A Real Time Artificial Intelligence System for Tennis Swing Classification

Kevin Ma

Oak Park High School, Oak Park Unified School District
899 Kanan Rd, Oak Park, CA 91377
kevinma0522@gmail.com

Outline

- Introduction
- System Architecture
- Data Acquisition and Feature Extraction
- Machine Learning Methods
- Experimental Results
- Discussion and Summary

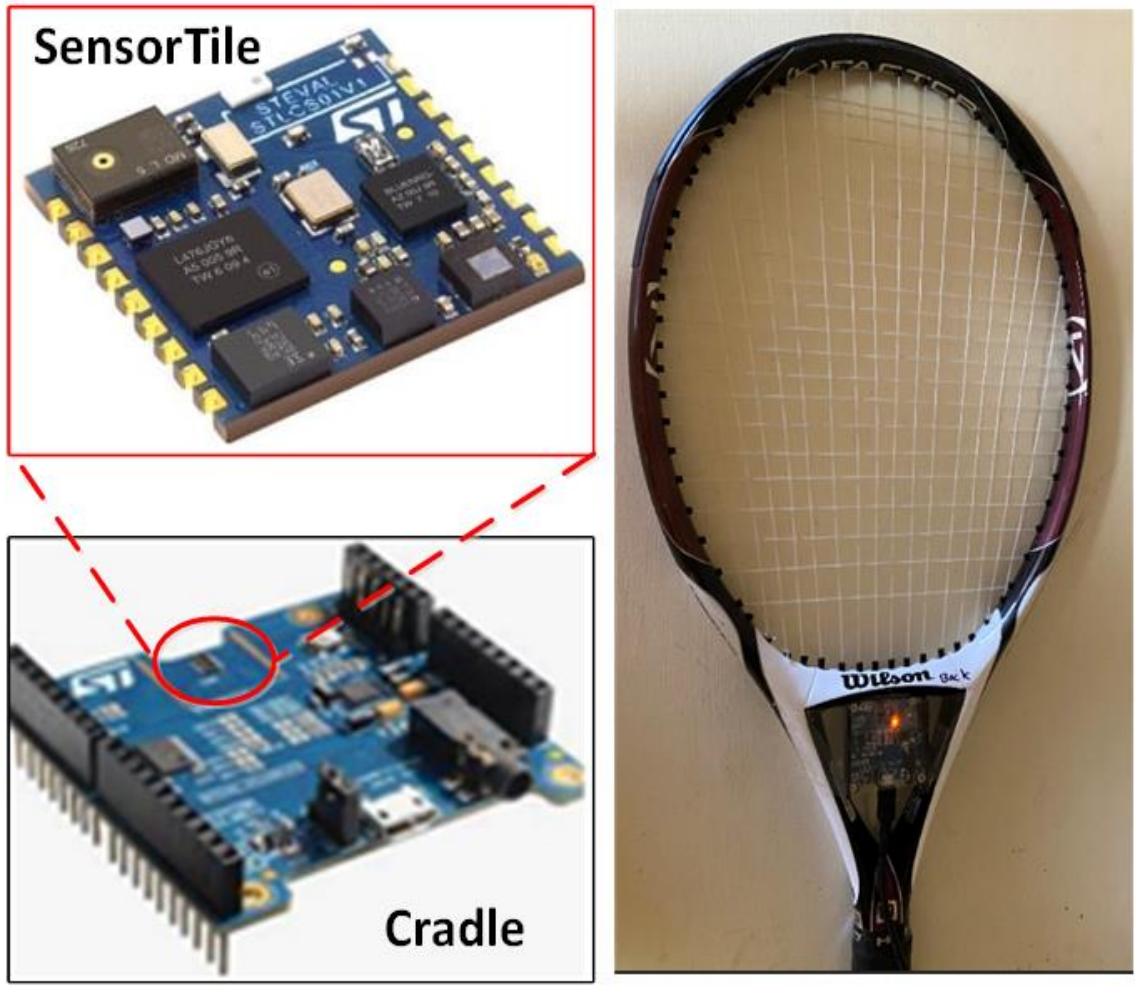
Introduction

- Stay At Home
- Tennis Training
  - Coaching: Expensive, hard to locate.
  - Social Distancing can’t be followed

