Objects Detection and Angles Effectiveness by Ultrasonic Sensors HC-SR04

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Abstract: ***Nowadays, Distance measuring of an agent is used, it is very important in many fields like: means of transport control, medical applications, economic, agent movement controls, detections, etc. This can be improved using different types of detection devises named "sensors" as such as: ultrasonic sensor, infrared sensors, laser light, radars in general, and so on. Ultrasonic Sensor is the cheapest one and it has great impact and challenges in comparison with others. In this paper, concerning the ultrasonic sensor to calculate the best reflections sound waves among the exterior surface of the shapes including the deviation of angles, then trying to find the best one through comparing error rate for each angle. In addition, locomotion area has been calculated for all three shapes with different locations starting by 0° of angle. Moreover, what if two ultrasonic sensors are used sequentially. This paper used Ultrasonic Sensor HC-SR04 with Arduino microcontroller. Uncertainty analysis also has been obtained for each.***

Keywords: Detection Devises, locomotion, Ultrasonic, Infrared, Sensor, Distance Measurement, Microcontroller, Agent, Radar, Laser

1. Introduction

In the world, sensors have many usages into different applications in many corporation, especially for measuring straight distance and speed, in addition system alert and detection objects too. With increasing the request for self-driven systems, the usage of sensors has been cumulated. Sensors are complicated devices that convert the physical parameters (e.g. temperatures, pressures, humidity, velocity, distance, and the like…) into a signal which can be measured electrically[1].

Choosing the sensors depending on the nature of the required project. Some difficulties appear when using Ultrasonic Sensors (UsS) because the sound wave is affected with material such as sponge, cotton, unshaped object[2]. Even It could be effected as well with wind, heat, humidity, etc. [3].

With UsS, there are many challenges; several researchers work on it, the latest research was about the applications effective for the positioning of transparent objects that measure and identify the objects like a glass bottle (transparent objects), The author has discussed an ultrasonic object location and shape perception system that can reach the distance intention in both width and depth directionally, step by step using sound signals sensor of an ultrasonic[3].

The fundamental one is the blind area. Within OSHA destiny cases from 1990 to 2007, finding the blind area was leading to cause of relevant construction equipment appears destines (Teizer and Hinze, 2011). OSHA stands for (Occupational Safety & Health administration). Additionally, technology-based devices is considered the blind areas of equipment that would help to limit and execute to minimize danger toward the workers (Hefner and Breen, 2003; Ruff, 2007). Moreover, the National Institute for OSHA provides blind area diagrams for 13 kinds of equipments and 41 models (NIOSH, 2012)[4].

H. He, et al. had designed a range measurement tools being used S3C2410. The accuracy improved by using temperature indemnity module[5].

Y. Jang, et al. had perused a mobile walking distance measurement system having 90% of perfection[6].

C. C. Chang, et al. had searched the ultrasonic measurement system for underwater operations. It uses ultrasonic suit, laser system besides camera based on system for 3-D location control of underwater carriage, he had found the error rate equal to (±1) for each 35cm, but when added GIC filter, the error was reduced to 0.6[7].

Pilli et al. Copyright (2011), Elsevier, explains in clear form the different ranges of sounds[8].

The remain of this paper has mentioned about a criteria and the mechanism concept through ultrasonic sensors, 3rd section contain the proposed system which contain in 4th and 5th Part the specific details around the equipment and tools (Hardware / Software) which were used in a proposal system. Section 6 was the proposed experimental procedure, 7th part is the experimental results, discussion is under 8th part, the Penultimate part is for recommendation. final section for the conclusion.

2. Criteria to Select Suitable Sensors

Many kinds of sensors can be found in the markets, it's very important to choose the suitable one, this selection should impact some criteria such: accuracy, range, distance, usability, cost and others[9].

In this project, a small model was built to do a real test by putting some objects (three different shapes and sizes) in front of this sensor, then make some estimations to find the best shape and locations that can deal with a static "UsS" by doing a comparison between them when the angle is changed (i.e. the angle is not equal 0 to the trigger). The basic embrace for choosing these three shapes (cubic, cylinder and cone) because these are the basic geometric for all shapes in the existence world. From these shapes all others geometric shapes can be obtained[10].

The concept of the work for UsS, is depending on the reflection of sound waves as in figure (1), the time duration that leaves the trigger muzzle until reflecting to the echo muzzle divided by 2 should equal to the distance of that object[11].

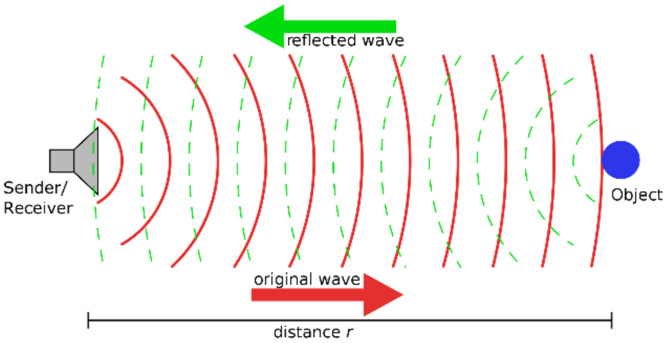

Figure (1): The Concept of Ultrasonic Sensor

Noticeably, ultrasonic has some cons like[12, 13]:
1) Pressure, temperature and humidity in the air; could affect the accuracy of calculations.
2) Objects with sharp edges; May not give a good echo.
3) A blind zone of a few cm's (i.e. 3cm or less) if the object is so close to the sensor.
4) Never works in vacuum space.
5) Contributions to attenuation of an ultrasound sensor may imply: Absorption, Reflection, Scattering, Refraction, Diffraction, Interference, and Divergence.

But in general, ultrasonic has many pros like[12, 13]:
1) For detection, no physical contact is required.
2) Light and color are not affected with sound waves.
3) Ultrasonic sensors can work effectively in varied environments as such as: air, solids, water or gases.
4) Suitable size in comparison to the others types.
5) Lowest cost in comparison to the other sensors.
6) Error rate is slight, normally around ±3cm (increases with range).

Meanwhile, of technology development, different kinds of sensing technologies have been developed and tested to prevent conflict within critical areas of construction equipment[14]. However, in different environments the performance of sensing technologies varies, such as mobile agents or even with static object. This variety appears many testing standards protocol to evaluate the whole system performance and the manner of objective. Nevertheless, concerning the optimum caution when these types of sensors are used that could be impacted with the person's life. Many resources talked about the constructions site, there are 9.7 person injured by the truck (constructions vehicle) per 100,000 construction workers in 2009[15].

