PROJECT REPORT

Fellowship: Undergraduate Research Opportunities Program 2023 (03/01/2023 - 12/31/2023)

Title: Developing an Open-hardware Oyster Behavior Monitoring System

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1. Introduction

Oyster on-bottom culture in the Gulf of Mexico yields high levels of production, but is subject to predation, dramatic salinity changes and variable recruitment (Walton et al., 2013). Alternative off-bottom aquaculture techniques, such as floating cages and longline bag culture, have been developed and are available to farmers but they are still underused (Walton et al., 2013), despite the advantages they represent. The success and profitability of oyster farming relies on high growth rates and low mortality rates, which may be maximized with alternative techniques. However, farmers currently lack an easy and rapid tool to determine how oysters are performing during their grow-out, which may contribute to why such techniques have not yet been embraced.

In oyster farming many environmental factors affect feeding, growth rate, and health (Campbell et al., 2019; Kennedy et al. 1996). Because oyster performance relies on their capacity to acquire energy through filtration, understanding how these factors impact valve opening behavior (VOB) can help improve farm management and maximize oyster growth potential and survival. Such techniques are already employed to monitor shellfish health around the world (Sow et al., 2011; Comeau et al., 2018), and serve as early-detection system for stream pollution (Kramer and Foekema, 2001), harmful algae blooms (Tran et al., 2010). The general technology to study and monitor VOB is simple and based on the measurement of voltage between a magnet and a Hall sensor glued on each valve of the oyster. However, commercially available tools are expensive (e.g., a set for $8,000; Figure 1) and are limited to short-term monitoring due to the lack of real-time data transfer capability and low data storage capacity. Developing low-cost VOB data loggers for field use in oyster aquaculture would help overcome these limitations.

In this project we designed, produced, and started to test an open-source and low-cost VOB data acquisition device (DAQ device). We here present the results of this study and the next steps we will take to further develop this tool. Making VOB data more accessible through the developed tool can provide useful insight into the environmental factors influencing oyster growth, in turn allowing investigators to better understand the role of growth conditions to improve production.

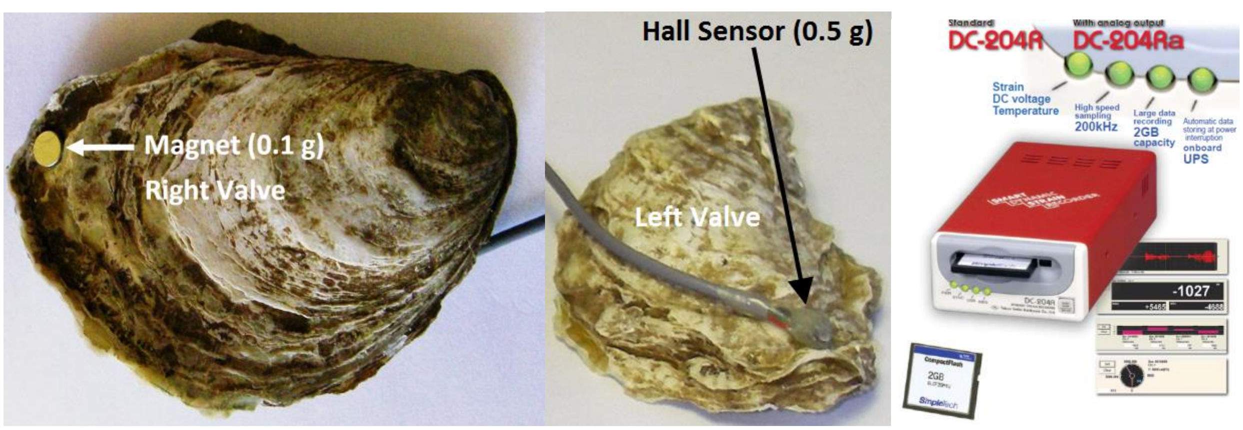

Figure 1. Oyster equipped with a magnet (left) and a Hall sensor (middle) connected to a commercial strain gauge meter (right) to continuously record valve opening behavior.

2. Objectives

For this project we proposed to design, fabricate, and test an affordable and open-hardware device to add new data collection capabilities that could help to improve the productivity of oyster aquaculture. Specifically, we wanted to:

- Objective 1: Design and fabricate prototype devices with features including data collection, storage, and transfer capabilities.
- Objective 2: Test the prototypes in the laboratory for operational ability and improve the designs.
- Objective 3: Evaluate advanced prototypes in the field for use with oysters grown in on- and off-bottom aquaculture systems.

