International Journal of Applied Mathematics, Sciences, and Technology for National Defense
Volume 1, Issue 1, 7 - 12.
e_ISSN: 2985-9352, p_ISSN: 2986-0776
https://www.journal.foundae.com/index.php/JAS-ND
DOI : https://doi.org/10.58524/app.sci.def.v1i1.168

Ultrasonic sensor system for detection of the objects position in two-dimensional plane

Adhi Kusumadjati*
Indonesia Defense University, INDONESIA

Jofim Yordaniel Napitupulu
Indonesia Defense University, INDONESIA

Roni Setiawan
Institut Teknologi Bandung, INDONESIA

Andrew Imada Samosir
Institut Teknologi Bandung, INDONESIA

Korhan Cengiz
Mühendislik Fakültesi, Trakya University TURKEY

Article Info

Article history:

Received: November 01, 2022
Revised: January 27, 2022
Accepted: February 16, 2023
Published: April 30, 2023

Keywords:

Ultrasonic sensor
Detection
Objects position
Two-dimensional plane

Abstract

Ultrasonic sensors are used to measure object distances accurately at a detection angle of 15 degrees to the sensor's normal plane with maximum distance of 4 m. By positioning three ultrasonic sensors in a triangular configuration, so it can determine the position of objects within the detection area. The purpose of this paper is to detect the position of an object in two-dimentional plane using three ultrasonic sensor. The sensors are positioned in triangular formation and the coverage angle is limited so that detection between sensors in the formation does not overlap or interfere with each other. Using the position data per unit of time, it is possible to find out the direction of movement of the object in real time.

To cite this article: Kusumadjati, A., Napitupulu, J. Y., Setiawan, R., Samosir, A. I., & Cengiz, K. (2023). Ultrasonic sensor system for detection of the objects position in two-dimensional plane. *International Journal of Applied Mathematics, Sciences, and Technology for National Defense, 1*(1), 7-12.

INTRODUCTION

National Defense needs better improvements that are influenced by increasingly advanced concepts and innovations (Akimkina et al., 2021; Briones-Peñalver et al., 2020; Foster, 2018; Dombrowski & Gholz, 2006). One form of mechanical enhancement is weapons (Jan & Jan, 2000). Security officers generally carry weapons at all times while carrying out tasks such as monitoring the scene, with an automatic aiming weapon system and a computerized system that can be used to anticipate victims (Gunawan et al., 2022; Wilia & Wulan Christianti, 2019). The application of this framework is to recognize objects on open surfaces, providing x and y frames arranged to indicate the position of the object. This can be a pretty precise reconnaissance frame. In this experiment, the triangular formation ultrasonic sensor has an important role in detecting objects accurately. This project will be very useful in the field of defense. Ultrasonic sensor which is maintained in its position to ensure that there is an object in front of it or passing in front of it. If an object is detected, data or information will be sent to the main system to be given the next command, which is to launch a shot. This project will play an important role in defense objectives.

In Paper (Koval et al., 2016) explains that the ultrasound system is divided into two, namely active and passive. In active ultrasound systems, it is used in the application of physical or chemical properties. The resulting output reaches a higher value. Applications on this system Ultrasound is used for cleaning, welding, drilling, and more (Yao et al., 2020; Kumar et al., 2017; Neugebauer &

***Corresponding Author**
Adhi Kusumadjati, Indonesia Defense University, INDONESIA, Email: adhikusumadjati@gmail.com

Stoll, 2004; Mason, 2000). Then the passive ultrasound output produces a large amount of contrast. Its main applications are measuring object distances, detecting defects in materials and measuring material thickness, measuring fluid flow and gases and also diagnostics in health care. The speed of sound depends on the type of environment in which the sound is moving, and the temperature at which it occurs in that environment. In this project we use an ultrasonic sensor, which is a passive system.

The experimental results (Appiah et al., 2020), show that ultrasonic sensors can be used to estimate objects or densities that enter the sensor's detection area. In the design that is made, the percentage of the area detected by the sensor in a period is used to determine the position of the object. The advantage of ultrasonic sensors is that they can help with basic problems in determining the position of objects on robots in environmental mapping (Andersone, 2016).