With scientific fields, normally Ultra-Sound waves (more than 20.000 db.) is prevailed, the frequency ranges varies as shown in figure (2)[1].

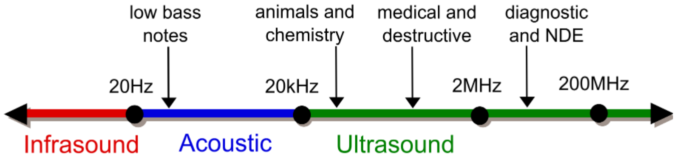

Figure (2): Range Diagram of Sound

3. The Proposed System

Generally, monitoring and tracing some objects provoke the researchers and developers to concentrate on the mechanisms that serves the people. The proposed system looking for improvement and increasing the facilities on the objects that traveling through the terminals of the airport (as an example). In some cases, it is a good idea to monitoring and giving a remote-indication to know the location in the garage whether empty or not, especially the garages that include many upper/lower levels with some useful benefits such auto timing counter, security for restricted area, etc.

As mentioned around these systems, of course the objects has many kinds of shapes, here, a comparative is applied between a cubic shape (square surface) and cylinder shape (circle section) and cone shape to see which one is better to reflect the sound wave depending on distance and size according to the properties of this sensors (HC-RS04). Then, method for enhancing the efficiency as appeared in the dissection section.

At the beginning, lets understand the algorithm, then the flowchart which in figure (3) for the mechanism in general.

THE ALGORITHM
1. System diagnostic of objects turn on
2. Began
3. Start Loop
4. Trigging 8 sonic pulses for 10 m_s
5. Began
6. Waiting for reflected waves
7. If time out
8. print the object not in range, then
9. Else
10. Print the distance in "cm" according to the sound wave reflection equation, then
11. End.
12. End Loop
13. End.

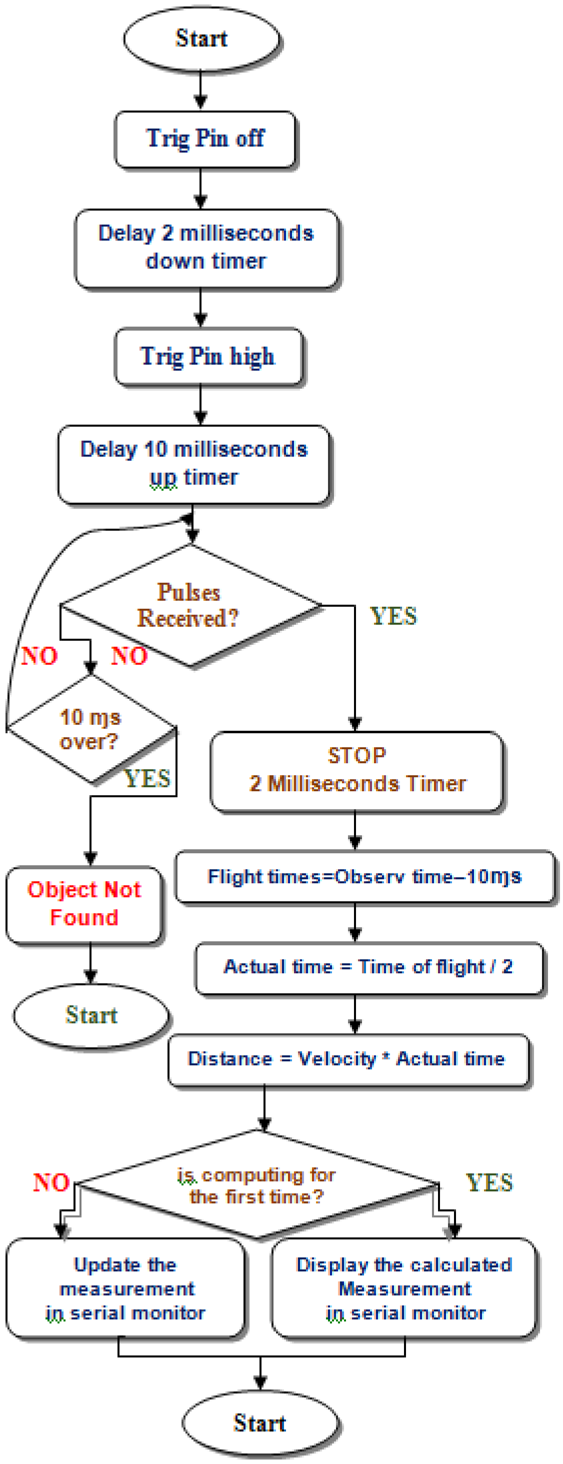

Figure (3): Flowchart of the experiment

4. Hardware Specification

a) Ultrasonic Sensor

In this test, the type of the ultrasonic sensor is HC-SR04 which is shown in figure (4), it has some good facilities, such that [2]:

1) Has a good facility to deal with arduino microcontroller friendly.
2) Has enough range to test.
3) Easy to use and combine electrically with various type of electric tools.
4) The price is suitable in the markets.
5) The wide usage in the life concentrates to the criteria of these kind of sensors being much more important.
6) The limited rang of this model is between 2-400 cm, one kit includes transmitter (named Trigger), receiver (named echo), control circuit and 4 pin. More details about HC-SR04 shown in table (1) [12].

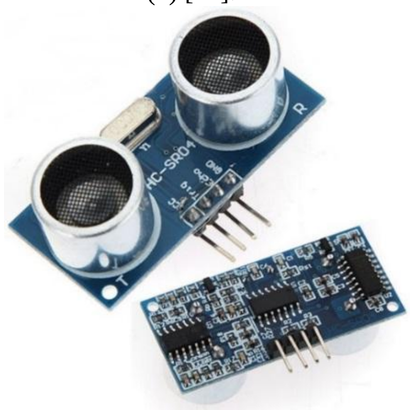

Figure (4): Ultrasonic Sensor HC-SR04

Table (1): Details of HC-SR04

HC-SR04 Details	Specs
Current Voltage(V)	DC 5 V
Ground Voltage(G)	0 V
Working Current(C)	15mA
Working Frequency(F)	40KHz
Range (Max/ Min)	400cm /2cm
Angle of Measure	5-15 degree
Trigger Signal	10uS TTL pulse
Echo Signal	Depend on max range of TTL
Dimensions	45*20*15mm

b) Arduino Microcontroller

Arduino UNO Board is used (see figure (5)), The technical specs as cleared up in table (2) [16]:

Figure (5): Arduino UNO Microcontroller Board

Table (2): Technical Specs of UNO

Kits	Specs
Microcontroller	ATmega328P
Operating Voltage	5V
Input V. (recommended)	7-12V
Input V. (limit)	>6, <20V
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O	20 mA
DC Current for 3.3V	50 mA
Flash Memory	32KB,0.5KB used by loader
Clock Speed	16 MHz
Length, Width	68.6 mm, 53.4 mm
Weight	25 g

c) Kits & Development Boards

The proposal recommended using some equipment:
1) USB Cable.
2) DuPont Line Male - Female.
3) DuPont Line Male - Male.
4) Breadboard 830 Point Solderless, MB-102.
5) Meter Ruler and protractor.
6) Even Board.
7) Obstacles (cubes, cylinders and cones).

