UCSD COSMOS 2022
Cluster 13: DAQ
Data Acquisition

Isabella Lu, Sannie Wan, Charlie Wright

Meet the Team

Charlie

Lynbrook High School '23
Still always airballs

Isabella

Lycée Français '24
The best at anagrams

Sannie

Aragon High School '23
Spice tolerance as low as Daisy.

Background

There has recently been many contributions to big ocean data. In order to understand the environment around us through robotics, sensors were placed on a buoy, which was towed by a boat. This was driven around Miramar Reservoir.

Project Scope

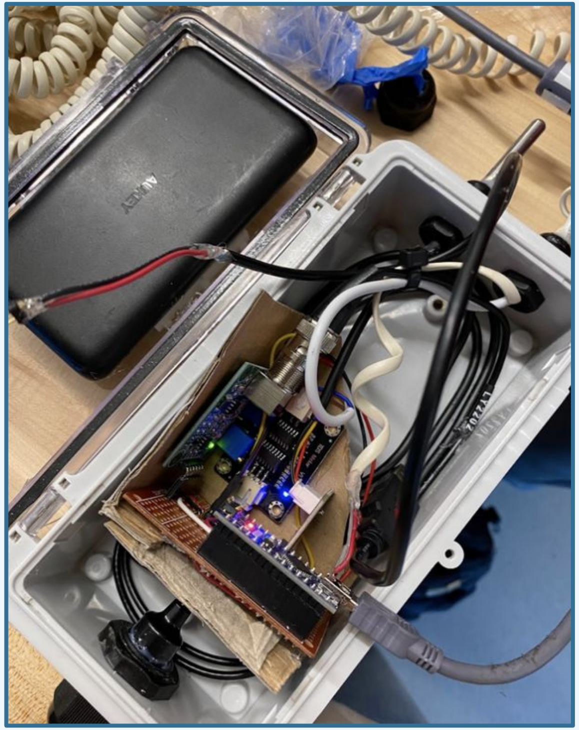
Goal: collect pH, total dissolved solids (TDS), and temperature data from Miramar Lake, and send it back to an onshore server for further analysis.

Tasks:

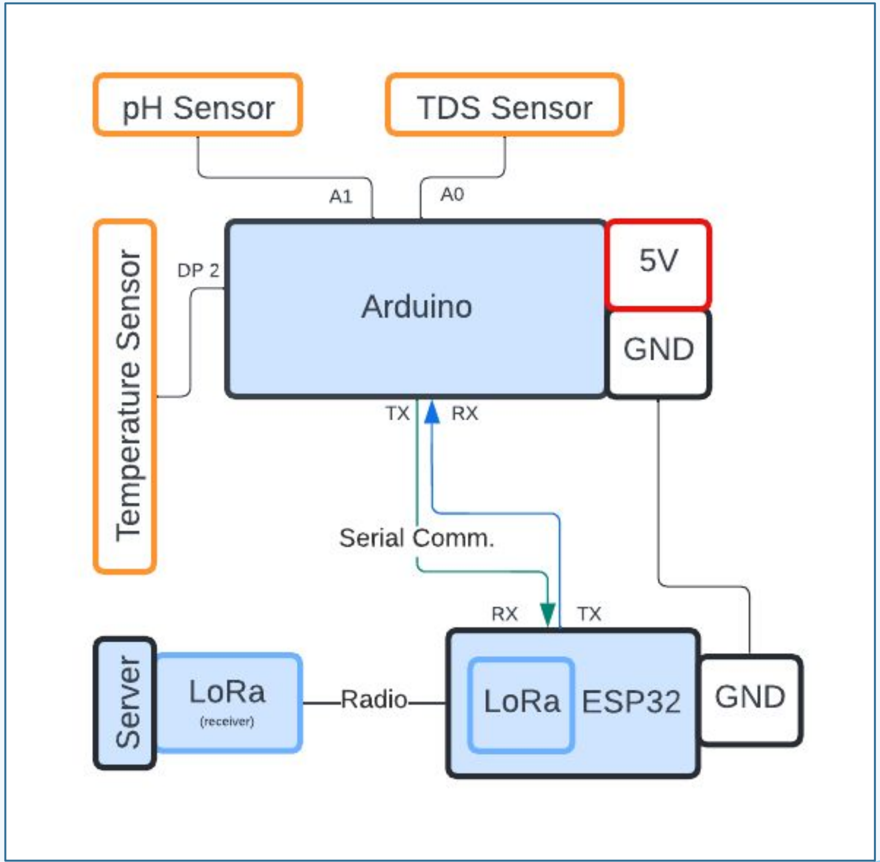
- Use pH, TDS, and temperature sensors
- Collect and transmit frequent and reliable data.
- Wire up the sensors in the buoy

