Senior Design Fall 24’ MAY 25-49

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Executive Summary

Pitch Perfect is a project designed to detect illegal pitches in slow-pitch softball. In slow-pitch softball, an illegal pitch is when a ball is thrown from the pitcher's mound to home plate by a pitcher, and that pitch either doesn't reach a minimum height of six feet or goes above a maximum height of ten-twelve feet. Currently, these pitches are called by an umpire, who also calls if a pitch is a ball or a strike and if a player is safe or out at each base. The reason for our device to detect illegal pitches is that players often disagree with illegal pitch calls made by an umpire. Visually determining six feet, ten feet, or if a ball is within that zone, can be very subjective and lead to lots of arguments throughout a game. Additionally, pitches that are below six feet are dangerous to pitchers, as they are easily hit right back at the pitcher. These are the main issues that Pitch Perfect aims to solve.

Our design requires us to identify an illegal pitch within the accuracy of one softball diameter (3.81 inches). Imagine an umpire eyeballing the height of a pitch, our program should have no more variance on calls than what a human umpire would give. We also must signal an illegal pitch to the batter, pitcher, and umpire when one occurs, and this signal must be as fast or faster than when an umpire would naturally make the call. Finally, we are required to not have our device interfere with the game, so it must be placed outside the field of play.

Our current design approach is to use a phone camera to view a softball game in real-time, track the softball throughout a pitch, determine the height of the softball throughout the arc, and, if the ball is detected to be illegal, output an "illegal" sound for players to hear. We are using the OpenCV library to track the softball because of its quick processing time and the quantity of material about it online. To migrate our application to mobile devices, we are using the Flutter framework. For hardware, the phone will either be mounted to the outside of a game fence or set up on a tripod outside of the fence. The user will connect the device to a speaker and go through a short calibration process. Once the system has been set up, the program will run for the remainder of the game, indicating pitch legality during that time. In the future, additional statistics including pitcher's accuracy, batting averages, and pitch speed may be viewed live or logged for later use.

Our current design will meet all of our design requirements so long as we are able to achieve the accuracy goal of within 3.81". Our next steps as we move forward into the spring semester are to improve our height accuracy to our specifications, migrate all of our code to a mobile application, and test our device. The tests will include usability, accuracy, speed, and availability. Accomplishing these tasks will allow us to have a product that meets our client's expectations.

Learning Summary

Development Standards & Practices Used

- ISO 5725-1:2023: Accuracy (trueness and precision) of measurement methods and results
- ISO 9241-210:2019: Ergonomics of human-system interaction
- ISO/IEC 25010:2023 Systems and software engineering- systems and software quality requirements and evaluation
- ICS 17.020: Metrology and measurement in general
- ICS 17450-1:2011: Model for geometrical specification and verification
- IEEE 1448a-1996: Standard for information technology- software life cycle processes

Summary of Requirements

- Detect illegal pitches within 3.8 inches of accuracy
- Be placed outside of the field of play during a game
- Alert players of illegal pitches at least as fast as an umpire
- Not put a large additional cost on softball leagues to use

Applicable Courses from Iowa State University Curriculum

List all Iowa State University courses whose contents were applicable to your project.

- COMS 2270
- COMS 2280
- COMS 3090
- COMS 3190
- ENGL 3140
- SP CM 2120
- PHYS 2310

New Skills/Knowledge acquired that was not taught in courses

List all new skills/knowledge that your team acquired which was not part of your Iowa State curriculum in order to complete this project.

- OpenCV development
- Python development
- Working with clients
- Mobile App. Development
- Cross-platform development (Flutter, React Native)

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List of Figures/Tables/Symbols/Definitions

1. Introduction

1.1. Problem Statement

Slow Pitch Softball is primarily a recreational sport, a chance for a team to have a good time, be active, and do it in a competitive environment without the stress of professional sports. That said, there are still rules that the players must follow. One such rule plagues pitchers, batters, and umpires everywhere: illegal pitches. All pitches must reach a minimum height, usually 6 feet, and not exceed a maximum height of around 10-12 feet, depending on the league. If a pitch does not meet these requirements, it is considered "illegal," and the batter does not have to swing at it.

Human error leads to more complications than the simple parameters may let you believe. An umpire standing behind home plate is the one who must call an illegal pitch. If he calls a pitch too late, a batter may have already begun to swing and be frustrated that they didn't have to swing at the pitch. If he inaccurately calls an illegal pitch, the pitcher will be frustrated with a fine pitch, suddenly becoming a free ball for the batter. Frustration about illegal pitches causes frustration amongst players who don't need to be there in a sport like Slow Pitch Softball. This is the crux of our problem.

We are tasked with finding a better way to call these illegal pitches. We will create an external device to detect a pitch's height accurately and quickly signal if it is illegal. Cutting out the subjectiveness of an umpire in illegal calls (and allowing them to direct their focus on the rest of the game) while making a call just as fast, if not faster, than one will make illegal pitches easier to deal with for everyone involved. We will use a camera and speaker system, such as a phone pointed at the pitcher, to track and call an illegal pitch.

1.2. Intended Users

The application we create to determine whether or not a pitch is legal or illegal will have three different users. These users consist of slow-pitch pitchers, hitters, and the umpires for the slow-pitch games. The pitchers can benefit from this application as they can fine-tune their pitches to the perfect height. The batters will benefit from this application as they will be informed that it is illegal and that they do not have to swing in plenty of time. Lastly, the umpires, typically umpiring as a side job, will benefit from this application because they will not have the pressure of being perfect at calling illegal pitches based on their eyesight and will be able to rely on the application itself to do it.

The pitchers that play slow pitch need this system to ease consistent illegal pitch calls. Right now, the pitcher relies on the umpire to call it early enough in the pitch's life cycle so that the batter knows they don't need to swing. Although it may sound like only a benefit for the batter, the batter knowing they don't have to swing allows for a safer environment for the pitcher as there is a smaller chance that the ball gets hit right back at the pitcher.

The batters that play slow pitch need this system, so they know when an illegal pitch is present, and they aren't required to swing. In slow-pitch softball, there is an unwritten rule to not hit the ball right back at the pitcher. If the batter has two strikes and the last pitch they see is illegal but not called, there is more of a chance the ball gets hit right up the middle, where parties from both

teams may be upset. This application will also allow the batter to be more specific on pitches they are swinging at so that they can be selective on when to swing and when to not.

The umpires that work during the slow pitch games need this application so that they are required to do less and can focus on watching the ball in play and the bases. The umpires benefit from this the most because they will have less weight on their shoulders on being consistent throughout the game on knowing the exact height of a pitch. They won't have to hear complaints from the teams about calling illegal too late or not calling illegal at all as the application will take that aspect out of their job, and no one can complain about it.

