ECE 445
Senior Design Laboratory
Project Proposal

Real-Time Golf Swing Tracker

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Contents

1 Introduction

1.1 Problem

Mastering the golf swing is a complex challenge with nuances that can be difficult to grasp without precise feedback. Current training methods often rely on professional coaching and visual observation, which might not be readily accessible or affordable for all golfers. Additionally, the subtle mechanics of a golf swing, including swing path, speed, and force, are not easily quantifiable through mere observation. There's a growing need for a more accessible and scientific approach to golf training that leverages modern technology to provide real-time, detailed feedback directly to the golfer.

1.2 Solution

We propose to develop the Real-Time Golf Swing Tracker equipped with an integrated sensor system and a companion mobile application to analyze and improve golf swings. The core of our solution involves embedding accelerometers, gyroscopes, and force sensors within the grip of a standard golf club. These sensors will capture critical data points such as swing speed, angle, and grip pressure during each stroke. This data is then processed by a microcontroller that filters and interprets the raw sensor outputs. The processed information is wirelessly transmitted to a mobile application that provides the golfer with immediate visual feedback and historical data analysis.

1.3 Visual Aid

We provide a visual aid of our Real-Time Golf Swing Tracker in Figure 1. Data gathered from the swing will be transferred into the mobile app through bluetooth.