The work of Damei Fu and Zhihong Zao in their discovery of a moving object with detection on an ultrasonic frame (Fu & Zhao, 2016), uses an ultrasonic sensor to identify moving objects. Ultrasonic sensors indicate the presence and always measure the details of these objects in determining the position and movement of these objects (Stiawan et al., 2019). The choice of this framework is still difficult to implement in the real world because it requires the development of more advanced sensor devices. Therefore, a sensor framework is needed that can accurately distinguish objects in two-dimensional space using NLOS (Non-Line-of-Sight) guidelines. Unpredictable displacement must be observable.

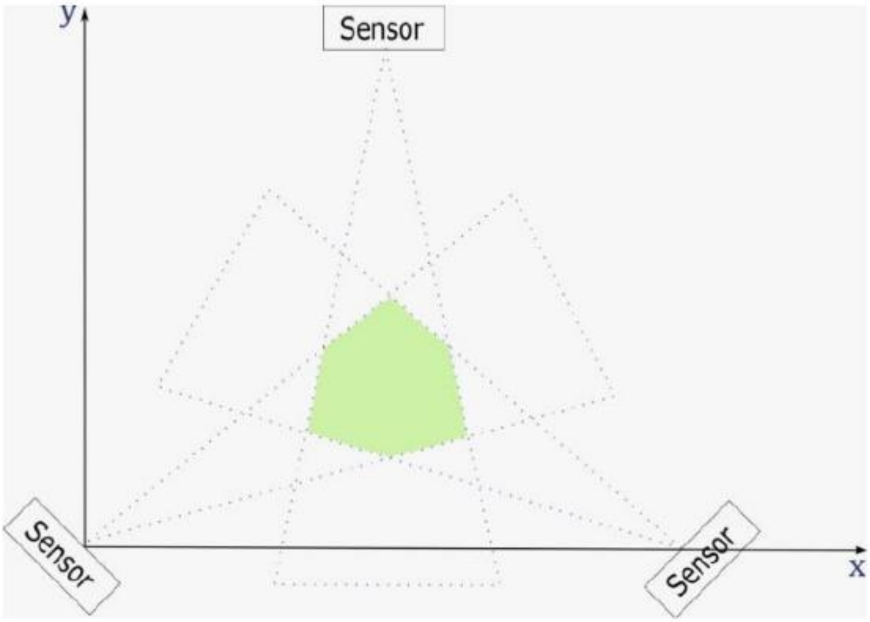

Figure 1. Ultrasonic Sensor System models

In this article, we construct a framework for object location in 2D space using a triangular arrangement. This setting results in the localization of the green location in Figure 1. This is possible because the ultrasonic sensor distinguishes nearby objects and clearly scans at a certain opening point. Furthermore, this setting can be used to avoid sensor errors that distinguish other sensors as objects of discovery sequentially as shown in Figure 2.