1.3. Empathy Map

1.3.1. Hears

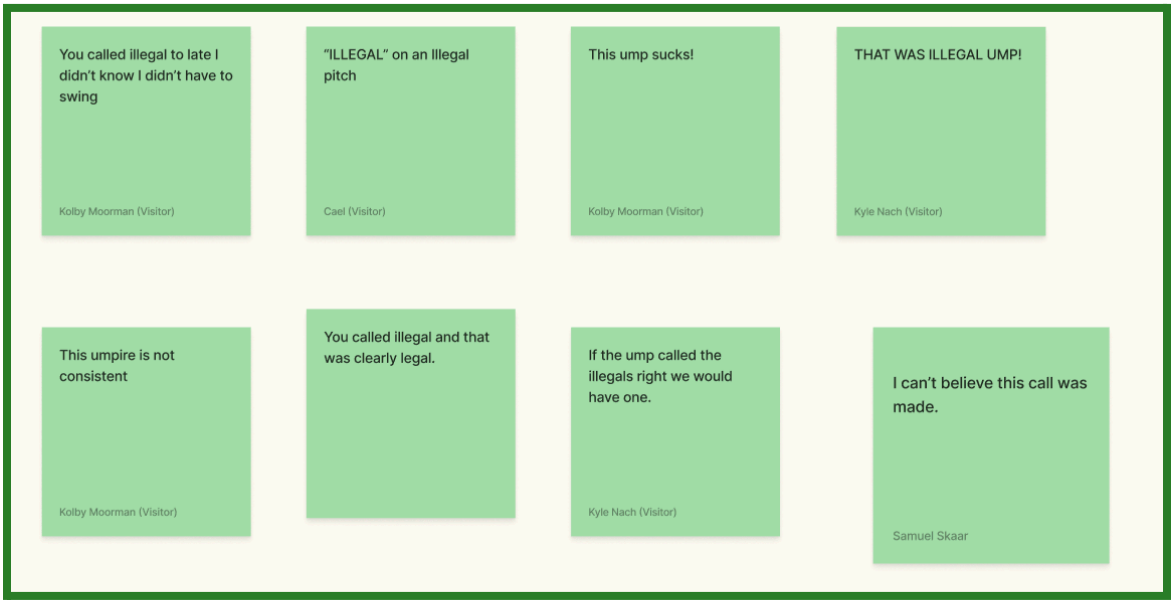


Figure 1.3.1

1.3.2. Sees

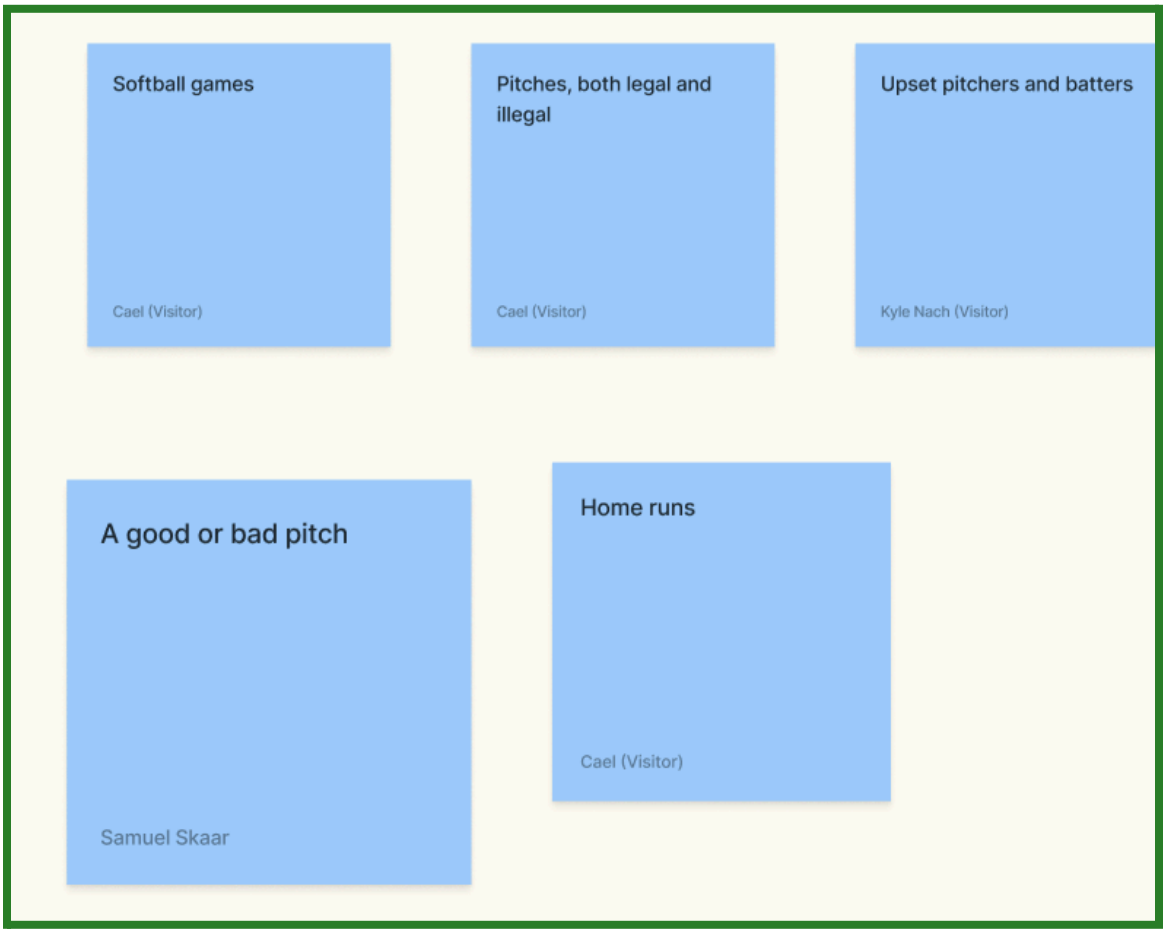


Figure 1.3.2

1.3.3. Thinks & Feels

Figure 1.3.3

1.3.4. Says & Does

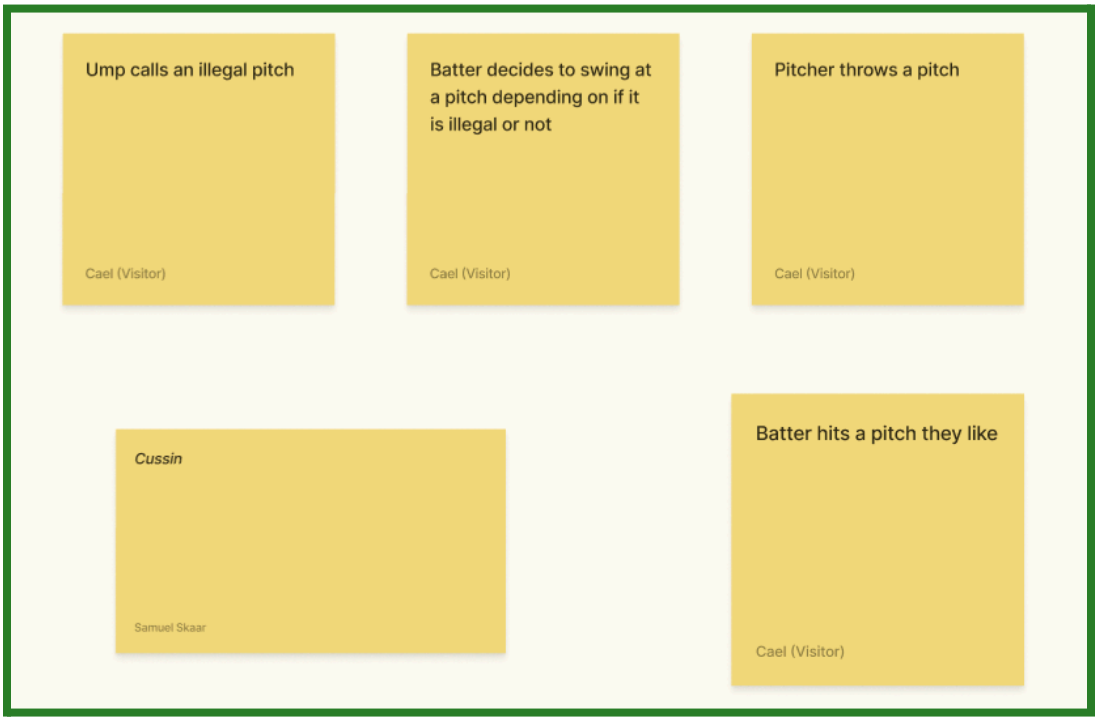


Figure 1.3.4

2. Requirements, Constraints, And Standards

2.1. Requirements & Constraints

Functional Requirements:

- Our device must be able to detect an illegal pitch lower than six feet (specification)
- Our device must be able to detect an illegal pitch higher than 10-12 feet (specification)
- Our device must be able to detect illegal pitches within 3.8 inches of accuracy (specification, constraint)
- Our device must alert players as fast or faster than an umpire (specification)
- An audible signal must be made upon detection of an illegal pitch (specification)
    - The signal must be loud enough for the batter, pitcher, and umpire to hear
- The device must be usable in a location where it does not interfere with the game (physical, constraint)
- The device must be usable in a location where it is not in danger from the game (physical, constraint)
- The device must be portable (physical, constraint)
- The device must have a fast enough camera to process a pitch, greater than 30fps (resource)
- The camera must have a resolution high enough to accurately process each frame, at least 1080p (resource)

User Interface Requirements:

- Our device should be simple for any softball player to set up and use (user experiential)
- Our device will have clear instructions for users to input needed measurements for calibration (user experiential)
- Our device should be cheap enough to not:
    - A) Effect league fees if leagues provide the device (no more than $10)
    - B) Be a large expense on a player or team (economic, constraint)
- Our interface should record and replay pitches (user experiential)
- Our interface should clearly indicate how a pitch was illegal (too high or too low) (user experiential)

2.2. Engineering Standards

Engineering standards are important because they give us as engineers a baseline for minimum requirements to ensure safety and health. These standards play a vital role to make sure we as users or consumers are given a quality product and not something that will just break shortly over time or not be able to perform certain actions it claims. Through these standards, engineers are given a minimum benchmark to ensure all of these standards and qualifications are met.

2.3. Engineering Standards in our Project

ICS 17.020: Metrology and measurement in general

This standard covers a variety of aspects in regards to measurements. The standard serves as a guideline for engineers to ensure consistency, accuracy and reliability in terms of measurements.

ICS 17450-1:2011: Model for geometrical specification and verification

This standard is part of the GPS standards that cover the geometric features of products. This standard ensures that measurements in a geometrical way are consistent and accurate throughout different procedures.

IEEE 1448a-1996: Standard for information technology- software life cycle processes

This standard provides a framework for the software development and management processes creating software processes. It establishes a common ground for definitions and processes that help software engineering teams follow best practices for large-scale software projects and development.

2.4. Engineering Standards Relevance in our Project

ICS 17.020 provides relevance to our slowpitch softball project because we are creating an application that relies solely on measurements. If the measurements are inconsistent or inaccurate, our application is useless and will give an unfair playing field in a softball game.

ICS 17450-1:2011 provides relevance to our slowpitch softball project because as we are gathering our measurements, we will be relying on geometrical measurements to ensure the measurements of the height are consistent and accurate.

IEE 1448a-1996 provides relevance to our slowpitch softball project because our project's end deliverable will be an application that users can use to track the height of a softball to determine whether or not a pitch is illegal. Throughout this process of creating our application, we will rely on the software life cycle process in order to deliver the best version of our product.

2.5. Engineering Standards that could be considered in our Project

ISO 5725-1:2023: Accuracy(trueness and precision) of measurement methods and results

ISO 9241-210:2019: Ergonomics of human-system interaction

ISO/IEC 25010:2023 Systems and software engineering- systems and software quality requirements and evaluation

2.6. Modifications to meet these standards

One modification we intend to make is improving our device calibration and how we detect height. We are not currently at a level of measurement accuracy that would comply with this engineering standard (ICS 1745-1:2011) so we need to do some more work to get there. Specifically, we are going to include more known variables during our testing to make sure we can accurately make certain measurements before we do full “game” testing.

We also intend to start considering our end-user interface. As of now, we have done minimal work on developing our application piece, which will be a large part of our deliverable. Going forward, we are devoting at least two of our five members each week to work on developing our user application and interface and will make sure that it complies with our third selected standard.

3 Project Plan

3.1 Project Management/Tracking Procedures

For Pitch Perfect, we will be using a hybrid style process where we adapt features from both the agile and waterfall management styles. We will use waterfall elements like fixed timeline and sequential progression. We chose to adapt these elements from waterfall because with our app, we cannot do things like track the height of a ball if we can't track the ball itself. We will, however be using Agile elements for the user interface as these tasks can be split up into a bunch of different smaller tasks and allow for more precise workflow. Our team also does weekly client meetings, which is a lot like agile. Throughout the semester we will create a job board with issues in Git Hub that we will assign to each team member so that no two people are working on the same issue and we can enhance the productivity of our group.