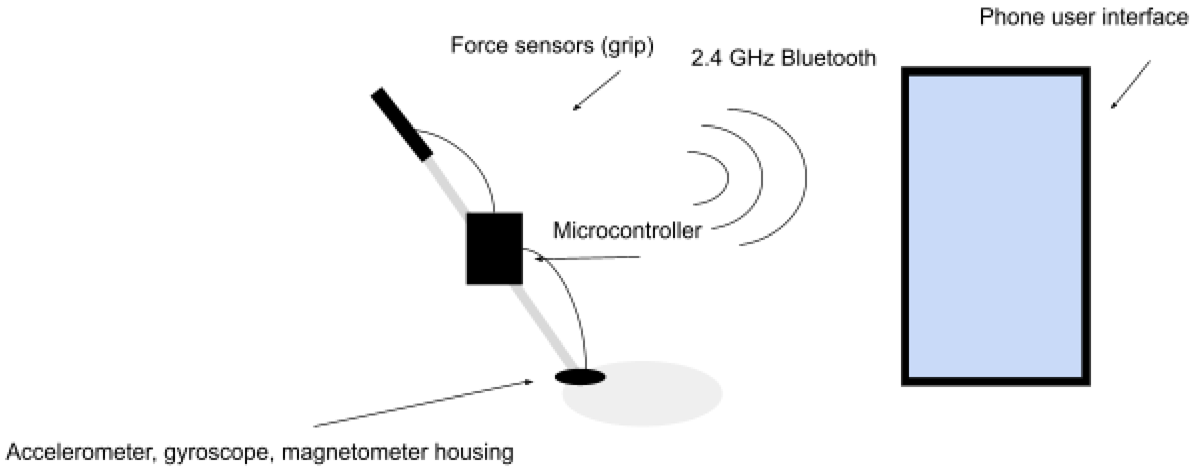


Figure 1: Visual Overview of Real-Time Golf Swing Tracker

1.4 High Level Requirements

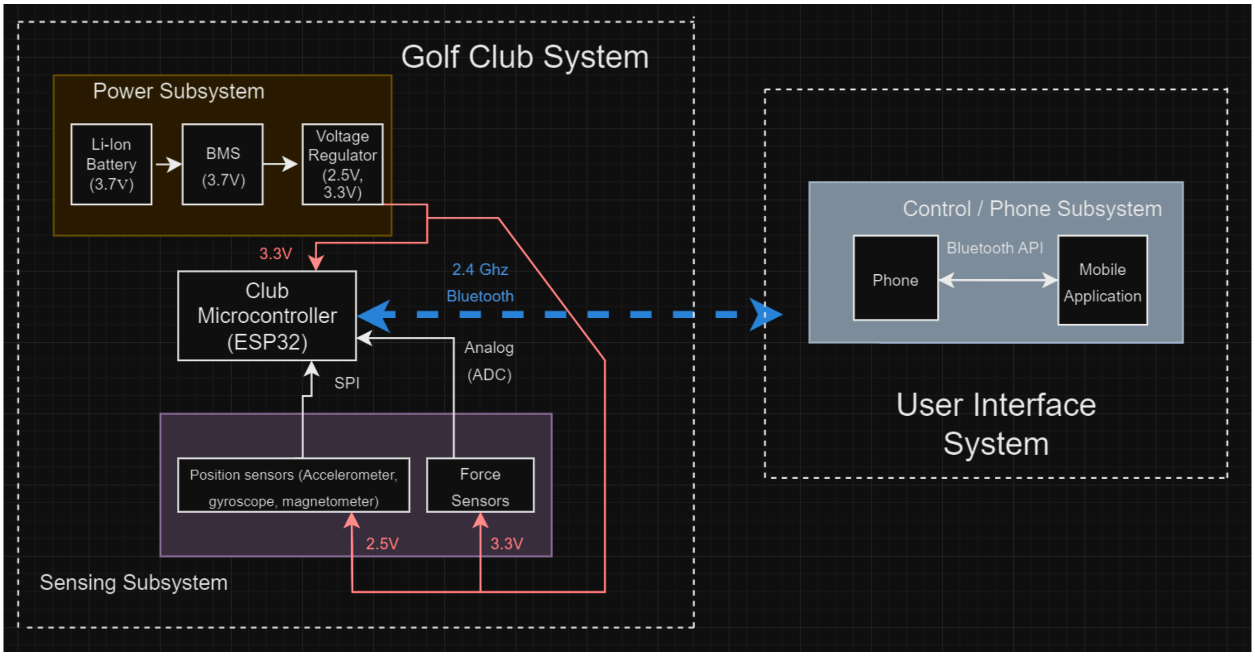
a. All sensors integrated into the Smart Golf Club, including accelerometers, gyroscopes, and force sensors, must maintain a tolerance of accuracy within 20%. This level of precision is essential to ensure that the data collected is consistently reliable and reflects true performance.

b. The user interface of the Smart Golf Club's accompanying mobile application is designed to display data in real-time, ensuring that all information is updated and presented to the user within 5 seconds following each golf swing. This prompt update allows golfers to immediately see the impact of their swings on parameters such as swing speed, angle, and force, facilitating on-the-spot adjustments and learning.

c. The total weight of the Smart Golf Club, after integrating all hardware systems including sensors, microcontroller, and power supply, should not exceed a 5% increase over the weight of a standard golf club. This stringent weight threshold is essential to ensure that the club retains a natural feel and balance, allowing golfers to swing with their usual technique without adaptation to added bulk.

2 Design

2.1 Block Design



2.2 Subsystem Overview

Our project is divided into a total of four subsystems as outlined below.

2.2.1 Power Subsystem

This subsystem ensures that all electronic components within the golf club are adequately powered during use. We will be using a lightweight, durable battery capable of providing consistent power to necessary subsystems for extended periods, ensuring usability through multiple rounds of golf. This battery cell will be replaceable.

2.2.2 Sensor Subsystem

This subsystem includes accelerometers, gyroscopes, and force sensors integrated into the golf club's grip. These sensors capture real-time data on swing speed, angle, and grip pressure. They will be attached right above the golf head, allowing for accurate sensing when the club swings up and down. Also, force sensors will be utilized to sense the grip force from our hands to the golf grip. We would insert sensors under the grip such that the pressure resulting from our hands will be transmitted to the microcontroller.

2.2.3 Microcontroller Subsystem

The microcontroller subsystem processes data from the sensors, executes filtering algorithms, and manages wireless data transmission to the mobile application. The ESP32 microcontroller will manage real-time data processing from all sensors while supporting Bluetooth communication for swing data transmission to the mobile application. Sensors will be connected to the microcontroller through the GPIO and ADC allowing for digital and analog transmission.

2.2.4 Mobile Application and Data Analysis Subsystem

A comprehensive app that receives data from the golf club's microcontroller. The user interface displays real-time analytics and historical trend analysis to help golfers understand and improve their swing techniques. High-level/process-intensive code will be run from the mobile application to perform any algorithms or potential ML to analyze golf swings. The application will most likely be exclusively hosted as an Android application for easier development.

