Düzce University
Journal of Science & Technology

Research Article

Distance Measurement and Object Detection System Based On Ultrasonic Sensor and XBee

Seda ÜSTÜN ERCAN [a,*], Mohammed Sufyan MOHAMMED [a]

[a] *Electrical and Electronics Engineering, Faculty of Engineering, Ondokuz Mayıs University, Samsun, TURKEY*
** Corresponding author's e-mail address: sedau@omu.edu.tr*
DOI : 10.29130/dubited.508604

ABSTRACT

In the past few years, research groups have focused on finding new solutions for objects detection in unknown and/or hazardous areas that can't be accessed by humans, in order to create monitoring system that can ensure the safety and security of machine and humans operating in such areas. The aim of this study is to design and implement an object detection system based on XBee and ultrasonic sensor, which is capable of detecting objects whether they are stationary or moving, and obtain their exact location, direction and distance. This system is capable of detecting objects whether they are stationary or moving and obtain their exact location, direction and distance. It constantly monitors an area of limited range and reports to authorities as soon as an object is detected two sets of alert can be activated at the same time. The first notification is an audible alert using a buzzer while the second one is a visual alert using personal computer screen with the help of graphical user interface. In addition to that, this system boasts many features such as low cost, tiny size, possible to carry and relocate with high efficiency and quality. Also it has a key advantage that is, this system doesn't require to be placed near the control room because it is able to monitor remote places and send the results wirelessly.

Keywords: *Object detection system, Distance measurement, XBee, Arduino, Ultrasonic Sensor*

Ultrasonik Sensör ve XBee Tabanlı Mesafe Ölçüm ve Nesne Algılama Sistemi

ÖZET

Son birkaç yılda, araştırma grupları; makine ve insanların güvenliğini sağlayabilen izleme sistemi oluşturmak amacıyla, insanlar tarafından erişilemeyen, bilinmeyen ve/veya tehlikeli olan alanlarda, nesnelerin algılanması için yeni çözümler bulmaya odaklandılar. Bu çalışmanın amacı, nesnelerin durağan veya hareketli olup olmadığını tespit edebilecek, tam konumlarını, yönlerini ve mesafelerini elde edebilecek XBee ve ultrasonik sensör tabanlı bir nesne algılama sistemi tasarlamak ve uygulamaktır. Bu sistem nesnelerin durağan veya hareketli olup olmadığını, konumlarını, yönlerini ve mesafelerini kesin olarak belirleme yeteneğine sahiptir. Sistem sürekli olarak belirli bir bölgeyi izler ve bir nesne tespit edilir edilmez aynı anda iki uyarı seti etkinleştirerek yetkililere rapor verir. İlki sesli, ikincisi ise grafiksel kullanıcı ara yüzü yardımı ile kişisel bilgisayar ekranını kullanan görsel bir uyarıdır. Buna ek olarak, bu sistem, düşük maliyet, küçük boyut, yüksek verimlilik ve kaliteli bir şekilde taşınabilmesi gibi birçok özelliğe sahiptir. Ayrıca uzak yerleri izleyebilmek ve sonuçları kablosuz olarak gönderebilmek için kontrol odasına yakın olmayı gerektirmeyen önemli bir avantaja sahiptir.

Anahtar Kelimeler: *Nesne algılama sistemi, Mesafe ölçümü, XBee, Arduino, Ultrasonik sensör*

Received: 18/10/2019, Revised: 02/04/2020, Accepted: 21/04/2020

I. INTRODUCTION

Movement detection of living beings or any other object might be interesting in numerous domains, like security systems, radars, the locations of industrial robots, depth of snow banks, liquid levels in reservoirs and automatic guidance systems. Majority of these applications require that the objects detection device to be non-invasive and not disturb the normal work environment, living beings or other devices in the detection's area. This include the choice of detached vectors for transporting the necessary information, with a high degree of immunity to other various factors except the state of movement. The objects detection device may be passive, but in this case, the moving organisms or objects must have a particular property that can be discovered. However, this condition limits the domain of the device applicability, but offers the feature of high discretion for detector. In active detection devices, a transmitter and a receiver detect the objects in a manner that does not affect the path of the process being monitored and does not impose any special restrictions for the detected objects [1, 2].

Measuring the distance in the narrow areas or dangerous regions that contains chemical or radioactive solution can be problematic sometimes. The tape measure is not suitable for this kind of distance measurement because the place is not appropriate or for any other reason. Various mechanisms have been suggested and developed for contactless distance measurements, while each method has their own features and disadvantages [3]. Infrared or optical sensors present good accuracy but a poor distance measurement domain. On the other side, laser or microwave based systems offer the possibility of a large range measurement of distance, with a rather weak resolution [4].

At most, the use of ultrasonic sensing technology (ultrasonic sensor) is the most inexpensive and reliable method for measurement of the distance. Ultrasonic sensors are useful in various applications areas under which other sensors (such as infrared or vision-based sensors) fail to give accurate results or operate such as poor lighting conditions or the presence of many transparent objects like windows or glass doorways [5]. The ultrasonic sensor operates using the echo location principle. A pulse of ultrasonic wave is created and transmitted by the ultrasonic sensor in a specific area and if there is any object in its path, the ultrasonic wave will be reflected. By calculating the time difference between the pulses transmitted and received, the distance to the detected object can be located [6]. An effective measurement depends on the reflection of the waves from the targets to the ultrasonic sensor. There are different influences that affect the reflection such as wind speed, random noises and the change of temperature [7]. The dimensions of the target also effect on the reflection and target detection, as explained below:

Surface: The target which has hard, smooth surface reflects large wave than soft surface. A soft target has a weak echo and the accuracy of the ultrasonic sensor will decrease.

Distance: The reflected signal decreases as the distance between the target and the ultrasonic sensor increases.

