Safe And Sound - Project Proposal

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1 Introduction

1.1 Objective

Anyone familiar with baseball is aware that all umpires are prone to human error, regardless of experience. One of their key tasks is to correctly call runners as safe or out, which requires a large degree of precision and accuracy. There is no shortage of plays that are merely too close to call for a traditional umpire. Although these close calls may be challenged, the final decision comes from humans and is therefore prone to human error and biases. Our group will solve this problem by designing a base, glove, and shoe system that “knows” with perfect precision whether a runner is safe or out.

1.2 Background

According to USA Today, there were 660 overturned umpire calls in the 2017 MLB season [1]. A subset of these missed calls come from calling runners as safe or out. Currently, the only technology used to challenge these calls are video replays [2]. However, these are still subjective methods prone to human error and biases in addition to not being implemented in every league.

1.3 High Level Requirements

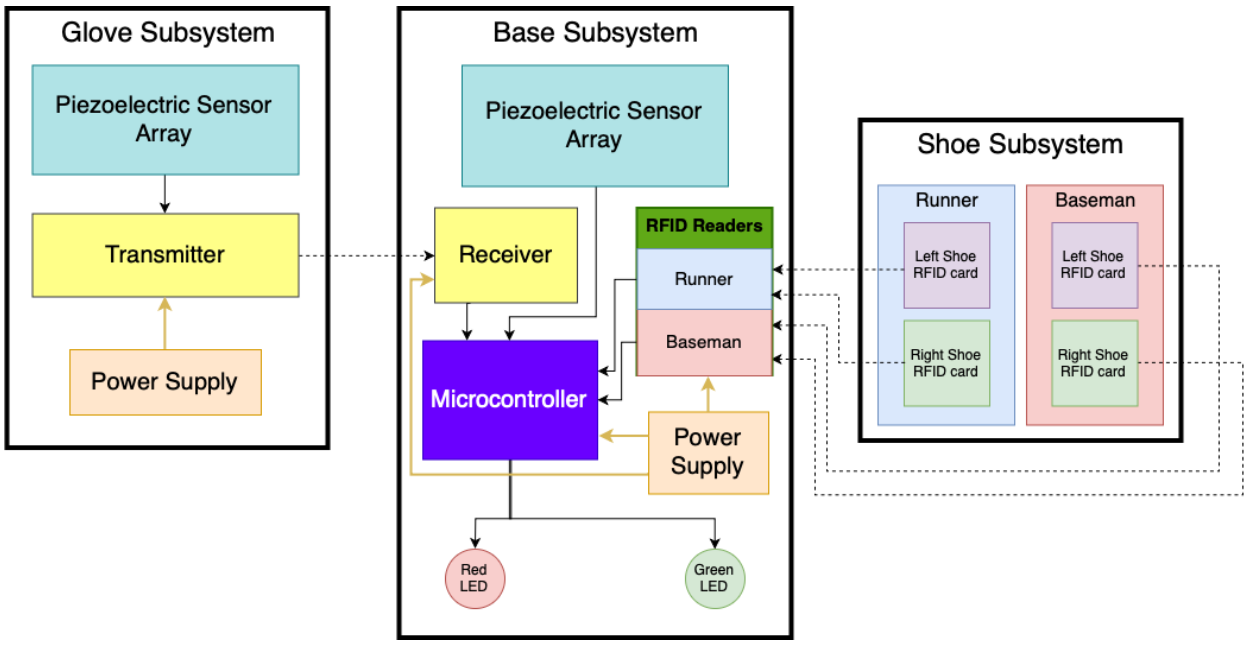
Safe and Sound must satisfy the three following requirements:

1. The base subsystem must set a red LED high if the runner is out. Otherwise, a green LED will be set high.
2. The base subsystem must be able to distinguish between runner foot contact and baseman foot contact.
3. The glove subsystem must be able to correctly recognize that a ball has been caught in it, and transmit this information to the base subsystem.