3. Materials and Methods

3.1. General framework

At the initiation of the study, the following priorities for the team of student workers were set:

1. The designed device needs to work accurately.
    - Able to consistently read data from a sensor of our choosing.
    - Able to log data to a permanent form of storage.
    - Be accessible via basic means: simply getting it from the storage (SD card).
2. The designed device needs to work conveniently.
    - Potentially make data accessible through website, or GUI based app.
    - Easy to connect multiple devices to one "controller" which funnels all data to the above.
    - User-friendly visualization of data.
3. As a last step, work on a refined look for the product.

Objective 1 was also divided into a hardware part and a software part. R. Durgum and J. Whitfield initially tasked with both aspects, focused on the development of the software, while N.T.K. Dinh and D. Alday joined the team midway through to handle hardware development.

The design of the open-source VOB monitoring system is built around the Arduino Nano, a widely available, low-cost microcontroller platform that is backed by extensive online resources and an active maker community. These single board computers (SBC) are cheap yet reliable and replaceable credit-card sized computers. They were used to function as a control unit to perform voltage measurements using a Hall sensor and transmit recorded data. We also explored the use of flex sensors to measure the odometry of the shells, as a potential other mean to record VOB, but Hall sensors were deemed more reliable (better consistency and accuracy).

The Arduino system offers flexible input/output options, including analog-digital conversion and the I2C (inter-integrated circuit) communication protocol that is widely used for connecting to peripheral devices such as external memory or Bluetooth modules. The system is composed of one master SBC that manages up to 4 SBC gathering data from one Arduino Nano with 8 Hall sensors. The master SBC stores the data into a database which can be displayed over a Wi-Fi network and exported into a CSV file format for raw data management. Data transfer from the master SBC to a computer can incorporate a Bluetooth

Low Energy module for connectivity with a laptop, allowing easy data transmission without the need to remove the card from the logger. The device is also set up to communicate data through Wi-Fi, although this requires the deployment to be near a Wi-Fi transmission.

This system is intended to be as expandable and reducible as possible; it can be set up as just one SBC acting as both data translator and server or have a fleet of SBCs record as many data sources as possible. It can also be both easily troubleshooted if anything were to be damaged or misplaced, as the master SBC configures new devices through a fleet management tool.

3.2. Hardware

Hardware used to build the open-source sensor included:

- Libre computer board AML-S905X-CC (Master SBC)
- Arduino Nano board ATmega328P 5V 16M
- A1302 Ratio Hall Effect Sensors
- 30 Jumper Wires
- SPST Rocker Switch
- Battery (or computer via USB-C cable)

3.3. Software

A process implementation chart was created to develop the software controlling the SBC (Figure 2). All software scripts have been uploaded to a GitHub repository (https://github.com/rnr-research-lsu/valvometry.git).

