Determining the Wind-Current Relationship Near Shorelines

Section 1, Team 4:
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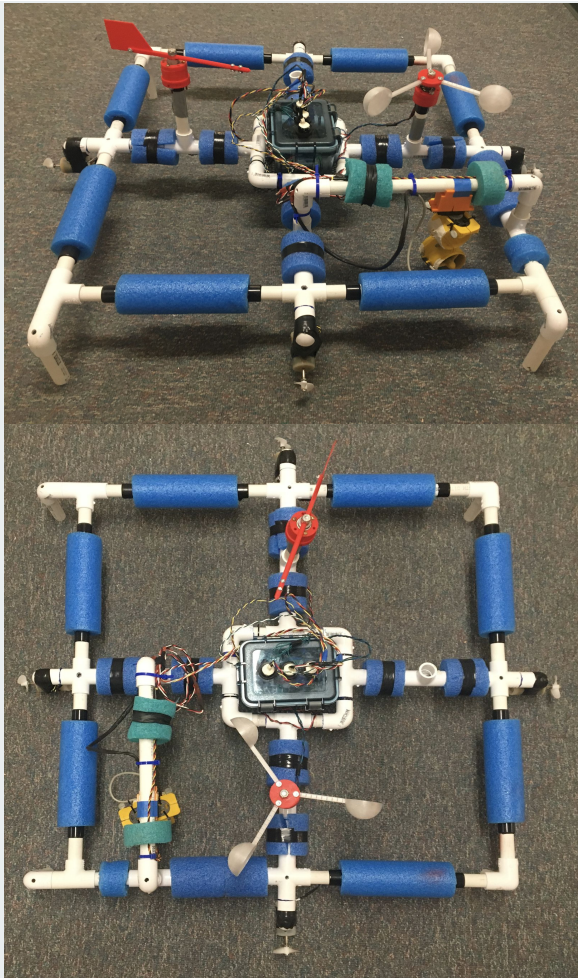


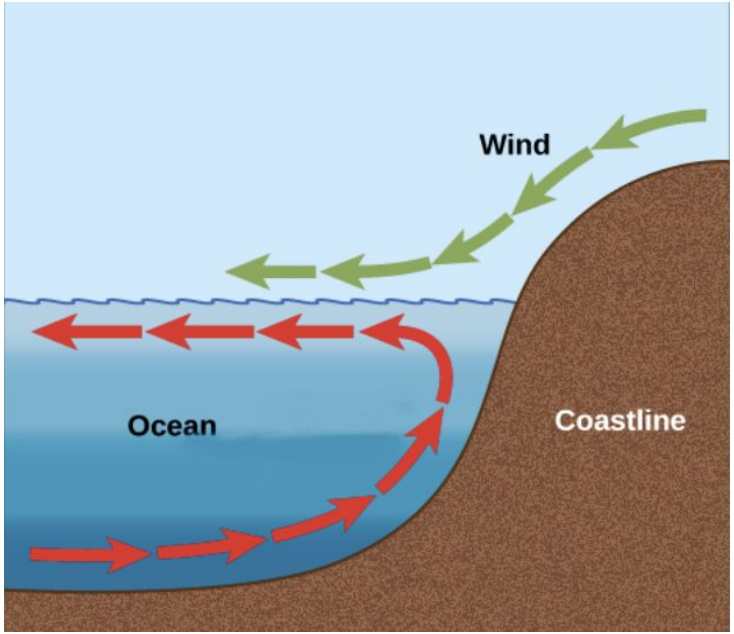
Background & Motivation

- Unknown wind-current relationship near shore
- Predict tide conditions given wind conditions
  - Wind and Water Turbines
  - Safety of beachgoers near shore

Scientific Goals

Our goal for this project was to **quantify the relationship between wind speed and surface current** speeds, using wind speed, wind direction and current velocity sensors.

- Measure wind speed
- Measure current in wind direction
- Measure current orthogonal to wind direction

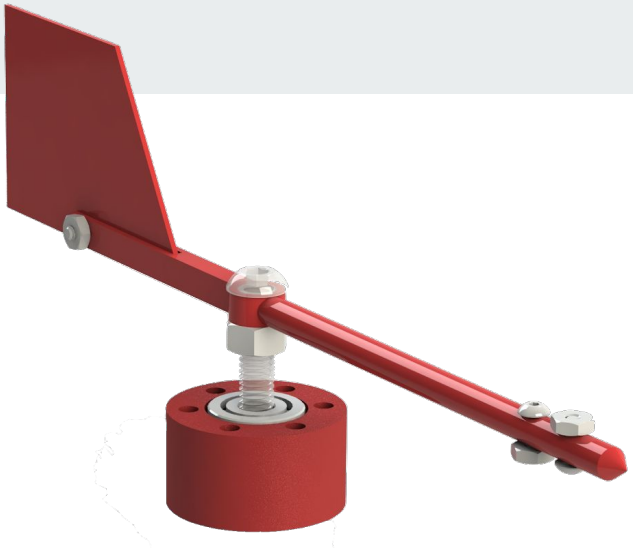


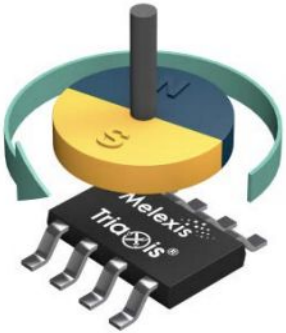
https://courses.lumenlearning.com/boundless-biology/chapter/biogeography/