3.2 Task Decomposition

We have broken down each functional component of our project into a separate task that must be solved, as well as a flow of how each of these components will flow together in our final design:

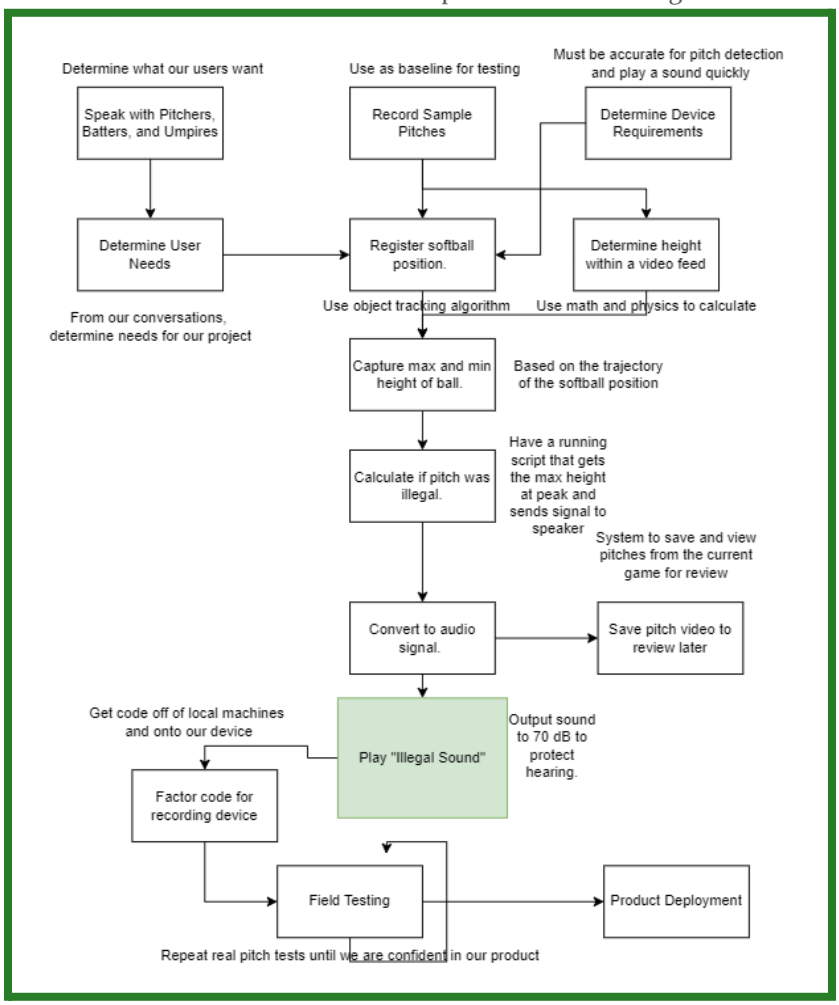


Figure 3.2.1

Many of our early tasks can be completed non sequentially, in a sprint style, such as our player interviews, pitch recordings, and client requirements. As we move forward with our project, much of our tasks fall into a waterfall style, as we cannot determine the height of a ball until we register its position, and we cannot determine an illegal pitch until we have registered its height, and so on and so forth. During our early development, we broke our team up to solve each sprint-like task, but as we got to the point where each task relied solely on an earlier task, we would break off our team to solve external tasks, such as our application development:

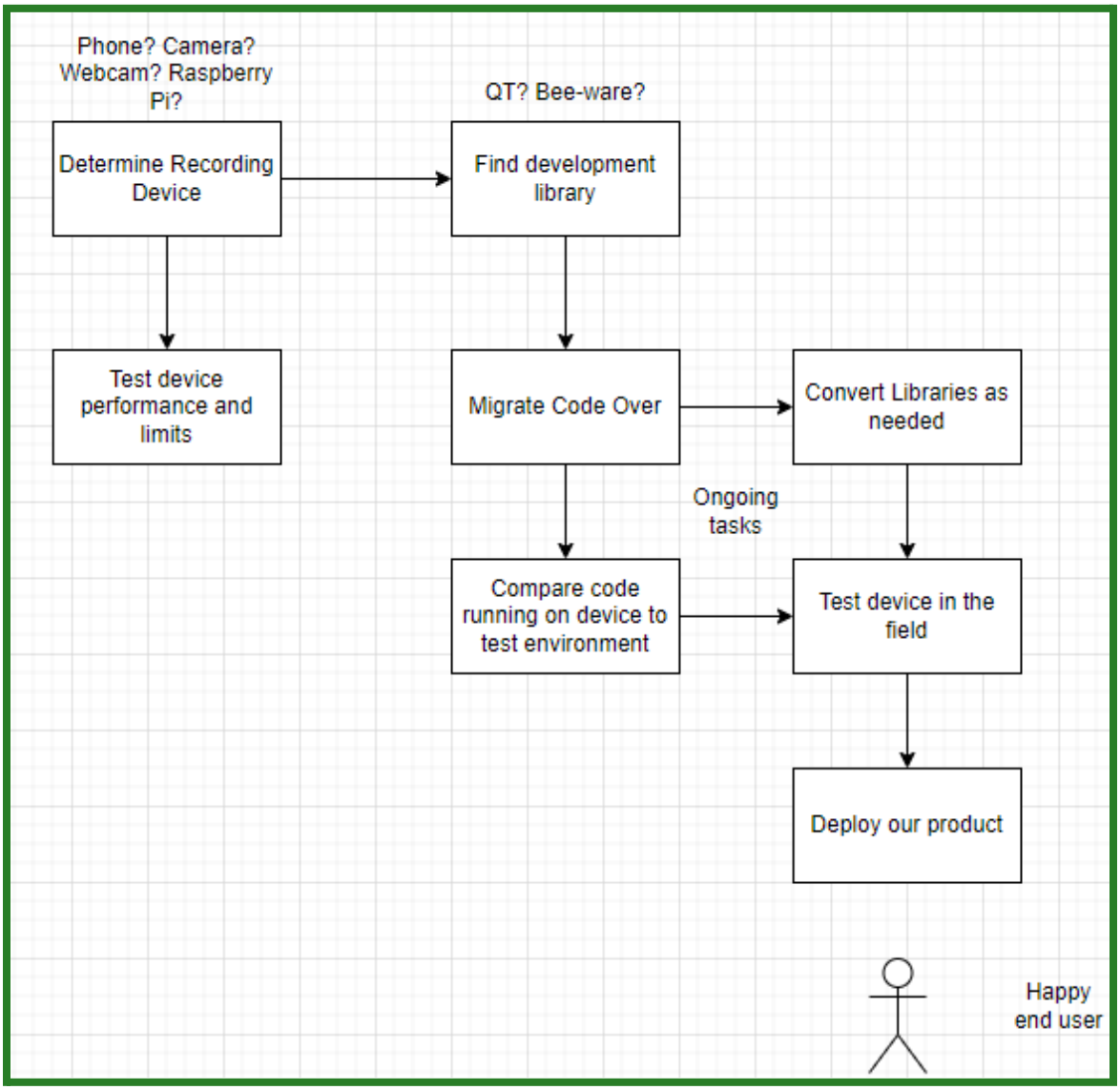


Figure 3.2.2

3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

Many of our milestones in our early development and prototyping process are defined by working features of our device, object detection, and tracking, tracking a pitch through its arc, tracking the height of a ball, and so on and so forth. Thus, we have broken down our developmental milestones, followed by our product accuracy milestones:

Development and Prototyping Milestones:

The device can identify and track a softball in ideal conditions.

The device can follow the arc of a softball throughout its pitch.

The device can track the height of a softball with an accuracy of 1 ft.

The device can play a sound within 0.5 seconds of detecting an illegal pitch.

The device can work with all unknown elements inputted by a user.

A working prototype to detect and call an illegal pitch in a live setting.

The device can accurately run for 10 consecutive pitches.

Product Accuracy Milestones:

The device can identify and track a softball in any lighting condition.

The device ignores all elements of the frame except for the arc of the pitch.

The device can accurately track the height of a softball throughout its arc within 4 in.

The device works with only the necessary elements inputted by a user (camera height).

The device can run for an entire softball game, for two hours.

Our device is complete.

3.4 Project Timeline/Schedule

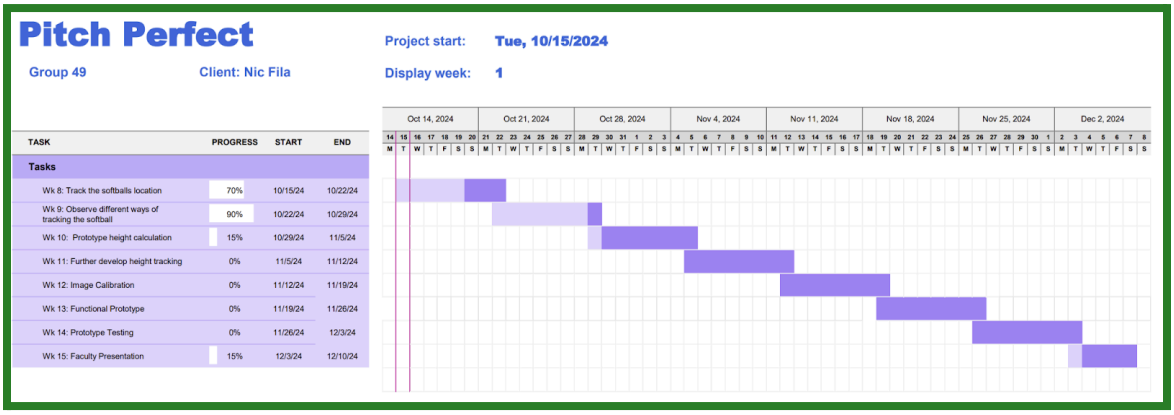


Figure 3.4

We as a group have set up a tentative schedule based on everything going smoothly. We have broken it down into 8 weeks for the remainder of the semester. These tasks range from tracking the softball location and height of the softball to prototyping and the faculty presentation. Throughout the semester these times could change depending on tasks being completed faster than expected or a little longer than expected however the deliverables of a prototype application and presentation upon it will be scheduled to be done by December 3, 2024.

3.5 Risks and Risk Management/Mitigation

A potential risk that comes from any live recording device is performance. How can you capture enough data in real-time and process it quickly enough to satisfy users, while still being accurate enough to satisfy our client's requirements? The more resolution our camera takes information in as, the more data we will have to process, and the more our framerate could suffer, and vice versa.

We can mitigate this risk by using a device with a natively powerful camera (such as an iPhone or similarly powerful camera) to give us options on our recording resolution, so we can scale to whatever level of performance is needed. We can also simplify our algorithms and use threading on our processes to keep our processing time low.

Another risk to the integrity of our device is the accuracy of our measurements. We want our device to be able to measure to the accuracy of one softball diameter (4 inches) when detecting illegal pitches. If something causes that accuracy to not be met, our device will not be seen as reliable and risks not being used by our users, or satisfying our client.

We can mitigate this risk by testing using as many known measurements as possible to make sure our device is meeting its accuracy requirements. Having recordings where a ball height is known, and seeing if our device can measure to that ball height, will allow us to avoid the guesswork of our accuracy during our development process. We can also mitigate this risk by introducing more components to our design, such as a second camera or more user-inputted fields, but that could compromise the simplicity of our end design.

Another risk comes from the nature of having a device in a sports setting: keeping the device safe. We do not want our camera to be hit with a flying softball and have our project break, but we also want it to be close enough that it can capture all the needed elements of the game.

We can mitigate the risk of our device being damaged by placing it outside the fence of a given softball field. This will protect it from any foul balls, while also still allowing it to record through the links of a fence.