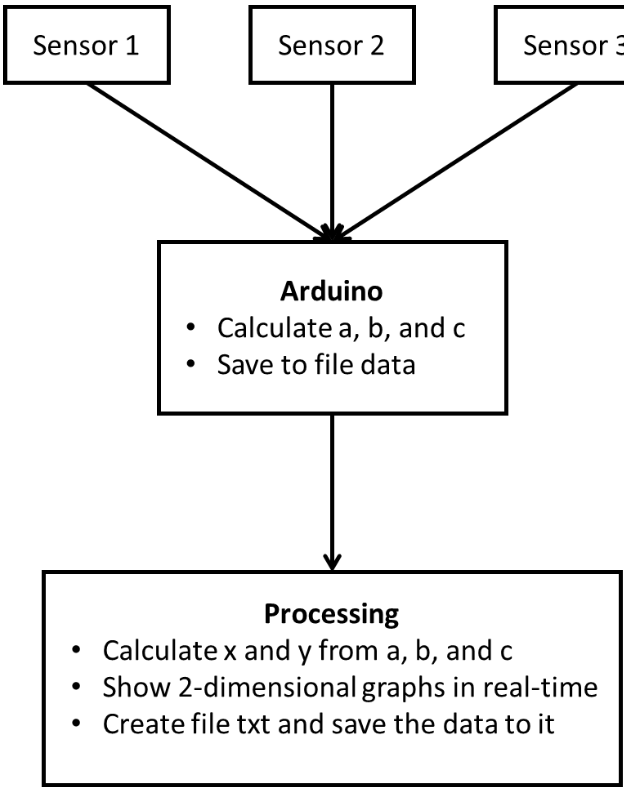

Figure 2. System Workflow Chart

METHOD

By arranging the ultrasonic sensors to form a triangle, this third sensor is connected to an Arduino Uno using a cable, so each sensor faces toward the midpoint between the other two sensors. This is done so that the signal emitted by this sensor is not caught by other sensors. The distance of each sensor can be varied between 1 meter to 4 meters (the maximum range of the ultrasonic sensor). The procedure of this experiment is shown in the flowchart of Figure 2.

When an object enters the range of the sensor as shown in Figure 3, each sensor recognizes the object and the value for each sensor reading should be varied. The data obtained from each sensor sent to the Arduino Uno microcontroller and then the calculation perform by this microcontroller in such a way so the values from each sensor is converted into object positions in two-dimension. The result is displayed on the computer in an image of the object's position in a Cartesian Coordinate. Assume the object enters a range or region with separation on lines a, b, and c.

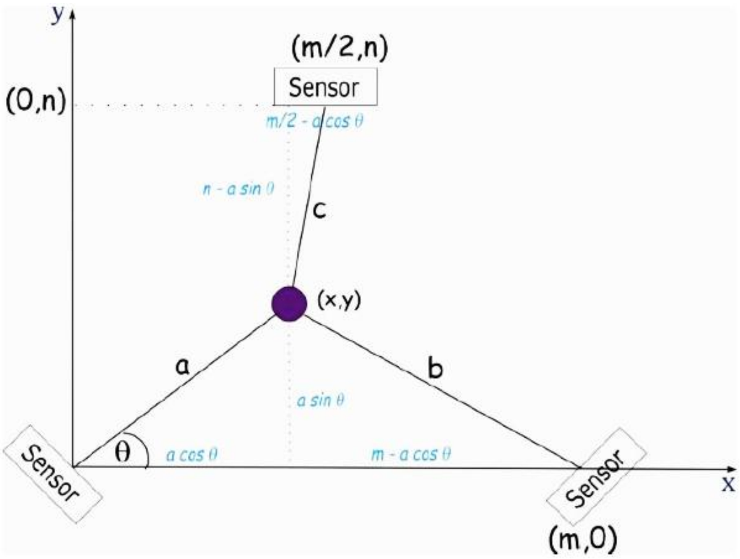

Figure 3. Mathematical calculation of the position of an object in a triangular sensor formation

Meanwhile, the value of θ is clearly unknown, representing the position of an unknown object in the detection area. Suppose an object comes to the sensing area, where the object has distances a, b, and c.

$$b^2 = (m - a\cos\theta)^2 + (a\sin\theta)^2 \tag{1}$$

$$b^2 = m^2 + a^2\cos^2\theta - 2am\cos\theta + a^2\sin^2\theta \tag{2}$$

and

$$c^2 = (n - a\sin\theta)^2 + \left(\frac{m}{2} - a\cos\theta\right)^2 \tag{3}$$

$$c^2 = n^2 + a^2\sin^2\theta + \left(\frac{m}{2}\right)^2 + a^2\cos^2\theta - am\cos\theta \tag{4}$$

By reducing b^2 with c^2, obtained:

$$am\cos\theta = c^2 + \frac{3}{4}m^2 - b^2 - n^2 \tag{5}$$

$$\theta = \cos^{-1}\left[\frac{1}{am}\left(c^2 + \frac{3}{4}m^2 - b^2 - n^2\right)\right] \tag{6}$$