5. Software Specification

a) ARDUINO 1.5.6-r2

Writing and uploading code to the board becomes easier based on using open-source arduino language, named as IDE Processing Language. It can work on all kinds of Windows, Mac Operating System, and Linux OS [16].

Nevertheless, the environment is written in Java language and based on Processing and others open-source software.

All kinds of Arduino boards can use this software [16]. However, the result can be monitored by the port serial online, or even offline thru saving the result into a database. The interface cleared by figure (6).

Figure (6): ARDUINO Interface Program1.5.6-r2

b) Fritizing 0.9.3bSoftware

It is an electrical engineering software program for designing a circuit; the proposed circuit is designed by this program to give some idea as in figure (7) which shows that the power connected to 5v / Red, Ground is available / Black, Pin3 for Trigger / Purple, Pin2 for Echo / Green.

In addition, it is important to mention that Auto CAD program is used as well for drawing some figures as a real scale for comparing the geometrics, as it is shown in the discussion.

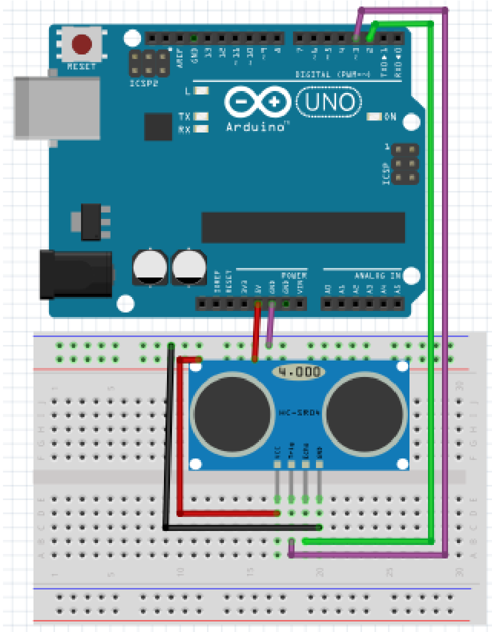

Figure (7): Sketch of Circuit

6. Proposed Experimental Procedure

Many kinds of experimental proposal has designed as a model test, here, there are a model with many cases for achieving some fantastic result that convoy some actual applications.

The stages of this study are illustrated as follows:
1) Using trigger for 10 nanoseconds for sending pulses.
2) Using 3 samples objects (cubes, cylinders and cones) with diameters 10cm, 20cm, 40cm for all objects). These different sizes to make a comparison among the distances according to the properties of the HC-RS04 sensor for recruitment of suitable projects, which could be needed.
3) Placing them face to face with Sensor based on different distances (50cm, 100cm, 200cm, 300cm and finally 400cm) these distances according to the limitation of properties .
4) Trying to displace the objects left or right to calculate the availability of locomotion with 0° of angle
5) The module sends 8 pulses as 40KHz and wait whether there is a pulse comeback as shown in figure (8) here below.
6) If there are reflect signals, the echo takes over this pulses, then the taken time that last from sending till receiving dividing by 2; the result will be equal to the distance of that object location (approximately) depending on the sound velocity of the status of the environment[1].

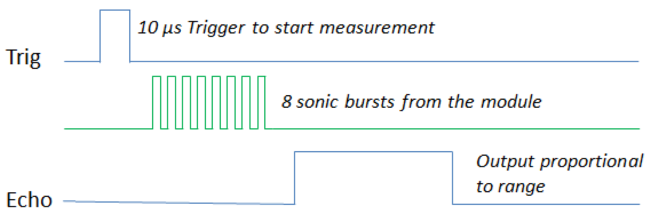

Figure (8): Timing Diagram of the HC-SR04 Module

This trip (sending from the system to impact the object, and then reflects to the system) is controlled by the microcontroller within a very tiny time (some microseconds) according to this simple equation [1]:

$$D = (T * V)/2$$

Where: [**D** = Distance in centimeters, **T** = Time in seconds, **V** = 346 meter in second, in condition of 25º Centigrade].

And the angle reflection waves is according to **"Snell's Law"** which it is convenient with transition's wave among more than one material (density)[17].

$$\frac{\sin i}{V1} = \frac{\sin r}{V1} = \frac{\sin R}{V2}$$

Where **[i** = Angle of Incidence, **r** = Angle of Reflection, **R** = Angle of Refraction, **V1** = Velocity in Medium1, **V2** = Velocity in Medium2].

In this paper, the latter part from the equation will be eliminated, that meant (V1, V2≅1) in our experimental.
The error correction equation for reflecting is used to make a comparative with actual results[18]:

$$Actual\ Distance = \sqrt[2]{(measured\ distance)^2 + 0.5(Distance\ Between\ Trigger\ and\ Echo)^2}$$

7) Additional to this test, maximum Locomotion of object try to find (left or right displacement gradually) before the wave's reflection losing the Rate of Return. Depending to the tables here above (The locomotion column), it can be noticed that the far object has more movement flexibility and the cylinder shape scatter the wave more than a cubic. Of course, the reason is the angle of trigger wave; it is emanated like a cone with 15-Degree angle or less. Nevertheless, with cones, the scattered increasingly because the total surfaces of impact area is less.

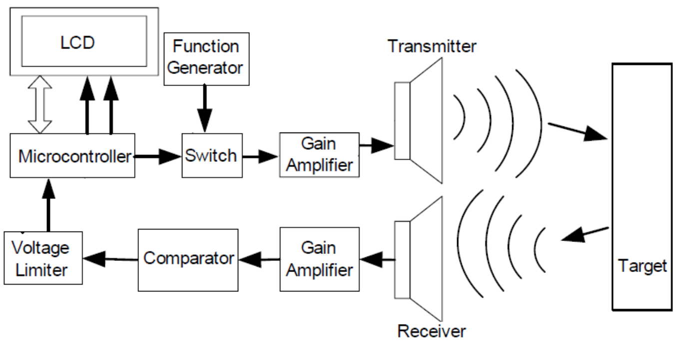

Figure (9): Block Diagram of wave's reflection [7].

