Skier’s Helpful Information Tracker

ECE 445 - Design Document

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Team #52

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Introduction

a. Problem

Slalom skiing is one of the main events in competitive waterskiing. In this event, the competitor starts by passing through an entrance gate, skis through a course with 6 fixed buoys, and finishes by passing through an exit gate. The scoring for this event comes from a combination of speed and the length of ski rope used. In this case, a faster speed and shorter rope will lead to a higher score. If a skier misses either gate or does not clear even a single buoy, their run is over, and they cannot score any more points. This means that competitive skiers are very precise in their passes and require precise feedback in order to get to the 'next level.'

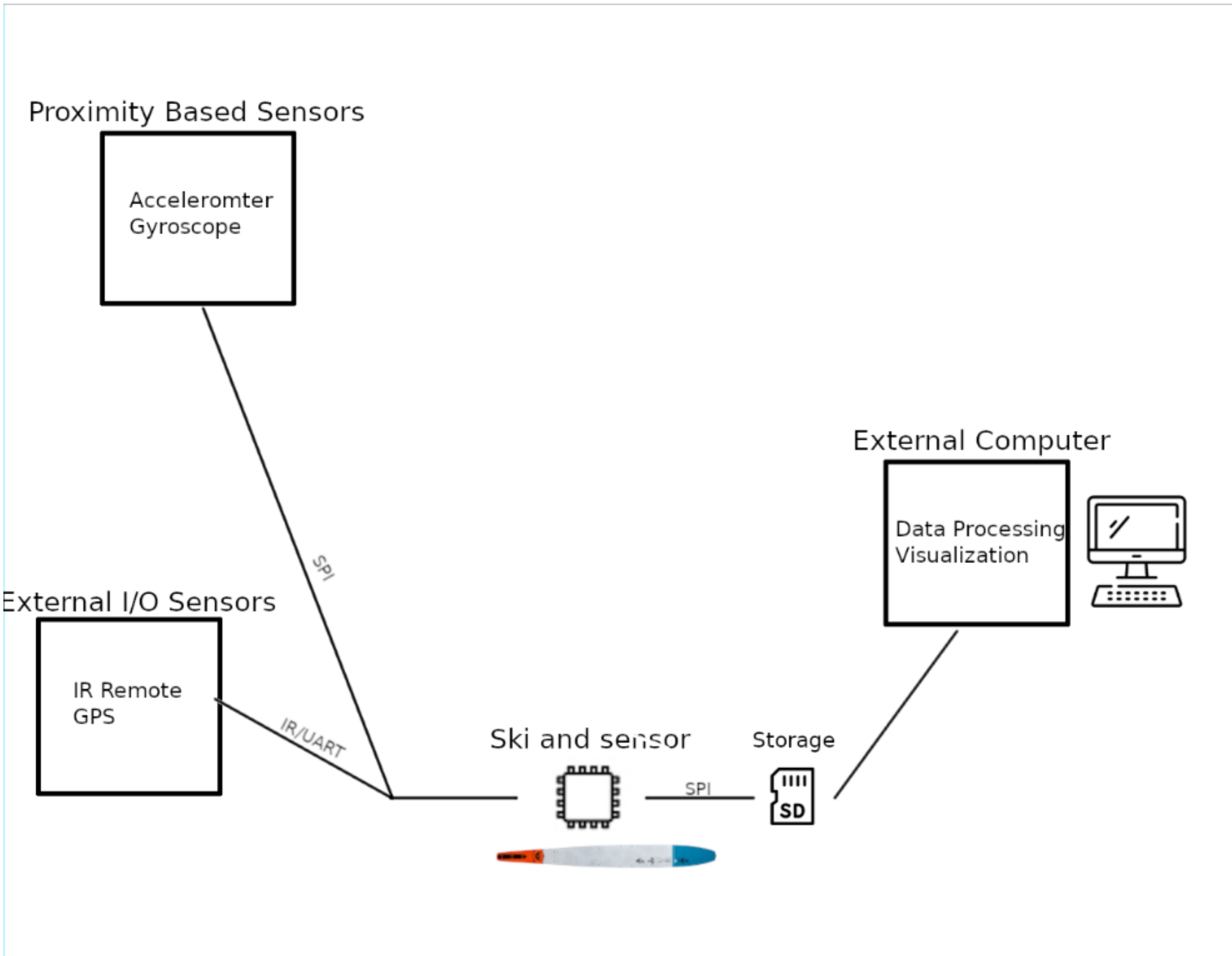
The main source of feedback for skiers is currently video playback and coaching advice. While videos are very easy to take with smartphones and accessible to almost anyone, video alone does not provide very detailed analysis of a skier's pass. A waterski coach is both expensive and difficult to find, so they are not accessible to everybody in the sport. This project aims to provide high-quality, precise feedback to slalom skiers in an affordable, accessible manner.

