software which is shown in Figure 2.

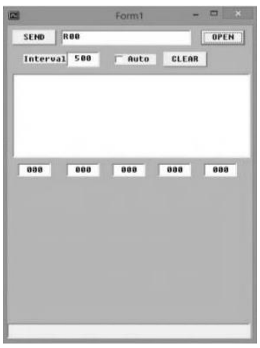


Figure 2 Visual basic prototype controller

2.2.2 Microsoft Excel

Besides visual basic 6, Microsoft Excel is used for calculation, graphing tools, and pivot tables. We can easily construct a map using Microsoft excel for underwater flood-bed imaging produced by the prototype via soundwave.

2.3 Data Collection

The data collected from the prototype is transferred to Microsoft Excel. Microsoft Excel will develop the mapping with the data given.

Table 1 example of data from prototype (labeled)

	depth				
time	S1	S2	S3	S4	S5
1	44	44	44	44	44
2	44	44	44	44	44
3	44	44	44	44	44
4	44	44	44	44	44
5	44	44	44	44	44
6	44	33	33	33	44
7	44	33	33	33	44
8	44	33	33	33	44
9	44	33	33	33	44
10	44	33	33	33	44
11	44	33	33	33	44
12	44	33	33	33	44
13	44	33	33	33	44
14	44	44	44	44	44
15	44	44	44	44	44
16	44	44	44	44	44
17	44	44	44	44	44
18	44	56	56	56	44
19	44	58	58	58	44
20	44	55	55	55	44
21	44	55	55	55	44

Then, we can view the result based on the color of the data by selecting the conditional formatting button.

2.4 Mapping

The data then is processed into a 3D mapping as shown in Figure 3.

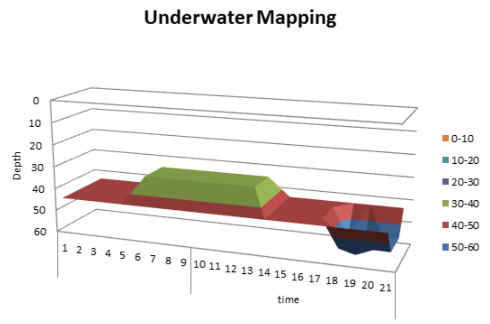


Figure 3 Mapping of result using Microsoft Excel

The map will show the shape and color which differentiate between the shallow part (green) and deep part (blue) of the surface underwater (red will the color for normal depth). 0-30 is mark as shallow surface, 30-50 are mark as normal surface and above 50 are mark as deep surface.

2.5 Amplifier Circuit

An amplifier is an electronic device used to increase the power of a signal. It does this by taking energy from a power supply and controlling the output to match the input signal shape but with larger amplitude [18]. In this prototype, amplifier will be used to control the noise from the sensor as the reading from the prototype won't be stable without it.

2.6 Power Supply

A power supply is an electronic device that supplies electric energy to an electrical load. The power supply can be either 9 volt or 12 volt depends on the depth we want the ultrasonic wave to reach. For this prototype, a 12 volt power supply is used to get the maximum depth of 3 meters.

2.7 Obstacle Materials

We have carried out three experiments for mapping the result from the prototype using a water tank is used instead of real flood in three situations i.e., no object, brick and, brick and PVC pipe as an object. Figure 4 and 5, shows brick and PVC pipe placed in the water tank.

Figure 4 Brick **Figure 5** PVC pipe

3.0 RESULTS AND DISCUSSION

Three experiments were conducted to find the viability of mapping the underwater depth information and to convert them into mapping data before relaying them to ground station. The results from the three experiments conducted using materials as shown below.

3.1 No Object

The first experiment is to ensure the prototype doesn't have any error. The prototype will move along the water tank and the results are shown in Figure 6 and 7.

