Soccer Team Gameplay Metrics

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1 Introduction

1.1 Objective

In recent years, the use of data analytics is sports have become more and more widespread. To get an edge in games, players and coaches use data to make decisions in training and gameplay [1]. However, in the sport of soccer, there isn't an easy way of collecting data for player-ball interactions. Currently, if someone wanted ball possession data over the course of a game, they would have to record it by hand. It's a tedious task, and mistakes could be made during the data collection process, so it would be more effective to automate the entire process instead.

We aim to build a system that is able to measure and calculate metrics for individual players over the duration of a soccer game. For this project, we will be focusing on metrics between the player and the ball rather than more personal metrics. We will collect data using a sensor system integrated into a ball, and present it to the user on an application after analyzing it. The metrics that we aim to gather include: passes between player A and B, bad passes, longest string of dribbles, time of possession, shots on goal, and so on.

1.2 Background

Currently, there are companies that make smart soccer balls like the Adidas or DribbleUp, but their balls are primarily used for personal training. For example, the Adidas miCoach smart ball only records speed and spin of a shot from a stationary ball position [4]. You have to press a button to let the ball know that you are about to shoot it. This wouldn't work as we require touch recognition is a live game environment. The DribbleUp ball focuses on AR tracking of the ball [3]. This works with amount of touches and juggles for a player but making sure that nothing comes in between the camera and the ball and that the player is not in motion and focused in the middle of the camera frame. This again would not work in a live game environment. These smart balls lack the ability to be used in a multiple player drill session or in an actual soccer match. Thus we need to come up with a new solution that would fit this criteria.

1.3 High-level requirements list

- Each touch of the ball by an individual player must be registered and captured by the system.
- The system cannot be wired and must all work on battery power
- An application must be able to process the data and display the metrics such as passes between player A and B, bad passes, longest string of dribbles, time of possession, and shots on goal.