Sensors & Circuitry

Weather Vane

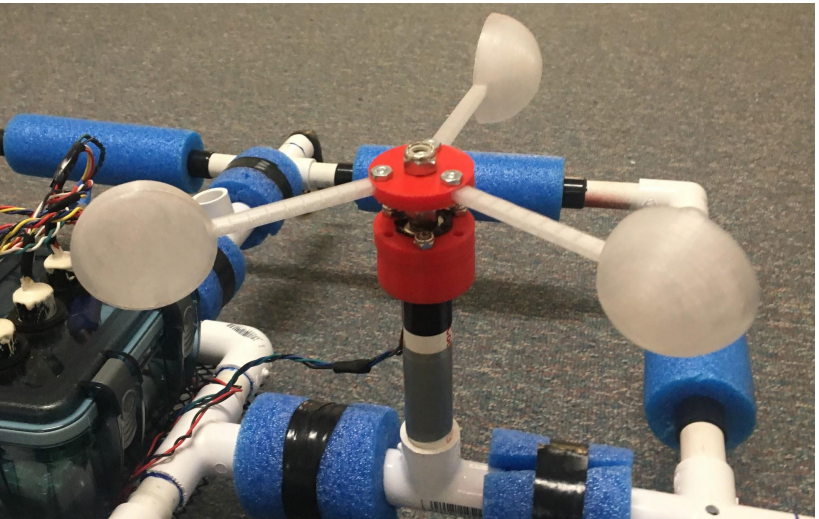
- E80 Reference Design
- MLX90316 Rotary Position Sensor
- Rail to rail, ratiometric analog output
  - 8% to 92% of V_{DD}
  - V_{DD} = 5V





Anemometer

- E80 reference design
- AH9246 Hall Effect Sensor
- Digital output
  - $1 \rightarrow V_{DD}$ = 3v3
  - $0 \rightarrow 0V$



Flow Sensor

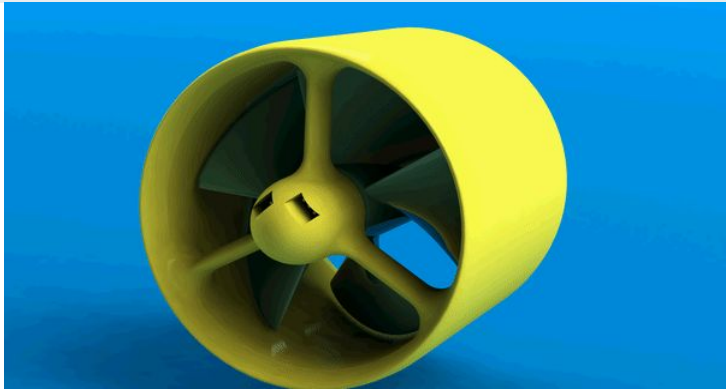
- Borrowed sensor from Prof. Clark, LAIR
- Modification to sensor
- A1324-26 Linear Hall Effect Sensor
- Digital output
  - $1 \rightarrow V_{DD} = 3v3$
  - $0 \rightarrow 0V$

