IC Chipz

Design Document

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Advisor/Client

Dr. Henry Duwe

Team

Andrew Kicklighter - Mobile Developer

Alexander Weakland - Mobile Developer

Nicholas Dykhuizen - Integration Developer

Justin Elsbernd - Integration Developer

Joshua Heiser - Embedded Developer

Paul Kiel - Embedded Developer

Contact

sdmay20-40@iastate.edu

https://sdmay20-40.sd.ece.iastate.edu

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Executive Summary

Development Standards & Practices Used

- Nvidia Jetson board
- YOLO image recognition API
- E-Con Systems camera
- Agile development

Summary of Requirements

- Functional mobile application for monitoring video and scoring
- Computer vision program to process scoring
- Two reliable camera locations for video capture
- Low error rate
- Product functions at 95%+ success rate with night time conditions
- Automated data collection
- Automated integration into analysis systems

Applicable Courses from Iowa State University Curriculum

- SE 319
- COM S 309
- CPRE 288
- SE 329/339
- CPRE 489

New Skills/Knowledge acquired that was not taught in courses

- Computer vision programming
- Data pipelines and integration techniques

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List of Definitions

Xamarin: A C#, cross platform mobile development toolkit made by Microsoft for Visual Studios

XAML: C# UI templates similar to HTML/XML

YOLO (You Only Look Once): A computer vision algorithm that detects objects in real-time

Data Pipeline: Organization and implementation of the way data flows through various modules

1 Introduction

1.1 Acknowledgement

We want to acknowledge our client for providing us with the necessary equipment to complete this project. This includes: the Nvidia Jetson board, Nvidia Jetson external hardware, wifi hardware, e-con camera, and past project progress from previous groups. We will be using the past project progress in conjunction with new technology. We also would like to acknowledge our advisor, Dr. Henry Duwe for assisting us throughout this project.

1.2 Problem and Project Statement

1.2.1 Problem Statement

Skeet shooting should be automatically judged and scored accurately for all tournaments and events. In today's world, there is becoming a shortage of reliable skeet shooting judges. If this problem continues to be ignored, the sport of skeet shooting will eventually be out of options for judges. To solve this issue, the team will use the implementation of an automatic scoring systems to fairly judge skeet shooting events.

1.2.2 Project Statement

As the sport of skeet shooting ages, the ability to find trained referees for the sport becomes more difficult. With a mobile automated scoring system the team plan to open up the sport of competitive skeet shooting to a larger audience by giving them a product that can accurately and affordably track their scores and improvement in the sport without the need for a real life referee.

As the project has already been started by a previous team of engineers, the team will pick up where the previous team left off by first developing a streamlined method for data collection. Data samples are an integral part in the development of a product like this where video data is processed and evaluated by a computer system. With a streamlined data collection platform, the team can then funnel our energy and focus into the development of the actual product with enough data to accurately test or platform.

As the last group worked on hardware purchasing and selection, this group's main goal with be the image processing of the aforementioned data. The group will attempt to find the best video analysis algorithms to accurately score when a clay pigeon is destroyed against a solid (black of night) colored background. This group believes that by focusing on data captured at night time that the device can more accurately and easily evaluate video data for where the clay pigeon flays and is destroyed.

The team hopes that a finished project can fairly and accurately dictate realtime skeet scores for singled shooters given nighttime conditions, and given this expectation, supply avid shooters with real time feedback without the need of finding a licensed referee.

1.3 Operational Environment

IC Chipz is a product that needs to be designed to be used to judge skeet shooting. This means that it will need to be a product that is durable and can survive in harsh conditions. This product will need to survive these conditions because since skeet shooting is primarily done outside, it will need to be able to survive most outside conditions. In this project, we want IC Chipz to be able to accurately score at night in various types of conditions (rain or shine and hot or cold).

1.4 Requirements

1.4.1 Functional Requirements

The IC Chipz project will have the following functional requirements:

- Mobile application to monitor video, keep records, and show scoring
- Program which uses image processing to decompose video to determine scoring
- Two reliable camera locations for video capture
- Low error rate
- Product functions at a 95%+ success rate given night time conditions with dark background.
- Automated data collection and flow into analysis systems.
- Automated data labeling
- The computer vision algorithm will be You Only Look Once (YOLO)

1.4.2 Economic/Market Requirements

The IC Chipz device economic requirements are to work with the given systems that the client has provided so that no new purchases are required unless absolutely necessary. The IC Chipz device is a personal project of Dr. Duwe's, so it will have a relatively limited budget compared to a project from a business like John Deere.

