Smart Tennis Racquet Sensor

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ELECTRICAL [+] COMPUTER
E N G I N E E R I N G

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Overview

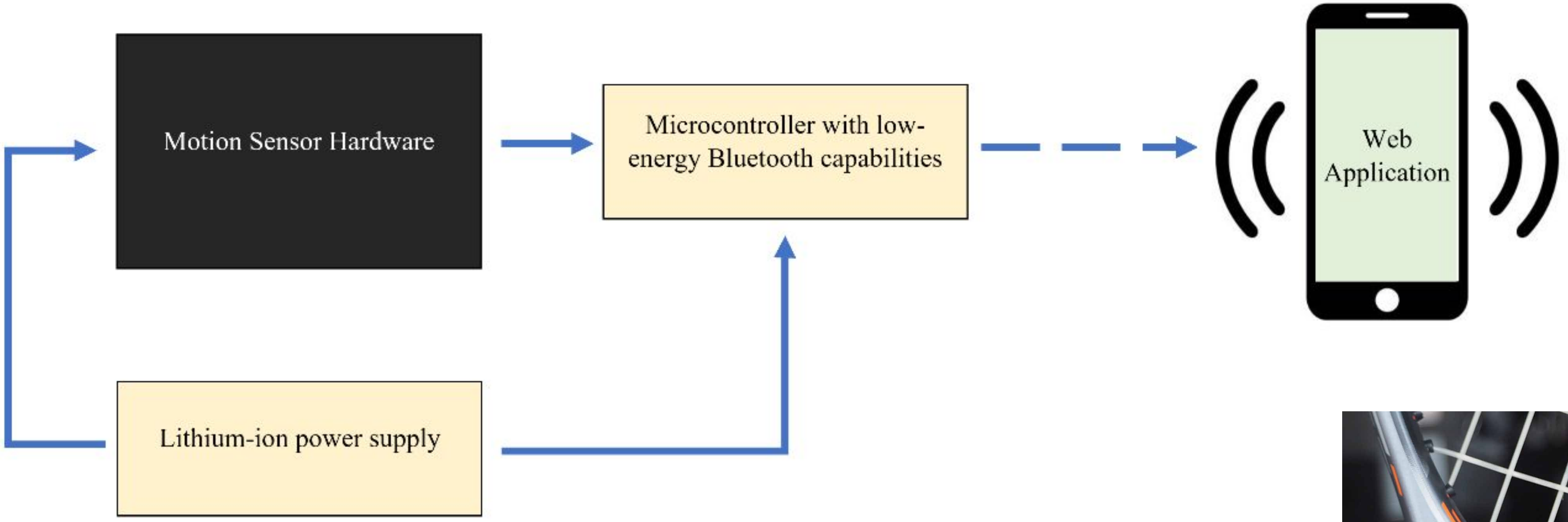
- Project Description and Goals
- Technical Specifications
- Design Approach and Details
- Project Demonstration
- Marketing and Cost Analysis
- Current Status

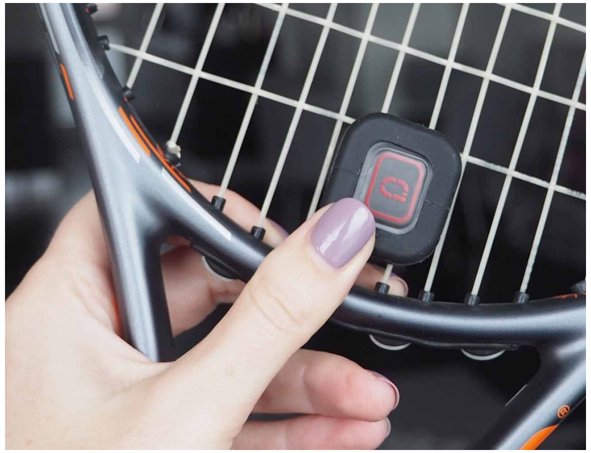
Project Description and Goals

Our goal is to increase access to high quality tennis analysis.

- Create a device that attaches to *any* tennis racquet that classifies and logs metrics including:
    - Swing Type
    - Swing speed
    - Ball impact location
- Our device will classify and run analysis on-device and send data to our web app for visualization.

System Design





Technical Specifications - Motion Capture

Our motion capture device must be able to handle a large amount of acceleration and capture high sudden impacts.

Table 1. Motion Capture Specifications

Item	Specification
Dual tri-axial accelerometers	± 16g for small accelerations ± 200g for large accelerations
Tri-axial gyroscope	± 2000°/s
Tri-axial magnetometer	± 8 Gauss
Tri-axial barometer	200-1100 hPa
Temperature sensor	± 0.5 K
Sampling rate	120-200 Hz
Power supply	1.71-3.6 V
Accuracy	1024-2048 LSB/g

Technical Specifications - Microcontroller

In order to run our algorithms and stream their results, our microcontroller requires a minimum amount of RAM and various communication protocols.

Table 2. Microcontroller Specifications

Item	Specification
Standard library version	C++11 or newer
Platform precision	32 bit
Communications protocols	Bluetooth LE, I2C, SPI
CPU Flash Memory	min. 16 KB

Technical Specifications - Overall System

Our overall device has weight and size constraints in order to fit on the racquet, and our algorithms have latency and accuracy requirements.