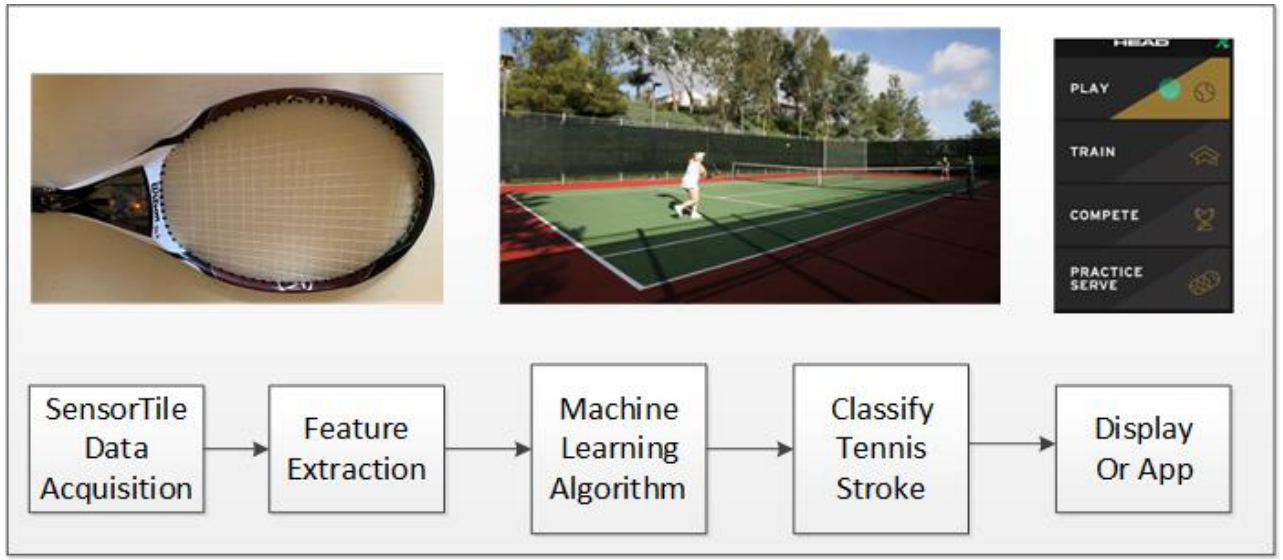
Introduction

- AI assisted system:
- Daily training that requires only one player.
- Live Sensor Data
  - Feedback on Stroke Accuracy

System Architecture



System Architecture



- ***SensorTile Data Acquisition Module***
- ***Feature Extraction Module***
- ***Machine Learning Module***
- ***Display Module***

Data Acquisition and Feature Extraction

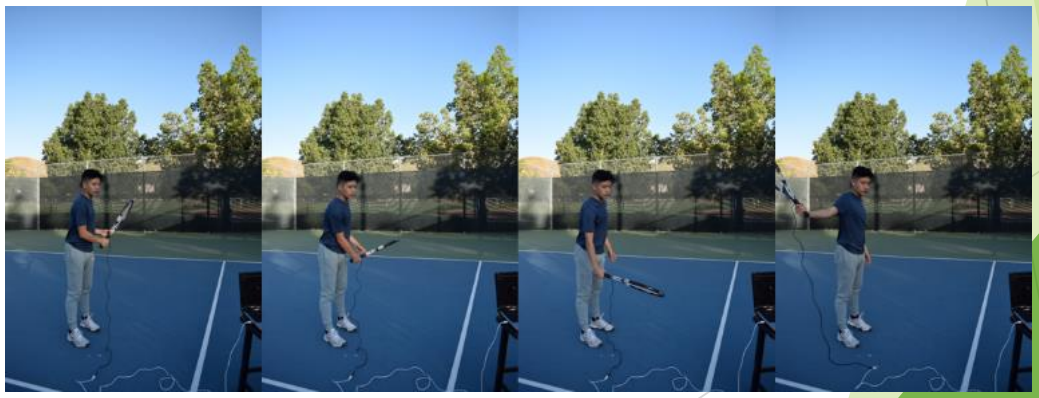
- SensorTile
  - MEMS Sensors
- 9-Dimensional Data
  - Accelerometer, Gyroscope, Magnetometer: each three axes x, y, z
- System Workbench
- 10 Hertz Collection Rate

