Individual Lab Report #4

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Team A / Team Avengers

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I. Individual Progress

In the ast two weeks I tested the ultrasonic sensors with different filters, different modes - analog & digital and different sampling rates. I tested the ultrasonic and IR sensors on grass, tress and checked if they detect obstacles that aren't exactly perpendicular to the sensors. Using the test results I performed two iteration of sensor arrangement and orientation for our UAV obstacle avoidance system . This iteration included mathematically finding the number of sensors and positions. First iteration included using only IR sensors and second iteration was using Maxbotix EZ MB 1010 ultrasonic sensors. Second iteration tests were successful. Hence we will be using 14 Maxbotix EZ MB 1010 ultrasonic sensors for our obstacle avoidance sytem. I have divided the work that I did in five areas as below.

1) Testing the ultrasonic sensors with different filters in analog/digital mode at different sampling rates
2) Testing the sensors to detect trees, grass and obstacles that aren't exactly perpendicular to the sensors
3) First iteration of obstacle avoidance system using IR sensors
4) Second iteration of obstacle avoidance system using Maxbotix EZ MB 1010 ultrasonic sensors
5) Testing the sequential pinging pattern for the Maxbotix ultrasonic EZ MB 1010 sensors to avoid interference

1) Testing the ultrasonic sensors with different filters in analog/digital mode at different sampling rates

Previously I had used mode filter for filtering the data obtained from ultrasonic sensors. Mode filter continuously took 9 readings and returned the mode of the 9 values as output. I obtained noisy output using this filter. Hence I next tried using running median filter. Running median filter gave accurate and consistent readings. Running median filter was also faster than the mode filter as it gave output after every reading while mode filter would first collect 9 readings, calculate its mode and give that result as the output.

I used running median filter with a buffer size of 15. I tried combination of analog /digital mode with different sampling rates for sensor (that is is different delays for loop). I placed the sensors at a constant distance from an obstacle and observed the output of the sensors. I obtained better results using digital mode than analog mode. Shown below is the table for the minimum sampling rate (that is the minimum loop delay) required for the two types of ultrasonic sensors to give accurate and consistent reading

Mode	Maxbotix EZ MB 1010 ultrasonic sensor	Maxbotix EZ MB 1040 ultrasonic sensor
Digital	25ms	10ms
Analog	50ms	25ms

2) Testing the sensors to detect trees, grass and obstacles that aren't exactly perpendicular to the sensors

Of the two ultrasonic sensors, EZ MB 1010 sensor has wide beam width (of 60 cm) whereas EZ MB 1040 has narrow beam width (of 10 cm). Because of narrow beam width EZ MB 1040 ultrasonic sensor cannot detect trees, grass and any obstacle that is not exactly perpendicular to the sensor. All the ultrasonic waves from the EZ MB 1040 sensor get deflected on trees, grass or oblique obstacles and as a result the sensor doesn't receives any waves back. Hence the EZ MB 1040 sensor is blind to trees and grass and oblique obstacles. EZ MB 1010 sensor doesn't face such issue as it has wide beam width which guarantees that at any time at least few waves reach back to the sensor. IR sensor faces no issue in detecting trees, grass or oblique obstacles. Below mentioned is a summary of the results I obtained.

	Maxbotix EZ MB 1010 ultrasonic sensor	Maxbotix EZ MB 1040 ultrasonic sensor	IR sensor
Detect trees	Yes	No	Yes
Detect grass	Yes	No	Yes
Can detect oblique obstacles (obstacles that are at an angle to sensor)	Yes	No	Yes
Oblique angle – angle at which if the sensor if tilted with respect to the obstacle then the obstacle won't be detected	N.A.	25-30 degree	N.A.

3) First iteration of obstacle avoidance system using IR sensors

Ultrasonic sensors have a general impression of having noisy data, interference problem by using multiple sensors and issue of unreliable data in presence of motors. Though by using good quality ultrasonic sensors, using filters and careful arrangement of sensors we can get rid of all the above issues I first did the math to calculate the number of IR sensors required to cover volume of 1.5 m around the UAV as IR sensors do not face any of the issues that ultrasonic do.

I used the cad drawing of the top view of our UAV, provided to us under the NDA by Bird Eye View Aerobotics to calculate the number of IR sensors required to detect an obstacle of 50 cm X 50 cm size (as specified in our requirements) within a volume of 1.5 m around the UAV. From my tests with IR sensor I found out that the IR sensors have no cone and can be assumed to be detecting along a straight line. Doing the calculation I found out that we would require 65 IR sensors to detect the whole volume of 1.5 m around the UAV. As 65 was a huge number this would not work and I had to think of other option.

