BUILDING THE FASTEST BOAT: QUANTIFYING THE EFFECTIVENESS OF A ROWER

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Introduction

Rowing has been a competitive collegiate and professional sport for more than a century and is one of the few sports that benefits athletes of both strength and technical prowess. The objective is to collect eight rowers who can propel a boat faster than any other through the water. There are many technical aspects that contribute to a single stroke and current coaching strategies are almost entirely based upon empirical trials and intuition, both of which are open to bias. If a coach was provided with quantified data and analysis of rowers on the team, strategies to maximize the speed of the boat and optimize the effectiveness of each rower are made more accessible and more actionable as compared to current methodolgy.

Our capstone project provides a device, nicknamed R.A.G.E. (Rowing Accelerometer and Gyroscope Evaluator), which is attached to an oar and collects acceleration data of the rower's strokes throughout the duration of a race or workout. The data is parsed through a post-processing algorithm that provides coaches with quantified, comparative conclusions of the rowers.

The Device and Parameters

To capture the mechanics of a stroke, the oar's linear and rotational acceleration profile are captured with an Arduino Nano three-axis accelerometer and gyroscope. Once all six accelerations are collected, they are stored on a SD card that is hard-wired to the Arduino, which can be removed and read for post-processing. The system is powered by a standard nine volt battery with an on/off switch to commence data collection.

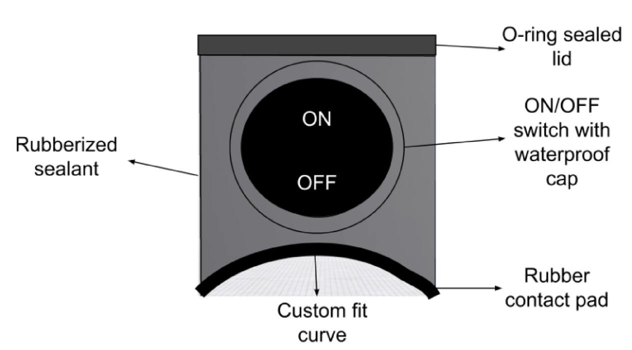

Figure 1: A side-view schematic of the R.A.G.E. device, with special custom features indicated

The system that contains the sensor and SD Card has a few unique features to accommodate the aquatic environment and oar geometry:

- The electronic components are housed within a sealed box with the geometry proportioned for a tight fit. The box itself is 3D printed with PLA filament.
- The lid is designed to form an airtight seal using a custom O-ring stock for waterproofing purposes.
- The bottom arc of the box is also custom designed to naturally fit the curvature of a standard competitive racing oar with additional neoprene rubber padding to decrease slip. Waterproof Velcro straps are utilized to attach the box onto the oar beneath the handle.
- Finally, the entire system is coated in a silicon marine epoxy to form a waterproof seal over the plastic filament. The on/off switch is also encased and sealed in a plastic button covering.