3.6 Personnel Effort Requirements

Task	Prep Hours	Work (Code) Hours	Explanation
Prototype Height Calculation	5	8	Doing the math to determine the height of a ball given the most known parameters + having the program compute that math.
Further Develop Height Tracking	0	10	Tweaking code to have the most accurate height. This includes detection for pitches thrown off center.
Image Calibration	10	20	Determining the process of setting up the camera and making the application do most of that work. This includes making the user

			experience as light as possible.
Functional Prototype	20	20	Prep time includes moving the application to an iPhone development platform. Work will include changing any threading or weird iPhone things, so basically a continuation of the code base transfer.
Prototype Testing	0	30	Make any changes needed to make the product as accurate as possible, even if it's on known heights and distances from the mound and plate.
Faculty Presentation	The semester	10 (each)	The semester is the preparation that we get for the presentation, but each individual can expect to work a significant number of hours to make the presentation as presentable as possible.

Table 1

3.7 Other Resource Requirements

To complete this project, we needed to acquire multiple resources. One is a phone fence mount to accurately and consistently measure pitch height. The following resource we required was a softball to test our height detection. And finally, we made a contraption with strings at 6ft and 10ft to help with calibration and testing. Some other resources that we could benefit from are a tripod, potentially a camera, and a speaker.

4 Design

4.1.1 Broader Context

We are designing this product for slow-pitch softball recreation leagues. They are all across the country and usually consist of working adults. Any league that decides to implement our product would benefit from it, but the most affected players would be pitchers, batters, and umpires, as they are the three main actors during a pitch. The main need addressed by our project is the desire for a reduction in arguments over illegal pitches, as they frustrate umpires and players. Having an external device make these calls can reduce frustration with umpires.

Area	Description	Examples
Public health, safety, and welfare	When a slow-pitch softball league uses our product, conflicts about illegal pitches will be reduced and lead to a smoother game experience. It also will help keep pitchers safe from dangerous low pitches.	Arguments with umpires are reduced, low illegal pitches are called consistently, and users must be outdoors to use the application increasing activity.
Global, cultural, and social	Slow-pitch softball leagues can use this product in any league or location, which is important because slow-pitch softball is a nationwide recreation activity.	A league in Iowa vs a league in California would get the same experience when using our application.
Environmental	To use our project effectively, we recommend that some sort of mount device be used. This would require extra purchases, which could lead to extra plastic being used for a tripod, but we aim to keep it minimal.	An increase in tripod and fence mount purchases could lead to an increase in waste from our users if thrown away.
Economic	We plan to keep our product as cheap as possible. Our application will be free for mobile users to use, and the external equipment to mount a phone can be found at or under $20. The largest expense may come to a league if they decide to use a league-purchased phone to run our product or a high-end Bluetooth speaker.	Our application will be free, the external equipment will remain cheap to users or leagues, and a league phone would be the largest expense though it is not a requirement to use the project.

Table 2

4.1.2 Prior Work/Solutions

Throughout research for products similar to our slowpitch application, we found a very widely known app that is able to be purchased for tennis and pickleball. Although they are not tracking the height of the ball, their main focus is on tracking the exact location of where a ball lands in order to tell whether it is within the boundaries or not of the given court. Although there is no way to access this code, it did allow us to gather some ideas for a user interface as well as let us know that this project is able to be accomplished [1].

Another similar product that we found was Flightscope. Flightscope is an application that can be used to track pitching and hitting data like horizontal launch, spin rate, and pitch velocity among others. This application is meant for both hitters and pitchers and allows them to review the analysis of their performance in different metrics. [2].

As far as object tracking there are various applications that are used today like tracking people. As a team, we did a few different methods after doing some thorough research on object tracking. This ranged from MOSSE to KCF tracker. MOSSE was one method that we strongly looked at after reading that it is OpenCV's fastest object-tracking method [3].

4.1.3 Technical Complexity

Our project contains multiple components and considerations, as well as challenging requirements within those components. Within our application, we must take in video input, and process the video in real-time while:

- identifying the softball within a pitch
- determining the position and height of that softball throughout a pitch
- determining if that softball pitch is legal or illegal

Factors like background video noise, game times, lighting conditions, camera perspective, camera location, and processing time cause these seemingly simple tasks to become much more difficult. Edge cases are everywhere, and techniques that work for certain situations can fail in others. Finding a way to consistently identify a ball in any lighting conditions and accurately track it. Determining height and positions requires math and physics to position accurately. With all of thi,s we also want a simple user interface and calibration process for our users, so we want to be able to accomplish all of this with only one camera. All of this has caused significant challenges to overcome within our project.

4.2 Design Exploration

4.2.1 Design Decisions

For our project, we must design three essential components to have a successful product. These include an accurate system that can track the height of a softball, a quick processing time that allows for an audio output the second it realizes the pitch is too high, and an application that can be deployed from a phone that is seamless and easy for the user experience.

Accurate System - An accurate system is the most critical design decision we have to make in order to have success with our project. If the system is inaccurate, there will be no use for any of our users as the human eye would be better and more accurate. The entire purpose of our system is to track the height of a softball, so without focusing on this detail, our project would be nonfunctional.

Quick processing time - Quick processing time is another important aspect of our project. If the processing time is too slow, our project is also useless because as a user of our project, they need to be able to hear that the pitch is illegal the second it becomes illegal, or they will lack the need for the system.

Application for phone - An application is also an important aspect of our project to allow users to actually operate the system. The application will allow users an easy setup to get the system up and running and allow for the other design aspects (Accurate System and Quick processing time) to work seamlessly together.

4.2.2 Ideation

We came up with an application after talking to users of our project. The application would make an easy and robust way for users to use our system and not require much time to set up at all. This would also make our pitch detection system available to anyone who wants to try it out whenever and wherever they are located without having to go and buy special equipment.

A few of our other ideas included:

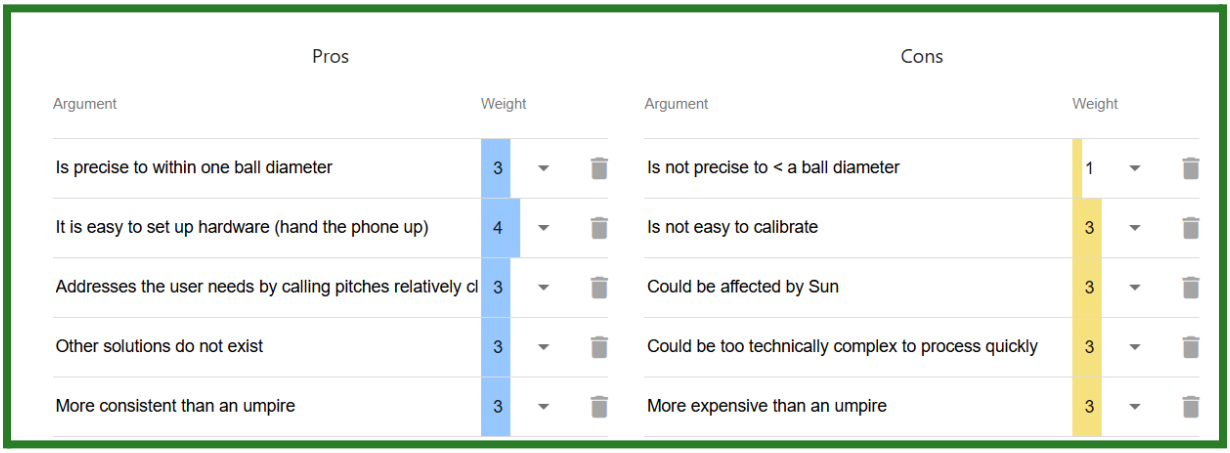
- Multiple camera systems set up around the outside of the ballpark. This would allow for easier integration and maybe even more accuracy to the exact millimeter of measurement.
- A sensor in the ground would alert the umpire that the pitch was illegal and allow for the umpire to be the one to call it “Illegal”.
- A player-focused detection where they had a clip-on camera and a gyro wristband in order to track that the pitch was illegal and alert the users.
- An in-play component where there was a chip inside of the ball that would alert the umpire the pitch was illegal.
- One singular camera would then alert the umpire that the pitch was illegal via vibration or light so he could make the illegal call.

4.2.3 Decision-Making and Trade-Off

We chose to do a round-table discussion that evaluated each proposed option for our pitch detection system. During this discussion, we identified the pros and cons of each idea, considering factors such as ease of user setup, cost, accuracy, durability, scalability, and overall feasibility. We also heavily favored our clients' wishes along with the initial interview we conducted with players.

While we considered using tools such as weighted decision matrices, we ultimately opted not to rely on formal tools. Instead, we continued our conversation and maintained an open dialogue until a clear direction emerged. This iterative discussion allowed for deeper consideration of practical trade-offs and ensured that all perspectives were heard, leading us to a well-rounded decision that best meets the needs of our intended users.

Moving forward toward the deployment of our application, we may choose to incorporate more structured tools, such as a weighted decision matrix, to help us further evaluate and weigh our options. This would provide a more systematic approach to refining our solution, ensuring that we continue to prioritize factors such as user needs, feasibility, cost, and scalability as we move from concept to implementation. By doing so, we can maintain alignment with our goals while making data-driven decisions that optimize the effectiveness and usability of our pitch detection system.



Pros		Cons	
Argument	Weight	Argument	Weight
Is precise to within one ball diameter	3	Is not precise to < a ball diameter	1
It is easy to set up hardware (hand the phone up)	4	Is not easy to calibrate	3
Addresses the user needs by calling pitches relatively cl	3	Could be affected by Sun	3
Other solutions do not exist	3	Could be too technically complex to process quickly	3
More consistent than an umpire	3	More expensive than an umpire	3

Figure 4.2.3

4.3 Proposed Design

4.3.1 Overview

Our design uses a camera to watch a slow-pitch softball pitch as it happens. As it records the pitch, it determines the height of the pitch and determines if the max height of the pitch is legal (between 6-12 feet). If a pitch is determined to be “illegal” or outside of these bounds, it will play a sound to alert the users that an illegal pitch was thrown. This will then be repeated for the softball game.

Our first component is the camera system, which we intend to be from a phone setup along the fence of a softball diamond. The phone will be out of play, on the outside of the fence, but still able to record each pitch. A setup process of identifying home plate, the pitcher’s mound, and showing a softball to allow for accuracy in our device.

The next component is our internal processing. This is the bulk of our “code” in this project, that determines the location, height, and legality of a pitch. We use libraries like “OpenCV” to help with this process, and then send our decision to our output.

Our final component is our output device. This could either be on our phone or an external BlueTooth speaker. This simply takes our processing decision and either plays or doesn’t play a sound. The full design is outlined in Figure 4.3.1 on the next page.

