Free Throw Form Analytics

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Introduction/Motivation

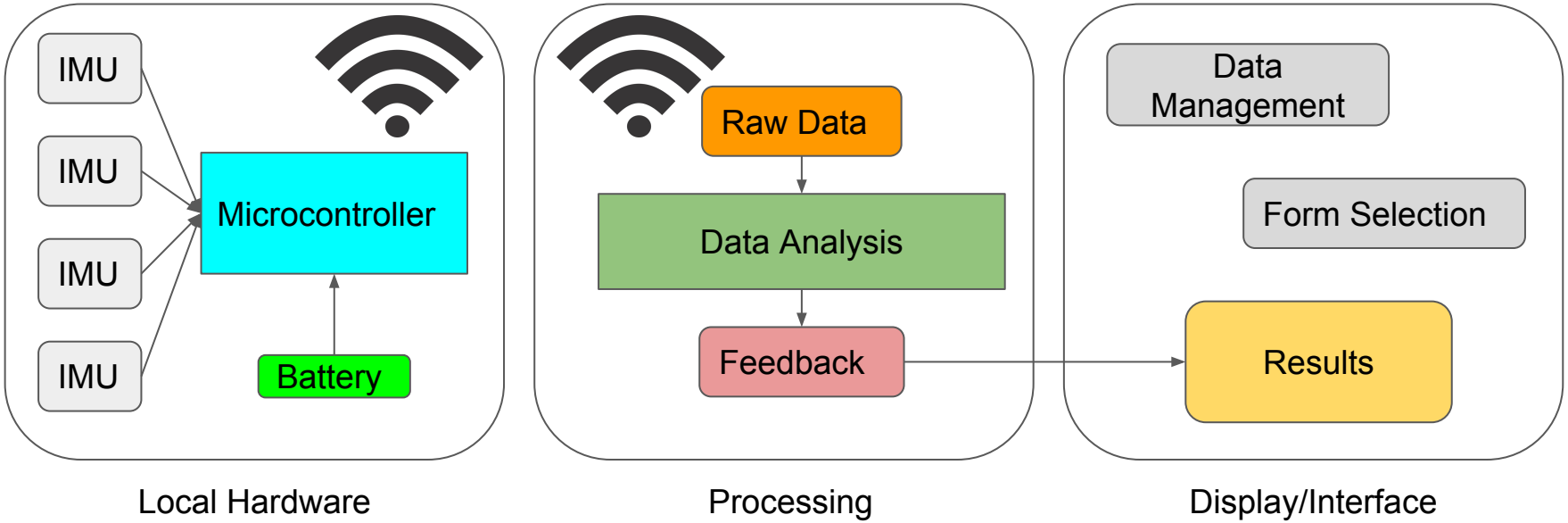
- How can we give feedback to users in order to train more intelligently?
- The system must be
  - Portable
  - Easy to use
  - Low-cost
  - Non-intrusive

Introduction

- Objective was to create a wearable device that will track the motion of a shooter’s free throw shots and provide feedback on their form
- This will allow the players to receive feedback on their form without the need for a coach to be there

- Target Audience - High school Basketball Players
- Cost - affordable for serious high school basketball players

Design Approach - Overview



What Happened

- Created lightweight, portable, and easy-to-use sleeve
- Met goals on data collection, battery life, and feedback to users
- Created user interface for users to obtain feedback on free throw shot

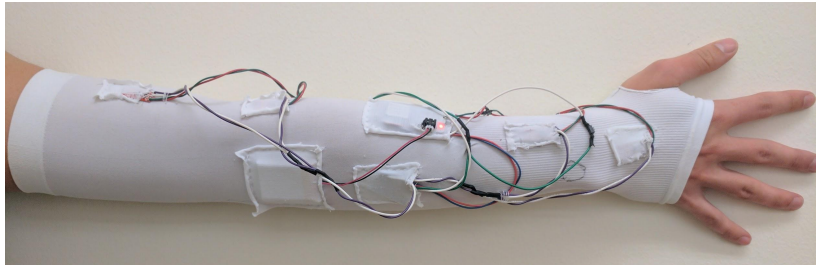
Data Collection

- Used sensor datasheet to build data collection and transmission software
- Early functionality tried to read, convert, filter, and transmit
- First major obstacles: memory limit, sampling speed, clock speed
- Final code for microcontroller is optimized for data collection speed - nothing occurs during recording beyond collecting sensor data and writing to flash
- System connects to wifi on first button click, and records on second

