OarTracker

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1 Introduction.

Rowing is one of the most popular Olympic sports in the United States[1], with over 75,000 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 extremely demanding both physically as endurance is built and mentally as technique is perfected.

2 Problem Statement and Proposed Solution.

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.

Our proposed solution to the above problem is a system that collects data from the oar and transmits the signals through a bluetooth enabled device. The 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 a 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 a smartphone. 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.

3 System Requirements.

Goal: A low impact waterproof system that can be attached to an oar and used to provide technique feedback to rowers.

For the system to function properly, there are numerous requirements that must be met. The system will contain oar sensors that communicate with a smartphone application via Bluetooth.

The oar sensors must be light, such that the stroke of the rower will not differ from a stroke taken without the sensor. This will allow the analysis done with the sensor to generalize to all strokes taken by the rower. Each oar sensor will contain an inertial measurement unit (IMU) - a combination of an accelerometer and a gyroscope that provides data related to the oar orientation - in addition to a Bluetooth enabled (BLE) microcontroller. The BLE microcontroller will collect the data provided by the IMU and transmit it to the smartphone via Bluetooth. The BLE microcontroller, a key part of the oar sensor, must be able to transmit over distances of at least 30 feet such that data can be transmitted to a smartphone in the boat. The power consumption of the oar sensor should be low enough that the size requirements for the oar sensor are not violated by the battery size needed.

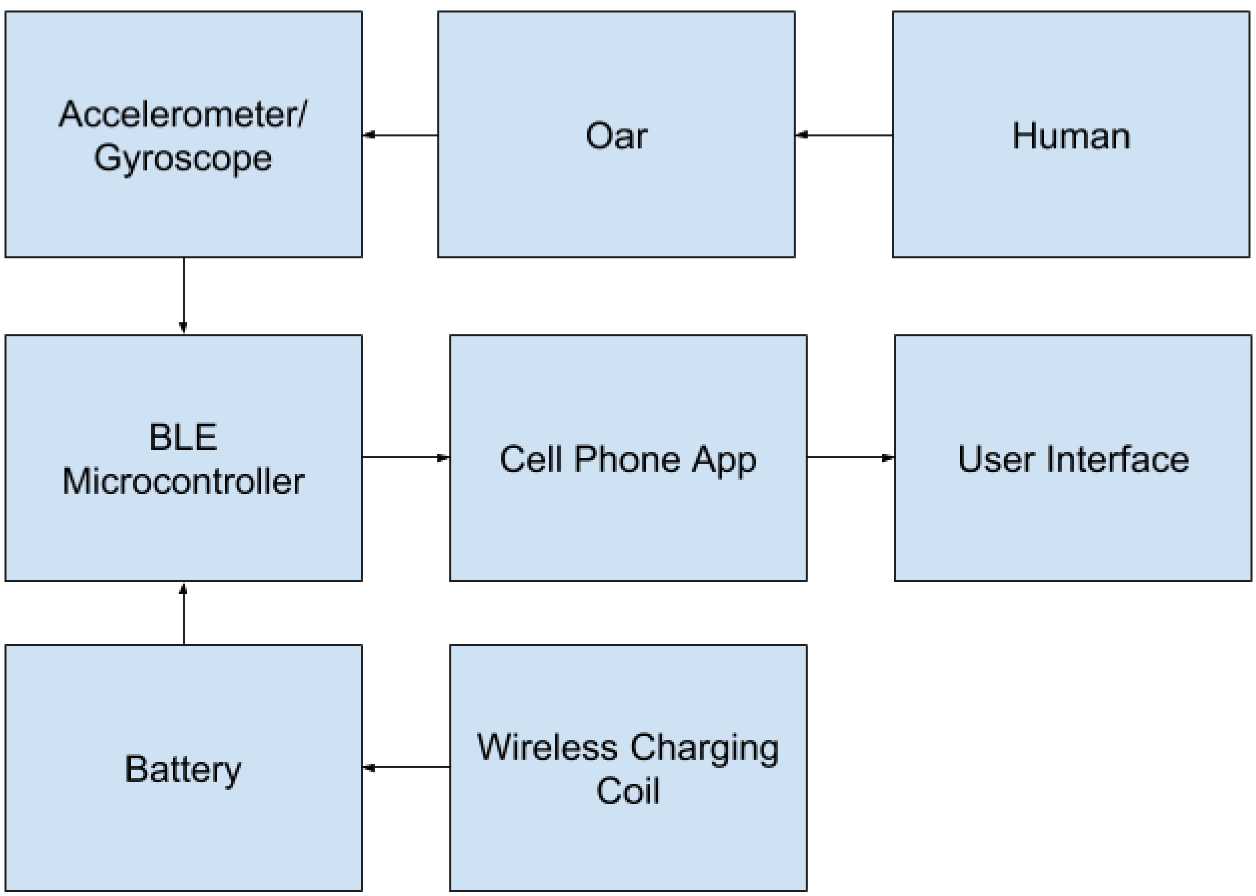
Additionally, the oar sensors must be waterproof so that they are able to function when submerged underwater. The waterproofing must be rated such that the electronics will remain dry throughout the length of a session - 2 to 3 hours. To accommodate the waterproofing, the oar sensors will be powered by a battery that can be recharged wirelessly, most likely a lithium ion battery. The battery should also be able to supply 3.3V for the length of a session and should be able to be recharged between sessions or within about 12 hours. The wireless charging module should be able to supply adequate power and should also support the Qi wireless charging standard.