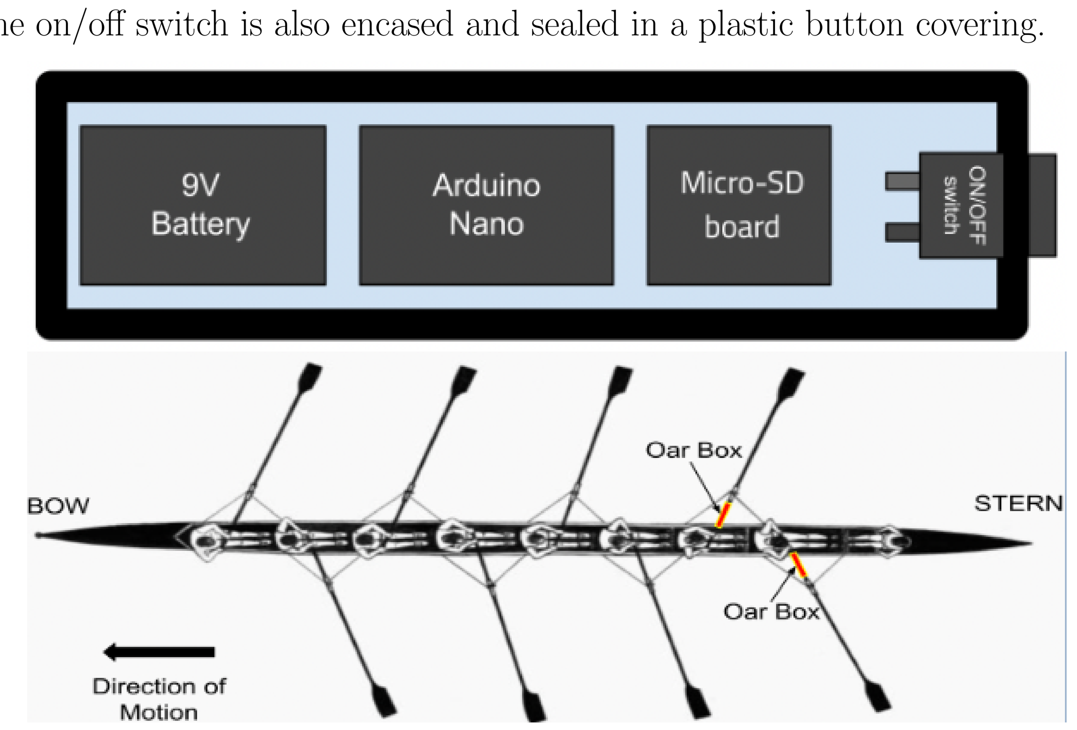

Figure 2: A top-down view of R.A.G.E. showing each of the four main electronic components and their locations within the system. Additionally, a top-down view of an 8 person boat displays the locations of the devices on the oars (small red indications).

These design choices were deliberate in order to best capture the main parameters of interest that have the greatest impact on a rower's performance. Firstly, a generalized acceleration profile is measured, which provides a summary of a rower's overall output using a phase average.

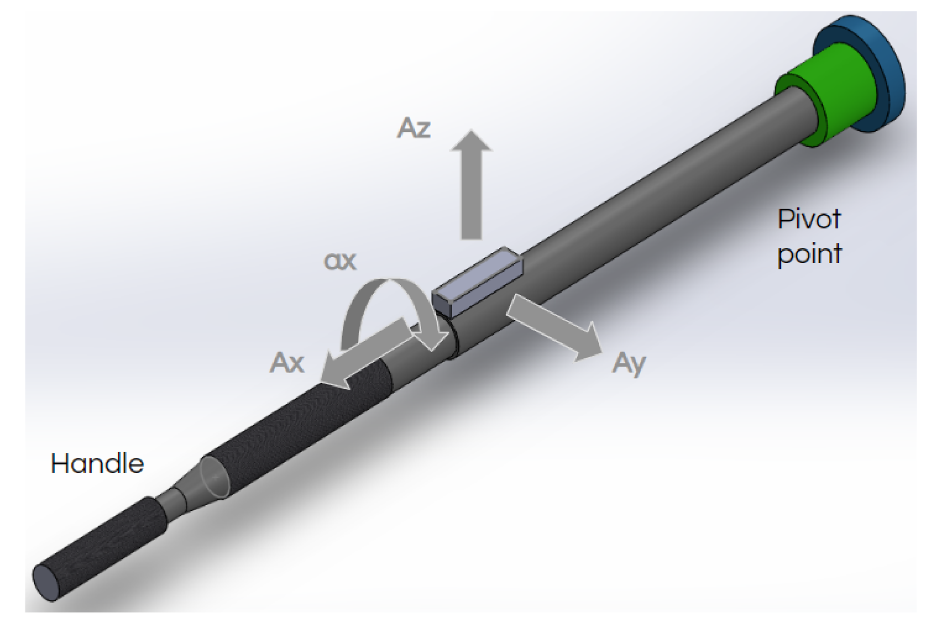

Figure 3: An orthographic projection of a standard oar with R.A.G.E. affixed beneath the handle with three positive axes (linear) and one rotational shown.