We communicated our data through serial communication from an arduino to ESP32.

Wiring diagram



Capsule wiring



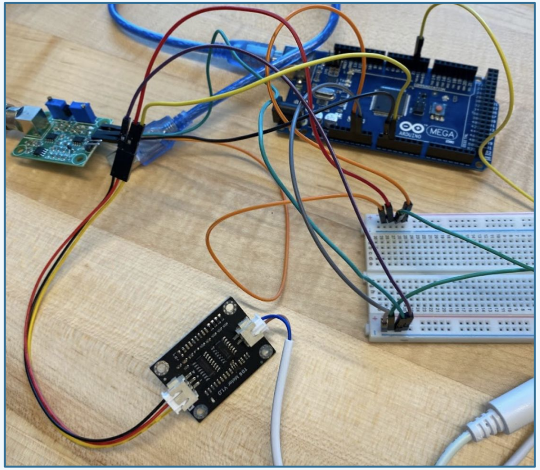
Materials

Hardware:

- Arduino Uno and Nano
- ESP32 with LoRa
- Protoboard, breadboard
- Sensors: pH, Total Dissolved Solids), and temperature
- 1000 ppm TDS calibration solution
- 4, 7, and 10 pH calibration solution
- Thermometer
- Capsule Hardware
- Motor
- Motor controller

Software:

- Arduino IDE
- Github
- Onshape



Prototyping with breadboard and sensors

Reliable Data Method

When taking the measurement of pH, we used:

- Oversampling (takes 10 values per function call)
- Averaging the six median values

pH oversampling →

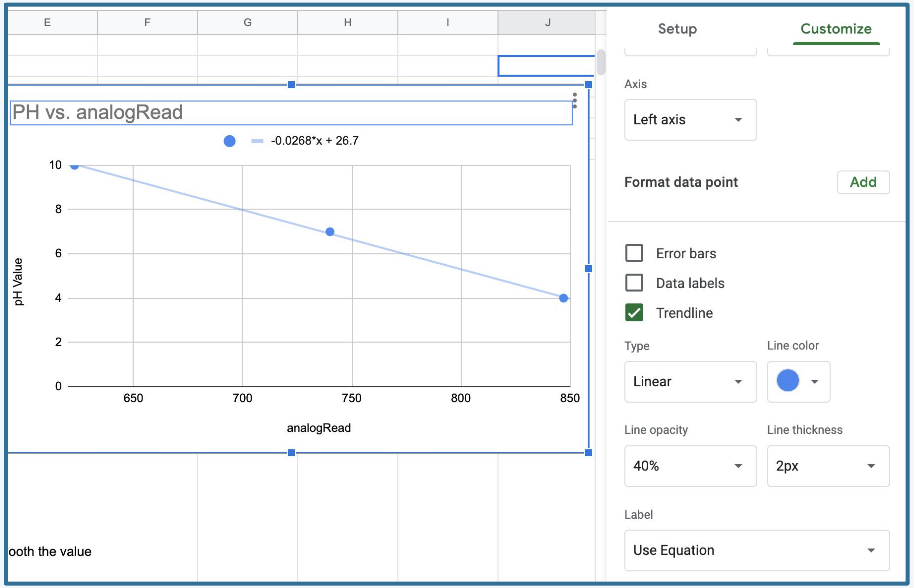
```
for(int i=0;i<10;i++)       //Get 10 sample value from the sensor for smooth the value
  {
    buf[i]=analogRead(SensorPin);
    delay(10);
  }

for(int i=0;i<9;i++)        //sort the analog from small to large
{
  for(int j=i+1;j<10;j++)
  {
    if(buf[i]>buf[j])
    {
      temp=buf[i];
      buf[i]=buf[j];
      buf[j]=temp;
    }
  }
}
avgValue=0;
for(int i=2;i<8;i++)                      //take middle 6 values
  avgValue+=buf[i];
float pHValue=(float)avgValue/6; //take the average value of 6 center sample
```