7. Proposed System & Experiment Results

When the test is activated, by putting some object as an obstacle for measuring the reflections of ultrasound waves, some cases shall be examined the detection of the obstacle, distance, location and front angle deviation (locomotion) for some differences objects diameters as shown in the two cases (schedules) below when angles vary between (0-20 Degree).

The comparison impact is to be applied depends upon the distance and sensor angle according to the cases that tested (cases1 group and cases2 group). Then some comparative done by Snell's Law, which was declared in section V. five cases of distances is used (50, 100, 200, 300 and 400 cm) for practical usefulness, and more than 4 meter not applicable because as known the chances of HC-RS04 is limited with this range. Additionally, the experiments study the effectiveness of different angles for the same five farness. The results can be seen in the tables below (cases1).

Moreover, two ultrasonic sequentially used (the gap between them was 15cm) as declared in details by (cases2).

By comparing these two proposals (**cases1** for one ultrasonic sensor, **cases2** for two ultrasonic sensors), some conclusions to reduce the error will be obtained for enhancement.

Case1:A.1 Table (3) Cubic with 10cm side

Cubic, (10cm)									
Angle (0º)				Angle (5º)		Angle (10º)		Angle(20º)	
Actual Distance	Read Dis. (cm)	Err. (%)	Locomotion from center	Read Dis. (cm)	Err. (%)	Read Dis. (cm)	Err. (%)	Read Dis.(cm)	Err. (%)
50(cm)	50-50.1	0.1	7(cm)	50.2-50.4	0.6	52-53	5	out	100
100(cm)	100-100.3	0.15	14(cm)	100.9-103	3.45	out	100	out	100
200(cm)	198-203	1.25	33(cm)	out	100	out	100	out	100
300(cm)	295-304	1.45	44(cm)	out	100	out	100	out	100
400(cm)	out	100	∞	out	100	out	100	out	100
		20.5%			60.8%		81%		100%
TOTAL ERROR RATE: (65.57 %)									

Case1: A.2 Table (4) Cubic with (20cm) side

Cubic, (20cm)									
Angle(0º)				Angle(5º)		Angle(10º)		Angle(20º)	
Actual Distance	Read Dis. (cm)	Err. (%)	Locomotion from center	Read Dis. (cm)	Err. (%)	Read Dis. (cm)	Err. (%)	Read Dis.(cm)	Err. (%)
50(cm)	50-50.05	0.05	11(cm)	50-50.1	0.05	50.1-50.3	0.4	out	100
100(cm)	100-100.1	0.05	19(cm)	100-102	1	101.2-102.4	1.8	out	100
200(cm)	200-201	0.25	40(cm)	202-204	1.5	out	100	out	100
300(cm)	299-301	0.31	52(cm)	out	100	out	100	out	100
400(cm)	398-402	1	60(cm)	out	100	out	100	out	100
		0.33%			40.5%		60.4%		100%
TOTAL ERROR RATE: (50.30 %)									

Case1: A.3 Table (5) Cubic with (40cm) side

Cubic, (40cm)									
Angle(0º)				Angle(5º)		Angle(10º)		Angle(20º)	
Actual Distance	Read Dis. (cm)	Err. (%)	Locomotion from Center	Read Dis. (cm)	Err. (%)	Read Dis. (cm)	Err. (%)	Read Dis. (cm)	Err. (%)
50(cm)	50-50.05	0.05	18(cm)	50-50.05	0.05	50-50.05	0.05	50.2-50.8	1
100(cm)	100-100.1	0.05	29(cm)	100-100.4	0.2	100-100.9	0.45	98.3-103.5	2.6
200(cm)	200-200.5	0.125	45(cm)	200.1-200.9	0.25	199-201.9	0.7	out	100
300(cm)	300-300.9	0.15	60(cm)	300.3-301.9	0.36	out	100	out	100
400(cm)	399.5-401	0.18	68(cm)	399-402.5	0.56	out	100	out	100
		0.11%			0.28%		40.24%		60.72%
TOTAL ERROR RATE: (25.33 %)									

Case1: B.1 Table (6) Cylinder with (10cm) Diameter

Cylinder, Diameter (10 cm), Height (10 cm)									
Angle(0°)				Angle(5°)		Angle(10°)		Angle(20°)	
Actual Distance	Read Dis. (cm)	Err. (%)	Locomotion from center	Read Dis. (cm)	Err. (%)	Read Dis. (cm)	Err. (%)	Read Dis.(cm)	Err. (%)
50(cm)	48.9-52.8	3.9	2(cm)	out	100	out	100	out	100
100(cm)	out	100	∞	out	100	out	100	out	100
200(cm)	out	100	∞	out	100	out	100	out	100
300(cm)	out	100	∞	out	100	out	100	out	100
400(cm)	out	100	∞	out	100	out	100	out	100
		80.7%			100%		100%		100%
TOTAL ERROR RATE: (95.17 %)									

Case1: B.2 Table (7) Cylinder with (20cm) Diameter

Cylinder, Diameter (20 cm), Height (20 cm)									
Angle(0°)				Angle(5°)		Angle(10°)		Angle(20°)	
Actual Distance	Read Dis. (cm)	Err. (%)	Locomotion from center	Read Dis. (cm)	Err. (%)	Read Dis. (cm)	Err. (%)	Read Dis.(cm)	Err. (%)
50(cm)	49.8-50.2	0.4	3(cm)	50.2-51	2.2	out	100	out	100
100(cm)	99.5-101.2	0.85	10(cm)	out	100	out	100	out	100
200(cm)	195.2-203	1.9	15(cm)	out	100	out	100	out	100
300(cm)	out	100	∞	out	100	out	100	out	100
400(cm)	out	100	∞	out	100	out	100	out	100
		40.6%			80.4%		100%		100%
TOTAL ERROR RATE: (80.25 %)									

Case1: B.3 Table (8) Cylinder with (40cm) Diameter

Cylinder, Diameter (40 cm), Height (40 cm)									
Angle(0°)				Angle(5°)		Angle(10°)		Angle(20°)	
Actual Distance	Read Dis. (cm)	Err. (%)	Locomotion from center	Read Dis. (cm)	Err. (%)	Read Dis. (cm)	Err. (%)	Read Dis.(cm)	Err. (%)
50(cm)	50-50.5	0.5	22(cm)	50.2-50.8	1	50.4-51.2	1.6	47.6-51	3.4
100(cm)	99.7-100.9	0.6	35(cm)	99.3-100.5	0.6	99.7-100.9	0.75	98-102	2
200(cm)	200.5-202.7	0.8	44(cm)	199.8-201	0.3	199-201	0.5	198-202	1
300(cm)	296-305	1.48	60(cm)	300-300.6	0.1	out	100	out	100
400(cm)	out	100	0(cm)	out	100	out	100	out	100
		20%			22%		40.5		41.2%
TOTAL ERROR RATE: (30.92 %)									

With the cases of cones (Case C: 1, 2 and 3), three model used (10cm base, 10cm height), (20cm base, 20cm height) and (40cm base, 40cm height). The result was analogous (out of range, error rate = 100%) for all cases, because the reflections waves scattered immediately to the several directions, except one cases (when two ultrasonic sensors sequentially used by actual distance (50cm) with (40cm) base and (40cm) height. as case (C.1) shown in table (9).