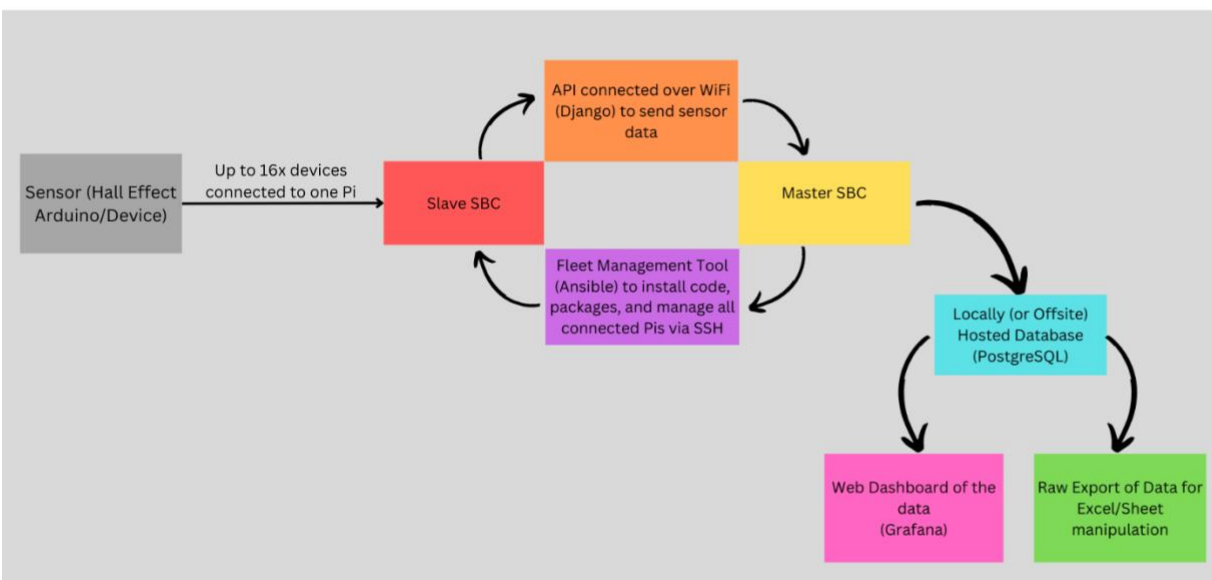

Figure 2. Software implementation chart.

3.4. Testing

Laboratory testing of the VOB monitoring system was conducted at the Food and Animal Science Wet Laboratory (LSU AgCenter). We used oyster shells from individuals used in on-going experiments conducted at the lab to evaluate the newly built sensors. Laboratory testing included tests of variability and reproducibility of voltage signals against various opening distances as well as comparisons with a typically used commercial device (strain gage meter DC 204R, Tokyo Sokki Kenkyujo Co., Shinagawa-ku, Tokyo, Japan; Figure 1).

4. Results

At the completion deadline for this project, objectives 1 and 2 were completed but field testing of the VOB monitoring system (objective 3) had not yet been conducted. Objective 1 was expected to take most of the time in this project.

4.1. Design

4.1.1. Hardware

The system schematics of the open-source VOB sensor are presented in **Error! Reference source not found.**. A graphical representation of the design is presented in **Error! Reference source not found.**. A battery or micro-USB connection may be used to power the system via the Libre computer board. This then powers the Hall effect sensors and nano boards through the connections shown in **Error! Reference source not found.**. The Hall effect sensors send their output data to the nano board which is then transmitted to the Libre computer board via a USB 2.0 connection. These Hall effect sensors are positioned onto the tip of oyster's opening along with a small magnet that is attached to the opposite shell. This allows for the collection of oyster's shell gape which is represented by the voltage recorded due to the Hall effect sensors distance from the magnet. This design allows for 8 Hall effect sensors to simultaneously collect data on 8 separate oysters.

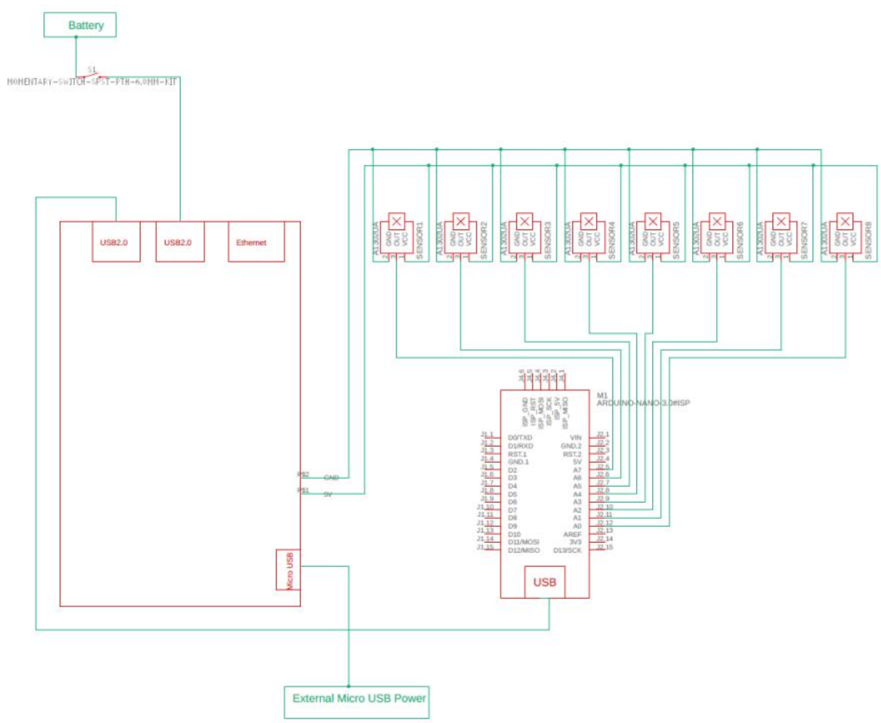

Figure 3. System schematics. Green lines represent connections between components. The Libre computer board (left) powers the system through either a battery or micro-USB. The Arduino Nano (bottom right) collects information from the Hall Sensors (top right) and transmits the data via USB2.0 to the Libre computer board for processing.

