Location Detection with Force Sensing Resistor (FSR) Matrix Array

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1 Abstract

Based on the problem of not having many online tools to track data from a pitches bullpen and analyze the data all in one, especially if you are not at a professional level, my goal is to create an interactive user interface of a strike zone used to plan out where a pitcher wants to throw a specific pitch, then have a pressure pad at home plate that can pin point where the pitch ended up and relay that spot back to a device. The device would also be used to store the data that will be used to calculate, possibly an accuracy heat map, and pitch command metrics ranging from the basic strike percentage to more detailed data like miss distances.

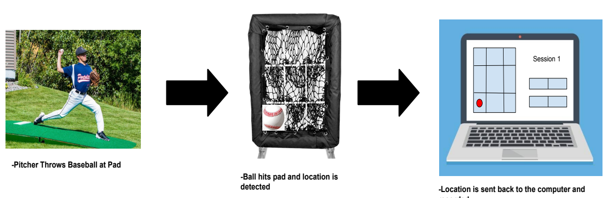

Figure 1: Graphical Abstract Diagram

2 Introduction

Baseball, especially at the college and higher levels, demands very precise and consistent - pitching performances. Coaches and players often rely on printed strike zone charts to manually record each pitch, track accuracy, and calculate performance statistics like strike percentage or pitch type effectiveness. While this method is familiar across the whole sport, it is pretty inefficient, difficult to maintain over time, and prone to errors, especially when - coaches have to dig through piles of paper or perform calculations manually on almost a daily basis. This project aims to try and modernize that process through a pitching strike zone analysis system. The primary component is a digital platform, possibly a website, mobile app, or desktop application, that would allow coaches or players to track each pitch on a visual strike zone interface. The system will automatically calculate useful statistics, store data for future use, and allow sorting by pitch type or location. Additionally, the project would try to explore a secondary, more experimental physical component using pressure-sensitive pads that could track if a pitcher hit the intended target and potentially measure force to estimate velocity. This would require custom hardware capable of withstanding high-speed impacts due to the rise in pitching velocity, and integrate with the computer or app interface. By combining a digital interface with some physical feedback, this project is aimed to lower the burden and inefficiency of manual tracking while keeping the quality and accessibility of pitching data that helps coaches focus more on training for the better of their team and players and less on paperwork. This project will contribute to both the modern baseball training wave, the coaching community, and the field of sports technology in many different ways. The main thing I wanted to focus on was digital efficiency in the hope that a project like this would replace outdated paper tracking systems like all the excessive pitching charts I have dealt with in my career. In the best-case scenario, this project would be a more streamlined, user-friendly app that can be adapted for desktop, web, or mobile use. Another big contribution would be real-time analysis of performance stats. This would mean coaches and players can access live statistics like strike percentages and pitch accuracy, saving time and improving decision-making for teams and players to become better and more efficient. A more difficult contribution would be pushing towards the innovation of physical pitcher feedback. Exploring pressure-sensitive pads introduces a new hardware element that is rarely used in bullpen settings, with potential for future integration into training equipment due to the constant growth of pitchers and velocity training in this modern era of baseball.

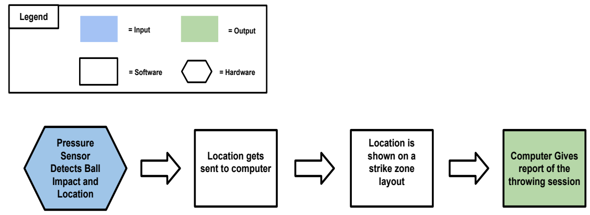

Figure 2: Data Architecture Diagram

3 Related Work

Modern technology has greatly changed the way baseball teams analyze the game and how they are able to develop players. From tracking how a player moves to using automated strike zones, these new tools are making it much easier to measure performance inside and outside of games. However, there are still a lot of gaps in who can use this relevant technology and how it works. This literature review looks at different studies on baseball technology, starting with general uses of pressure sensors and then looking at research about strike zones and new automated systems being used today. The literature reveals the growing - trends in baseball technology aimed at improving pitching accuracy and performance analysis to help pitchers at many different levels. Early research on pressure sensors and baseball analytics provides a foundation, while recent studies on automated strike zones and pitch-tracking systems highlight the relevance of sensor-based solutions. This review really shows the need for further innovation in strike zone analysis, especially bringing the proposed pressure pad system to light as a valuable tool for coaches and players seeking more accurate and efficient data collection.