With the value of θ known, the Cartesian coordinates of the object can be found by changing the known polar coordinates through the coordinate transformation as follows:

$$x = a\cos\theta \tag{7}$$

$$y = a\sin\theta \tag{8}$$

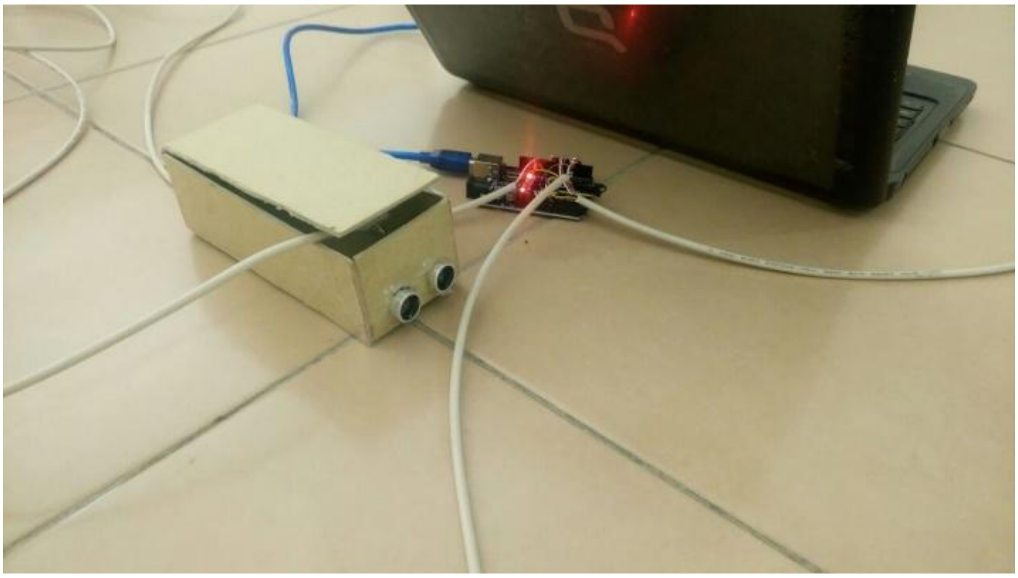

Figure 4. Display Position of objects on the day 2 hours 13 minutes 49 seconds 53

Figure 5. Position of object (bottle) on day 2 hours 13 minutes 49 seconds 53

Performing Measurement Testing the system using a plastic bottle filled with air as the object being measured. Then on the computer, run the processing application to monitor the measurement results directly and display them in graphical form as shown in Figure 6.

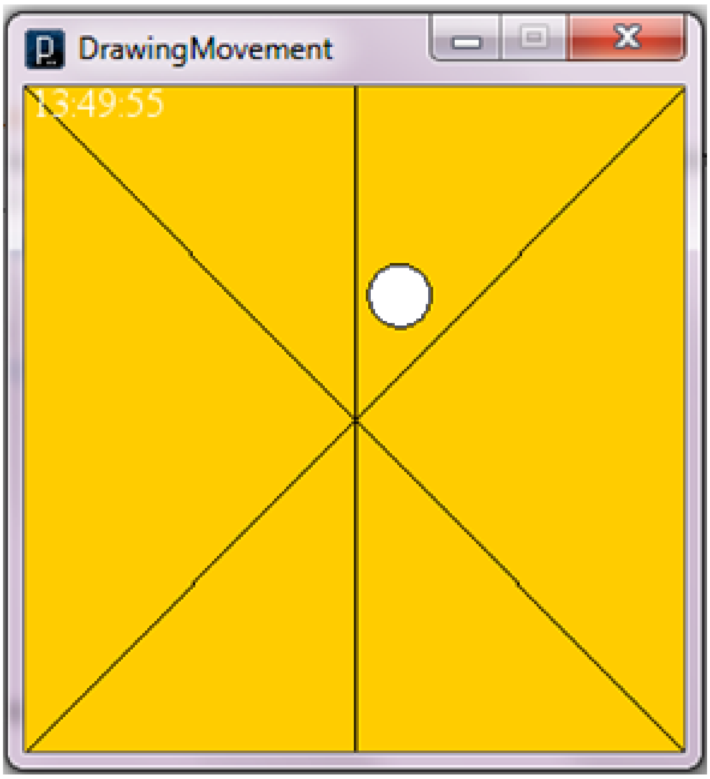

Figure 6. Display Position of objects on the day 2 hours 13 minutes 49 seconds 53

RESULTS AND DISCUSSION

The results of the information from the program given to this system are information on days, hours, minutes and seconds on the Cartesian side facilitating objects that are recognized at that time. For the level of accuracy, the position of the object is measured using a tape measure.