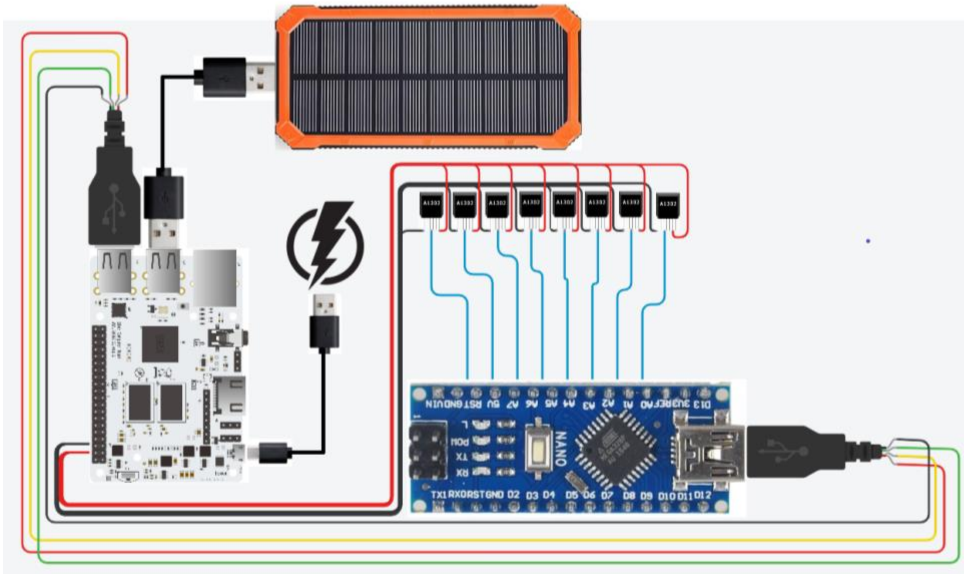

Figure 4. TinkerCAD digital design graphically representing the physical model from Figure 2. The battery is represented by the battery pack (top). Micro-USB power is represented by the cable leading to the electric symbol (middle). The left PCB represents the Libre computer board, while the right PCB represents the Arduino Nano. The eight black components in the middle represent the Hall Sensors connected to blue (data), black (ground), and red (power) wires.

4.1.2. Software

During this project we completed the first two blocks of the software implementation chart (Figure 2). We successfully read data from a single Arduino Nano using serial communication over USB, and we were able to store that saved data into a JSON file format which was saved into a PostgreSQL database. We are currently working towards having another SBC handle data organization and data visualization via Django web requests and a Grafana web dashboard respectively. We are also working towards expanding our Python code to incorporate multiple Arduino Nanos connected to the Libre computer board, making this system very versatile and easy to modify for later use.

4.2. Testing

Compared to the commercial sensor, the voltage of the open-source sensor showed an opposite trend against distance from magnetic source (Figure 5). This may originate from the type of magnet used or the processing of the signal by the commercial strain meter, which we could not evaluate nor modify. However, the shape of the rate of change in the relationship between voltage and distance is similar, with an exponentially decreasing or increasing voltage with distance for the commercial and open-source sensors, respectively, before reaching a plateau. The open-source sensors seemed to reach that plateau at a shorter distance (~10 cm) than the commercial sensor (~20 cm). This difference is not meaningful for applications to oyster VOB recording as oyster gape typically varies between 0 and a few cm. The open-source sensors also showed great reproducibility between each other (Figure 5; Appendix).