Case 1: C.1 Table (9) Cone (40cm) base, (40cm) height by 2 UsS

Cone (40cm) base, (40cm) height - by 2 Ultrasonic Sensors									
Angle(0°)				Angle(5°)		Angle(10°)		Angle(20°)	
Actual Distance	Read Dis. (cm)	Err %	Locomotion from Center	Read Dis. (cm)	Err %	Read Dis. (cm)	Err %	Read Dis. (cm)	Err %
50(cm)	47-53	6	25(cm)	out	100	out	100	out	100
100(cm)	out	100	∞	out	100	out	100	out	100
200(cm)	out	100	∞	out	100	out	100	out	100
300(cm)	out	100	∞	out	100	out	100	out	100
400(cm)	out	100	∞	out	100	out	100	out	100
		81.2%			100%		100%		100%
TOTAL ERROR RATE: (95.05 %)									

When two ultrasonic sensors sequentially used with remnants shapes (Cubic and Cylinder), the error rate noticeable reduced, some of cases the error rate considered as negligible (approximate to zero) as shown in tables (cases2) below:

Case2: A.1 Table (10) Cubic with 10cm side by 2 UsS

Cubic (10cm) - by 2 Ultrasonic Sensors									
Angle(0°)				Angle(5°)		Angle(10°)		Angle(20°)	
Actual Distance	Read Dis. (cm)	Err %	Locomotion from Center	Read Dis. (cm)	Err %	Read Dis. (cm)	Err %	Read Dis. (cm)	Err %
50(cm)	50	0	20(cm)	50	0	49-51	2	47-55	8
100(cm)	100	0	30(cm)	100	0	97-105	3.5	out	100
200(cm)	200	0	55(cm)	199-202	0.75	out	100	out	100
300(cm)	299-301	0.33	70(cm)	out	100	out	100	out	100
400(cm)	out	100	∞	out	100	out	100	out	100
		20%			40.15%		61.1%		96%
TOTAL ERROR RATE: (54.31 %)									

Case2: A.2 Table (11) Cubic with 20cm side by two UsS

Cubic (20cm) - by 2 Ultrasonic Sensors									
Angle(0°)				Angle(5°)		Angle(10°)		Angle(20°)	
Actual Distance	Read Dis. (cm)	Err %	Locomotion from Center	Read Dis. (cm)	Err %	Read Dis. (cm)	Err %	Read Dis. (cm)	Err %
50(cm)	50	0	30(cm)	50	0	50	0	50-53	5
100(cm)	100	0	44(cm)	100	0	98-102	1	98-102	2
200(cm)	200	0	62(cm)	199.5-201	0.37	197-202	1.25	out	100
300(cm)	300	0	74(cm)	296-303	1.1	out	100	out	100
400(cm)	398-403	0.6	88(cm)	out	100	out	100	out	100
		0.12%			20.2%		40.4%		61.4%
TOTAL ERROR RATE: (30.5 %)									

Case2: A.3 Table (12) Cubic with 40cm side by two UsS

Cubic (40cm) - by 2 Ultrasonic Sensors									
Angle(0°)				Angle(5°)		Angle(10°)		Angle(20°)	
Actual Distance	Read Dis. (cm)	Err %	Locomotion from Center	Read Dis. (cm)	Err %	Read Dis. (cm)	Err %	Read Dis. (cm)	Err %
50(cm)	50	0	35(cm)	50	0	50	0	50-51	1
100(cm)	100	0	50(cm)	100	0	100	0	99-101	1
200(cm)	200	0	70(cm)	200	0	199-201	0.5	195-203	2
300(cm)	300	0	92(cm)	300	0	out	100	out	100
400(cm)	399.5-400	0.06	108(cm)	399-401	0.2	out	100	out	100
		0.01%			0.04%		40.1%		40.8%
TOTAL ERROR RATE: (20.2 %)									

Case2: B.1 Table (13) Cylinder with (10cm) Diameter by 2 UsS

Cylinder, Diameter (10cm), Height (10cm) - by 2 Ultrasonic Sensors									
Angle(0°)				Angle(5°)		Angle(10°)		Angle(20°)	
Actual Distance	Read Dis. (cm)	Err %	Locomotion from Center	Read Dis. (cm)	Err %	Read Dis. (cm)	Err %	Read Dis. (cm)	Err %
50(cm)	49.8-50.3	0.5	15(cm)	48.5-51.6	3.1	46-53.6	7.6	out	100
100(cm)	48.6-52.6	2	25(cm)	96.8-103	3.1	out	100	out	100
200(cm)	45.6-55	2.3	44(cm)	out	100	out	100	out	100
300(cm)	out	100	∞	out	100	out	100	out	100
400(cm)	out	100	∞	out	100	out	100	out	100
		40.9%			61.2%		81.5%		100%
TOTAL ERROR RATE: (70.9%)									

Case 2: B.2 Table (14) Cylinder with (20cm) Diameter by 2 UsS

Cylinder, Diameter (20cm), Height (20cm) - by 2 Ultrasonic Sensors									
Angle(0°)				Angle(5°)		Angle(10°)		Angle(20°)	
Actual Distance	Read Dis. (cm)	Err %	Locomotion from Center	Read Dis. (cm)	Err %	Read Dis. (cm)	Err %	Read Dis. (cm)	Err %
50(cm)	50	0	**25(cm)**	50	0	49-51.1	2.1	out	100
100(cm)	100	0	**38(cm)**	98.8-101.8	1.5	96-103	3.5	out	100
200(cm)	199-202	0.75	**52(cm)**	196.2-202	2.9	out	100	out	100
300(cm)	296-302	1	**66(cm)**	out	100	out	100	out	100
400(cm)	395-404.4	1.1	**78(cm)**	out	100	out	100	out	100
		20.5%			40.8%		61.1%		100%
TOTAL ERROR RATE: (55.6%)									