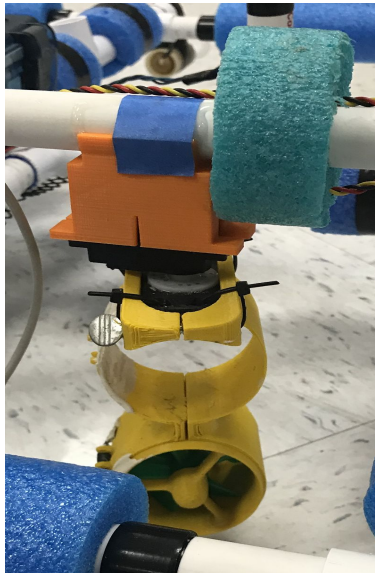
Servo

- PWM signal to control
  - Imported library
- $V_{DD} = 5V$

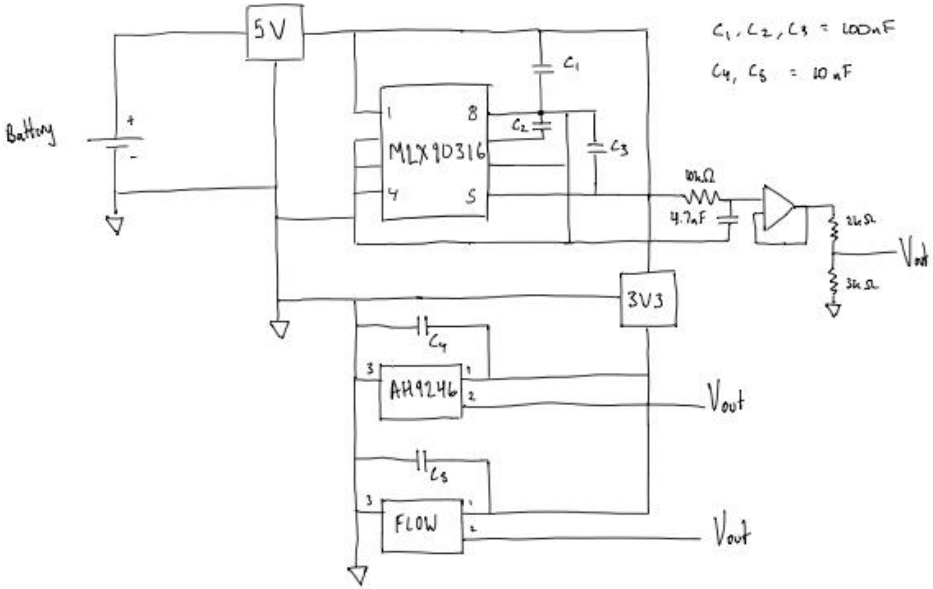
Mechanical

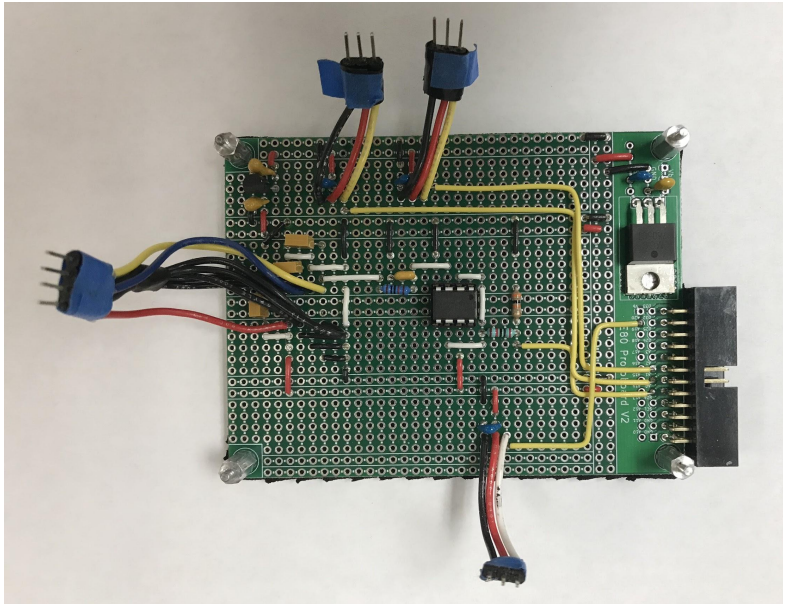
- Flow sensor to Servo adapter to avoid permanent modification to sensor
- Servo to PVC adapter





Circuits


5V
Battery
+
-
C1
C2
C3
MLX90316
1
8
4
5
10kΩ
4.7nF
2kΩ
3kΩ
Vout
3V3
C4
AH9246
3
1
2
Vout
C5
FLOW
3
1
2
Vout
C1, C2, C3 = 100nF
C4, C5 = 10nF