3.1 General Applications of Pressure Sensors

Hobson discusses the Swing Catalyst system [1], which uses a pressure sensor to analyze a player's back foot and back leg load in a baseball swing. While this research focuses on hitting mechanics rather than pitching, it shows how pressure-sensitive technology can create heat maps for performance analysis. Similarly, an article by Technetron Electronics [2] provides a detailed guide on using pressure sensors with Arduino, offering foundational knowledge for implementing sensor-based systems.Though neither study directly addresses pitching, they lay the groundwork for understanding pressure sensor technology in a baseball-related matter.

3.2 The Idea of Automated Strike Zone Systems and What They Are

Major League Baseball's (MLB) commissioner Rob Manfred and Ronald Blum [3] discuss the possible implementation of the Automated Ball-Strike (ABS) system [4], often referred to as "robot umpires" which is a system that would call every pitch and relay the ball or strike call back to the home plate umpire through an earpiece, or using a replay system that allows players to challenge certain calls when they want. These sources explain how automation improves accuracy and reduces human error in umpiring. Steve Pokin [5] then extends this discussion by examining the obvious differences between digital strike zones shown on broadcasts and the actual MLB definition of one. These studies emphasize the challenges of trying to make strike zone calls more consistent and emphasize the potential for technology-based solutions like the one proposed in this research.

3.3 Data Collection by Technology in Baseball

Pourciau from TopVelocity [6] introduces the metrics Stuff+, Location+, and Pitching+,-which evaluate pitch characteristics such as velocity, spin rate, and placement to use to improve pitchers training. These data-driven approaches highlight the increasing role of analytics in modern baseball. Also, in Ming-Chia Yeh's article I found [7], they explored the use of a sensor-embedded baseball to analyze pitching mechanics. Their study connects finger attributes to spin rate and velocity, showing the potential for embedded sensors in performance assessment. Even though they focused on data collected from within the baseball itself, their findings back up the importance of precise pitch tracking which is an element important to this research.

3.4 New Technologies for Pitch Tracking

These newer resources discuss real-time pitch-tracking systems that closely line up with the goals of this study. For example, SensorEdge's SensorMound [8] utilizes over 2,000 sensors to provide biomechanical feedback on pitching mechanics, offering relevant data about stride length, weight distribution, and foot orientation. Similarly, Rapsodo's Pro 2.0 [9] uses dual-camera technology to track over 20 pitching metrics like pitch speed, ball spin rate, and vertical and horizontal movement. It also generates video and 3D visualizations to make practice more realistic and helpful for pitchers. Finally, Command Trakker [10] presents an interactive pitching target that records pitch location and type, mirroring the intended functionality of this project's possible pressure pad system and interactive strike zone user interface.

4 Design

1. Arduino Microcontroller- This is the "brain" of the entire system. Sends scanning signals to the matrix array (row/column selection). Reads analog voltage changes from the circuit when the FSR is pressed. Converts the raw electrical signals into digital values that the computer can interpret. Powered and programmed through USB from the computer.

2. Breadboard Circuit- Interfaces between the Arduino and the FSR. Contains the necessary wiring for row and column control lines and includes resistors, multiplexers, and shift registers to properly read each sensor element. Ensures that only one row or column is active at a time during scanning, preventing signal overlap or floating values.

3. Force Sensing Resistor Array or "The Pad"- This is a grid of force-sensing resistors arranged like rows × columns. When you press the pad, resistance decreases → voltage changes → Arduino detects the force. The ribbon cables connect its row and column pins to the breadboard circuit and allow detection of where and how hard the impact occurs.

4. Computer Interfaces- Receives the processed matrix values from the Arduino. Runs the Arduino code and serial monitor and maps it to the Python FSR Matrix Touch Display.