Sleeve Construction

- Pockets used to hold components allow for expanding
- Markings for wrist bone and elbow to have consistent IMU Placement
- Battery position
- Sewing on pockets easier with manakin or wearing arm
- Future: wrap components in plastic to limit sleeve deterioration, elastic thread
- Measurements for sensor position

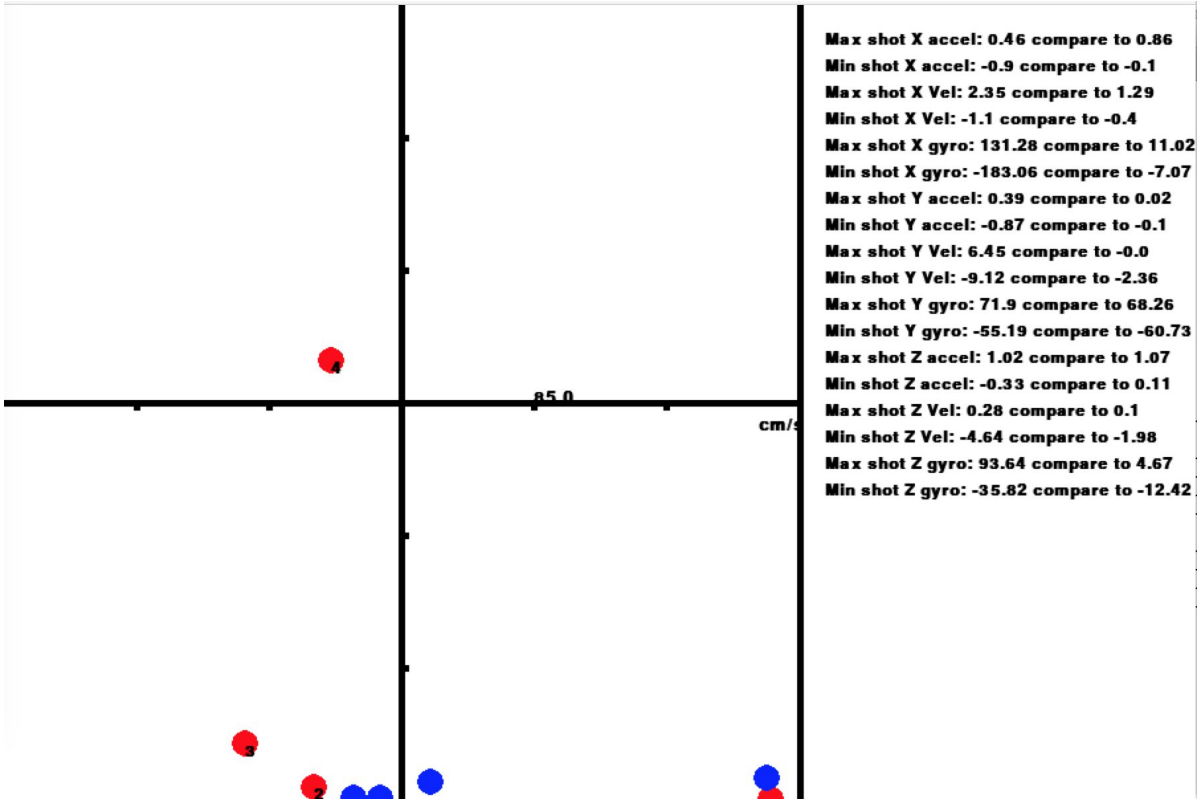
Item	Quantity	Cost
Sleeve	1	$8.50
IMU	4	$14.95
Microcontroller	1	$15.95
Multiplexer	1	$6.95
Battery	1	$9.95
Total		**101.15**



Data Processing

- Data is first filtered using a low pass filter to remove noise
- Scans for a moment in which all sensors are parallel to the ground and motionless
- Gyroscope bias is removed, and initial position and orientation are calculated based on the data from that moment
- Velocity and orientation are then calculated using Euler discrete integration