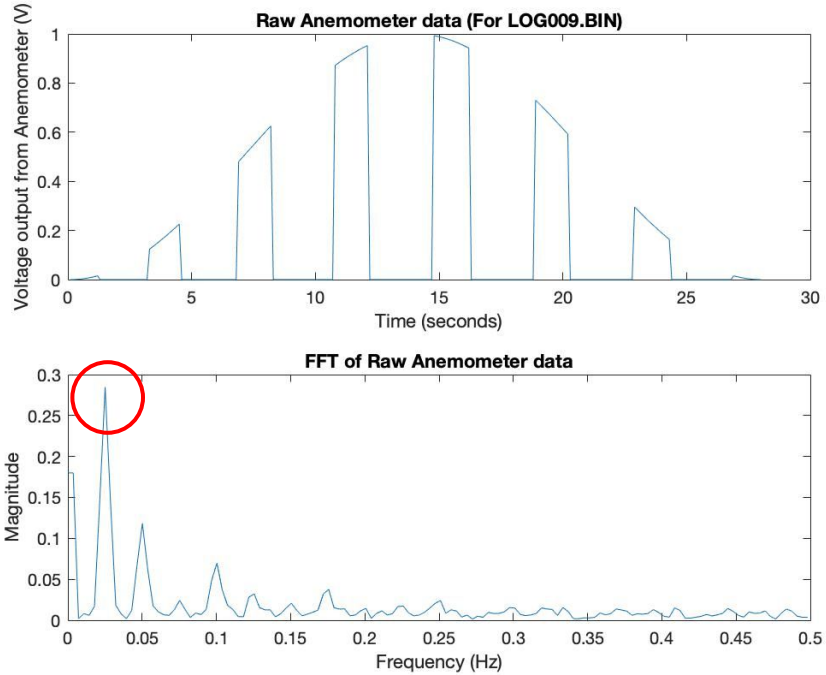
Sensor Calibration

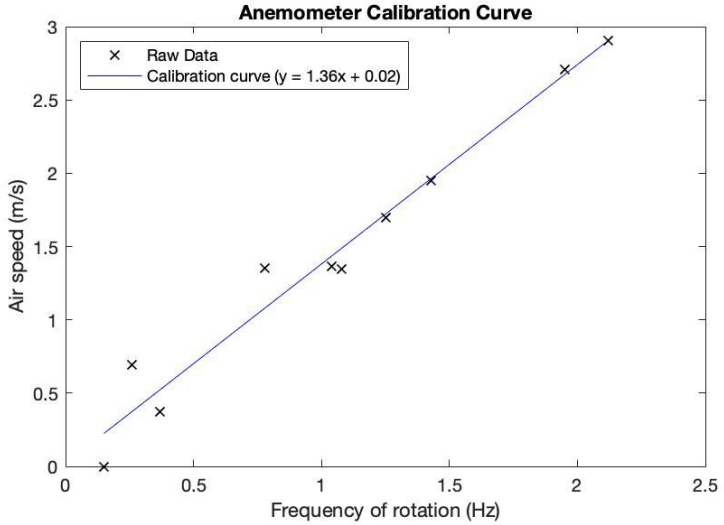
Anemometer and Flow Sensor

- Calibrated in wind tunnel
- Fourier Analysis of output voltage
  - with Hann window
- Air to water velocity conversion

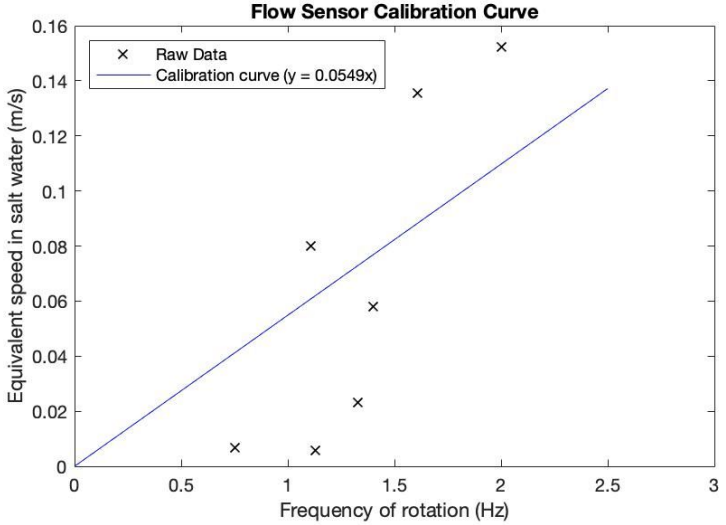
$$\text{Reynolds number (Re)} = \frac{V_{water} l}{\nu_{water}} = \frac{V_{air} l}{\nu_{air}}$$

$$V_{water} = V_{air} \frac{\nu_{water}}{\nu_{air}}$$





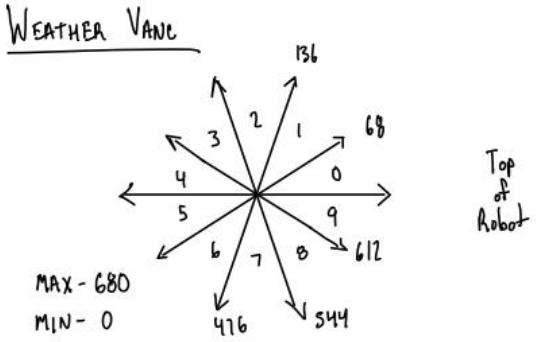
$R^2 = 0.6624$, Error in Slope: ± 0.0679
Error in y-int: 0.854

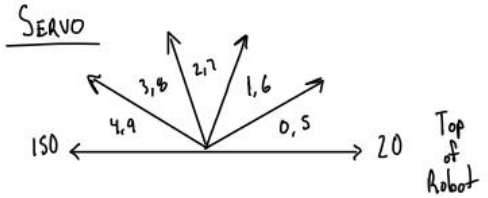


$R^2 = 0.6998$, Error in Slope: ± 0.3803

Weather Vane to Servo Conversion

- Discretized the weather vane's θ value into 10 segments along 360°
- If θ > 180°, subtract 180° from θ because the polarity of the sensor doesn't matter