2 Design

2.1 Block Diagram

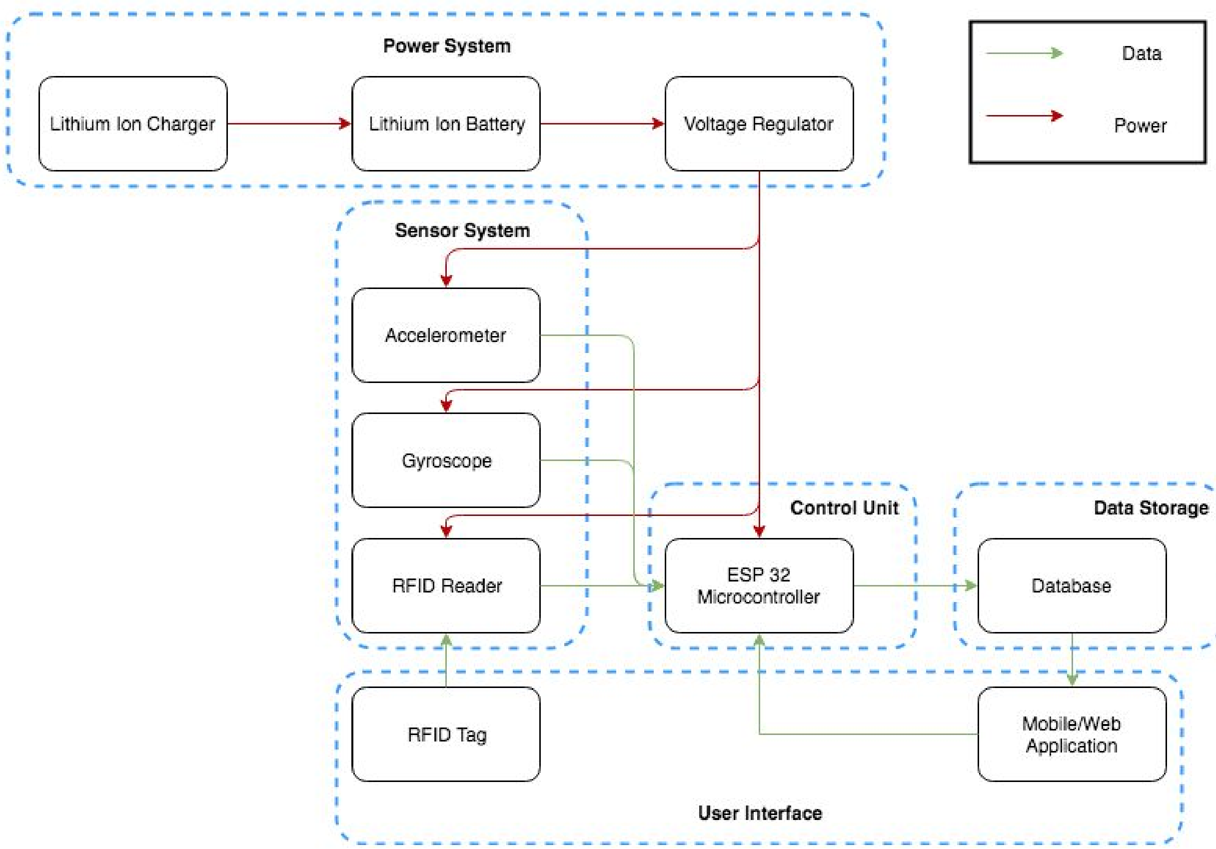

Figure 1. Block Diagram

2.2 Physical Design

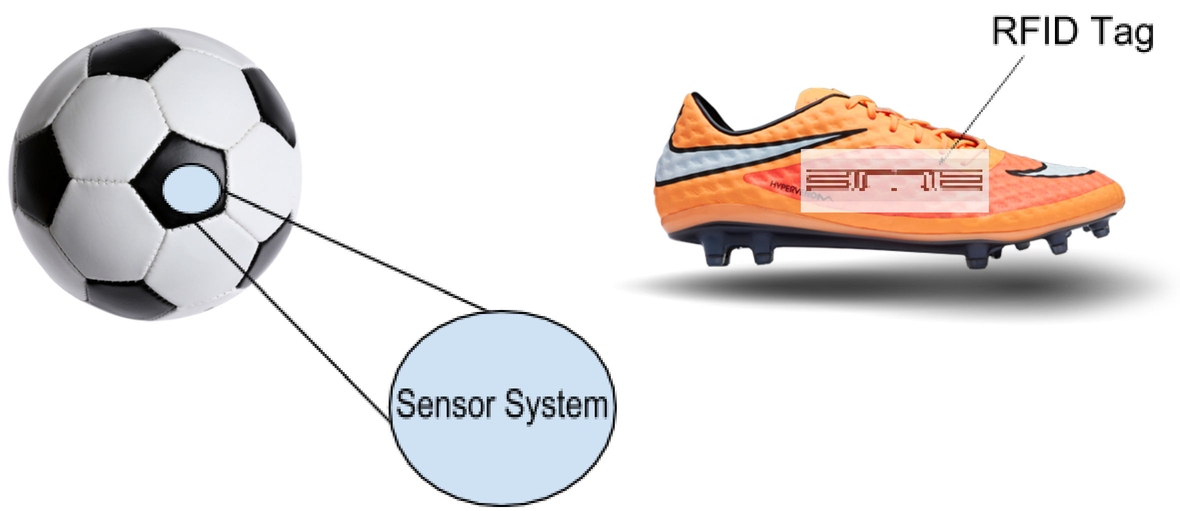

Figure 2. Physical Design

The sensor system and battery will be integrated inside a high density foam soccer ball. RFID tags will be stuck on a player's soccer cleats. The RFID tag is really thin and it will be just in a form of a sticky sheet of paper that a player can stick on their cleats.