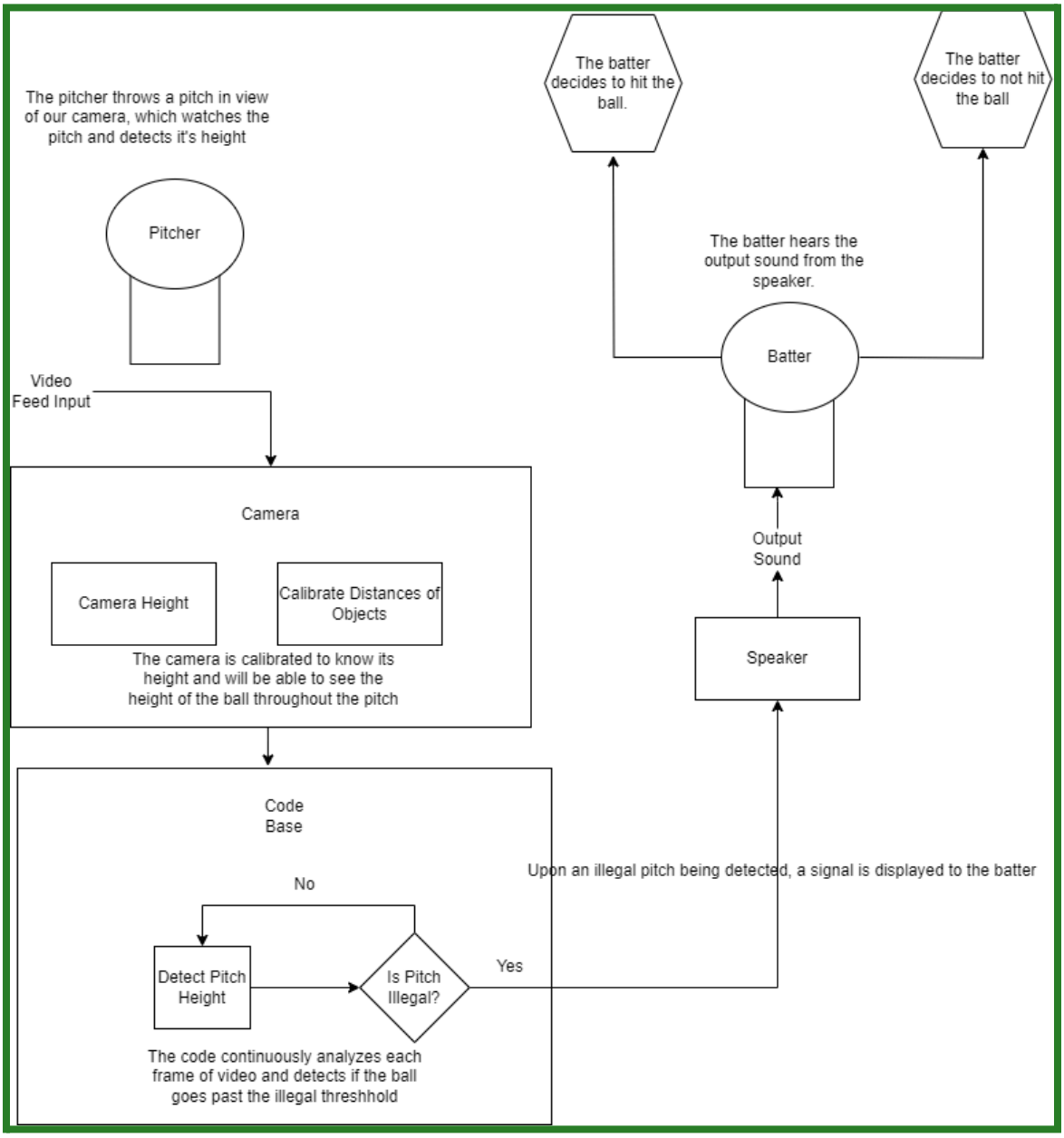


Figure 4.3.1

4.3.2 Detailed Design and Visual(s)

Our design includes a phone mounted to the outer fence of a softball field. The phone will have our Perfect Pitch app installed on it. Our app is made with the QT framework integrating OpenCV to perform real-time image processing for height determination basic design pictured in figure 4.3.2.2. The camera must then be calibrated by camera height, distance from the camera to the plate, and mount to ensure precise measurements and connected to a wireless speaker wire. With the phone set up, the application will run a script that plays audio when the ball goes over or under a specified height range. The phone will be set up in one of the green boxes in Figure 4.3.2.1.