Case 2: B.3 Table (15) Cylinder with (40cm) Diameter by 2 UsS

Cylinder, Diameter (40cm), Height (40cm) - by 2 Ultrasonic Sensors									
Angle(0°)				Angle(5°)		Angle(10°)		Angle(20°)	
Actual Distance	Read Dis. (cm)	Err %	Locomotion from Center	Read Dis. (cm)	Err %	Read Dis. (cm)	Err %	Read Dis. (cm)	Err %
50(cm)	50	0	**33(cm)**	50	0	50	0	49-52	3
100(cm)	100	0	**48(cm)**	100	0	99-102	3	196-203	3.5
200(cm)	200	0	**66(cm)**	199.2-200.5	0.3	197-203	1.5	out	100
300(cm)	300	0	**80(cm)**	298-302	0.6	out	100	out	100
400(cm)	398.7-401	0.2	**98(cm)**	396-402.4	0.8	out	100	out	100
		0.04%			1.7%		40.9%		61.3%
TOTAL ERROR RATE: (25.9%)									

For examples about these tests, it could see some result how it's computed and obtained the parameters before estimating the total average of errors for each distance, angle and locomotion through serial monitor of Arduino interface.

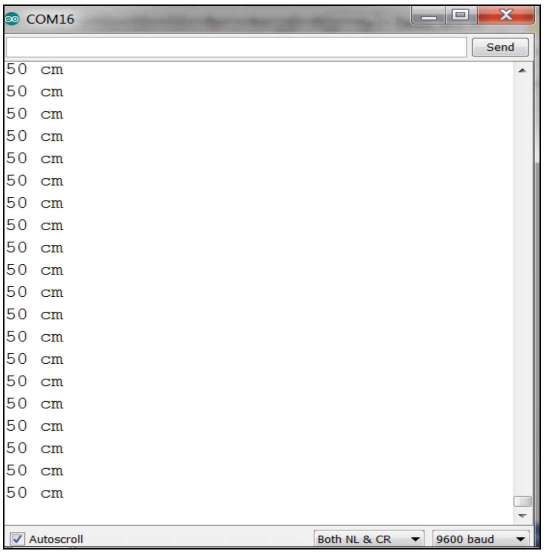

Figure (10): Test distance for case1: A.1 and case2: A1

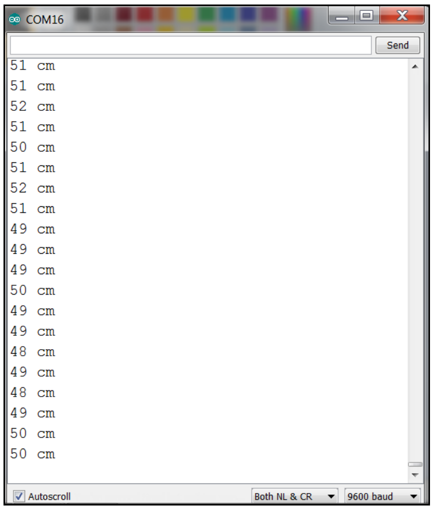

Figure (11): Test distance for case1: B.1

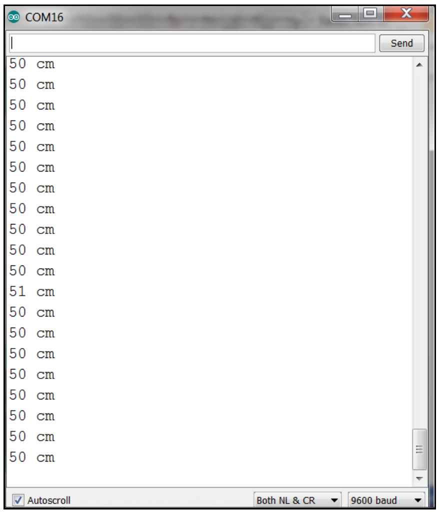

Figure (12): Test distance for case2: B.3

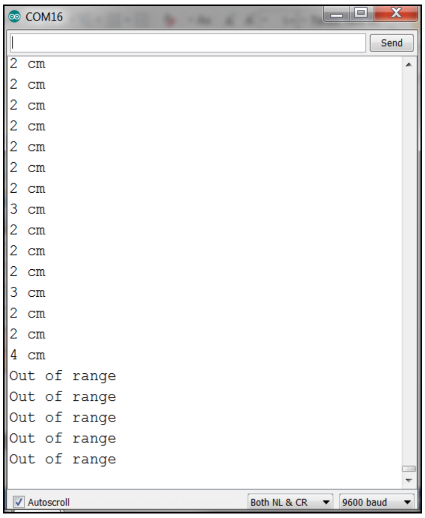

Figure (13): Test locomotion for case1: B.1

Finally, some image attached to clarify and give some details about the real test how it is done.

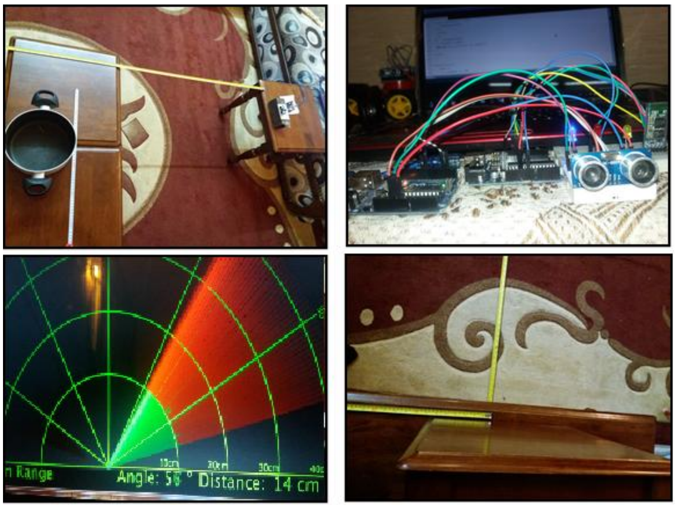

Figure (14): General images for testing and measuring

8. Discutions

As a result, for these three shapes, it is clear that one of them (cone) is not practical for using as an object for detection. This is logically, but with others, the matter is different. Theoretically, according to the tables here above, some errors appeared as the reader can be recognized it. Using mathematical error correction equation, in (cases1, by one sensor) it was found that the result is more than admissible with close distances; for instance: apply the equation on (case1: A, actual distance = 50) the result would be (0.9%), but the result is (0.1%) as error rate. Nevertheless, with much more distances, factually the accuracy of this equation not suitable with different shapes; for an example, if the equation was applied with (case: B.2, actual distance = 200) the result would be (0.45%) but real result was (1.9) as error rate. In addition, it is important to refer indirectly to that, the humidity, atmospheric pressure and temperature as influencing factor affected the accuracy of the reading results. Generally, these categories influence total error rate.