2.3 Functional Overview & Requirements

2.3.1 Power System

- **Lithium Ion Battery**
  A soccer ball cannot be plugged in during a game, so we will have to use a portable power source to power the electronics inside the ball. Since none of the components we plan to use require high voltage or current, we will use a lithium ion battery as the power source. (3.7V to 4.2V output)

Requirements	***Verification***
1. The battery must be able to sustain up to 250 milliamps of current draw at 3.3 volts for a quarter of a soccer match length (~22.5 minutes)	1. A. Fully charge the lithium ion battery to 4.2V. B. Connect it to a load that draws 250mA of current. C. Leave the load connected for 22.5 minutes.

	D. Disconnect it from the load and use a voltmeter to check that the voltage is above 3.7V.

- **Lithium Ion Charger**
  The charger will regulate voltage and current going into the battery during the charging process.

Requirements	***Verification***
1. The charger must be able to charge the battery to 4.2 volts with a continuous current of >100 mA from a 5V USB power source.	1. A. Discharge the lithium ion battery to 3.7V. B. Connect the charger to a 5V USB source with the battery connected. C. Use a voltmeter and an ammeter to monitor the voltage and current of the charging IC to make sure that it charges with a current of at least 100mA, and stops at 4.2V.

- **Voltage Regulator**
  The voltage of a lithium ion battery varies depending on how much charge is left. Some sensors require a stable voltage input in order to operate properly.

Requirements	***Verification***
1. Able to step down battery voltage to 3.3V ± 1% while maintaining a 250 mA peak current.	1. A. Connect the regulator input to a 5V lab supply. B. Connect the output of the regulator to a 250 mA load. C. Verify that the voltage is within 1% of 3.3V using a voltmeter.

2.3.2 Sensor System

- **Accelerometer**
  The accelerometer provides data on the current speed of the ball. This will enable additional metrics to be computed, and will also help determine when the ball goes out of play.

Requirements	***Verification***
1. Measure a minimum of ±4g of acceleration, and at least has 3 degrees of freedom.	1. We will compare the accelerometer to an already working accelerometer sensor on iPhone XR. A. Attach the sensor on the phone and test with different forces on movement and compare the change in the data on both sensors

- **Gyroscope**
  The gyroscope will provide data on the current spin and orientation of the ball. This will enable us to determine the spin on a shot or pass as well as provide data to help us determine other factors, like if the ball is stationary or not.

Requirements	***Verification***
1. The gyroscope must be able to measure 2000 to 4000 degrees per second in 3-axis.	1. Compare the gyroscope to a already working accelerometer sensor on iPhone XR. A. Attach the sensor on the phone and test with different forces on angular movement and compare the change in the data on both sensors

- **RFID Reader**
  The RFID reader provides the primary method of detecting the person that is in contact with the ball. It will read the RFID tag of the player in possession and send that information to the microcontroller.

Requirements	***Verification***
1. Must at least have a detection distance of the radius of a soccer ball (~11 cm). 2. Read time should be faster than the smallest contact time of a typical kick (~8 ms)[2]	1. Place the RFID tag at a distance of 11cm and check if the sensor can read it. 2. Move the RFID tag in the field of the RFID reader at a speed that would make it in contact for about 8ms and verify if there is a read.

2.3.3 User Interface

- **RFID Tag**
  Each player will have an unique RFID tag attached to their cleats to be identified with.

Requirements	***Verification***
1. The RFID tags should be about as thin as possible (same thickness as a piece of paper) and must be embedded in a sticker so that it is easily attached inside or on the cleat. 2. Each tag should have a unique identifier/data string.	1. Measure the thickness of the tag and observe if it can be embedded or not. 2. A. Move the tag to where the RFID reader can read and see if the tag reads. B. Read each tag multiple times to see if the tag is unique and that the tag reads remain the same for the same tag.

- **Web/Mobile Application**
  The application is the processing and visualization of the data that shows player's stat and analysis.