4) Second iteration of obstacle avoidance system using Maxbotix EZ MB 1010 sensors

Beam pattern of Maxbotix EZ MB 1010 ultrasonic sensor is as follows

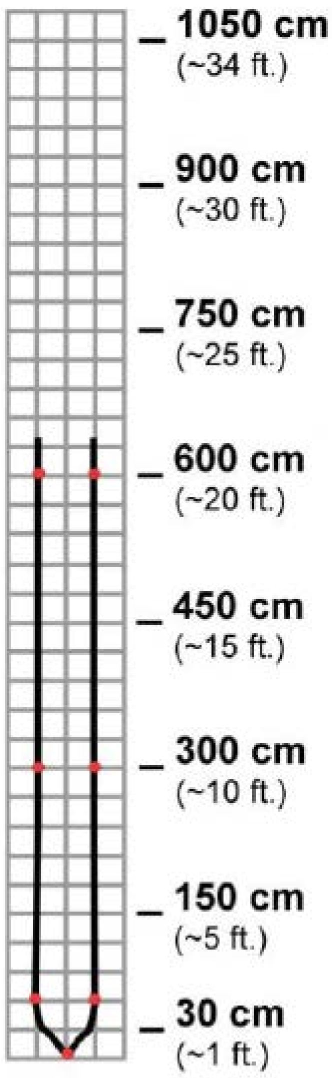


Figure 1 Source: LV Maxbotix EZ MB 1010 datasheet

I decided to use LV Maxbotix MB 1010 sensor for our obstacle avoidance because of the following reasons

- As in figure 1this sensor has range of 650 cm and beam width of **60 cm**. (whereas IR sensor has range of 250 cm and beam width of **3 cm**)
- This sensor has no issue detecting trees, grass and obstacles that aren't perfectly perpendicular to the sensor
- Ultrasonic sensors give unreliable output when placed near motors on UAV or near power cables. But considering our UAV is big (around 1 m X 1.5 m) we can avoid placing ultrasonic sensors near motors or power cables
- I did test sequential firing of ultrasonic sensor to avoid interference among sensors and obtained reliable results. (this test is explained in section 5)

I did perform tests to verify the beam pattern shown in figure 1 and obtained similar results. Hence using this results I did the math and calculated that we require 14 ultrasonic sensors. We are provided with a scaled cad drawing of top view of our UAV as part of NDA. Hence an approximate figure showing the calculations I did to find the the number of sensors is shown below.