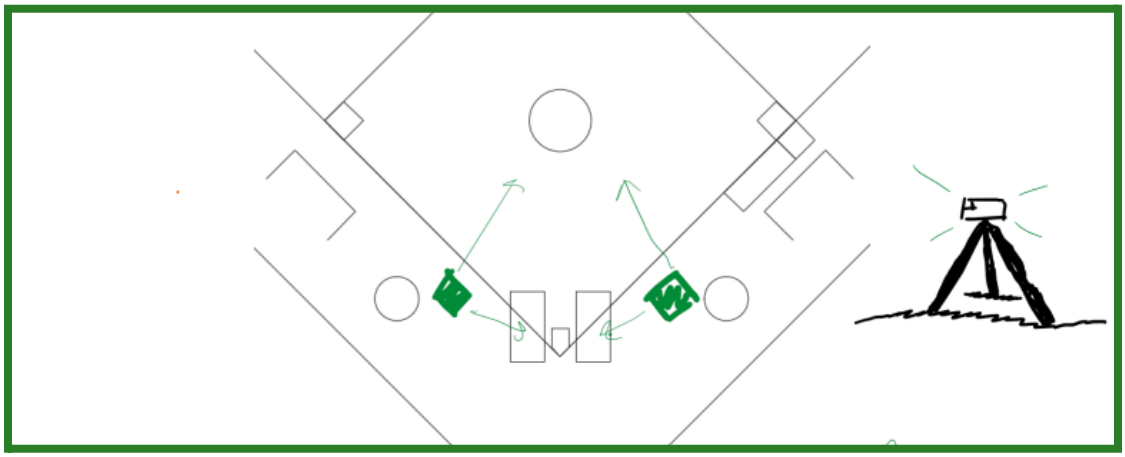


Figure 4.3.2.1

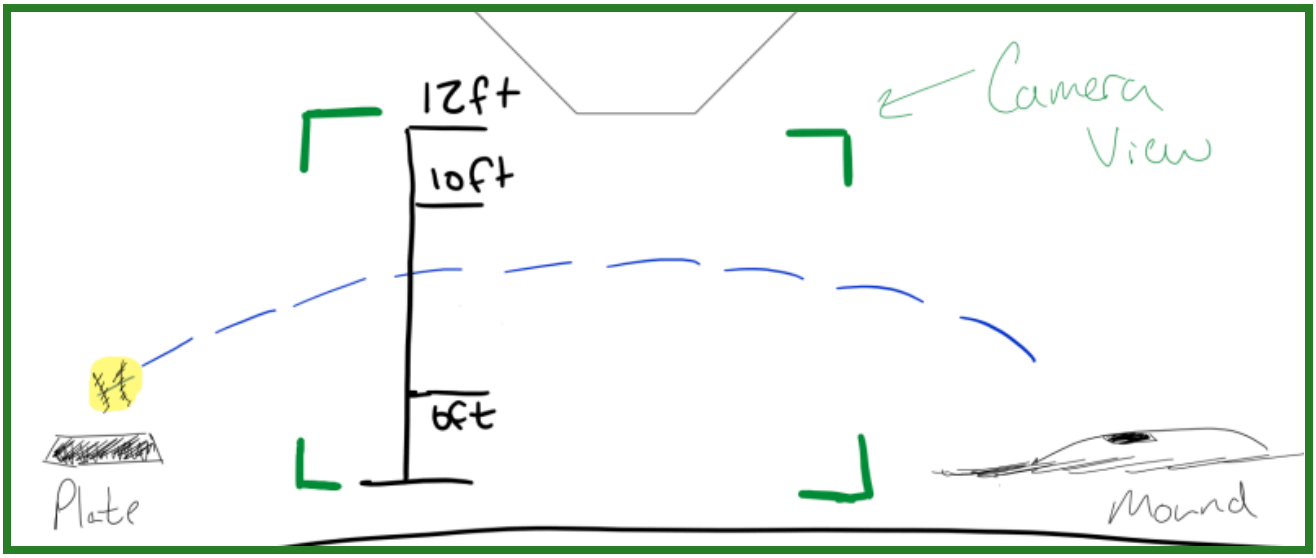


Figure 4.3.2.2

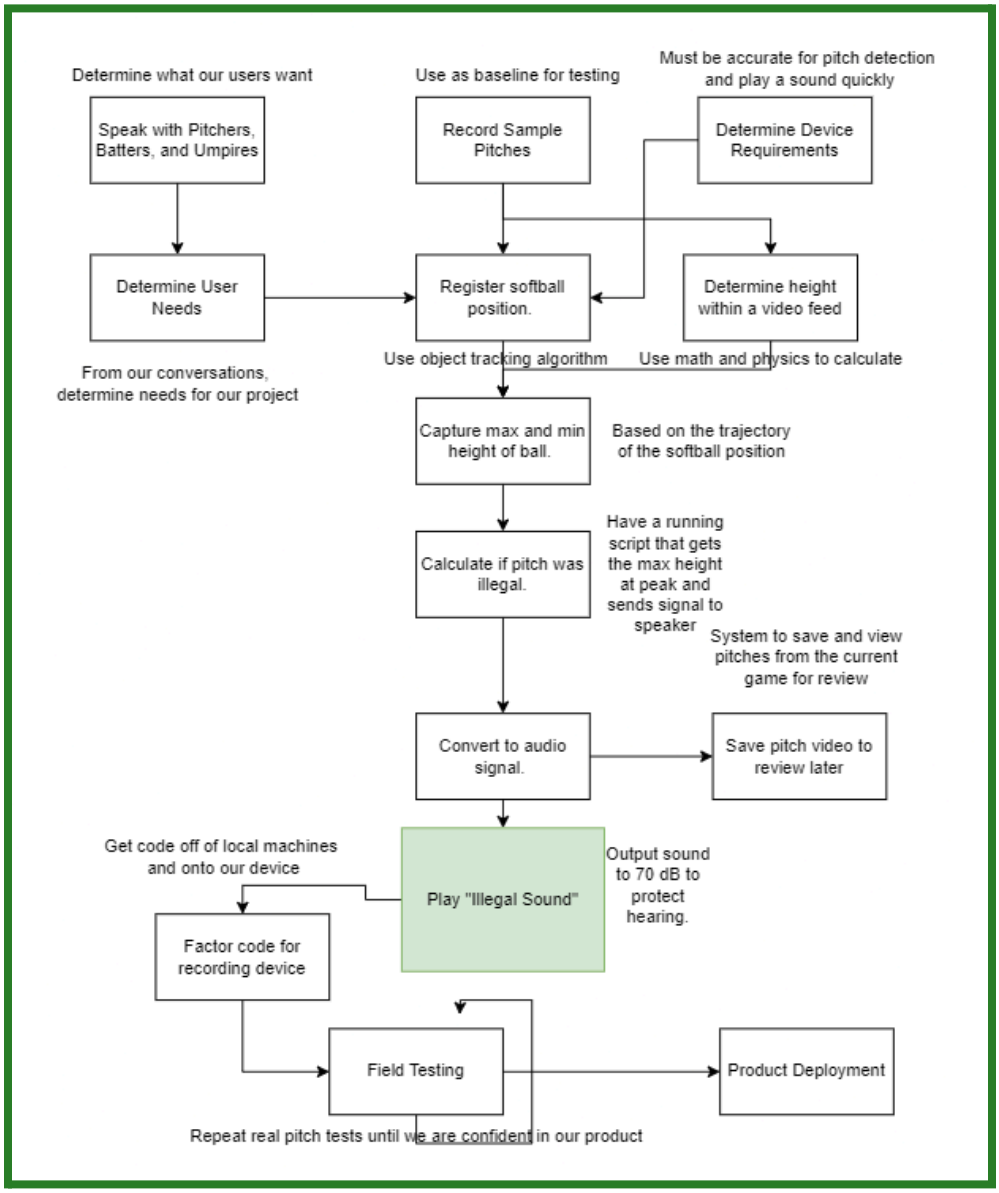


Figure 4.3.2.3

4.3.3 Functionality

The users of the game should be hands-off with the device after set-up. Pitchers will throw the ball and given their pitches' performance, an audible sound will be played so the batter can react to an illegal pitch. The umpire is also responsible for recalibrating the ball's color after every inning to ensure correct readings.

4.3.4 Areas of Concern and Development

Currently, our design is on track to meet our user needs. It is at the point where we can accomplish all of our tasks to varying degrees of success, but we are able to see where we need to go moving forward. The largest areas of concern we have moving forward are:

1. Device performance
    a. How well will our code perform on various phones when running our application? Our code runs fantastically in a development environment on our computers, but we are a little concerned about how universally the performance will scale between devices.
2. Device Accuracy
    a. Our code is able to track a softball position and height to decent success, but not to the accuracy of 4 inches that we are shooting for. This is another area of concern for us moving forward.
3. Device Simplicity
    a. We want our device to be usable with one camera and have a minimal setup and calibration process. We are slightly concerned about how possible this will be to achieve our desired accuracy.

To solve these problems and concerns, we are currently focusing a lot of our efforts on research and development. We are seeing what libraries are out there that solve these problems, and implementing test versions to see how we can solve one problem at a time. We also bring these up to our advisors each week to see what problems we can solve, and what concerns are irrelevant.

4.4 Technology Considerations

We are currently planning on using phones for our camera and application. There are multiple strengths and weaknesses that come along with using a phone for object detection and tracking.

Strengths:

1. Allows users of all kinds the ability to use our product as there is no needed extra hardware
2. Users won't have to worry about purchasing anything for the system to run as expected
3. Seamless setup for the user

Weaknesses:

1. The quality of the video may not be as good as a high-quality camera
2. Could be a little slower processing time than it would be if we had something like a Raspberry Pi
3. Each phone is different so we need to be extra careful with how our tracking is done

4.5 Design Analysis

So far our design is able to track a softball throughout the motion of a pitch and give a height estimate within about 1-2 feet of accuracy. We have also developed app prototypes on an iPhone using the framework QT and will begin to migrate our code over there shortly. Our proposed design has been working so far, but it will require fine-tuning (specifically in the height tracking and softball calibration).

For our future planes, we are continuing to hone our accuracy for detection and height and will continue to test our code on various phone devices. We feel that our current design will allow us to reach our goals, we just need to spend more time improving our components. The OpenCV library is working as expected for our object tracking needs, and we do not feel the need to change our usage right now.

5 Testing

Testing with recordings: We currently have a bunch of video recordings that we took that consist of live gameplay as well as testing where we knew all controllable variables. In terms of controllable variables, we have gathered two 10-foot PVC pipes and attached strings at 6 feet and 10 feet high so that we know the range of a legal pitch.

Testing live: Next semester after getting our height tracking down to what we think is an appropriate range, we will begin going to games and testing the operation of our application to gauge whether or not the application is quick enough for live feedback.

Testing time amount: One constraint we haven't been able to cover yet is the idea of a potential memory issue or code crash as a game could span up to a few hours. After gathering a consistent height-tracking application, we will want to attend a game and start the application, and observe any issues.

Testing with umpire: Next semester, we want to gather a panel of umpires and record some pitches using our application and check to see what they thought each pitch was and what we gathered from our application.

5.1 Unit Testing

We aren't able to use Unit Tests at this point because inputs and outputs are not virtual and cannot be simulated in terms of exact height.

5.2 Interface Testing

Our application will consist of two interfaces. One is the home page where a user can select to go into the pitch detection and a settings page where the user will be able to set their max height (10 or 12 feet). As of now our plan is to use Flutter to create our application and within Flutter there is a tool called Flutter Driver that allows developers to write integration tests.

5.3 Integration Testing

Critical integration paths in our design come from tools that will include components to identify a softball's position, a softball's height, the ground, a baseline height at the pitcher's mound, and a baseline height at home plate. We will test how systems that find all of these components integrate by testing them first in environments where other variables are controlled to verify correctness before moving to full system testing.

5.4 System Testing

To test our entire system, we will be running live pitch tests at a softball diamond with our device outside of the fence, as if it were an actual game. We will throw both legal and illegal tests to ensure that our device is making correct calls and ensure that all components mentioned in 5.3 are working as expected at full scale.

5.5 Regression Testing

To ensure that new additions do not break app functionality, we have multiple "experiment" folders for our members to work in to ensure they are able to mess around with code without it affecting the main app. We are also utilizing Gitlab, which allows code branching features to ensure that we can verify new features as a group before anything is pushed to our main branch.

5.6 Acceptance Testing

To ensure our device meets its functional requirements, we will test it against an umpire to make sure it is at least as consistent, accurate, and fast as an umpire. We will also test that the height tracking throughout a pitch is within 3.8 inches of accuracy, as that is our goal.
For our users, we will perform usability testing for our application setup process to ensure that it is easy to use and improve our user interface with feedback as we receive it.

5.7 Results

Currently, our main results come from our process of tracking a ball and identifying a ball's height. We are able to consistently track a ball throughout a pitch in its entirety if we know the lighting conditions ahead of time (day, night, overcast, etc). The next step we are working towards is testing methods to track a ball in any lighting conditions.

For our height tracking, we are able to determine the height of a ball within roughly 8 inches of accuracy. This is a great start, and we are going to continue improving and testing our algorithm going forward to achieve our 3.8-inch goal.

6 Implementation

Our current implementation focuses on object tracking and height detection. We use the library "OpenCV" to accomplish this. For softball detection, we use a color mask to search for the neon-yellow of a softball and track the movement of that color to determine where that ball is during a pitch. In Figure 6.1 below, you can see a ball being tracked and having its arc displayed, while also seeing the color mask used to identify the ball below it.

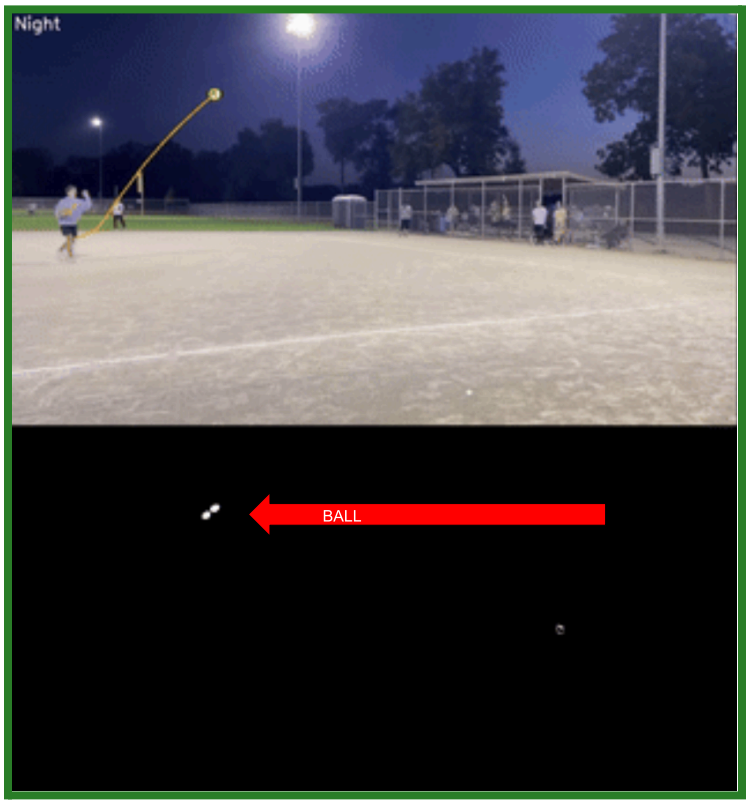


Figure 6.1

To track the height of our softball, we are using fixed height points at the pitcher's mound and home plate to determine a known height conversion for the start and the end of a pitch, and linearly interpolating between the two measurements to find the height of a ball throughout it's arc. We use a line between the pitcher's mound and home plate as a mark of the ground for the ball. In Figure 6.2 below, a sample pitch is visible with a 10 ft pole at the start and end of the pitch that we have used as a test for this method.