Requirements	***Verification***
1. It must be able to correctly compute and display stats in a table/list and have interactive	1. A. Enact a scenario where we personally calculate the completed passes, dribbles, misplaced passes etc.

features that allow the users to select the items to display.	B. Check if the algorithms and application calculate and display the same values

The algorithm processes the IMU data collected inside a certain time window with some filters (e.g. a low pass filter to remove noise and gaussian filter to detect kicking impulse) to determine the last state of the ball's movement. If the ball was stationary for some time over the threshold (e.g. 2 seconds) then the ball was out of play (e.g. free kick, corner,etc.) and no stat computation will be done. If a kick action was detected then combined with RFID data the algorithm should determine whether the ball was dribbled or passed. The RFID data is interpreted as the possession of the ball. If the change of possession was between the players in the same team then the pass is good. If there was no change in possession (RFID reading didn't change) then it was a dribble. If the change happened between two players from different team then it was a interception or bad pass. Each action is time stamped and stored back to the data container throughout the game. Given the time interval an analysis can be computed such as average pass rate, rate of successful pass, and most consecutive successful pass, etc.

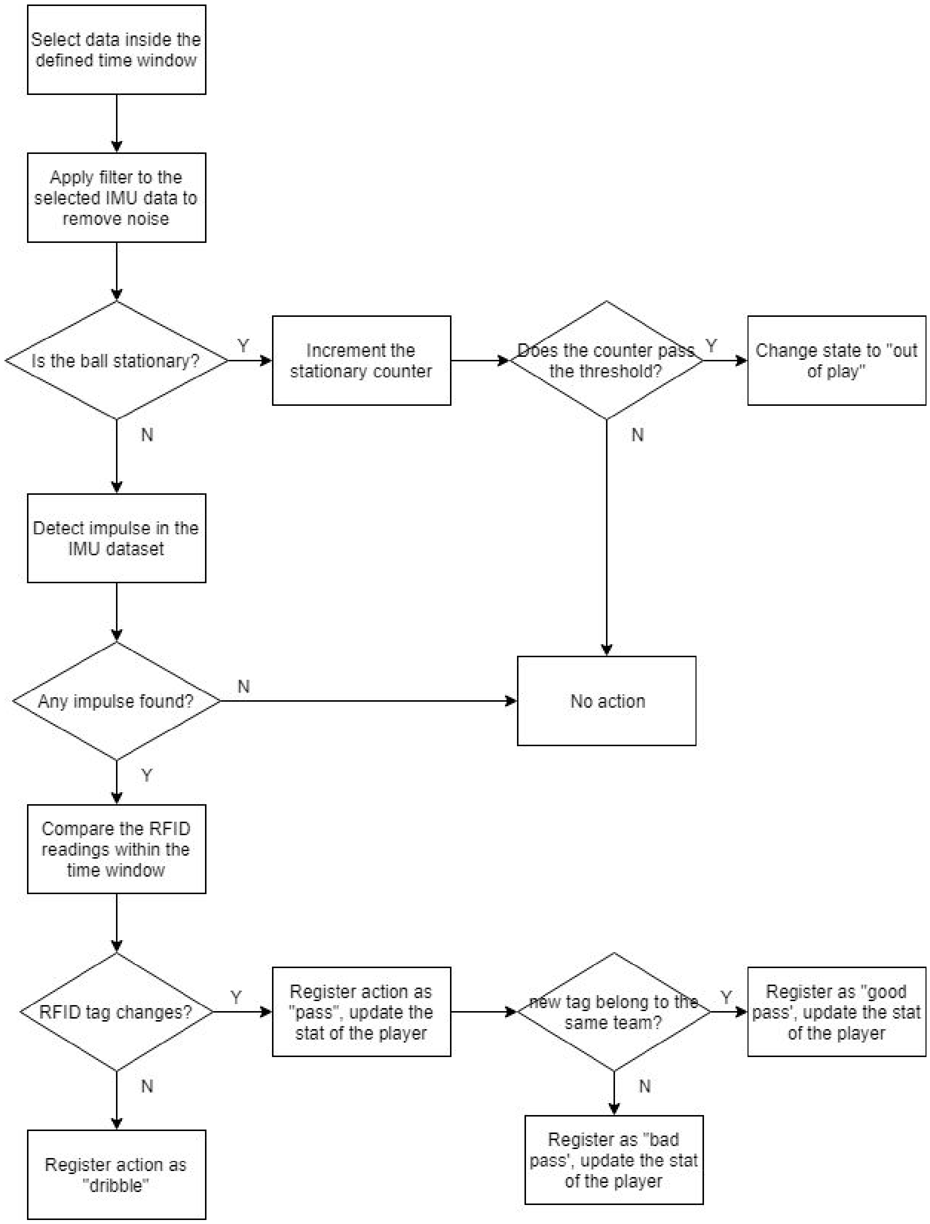

Figure 3. Processing algorithm for each time window

2.3.3 Control Unit

- **Microcontroller**
  A microcontroller unit is needed to pull data from the sensor systems and push it to an external data storage system.

Requirements	***Verification***