2.3 Subsystem Requirements

2.2.1 Power Subsystem

a. The subsystem must supply at least 500mA, continuously at 3.3V ± 0.1V.
b. The subsystem must integrate a charging circuit capable of fully charging the battery within 2 hours.
c. The battery should last for at least 10 holes of golf on a single charge without performance degradation.

2.2.2 Sensor Subsystem

a. All sensors must maintain a tolerance of accuracy defined in tolerance analysis (2.3) to ensure reliable data.
b. This subsystem must function effectively under the environmental conditions typically experienced on a golf course (rain, strong wind).
c. Accelerometers and gyroscopes must update their readings at least 1000 times per second to capture dynamic swing data accurately.

2.2.3 Microcontroller Subsystem

a. The microcontroller subsystem must have sufficient processing power to handle data from multiple sensors without lag, ensuring data processing latency of less than 500 milliseconds.

b. This subsystem requires embedded Bluetooth capability with a range of at least 10 meters to maintain connection with the mobile application.

2.2.4 Mobile Application and Data Analysis Subsystem

a. This subsystem must update and display data within 5 seconds of receiving it to ensure real-time feedback.
b. It requires robust error handling to manage potential data transmission errors over Bluetooth.
c. Our subsystem should be compatible with major mobile operating systems (iOS and Android) to ensure wide accessibility.

2.3 Tolerance Analysis

a. Sensors
    i. The force pressure sensor has a part-to-part repeatability of around 4% and 2% uncertainty of force readings from a single component. Given that, the uneven pressure given by a golf grip, and the variance of data through the microcontroller being received over 2.4GHz RF, we hope to expect a 10% accuracy tolerance of the force sensors.
    ii. On the MPU-9250, we can expect a range of 16g for the accelerometer, 2000 dps for the gyroscope, and 4800µT for the magnetometer. Given our application, we can hope to expect a 5% tolerance.
b. Wireless communication and user interface
    i. We want at least 100 Kbps, a latency of 20-30 ms, and a less than 1% packet loss from our bluetooth transmission and our android app to crash less than once per hour of use.
c. Power
    i. We would aim for our li-ion and voltage regulator to be within 3% range of 3.3V and 10% range for current draw across all subsystems.

There are two main systems that require analysis in our project, the wireless communication latency with the amount of data we are processing, and ensuring we sample our sensors at an adequate rate to reach the information processing desired while also not putting too large of a strain on the ESP32's small digital memory.

The MPU9250 has 3 axes on each of its sensors; accelerometer, gyroscope, and magnetometer. We are given that BLE4.2 has a throughput of 700 kb/s, the 9 sensors on our IMU operate at 32 kHz, and the ESP32 GPIO pins can reach a theoretical 240 MHz rate which is plenty to reach the desired data rate. The force sensors are resistive so it is through the ADC pin, which is 6 µs on the ESP32. Given that we can find the frequency using

$$fmax_{ADC} = \frac{1}{6*10^{-6}} = 166.67kHz$$

Which is also well above the desired range of frequency we want to send to the web-app. With all this in mind and given the fact that each data point will be 4 bytes as a float, the hardware involved is viable to collect data fast enough to reach our specifications.

3 Ethics and Safety

Regarding ethics, our group will follow the IEEE Code of Ethics:

1. **"To Uphold the highest standards of integrity, responsible behavior, and ethical conduct in professional activities"** [1]
   In order for this code to be effective, our group will maintain a strict schedule of weekly meetings to review and discuss accomplishments and improvements. This way, we will be able to continue to keep a high standard of professionalism.
2. **"To treat all persons fairly and with respect, to not engage in harassment or discrimination, and to avoid injuring others"** [1]
   To ensure that no one gets harmed throughout the semester, we created a group chat in our phone / discord so that no one gets left behind. Also, when only two people can make it to meetings, we have created a Github repository to keep track of what was done to store information for the next meetings. Moreover, since we are handling a golf club that may lead to dangerous situations, we need to ensure enough distance between members when the swinging happens and that no one is swinging alone, but with a team member present in the same room for secondary assistance.

4 References

[1] IEEE. “”IEEE Code of Ethics”.” (2016), [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html (visited on 09/19/2024).