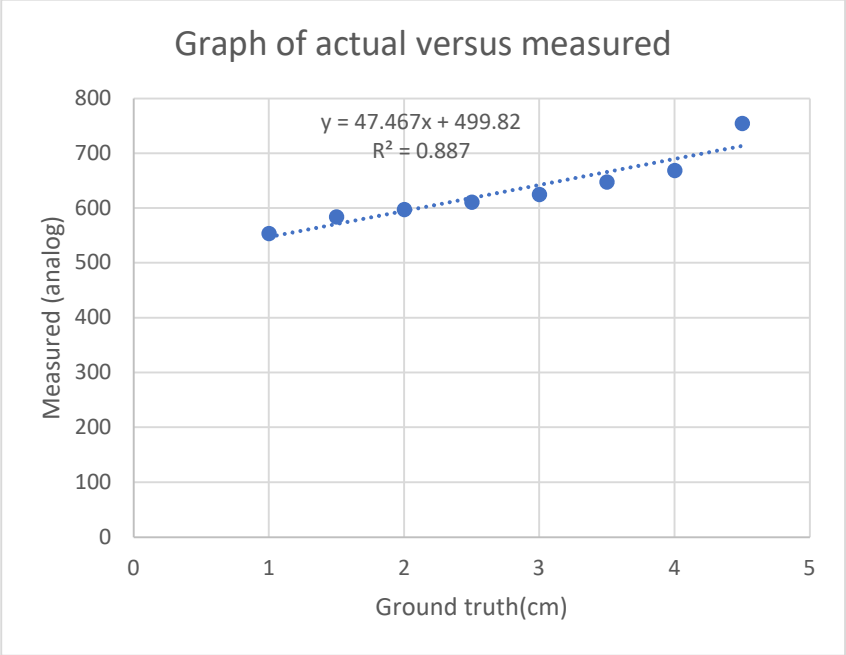
After collecting the data from all the tests we did, we complied all that data into the table below.

| | Sensor Readings | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| True Value(cm | 1 | 1(cm) | 2 | 2(cm) | 3 | 3(cm) | 4 | 4(cm) | 5 | 5(cm) | Average | Average in cm | Std | Deviation | Error |
| 1 | 554 | 1.141425 | 553 | 1.120357 | 553 | 1.120357 | 554 | 1.141425 | 554 | 1.141425 | 553.6 | 1.132997662 | 0.011539 | 0.021067 | 13.29977 |
| 1.5 | 585 | 1.79451 | 584 | 1.773443 | 584 | 1.773443 | 584 | 1.773443 | 585 | 1.79451 | 584.4 | 1.781869509 | 0.011539 | 0.021067 | 18.7913 |
| 2 | 600 | 2.110519 | 597 | 2.047317 | 597 | 2.047317 | 596 | 2.02625 | 597 | 2.047317 | 597.4 | 2.055743991 | 0.03195 | 0.084269 | 2.7872 |
| 2.5 | 612 | 2.363326 | 612 | 2.363326 | 610 | 2.321192 | 610 | 2.321192 | 612 | 2.363326 | 611.2 | 2.346472286 | 0.023078 | 0.042135 | -6.14111 |
| 3 | 625 | 2.637201 | 625 | 2.637201 | 625 | 2.637201 | 625 | 2.637201 | 625 | 2.637201 | 625 | 2.637200581 | 0 | 0 | -12.0933 |
| 3.5 | 648 | 3.121748 | 648 | 3.121748 | 648 | 3.121748 | 648 | 3.121748 | 647 | 3.10068 | 647.8 | 3.117534287 | 0.009422 | 0.021067 | -10.9276 |
| 4 | 669 | 3.56416 | 669 | 3.56416 | 669 | 3.56416 | 669 | 3.56416 | 669 | 3.56416 | 669 | 3.564160364 | 4.97E-16 | 0 | -10.896 |
| 4.5 | 755 | 5.375945 | 754 | 5.354878 | 754 | 5.354878 | 755 | 5.375945 | 754 | 5.354878 | 754.4 | 5.363305033 | 0.011539 | 0.021067 | 19.18456 |

Due to the nature of this lab and the unit of the sensor readings, to be able to work with the data, first we used the scaling method to convert data from analog to cm, to do that, we plotted a graph of the analog values vs the true value and then created the new formula below for the conversion