Secondly, the algorithm also tracks drive time, or the time the oar blade is spent submerged, to see if the rower consistently applies their power over the duration of a set. Finally, a sample standard deviation is taken of the phase average in order to highlight aspects of the drive where more variation may occur, with the ultimate goal being to minimize this variation. All of these pieces of data are combined to encapsulate the core components of a stroke, with each being recorded at 250 Hertz to produce viable, but not excessively noisy data.

Data Analysis and Results

In order to verify the system operated as expected, trials were conducted with indoor rowing tanks before on-water testing, which allowed for stroke mechanics to be evaluated without any boat inertia impacting the results. The drive was isolated using an orientation-based logic statement, as well as a derivative-based logic statement. The oar needs to be in an upright position, squared, and experiencing a negative acceleration in the vertical (z) direction to trigger the first flag of the drive. The opposite conditional statements are used to find when the drive has been concluded and the blade is removed from the water. The A_y values, representing the rower's acceleration, are isolated for each drive using these two points for the entire set.

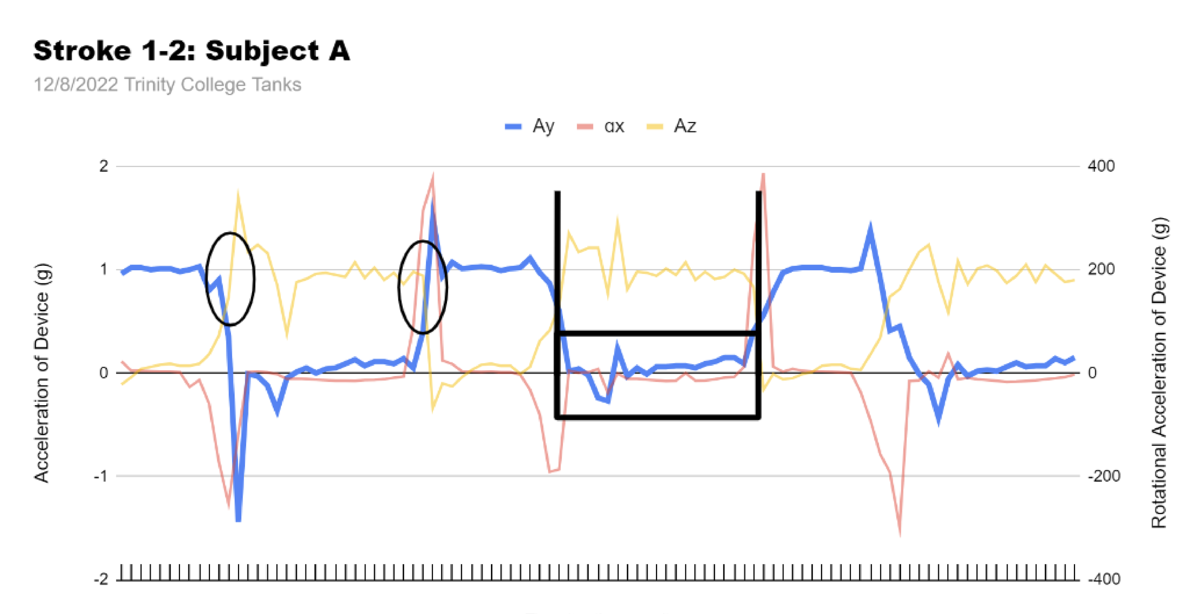

Figure 4: A sample of indoor tank data with the black circles indicating the conditional check locations of the beginning and end of a drive. The box contains the accelerations (linear x and y) within the drive of the stroke.

