TENNIS SWING ANALYZER

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INTRODUCTION

Objective

When playing tennis, tennis beginner often resort to their wrist or forearm to perform a strong forehand or stroke. Such badly performed swing do not necessarily result a weak stroke and is hard for beginners to realize. However, if the players keep performing bad swings, in the long run these non-standard swings could a accumulate hard to their body, resulting diseases such as wrist injury and tennis elbow. Therefore, it is important not only to hit the ball properly but also to hit the ball with a well performed swing.

We want build a tennis racket swinging analyzer that can analyze and determine if a swing is standard or not for tennis beginners. It measures the player's motion using a set of acceleration sensors. Their data are retrieved and calibrated by a micro-controller and then transmitted to personal computer via Bluetooth devices. We plan to take several standard swings and non-standard swings, collect their acceleration data and label them standard or non-standard respectively. A classifier would be trained on these data to determine whether the swing is a good swing or not and a speaker will directly report the result to the user in real time.

Background

There have been several well developed product on the market. Most of them focus on the recording characteristics such as intensity, speed, and trajectory of each swing. One example is Zepp Tennis Swing Analyzer, which is a small sensor integration attached to the bottom of the racket and transmit the collected data to a mobile device for ad hoc analysis. Another set of products focus on analyze the player's performance in a full match. Pivot, product from TuringSense is a system consist of a total of 14 sensors that aims to analyze people's 360-degree motion [1]. While this product is provides professional insight into the player's performance, it is of high price and is hardly affordable for amateur tennis beginners.

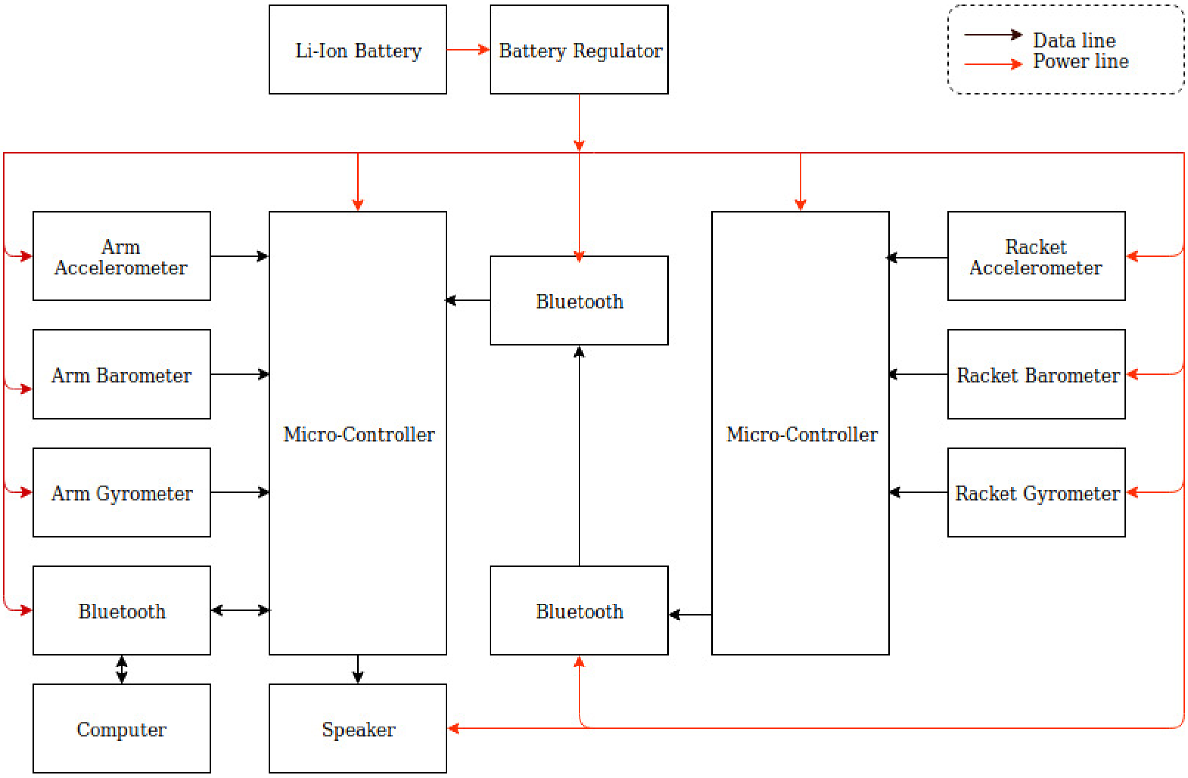
We observes that the critical part of a standard swing is the wrist part, which controls the racket to roll over or whip over the ball but should remain a laid back position before, at and after hitting the ball [2]. It is through spinning the wrist that the racket head achieves the highest speed, yet such spinning is strictly constrained in order to perform steady strokes. Most non-standard strokes could be attributed to an unconstrained wrist movement. We therefore simplify the design to use only two sets of sensors to measure the accelerations of mainly the wrist and forearm movements. This design would capture the most important part of a tennis swing and provide a good insight into the whole swing motion.

High-Level Requirements

1. Accelerometers successfully measure the acceleration of racket and wrist.
2. The classifier correctly classifies a good swing and a bad swing.
3. Players can directly get feedback of the performed swing from speaker.
4. The design is affordable for amateur tennis players.