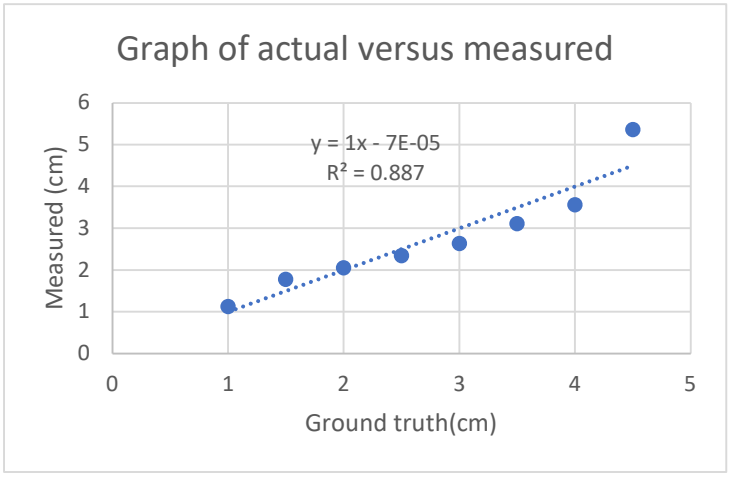

Formula used to scale

$$x = \frac{1}{47.467}y - \frac{499.82}{47.467}$$

**Results (of the characteristics measured to quantify the performance of the sensor)**

- Range: As can be observed from the table, accurate within the manufacture spec (1.5 – 4cm).

- Linearity/ Sensitivity: These are measurements that can only be gotten through further analysis and one of the fastest and best ways is through plotting a graph of the ground truth vs the average of the sensor readings.

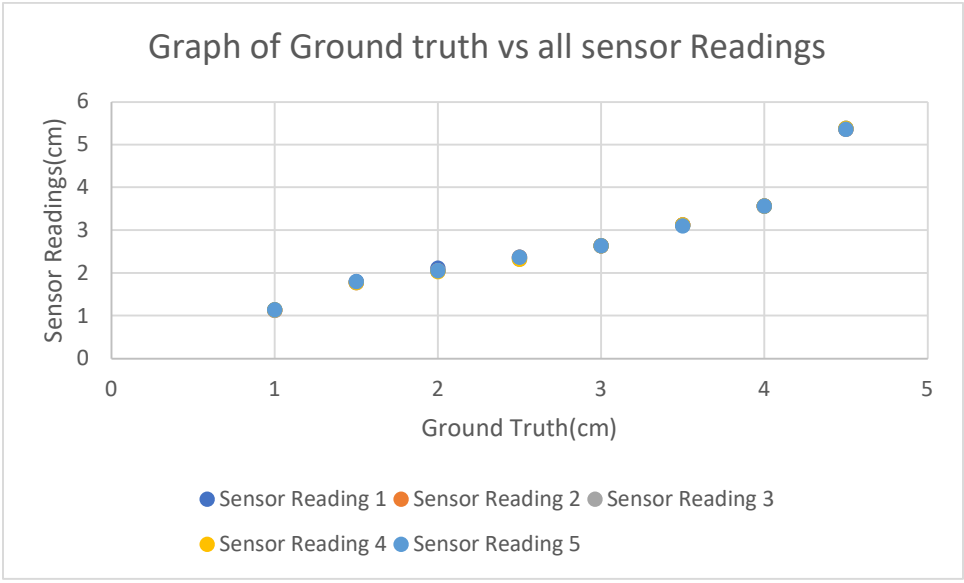



  - From the graph above, we can see that R^2 has a value of 0.887. The relationship is not quite linear but this is to be expected due to water waves (leading to fluctuations of the readings)

  - We can also qualify the sensor to be quite sensitive with a sensitivity of 1!

- Resolution: This was a characteristic we would not quite quantify due to too much uncertainty! Looking at the error column in the table above, we could observe how much uncertainty we were dealing with thus making resolution hard to quantify

- Accuracy/Precision/Repeatability: These are measurements that can also only be gotten through further analysis and one of the fastest and best ways is through plotting a graph of the ground truth vs all the sensor readings.



- From the graph above, we can see that all the points overlap the ground truth and from the table above we can standard that the average standard deviation is less than 1 which shows that the sensor is reliably accurate and precise.

- Repeatability was one that we observed much more than ever through the whole testing process. We did this test more than once and we notice almost if not same readings for values within the range every time the test was carried out which even if we boil down to the graph and table above, we can notice the %error being almost negligible

- Drift

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.5 | 612 | 2.363326 | 612 | 2.363326 | 610 | 2.321192 | 610 | 2.321192 | 612 | 2.363326 | 611.2 | 2.346472286 | 0.023078 | 0.042135 | -6.14111 |
| 3 | 625 | 2.637201 | 625 | 2.637201 | 625 | 2.637201 | 625 | 2.637201 | 625 | 2.637201 | 625 | 2.637200581 | 0 | 0 | -12.0933 |
| 3.5 | 648 | 3.121748 | 648 | 3.121748 | 648 | 3.121748 | 648 | 3.121748 | 647 | 3.10068 | 647.8 | 3.117534287 | 0.009422 | 0.021067 | -10.9276 |

As we can see in the rows data above, the 5 sensor readings were $\pm$ 0.2 cm within the ground truth

Summary and Conclusion

The sensor was mostly well within the specifications provided by the manufacturer with a few gives or takes but considering educational setting the sensor was made to be used in, we safely conclude that the sensor does work well for that sensor and since we have now made up for its lack with our time effort, we could very well modify the sensor to be used for settings outside which it was made to be used!