Angle: Objects tilting degree ultrasonic waves are affected by the reflection method of the object. The echo is gained only from regions normal to the sensor otherwise no echo will be detected due to the scattering of the signal as it is reflected from the object.

Size: A large target has bigger surface area to reflect the wave than a small target [8].

There are many great applications of ultrasonic sensing technique since its inception, such as obstacles detection for guidance in mobile robotics applications, home security systems, measuring water or liquid level in tanks, distance measurement and objects proximity detection systems. These innumerable smart applications have made it easy to solve different technical issues quickly and less expensive without compromising stability, safety and quality. Many examples on that are present in academic literature as can be seen in the following review. In [9] Singh et al. presented a security system for buildings and homes to detect the movement of the human body and produce a necessary alarming message using ultrasonic sensor. Dey et al. designed and implemented in [10] smart walking stick for visually impaired people that uses ultrasonic sensor HC-SR04 to detect obstacles in the blind person's path and uses the buzzer as an alert. A smart collision avoidance system has been proposed as a prototype in [11] which uses ultrasonic sensor for obstacle detection to avoid vehicle accidents and provides maximum safety to the drivers. Gupta et al. in [12] addressed the utilization of ultrasonic sensing capability for water depth measuring. Distance measurement using ultrasonic sensing technology have seen good interest in terms of researches and studies in the few past years. For instance, the design of distance measurement system was presented in [13] based on ultrasonic sensor and S3C2410 microcontroller, temperature compensation module was added to the design to improve the accuracy. In [14] two separate modules of ultrasonic transmitter and receiver were attached to a P89C51RD2 microcontroller development board to determine distance from 5 cm to 50 cm. A combination of three different sensors with a microcontroller type PIC16F877A was implemented in [15] to design an intelligent system for many applications, the ultrasonic sensor is one of these sensors, which functioned to determine a distance to the targets. In [16] ultrasonic sensor was interfaced to a microcontroller type peripheral interface controller (PIC) to measure distances up to 2.5 m, ultrasonic distance detector would give an light emitting diode (LED) Indication when the object is too near around less than 10 cm. In [17] a parallax ultrasonic sensor module was mounted on a mobile robot called Pro-Bot 128 to determine distances from 20 mm to 200 mm. A spartan 3e field programmable gate array (FPGA) board was used with an ultrasonic sensor in [18] to detect obstacles with a distance from 20 cm to 100 cm at a room temperature. A cheap and popular HC-SR04 ultrasonic sensor interfaced to the AVR ATmega16 microcontroller was used for objects detection and to compute distance up to 2,5m, the computed distance is displayed via a liquid crystal display (LCD) [19]. While in [20] Matlab was used to implement a graphical user interface (GUI) show object detection information and measured distance. In [21] it has been proved that the use of Arduino Uno microcontroller coupled with the ultrasonic sensor type HC-SR04 is able to detect objects inside an angle of 180 degrees and at distances between 2 centimeters and 4 meters with acceptable accuracy. In other similar work [22] Dutt designed an object detection and distance measurement system which fully linked to the objectives of our study. It also uses HC-SR04 ultrasonic sensor with Arduino Uno microcontroller to detect the objects and uses a computer screen for displaying the sensed data graphically through Processing Development Environment software. However, this system is unable to transmit the sensed data or information wirelessly over long distances.

In this study, distance measuring and object detection system was designed and implemented using Zigbee technology and ultrasonic sensing technology. The principles of operations are that as soon as object is detected around the ultrasonic sensor, the proposed system will issue a sound to alert the authorities and will also display the information of these objects such as location, direction and distance graphically on the computer screen. XBee and Zigbee wireless technology enable the report of results without the need for the system to be near the control room. The main feature that distinguishes this proposed system from similar work found in academia is that it combines XBee module and Zigbee protocol with ultrasonic sensor in order to obtain a system that can support several nodes, sends data over distant area and consumes low power achieving the task.

II. PROPOSED SYSTEM

A. SYSTEM OVERVIEW

The proposed system consists of two main components: a wireless sensor network (WSN) and a main controller unit which mainly refers to the personal computer (PC). The WSN will be used to constantly monitor the motion of objects in a specific area while the main controller unit will receive, analysis the sensed data, and display the results graphically on the computer screen with the help of Processing Development Environment software. WSN is the combination of embedded system and wireless communication technologies (such as Zigbee, Wi-Fi and Bluetooth) which allows data transmission among the sensor nodes over ad-hoc wireless networks [23]. WSN consists of a set of small sensing nodes, each node contains three circuits: collection, computation and communication circuits. The collection unit has series of sensors, computation unit contains microcontroller and memory and finally the communication unit contains transceiver to transmit and receive data [24]. For the current system, the WSN defines two types of nodes: sensing node and sink node. The sensor node, is responsible for detecting objects in a specific area and measure the distance to these objects and reporting it to the sink node. The sensor node includes Arduino microcontroller, ultrasonic sensor and servo motor. Both ultrasonic sensor and servo motor are controlled and powered by the Arduino microcontroller. The ultrasonic sensor is mounted on the servo motor so as the servo motor move from right to left with angle ranges between 15˚ and 165˚, the ultrasonic sensor will rotate alongside it. The Arduino microcontroller process the analog data collected from ultrasonic sensor. When the Arduino has the data interpreted, it transmits the sensed information to the sink node using XBee module. The sink node will gather all data from the sensor node and send it to the main controller unit for displaying. The main component in the sink node is the Arduino Uno microcontroller. It uses the same XBee module as the sensor nodes for communication process. The sink node uses a buzzer for alarm purposes. Figure 1 illustrates the block diagram of the proposed system.