The smartphone application will communicate with the oar sensors via Bluetooth: the smartphone will serve as the master and should be able to communicate with four slave devices. The application should run on an Android phone and provide the user with useful technique feedback. To accomplish this goal, the application should have an intuitive GUI and should also implement signal processing algorithms to display the most useful diagnostic information. The application should also be able to save information from the session so that rowers can track their performance over time.

Installation of the system should be straightforward: the application should be available for download and the oar sensors will include a way to attach them to the oar. The oar sensors should also include orientation indicators so that the proper measurements are made and the analysis will be correct.

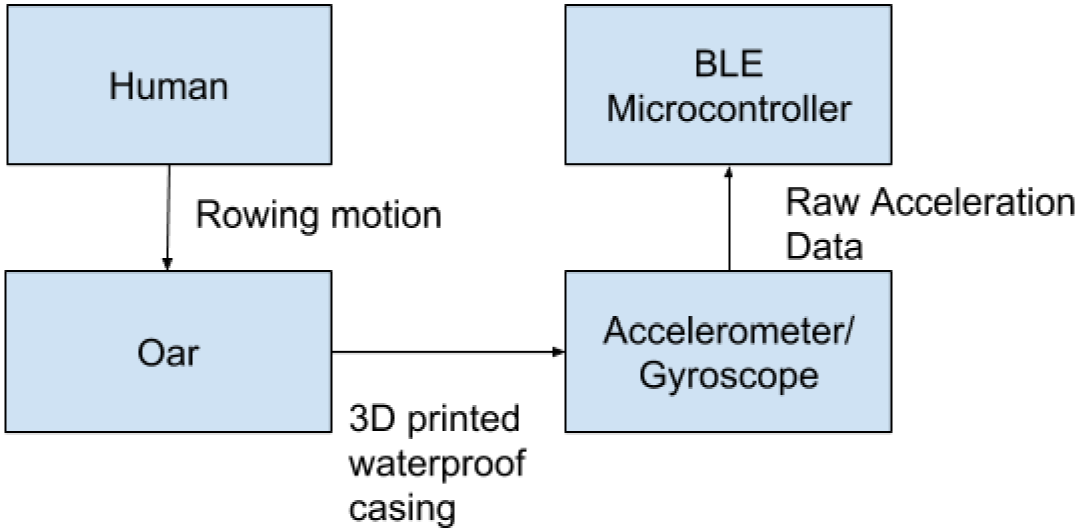
4 System Block Diagram.

4.1 Overall System:



4.2 Subsystem and Interface Requirements:

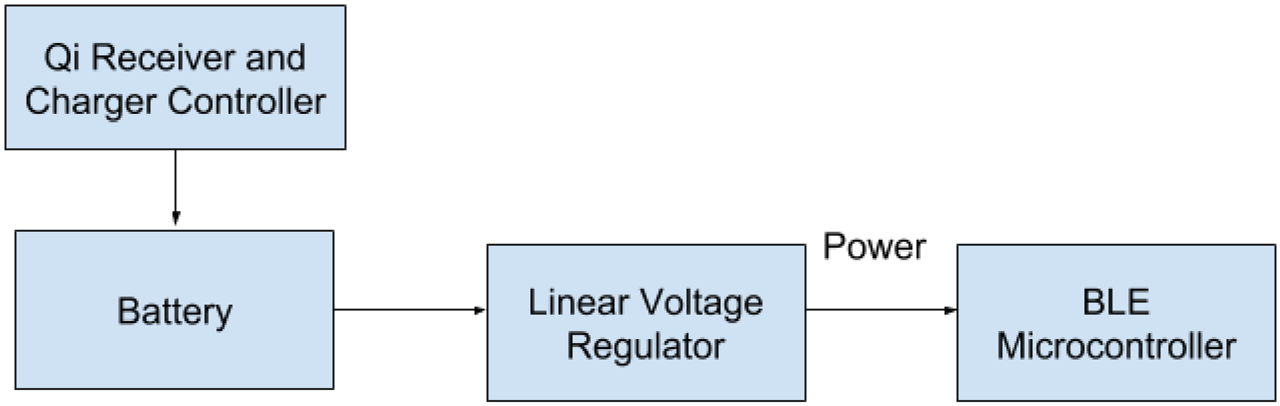
Oar and IMU Subsystem:



Subsystem Requirements:

1. Monitor rowing motion
    a. IMU with accelerometer and gyroscope tracks movement and orientation in X, Y, and Z
    b. Raw data is sent to BLE microprocessor
    c. Low power draw to comply with battery life requirements
    d. PCB manufactured to contain IMU and BLE microprocessor
2. Waterproofing
    a. 3D printed waterproof casing should protect hardware
        i. Should be large enough to contain PCB, battery, and wireless charging coil
    b. Can be easily attached to oar
3. IMU to BLE microcontroller interface
    a. Serial communications (I2C) to send sensor readings to the microcontroller
    b. Interface supports the maximum sample rate from the IMU

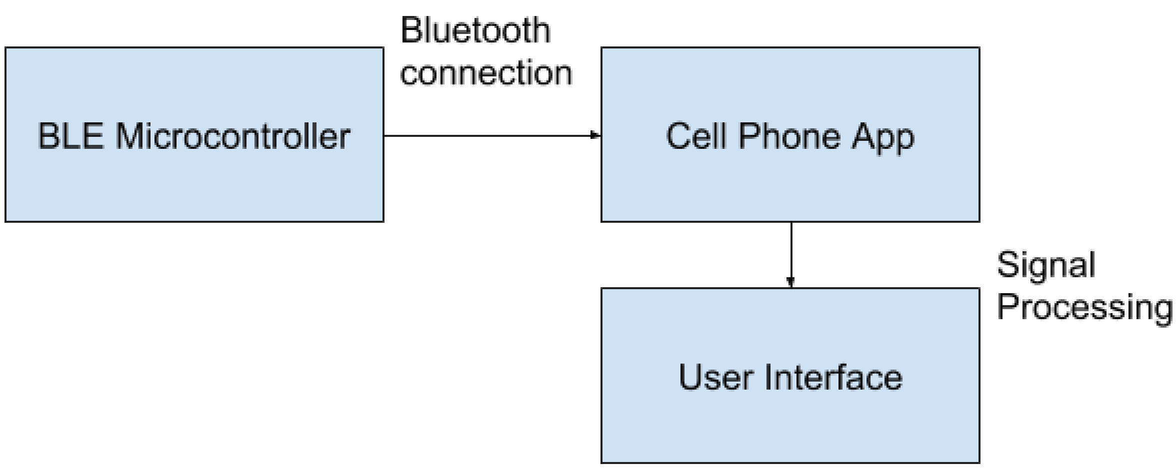
Wireless Charging Battery Subsystem:



Subsystem Requirements:

1. Qi receiver must reliably communicate with a Qi transmitter
2. Charger controller must regulate battery charging
3. Linear voltage regulator must convert output from battery into constant 3.3 V in order to power the BLE microcontroller

Data Processing Subsystem:



Subsystem Requirements:

1. Bluetooth interface
    a. Oar units able to send data to Android smartphone
    b. Smartphone can receive data from 4 oar units
2. Signal Processing
    a. Recognize key events throughout a stroke
    b. Determine timing differences between rowers
3. Cell phone application
    a. GUI
        i. Display stroke information for all rowers based on the results of signal processing

ii. Display timing comparisons and indicate if a rower is consistently out of sync

b. Can communicate with 4 oar units via Bluetooth

4.3 Future Enhancement Requirements:

- *8 person boat compatibility*: As a reasonable goal for the project, we have chosen to design the system for a 4 person boat. With this goal, the Bluetooth interface will be less complicated to manage and can be implemented under the time constraint of the project. However, once the system is working on a 4 person boat, it could be extended to work with an 8 person boat by modifying the Bluetooth interface and smartphone application to work with more than 4 slave devices.
- *Visualization of the oar*: The initial requirements for the GUI simply require a way to display the data to the user. This could be expanded such that the analysis is presented in a more intuitive format, such as a visualization of each oar based on the timing and position information.
- *Direct transmission to coach*: The prototype will involve components within the boat only, but could be enhanced to allow stroke data to be sent directly to a coach on the bank or in another boat. This would involve working with the Bluetooth connectivity of each unit to ensure that it would be powerful enough to transmit to the coach. The coach would then be able to provide real time feedback to the rowers instead of analyzing the data after the session.
- *Store session information*: The prototype will display instantaneous stroke diagnostic information, but in the future it would be useful to incorporate the ability to store all information from a session. This data could then be analyzed further and sessions could be compared over time to track progress.