Sensors Calibration

We took three known data points for pH, plotted them in a scatter chart in Google Sheets and used the trendline tool to find the equation relating the analog value to the actual pH value.

```
pHValue=-0.0268*pHValue + 26.7;
return pHValue;
```

Then, we plugged in that equation into our Arduino code.



Line of best fit on Google Sheets

Challenges

- Synchronization of different electrical components–communication with other teams to coordinate "who sends what and when"
- Uploading code to the ESP32
- Flooding in the buoy
    - Had to re-calibrate and test all sensors as well as replace some
- Sensor inconsistency, especially with the pH and TDS sensor

Buoy 1 with pH sensor (left) and temperature sensor (right). TDS sensor not shown.

Field testing Results

- In a controlled environment, the sensor readings had very high accuracy
- Immediately after dropping in the lake, pH was inaccurate: 15-18
  - Realistic pH: 7-8
- TDS might be too high: ~1000 ppm
  - Realistic TDS: 50-300
- 2136 data points around the lake were collected
- Data was gibberish initially during testing due to a wiring malfunction, troubleshooted at the lake

Opportunities for further research

- Understand the root causes of wrong data values
  - Possible reasons: wind, not fully submerged, current, temperature
  - We tested fast-flowing sample lake water with pH sensor. The pH didn't change significantly. According to our observations, current did not affect pH.
  - Temperature of the lake was not in the extremes
- More verification such as pH test strips
- More time for field testing
- Testing sensors deeper in the lake

Poster

Abstract

Large-scale data collection of the oceans have recently made its mark in research and the industry, and understanding the bodies of water around us and human impact on them is more important than ever. The Data Acquisition (DAQ) team was tasked with collecting and transmitting frequent and reliable sensor data from an Arduino on a buoy to an onshore server for further analysis. To improve sensor accuracy, we calibrated sensors and oversampled the sensor outputs. We successfully collected and transmitted 99.95% of 2147 records to the base station.

Figure 1: Buoy 1 with pH sensor (left) and temperature sensor (right). TDS sensor not shown.

Project goals & guidelines

DAQ was tasked to use the given pH, TDS, and temperature sensors to collect and transmit frequent and reliable data.

Sensors Calibration

Temperature: Read temperature data from digital input pin and compared with external thermometer readings. No calibration was required as the values matched.

TDS: Built-in software calibration found through documentation. Used an Arduino library to calibrate the TDS sensor simply by placing the sensor in 1000 ppm calibration solution and entering in the actual value in the Arduino IDE Serial Monitor.

pH: Read value from analog pin and graphed the pH vs. the analog value to determine the ordinary least squares (OLS) model. Then we implemented the equation into our code.

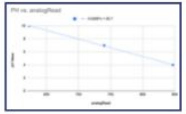


Figure 2: pH Sensor OLS model fit through 3 known data points with calibration solution.