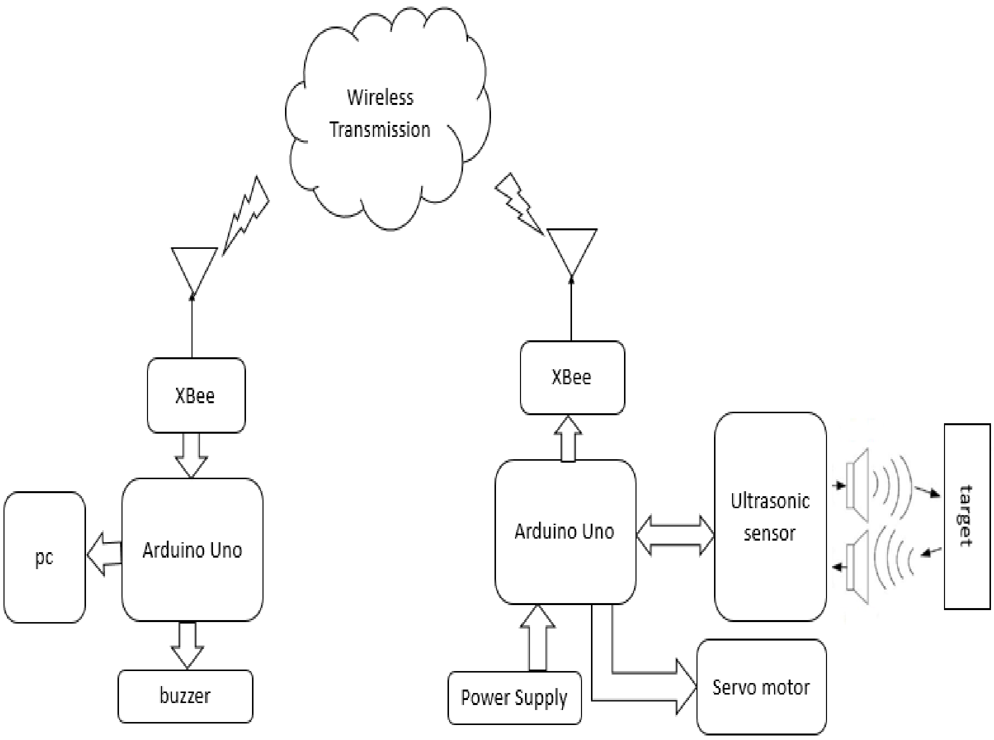
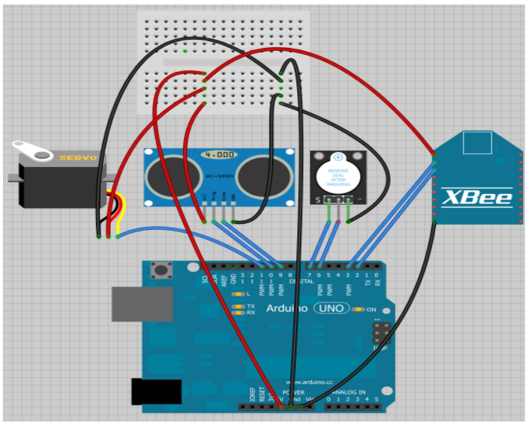


Figure 1. *Block diagram of the proposed system*

B. SYSTEM DESIGN AND IMPLEMENTATION

The connection between system's different electronic components of the sensing and sink nodes was designed using Fritzing [25] environment as shown in Figure 2 and Figure 3 respectively. In the sensing unit, the trigger pin of the ultrasonic sensor is connected to the pin 10 of the Arduino, the echo pin is connected to pin 9 of the Arduino and the control line of the servo motor is connected to pin 11 of the Arduino. XBee's DIN (RX) and DOUT (TX) are connected to pin 2 and pin 3 of the Arduino microcontroller. The I/O, VCC pins of the buzzer are connected to 6, 7 pins of the Arduino. The VCC pin of the servo motor, XBee and the ultrasonic sensor are connected to the 5V pin of the Arduino while the GND pin of the XBee, servo motor, buzzer and the ultrasonic sensor are connected to the GND pin of the Arduino microcontroller. In the sink unit, XBee's DIN (RX) and DOUT (TX) are connected to pin 2 and pin 3 of the Arduino microcontroller. The I/O, VCC pins of the buzzer are connected to 6,7 pins of the Arduino. The VCC pin of the XBee is connected to the 5V pin of the Arduino while the GND pin of the XBee and the buzzer are connected to the GND pin of the Arduino microcontroller.



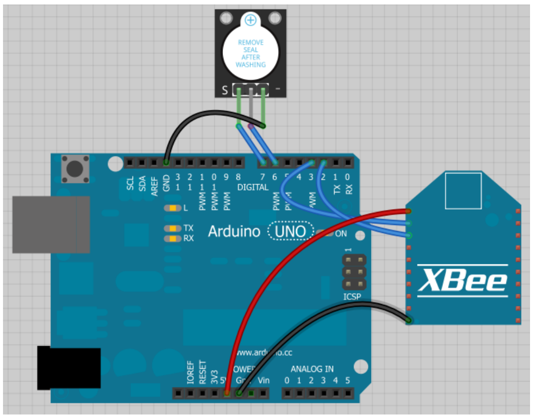
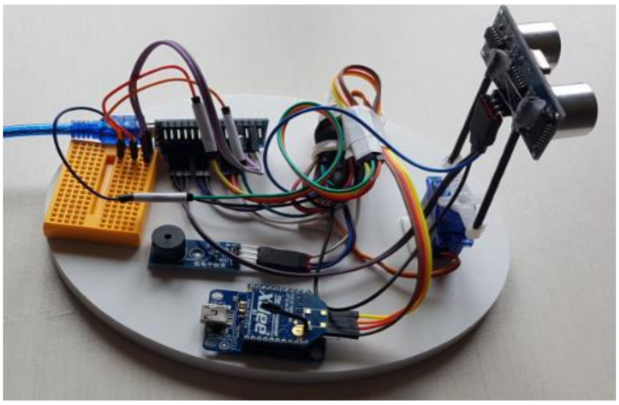


Figure 2. *Sensing unit diagram on fritzing*

Figure 3. *Sink unit diagram on fritzing*

Figure 4 shows the implementation of the sensing unit for the system on a breadboard. It shows that the ultrasonic sensor is mounted on the servo motor and both of them are attached to the Arduino microcontroller. It can also be noted that the XBee module is placed on the board which will be used as a sender. Figure 5 illustrates the implementation of the sink unit for the system on a breadboard. The XBee module and the buzzer are connected to the Arduino Uno microcontroller via the respective pins.