1. The microcontroller must have enough pins to support the sensor system and run off a 3.7V to 4.2V lithium ion battery. Ideally, it will also have wifi+bluetooth capabilities to utilize cloud storage	1. A. Wire the microcontroller according to the schematic (TODO). B. Program a simple blink script and verify that it works.

- **Data Storage and Transmission**
  The receiving server establishes the wireless connection with the device controller via wireless network. The IMU data will be time stamped and continuously logged throughout the duration of the game. The RFID data will be logged only if the RFID reader has the reading. Otherwise, the RFID data should be empty or meaningless. The RFID data will also be time stamped. The data needs to be stored inside a structured container (either a database or csv format file) so that it can be pulled out and analyzed for the metrics we want.

Requirements	***Verification***
1. The storage system must have enough capacity enough to store sensor data recorded every 0.2 seconds over the length of a soccer match (90 minutes).	1. A. Calculate and/or sample the amount of data the sensors generate per minute and multiply it by 90 to get total data size over 90 minutes. B. Verify that the size of the storage is greater than the amount calculated in part A.

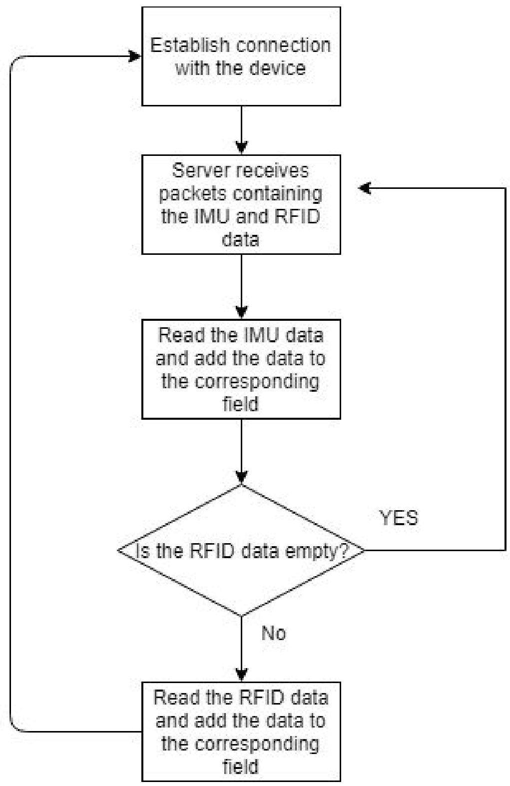

Figure: Receiver actions

2.4 Risk Analysis -> Tolerance Analysis (TODO)

The sensor system poses the greatest risk to our project. Our whole system and project is based around the success of receiving the data from the sensors, especially the RFID reader. The RFID reader poses the greatest challenge. It should be able to read the tags really quickly when the players touch the ball. It needs to be able to read the tag faster than the contact time of the soccer ball to a players cleat, which can be really fast, sometimes under 10ms. If the reader fails to read the tags then our project will not achieve the proposed goal. Our biggest focus will be in ensuring minimal read times and as accurate as possible reads.