b. Solution

Our solution involves a Printed Circuit Board that will house sensors to get data on ski runs. The main sensors are a GPS for positioning on the run, an accelerometer to get acceleration and speed data, and a Gyroscope for getting the tilt of the ski. We will be using a microcontroller to read and format this data and write it to an SD card. Also housed in the PCB will be a battery and battery management for power, some status LEDs for debugging and information while skiing, and an IR receiver for wireless control.

The second part of our product is data analysis. We figured that the data analysis required for this project is too processing-intensive to be done a micro controller, so we plan to save all sensor data to an SD Card. This SD card will be removed from the device after the skier has performed their runs and inserted into a computer program. The program will use Kalman Filtering, Google Maps API, and more data processing to convert the data into something that can be used by the skier for their information.

c. Visual Aid


Proximity Based Sensors
Acceleromter
Gyroscope
SPI
External Computer
Data Processing
Visualization
External I/O Sensors
IR Remote
GPS
IR/UART
Ski and sensor
Storage
SPI
SD

d. High Level Requirements

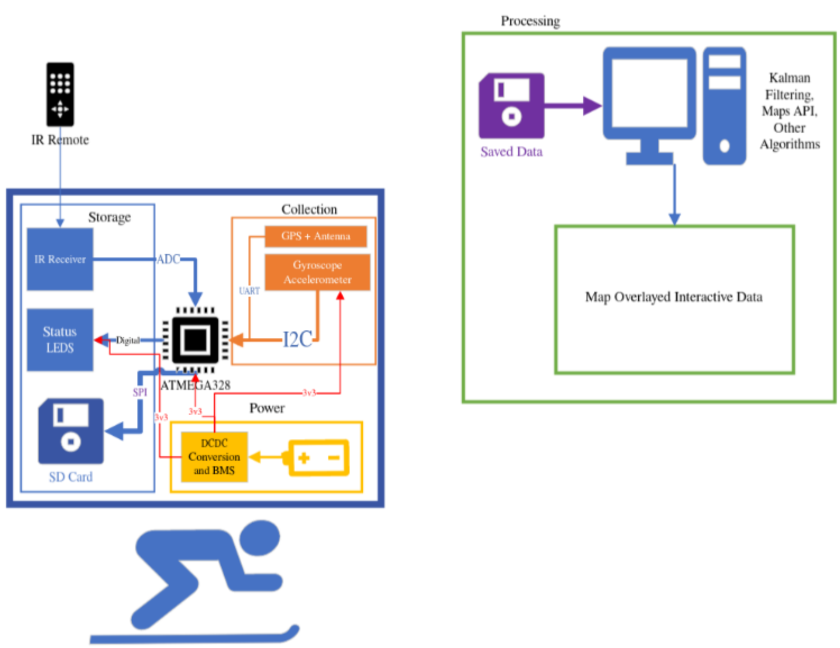
1. Waterproofness and Efficacy for Skiing:
    a. We require that our device can be submerged at up to 10 feet for 3 minutes to test initial waterproofing. The next part is that the device must be successfully attached to the ski so that it does not fall off or get wet during a water-skiing run.
2. Accuracy:
    a. We want to make sure the data we collect is accurate. Our GPS should be accurate to within 3m. Our accelerometer should provide accurate acceleration and speed within 10%. Our gyroscope should also be able to provide tilt accuracy in all dimensions within 5%.
3. Multiple Passes:
    a. Since a skiing run includes more than one pass in a short amount of time, it is important that we can save multiple runs without opening and manually resetting the ski tracker. We will use an IR receiver and transmitter to start and end each run. This can be held by someone on the boat or even attached to the skier. We want to be able to house 10 passes before the SD card needs to be shifted out.