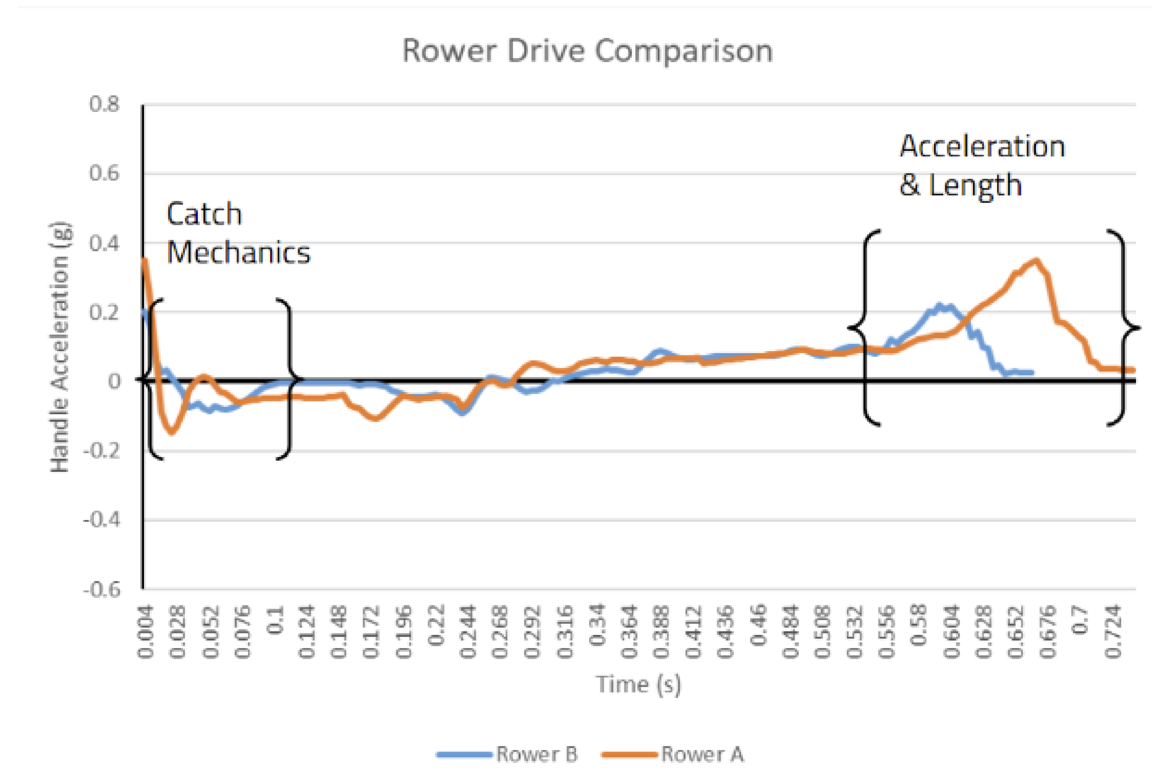

Figure 5: Phase averaged acceleration profiles of two rowers from indoor tank sessions. Note the longer duration of drive for Rower A and the greater slope at the catch mechanics, indicating a quicker entrance into the water. Rower A is outperforming Rower B in both mechanics and power.

Through comparing rowers' phase averaged strokes, we can gain a greater understanding of how rowers can improve. In Figure 5, Rower A is a proficient rower because we can identify differences between the two rowers, and technical changes that can be made. For example, Rower A has a more rapid catch, identified by the quick initial dip and return to zero, as compared to Rower B's prolonged dip and return to flat line. Additionally, Rower A drives for longer and accelerated more at the release as compared to Rower B. This comparison between two rowers would allow a coach to accurately determine which rower may contribute more to a lineup in a boat.

