Senior Design Proposal
Team FrEE SpEEd

Braeden Benedict, Joe McGrath, Nick Rasdon, Brooks Meadowcroft, Abby Greentree

1 Introduction.

Rowing is one of the most popular Olympic sports in the United States [1] , with over 75 thousand active participants and the third largest U.S. delegation to the Olympic Games. [2] Success in the sport requires a unique mix of technique and physical conditioning that is often cultivated over the course of many years. Training for the sport is therefore often extremely demanding both physically as endurance is built and mentally as technique is perfected.

2 Problem Description.

In rowing, technique is often more important than strength. It is therefore important for team members to continue to improve their technique through analysis of different parts of their stroke. One of the more important technical aspects of rowing is the coordination of movements between rowers: feathering, roll ups, and catches should all be in sync. Traditionally, technique analysis has been done visually by a coach, but it can be difficult and expensive to find a coach with enough expertise to extract the maximum performance from a boat. Additionally, it is unlikely that a coach would be able to provide useful feedback to multiple people at once without the use of an external device. While there are commercial devices that help with technique analysis by measuring the forces at the oarlocks [3], there is a need for low cost device that can be easily added to an existing setup.

3 Proposed Solution

Our proposed solution to the above problem is a system that collects data from the oar and transmits the signals through bluetooth enabled device. Then processes the data to give feedback to coaches with a visual representation of the boat as a whole.

On the oar there will be an accelerometer and gyroscope that will collect data of the oar orientation in 3 dimensions. This will be connected to a microcontroller, mounted onto the oar, and covered in plastic so that it is waterproof. The microcontroller will be bluetooth enabled with a radius of roughly 100 meters in order to send data to someone like a coach or coxswain who is also in the boat.

This raw data will be sent to the bluetooth enabled device such as an IPad. In order to get the data that we want to show the user, we first will need to normalize the direction of the accelerometer data using the gyroscope so that the data is being seen in the right direction relative to the boat and the water. Then we will need to take the acceleration data and remove the boat's acceleration as a whole so that we are getting just the acceleration of each rower's oar. These data points will all have to be synced up and recorded at their correct timestamps in order to accurately portray what each rower is doing on each catch.

Once we have the data we want we will transfer that into a GUI with matlab, c, or python. This GUI will show a visual representation of each rower and the boat as a whole so that the coach or coxswain can get feedback on important things such as catch timing, feathering/roll-up timing and depth and length of stroke. The coxswain or coach will be receiving real time data to allow them to correct timing or stroke immediately.

4 Demonstrated Features

To implement the solution this project will be need to withstand typical rowing conditions; sensors will be able to attach to oars, and a processing unit will be attached to the boat itself. Each device will be contained in a waterproof casing and will be battery powered. The sensors on the oars will reliably communicate data to the processing unit, with a connection range of 20 meters. The data collected from the accelerometers in the sensor units will be normalized so that the orientation of the sensor and the acceleration of the boat itself will be taken into account, thus allowing for the stroke of an individual rower to be analyzed. We will develop an algorithm that will detect the catch in the stroke, and that stroke will be matched with a timestamp which will allow for comparison between the catch times of all rowers in the boat. Additionally, the position of the oar, the stroke rate, feathering times, and roll up times will be extracted from the data. All data that is collected and processed will be displayed with a GUI so that a coxswain or coach can easily see how each rower is performing.

5 Available Technologies

There are four major technological hardware components to this project: 1) a Bluetooth Low Energy (BLE) enabled microcontroller, 2) an accelerometer, 3) a gyroscope, 4) Qi wireless charging.

There are a number of BLE microcontrollers available which would be suitable for our needs. These include the RSL10 from ON Semiconductor and the CC2640R2F from TI. Important considerations when choosing a microcontroller will be its power consumption and available digital inputs. These devices are BLE 5 enabled, which provides a longer range and lower power consumption than previous bluetooth protocols.

There are many MEMS accelerometers which will fit our needs. We will be looking for a low-power, 3-axis accelerometer with a digital output via SPI or I2C. The ADXL345 is an accelerometer which fits these requirements which has been used for previous senior design projects. Ideally, the accelerometer will also include some sleep and wake-up functionality which will put it into a low-power mode when the oars are not moving.

Choosing a MEMS gyroscope to fit our needs is somewhat more challenging than selecting an accelerometer. We can probably get away with using a 1-axis gryoscope since there is primarily 1 axis of interest, which is along the shaft of the oar. Like the accelerometer, we will be looking for something which is low-power and has a digital output via SPI or I2C. These are available; however, there are a number of combined accelerometer/gyroscope chips, referred to as inertial measurement units (IMU). This includes the MPU-6050, which is a 6-axis device and includes an onboard Digital Motion Processor. A device such as this may be our best option, as it will reduce PCB board space and system complexity. These advantages need to be balanced with potential disadvantages such as a possible increase in power consumption and cost.

Finally, our device will ultimately need to include wireless charging, which will be highly preferable over a wired charging method or primary cell batteries since this needs to be a sealed, waterproof system. An off-the-shelf solution for this is the Qi wireless inductive charging standard. One chip which we could use for receiving power and rectification is the TI bq51222. There are many coil antennas available for purchase which we could use.

6 Engineering Content

The hardware engineering that we will need to complete includes picking out an microprocessor that fits our specifications. We will design a printed circuit board that includes the selected microprocessor and integrates an accelerometer and gyroscope sensor. The board will need to include its own power supply since it it will operate on the water. The team will have to solve how this power supply will be recharged, possible implementing wireless charging. We will need to collect and packetize the data and use a Bluetooth link to send that data to the end user where it will be processed. The team will also have to worry about how our board physically interfaces with the boat. It will need to be waterproof and have an external component that physically mounts the device to the oar. We will need to manufacture as many copies of the board as we have rowers, most likely four or eight.

The software engineering that the team will need to accomplish will be very challenging and crucial to the success of the project. Either the coxswain or the coach will have an IPad or some other computing device that receives the bluetooth signal from all of the the oars. This poses another problem that our team will need to solve, of how one device will receive eight signals in real time. Once we receive all the data packets successfully, we will need to process that data that provides a meaningful solution to the proposed problem we are seeking to solve. We will need to seperate the ‘dynamic’ data in order to isolated the motion of the oar separate from the motion of the boat itself. We will have to come up with an algorithm that processes that data and achieve the following objectives: (1) synchronizes all data packets with each other, (2) takes the raw accelerometer and gyroscope data and converts it to position of the oar, (3) detects the time of the catch and shows the user which of the oars are out of sync with the rest of the boat. Our team may add further objectives to the scope of the project if we accomplish our core objectives. Accomplishing these goals will be dependent on solving the problems listed previously. Our team considers converting the raw accelerometer and gyroscope data into an accurate position of the oar to be our biggest challenge and most crucial to the success of the project.

Once the design has been completed we will go through a series of tests and improvements leading up to the implementation of our design. We will first test using a prototype board with an accelerometer and gyroscope to evaluate our data processing algorithms. We will then test with an on land simulation of a single rowing stroke to verify our accuracy. From there, we can test our device using multiple oars. Ultimately, we hope to implement our project in a boat of the University's crew team.

7 Conclusions

This project aims to provide rowers with a way to visualize their performance and thus improve upon their technique. To achieve this we will design a system which tracks a rower's movements through sensors attached to the oars; the data provided by the sensors will then be processed and displayed in a format that allows for a coach or coxswain to easily see where the rower is lacking in their technique.

8 References

[1] http://www.usrowing.org/about-us/
[2] http://www.usrowing.org/rowing-quick-facts/
[3] http://www.peachinnovations.com