Arduino Based 3D Trilatration System

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***Abstract*— Trilateration is the process that uses locations of points by measurement of distances, using the geometry of circles, spheres or triangles to calculate a particular point. Computer generated graphics is used in various places of design generation such as automobile designing, map designing and various areas of graphics generation. The conventional method uses Computer Aided Drawings (CAD) and it requires a working knowledge of the softwares used and the process takes time to turn a nonverbal information into visual form. It is much easier to draw directly than on CAD. This paper shows an arduino based system to design and implement these computer-generated designs directly on 3D space using ultrasonic sensors and the method of trilatration.**

Key words: **Trilatration, Computer Aided Drawings, 3D modelling, 3D positioning, Ultrasonic Sensors.**

I. INTRODUCTION

These days computer generated graphics are used almost everywhere. The ease of using various softwares for the generation of graphics and designs makes the process simpler. But a lot of work goes in learning and understanding of the software. The process will become much simpler if the design can be implemented by drawing the design directly on a 3D space. This can be achieved by using the technique of 3D Trilatration. Trilateration is a method to determine the position of an object based on simultaneous range measurements from three stations located at known sites [1]. Trilatration is widely used in Global Positioning System (GPS) for the purpose of navigation. There are several ways to implement trilatration such as by using 3D point cloud [3], radio-tomographic imaging [4] and by using Ultrasonic Sensors [5] and point positioning can also be calculated using other methods as given in [2]. This paper deals with the application of 3D Trilatration using ultrasonic sensors and arduino uno for the implementation of 3D canvas and the future scope for improvements.

This paper is organized in a following way: Theory to calculate co-ordinates for system is given in II, the implementation of system is given in III and the results and coclusion is discussed in IV and V respectively.

II. CO-ORDINATES CALCULATION

The intersections of the surfaces of three spheres is found by formulating the equations for the three sphere surfaces and then solving the three equations for the three unknowns, x, y, and z. To simplify the calculations, the equations are formulated so that the centers of the spheres are on the z = 0 plane. Also, the formulation is such that one center is at the origin, and one other is on the x-axis. It is possible to formulate the equations in this manner since any three non-collinear points lie on a unique plane. After finding the solution, it can be transformed back to the original three-dimensional Cartesian coordinate system.

The trilateration method would provide the required details required to calculate the coordinates accurately and effectively. The equations of the sphere can be solved to get cartesian equivalent coordinates which is much more familiar and easy to interpret and are shown as below

$$d1^2 = x^2 + y^2 + z^2$$

$$d2^2 = x^2 + (y-l)^2 + z^2$$

$$d3^2 = x^2 + y^2 + (z-l)^2$$

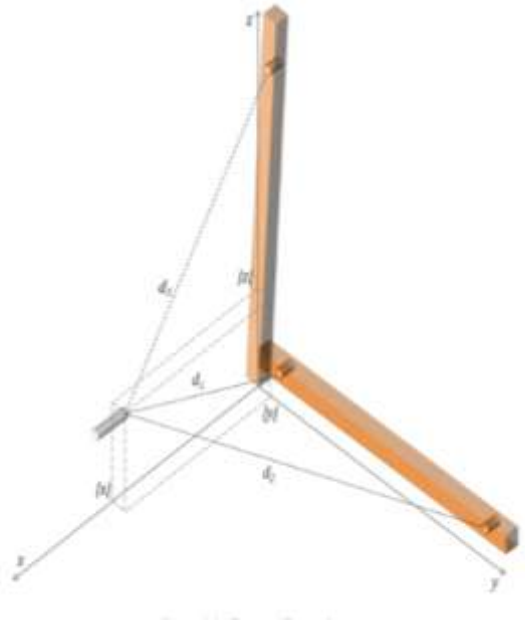

Figure 1 Co-ordinates Calculation

III. IMPLEMENTATION OF THE SYSTEM

The system works as a 3D canvas which enables the user to draw directly on space in three dimensions and the generated graphics appears onto the monitor screen. The essential components required to implement this system includes: ultrasonic sensors, Arduino uno and the python program that captures, process and plot the data respectively.

The system uses four ultrasonic sensors out of which one ultrasonic sensor acts as a transmitter and rest of the three ultrasonic sensors are used as receivers. The block diagram of arduino based 3D trilateration system is shown in figure 2.