Tennis Stroke

(a) Topspin Forehand

(c) Topspin Backhand

(b) Subpar Forehand



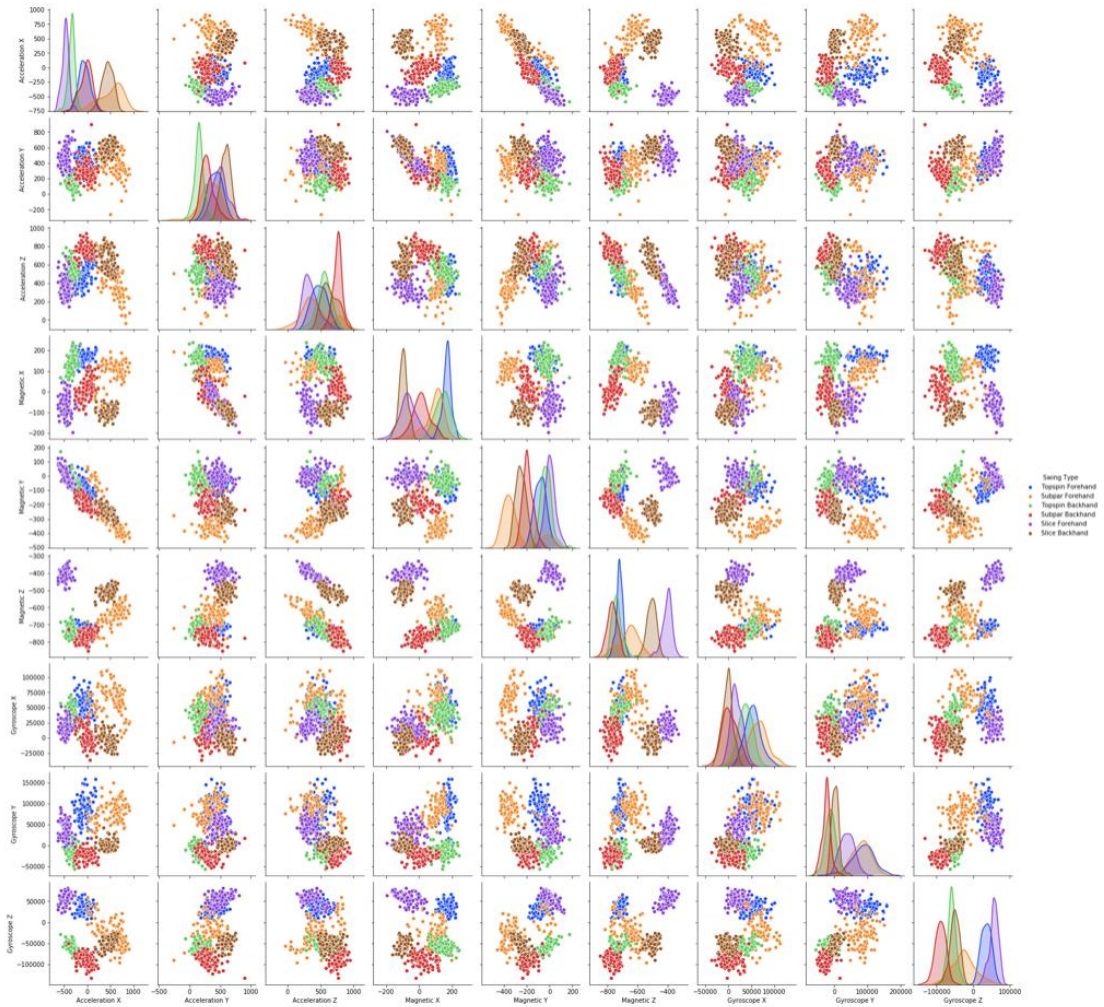
(d) Subpar Backhand

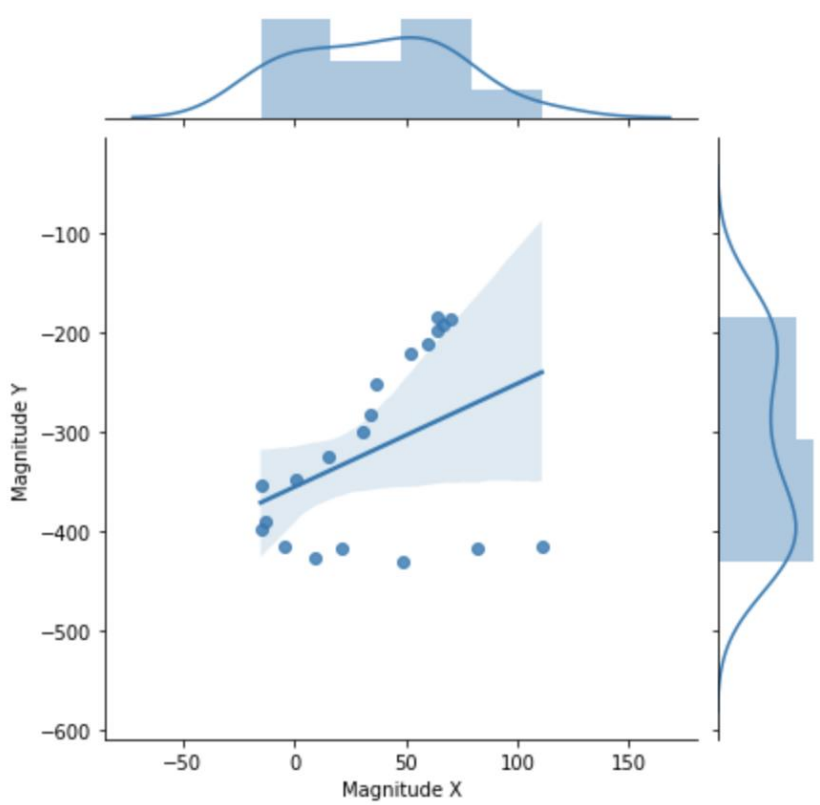
Tennis Stroke