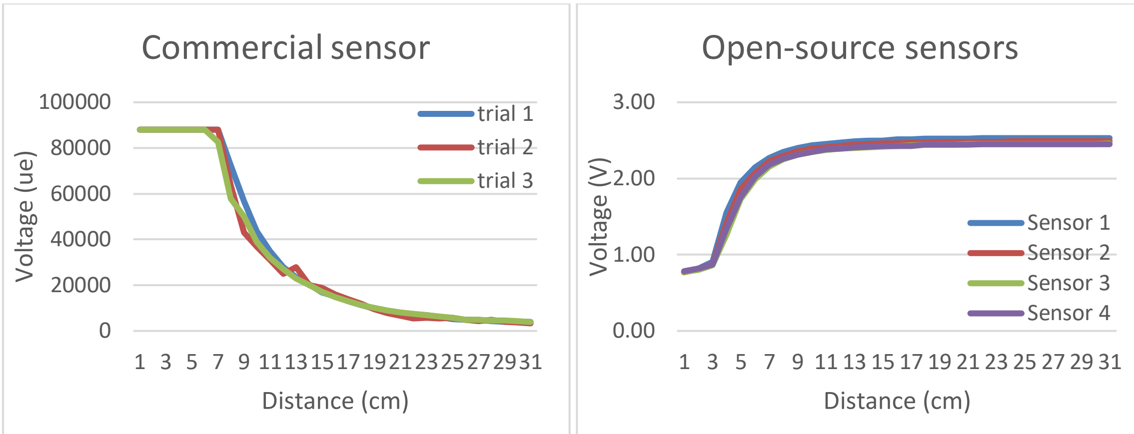

Figure 5. Comparison of voltage output obtained with commercial sensor (left) and open-source sensor (right).

5. Discussion

Oysters grow in estuaries and along coastlines, which exhibit constantly changing environmental conditions. When temperature, salinity, dissolved oxygen, and food availability become stressful, oyster can only close their shell to seclude their soft body from the water. Technological means to record oyster behavior usually involve expensive devices that prevent farmers from accessing critical data on grow-out conditions. The device we developed in this project is freely accessible for a low budget (<$100) and enables one to monitor VOB to identify key environmental stressors and act accordingly.

To continue the hardware development, the first version of the VOB sensing device was connected on a breadboard with temporary joints as shown in Figure 4. With potentially harsh environments and to withstand rough handling a printed circuit board will be designed and manufactured. The permanent joints will also increase the reliability of the sensor connections, signal, and consolidate total device space. Insulated cables with permanent connections to the sensors will be created to provide the range needed from the sensor/oyster location and the Arduino. As displayed in Figure 4, we will connect up to eight sensors to one Arduino, which will undergo testing to reduce any signal interference or crosstalk. Bluetooth connection will be added to remotely connect to and update or download data can be done without opening or disrupting the sensing device. Other options could involve cellular networks, but this requires a lot more resources and technology.

Power consumption will be evaluated to determine the battery capacity needed. Solar and/or wind powering devices will then be added to create a standalone powered device. QWIIC connectors will also be added for optional use of adding environmental sensors to measure air (i.e. volatile organic compounds, etc.) or water (i.e. phosphorous, dissolved oxygen, etc.) changes in the local oyster environment. This can be done either via pHAT boards that attach to the Libre computer board, or sensors directly plugged on the Arduino Nanos.

To continue software development, we will finalize the data stream from the single sensor/Arduino Nano to the master Libre computer board to a PostgreSQL database that publishes to a website dashboard for visualization and direct download. Scaling will need to be tested to amplify that many sensor datasets can flow to the dashboard/download while being parsed appropriately to not confuse data sampling location or meaning. Once the coupling of the eight sensors from one Arduino Nano to one master Libre computer board outputting to the dashboard/download is reliable, scaling to four slave Libre computer board (one Arduino per slave Libre totalling at 32 sensors) to one master Libre computer board will be conducted and tested. The capacity of the developed device allows one to monitor 32 oysters at the time compared to 4 with the commercial device. We plan to introduce a fleet management tool to the entire system to allow for easy configurability.

Dashboard visualization will likely evolve through this process, undergoing several re-designs to provide the most valuable information in a user-friendly design. Currently, the workflow uses batch processing to send data at set intervals to the database, we will evaluate if the need for real-time internet of things (IoT) continuous collection and processing is beneficial. As more data is collected, both methods will come with increased monthly cost for data storage, cybersecurity, and processing services.

Enclosure development will then begin to identify current pains in the use of a manually modified ice chest/container to either a specific adapter or a uniquely designed enclosure for the VOB sensing device and user. Testing under field conditions should be undertaken as part of an on-going parallel study (Sea Grant core project) in the spring of 2024. Current ideas for a custom enclosure include 3D printing a much smaller enclosure than what is currently used with attachments for the solar/wind powering hardware, easy dock anchoring, and a watertight seal around all ports for the sensor cables. This enclosure will also provide the opportunity to add accessible buttons/screens as useful. Scalable manufacturing will then be pursued.

Current adapter ideas include using a specific drill/hole saw to create a standard hole size and a two-part custom designed port that can be fitted to provide a watertight seal around the sensor cables that could be used with any ice chest/container available. Additionally, a similar process to add in button (on/off/switch to solar/switch sensors)/screen options could be created as well.