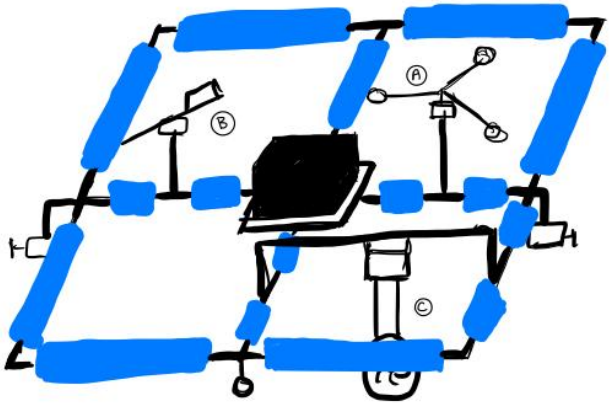


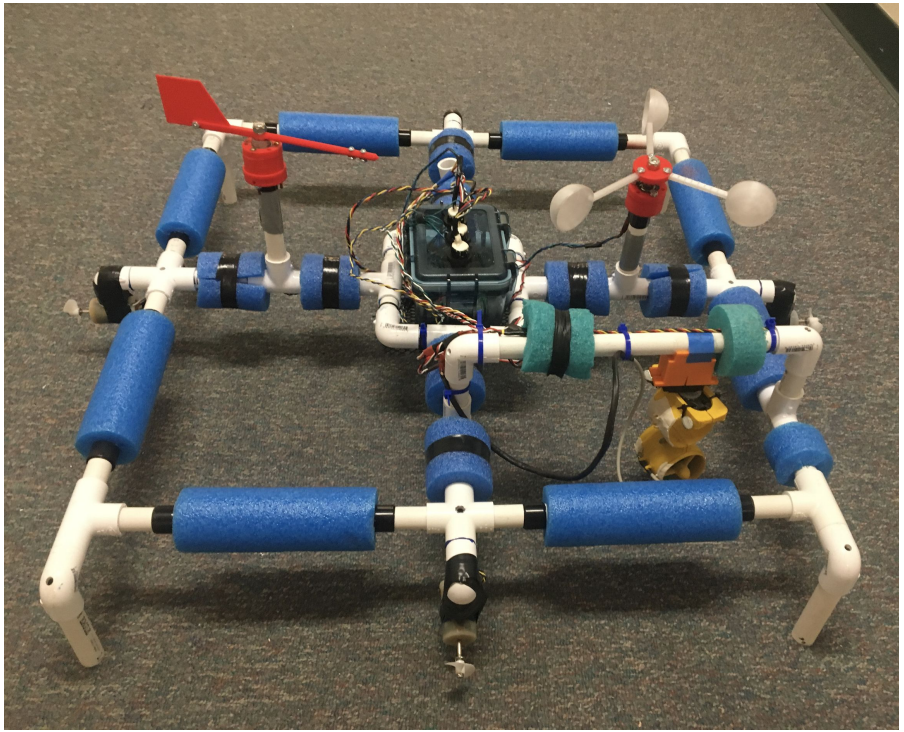


Mechanical Design

Mechanical Design

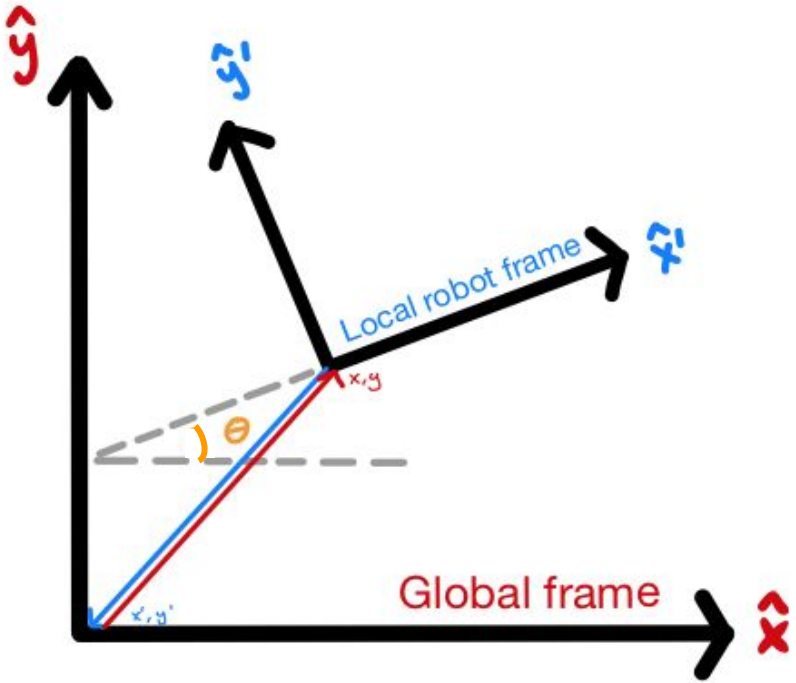
- Large surface area
- High buoyancy
- Avoid interference between our sensors
- Holonomic movement
- Minimize impact from wind
  - Low profile
- Keep motors away from electronics and IMU





Control Loop

Coordinate Conversion



$$\Delta X = R_{Earth} \cdot \Delta\text{Longitude} \cdot \cos(\text{Latitude}_{\text{origin}})$$
$$\Delta Y = R_{Earth} \cdot \Delta\text{Latitude}$$