Creating User Interface - Mickeal



Meeting Specifications

Attribute	Proposed Specification	Prototype Specification
Battery Life	>2 hrs	>3.5
Sampling Rate	30-60 Hz	33 Hz
Linear Acceleration Range	±15 *g*	Up to ±15 *g*
Linear Acceleration Accuracy	± 1 m*g*	± 1 m*g*
Rotational Velocity Range	± 1500 dps	Up to ±2000 dps
Rotational Velocity Accuracy	± 100 mdps	± 100 mdps
Spatial Data Points	4	4 IMUs
Sensor Communication	I2C	I2C
Interface	Web Application	Python Software Application

Meeting Specifications

Proposal Shall	Result
be a wearable sleeve	Sleeve is fully functional and wireless.
fit average young adult males	13 inches (flexed) [1], sleeve expands to 25 inches
transmit data from the sleeve wirelessly	Sleeve Transmits Via Wi-Fi (802.11 b/g/n)
not restrict normal arm movement in any considerable way	Range of motion tests passed from physical therapy checklist [2]
start and stop shot recording with the press of a button	Prototype has button for control
be built with a wireless enabled microcontroller package	Microcontroller has built-in Wi-Fi

[1]"Are You an Average Man?", Elitefeet.com, 2017. [Online]. Available: http://www.elitefeet.com/are-you-an-average-man.
[2]Washington State DSHS, "Range of Joint Motion Evaluation Chart", 2014.

Meeting Specifications

Proposal Shall	Result
display an RGB LED that provides device status indication	RGB found to be unnecessary, on-board LED used instead
be powered using a rechargeable lithium ion battery	Prototype uses 800 mAh lithium ion battery
operate for a minimum of 2 hours	Tested to operate at least 3.5 hours
operate from -20°C to 60°C	All components rated -20°C to 60°C minimum operating rage. (Battery charging minimum 0°C)
save form data locally for future comparison	Software application saves shots into cloud database
allow users to select a primary comparison form	Software application allows users to compare any two shots

Wills

- allow the user to visually compare free throw forms
  Partially met.
- operate in real time
  Not met.
- save data to the cloud for the user to access from any device
  Met.
- provide feedback accessible on any browser
  Not met.

Challenges

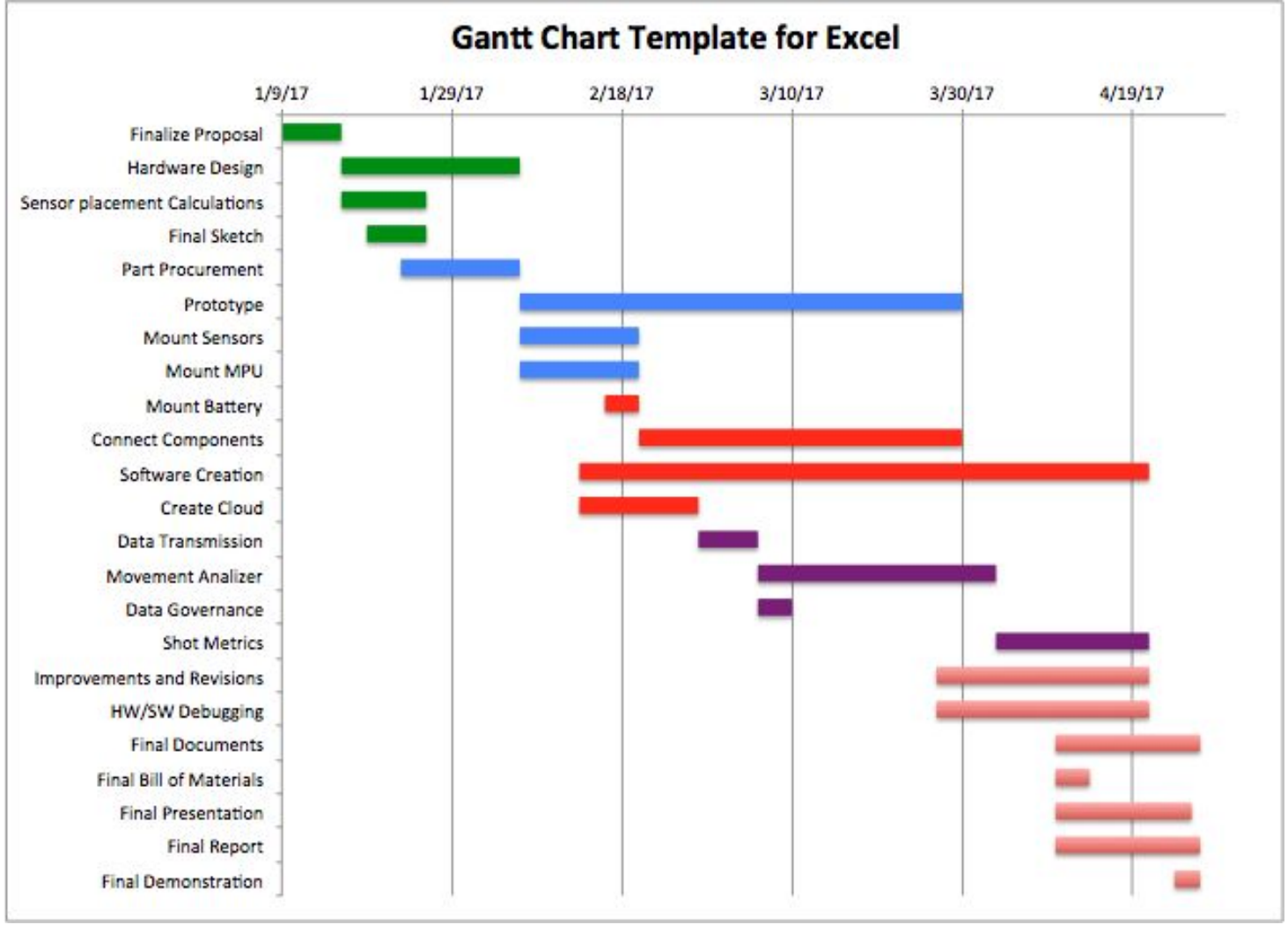
- Had to write library to communicate with sensors from datasheet directly
- Original data reading was very slow, had to optimize code for reading sensors
- Microcontroller only supports slower I2C speeds
- Microcontroller only has 44 kb of RAM, had to optimize for storage