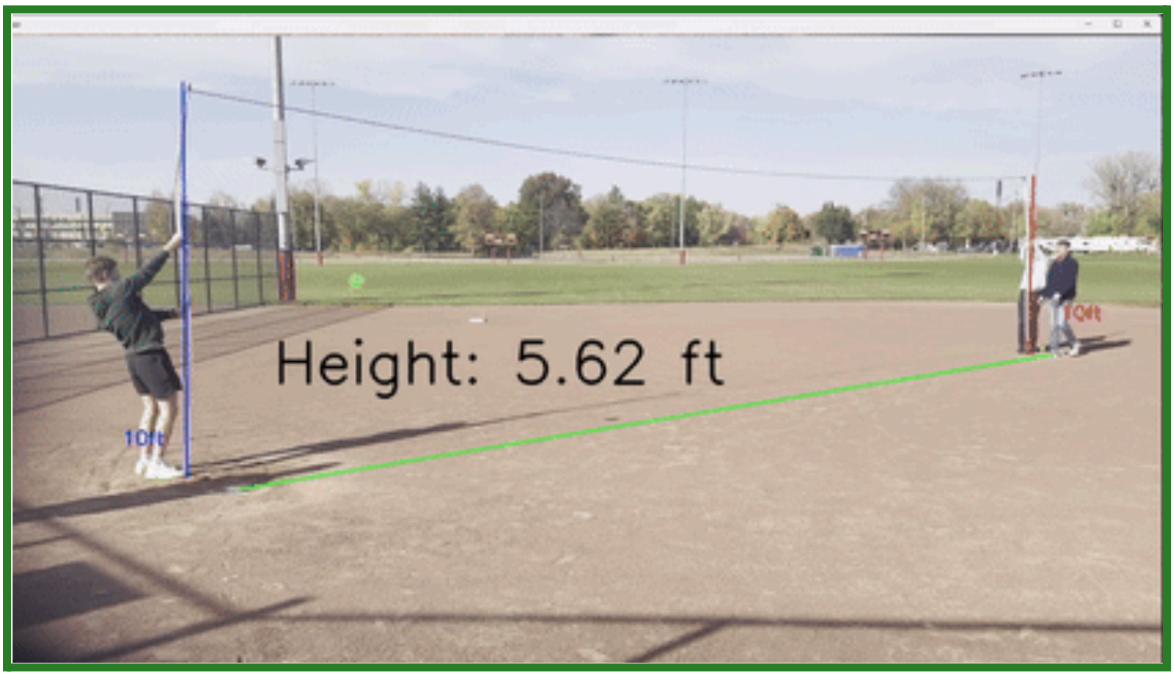


Figure 6.2

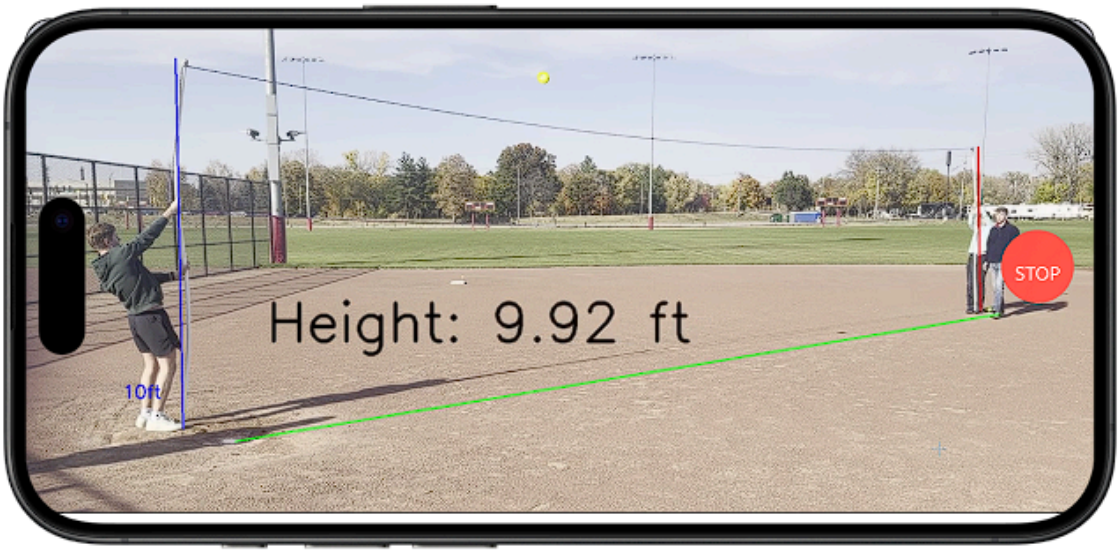


Figure 6.3

7 Ethics and Professional Responsibility

7.1 Areas of Professional Responsibility/Codes of Ethics

Area of Responsibility	**Definition**	**Relevant Items from SE Code of Ethics**	**How our team has interacted with area**
Work Competence	Ability to complete work quickly, correctly, and to a standard quality.	2.01: Providing service in their area of competence 3.01: Strive for a high quality	Our team has weekly meetings where we work on our project and expect a high level of quality from each other.
Financial Responsibility	Ensure products are given at a high value and reasonable price.	6.10: Avoid associations with conflicting businesses. 3.01: Strive for a high-quality and acceptable cost	Our team is considering the financial costs of leagues throughout our project and attempting to mitigate them.
Communication Honesty	Reporting work done honestly to clients, stakeholders, and advisors.	6.08: Take responsibility for detecting and reporting errors. 8.03: Produce well written documentation.	Our team communicates progress honestly in weekly reports and weekly client/advisor meetings.
Health, Safety, Well-Being	Minimizing health and safety risks for those involved in a system.	6.06: Obey all governing laws in work	Our project aims to reduce pitches that can pose a danger to pitchers, adding an element of safety to leagues.
Property Ownership	Respecting all personal property, ideas, and information of others.	5.09: Ensure a fair ownership of any software or process. 7.03: Credit fully the work of others.	Our team uses many external libraries and is making sure they are referenced and acknowledged in our code base.
Sustainability	Respecting the environment and natural resources.	3.15: Treat all maintenance with the same professionalism as development	Our team aims to reduce the necessary waste and carbon emissions on our project by requiring minimal external equipment.

Social Responsibility	Ensure products are a benefit to society.	4.04: Do not engage in deceptive practices	Our team is ensuring our project is accurate to allow it to be useful to slow-pitch leagues.

Table 3

Our team is performing well within the social responsibility area. We want our project to be useful to leagues and a net benefit to society, and to do that it is necessary that our project is intuitive and accurate. We are focusing greatly on these aspects during our development.

Our team could improve within the health, safety, and well-being area. During our testing process, we have been lax with our equipment treatment and could have caused damage to our equipment in the process, or ourselves. We aim to focus more on this as we test our product in-game scenarios going forward.

7.2 Four Principles

	Beneficence	Nonmaleficence	Respect for Autonomy	Justice
Public Health, Safety, and Welfare	Our project relates to outdoor activities, which can help encourage physical activity among users	We aim to reduce conflict by having our device resolve illegal pitch arguments	Leagues have the choice of how much they wish to use our project	Our project is unbiased to different teams and leagues, it will be consistent throughout every game
Global, Cultural, and Social	Our project design is made to be easily accessible by many users	We hope our product can prevent disputes and conflicts among many slow-pitch games, not just in Iowa	Teams have a choice to rely on an umpire or use our project	Calls are consistent across teams and leagues
Environmental	Our app may cause extra plastic purchases for equipment	The equipment needed to run our app is minimal and does not cause much extra manufacturing.	Players have the choice of what phone our app is run on, as well as how our app is set up on a field	The purchases we recommend for our project do not need to be disposed of and can be reused many times.
Economic	Our project requires minimal external	We aim to not increase league costs for	Only one device is needed, so players/leagues	Only one team needs to provide the device for

	hardware purchases	slow-pitch softball	have the choice of who provides the device	both teams to use during a game

Table 4

We are greatly focusing on the Public Health, Safety, and Welfare/Nonmaleficence cell. A large reason that our project was proposed was to reduce arguing between players and umpires over illegal pitch calls. By having our device be unbiased and consistent, we really aim to reduce issues and disputes that show up.

An area we may be lacking in is Environmental/Beneficence. We do not plan on affecting the environment much with our project, but we do recommend the purchase of either a tripod or fence mount for best use in our project. Because these are usually made of plastic, this could cause extra plastic purchases and extra pollution, but we aim to make this a very minimal part of our project.

7.3 Virtues

Team Virtues:

- Fairness - *treating people justly, not letting your personal feelings bias your decisions about others* (viacharacter)
    - Our team believes in those getting what is earned from them. If you do something correctly, you should not be penalized for it, and someone else's bias shouldn't cause you to be.
    - If a pitcher throws a legal pitch, we believe it is fair to have it be called legal, not incorrectly called by an umpire.
    - If a pitcher throws an illegal pitch, it is fair to the batter to not have to swing at it.
    - We are developing our project to be accurate and consistent, allowing for fairness in its calls.
- Determination - *A quality that makes you continue trying to do or achieve something that is difficult* (virtuesforlife)
    - Our team believes in working hard to try and accomplish a goal, and continuing to do so until that goal is met.
    - We are modeling this virtue by continuing to solve problems we encounter until they are fixed, like making sure our height tracking is to our required accuracy for example.
- Flexibility - *Willing to change or to try different things* (virtuesforlife)
    - Our team understands that things don't always work and changes need to be made at times.
    - As a team, we have tried different algorithms for implementing height tracking and softball detection as we find what does and doesn't work.
    - When team members have busy moments in their schedules, we understand and are flexible with their expectations during those times.

Individual Virtues:

- Cael Schreier
    - Demonstrated: Appreciations
        - This is important to me because I feel that when someone does something well, they deserve recognition for it.
        - I demonstrate this by making an effort to acknowledge what other members have done and thank them for the work they are putting in.
    - Not yet demonstrated: Cleanliness
        - Specifically, this is important to me in keeping my code documented and organized to allow others to easily understand it.
        - I have not been documenting my code very well up to this point, so cleaning up my comments and focusing on how my functions are laid out will allow me to improve on this virtue going forward.

- Samuel Skaar
    - Demonstrated: Inclusivity
        - This is important to me because I believe a functioning team needs all of its members to contribute. During certain stretches of a project, one member of a team may not be as effective as the others. It is still important to keep that person engaged in the project so that when the task changes to something they may be more proficient in, they're ready to go and don't feel left out or behind.
        - I demonstrated this when we were building our pole and string guides and purchasing materials at Lowe's. Some team members may maybe more effective in a coding environment than building things from the store. But bringing the team along so they see what we were working with was important when they used footage of that equipment to start our first real demonstration. It also helps with team bonding!
    - Artistry
        - I really like the creative elements of the project and making things look a step above what is required of the presentations. Typically I would have expressed that interest in making even this document look nicer than it does. I just didn't manage my time effectively to make that happen this semester.

        - Next semester I really want to make sure that our presentation of our product is something that could be seen by “investors.” Not that we will have any watching us, but I think that type of creative feel and sales pitch is befitting the project.

- Kolby Moorman
    - Demonstrated: Open-mindedness
        - This is important to me because when working as a team, I find it very important to listen to others' ideas on top of my own as well as take their advice on different ways to go about things.
        - I demonstrated this by looking into multiple front-end frameworks that could be beneficial to our project rather than just going with one I felt most comfortable with.
    - Not yet Demonstrated: Organization
        - This is important to me because if I myself am not organized with my work others on my team may not be able to see what I am doing or how I am doing something.
        - I haven’t been as organized as I would like to be as I have been going through multiple different front-end frameworks to try and find the perfect fit for our group. I have finally found one that can help me to be better organized when coming to group meetings to share the progress I have made.