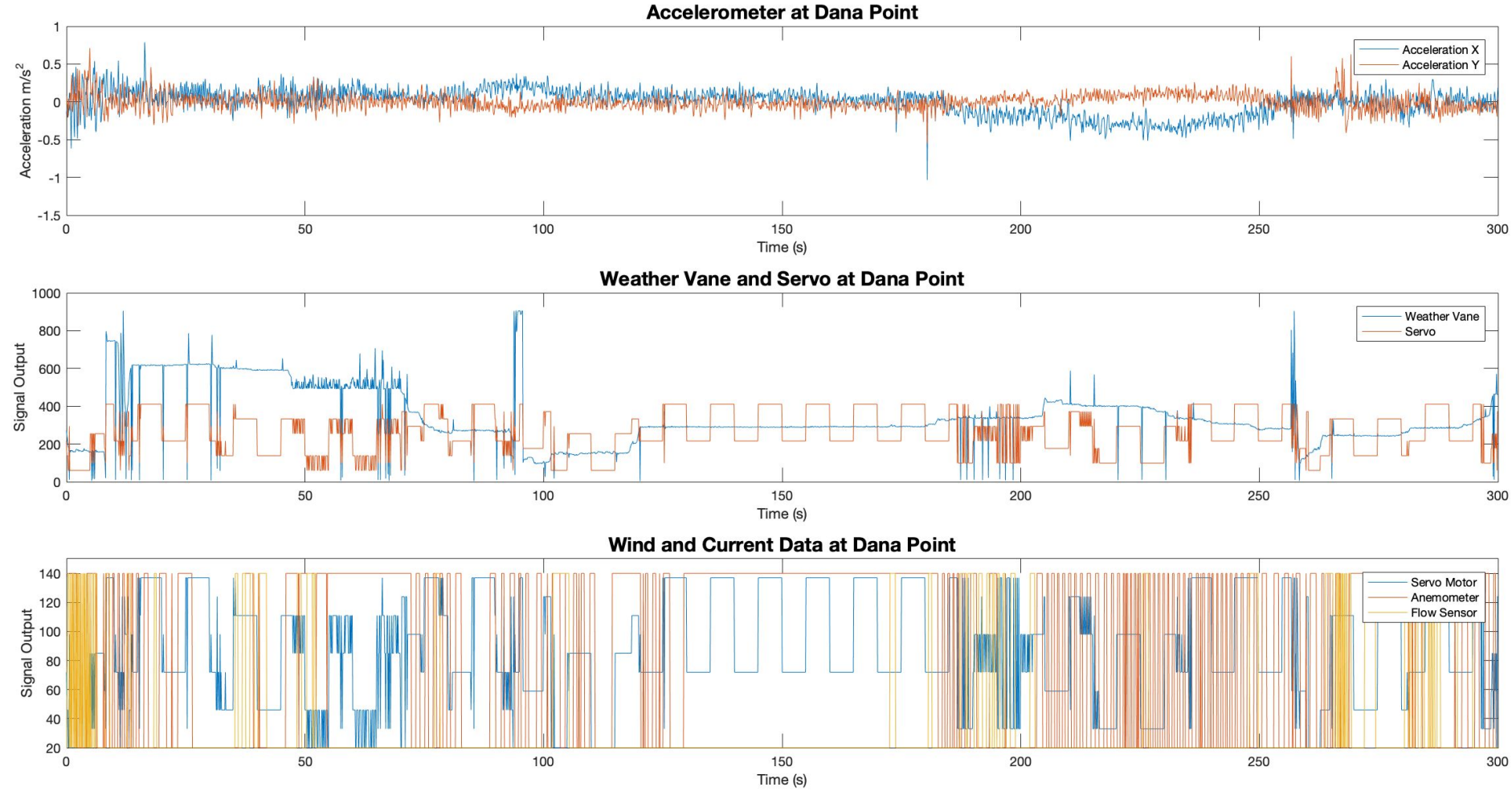
$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