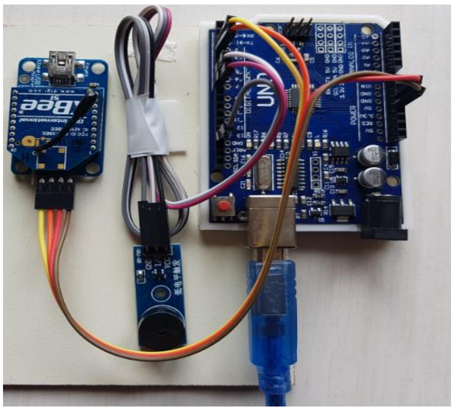


Figure 4. *Sensing unit on the breadboard*

Figure 5. *Sink unit on the breadboard*

In the next figure (Figure 6) a working prototype of the system is shown, the unit on the right comprises the sensing unit with the Arduino board, XBee module, servo motor and the ultrasonic sensor. As for the sink unit on the left it also consists of XBee module, a buzzer and the Arduino Uno microcontroller with a serial connection to the main control unit (PC). It is worth noting that the units are powered from separate power sources.

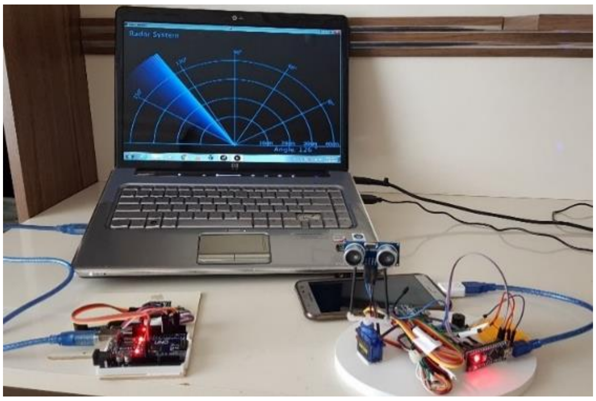


Figure 6. *The proposed system fully*

III. MATERIAL AND METHOD

A description of the components used to build the proposed system (sensing and sink nodes) are explained below.

A. ARDUINO UNO

Arduino Uno development board is shown in Figure 7 [26]. It is a microcontroller based on ATmega328P. It is designed for projects that require more I/O lines, more sketch memory and more RAM. It has 14 digital input/output pins (of which 6 can be used as PWM outputs) and 6 analog input/output pins used to interface different expansion boards and other circuits, 32 kbyte flash memory, serial communication interfaces, a 16 MHz quartz crystal, a power jack and a reset button. Arduino Uno can be powered via USB connection or with an external power supply (such as an AC-to-DC adapter or battery). The open-source Arduino Software (IDE) is used to programming the Arduino microcontroller and makes it easy to write code and upload it to the board. It can be used with all kinds of Arduino boards and runs on Windows, Mac and Linux [27].

Figure 7. *Arduino Uno*

B. ULTRASONIC SENSOR HC-SR04

As it is known that ultrasonic sensors have recently become the famous measuring tools because of their simplicity and affordability. The accuracy of ultrasonic sensing technology depends on the value of the sound velocity in the propagation medium, any unexpected change affects the result. The sound velocity in the air is about 340 m/s at 15° C and it changes by the temperature. Ultrasonic sensor HC-SR04 module offers about 2 cm to 400 cm range measurement function with high accuracy. The effective angle is less than 15 degrees along with the accuracy up-to 3 mm. HC-SR04 module as shown in Figure 8 has four pins namely VCC, Trigger, Echo and GND. It contains transmitter (Tx) used to transmits waves to detect the objects, receiver (Rx) which receive the waves from detected objects and control circuit [28]. Ultrasonic sensor HC-SR04 can determine distance to the objects by using (IO trigger pin) for at least 10 us high-level signal, to transmit eight 40 kHz and looks if there is a reflected signal, if the signal returned back through high level time of high output IO duration is the time from sending to receiving [29].

Figure 8*. Ultrasonic sensor HC- SR04*

C. XBEE

Zigbee is a new universal technology for wireless communication that uses IEEE 802.15.4 standard [30]. It has many features like low-cost, simplicity to develop and deploy, very low power consumption, support of large number of nodes, robust security and high data reliability also it has fault tolerance, self-healing and self-routing features which makes it one of the best to be used as compared to Wi-Fi and Bluetooth technologies [31]. It supports peer to peer, point to point and point to multipoint wireless communications and also supports mesh network topology. The main purpose of mesh network is that if one of the links fails it does not paralyze the whole network and the other nodes will communicate without interruption [32]. XBee is the hardware that carries Zigbee communication protocol manufactured by Digi International Company as shown in Figure 9 [33]. It is usually used in wireless communications as a transmitter and receiver. XBee has ability to work for years on inexpensive batteries. XBee modules have different types of antenna that enable them to cover different ranges and they usually use 2.4 GHz of operating frequency with 250 Kbps speed. XBee shield must be used to connect to the Arduino microcontroller. XBee can be programmed using the X-CTU software [34].

Figure 9. *XBee*

D. SERVO MOTOR SG90

The servo motor SG90 shown in Figure 10 is a small, lightweight electrical device with high output energy [35]. Servo motor can rotate nearly 180 degrees (90 in each direction) and works like others standard motors but smaller. It can rotate or push the objects with great accuracy. It has three wires: GND, VCC and signal [36].