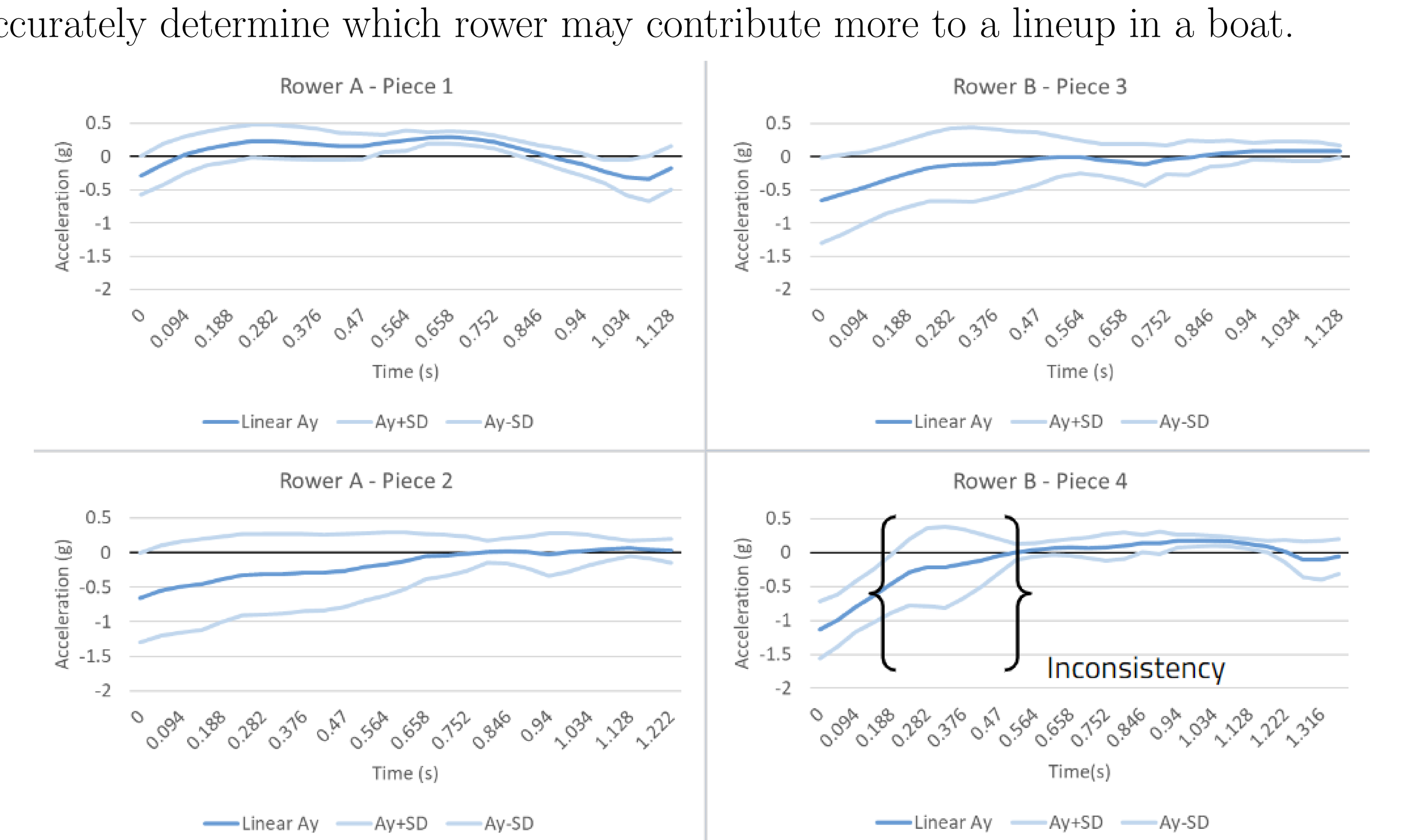

Figure 6: Four sets of phase averages from two female rowers from on-water trials. Note that Rower B is generally a more consistent rower due to a smaller standard deviation, while Rower A produces slightly more power to overcome the drag forces of the boat.

Due to acceleration correlating with forces ($F = m\vec{a}$), boats typically experience a negative acceleration due to drag forces slowing the shell down from the water, air, and boat inertia. Conversely, positive acceleration values correlate to blade thrust effectively being applied, which overcomes the net drag forces and propels forward. In Figure 6, Pieces 2 and 3 are notably worse pieces as compared to Pieces 1 and 4 due to this above reasoning. Additionally, Rower B is a largely consistent rower, as seen by the reduced standard deviation. At 3/10ths of a second, however, there is a large increase in standard deviation, suggesting the rower is inconsistently accelerating in this region, which is a coachable point the rower could begin to focus on.