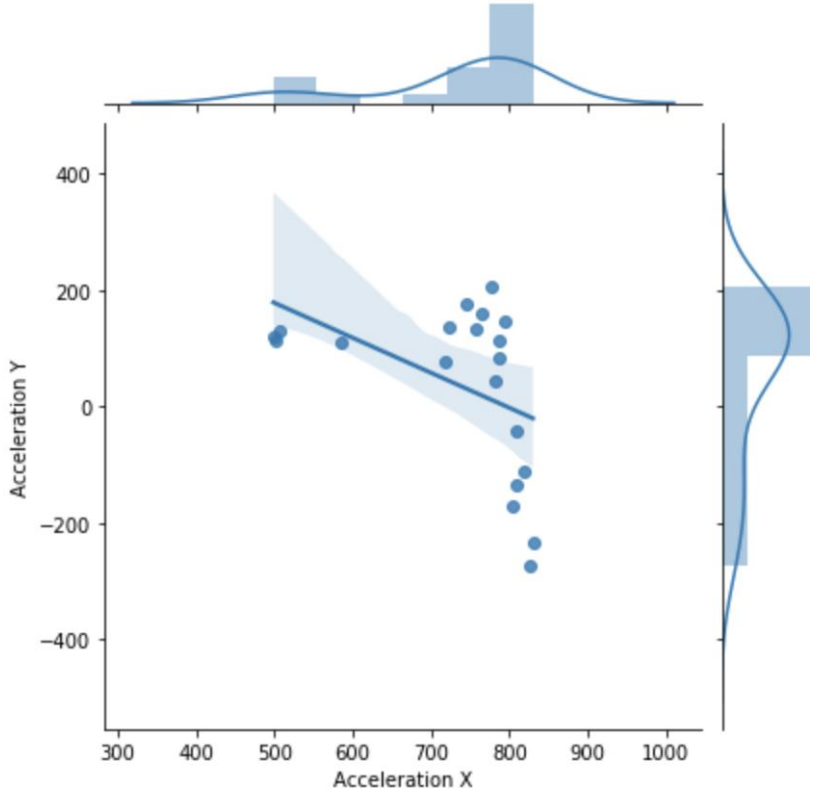
(e) Slice Forehand

(f) Slice Backhand

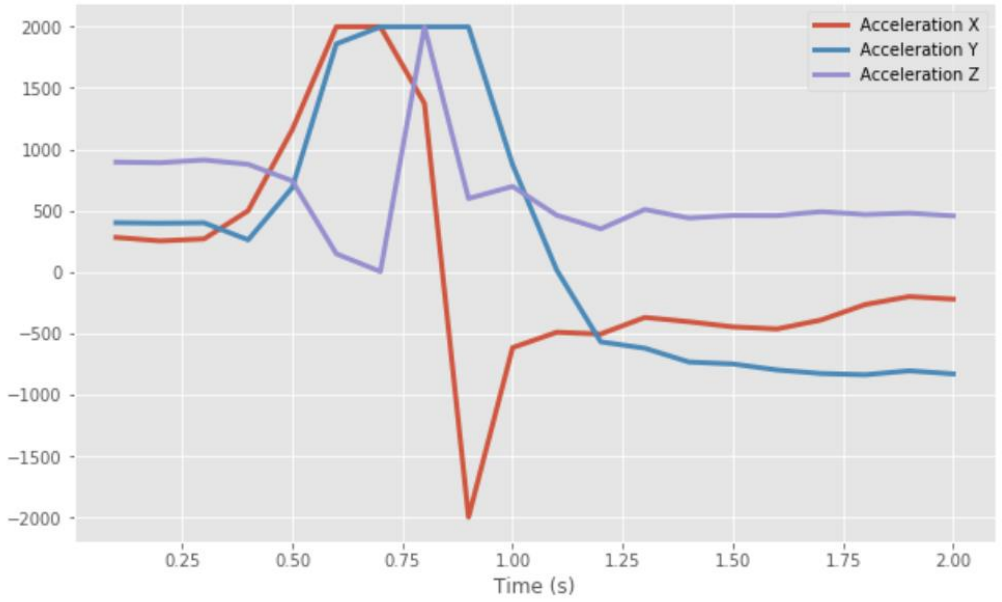
Correlation Graph

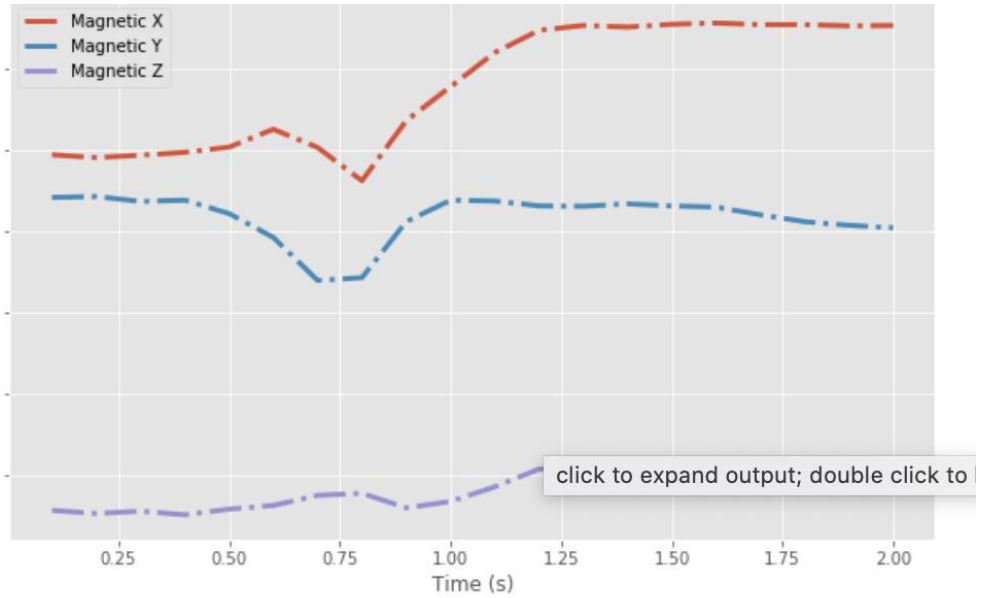