Table 1. The results of measuring the length of the side of the triangle are accompanied by a measurement of time

Year	Months	Days	Hours	Minutes	Seconds	a	b	C
2016	12	2	13	49	53	174	174	141
2016	12	2	13	49	53	174	173	141
2016	12	2	13	49	54	174	173	140
2016	12	2	13	49	54	173	174	141
2016	12	2	13	49	55	176	173	141
2016	12	2	13	49	55	173	173	141
2016	12	2	13	49	56	175	173	141
2016	12	2	13	49	56	174	174	142
2016	12	2	13	49	57	173	174	141
2016	12	2	13	49	57	174	174	141

Basen on the Table 2, the system output results for experiments in this experiment are quite accurate. The average error rate for the x-coordinate feature is 7.724351% and the average error rate for the y-coordinate feature is 7.246023%. The object in Figure 5 must be positioned exactly in the middle of Figure 4. However, as shown in Table 1 and Figure 4, the detected object is always further away in the system than the results of direct measurements. This is possibly due to the accuracy and characteristics of the ultrasonic sensor used in this paper.

Table 2. Results By system and measurement by tape measure

No	x system output	y system output	x measurable	y measurable	error x (%)	error y (%)
1	171.074058	181.7752505	158.2	171.7	8.137837	5.867939
2	173.730667	159.6775691	158.3	140.9	9.747737	13.32688
3	171.784557	177.677895	158.9	168.1	8.108595	5.697736
4	169.368849	185.2589417	156.4	174.3	8.292103	6.287402
5	175.986801	152.1554055	163.4	150.9	7.703061	6.476841
6	172.48143	163.3849287	158.4	154.4	8.889792	5.819254
7	174.899175	155.9395715	161.6	143.2	8.229688	8.896349
8	173.448396	163.8439179	162.1	151.8	7.000861	7.93407
9	169.368849	185.2589417	163.9	173.9	3.336699	6.531881
10	171.074058	181.7752505	158.7	172.1	7.797138	5.621877

Ultrasonic sensors as proximity sensors have been explained that ultrasonic sensors are able to adapt to environmental conditions. these sensors contain a noise measurement system and the facility to convert the movement of objects automatically from the signal used to transmit the wave, thereby generating best accuracy under different conditions. So, in our experiment, the measurement is not disturbed by the environment because it is already under normal conditions or normal temperature.

In this project, it is possible to design a triangular formation ultrasonic system that controls the triggering and positioning of weapons with the help of an Arduino, servomotor, and ultrasonic sensors, which can detect the position, and distance of obstacles blocking them, and rotate them. them into a form that can be represented visually. Arduino processing software. This system can be used in defense for object detection and destruction systems. System range depends on the type of ultra-sonic sensor used. In this experiment using the SR04 sensor which can reach 4 meters

CONCLUSION

This Ultrasonic Sensor System triangle formation successfully detects objects in 2D space and finds objects without directing the sensor to these objects. The output accuracy of this system is quite good. The average measurement error rate is about 7%. Based on our research results, we can conclude that the 2D object localization tool works well and is very responsive. The object location is quite good, but it can be further improved by increasing the quality of the ultrasonic sensor.

This project has succeeded in proving the value of the accuracy of the position of the detected object. Furthermore, in the next research we can used this system to develop guidance system based on ultrasonic sensor.