While the custom adapter option will most likely be cheaper and provide more unique combinations to meet end-user needs, the custom enclosure could provide an all-in-one data collection system with little user installation/instrumentation knowledge or application needed. The development of such open-source tools is critical to the sharing and application of scientific advances. Furthermore, it benefits both the scientific community with more accessible and cheaper resources and the public with easily used and available tools.

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7. Appendix

Table A1. Commercial sensor testing conducted in triplicate with the same sensor connected to one strain recorder.

TML DC-204R Strain Recorder (Commercial Sensor)						
Distance (mm)	trial 1	trial 2	trial 3	Average	StDev	Error
0	88028	88028	88028	88028.00	0	0
1	88028	88028	88028	88028.00	0	0
2	88028	88028	88028	88028.00	0	0
3	88028	88028	88028	88028.00	0	0
4	88028	88028	88028	88028.00	0	0
5	88028	88028	88028	88028.00	0	0
6	88028	88028	82700	86252.00	3076.122	1776
7	72350	63700	58000	64683.33	7225.36	4171.564
8	56850	43000	50000	49950.00	6925.135	3998.229
9	43700	37000	39000	39900.00	3439.477	1985.783
10	35000	31000	32000	32666.67	2081.666	1201.85
11	27900	25000	27000	26633.33	1484.363	856.9973
12	23400	28000	22800	24733.33	2844.878	1642.491
13	20200	20100	20000	20100.00	100	57.73503
14	16800	18800	17000	17533.33	1101.514	635.9595
15	15000	15800	14700	15166.67	568.6241	328.2953
16	13150	13900	13000	13350.00	482.1825	278.3882
17	11300	11900	11280	11493.33	352.3256	203.4153
18	9900	9500	10000	9800.00	264.5751	152.7525
19	8500	7800	8950	8416.67	579.5113	334.581
20	7700	6500	8200	7466.67	873.6895	504.4249
21	7300	5500	7400	6733.33	1069.268	617.342
22	6900	5800	6900	6533.33	635.0853	366.6667
23	6000	5500	6400	5966.67	450.925	260.3417
24	5100	5700	5600	5466.67	321.455	185.5921
25	4900	5000	5000	4966.67	57.73503	33.33333
26	4900	4400	4800	4700.00	264.5751	152.7525
27	4300	4800	4600	4566.67	251.6611	145.2966
28	4000	4000	4500	4166.67	288.6751	166.6667
29	4000	3700	4200	3966.67	251.6611	145.2966
30	3950	3300	3900	3716.67	361.7089	208.8327

Table A2. Open-source sensor testing conducted on four sensors.

Open-Source Sensor Range							
Distance (mm)	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Average	StDev	Error
0	0.77	0.77	0.77	0.78	0.77	0.00631	0.003155
1	0.82	0.81	0.80	0.82	0.81	0.008165	0.004082
2	0.90	0.88	0.86	0.87	0.88	0.016997	0.008498
3	1.55	1.42	1.26	1.35	1.39	0.121331	0.060666
4	1.94	1.86	1.73	1.76	1.82	0.098784	0.049392
5	2.14	2.07	1.99	2.03	2.06	0.0646	0.0323
6	2.27	2.22	2.16	2.18	2.21	0.049991	0.024995
7	2.35	2.30	2.25	2.26	2.29	0.044555	0.022278
8	2.40	2.35	2.31	2.31	2.35	0.04272	0.02136
9	2.44	2.39	2.35	2.35	2.38	0.042109	0.021054
10	2.46	2.41	2.37	2.38	2.41	0.03814	0.01907
11	2.47	2.43	2.39	2.39	2.42	0.037218	0.018609
12	2.49	2.44	2.40	2.41	2.43	0.038718	0.019359
13	2.50	2.45	2.41	2.42	2.44	0.038718	0.019359
14	2.50	2.46	2.42	2.42	2.45	0.037454	0.018727
15	2.51	2.46	2.43	2.43	2.46	0.037749	0.018875
16	2.51	2.47	2.43	2.43	2.46	0.037454	0.018727
17	2.52	2.47	2.44	2.44	2.47	0.037749	0.018875
18	2.52	2.48	2.44	2.44	2.47	0.038042	0.019021
19	2.52	2.48	2.44	2.44	2.47	0.038297	0.019149
20	2.53	2.48	2.45	2.44	2.47	0.038909	0.019454
21	2.53	2.48	2.45	2.45	2.48	0.037749	0.018875
22	2.53	2.48	2.45	2.45	2.48	0.037749	0.018875
23	2.53	2.48	2.45	2.45	2.48	0.037859	0.01893
24	2.53	2.49	2.45	2.45	2.48	0.038297	0.019149
25	2.53	2.49	2.45	2.45	2.48	0.038297	0.019149
26	2.53	2.49	2.45	2.45	2.48	0.038297	0.019149
27	2.53	2.49	2.45	2.45	2.48	0.038297	0.019149
28	2.53	2.49	2.45	2.45	2.48	0.038297	0.019149
29	2.53	2.49	2.46	2.45	2.48	0.036667	0.018333
30	2.53	2.49	2.46	2.45	2.48	0.03594	0.01797