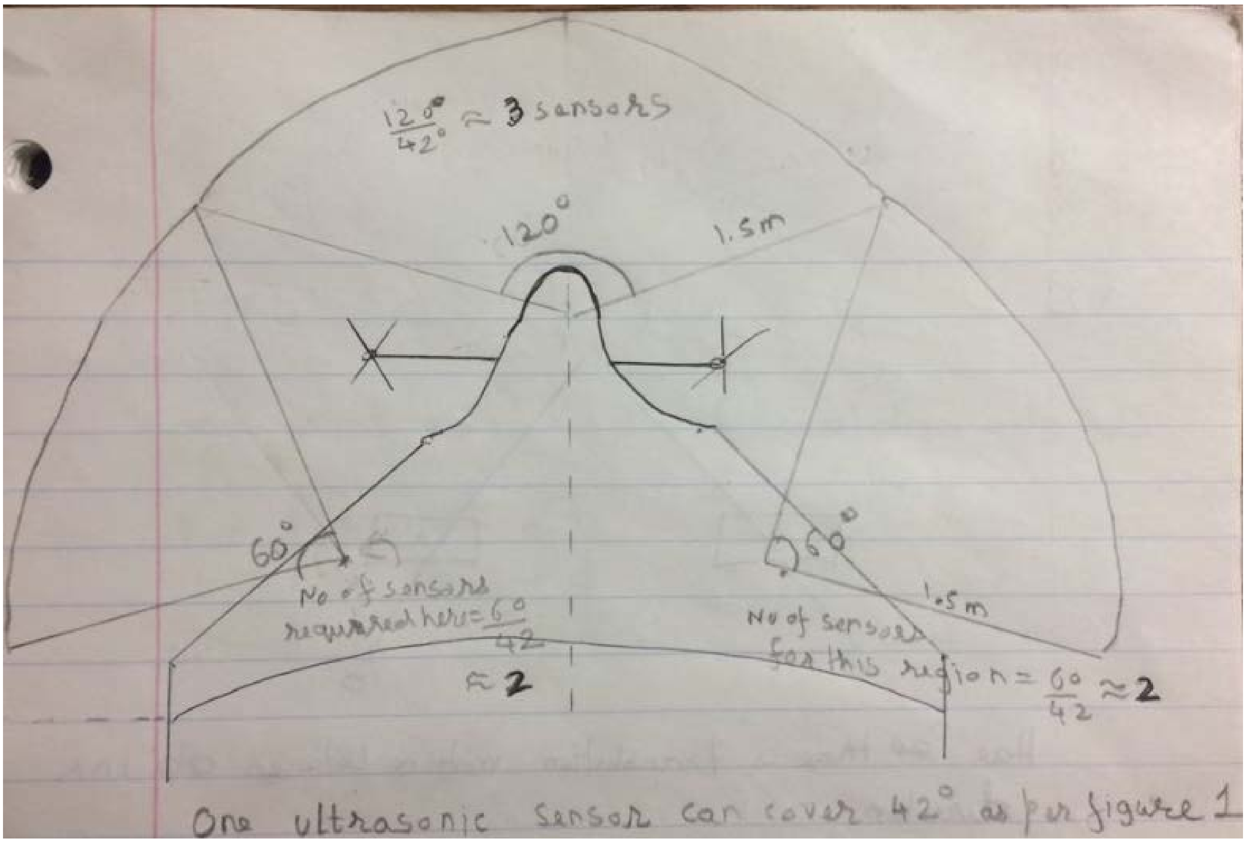


Figure 2 Ultrasonic Sensor placement

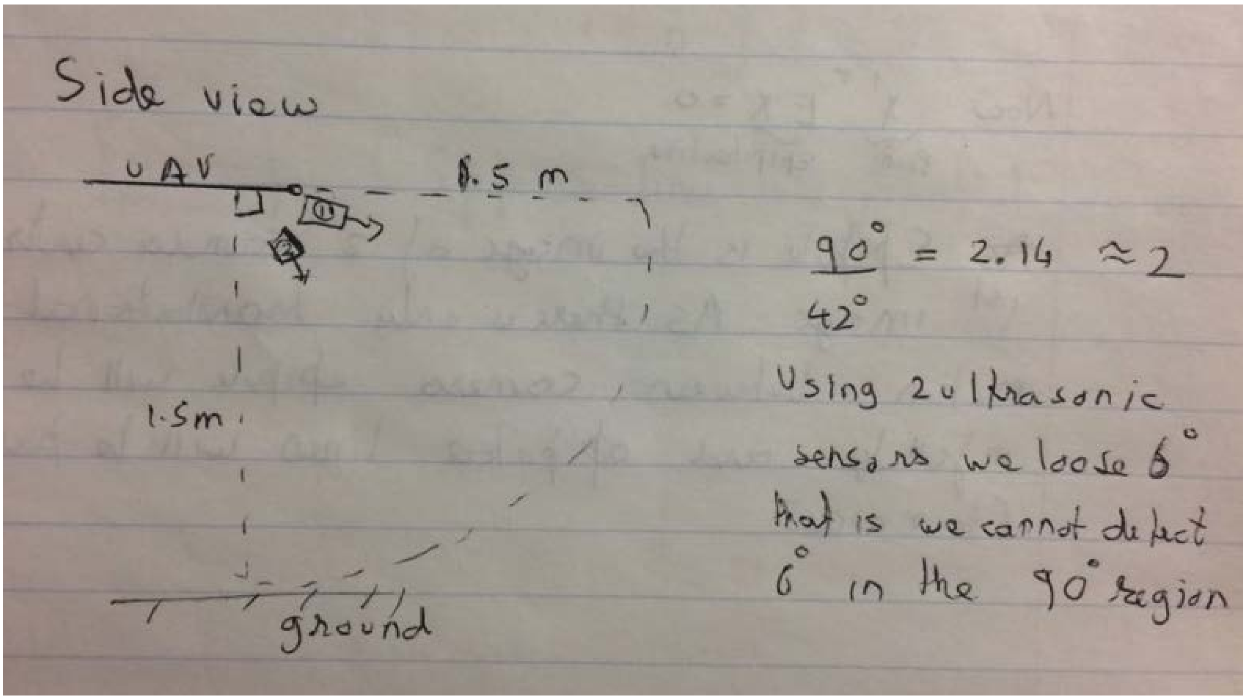
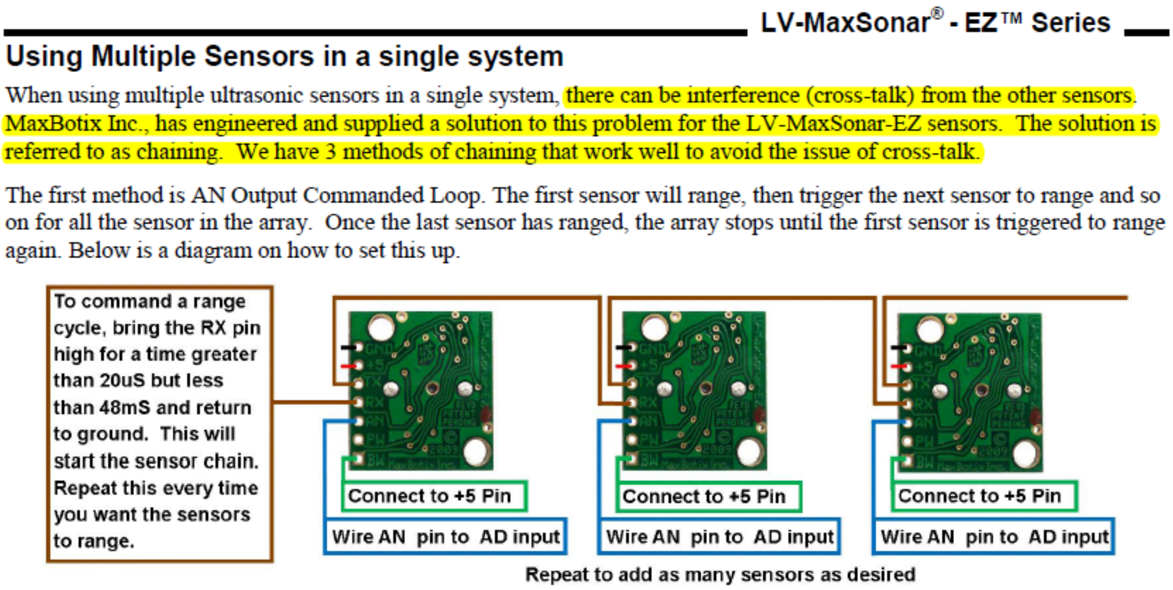