Materials

Hardware:

- Arduino Uno or Nano
- ESP32 with LoRa
- Protoboard, breadboard
- Sensors: pH, Total Dissolved Solids), and temperature
- 1000 ppm TDS calibration solution
- 4, 7, and 10 pH calibration solution
- Thermometer
- Capsule Hardware
  - Motor
  - Motor controller

Software:

- Arduino IDE
- Github
- Onshape
- DF Robot TDS libraries

Serial communication

Serial communication through Tx/Rx pins was implemented between Arduino and ESP32 via a comma separated String in the order of temperature (°C), TDS (ppm), and pH. Data was sent over serial to the computer during testing.

```
10:56:57.525 -> 24.50,1004.09,7.94
10:56:59.643 -> 24.50,1008.83,7.94
10:57:01.754 -> 24.50,1004.09,7.97
```

Figure 3: Serial monitor output sample

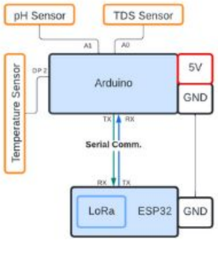


Figure 4: Wiring diagram for sensors, Arduino, and ESP32

Methodology

- Programmed the Arduino to read and print data from each individual sensor
- Combined sensor code to have all 3 sensors reading and printing data simultaneously
- Identified Serial as the communication method between Arduino and ESP32 due to its simplicity
- Started from Arduino to laptop communication, then Arduino to Arduino, then Arduino to ESP32 communication through Tx/Rx pins, gradually ramped up difficulty to achieve desired result
- Tested serial communication with longer wires for buoy 2.
- Sensors:
  - Programmed the sensors independently
  - Calibrated the sensors if necessary
- Jumper-wired the sensors to the Arduino Mega with breadboard for buoy 1
- Designed capsule-pulley system to collect data at various depths–we decided on Arduino Nano for its space efficiency
- Designed a solder-able prototyping board for Arduino Nano for buoy 2 to be contained in the capsule

Figure 5: Sensors

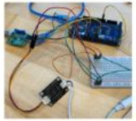


Figure 6: Wiring of Sensors

Figure 7: Buoy 2 Capsule

Figure 8: Collecting data at the lake

Acknowledgements

Professor Jack Silberman Ph.D.
Lecturer: Ivan Ferrier
Teacher Fellow: J. Michael Tritchler
Teacher Assistants: Melody Gill, Devanshi Jain, Dallas Dominguez
An additional thank you to our counselors, teachers, and parents who made it possible for us to be here!

Challenges & Opportunities

- Synchronization of different electrical components–communication with other teams to coordinate "who sends what and when"
- Inverted ground and signal wires
- Declared the wrong analog pins
- Compatibility issues with ESP32, uploading code to the ESP32
- Balancing the capsule's weight with the strength of the motor
- Completing tasks/troubleshooting quickly to prepare for single field day
- Sensor inconsistency, especially with the pH and TDS sensor
- Keeping track of different code files

Conclusion

The end result was characterized by various successes as well as potential improvements.

During field test day, pH readings were accurate until immediately after descent into the water. We received data telling us the lake had a pH of 15-18. We took a sample of the lake water back, and without any modifications of the system, the sensor read pH values of around 8, a much more feasible range.

For further research and development of this project, it would be beneficial to understand the root causes of errant data values and enact more verification such as pH test strips. In a controlled environment, the pH readings had very little error during calibration. On the lake, many factors may have affected the accuracy: current, waves, wind, and other natural causes.

Quick troubleshooting during field testing proved valuable, as communication with the base station was fast and reliable. Also, meticulous calibration of the sensors and electrical components allow us to eliminate low-level issues and think more creatively.

Thank you!

A special thank you to Professor Jack Silberman Ph.D., Lecturer Ivan Ferrier, Teacher Fellow J. Michael Tritchler, and TA's Dallas Dominguez, Melody Gill, Devanshi Jain