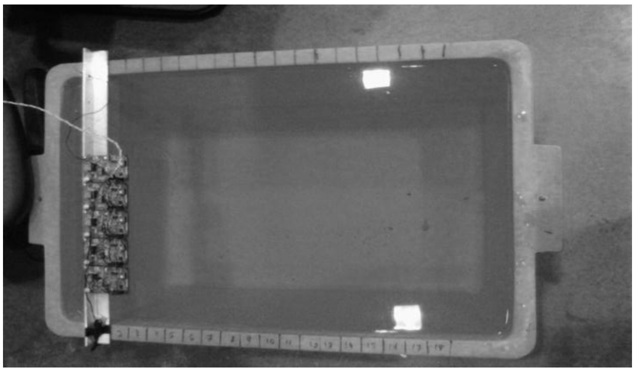


Figure 6 Sensor with empty water tank

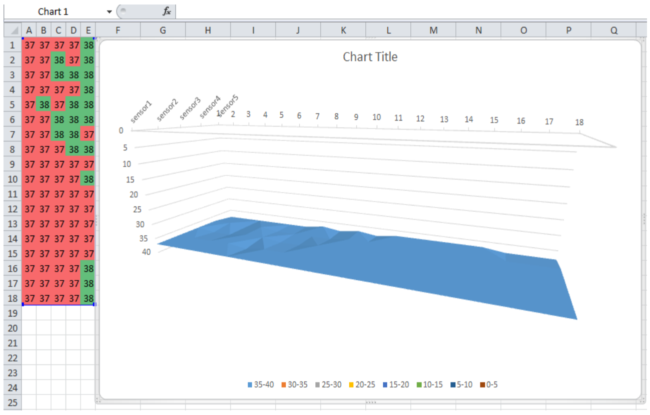


Figure 7 Mapping result

In this result we can see that the sensors are functioning. The depth of the water in the tank was confirmed by the sensors.

3.2 Brick As An Object

The second experiment is to test the prototype with an obstacle in the water. We used brick because it's a solid material and will easily bounce back the sound signal.Results are shown in Figure 8 and 9.

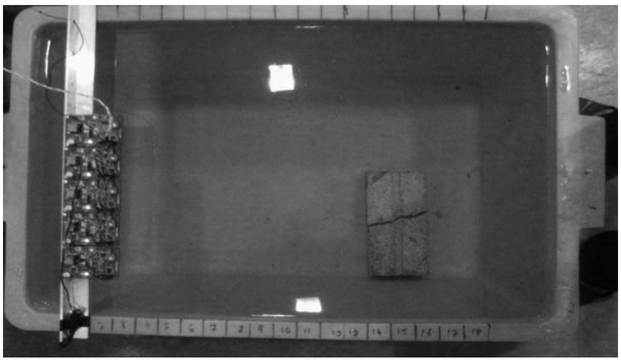


Figure 8 sensors with brick as object

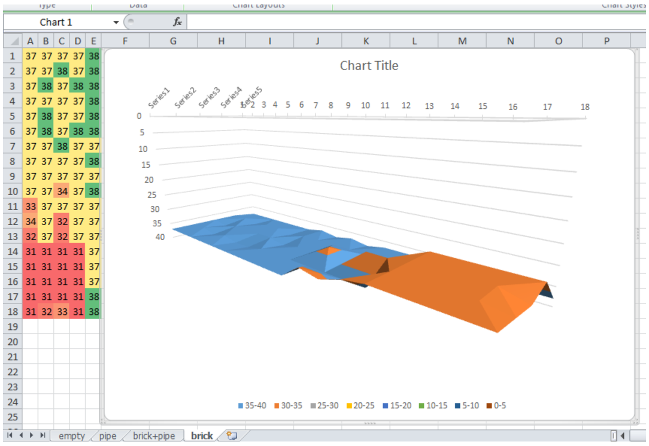


Figure 9 Mapping result

In this mapping result, the sensors detected the brick at the frequency of 200 kHz due to the thickness of the brick which is more than 3.75mm. The data was processed by the software program to create a shallow part on the map where in Figure 9 the blue section is deeper than the orange section.