Figure 10*. Servo motor SG90*

E. BUZZER YL-44

Figure 11 shows the buzzer YL-44 module which used for alarm purpose [37]. When a target is detected by the system the buzzer makes a sound as an indication for target detection. It has three wires: GND, VCC and I/O.

***Figure 11**. Buzzer YL-44*

Processing is an open source integrated development environment (IDE) and computer programming language built for several purposes such as new media art, electronic projects applications and visual design communities with the purpose of teaching the fundamentals of computer programming in a visual context and to serve as the foundation for electronic sketchbooks. One of the stated aims of processing is to act as a tool to get non-programmers started with programming, through the instant gratification of visual feedback. The software builds on the Java language, but uses a simplified syntax and graphics programming models. It has many useful specifications such as accessing free to download and open source, interactive programs with 2D-3D, running on GNU/Linux, Mac OS X, and Windows, and well documented etc.

The proposed system works on a principle similar to radar or sonar. As shown in the flowchart (Figure 12) below the sensing process is started by sending a trigger signal to the ultrasonic sensor from the Arduino microcontroller. This signal must be a pulse with 10µS high time. When the ultrasonic sensor receives a valid trigger signal it uses the transducer to generate ultrasonic waves and transmit these waves continuously in different directions by rotating with help of the servo motor. These waves spread in the air and returns back after discovering an object. The echo of this ultrasonic wave is sensed by the ultrasonic sensor again and its features are analyzed. By calculating the time difference between the waves transmitted and received the ultrasonic sensor can locate the distance to the objects. Then, the results will be transmitted to the sink node wirelessly via XBee module. The sink node will gather all data from the sensing node and send it to the main controller unit for displaying.

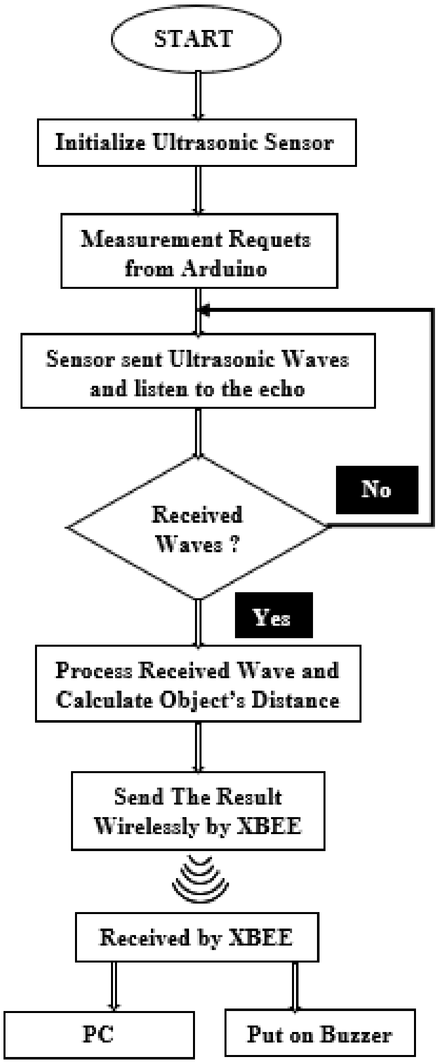


***Figure 12**. Flow chart of the system*

The GUI displayed on the personal computer screen was designed using a "processing development environment" software as depicted in the Figure 13 below. The half circular area represents the detection range in which the ultrasonic sensor operates. The ultrasonic sensor covers the area (from 0° to 180°) with the help of the servo motor that the sensor is fixed on. The straight line displayed on the monitor screen represents the current orientation of the ultrasonic sensor. The dots on the screen represent the objects in the detection range. The text in the line below the detection area gives exact details about the detected object in terms of distance and X and Y coordinates. This result was displayed on the monitor screen alongside a sound alarm from the buzzer to notify the operator.

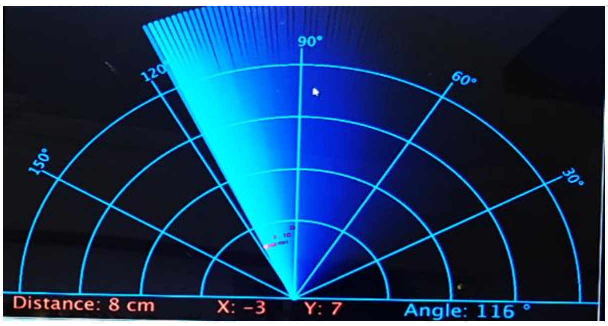
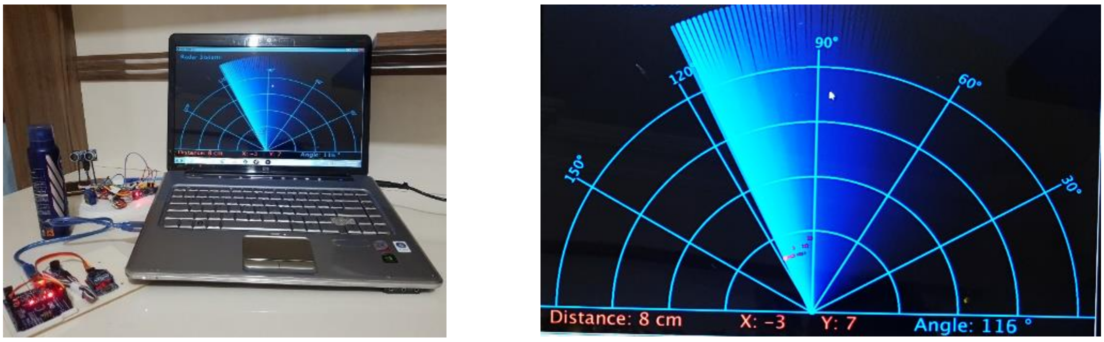