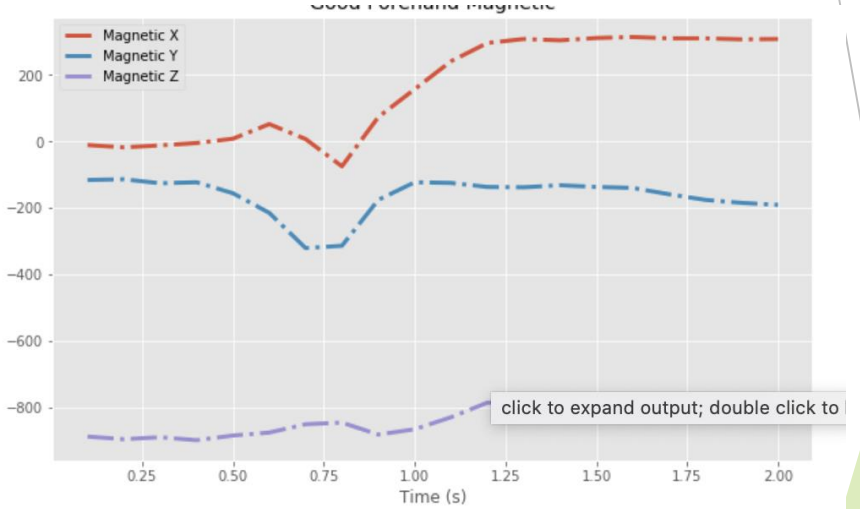

Magnitude Y
Magnitude X
−100
−200
−300
−400
−500
−600
−50
0
50
100
150


Acceleration Y
Acceleration X
400
200
0
−200
−400
300
400
500
600
700
800
900
1000