Design

A) Physical Design

*Waterski not included with product

B) Block Diagram



C) Power Subsystem –

The power subsystem will be a compact system that provides power to the other subsystems both for data collection and storage. We will strike a balance between weight and capacity to ensure that the device can function for an extended period without needing to recharge the batteries while also not inhibiting the skier's run.

Requirements	Verification
The battery will last for two hours to ensure that the skier can successfully use the device to record multiple passes, even if they take a break for a period of time.	When running initial tests for other subsystems, we will leave the device on for this period of time and monitor the battery status LEDs.
Each component will be supplied with 3.3 VDC (+/- 0.1 V) with a maximum of 1.5 A of current.	We will use a multimeter to check voltage across test loads (resistors) before applying the battery to real components. We will use a fuse to ensure that current does not exceed its maximum value.

D) Collection Subsystem –

This subsystem consists of sensors used for data collection during ski passes. The key data we want to collect is location, speed, acceleration, and tilt. We will be using a GPS for position and speed data, an accelerometer for acceleration, and a gyroscope for tilt data. The data will be passed to our Microcontroller to be processed and stored. The GPS uses UART to communicate with the MCU while the gyroscope and accelerometer use I2C. The MCU will be able to read the data, format it, and send it off to our Storage Subsystem.

Requirements	Verification
MCU must be able to format the data fast enough so that the 10Hz, or potentially higher, sensor polling does not overflow any buffers	Will test with actual runs and see if we have all data saved. Will use GPS clock and system timer to see if data is correctly polled.
Ability to save "calibration" data. The GPS must be able to save data of the first and last gates so our Processing Subsystem can lay out the course.	Will test in either parking lot or lake depending on weather conditions. Will be able to check data on our SD card.

E) Storage Subsystem –

This subsystem will consist of three things, a mode selector, status LEDs, and a storage device. We will use an SD card as our storage device, this will be what is the go between our collection and processing subsystems. After a successful day of skiing, the skier will be able to take the SD card out of the device and into a computer to run the processing subsystem. For our mode selector, we will use an IR receiver and remote that can be controlled from the boat so the skier can focus on skiing. For the status LEDs, we can transmit information about whether the device is ready, actively recording a run, or an error.

Requirements	Verification
IR receiver and remote will be able to have multiple functions that are mapped in the MCU to do different things.	Using an IR Remote with only one IR receiver, we will verify first by using LEDs to represent the distinct functions. After testing, we will map them to different collection functions such as start new pass, calibrate, and reset.
The SD Card must be able to store 10 full passes of the ski without being offloaded.	We will test in either a parking lot or lake depending on what weather permits. We will attempt 10 passes and a calibration run and then look at if the SD card was able to hold all the data.
The Status LEDs must be able to show all device states. We will have states for Calibration Mode, Standby Mode, Active Mode, and Error mode.	This will be tested by using the IR remote to cycle through all modes and will be verified by visual inspection.

F) Processing Subsystem –

Our processing subsystem is the final of our parts as it will take data that has already been used by the other three. This subsystem is located off our PCB device and off the ski on a host computer. The processing subsystem will let a skier understand the data. There are two main parts of the subsystem, smoothing and display. For smoothing, we will be using Kalman Filtering and other algorithms to take our data from the collection subsystem and make it more usable. Next, we will use the Google Maps API and other display APIs to get our data in a readable manner. We will be able to show how the skier did on their pass using a combination of these two things.