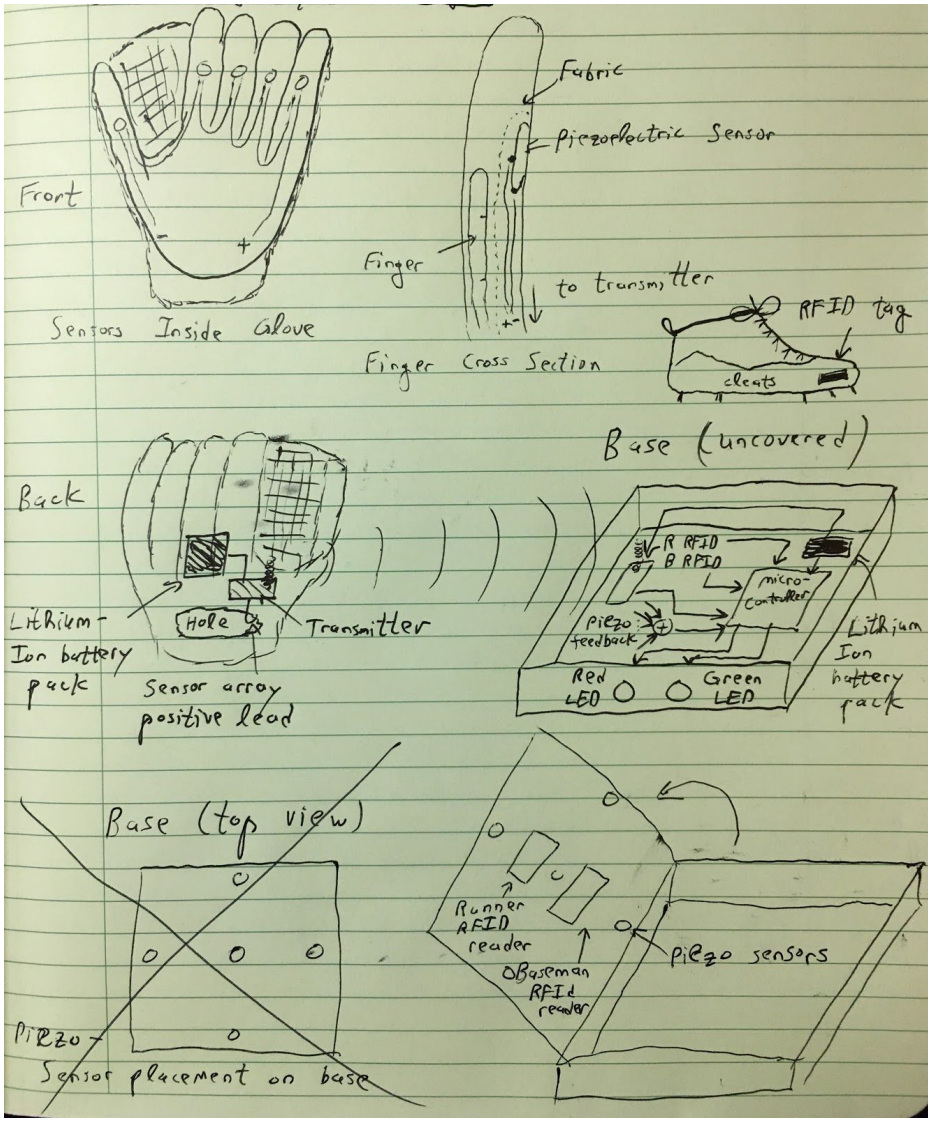
2 Design

Safe and Sound will be designed using three subsystems: a glove, base, and shoe subsystem. The glove and shoe subsystems will act as edge devices, detecting relevant changes from each player. Meanwhile, the base subsystem will take on the role of as the central device by receiving updates from the glove and shoe subsystems as the game state changes.

2.1 Block Diagram



2.2 Physical Design



The placement of sensors in the glove and base subsystems will be crucial to accurately detect catches and foot contact. Our plan is to line the inside of each finger in the glove with a piezoelectric sensor, wire them all in series, and route the positive lead of this connection through the back opening in the baseball glove to the transmitter mounted on the back. The transmitter can be powered with a lithium-ion battery pack mounted next to it. Another lithium ion battery pack can be placed inside the base subsystem to power its microcontroller, RFID readers, and receiver. Between five and nine piezoelectric sensors will line the inside of the base's cover to detect physical foot contact. Lastly, the red and green LEDs will be mounted on the side of the base for easy viewing.

2.3 Functional Overview and Block Requirements

2.3.1 Glove Subsystem

The glove subsystem's primary responsibility will be to continuously send piezoelectric sensor feedback to the base subsystem. It will utilize an array of piezoelectric sensors wired in series and placed along different points inside the baseman's glove. We think piezoelectric sensors are the ideal choice for this task since they don't require external power and are both flat and compact; making it easier to place them inside a baseball glove.

While the glove subsystem is active, it will continuously send its piezoelectric feedback to an onboard RF transmitter. The role of this transmitter is to wirelessly send all piezoelectric sensor feedback in the glove to the base subsystem's receiver. Using an HC-12 transceiver module may be the best option considering it's relatively cheap and compact.