***Figure 13**.* Designed GUI

IV. EXPERIMENTAL RESULTS

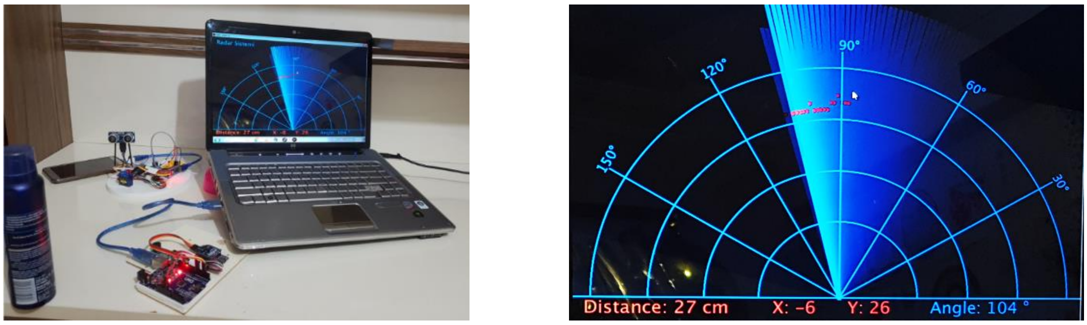
The system prototype with the dual Arduino boards and XBee modules, servo motor, ultrasonic sensor and buzzer was tested in real time. The materials such as wood, aluminum and glass (due to their popularity in many applications) were chosen as obstacles or objects to validate the proposed system operations. The above mentioned prototype was tested in different scenarios regarding positioning of the sensor node and sink node and the distance that can be covered using XBee modules. In addition to that many tests have been performed to measure the distance and angle of targets in the system's sensing area and determine the exact location of these objects. The tests were achieved by placing a set of targets on different distances and angles from the proposed system. Some of these tests are explained below:
The sensing node with the ultrasonic sensor fixed on the servo motor is shown at the back of the picture, while the sink node is shown at the front of the picture with a personal computer acting as the main control unit and a display screen in the same time as shown in Figure 14 (a). A blue shape representing the fixed target was placed at 8 cm away from the sensing node in the first test as can be seen in Figure 14 (a). The red points displayed on the GUI represent the target at a distance 8 cm from the ultrasonic sensor with some error as shown in Figure 14 (b).



(a) ***(b)***

Figure 14. (a) *One fixed target at 8 cm distance* ***(b)*** *The monitor screen in case target at 8 cm*

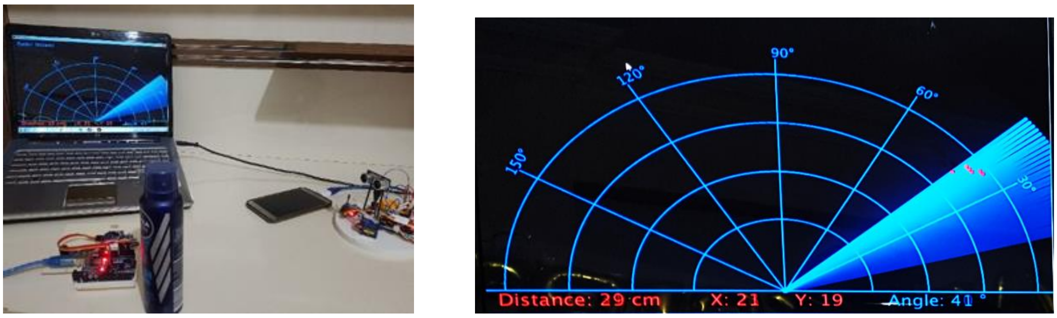
In the second test, the same target that used in the test 1 was used but now at 27 cm away from the system as shown in figure 15 (a). From Figure 15 (b) it can be seen that the target on the designed GUI and the measured distance is 27 cm, which shows that the system successfully detected the change in the distance.



(a) ***(b)***

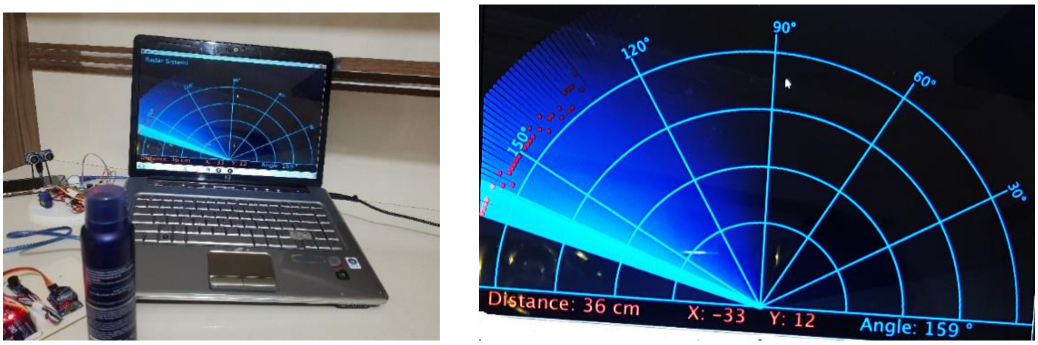
Figure 15.(a) *One fixed target at 27 cm distance* ***(b)*** *The monitor screen in case target at 27 cm*

The targets was fixed at different angles to the right and the left of the sensor and the ultrasonic sensor detected them successfully as shown in the Figure 16 (a) and (b) and Figure 17 (a) and (b) respectively.