Table 3. Overall System Specifications

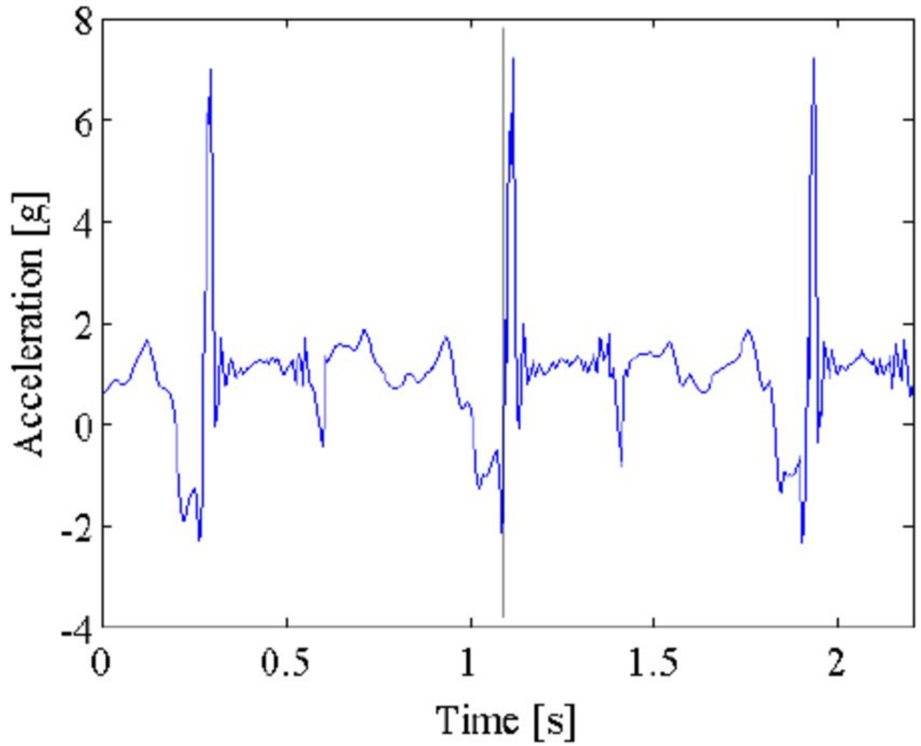
Item	Specification
Weight	< 0.7 oz
Size	35x25x8 mm
Casing	durable and flexible material, Epoxy
Battery	155 mAh lithium-ion battery
Latency	150-400ms
Shot Classification Model Performance (F1-Score)	≥ 90%
Shot Speed Prediction Error (Root Mean Square Error)	5 mph
Ball Collision Location Prediction Error (Root Mean Square Error)	5 inches

Data Collection

1. Data Collection
   a. Various kinds of swings in real game-play
      i. Multiple people with different skill levels
      ii. Perhaps have an additional class for Other/Bad form swings
   b. Ground Truth of swing speeds
      i. Baseball radar gun
   c. Ground Truth of location of ball collision
      i. Divide into 4 quadrants + center (sweet spot)
2. Metrics
   a. 3 acceleration axes and 3 gyroscope axes
   b. 2 scales: 16 G and 200 G

Data Processing

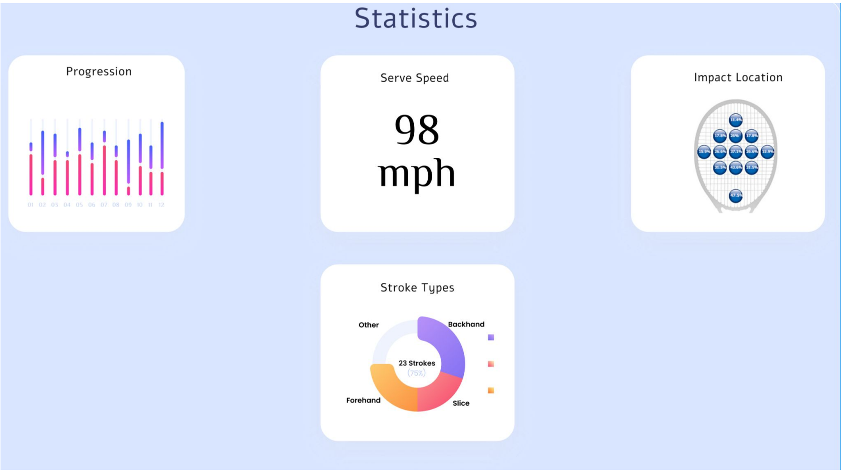
1. Activity Segmentation
    a. When is swing happening vs. running/swing preparation
    b. Algorithms to try:
        i. Threshold (baseline)
        ii. Dynamic time windowing
        iii. Neural Network
            1. Filtered acc/gyr XYZ values
            2. FFT data
        iv. Convolutional Neural Network
            1. 1D kernels for each acc/gyr XYZ
2. Activity Recognition
    a. NN and CNN
    b. Long-Short Term Memory Network?



Project Demonstration

Before the expo, we intend to test our product in a real tennis game. This can be done with the help of recreational or professional tennis players.

For the expo, we intend to demo our product by having a team member swing the racquet. We will have our web app streaming to a display allowing judges to view the results in real time.



Marketing and Cost Analysis

Total Projected Cost: $49.00

Component	Estimated Cost
Microcontroller with ± 16 G accelerometer	$20.00
3D Printed Packaging	$0.50
Lithium Ion battery and Charger	$13.00
Epoxy Casing	$0.50
± 200 G absolute orientation sensor with gyroscope, magnetometer, barometer and temperature sensor	$15.00
Total	$49.00

Current Status

- High impact bluetooth disconnect problem solved
  - Attributed to poor battery connections in the spring mechanism
  - Switched to LiPo design with soldered connections to proto board
- Data collection at the courts on Saturday
  - Still processing and looking through the data
- Current issues
  - Dropped bluetooth packets when the range is greater than ~ 10ft
    - Data logger breakout has been ordered for SD card integration
- Other efforts
  - Web app starting this week

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Questions?