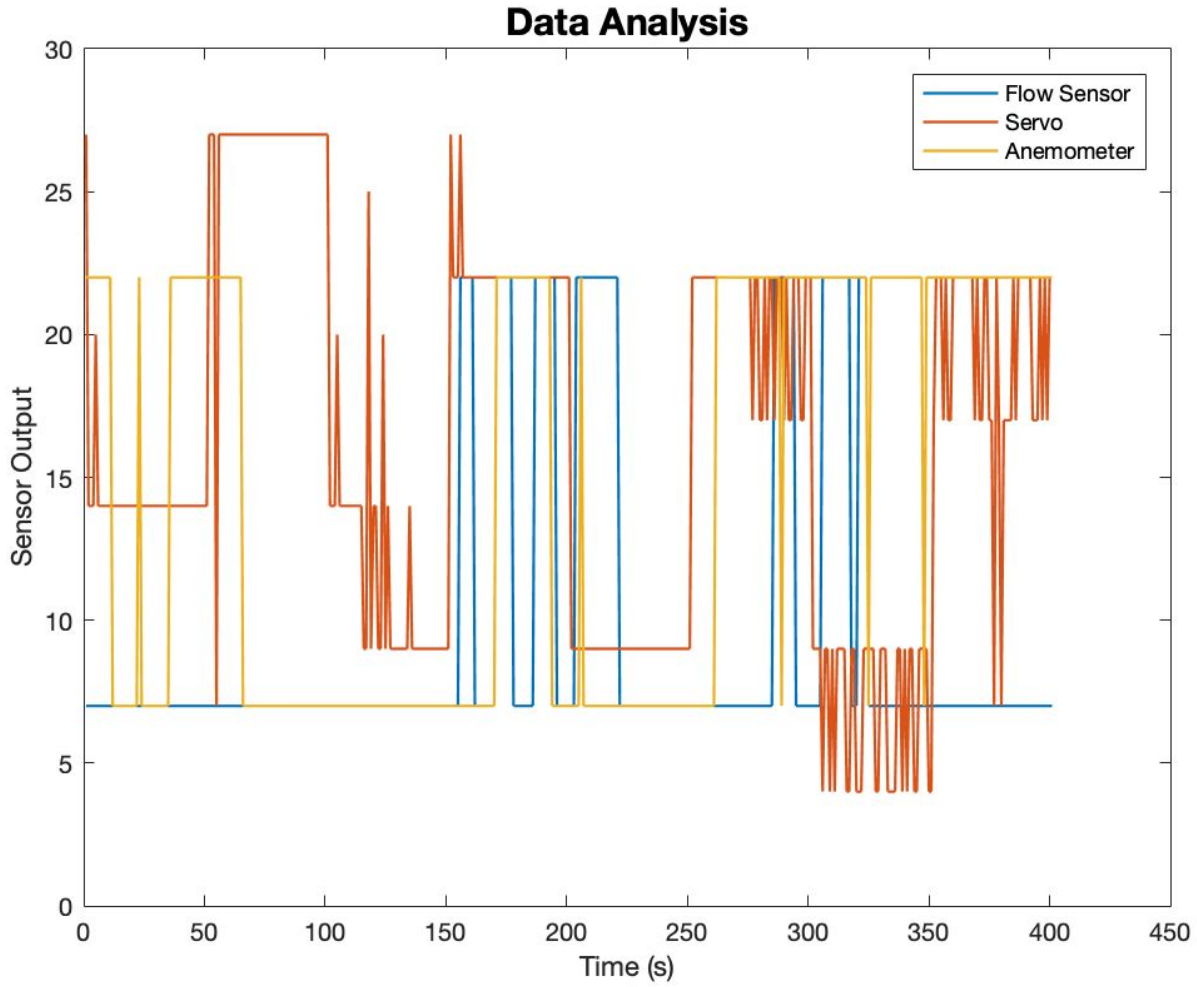
Deployment

What went wrong, and how we adapted

- Weather Vane to Servo Calibration
- Don’t read and drive
- Motor control

Results

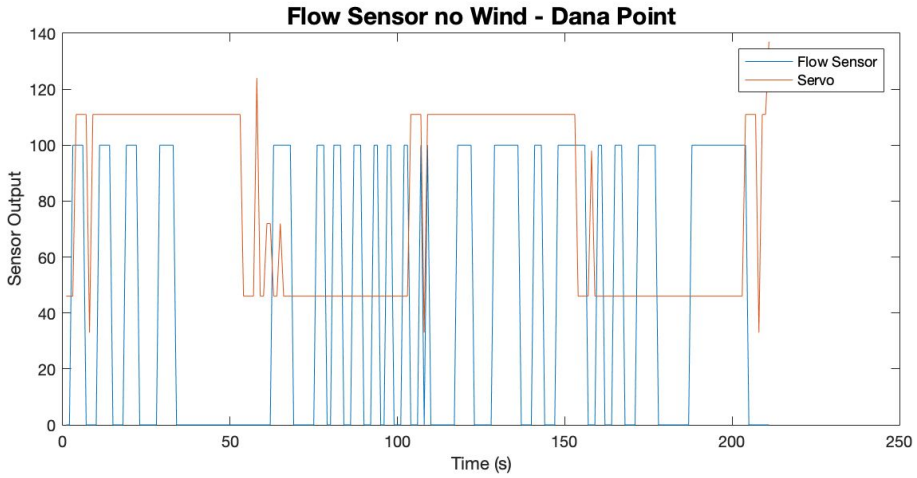

Accelerometer at Dana Point
Acceleration m/s^2
Acceleration X
Acceleration Y
Time (s)
Weather Vane and Servo at Dana Point
Signal Output
Weather Vane
Servo
Time (s)
Wind and Current Data at Dana Point
Signal Output
Servo Motor
Anemometer
Flow Sensor
Time (s)

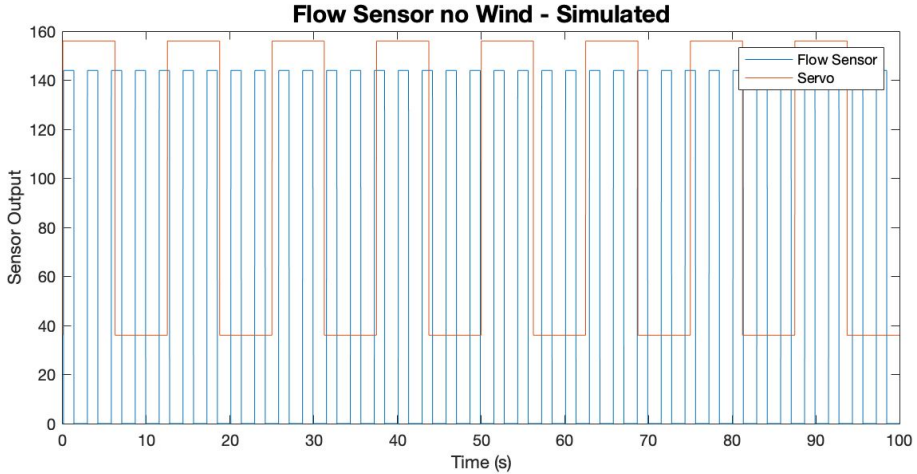

Data Analysis
Flow Sensor
Servo
Anemometer
Sensor Output
Time (s)
0
5
10
15
20
25
30
0
50
100
150
200
250
300
350
400
450