Table A3. Open-source sensor 1 testing trials

Open-Source Sensor 1 Trials						
Distance (mm)	trial 1	trial 2	trial 3	Average	Stdev	Error
0	0.77	0.77	0.77	0.77	0	0
1	0.81	0.82	0.82	0.82	0.005774	0.003333
2	0.92	0.92	0.87	0.90	0.028868	0.016667
3	1.62	1.5	1.53	1.55	0.06245	0.036056
4	1.95	1.96	1.92	1.94	0.020817	0.012019
5	2.15	2.14	2.14	2.14	0.005774	0.003333
6	2.25	2.27	2.29	2.27	0.02	0.011547
7	2.33	2.35	2.37	2.35	0.02	0.011547
8	2.4	2.4	2.41	2.40	0.005774	0.003333
9	2.44	2.43	2.44	2.44	0.005774	0.003333
10	2.46	2.46	2.45	2.46	0.005774	0.003333
11	2.47	2.47	2.47	2.47	0	0
12	2.48	2.49	2.49	2.49	0.005774	0.003333
13	2.49	2.5	2.5	2.50	0.005774	0.003333
14	2.5	2.5	2.5	2.50	0	0
15	2.51	2.51	2.51	2.51	0	0
16	2.51	2.51	2.51	2.51	0	0
17	2.52	2.52	2.52	2.52	0	0
18	2.52	2.52	2.52	2.52	0	0
19	2.52	2.52	2.52	2.52	0	0
20	2.53	2.53	2.52	2.53	0.005774	0.003333
21	2.53	2.53	2.53	2.53	0	0
22	2.53	2.53	2.53	2.53	0	0
23	2.53	2.53	2.53	2.53	0	0
24	2.53	2.53	2.53	2.53	0	0
25	2.53	2.53	2.53	2.53	0	0
26	2.53	2.53	2.53	2.53	0	0
27	2.53	2.53	2.53	2.53	0	0
28	2.53	2.53	2.53	2.53	0	0
29	2.53	2.53	2.53	2.53	0	0
30	2.53	2.53	2.53	2.53	0	0

Table A4. Open-source sensor 2 testing trials

Open Source Custom Sensor 2 Trials						
Distance (mm)	trial 1	trial 2	trial 3	Average	StDev	Error
0	0.77	0.77	0.77	0.77	0	0
1	0.8	0.81	0.81	0.81	0.005774	0.003333
2	0.85	0.9	0.89	0.88	0.026458	0.015275
3	1.28	1.52	1.45	1.42	0.123423	0.071259
4	1.83	1.88	1.86	1.86	0.025166	0.01453
5	2.02	2.1	2.08	2.07	0.041633	0.024037
6	2.22	2.23	2.22	2.22	0.005774	0.003333
7	2.28	2.31	2.3	2.30	0.015275	0.008819
8	2.35	2.36	2.35	2.35	0.005774	0.003333
9	2.39	2.39	2.39	2.39	0	0
10	2.41	2.42	2.41	2.41	0.005774	0.003333
11	2.42	2.43	2.43	2.43	0.005774	0.003333
12	2.44	2.44	2.44	2.44	0	0
13	2.45	2.45	2.45	2.45	0	0
14	2.46	2.46	2.46	2.46	0	0
15	2.46	2.46	2.46	2.46	0	0
16	2.47	2.47	2.47	2.47	0	0
17	2.47	2.47	2.47	2.47	0	0
18	2.47	2.48	2.48	2.48	0.005774	0.003333
19	2.48	2.48	2.48	2.48	0	0
20	2.48	2.48	2.48	2.48	0	0
21	2.48	2.48	2.48	2.48	0	0
22	2.48	2.48	2.48	2.48	0	0
23	2.48	2.49	2.48	2.48	0.005774	0.003333
24	2.49	2.49	2.49	2.49	0	0
25	2.49	2.49	2.49	2.49	0	0
26	2.49	2.49	2.49	2.49	0	0
27	2.49	2.49	2.49	2.49	0	0
28	2.49	2.49	2.49	2.49	0	0
29	2.49	2.49	2.49	2.49	0	0
30	2.49	2.49	2.49	2.49	0	0