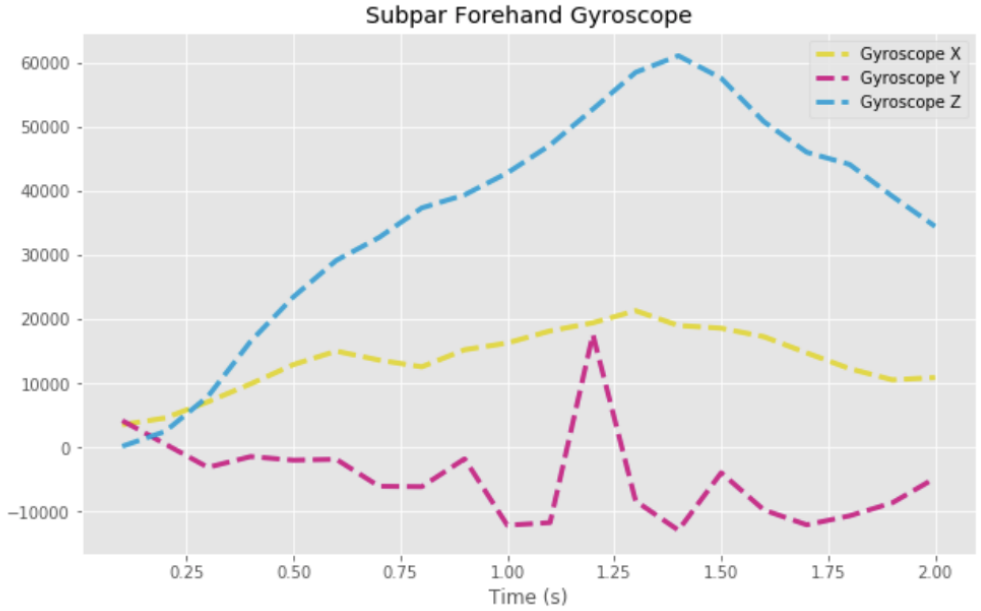
9-Dimensional Data for Topspin Forehand

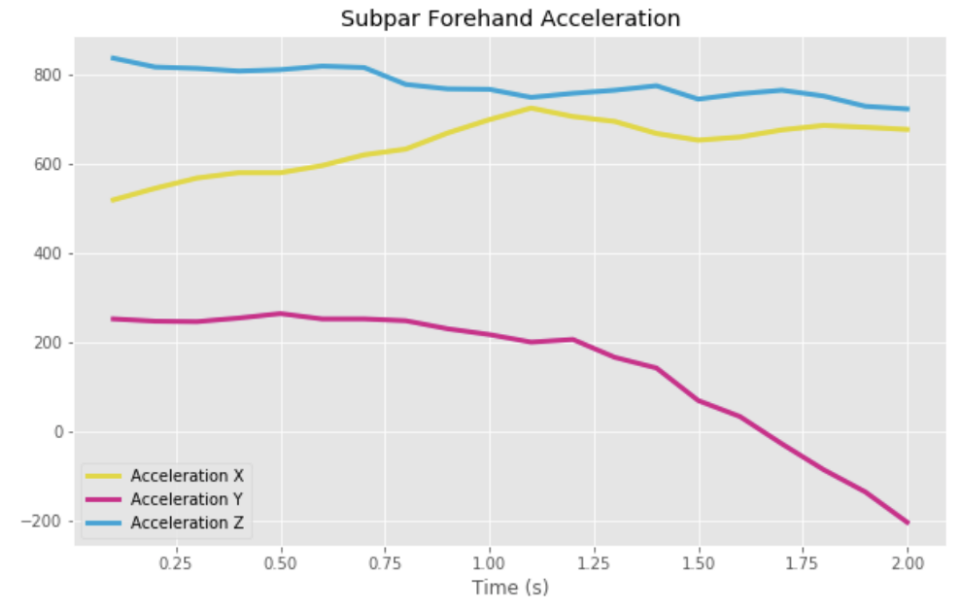


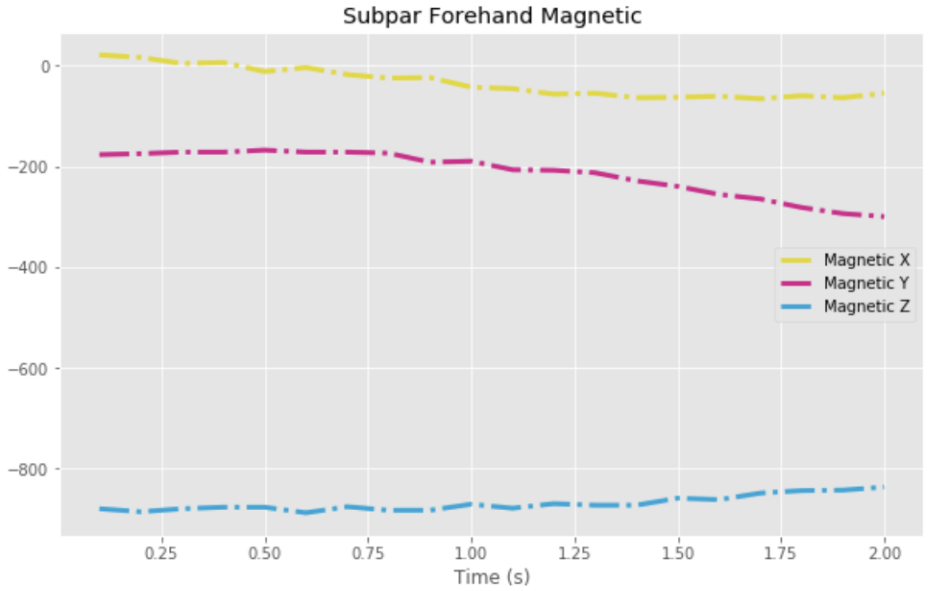




9-Dimensional Data for Subpar Forehand







Machine Learning Methods

- ***Support Vectors Machine (SVM)***
- ***Neural Networks***
- ***Decision Trees***
- ***Random Forrest***
- *K Nearest Neighbors (KNN)*

