Automous Detection of Sail Luffing

Halie Murray-Davis
Andrew Bennett

Olin Intelligent Vehicles Laboratory

Olin College of Engineering

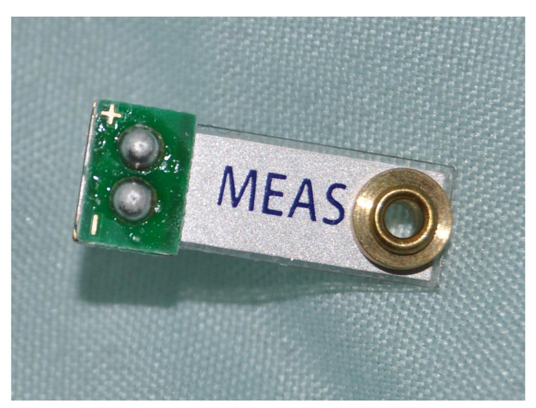
The Problem

Visable ripples in fore sail caused by luffing. Photo from: wikimedia, Myrabella

If not properally audjusted, sails "luff" or flap in the wind. This flapping is caused by a momentary reversal of pressure across the sail. This is undesirable because it reduces hull speed and stresses the sail rig. Current sail control employs open loop methods. If the advent of luffing can be sensed, closed loop control can be used. This is beneficial, especially for extended deployment of robotic sailing platforms in highly uncertain environments, like the open ocean.

The Sensors

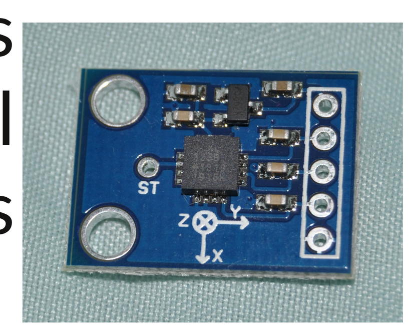
Minisense 100



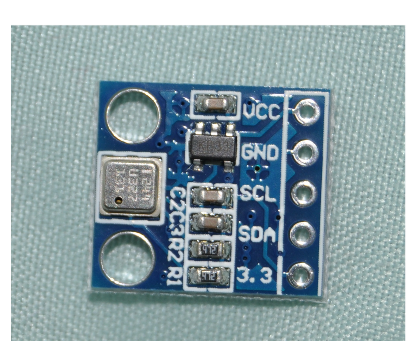
Piezoelectric sensor senses vibrations induced in sail by luffing. The white, piezoelectric strip deforms as the brass counterweight moves. This deformation creates a voltage. The signal is quasiperiodic.

ADXL 335

Analog acceleration sensor which senses the acceleration from the physical movement of luffing. Output describes luffing sail motion.



BMP 180



The sail luffs as a result of air pressure changes. I2C air pressure sensor detects luffing by sensing changes in air pressure along the surface of the sail. This directly measures the physical effect which propells the hull forward.

Method

An instrumented sail was placed atop a car on a low wind night. The car was driven at 20 mph in a straight line away from flow obstructions to establish laminar flow across the sail. A camera was directed toward the sail and used to record the centroid of light from a LED placed on the sail near the sensors as a visual marker. We use this sail position data to validate sensor output.

Data Analysis

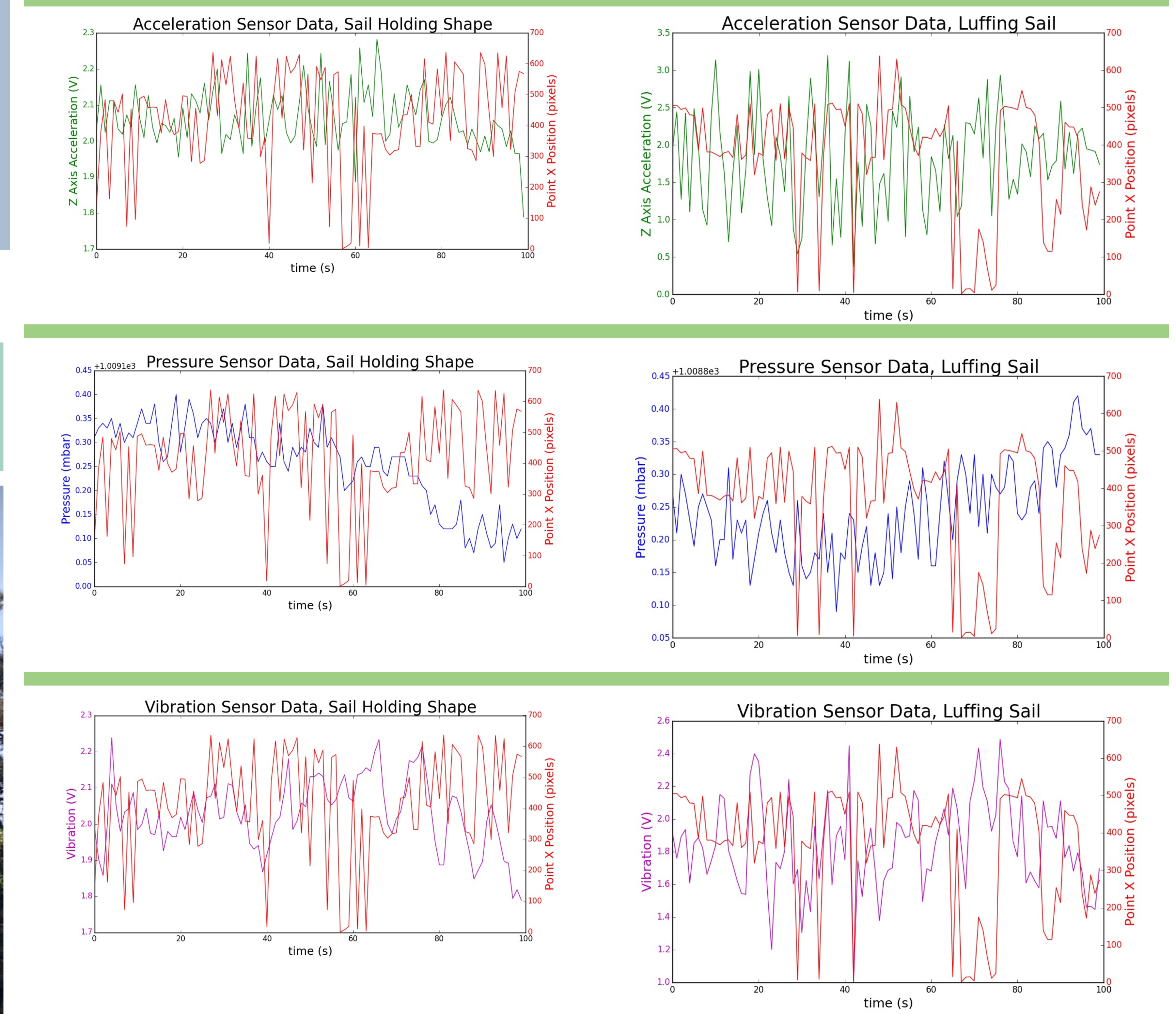
For the acceleration and vibration data, we compute an online value of the mean and maximum with a moving time window (30 values reading at approximately 16 htz). For the pressure data, we use the same moving time window, but, compute an estimate of the varience.

Acknowledgements

The authors would like to thank the Claire Boothe Luce foundation for funding this research.

Results

Comparison of raw sensor data with sail position while holding shape (column 1) and luffing (column 2). Data becomes more erratic as sail luffs.



Data is processed using described data analysis methods. Result enables real-time clasification of sail state using thresholding method. This can be seen in the plot of processed data as sail transitions from luffing to holding shape.