3.1 Brick and PVC Pipe as an object

The final experiment is to test out the brick and PVC pipe together as obstacles. The result is shown in Figure 10 and 11.

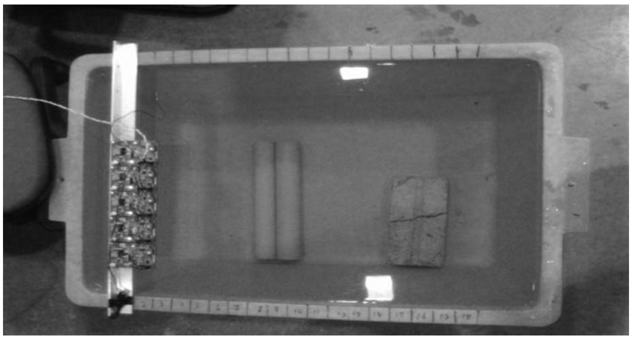


Figure 10 sensors with brick and PVC pipe as object

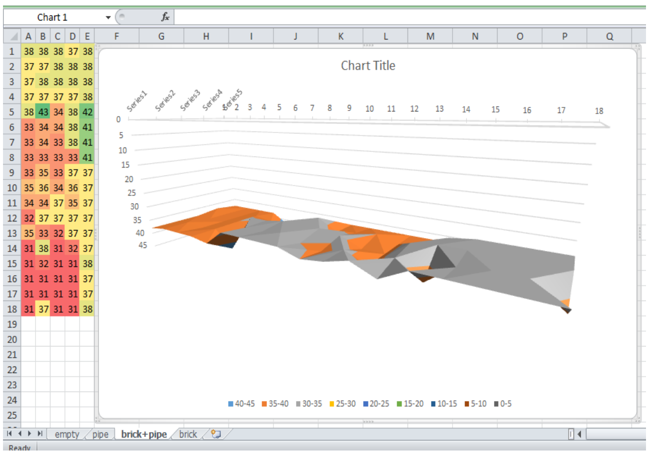


Figure 11 Mapping result

In this experiment, the sensors need to pass by the two obstacles, namely PVC pipe and the brick. The result showed that the brick is clearly mapped to be shallow while the PVC pipe, the data indicated that there are some parts that are not detectable. This is due to strength of the sensors frequency of 200 kHz which will penetrate an object that is less than 3.75mm, and not bounced back.

4.0 CONCLUSION

From the study, it is found that the results collected from the three experiments using water tank as simulated flood situation has potential to be applied at actual flood area. Moreover, additional sensors can be installed to improve map coverage and view of depth. Besides, mapping of obstacles for deep and shallow areas can be improved using multi-angle beam sensors to increase accuracy.

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References

[1] M. Raju, 2001. Ultrasonic Distance Measurement With the MSP430. TAG: Pizo Drive Circuit. *Mixed Signal Processors.* 1(3): 1-18.

[2] M. H. F. Rahiman, R. A. Rahim, and H. A. Rahim, Feb. 2011. Gas Hold-Up Profiles Measurement Using Ultrasonic Sensor. *IEEE Sens. J.* 11(2): 460-461.

[3] R. Longo, S. Vanlanduit, G. Arroud, and P. Guillaume, Jan. 2015. Underwater Acoustic Wavefront Visualization by Scanning Laser Doppler Vibrometer for the Characterization of Focused Ultrasonic Transducers. *Sensors (Basel)*. 15(8): 19925-36.

[4] K. R. Waters and P. H. Johnston, Nov. 2005. Tomographic Imaging Of An Ultrasonic Field In A Plane By Use Of A Linear Array: Theory And Experiment. *IEEE Trans. Ultrason. Ferroelectr. Freq. Control*. 52(11): 2065-2074.