Requirement 1: The piezoelectric sensor array should produce a signal upon ball impact distinguishable from noise
Requirement 2: The transmitter should continuously be sending the sensor feedback to the base subsystem's receiver while the glove subsystem is active.

2.3.2 Base Subsystem

The base subsystem will act as the brain of Safe and Sound. Based on feedback from its RFID readers, the glove's piezoelectric sensors, and its own piezoelectric sensors, it will decide whose foot made first contact with the base and if the baseman was holding the ball. All RFID and sensor feedback will be routed into an onboard microcontroller.

Figure 1. Pseudocode

```
caught ← FALSE
basemanFoot ← FALSE

REPEAT:

switch (event):
  case CATCH:
       caught ← TRUE
       goto REPEAT
  case RUNNERFOOT:
       if (caught and basemanFoot)
            return OUT
       else
            return SAFE
  case BASEMANFOOT:
       if (caught)
            return OUT
       else
            basemanFoot ← TRUE
            goto REPEAT
```

Using both piezoelectric sensors and RFID readers in the base will allow for more precise foot contact detection in a two-factor authentication process. As a player's foot approaches the base before making contact, their RFID reader in the base should send a signal to the microcontroller indicating foot contact is about to occur. When foot contact is made with the base, the piezoelectric sensors will produce a distinct signal (similar to the glove subsystem) that will be sent directly to the microcontroller. Since the RFID readers will take care of player identification, the base's piezoelectric sensors will be player agnostic.

The microcontroller must be able to distinguish time differences between events. It can accomplish this by implementing the pseudocode shown in Figure 1. As relevant signals are received by the microcontroller, we can set the appropriate variables in the pseudocode. When a safe or out decision is eventually made, the microcontroller will light up the proper LED to make its decision known to outside observers.

Another key requirement of the base subsystem will be wireless communication with the glove subsystem. It will utilize an RF receiver to gain real time access to the glove's piezoelectric sensor feedback. This could also be accomplished using the same transceiver module present in the glove subsystem (HC-12).

Requirement 1: The base's RFID reader for the runner must send a signal to the microcontroller whenever either of the runner's feet approach the base.
Requirement 2: The base's RFID reader for the baseman must send a signal to the microcontroller whenever either of the baseman's feet approach the base.
Requirement 3: The base must have real time access to the glove's piezoelectric sensor feedback.
Requirement 4: The microcontroller must make the correct safe or out decision based on the arrival of these events, and set the proper LED.

2.3.3 Shoe Subsystem

The shoe subsystem will be the simplest of the three. It's sole responsibility will be informing the base subsystem that the shoes of either the runner or baseman are about to contact the base. Each shoe of the runner and baseman will be equipped with unique RFID tags and will communicate with the base subsystem's RFID readers. Since RFID tags are passive, the shoe subsystem will not require any external power.

Requirement 1: Each shoe should be detectable by the base's RFID readers immediately before making physical contact.
Requirement 2: The runner's shoe tags should not be recognized by the baseman's RFID reader in the base, and vice versa.

2.5 Risk Analysis

The base subsystem will probably be the most difficult to develop and perfect. It must be capable of distinguishing between two piezoelectric sensor events (foot contacts) that may occur at nearly identical times. At the same time, it must have uninterrupted real-time access to the glove's sensor feedback broadcast. The glove subsystem will also introduce a major challenge by ensuring reliable wireless communication with the base subsystem at all times.

3 Ethics and Safety

Throughout the development of this project, we will seek to preserve the safety of players' feet and our electronics. Thus, in order to best do so, our project will not be implemented in the rain to protect players and the system itself from harm. Furthermore, we will to the best of our ability mitigate risks by following the IEEE Code of Ethics in order "to hold paramount the safety, health, and welfare of the public" [3]. It will be our job to develop a safe product that could be used for baseball leagues of all age levels.

4 References

[1]"Number of MLB reviews, overturned calls drop in 2017", *USA Today*, 2017. [Online]. Available:https://www.usatoday.com/story/sports/mlb/2017/10/01/number-of-replays-overturned-calls-drop-in-mlb/106223230/. [Accessed: 01- Feb- 2019].

[2]"Replay Review", *Major League Baseball*, 2018. [Online]. Available: http://m.mlb.com/official_rules/replay_review. [Accessed: 01- Feb- 2019].

[3]Ieee.org, "IEEE Code of Ethics", 2019. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 01- Feb- 2019].