- Drew Kinneer
    - Demonstrated: Adaptability
        - With the nature of this project what we are working on and how the approach we take is always changing. Adaptability is important to me so that as a team we can pivot to new potential ideas and not be narrow-minded in how we tackle this project
        - I have shown adaptability by taking feedback from other members of the team and advisors and making adjustments to our overall approach for object tracking.

- Not yet Demonstrated: Thoroughness
    - When planning a project it is very important to do research to see what has been done previously and to know what is possible. This virtue is important to me as it is valuable that certain approaches are not missed when coming up with designs.
    - In some aspects of motion tracking with OpenCV, more research could have been done to research more specialized techniques used to apply to our project. And I could have been more thorough in my research.

- Kyle Nachiengane
    - Demonstrated: Perseverance
        - This virtue is important to me because it is crucial in this project. There are always challenges in any project, and I must stay focused and push through difficulties. I must make sure that problems are addressed and not overlooked.
        - I have shown perseverance by continuously trying to get a mobile application with OpencV integrated always trying different things despite many frameworks and online sources not emulating on my device.
    - Not yet Demonstrated: Proactiveness
        - Proactiveness allows me to plan for future issues before I halt my work. This allows me to progress smoothly and get things done in a timely manner.
        - I have not been planning ahead on issues I may face. I will take more proactive approaches in my work, like creating test scenarios or researching before implementing a feature. I will continue preparing the mobile app to be ready for ball-tracking integration. This will help keep me on track.

8 Closing Material

8.1 Conclusion

In conclusion, we aim to reduce slow-pitch softball conflicts about illegal pitches. We are doing this by developing a mobile application to use a phone camera to view a pitch in live time. We then will

determine the position and height of the softball throughout the pitch, and determine if the height is within the legal pitch requirements. If it is not, we will output an "illegal" noise to alert the players of the illegal pitch. Current constraints come from the complexity of consistently tracking a ball's position and height, which is the main hindering factor in our process so far. We feel that we are on track to reach our goals by the completion of this project, and will continue to work throughout the next semester.

8.2 References

[1] ACM Ethics, "Software engineering code," *ACM Ethics*, 2018. https://ethics.acm.org/code-of-ethics/software-engineering-code/

[2] "Virtues List - Virtues For Life," *Virtues For Life*, 2010. https://www.virtuesforlife.com/virtues-list/

[3] E. Baccellieri, "How MLB Pitch Tracking Works: Behind Baseball's Complex System," *Sports Illustrated*, Nov. 15, 2023. https://www.si.com/mlb/2023/11/15/how-it-works-mlb-pitch-tracking-baseball-statcast

[4] A. Rosebrock, "OpenCV Object Tracking," *PyImageSearch*, Jul. 30, 2018. https://pyimagesearch.com/2018/07/30/opencv-object-tracking/

[5] "Main page," *FlightScope Softball*. https://softball.flightscope.com/

8.3 Appendices

To get us started at the beginning of this project, we used simple tutorials on Python Development and OpenCV ball tracking. Although most projects were immediately abandoned after answering the question or teaching the concept we were hoping to learn, one video on YouTube found its way into all of the workflows as a starting point. "Ball Detection Using OpenCV in Python" from *CodeSavant* was a great tool for us to get started initially.

[1] CodeSavant, "Ball Detection Using OpenCV in Python," YouTube, https://youtu.be/RaCwLrKuS1w?si=VmYMcoLu-q4PcCe- (accessed Dec. 7, 2024).

9 Team

9.1 Team Members

1) Cael Schreier

2) Drew Kinneer

3) Kolby Moorman

4) Sam Skaar

5) Kyle Nachiengane

9.2 Required Skill Sets for Your Project

a. Python and C++ Programming
b. Live image processing
c. Object detection
d. Height Analysis
e. Mobile Development
f. Team communication

9.3 Skill Sets covered by the Team

a. Python and C++ Programming: All team members
b. Live image processing: Drew, Cael, Sam
c. Object detection: Drew, Sam, Kolby
d. Height Analysis: Cael, Kyle
e. Mobile Development: Kyle, Kolby
f. Team communication: All Team members

9.4 Project Management Style Adopted by the team

a. Waterfall style management and development for sequential tasks

9.5 Initial Project Management Roles

a. Cael Schreier: Bookkeeper and Code Review
b. Andrew Kinneer: Lead System Designer
c. Kyle Nachiengane: Lead Testing Engineer
d. Sam Skaar: Coordination and Documentation Lead
e. Kolby Moorman: Lead Frontend Developer

9.6 Team Contract

Team Members:

1) Cael Schreier

2) Drew Kinneer

3) Kolby Moorman

4) Sam Skaar

5) Kyle Nachiengane

Team Procedures

Day, time, and location (face-to-face or virtual) for regular team meetings:

a. Weekly Client/Advisor Meetings: Mondays, 10:00 AM - 11:00 AM, Durham 363
b. Weekly Team Meetings: Thursdays, 2:00 PM - 4:00 PM, Virtual

2. Preferred method of communication updates, reminders, issues, and scheduling (e.g., e-mail, phone, app, face-to-face):

a. Discord and face-to-face for team
b. Email for advisor communication

3. Decision-making policy (e.g., consensus, majority vote):

a. Majority Vote

4. Procedures for record keeping (i.e., who will keep meeting minutes, how will minutes be shared/archived):

a. All Records are saved in a group Google Drive folder
b. Cael Schreier serves as the main note taker for weekly meetings, notes are kept in Google Drive
c. All code is saved in a group Gitlab repository, team members are expected to push their code regularly.

Participation Expectations

1. Expected individual attendance, punctuality, and participation at all team meetings:

   a. Mandatory in-person attendance for every advisor meeting
   b. Hybrid attendance for group meetings depending on what needs to be done

2. Expected level of responsibility for fulfilling team assignments, timelines, and deadlines:

   a. All team members will equally contribute to team assignments, as well as continue to make meaningful contributions toward the progress of the overall project every week, and report that progress at each client/advisor meeting.
   b. A group review will be done before each submission.

3. Expected level of communication with other team members:

   a. Always communicate what you are working on and what your progress is
   b. If you fall behind or get ahead, let the team know so tasks can be redelegated if
   c. needed
   d. Use Discord and or Email to communicate meeting and work updates.

4. Expected level of commitment to team decisions and tasks:

   a. Team members are expected to commit between 4-7 hours of work per week on our project.
   b. Everyone voices their thoughts on tasks, even if it's brief
   c. Be present at every meeting and class period

Leadership

1. Leadership roles for each team member (e.g., team organization, client interaction,

individual component design, testing, etc.):

   f. Cael Schreier: Bookkeeper and Code Review
   g. Andrew Kinneer: Lead System Designer
   h. Kyle Nachiengane: Lead Testing Engineer
   i. Sam Skaar: Coordination and Documentation Lead
   j. Kolby Moorman: Lead Frontend Developer

2. Strategies for supporting and guiding the work of all team members:

   a. Each member of the team will have their assigned responsibilities, however each member does not have to only work on responsibilities assigned to their role. Collaboration and review will be important at each step of the process of this project. Each member is encouraged to reach out and ask for help if they are stuck in any step of their role. After meetings, deadlines will be set for what each

member wants to accomplish for the project.

3. Strategies for recognizing the contributions of all team members:

a. The end-of-semester documentation will highlight each team member's contributions to the project. Internally, a healthy culture of “giving props” is sufficient.

Collaboration and Inclusion

1. Describe the skills, expertise, and unique perspectives each team member brings to the team.

a. Kyle Nachiengane

i. Experience working with sensors capturing live data.

ii. Keeping a positive attitude within the team.

iii. Skilled in problem-solving and finding issues in systems.

b. Cael Schreier

i. Skilled in debugging and analyzing code

ii. Experience in working with clients and client communication

iii. Embedded Systems experience

c. Kolby Moorman

i. Experience working in both frontend and backend.

ii. Skilled in picking up new technologies and programming languages

d. Sam Skaar

i. Skilled in design documentation, team coordination, and leadership.

ii. Have played softball and sports in general.

iii. Embedded Systems Experience (C#)

e. Andrew Kinneer

i. Lots of experience with cloud computing solutions

ii. Skilled in backend development

iii. Experience in working in a team environment

2. Strategies for encouraging and supporting contributions and ideas from all team members:

a. During our weekly meeting, we will have a 10-15 minute standup where we talk about what we did the past week and what we plan to do the following week. This will also be a time to ask questions, communicate with other team members, and hold people accountable.

b. There are no bad ideas/questions!

3. Procedures for identifying and resolving collaboration or inclusion issues

a. Team members are encouraged to bring up any concerns directly during regular team meetings or through an anonymous feedback form, ensuring that everyone feels comfortable sharing without fear of judgment. If a team member feels the environment is obstructing their ability to contribute, they will communicate this with the designated team leader or through a group discussion, and we will work together to address the issue promptly and adjust the team dynamics if needed.

Goal-Setting, Planning, and Execution

1. Team goals for this semester:

a. Have a well-researched and tested design by January
b. Communicate promptly and clearly with team members and our clients
c. Start tasks early to allow proper testing time
d. Have fun!

2. Strategies for planning and assigning individual and teamwork:

a. First based on interest
b. Second, based on previous experience
c. Thir,d based on the urgency of tasks
d. Lastly based on the time and availability of members

3. Strategies for keeping on task:

a. “Assign” weekly tasks so that something is being done every week
b. Check-in multiple times a week with each other to make sure tasks are being completed

Consequences for Not Adhering to Team Contract

1. How will you handle infractions of any of the obligations of this team contract?

a. Schedule a meeting with all of the team members to ask why and figure out a solution so that it doesn't happen again

2. What will your team do if the infractions continue?

a. If the infractions continue, gather Dr. Fila, Dr. Duwe, and Dr. Jones to gather their opinions on a solution to the infractions.

****

a) I participated in formulating the standards, roles, and procedures as stated in this contract.

b) I understand that I am obligated to abide by these terms and conditions.

c) I understand that if I do not abide by these terms and conditions, I will suffer the consequences as stated in this contract.

1) ____Cael Schreier_____ DATE _____9/17/24_____

2) _____Kyle Nachiengane_____ _____ DATE _____9/17/24_____

3) _____Kolby Moorman_____ _____ DATE _____9/17/24____

4) _____Andrew Kinneer_____ DATE _____9/17/24___

5) _____Samuel W. Skaar_____ DATE _____9/17/24__