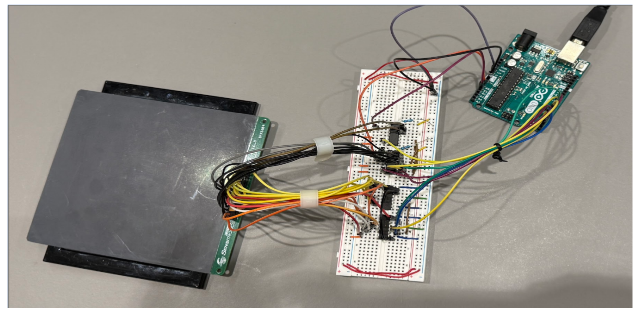

Figure 3: Connected Arduino, Circuit, and FSR

5 Evaluation Plan

My testing was not necessarily extensive, but I put a large focus on the accuracy of the pressure detection, hit localization, and response time. Since I am not into the full ball throw progression yet, I don't have to worry about durability testing, but that would be the biggest test once it is ball detectable. But to be able to check the three main criteria, I had to first test the Arduino Code, the circuit voltages and resistance, and the Python Display code very often. Once I was through all the troubleshooting, I was able to make a simple display through Python to translate the pad touches into a real-time dot that matched up with the pad orientation, which ended up working very well.

Overall, the evaluation showed that the prototype performs reliably in detecting pressure, locating hits, and delivering usable feedback.

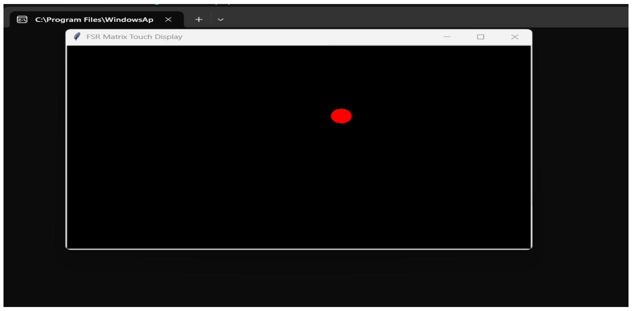

Figure 4: FSR Matrix Touch Display during contact

While accuracy drops slightly on edge cells and sensitivity varies between sensors, the system functioned well enough to demonstrate the concept of a low-cost, matrix-based strike-zone detector.

6 Risks and Challenges

Despite my belief that there is strong potential for this project, a few possible risks have come to my attention. The first one that came up is hardware feasibility. This is because the physical pressure pads may be too fragile due to the wide range of force production possible with a baseball, expensive due to a limited budget, or too complex to prototype with limited time and skills. Expanding off of this risk, another one is sensor accuracy. The reliability of things like impact detection and velocity readings through pressure pads is not guaranteed without access to higher-quality equipment or lab conditions, again due to the high force output and possible spin rates. On the computer side of the project, there may be user interface challenges since I am trying to design an intuitive and error-free input system for pitch tracking, which might require more refinements than anticipated. Also, managing the data collection and ensuring storage and retrieval of data goes smoothly without a full backend or cloud setup may require extra attention to avoid bugs or data loss. In consideration of the project overall, a risk for me could be time constraints. Being able to balance both the software and hardware development may be challenging within a semester. The digital portion will definitely be prioritized, but the physical portion may remain at the prototype stage or have to be simplified, depending on usefulness or progress towards the end of the semester.

7 Future Work

A major future improvement would be building a full-size, vertical strike-zone pad similar to what pitchers use in training facilities. This specifically could include a larger sensor array by expanding the current 16×10 matrix to a full strike-zone size, so the athlete can throw while standing normally. To make this possible, it would need a very durable backing or safety layer because the sensors need to be mounted behind a flexible but durable cover that can absorb lots of impact from baseballs without damaging the electronics. To use a much larger pad, it would need better impact detection, which could mean using a larger FSR matrix or multiple smaller ones sectioned off into a 3x3 grid like a nine-pocket stand that is more commonly used. It could also integrate some type of accelerometer on the entire frame so that it is able to estimate ball velocity on impact. These are important upgrades because they would allow realistic pitching mechanics at a standing distance and/or full motion with more accurate strike-zone feedback, and turn the prototype into a full training tool, not just a desk-top experiment. Also, off of the main idea, another idea I had that I was unable to do was having saved sessions and/or a database that automatically stores all throw data, calculates accuracy metrics, and generates long-term tracking across sessions.

8 Acknowledgments

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