Data Processing Classification

- Support Vectors Machine Classification Accuracy

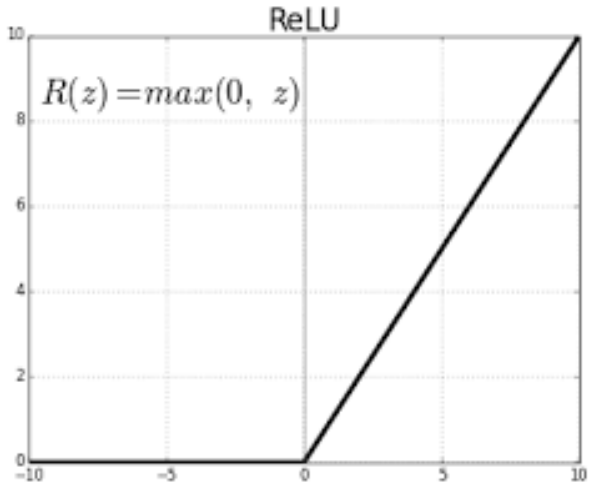
TABLE I. SVM CONFUSION MATRIX

		True Tennis Swing						Precision
		C1	C2	C3	C4	C5	C6	
Predicted Tennis Swing	C1	63	0	0	0	0	0	1.00
	C2	0	50	0	1	0	0	1.00
	C3	0	0	58	0	0	0	0.98
	C4	0	0	0	60	0	0	0.98
	C5	0	0	1	0	59	1	0.94
	C6	0	0	0	0	4	63	0.98
Recall		1.00	0.98	1.00	1.00	0.97	0.94	
Classification Accuracy=98.06%								

Data Processing Classification

- Neural Network
  - System of layered perceptron. Weights and biases.
- For our purposes:
  - 180, relu
  - 10, relu
  - 1, softmax

$$\sigma(\vec{z})_i = \frac{e^{z_i}}{\sum_{j=1}^{K} e^{z_j}}$$



Data Processing Classification

A neural network fixes the number of these basis functions. A neural network is composed of a system of layered perceptrons, or “nodes” that attempt to emulate the neurons in a real human brain.

TABLE II. NEURAL NETWORKS CONFUSION MATRIX

		True Tennis Swing						Precision
		C1	C2	C3	C4	C5	C6	
Predicted Tennis Swing	C1	62	0	0	0	0	0	0.98
	C2	0	54	0	0	0	0	1.00
	C3	1	0	62	0	0	0	1.00
	C4	0	0	0	51	0	0	1.00
	C5	0	0	0	0	62	0	1.00
	C6	0	0	0	0	0	68	1.00
Recall		1.00	1.00	0.98	1.00	1.00	1.00	
Classification Accuracy=99.72%								