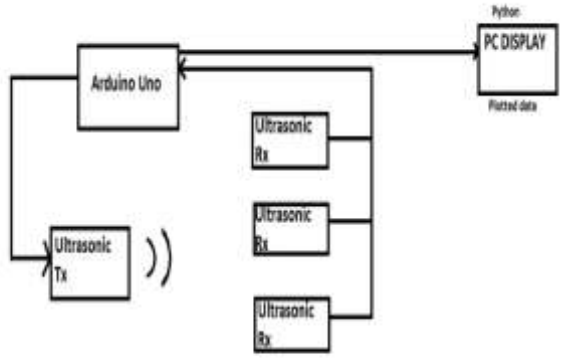

Figure 2. Block diagram of arduino based 3D trilatration system for modelling

The ultrasonic sensors are connected at 3 axes of the coordinate system all connected to the centralized controller. One of the sensors acting as the transmitter are separately wired so that it is mobile. This is very important since the user would use it for movement. Rest of the three sensors is mounted on an 'L' shaped stand acting as receivers. The ultrasonic receiver captures the ultrasonic pulses sent by the ultrasonic transmitter. The data from this system is gathered via an embedded processor which will in turn process and provide real time output on the screen of the computer. This data is plotted using a program which is written to capture the signal from the three receivers attached to the three ends of the frame structure. The controller platforms we decided upon is Arduino. It is easier to code and can be used to interface any kind of sensors and peripherals. The data is plotted using python program. The python code running on PC will provide handshake signals with arduino uno after successfully establishing serial connection. It sends signals when user provides input on an intuitive GUI to arduino uno and listens for the coordinates or data provided in return. It then plots the received coordinates on a 3D plot using matplotlib library. The program provides a useful easy to use GUI for interaction. This is done using spyder IDE.

Arduino consists of 6 analog pins namely A0 to A5 and 14 digital pins D0 to D13.There are 2 power supply pins that is 3V and 5V. The interfacing of ultrasonic sensor with arduino is shown in figure 3. The ultrasonic sensor consists of 4 pins as Vcc, trigger, echo and ground. Trigger pin is an Input pin. This pin has to be kept high for 10us to initialize measurement by sending the ultrasonic waves. Echo pin works as output pin. This pin is high for a period of time which is equal to the time taken for the ultrasonic wave to travel back to the sensors. This is how the distance is calculated using a single ultrasonic sensor. This setup was further modified for working with three receivers and one transmitter to calculate the co-ordinates. The transmitter section only uses the trigger pin so as to send a pulse and the receivers uses all trigger as well as echo to capture the respective distances from each receiver to the transmitter. These distances are used to calculate the co-ordinates.

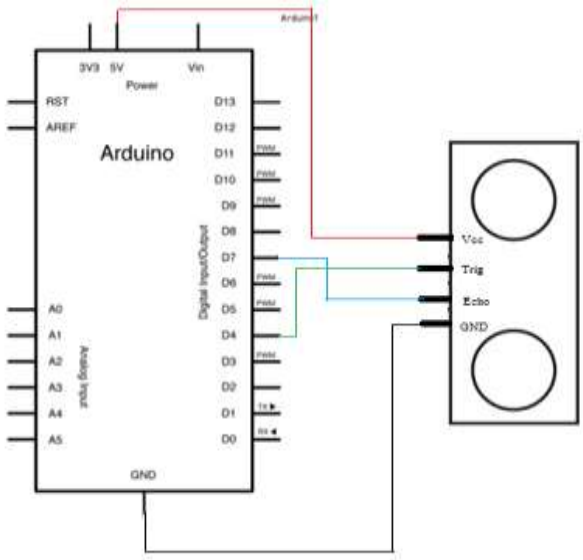

Figure 3. Interfacing of ultrasonic sensor with arduino

All the connections are connected accordingly; it is then simulated using Proteus. In figure 4, the connection diagram of the system is shown.

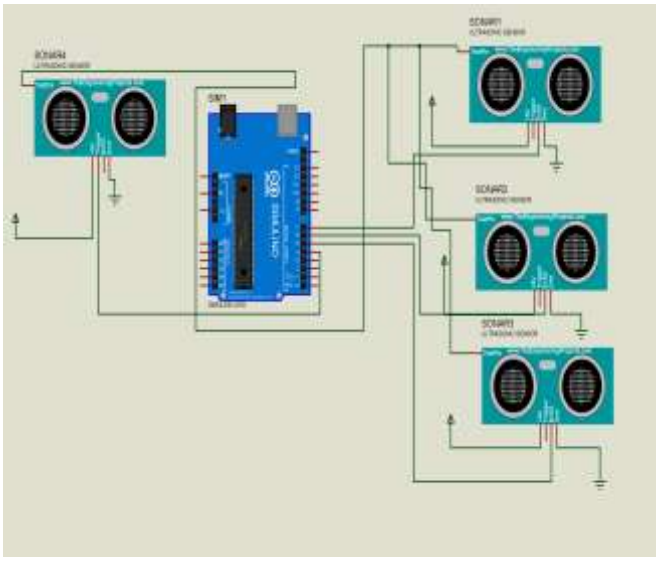

Figure 4. Connection diagram of arduino based 3D trilatration system in Proteus

The system is mounted on an 'L' shaped stand with three stationary ultrasonic receivers attached on the its vertices. The ultrasonic transmitter is mobile and is free to move which acts as pen for the 3D canvas system. The hardware is made on a wooden frame with a fixed distance between each ultrasonic receiver. Small holes are made to precisely fit the ultrasonic sensors on the 3 axes. The sensors are mounted on these holes. The measurements regarding various positions of the sensors from axes (dxz and dyz) are taken and at appropriate positions at 30 cm and 45 cm for the sensors and are marked accordingly.