5 High Level Design Decisions.

Inertial Measurement Unit (IMU): An inertial measurement unit will be used to measure the characteristics of the stroke because it contains both an accelerometer and a gyroscope, allowing the acceleration and orientation of the oar to be determined. Both of these measurements are needed so that the oar can be tracked throughout the stroke. Additionally, IMUs are available in packages that can be easily incorporated into a PCB. The IMU will be powered by the battery at 3.3V and an internal clock will be used. One possible option for the IMU is the BNO080 made by Hillcrest Laboratories[4].

This sensor is able to communicate via I2C, has low power consumption, and will provide the information needed to determine stroke characteristics.

IMU to BLE Microcontroller: I2C was chosen as the serial interface between the sensor and microcontroller because for testing with an Arduino, I2C will be the interface. Therefore, to reduce the number of changes between testing and building a prototype, I2C will also be used to communicate with the IMU in the prototype.

BLE Microcontroller: The processing on the oar unit will be handled by a Bluetooth enabled microcontroller. The BLE microprocessor must be able to handle I2C communications with the IMU so that samples may be taken and subsequently transmitted to the smartphone over Bluetooth. Bluetooth was chosen as the transmission technology because of its low power use, which will keep the required battery size to a minimum. Additionally, long distance transmissions are not necessary as all components will be close together, so a more powerful technology is not required. The BLE microcontroller will be powered by the battery at 3.3V.

Wireless Charging: Qi wireless charging was selected as the method for recharging the battery because this will allow the device to be completely waterproof. It is possible to implement waterproofing without wireless charging, as can be seen in many popular devices, but it will be less of a risk to completely close off all of the electronics in the device.

Cell Phone App: A cell phone app was chosen to serve as the GUI because it is easily accessible given the ubiquity of mobile phones. Additionally, the small form factor is essential as the device must be small enough to fit in the boat without hindering performance. There are available libraries that can assist us with developing communication between the application and the bluetooth devices. The phone also has access to more memory and processing power, allowing a more advanced analysis to be done.

6 Open Questions.

One thing we are unsure of how to successfully accomplish is the mobile application. No one on our team has experience in developing mobile applications. For our system to be successful we will have to develop an application that can communicate with several bluetooth devices. Switching between several bluetooth devices will be a challenge, and this feature may not work in the way we are planning for it to work.

Another aspect that could hinder our project's success is time delays. We will experience time delays in many of the subsystems: time it takes for the microprocessor to analyze the sensor data and identity the catch, time it takes for the data to be transmitting from the devices on the oars to the mobile application (specifically this will include switching time between the phone and the devices), and processing time it takes for the mobile application to display the data. Each of these time delays should be inconsequential on its own, but may compound to a consequential error between physical catch time of the rowing, and the catch time displayed in the mobile application.

An additional open question is the calibration of the sensors. Identifying the moment of the catch will require the program to have accurate threshold values for the gyroscope and accelerometer data. This means that for a robust program, we should calibrate the sensor at the beginning of each session to ensure the threshold values are accurate. If the threshold values are off, then the program will be unable to identify the part of the stroke, making our system useless.

We will likely need to prototype the wireless charging subsystem before we build the full board. Since wireless charging is not the main goal of this project, it is possible that we will decide to use a 3V coin battery instead if we determine that this subsystem is too complex to implement in our prototype device.

7 Major Component Costs.

Component	Possible part or source	Cost ($)
Bluetooth microcontroller	RSL10, CC2640R2F, or nRF51822	8.22, 5.36, 4.03
6 axis inertial measurement unit (IMU)	BNO080, ADXL345	13.48
PCB/stencil	Oshpark	25
3D printed case	Notre Dame 3D printer	0
Qi receiver/battery charger IC	BQ51051B	4.76
Buck/boost converter	TPS63030	2.20
Battery	HPL402323-2C-190mAh	7.14

Charging coil	IWAS-3827EC-50	3.39
Qi transmitter	Yootech wireless charger (Amazon)	14.99

Based on the data above, we estimate that the cost per device for components and PCB will be around $60. It is our goal to make several of these devices. Additionally, we will need to buy a Qi charger, which is a one-time cost.

8 Conclusions.

This project will produce a device that is capable of providing vital technique analytics to rowers, enabling them to push their limits as they perfect their strokes. As a lightweight device that can be attached to an oar, this solution is easier to install than other existing solutions, where the oar or oarlock must be replaced with a version with built in sensors[3]. The system will be able to collect the necessary acceleration and orientation data, transmit this data to a cell phone, and extract technique information from this data before displaying the results to the user. The oar sensors will provide rowers and coaches with a deeper awareness of the subtle changes that can make or break a race, and will serve as an essential tool on the path to victory.

References

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[3] http://www.peachinnovations.com
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