Using these two samples, it was found easily by chart (1) that the square surface is better for reflect the sound's waves, but it is very sensitive for any angle deviation, and the waves is more scattered with cylinder shape, but with cylinder there are no problem if turning the object continuously with 360º up on itself. Because as it knowing the cylinder shape came from the circle (2-D) and there are no different angle on the surface of circle shapes according to the sensors. By chart (2) can found clearly that using 2 UsS in sequential can introduce the perfectly usage of these type of sensors.

With these cases, the result discovered that the locomotion area is working much better with cubic shapes than cylinders. This experimental clarify that the cylinder very sensitive for reflection sound wave, the sound wave could scattered. Chart (3) explained it in detail. And chart (4) explained it if two UsS has been used.

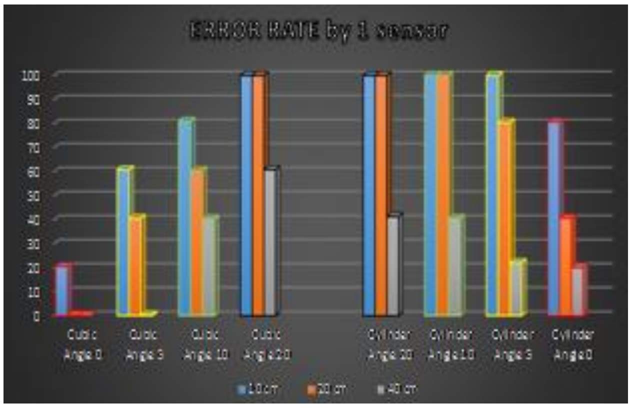

Chart (1): Comparative of Error Rate between Both Cubic and Cylinder Shapes by 1 sensor

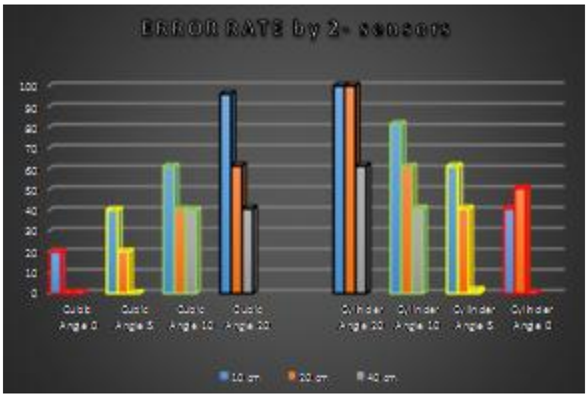

Chart (2): Comparative of Error Rate between Both Cubic and Cylinder Shapes by 2 sensor

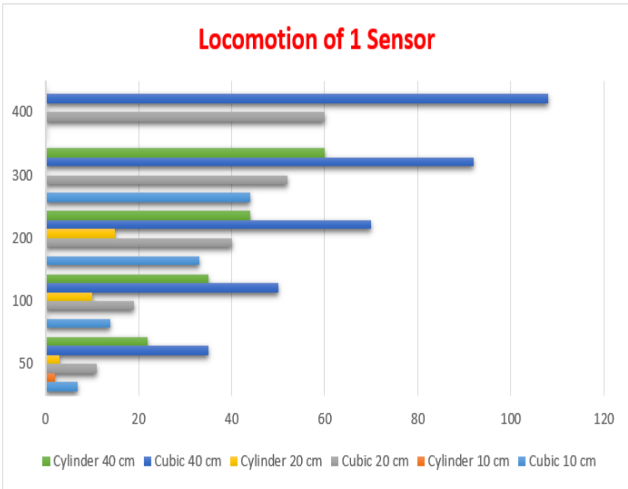

Chart (3): Locomotion Area of 1 sensor

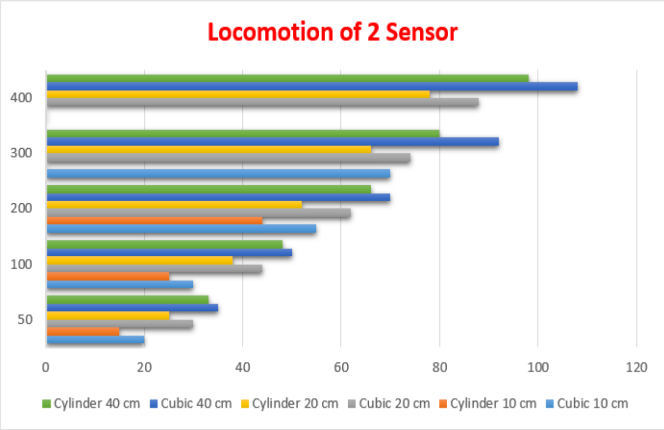

Chart (4): Locomotion Area of 2 sensors

Finally, for all kinds of objects, when use more than one sensor, the accuracy and efficiency definitely could be achieved close to the actual distance. But using two sensors, it could detect objects range more accurately close to real distance in the environment, sometime can be reduced the error rate less than a half. As an example to clear how cube (40 side) with angle (20º) and Cylinder (40 Diameter) with angle (20º) reduced the error rate.

9. Recommended Solution

However, using two ultrasonic sensors sequentially with (15cm) as a gap between them, the error rate shall be reduced, that means the accuracy and the efficiency are increased more than twice at the very least. As knowing, UsS need a front face object. For making cone shape suitable The vertical angle must be aligned to the base and this means that it will face the ultrasonic sensor directly without deviation**,** It will be as a triangular shape in two dimensions.

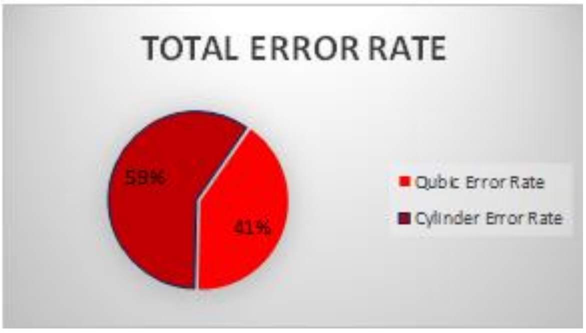

Chart (5): The comparative percentage of error by 1 sensor

The result for these two cases as these two charts appeared that the cubic shape is better than cylinder shape. as a whole, the total error cases for cubic=(47.06%), for cylinder= (68.78%) chart (5) noticed it by one sensor. But with two sensors the total error rate with cubic shape was (35%) and with cylinder was (50.8%) which both has been detected by 2 sensors, as chart (6) shown. Finally, charts (8,9) illustrates the total error and total locomotion in case of one sensor or two.