Figure 3 Side view for the angular sensor placement

As from figure we need 7 (in one plane) X 2 (at angular positions) = 14 ultrasonic EZ MB 1010 sensors to cover the volume of 1.5 m around the UAV.

5) **Testing the sequential pinging pattern for the Maxbotix ultrasonic EZ MB 1010 sensors to avoid interference**

Maxbotix has provided with an arrangement on the sensors to sequentially fire the sensors.


LV-MaxSonar® - EZ™ Series

Using Multiple Sensors in a single system

When using multiple ultrasonic sensors in a single system, there can be interference (cross-talk) from the other sensors. MaxBotix Inc., has engineered and supplied a solution to this problem for the LV-MaxSonar-EZ sensors. The solution is referred to as chaining. We have 3 methods of chaining that work well to avoid the issue of cross-talk.

The first method is AN Output Commanded Loop. The first sensor will range, then trigger the next sensor to range and so on for all the sensor in the array. Once the last sensor has ranged, the array stops until the first sensor is triggered to range again. Below is a diagram on how to set this up.

Figure 4 Sequential firing of ultrasonic sensors as per LV MAxbotix EZ MB 1010 datasheet

I connected two ultrasonic sensors in the Analog Output commanded loop as mentioned in figure 4. I obtained correct and reliable results using this arrangement.

II. Challenges

Bird Eye View Aerobotics provided us with top view of the UAV which only had the length and breadth of the UAV mentioned. It had no measurements of the curvatures of the UAV. So it was difficult to do calculations for finding the exact number of required sensors. However as the top view of UAV was a scaled version of the actual UAV I used the scaling factor to find the actual measurements and did the required calculations to find the number of sensors required to cover volume of 1.5 m around UAV.

III. Teamwork

Tushar got the April tag detection working on Odroid. He initally installed Ubuntu, ROS and Open CV on odroid. He has designed an nested april tag by embedding a smaller april tag in a bigger april tag. This arrangement helps the camera to detect bigger april tag from farther distance and the smaller one from closer distance. To improve the speed of the algorithm he used combination of april tag detection and Lucas Kanade tracking.

Adam designed one master and eight slave PCB for the obstacle avoidance sensor system that I will develop. Once the UAV arrived he started working on the assembly of the UAV. He installed motors, prepared the connecters for motors and interfaced the landing gear. Sean initially worked on the UGV.

He along with Adam redid the mechanical and electrical assembly of the UGV. Later Sean did the mechanical assembly of UAV. Adam and Sean also helped me in my sensor tests.

IV. Future Work

Once we receive our 14 ultrasonic sensors I will mount all the sensors on the UAV mock-up, test different orientations of sensors, test sequential pinging pattern code for the sensors and visualizing the resulting data.