Requirements	Verification
The data smoothing and filtering will make our GPS, accelerometer, and gyroscope data more accurate and smoother.	We should be able to see a difference in accuracy between the pre- and post-smoothed data after it has been displayed on a map
Using the Maps API, we should be able to create an interactive map that links our data to a map so that the skier can see how they did during the run.	We will verify this by taking our pass and calibration data and displaying all data points collected on a map, the 2 gates and 6 buoys.

G) Tolerance Analysis –

The important tolerance to consider when designing the tracker is the geforce exerted on the skier by the pass they are taking. We need to ensure that our components will stay neatly inside the box and not be damaged by the motion forces applied by the pass. The following math is an estimation of geforce simply using other skier's pass data.

Constants:
70mph=31.3m/s (estimated max speed of a pro)
30mph=13.4m/s (estimated speed at the bouy)
38ft=11.6m (distance between the ball and the center of the wake)

$$V_{final}^2 = V_{initial}^2 + 2 * a * d.$$
$$a = \frac{31.3-13.4}{2*11.6} = 34.5m/s$$
$$g = 9.81m/s$$
$$geforce = \frac{34.5}{9.81} = \ 3.5g$$

We found that this level of geforce will be no problem for the waterproof box and velcro system ordered. The maximum geforce rating of the system is well above 10g, and the mounting holes in the PCB as well as Styrofoam for the box will ensure that the components will not be damaged during skiing.

Cost

A) Cost Analysis –

Component	Price
Gy-521 MPU-6050 (Gyro + Accelerometer)	$13.71
SD Card	$10
SD Card Reader	$9
TSOP93438 (IR Receiver)	$1.06
44 Key RGB LED Strip Light Remote (IR Remote) from Amazon	$6.99
2011 3.7V 2AH Lipo Battery	$12.50
GPS	$31.99

ATmega328-AU (MCU)	$2.24
Clear Waterproof Case	$30 +/- $5
USB-C Charging Port	$7.35

B) Schedule –

Week	Everyone	Jack	Ryder	Sam
Week 1 of 02/26	Design Check	Board Schematic and finish part selection	Help with Board Schematic & Bread Board Testing	Start learning Maps API and create mock data for testing
Week 2 of 03/04	Finalize Design	Finish Layout	Help with Layout and Start Firmware	Use Maps API on mock data
Week 3 of 03/11	Spring Break	Spring Break	Spring Break	Spring Break
Week 4 of 03/18	Discuss hardware with machine shop	Solder and test board, revise board design	Work on simple firmware on board and help revise board	Begin Kalman Filtering on Mock Data
Week 5 of 03/25	Individual progress reports	Help with firmware, revise board again	Work on updating firmware to link all subsystems	Using Mock data, finalize software workflow
Week 6 of 04/01	Finalize	Finalize Board design and one last board run	Finalize Firmware for on board design	Apply Software to real data
Week 7 of 04/08	Finalize	Hardware	Firmware	Software
Week 8 of 04/15	Mock	Demo	Mock	Demo
Week 9 of 04/22	Final	Demo	Final	Demo
Week 10 of 04/29	Final	Presentation	Final	Presentation

Ethics and Safety

Ethical Issues:

Since the data will be processed externally, location data will be available to potentially be misused. To avoid any potential misuse of this data, it will be saved on an SD card instead of being sent to the internet.

Safety Issues:

Outside of the safety risks associated with waterskiing, this device will not add any extra risk to the sport.

IEEE or ACM Code of Ethics Citations:

The ACM Code of Ethics section 1.6 discusses respecting privacy. Our product will make sure to store no information for outside parties to access. While we must store location information for usage by our processing algorithms, we will not access other users' data, and all data will be held locally.