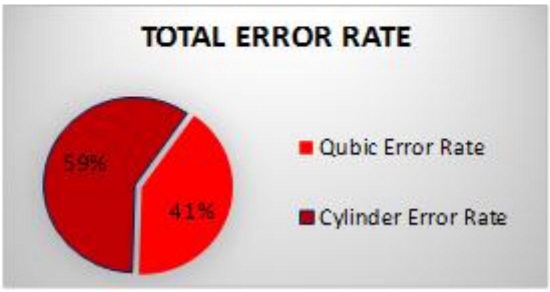

Chart (5): The comparative percentage of error by 1 sensor

The total rate of area that calculated for locomotion; appears that the cubic shape is much better than cylinder (total rate locomotion area for cubic= 33.33cm, and the total rate of locomotion area for cylinder = 12.7) as seen in chart (6). But chart (7) clarify the rate of locomotion area of cubic= (55%) and cylinder=(44%) which they detected by 2 sensors which both has been detected by 2 sensors, as chart (7) shown.

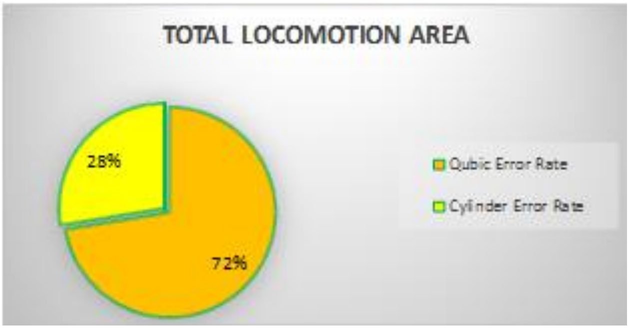

Chart (6): The percentage of locomotion area by 1 sensor

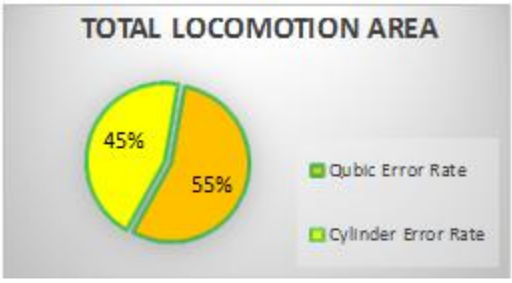

Chart (7): The percentage of locomotion area by 2 sensors

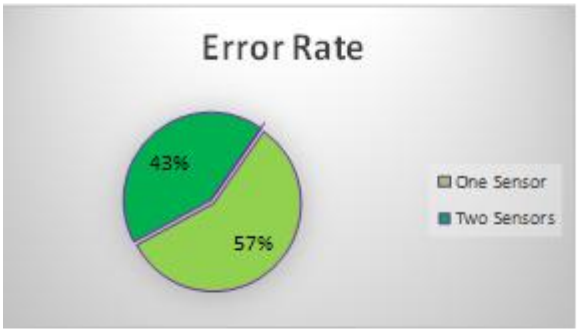

Chart (8): Error for both shape by 1 sensor

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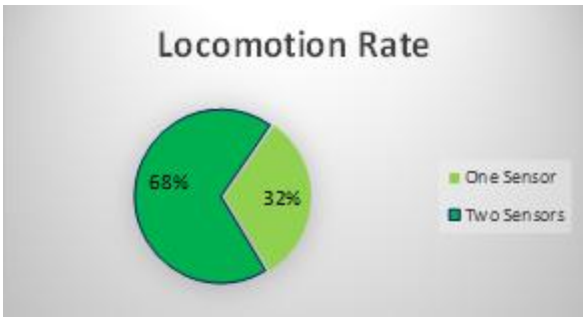

Chart (9): Error for both shape by 1 sensor

In some cases, cubic has better to be used as an obstacle with these sensors, but should have an angle near to (0) degree in front face of the trigger. It is important to point out that the concavity and the convexity are considered as impact factors that affect the result. Otherwise, cylinder shape is more suitable even if it has mobility as self-turning case. Despite that as figure (14), (15) clarifies that bigger diameter in cylinder shape is needed as adequate surface in comparison with square shape. The proposal found that the cube with (11 cm) side has the same reflection wave as a (40cm) diameter of cylinder. Nevertheless, as showing that the cylinder with 40cm diameter is failed when located at (400cm) in front face of ultrasonic sensors, by calculating the rate by Auto CAD program, just found that it need for a (120cm) diameter of cylinder for equaling to 16cm of cubic side. It should mention that there are a weak reflection area belong to the cylinder can give some useful reflection with less accuracy.

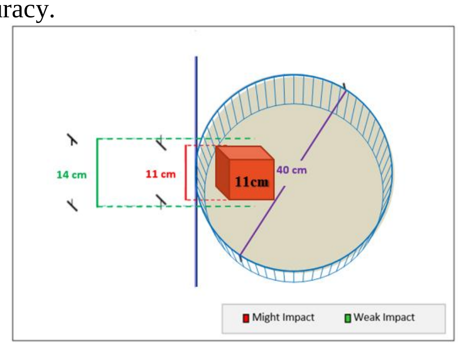

Figure (14): Tangent of 40cm diameter of Cylinder

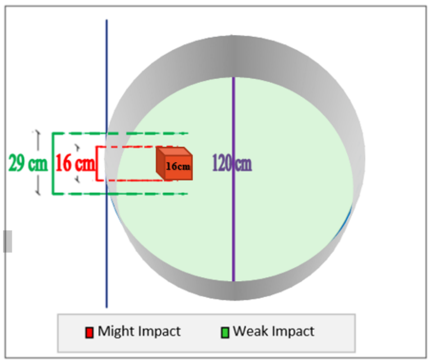

Figure (15): Tangent of 120cm diameter of Cylinder

10. Conciliation

The approach that presented in the paper is outfit and the performance was interesting for measuring the obstacle distance with sensitivity for three shapes and multistage of angles. HC-SR04 and Arduino Microprocessor were satisfied for these cases as a result are admissible with different shapes and locations. The trigonometry as an algorithm was successfully getting minimal errors, each obstacle detection is a very good to be used in variety kinds of applications, cubes and cylinder depending on the demand of use. It be clear that the biggest size is more precisely for detecting objects and have more flexibility of movements. The angles is very sensitive for reflecting the sound waves, the echo pin work better with face-to-face objects. By using two ultrasonic sensors, the qualification of detection be more impact.

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