Challenges

- Not able to collect data quickly enough to use acceleration to recreate position
- Ideal would be better sampling rate or IMUs without gravity
- Special Euclidean groups combine position and orientation to estimate each sensor’s configuration, and then gravity is removed from acceleration measurements based on sensor orientation
- Inherent error and low sampling rate cause error to build in orientation estimate; position calculations suffer from gravity itself as well as the attempt to correct for it

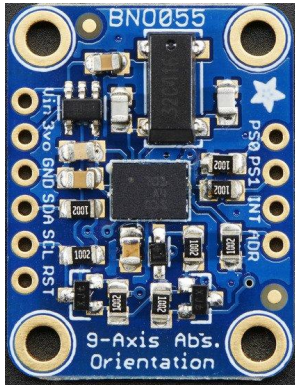
Scheduling

- Hardware to Hardware integration took much longer than anticipated
- Hardware issues caused increased shipping time and multiple parts orders
- This slowdown in production made it difficult to correct late stage issues
- Tried to create software and hardware in parallel but software production reached a bottleneck when actual shot data was necessary
- Creation of useful metrics became a challenge with time constraints


Gantt Chart Template for Excel
1/9/17
1/29/17
2/18/17
3/10/17
3/30/17
4/19/17
Finalize Proposal
Hardware Design
Sensor placement Calculations
Final Sketch
Part Procurement
Prototype
Mount Sensors
Mount MPU
Mount Battery
Connect Components
Software Creation
Create Cloud
Data Transmission
Movement Analizer
Data Governance
Shot Metrics
Improvements and Revisions
HW/SW Debugging
Final Documents
Final Bill of Materials
Final Presentation
Final Report
Final Demonstration

Future Work

- We believe challenges that we faced in recreating position can be solved with better hardware
- Recommend future teams looking into IMUs that report linear acceleration and remove gravity bias in hardware
- Recommend a microcontroller that supports faster I2C speeds for better sampling rate
- Recommend having feedback supported via web or mobile app so users can obtain instant feedback



Adafruit IMU with Linear Acceleration Capability

Future Work

- Many additional possibilities exist for motion tracking using IMUs
- Once some of these challenges are overcome, can easily be expanded to additional sports
- Great possibilities in medical, veterinarian, and physical rehabilitation applications