Data Processing Classification

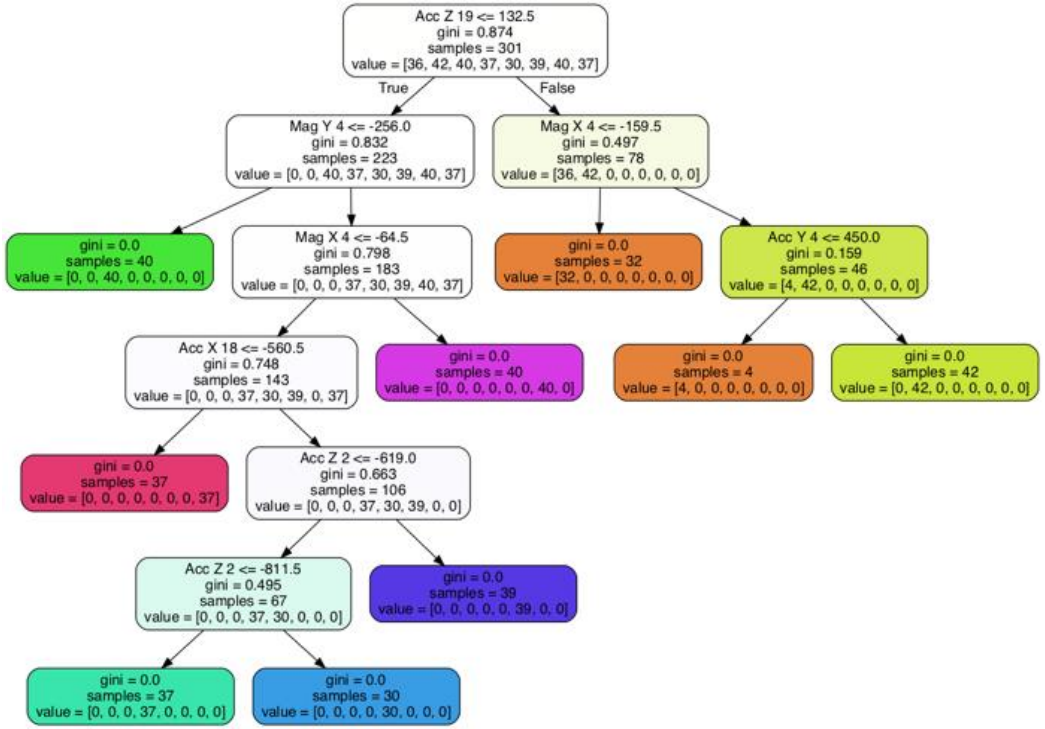
Decision trees are traditional methods of classification.

TABLE III. DECISION TREE CONFUSION MATRIX

		True Tennis Swing						Precision
		C1	C2	C3	C4	C5	C6	
Predicted Tennis Swing	C1	58	1	2	2	0	0	0.92
	C2	2	55	0	0	1	1	0.96
	C3	1	0	60	5	0	0	0.97
	C4	2	1	0	51	0	0	0.88
	C5	0	0	0	0	53	3	0.96
	C6	0	0	0	0	1	61	0.94
Recall		0.92	0.93	0.91	0.94	0.95	0.98	
Classification Accuracy=93.89%								

Data Processing Classification

- Random Forrest
  - Built off many decision Trees lumped together to prevent overtraining.



Data Processing Classification

Random Forest is an ensemble method, which combines many weaker classifiers into a strong final classifier. A random forest is essentially a “forest” of decision trees that split the oblique hyperplanes, which are able to obtain accuracy without overtraining.

TABLE IV. RANDOM FORREST CONFUSION MATRIX

		True Tennis Swing						Precision
		C1	C2	C3	C4	C5	C6	
Predicted Tennis Swing	C1	49	0	0	0	0	0	0.96
	C2	1	61	0	0	0	0	1.00
	C3	1	0	57	0	0	0	0.97
	C4	0	0	2	55	0	0	0.98
	C5	0	0	0	1	57	0	1.00
	C6	0	0	0	0	0	76	1.00
Recall		1.00	0.98	0.98	0.96	0.98	1.00	
Classification Accuracy=98.61%								

Data Processing Classification

The K-nearest Neighbors model, also known as k-NN, is a model that examines the location of new data relative to training data.

TABLE V. K NEAREST NEIGHBOR CONFUSION MATRIX

		True Tennis Swing						Precision
		C1	C2	C3	C4	C5	C6	
Predicted Tennis Swing	C1	62	0	0	0	0	0	1.00
	C2	0	54	0	0	0	0	1.00
	C3	0	0	62	1	0	0	0.98
	C4	0	0	1	50	0	0	0.98
	C5	0	0	0	0	62	0	1.00
	C6	0	0	0	0	0	68	1.00
Recall		1.00	1.00	0.98	0.98	1.00	1.00	
Classification Accuracy=99.44%								

Data Processing Classification

Table VI shows the classification accuracies for tennis player 2 through tennis player 6. The data collection methods are the same as player 1, whose results are shown in Table I through Table V. We still used 70% of the collected data from each player as training data and the remaining 30% as test data.

TABLE VI. CLASSIFICATION ACCURACY FROM PLAYER 2 THROUGH PLAYER 6

		SVM	Neural Network	Decision Tree	Random Forrest	K-NN
Other Team player	P2	90.82%	100%	84.69%	96.94%	87.76%
	P3	93.75%	100%	95.54%	93.75%	96.43%
	P4	98.06%	100%	94.79%	98.96%	97.91%
	P5	96.30%	98.76%	91.35%	95.49%	87.85%
	P6	98.86%	100%	93.18%	96.24%	97.73%

Discussion and Summary

- Distinct swing machine learning classification
- Individual and team training
- Low costs
- Feedback without social contact.

Future Works

- Principal Component Analysis
- Wireless implementations
- Using Physics-Guided Machine Learning Method to reduce the training sample size