The 'L' shaped mount is fixed on a supporting platform. The 'L' shaped frame arrangement is shown in figure 5.

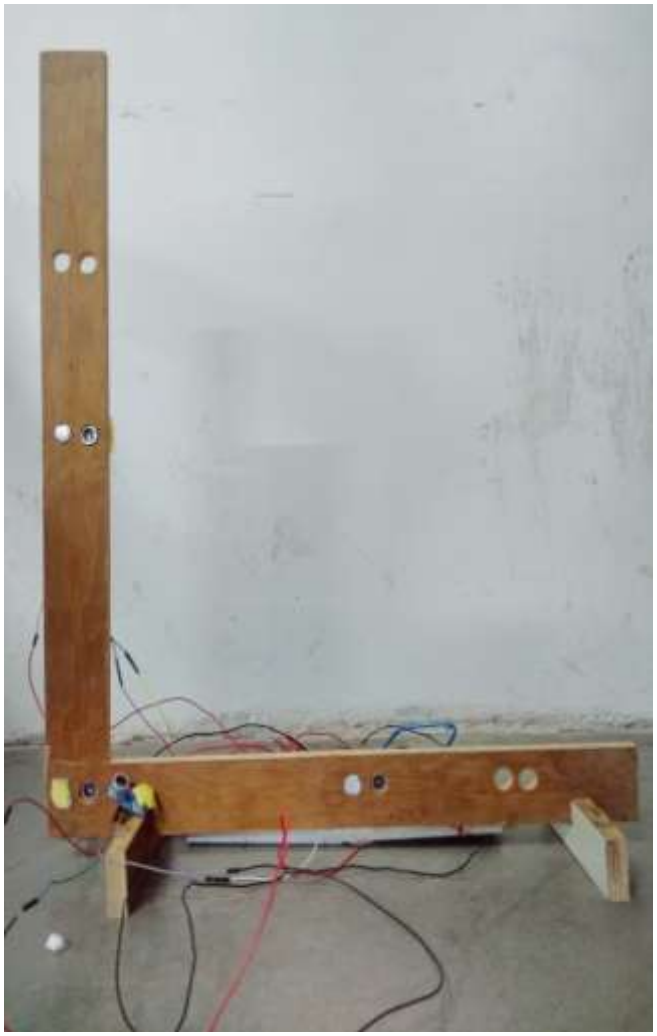

Figure 5. Hardware arrangement of arduino based 3D trilatration system for modelling.

The software part of the system consists of IDE for Arduino which is Arduino Studio for programming and compiling of Arduino program. Another part of the software that deals with the plotting of co-ordinates on pc will run on python program.

IV. RESULTS

The co-ordinates from arduino are taken via serial communication and these co-ordinates are then read by the code written in python using spyder 2.5.5 IDE. These co-ordinates are then plotted using matplotlib library in python making it work as a 3D canvas. The figure 6 shows the plotted co-ordinates on python.

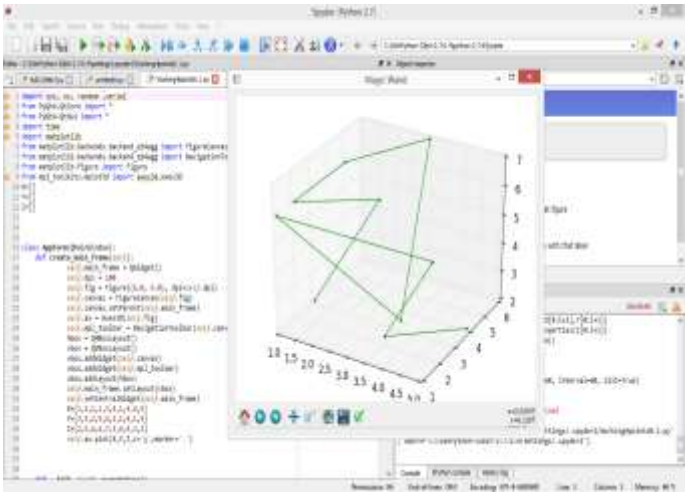

Figure 6 shows the plotted co-ordinates on python

V. CONCLUSION

This paper gives a simple approach to 3D trilatration using arduino and ultrasonic sensors for the implementation of a 3D canvas system. The system provides an easy way to draw directly on a 3D canvas to generate design directly on screen by plotting co-ordinates calculated by trilatration process unlike the conventional method of drawing using a CAD based software.

VI. FUTURE SCOPE

The system is slightly prone to noise as the movement of hand is not that steady. This can be minimized in future by various methods such as by taking mean of the point over certain span or making a design modification on the system to avoid interferences. Further the system can be made wireless using ZigBee, Bluetooth, or Wi-Fi modules and integrating it with a professional 3D modelling tools like Maya, 3Dmax, blender etc. and improving the working range of the system.

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