(a) *(b)*

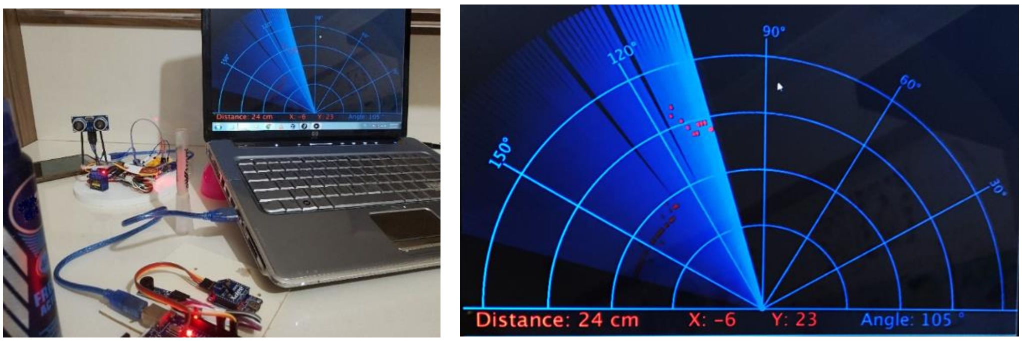
Figure 16.(a) *One fixed target at 29 cm distance* ***(b)*** *The monitor screen in case target at 29 cm*



(a) *(b)*

Figure 17. (a) *One fixed target at 36 cm distance* ***(b)*** *The monitor screen in case target at 36 cm*

In the third test, two fixed targets were used as shown in Figure 18 (a). The ultrasonic sensor is located in the back of the picture with two different objects in front of it at different distances. The objects are shown by two series of continuous dots that define the shape, distance and angle of the targets as represented on the computer screen graphically in Figure 18 (b).



(a) *(b)*

Figure 18. (a) *Two fixed targets at different distances* ***(b)*** *The monitor screen in case target at different distances*

V. CONCLUSION

In this paper, a prototype of distance measurement and object detection system was designed and implemented successfully using Zigbee technology and ultrasonic sensing technology. This system can monitor a particular area and detect the location, direction and distance of the object that comes its way and convert it into a model that can be visually represented. This system was developed by using XBee chip which enabled the transmission of the information wirelessly, giving the system the ability to monitor an area away from the control room. Many tests were conducted on the designed system with one or more than one object at different distances and orientations, the tests included a moving object also. The readings were in close margin to reality and the obtained error proved to be negligible. The

employment of XBee module for the transmission of sensed data between the system nodes presented advantage such as security and low power consumption to the system while covering a wider range as compared to other communication technologies. In addition to that Zigbee protocol and XBee module allows the implementation of several nodes at different locations which can be further developed or modified according to the arising needs.
The proposed system can be used in robotics systems to avoid obstacles and collisions, automated guided vehicles, finding the depth or level of any medium and measuring general distances, etc. Moreover, the proposed system can be used in areas that are inaccessible to humans and also in areas where there is a risk to their lives. We can enhance the proposed system in the future by increasing the range of objects detection, by utilizing a fully 360 degrees rotational servo motor and also by mounting surveillance webcam to it which turns on when an object is detected. Further modifications, the proposed system could be a mobile robot system capable of avoiding obstacles or detecting objects and measuring the distance at the same time. Internet of things technology serves well in such applications. It can be integrated into the proposed system, and so the sensed data can be monitored using a smartphone remotely. Although it is outside the scope of the research work, it also looks like a possible extension in the future.

VI. REFERENCES

[1] V. Chen, F. Li, S.-S. Ho and H. Wechsler, “Micro-Doppler Effect in Radar: Phenomenon, Model, and Simulation Study,” *IEEE Transactions on Aerospace and Electronic Systems*, vol. 42, no. 1, pp. 2-21, 2006.

[2] A. Balleri, K. Woodbridge and K. Chetty, “Frequency-Agile Non-Coherent Ultrasound Radar for Collection of Micro-Doppler Signatures,” in *Proc. 2011 IEEE RadarCon (RADAR)*, 2011, pp. 045 – 048, doi: 10.1109/RADAR.2011.5960496.

[3] M. V. Paulet, A. Salceanu, and O. M. Neacsu, “Ultrasonic Radar,” in *Proc 2016 Int. Conf. and Exposition on Electrical and Power Engineering (EPE)*, 2016, pp. 551-554.

[4] Rawaz H. Abdullah, “Design and Implementation of Ultrasonic Based Distance Measurement Embedded System with Temperature Compensation,” *International Journal of Emerging Science and Engineering (IJESE)*, vol. 3, no. 08, pp. 30-37, 2015.

[5] R. Raišutis, O. Tumšys and R. Kažys, “Feasibility Study of Application of Ultrasonic Method for Precise Measurement of the Long Distances in Air,” *Ultragarsas Journal*, vol. 65, no. 1, pp. 7-10, 2010.

[6] M. Kaur and J. Pal, “Distance Measurement of Object by Ultrasonic Sensor HC-SR04,” *International Journal for Scientific Research & Development (IJSRD)*, vol. 3, no. 05, pp. 503-505, 2015.

[7] D. Grumney, “Ultrasonic Transmitters vs. Guided Wave Radar for Level Measurement,” 2011. [Online]. Available: http://ww1.prweb.com/prfiles/2011/03/08/1166254/RadarLevelwhitepaper.pdf

[8] S. Monisha, D. R. Ratan and D. S. Luthra, “Design & Development of Smart Ultrasonic Distance Measuring Device,” *International Journal of Innovative Research in Electronics and Communications (IJIREC)*, vol. 2, no. 3, pp. 9-23, 2015.

[9] A. P. Singh, A. K. Sharma, A. Pandey and P. Kriti, “A Review on Ultrasonic Radar Sensor for Security System,” *Journal of Emerging Technologies and Innovative Research (JETIR)*, vol. 3, no. 4, pp. 137-139, 2016.

[10] N. Dey, A. Paul, P. Ghosh, C. Mukherjee, R. De and S. Dey, "Ultrasonic Sensor Based Smart Blind Stick," *Proc IEEE Int. Conf. on Current Trends towards Converging Technologies (ICCTCT)*, 2018, pp. 1-4.

[11] B. Varghese, R. T. Jacob, F. Kamar and R. A. Saifudeen, "Collision Avoidance System in Heavy Traffic and Blind Spot Assist Using Ultrasonic Sensor," *International Journal of Computer Science and Engineering Communications (IJCSEC)*, vol. 2, no. 1, 2014.