Table A5. Open-source sensor 3 testing trials

Open Source Custom Sensor 3 Trials						
Distance (mm)	trial 1	trial 2	trial 3	Average	StDev	Error
0	0.77	0.77	0.78	0.77	0.005774	0.003333
1	0.8	0.8	0.8	0.80	1.36E-16	7.85E-17
2	0.85	0.87	0.87	0.86	0.011547	0.006667
3	1.12	1.49	1.18	1.26	0.198578	0.114649
4	1.65	1.81	1.72	1.73	0.080208	0.046308
5	1.94	2.01	2.03	1.99	0.047258	0.027285
6	2.13	2.17	2.17	2.16	0.023094	0.013333
7	2.24	2.25	2.26	2.25	0.01	0.005774
8	2.31	2.31	2.32	2.31	0.005774	0.003333
9	2.34	2.35	2.35	2.35	0.005774	0.003333
10	2.37	2.37	2.38	2.37	0.005774	0.003333
11	2.39	2.39	2.39	2.39	0	0
12	2.4	2.4	2.41	2.40	0.005774	0.003333
13	2.41	2.41	2.42	2.41	0.005774	0.003333
14	2.42	2.42	2.42	2.42	0	0
15	2.43	2.43	2.43	2.43	0	0
16	2.44	2.43	2.43	2.43	0.005774	0.003333
17	2.44	2.44	2.44	2.44	0	0
18	2.44	2.44	2.44	2.44	0	0
19	2.44	2.44	2.44	2.44	0	0
20	2.45	2.45	2.45	2.45	0	0
21	2.45	2.45	2.45	2.45	0	0
22	2.45	2.45	2.45	2.45	0	0
23	2.45	2.45	2.45	2.45	0	0
24	2.45	2.45	2.45	2.45	0	0
25	2.45	2.45	2.45	2.45	0	0
26	2.45	2.45	2.45	2.45	0	0
27	2.45	2.45	2.45	2.45	0	0
28	2.45	2.45	2.45	2.45	0	0
29	2.46	2.45	2.46	2.46	0.005774	0.003333
30	2.46	2.46	2.46	2.46	0	0

Table A6. Open-source sensor 4 testing trials

Open Source Custom Sensor 4 Trials						
Distance (mm)	trial 1	trial 2	trial 3	Average	StDev	Error
0	0.79	0.78	0.78	0.78	0.005774	0.003333
1	0.82	0.82	0.81	0.82	0.005774	0.003333
2	0.87	0.87	0.88	0.87	0.005774	0.003333
3	1.23	1.43	1.38	1.35	0.104083	0.060093
4	1.73	1.8	1.74	1.76	0.037859	0.021858
5	2	2.03	2.05	2.03	0.025166	0.01453
6	2.16	2.2	2.18	2.18	0.02	0.011547
7	2.26	2.27	2.26	2.26	0.005774	0.003333
8	2.3	2.32	2.32	2.31	0.011547	0.006667
9	2.34	2.35	2.36	2.35	0.01	0.005774
10	2.38	2.38	2.38	2.38	0	0
11	2.39	2.4	2.39	2.39	0.005774	0.003333
12	2.4	2.41	2.41	2.41	0.005774	0.003333
13	2.41	2.42	2.42	2.42	0.005774	0.003333
14	2.42	2.43	2.42	2.42	0.005774	0.003333
15	2.43	2.43	2.43	2.43	0	0
16	2.43	2.43	2.43	2.43	0	0
17	2.44	2.44	2.44	2.44	0	0
18	2.44	2.44	2.44	2.44	0	0
19	2.44	2.44	2.44	2.44	0	0
20	2.44	2.44	2.44	2.44	0	0
21	2.45	2.45	2.45	2.45	0	0
22	2.45	2.45	2.45	2.45	0	0
23	2.45	2.45	2.45	2.45	0	0
24	2.45	2.45	2.45	2.45	0	0
25	2.45	2.45	2.45	2.45	0	0
26	2.45	2.45	2.45	2.45	0	0
27	2.45	2.45	2.45	2.45	0	0
28	2.45	2.45	2.45	2.45	0	0
29	2.45	2.45	2.45	2.45	0	0
30	2.45	2.45	2.45	2.45	0	0