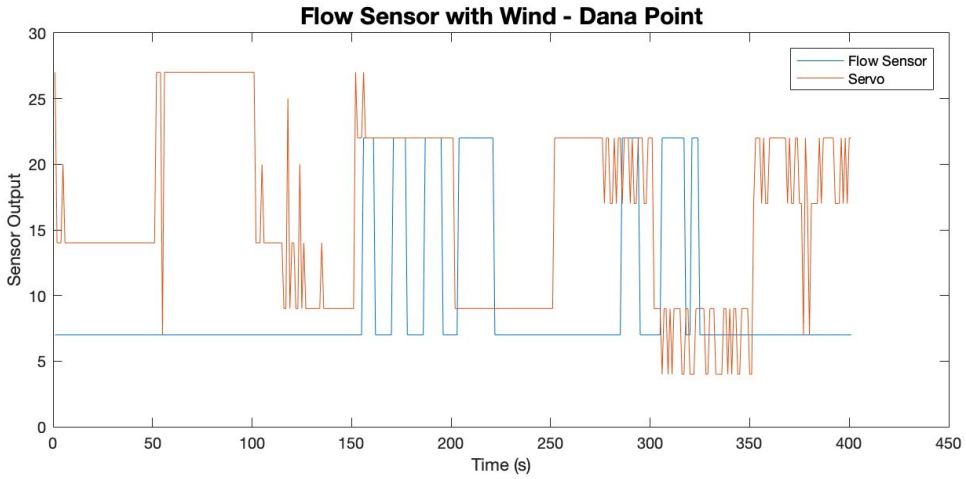
Results

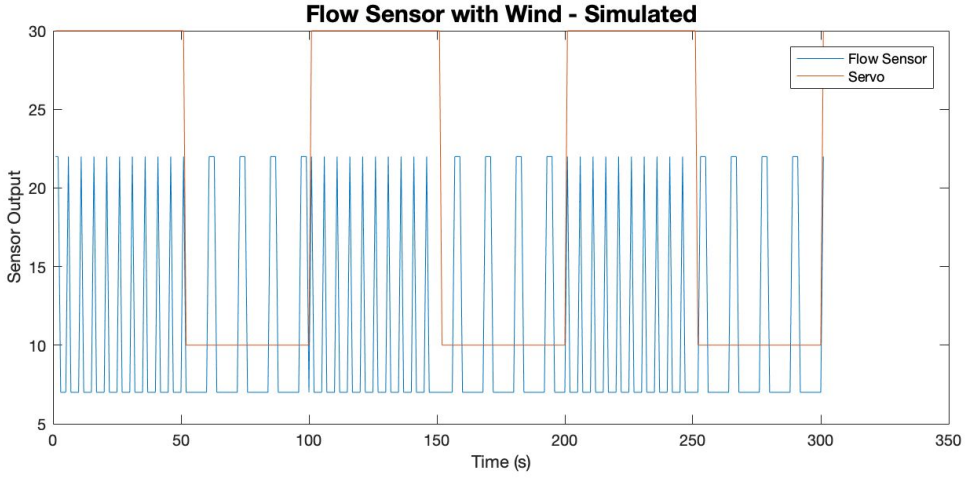
Trial	Wind Speed (m/s)	Current parallel to wind (m/s)	Current perpendicular to wind (m/s)	% Difference
1	0	0.060389 ± 0.023	0.06588 ± 0.025	9.1%
2	3.57 ± 2.41	0.0161 ± 0.0061	0.0102 ± 0.0039	36.6%
3	2.19 ± 2.06	0.0154 ± 0.005846	0.00878 ± 0.003341	43.0%

Comparison of Data to Model


Flow Sensor no Wind - Dana Point
Flow Sensor
Servo
Sensor Output
Time (s)
0
20
40
60
80
100
120
140
0
50
100
150
200
250


Flow Sensor no Wind - Simulated
Flow Sensor
Servo
Sensor Output
Time (s)
0
20
40
60
80
100
120
140
160
0
10
20
30
40
50
60
70
80
90
100


Flow Sensor with Wind - Dana Point
Flow Sensor
Servo
Sensor Output
Time (s)
0
5
10
15
20
25
30
0
50
100
150
200
250
300
350
400
450


Flow Sensor with Wind - Simulated
Flow Sensor
Servo
Sensor Output
Time (s)
5
10
15
20
25
30
0
50
100
150
200
250
300
350

Conclusion

- Data suggests a correlation
  - Significant difference between current in direction of wind and without
- Recommendations for Future Work
  - More measurements
  - Numerical effect of wind on current
- Lessons Learned
  - Constructing reliable systems requires extensive preparation

Acknowledgement

Professor Clark and Ben Chasnov ‘16

References

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Questions?