[12] S. D. Gupta, I. M. Shahinur, A. A. Haque, A. Ruhul and S. Majumder, "Design and Implementation of Water Depth Measurement and Object Detection Model Using Ultrasonic Signal System," *International Journal of Engineering Research and Development*, vol. 4, no. 3, pp. 62-69, 2012.

[13] H. He, and J. Liu, "The Design of Ultrasonic Distance Measurement System Based on S3C2410," *IEEE Int.Conf. on Intelligent Computation Technology and Automation*, 2008, pp. 44-47.

[14] A. K. Shrivastava, A. Verma and S. P. Singh, "Distance Measurement of an Object or Obstacle by Ultrasound Sensors Using P89C51RD2," *International Journal of Computer Theory and Engineering*, vol. 2, no. 1, pp. 64-68, 2010.

[15] H. A. Al_Issa, S. Thuneibat and M. Abdesalam, "Sensors Application Using PIC16F877A Microcon-troller," *American Journal of Remote Sensing*, vol. 4, no. 3, pp. 13-18, 2016.

[16] M. S. Arefin and T. Mollick, "Design of an Ultrasonic Distance Meter," *International Journal of Scientific & Engineering Research*, vol. 4, no. 3, pp. 1-10, 2013.

[17] R. Tarulescu, "Usage of Parallax Ultrasonic Sensors in Distance Measurements," *Annals Of The Oradea University Fascicle of Management and Technological Engineering Journal*, vol. XXII (XII), 2013/1, no. 1, pp. 393-396, 2013.

[18] K. Srilakshmi, K. Anitha, P. Rajesh Kumar and G.R.L.V.N. Srinivas Raju, "Design and Implementation of Distance Measuring Digital Hardware," *International Journal of Electronics & Communication Technology (IJECT)*, vol. 2, no. 1, pp. 222-225, 2011.

[19] R. P. Thomas, K. K. Jithin, K. S. Hareesh, C. A. Habeeburahman and J. Abraham, "Range Detection Based on Ultrasonic Principle," *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol. 3, no. 2, pp. 7638-7642, 2014.

[20] A. Jain, A. Thakrani, K. Mukhija, N. Anand and D. Sharma "Arduino Based Ultrasonic Radar System using Matlab," *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*, vol. 05, no. 4, pp. 215-218, 2107.

[21] Z. A. Aldoulah, "Application of Ultrasonic Radars in a Real-time Distance Detection System for Individuals with Visual Impairment," M.S. thesis, Department of Electrical Engineering, The University of Toledo, USA, 2017.

[22] A. Dutt, *Arduino Based Radar System*, GRIN Publishing, 2014.

[23] H. M. A. Fahmy, "WSNs Applications," *Wireless Sensor Networks Concepts, Applications, Experimentation and Analysis*, Singapore, Springer, 2016, pp. 198-199.

[24] N. Patel, H. Kathiriya and A. Bavarva, "Wireless Sensor Network Using Zigbee," *International Journal of Research in Engineering and Technology*, vol. 2, no. 6, pp. 1038-1042, 2013.

[25] A. Knörig, R. Wettach, J. Cohen, "Fritzing- A Tool for Advancing Electronic Prototyping for Designers", *Proceedings of the Third International Conference on Tangible and Embedded Interaction (TEI'09)*, pp. 351-358, 2009.

[26] “Arduino Uno,” [Online]. Available: https://datasheet.octopart.com/A000066-Arduino-datasheet-38879526.pdf

[27] N. A. Latha, B. R. Murthy and K. B. Kumar, “Distance Sensing with Ultrasonic Sensor and Arduino,” *International Journal of Advance Research, Ideas and Innovations in Technology*, vol. 2, no. 5, pp. 1-5. 2016.

[28] G. A. Francis, M. Arulselvan, P. Elangkumaran, S. Keerthivarman and J. V. Kumar “ Object Detection Using Ultrasonic Sensor,” *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, vol. 08, no. 06, pp. 207-209, 2019.

[29] “Ultrasonic Ranging Module HC - SR04 Datasheet: University of Texas at Austin”, September 2015. [Online]. Available: http://users.ece.utexas.edu/~valvano/Datasheets/HCSR04b.pdf

[30] D. Gislason, “Hello Zigbee,” *Zigbee Wireless Networking*, Newnes, USA: Elsevier, 2008, pp. 3-4.

[31] M. F. Mosleh and D. S. Talib, “Hardware Implementation of Wireless Sensor Network Using Arduino and Zigbee Protocol,” *Information Technology, Engineering and Technology Journal*, vol. 34, no. 5, pp. 816-829, 2016.

[32] C. Ouyang, “Design and Implementation of a Wireless ZigBee Mesh Network,” M.S. thesis, *Vaasan Ammattikorkeakoulu*, Applied Sciences Univ, Amsterdam, Holland, 2014.

[33] “DIGI XBEE® S1 802.15.4 RF MODULES,” [Online]. Available: https://www.digi.com/pdf/ds_xbeemultipointmodules.pdf

[34] J. E. R. Pallares, “Wireless Sensor Network Implementation with Arduino and Xbee,” M.S. thesis, *Dept Telecommunication Engineering and Management*, Polytechnic Univ, Barcelona, Spain, 2015.

[35] “SG90 9g Micro Servo Data Sheet,” [Online]. Available: https://cdn.instructables.com/ORIG/FA2/O1SS/J7ARLNBW/FA2O1SSJ7 AR LNBW.pdf

[36] S. Mehta, S. Tiwari, “Radar System Using Arduino and Ultrasonic Sensor,” *International Journal of Novel Research and Development*, vol. 03, no. 4, pp. 14-20, 2018.

[37] “Piezoelectric Sound Components,” [Online]. Available: https://www.arduino.cc/documents/datasheets/PIEZO-PKM22EPPH4001-BO.pdf