[5] M. R. Holland and J. G. Miller. 1988. Phase-Insensitive And Phase-Sensitive Quantitative Imagingof Scattered Ultrasound Using A Two-Dimensional Pseudo-Array. *IEEE Ultrasonics Symposium*. 5(11): 815-819.

[6] Y. Humeida, V. J. Pinfield, R. E. Challis, P. D. Wilcox, and C. Li, Sep. 2013. Simulation Of Ultrasonic Array Imaging Of Composite Materials With Defects. *IEEE Trans. Ultrason. Ferroelectr. Freq. Control*. 60(9): 1935-48.

[7] M. Hafiz Fazalul Rahiman, Z. Zakaria, R. Abdul Rahim, and W. Nyap Ng, Jun. 2009. Ultrasonic Tomography Imaging Simulation Of Two-Phase Homogeneous Flow. *Sens. Rev.* 29(3): 266-276.

[8] S. Z. M. Muji, C. L. Goh, N. M. N. Ayob, R. a. Rahim, M. H. F. Rahiman, H. a. Rahim, M. J. Pusppanathan, and N. S. M. Fadzil, Oct. 2013. Optical Tomography Hardware Development For Solid Gas Measurement Using Mixed Projection. *Flow Meas. Instrum.* 33: 110-121.

[9] N. Muzakkir, N. Ayob, M. Jaysuman, R. Abdul, M. Hafiz, F. Rahiman, and F. Rahman. 2013. Design Consideration for

Front-End System in Ultrasonic Tomography. *Jurnal Teknologi.* 5: 53-58,.

[10] R. A. Rahim, K. T. Chiam, M. H. F. Rahiman, and P. Jayasuman. 2009. Processor-Based Optical Tomography System. *IEEE Sensors Journal.* 9(9): 1076-1083,

[11] E. J. Mohamad, R. A. Rahim, L. P. Ling, M. Hafiz, F. Rahiman, O. Mohd, F. Bin, N. Muzakkir, and N. Ayob. 2012. Segmented Capacitance Tomography Electrodes : A Design and Experimental Verifications. *IEEE Sensors Journal.* 12(5): 1589-1598.

[12] R. A. Rahim, M. H. F. Rahiman, L. L. Chen, C. K. San, and P. J. Fea May 2008. Hardware Implementation of Multiple Fan Beam Projection Technique in Optical Fibre Process Tomography. *Sensors*. 8(5): 3406-3428.

[13] R. Sathishkumar, A. Vimalajuliet, J. S. Prasath, K. Selvakumar and V. H. S. Veer Reddy 2011. Micro Size Ultrasonic Transducer For Marine Applications. *Indian Journal of Science and Technology*. 4(1): 8-11.

[14] Y. Li and S. Member, 2006. Position and Time-Delay Calibration of Transducer Elements in a Sparse Array for Underwater Ultrasound Imaging. *IEEE Transactions On Ultrasonics, Ferroelectrics, And Frequency Control.* 53(8): 1458-1467.

[15] A. Bellettini and M. Pinto, Jul 2009. Design and Experimental Results of a 300-kHz Synthetic Aperture Sonar Optimized for Shallow-Water Operations. *IEEE J. Ocean. Eng.* 34(3): 285-293.

[16] W. Zhehao and L. Xia, March, 2015. An Improved Underwater Acoustic Network Localization Algorithm. *Communications System Design*. 3: 2-3.

[17] A. B. Hassan, M. S. Abolarin, and O. H. Jimoh, 2006. The Application of Visual Basic Computer Programming Language to Simulate Numerical Iterations. *Journal of Robotics, Networking and Artificial Life.* 9: 125-136.

[18] R. R. Harrison, C. Charles, and S. Member. 2003. A Low-Power Low-Noise CMOS Amplifier for Neural Recording Applications. *IEEE Journal Of Solid-State Circuits.* 38(6): 958-965.