3 Cost and Schedule

3.1 Cost Analysis

We consider the 11 weeks of the semester of work on the project. The estimation for hourly work pay is $40/hour. Considering that for the 11 weeks of work we put in 12 hours/week per person. The total labor costs add up to:

$$3(people) \cdot 12\frac{hours}{week} \cdot 11\ weeks \cdot 40\frac{\$}{hour} = \$15,840$$

Part	***Quantity***	***Cost***
3.7V Lithium Ion Battery - 1200mAh (Generic, Adafruit)	1	$9.95
Li-Ion Charger Board (MCP73833, Microchip)	1	$12.50
Voltage Regulator (STMicroelectronics, LD1117V33)	1	$1.25
IMU ACCEL/GYRO/MAG I2C 28LGA (Bosch sensortec, BNO055)	1	$12.10
RFID Reader (ID-Innovations, ID-20LA)	1	$34.95
RFID Tag	10	$10
Microcontroller (Espressif, ESP32)	1	$15

3.2 Schedule

Week	***Tasks***	***Members***
2/18		
2/25		
3/4		
3/11		
3/18		
3/25		
4/1		
4/8		
4/15		
4/22		

4 Ethics and Safety

4.1 Ethical Issues

- **Honesty and Integrity**

The testing and demo of our project involves data collection and processing. IEEE code of ethics, #3 [5] and ACM code of ethics 1.3 [6] address the issues of honesty, and mention that fabricating or falsifying data is strictly prohibited. We promise we will never manipulate data and forge results to make our product look like it works when it doesn't in our development and testing.

- **Equality**
  The working environment consists of people from different backgrounds with different roles such as our TA, teammates, and instructors. According to IEEE code of ethics #7 and #8 [5], ACM code of ethics 1.4 [6], we should treat everyone equally. We will respect and accept others' criticism and advice, and treat all individuals involved in this project equally and professionally and not engage in act of discrimination.
- **Copyright**
  In the software development part in this project, we will possibly use libraries and frameworks published by other people or organizations. According to ACM code of ethics 1.5 [6], we should respect and follow the permission of usage and license agreements of any outsourced software involved. We will give proper credit to authors of open source code that we use.
- **Damage prevention**
  IEEE code of ethics #9 [5] states that we should avoid injuring others, their property. To ensure this, we will evaluate the system stability and potential risk during the development and before testing. Actions will be taken immediately and accordingly when incident occur to prevent or minimize the damage to individuals and surroundings.

4.2 Safety Issues

The main safety risk in our project lies with our usage of a lithium ion battery.

The ball we plan on prototyping with is made of foam, which is flammable. The battery and hardware generates heat during operation, which may lead to overheating and can cause battery failure and fire. To prevent this, we will examine the thermal condition of the system during our development and decide whether to add a cooling design to the project. In addition, we will monitor the temperature inside the foam ball using a temperature sensor during the testing.

The battery may explode or burn when overcharged. During the building process, we will test the charging circuitry and make sure the charging voltage is correct before attaching the battery to the charging circuit.

Since lithium ion batteries have a tendency to catch on fire when damaged or pierced [7], we will try to isolate the hardware as much as possible by 3D printing an enclosure for it. The soccer ball should also have the capability to operate outdoor and moisture could damage the hardware leading to short circuit. The enclosure will help for this problem as well.

References

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[3]Kickstarter. (2019). *DribbleUp Smart Soccer Ball*. [Online] Available at: https://www.kickstarter.com/projects/dribbleup/dribbleup-smart-soccer-ball [Accessed 5 Feb. 2019].

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[5]Ieee.org. (2019). *IEEE Code of Ethics*. [Online] Available at: https://www.ieee.org/about/corporate/governance/p7-8.html [Accessed 6 Feb. 2019].

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