DESIGN

Block Diagram



Functional Overview

Sensoring Subsystem

We plan to have two sensorsets, each set consists of a accelerometer, a gyroscrope and a barometer, with one set on the forearm and the other on the racket. Each subsystem is powered separately. By using data collected from three sensors, we can track each swing position in order to keep track of racket's motion in a higher accuracy.

Block Requirement:

1. Able to return the acceleration sampled at a rate of 100Hz

Arm Microcontroller Subsystem

The microcontroller will calibrate the sensor and setup the Bluetooth at the beginning. Then it takes sampling data from the three sensors at a frequency of 100Hz. Then it performs Kalman filter to get a combined estimation of the position, rotation and acceleration of the racket.

In the training phase, the data will be preprocessed and then send to Bluetooth device. In the application phase, after preprocessing the data, it perform classification directly using trained classifier transported from the computer and signal the speaker to report the result.

We plan to use Teensy 3.2 microcontroller. It is a micrcontroller with 32 bit ARM cortex and it contains 64kB RAM and 34 digital pins as well as support for real time FFT computation. It has an input voltage of 3.3V and operating current of 250mA It can be ordered from Sparkfun[1].

Block Requirement:

1. Support real time FFT computation.
2. At least memory of 16 kB and above.
3. Support 3 ports to connect sensors
4. Support 2 Bluetooth module.

[1] https://www.sparkfun.com/products/13736

Racket Microcontroller Subsystem

The microcontoller subsystem on the racket is similar to Arm Microcontroller because it also needs to calibrate the sensors on the racket and setup the Bluetooth. However, it does not need to perform signal processing such as Kalman filter because it only collects data from the sensors and transmit them via bluetooth to Arm Microcontroller for further processing in both training phase and application phase.

Since the microcontroller on the racket does not require any additional features that Teensy 3.2 would not support. It will be simplier to reuse the same microcontroller as the racket microcontroller subsystem.

Block Requirement:

1. At least memory of 16 kB and above.
2. Support 3 ports to connect sensors
3. Support 1 Bluetooth module.

MC-MC Bluetooth Subsystem

Transmit data from Racket Microcontroller to Arm Microcontroller. **Block Requirement**:

1. At least memory of 10 kB or above.
2. The data sent from the Racket Microcontroller must be able to received by the Arm Microcontroller with successful rate at least 90%

MC-PC Bluetooth Subsystem

Transmit data to the personal computer in training phase and do nothing in application phase. This is a one-way communication from microcontroller to the computer.

Block Requirement:

1. At least memory of 10 kB or above.
2. The data sent from the Racket Microcontroller must be able to received by the Arm Microcontroller with successful rate at least 90%

Computer

The computer would receive data from Bluetooth. In the training phase, the computer would be collecting a set of standard and non-standard swing accerlation data, labels manually. Features are extracted and a classifier (may consider using RNN or HMM) is trained using these features and labels.

In application phase, the trained classifier will be stored on Arm Microcontroller and all the task would be performed on micro-controller.

Block Requirement:

1. The classifier needs to reach a sufficiently high($\geq 90\%$) accuracy in classifying good and bad swings.

Power System

A Lithium button battery will be used to power microcontroller subsystem and sensoring subsystem.

Block Requirement:

1. Provide stable $3.3V$ voltage for microcontroller subsystems and sensor subsystems.
2. Provide a maximum current of at least $300mA$ for microcontroller subsystems and sensor subsystems.

Risk Analysis

Since our project is mainly depended on the three sensors, accelerometer, barometer, and gyroscope, the data received by these sesnors need to be precise in order to allow classifier to classify correctly. In other words, the measurement from these data needs to have less bias as possible. Also, another main requirment for this project would be the classifier to be able to classify in high accuracy. If the classifier fails to classify correctly due to incorrect estimation of the position or biased measurements, then the project will not succeed.

SAFETY AND ETHICS

There are several possible safety hazards in our design. Lithium battery can explode if it is overcharged or heated. We will monitor its temperature and make it open circuit whenever it reach dangerous temperature

As an electrical device used in tennis courts, moisture and temperature should be taken into consideration of protection consideration. Water can lead short circuit and direct sun light may heat up the PCB to dangerous temperature. We want to cover our design with material that can isolate board from water but not accumulate heat inside, making our design work in appropriate temperature and moisture.

Our design will analyze player's swing and compare the captured data with standard swing models stored in system, then classifying those swings to be good or not by machine learning algorithm. This implies IEEE Code of Ethics, # 3:"To be honest and realistic in stating claims or estimates based on available data. "[3] The swing analyzer will only calculate reflect on recorded player's swing data and won't fabricate output.

We believe our design can help tennis beginners maintain a proper swing posture and prevent them from harming their health. It shows an implementation of IEEE Code of Ethics, # 5 and #7 : "To improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies, including intelligent systems.""To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others." [3]

Unfortunately, the analyzer will classify players' swings as "good" or "bad". The result of classification can be used to appropriately to attack tennis beginners, which may violate IEEE Code of Ethics,# 9 "to avoid injuring others, their property, reputation, or employment by false or malicious action".[3] Apparently, we do not have good solutions to that and can only advice player's to view the analyzing result as relevant reference instead of unquestionable answer.

REFERENCES

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