AUTHOR CONTRIBUTIONS

Each author of this article played an important role in the process of method conceptualization, simulation, and article writing.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

Akimkina, D., Khrustalev, E., Baranova, N., & Loginova, D. (2021). Technology transfer of the military-industrial complex as a factor in increasing the science intensity of the civilian industry. *SHS Web of Conferences*, 114(2021), 01027. https://doi.org/10.1051/shsconf/202111401027

Andersone, I. (2016). Probabilistic Mapping with Ultrasonic Distance Sensors. *Procedia Computer* Science, 104, 362–368. https://doi.org/10.1016/j.procs.2017.01.146

Appiah, O., Quayson, E., & Opoku, E. (2020). *Ultrasonic sensor based traffic information acquisition system; A cheaper alternative for ITS application in developing countries*. In Scientific African (Vol. 9). Elsevier B.V. https://doi.org/10.1016/j.sciaf.2020.e00487

Briones-Peñalver, A. J., Bernal-Conesa, J. A., & de Nieves Nieto, C. (2020). Knowledge and innovation management model. Its influence on technology transfer and performance in Spanish Defence industry. *International Entrepreneurship and Management Journal*, 16(2), 595–615. https://doi.org/10.1007/s11365-019-00577-6

Dombrowski, P., & Gholz, E. (2006). *Buying Military Transformation: Technological Innovation and the Defense Industry*. Columbia University Press. https://doi.org/10.7312/domb13570

Foster, D. (2018). *Arms and Innovation: Entrepreneurship and Alliances in the Twenty-First-Century Defense Industry.* Naval War College Review, 63(3). Available at: https://digital-commons.usnwc.edu/nwc-review/vol63/iss3/14

Fu, D., & Zhao, Z. (2016). Moving object tracking method based on ultrasonic automatic detection algorithm. *rvfzgv* 515–519. https://doi.org/https://doi.org/10.1109/ICIST.2016.7483468

Gunawan, Y., Aulawi, M. H., Anggriawan, R., & Putro, T. A. (2022). Command responsibility of autonomous weapons under international humanitarian law. *Cogent Social Sciences*, 8(1), 1-16. https://doi.org/10.1080/23311886.2022.2139906

Jan, T.-S., & Jan, C.-G. (2000). Development of weapon systems in developing countries: a case study of long range strategies in Taiwan. *The Journal of the Operational Research Society*, 51(9), 1041-1050. https://doi.org/10.2307/254225

Koval, L., Vaňuš, J., & Bilík, P. (2016). Distance measuring by ultrasonic sensor. *IFAC-PapersOnLine*, 49(25), 153–158. https://doi.org/10.1016/j.ifacol.2016.12.026

Kumar, S., Wu, C. S., Padhy, G. K., & Ding, W. (2017). Application of ultrasonic vibrations in welding and metal processing: A status review. *Journal of Manufacturing Processes*, 26, 295–322. https://doi.org/10.1016/j.jmapro.2017.02.027

Mason, T. J. (2000). Large scale sonochemical processing: aspiration and actuality. *Ultrasonics Sonochemistry*, 7(4), 145–149. https://doi.org/10.1016/S1350-4177(99)00041-3

Neugebauer, R., & Stoll, A. (2004). Ultrasonic application in drilling. *Journal of Materials Processing Technology*, 149(1–3), 633–639. https://doi.org/10.1016/j.jmatprotec.2003.10.062

Stiawan, R., Kusumadjati, A., Aminah, N. S., Djamal, M., & Viridi, S. (2019). An Ultrasonic Sensor System for Vehicle Detection Application. *Journal of Physics: Conference Series*, 1204, 012017. https://doi.org/10.1088/1742-6596/1204/1/012017

Wilia, A., & Wulan Christianti, D. (2019). The use of autonomous weapon systems in armed conflict : legality and challenges for future weapon regulation. *Padjadjaran Journal of International Law*, 3(2), 276–293. https://doi.org/10.23920/pjil.v3i2.322

Yao, Y., Pan, Y., & Liu, S. (2020). Power ultrasound and its applications: A state-of-the-art review. *Ultrasonics Sonochemistry*, 62, 104722. https://doi.org/10.1016/j.ultsonch.2019.104722