1.4.3 Environmental Requirements

The IC Chipz device should work in any outdoor conditions with no change in performance. It should still be able to have the same desired accuracy for every condition on detecting live or dead clay pigeons

1.4.4 UI Requirements

The IC Chipz mobile application should have the following requirements:

- Track the score of the round
- Display whether the clay pigeon is dead or alive after a shot
- The application should output a final scorecard when the round is over
- The ability to review video to dispute a call
- The UI should be organized and easy to use
- The application should store past rounds in a database

1.5 Intended Users and Uses

In IC Chipz, there are two main intended users of this product. The first intended user will be the referees who are judging the skeet shots. They will use this product because it will help them accurately check and see if a clay pigeon has been successfully shot or not, both through the computer vision and through the video feedback through the app. This means that the referees will be able to give the players a much more accurate score. The second main user of this product is the players in Skeet shooting. They will use this product because it will help them keep track of their score without the need of always having a referee. It will also help them because they can use the video feedback in order to study their shots which can be used to help them become better players.

1.6 Assumptions and Limitations

1.6.1 Assumptions

- All skeet shots will take place at night at the request of the client

- The user has an Android/iPhone that they can use so that IC Chipz can send the video feed to that mobile application.
- The skeet range is up to official skeet standards
- The skeet match follows the official skeet match rules

1.6.2 Limitations

- Only be able to visit the test range about once a week
- Weather will be a limitation during the winter
- The Jetson board has the potential to struggle to handle the video that is being transferred to it by the E-Con camera.
- The camera is not an extremely high resolution or FPS camera, which can cause difficulties in picking up small chips flying off of the clay pigeon

1.7 Expected End Product and Deliverables

The IC Chipz final product is a portable scoring device which can be deployed before beginning a skeet round and score 95% of shots successfully. The portable device comes with the ability to pair with a mobile application which acts as a front end interface to the device. Users are able to view current round scores, challenging invalid or wrong scores and access post round information.

- Machine Vision Functional at 95% Accuracy
    - The machine vision portion of the application must meet a 95% accuracy; this means the application must detect a broken clay target 95% of the time.
- Data Collection Mechanism
    - The mobile application and portable device have a data collection mode allowing them to add additional data points to a data set or data sets.
- Auto Data Parsing and Data Labeling
    - With collected data, the portable device shall automatically splice and parse the data into buckets of hits and misses
- Skeet shot scoring [At Night]
    - Machine vision functionality of 95% initially works at night or on darker days
- Skeet shot scoring [At All Times of Day]
    - Machine vision functionality of 95% upgraded to work at all times of day and potentially in unfavorable conditions
- Mobile Application to Review Scores

    - Mobile application has a score review process to allow invalid scores to be challenged and reversed if necessary
- Mobile Application for Post Round Information
    - Post round statistics information displayed after each round

2 Specifications and Analysis

2.1 Proposed Design

IC Chipz has broken down into three sub teams for the project: Mobile Application, Embedded System, and Data pipeline/integration development. Each team is approaching a problem in their area by testing, reviewing, and updating as necessary. The group will continue approaching this design in small steps in sub-teams with the end goal being the image processing of the collected data from the skeet shooting, as the previous years team focused on hardware development.

The team has defined the problem statement with our client, the purpose of the project, and its value. The group has also begun the concept process of the design, The Integration/Data Team has created a top level design of the data flow which will allow the team to find a single concept that works best for our project and continue brainstorming. Approaching the planning, the team has identified the people/team, tasks, task durations, and budget needed. The design planning portion of the project will focus on translating the customer requirements and systems engineering model into a working prototype that can successfully track if a target was hit or not hit under specific conditions.

So far as a team we have implemented most of the mobile application, the WiFi connection, and the algorithm to detect objects in real-time (YOLO) on the board.

2.2 Design Analysis

The embedded systems team has created a python script that goes through the train and test data sets to establish what is good and what needs to be updated. The team also continued to look into the "Houston" code from last year to determine what is good, and what needs to be changed/updated.

The Integration and Data Team has created a top level design of the data flow from the embedded system to the mobile application which will assist in ideas for the data pipeline.

The Mobile Application Team has tried and tested the existing mobile application code to see if it sufficient enough for the team's needs and if the UI is simple enough to navigate. The code from the years previous team was not well documented and the

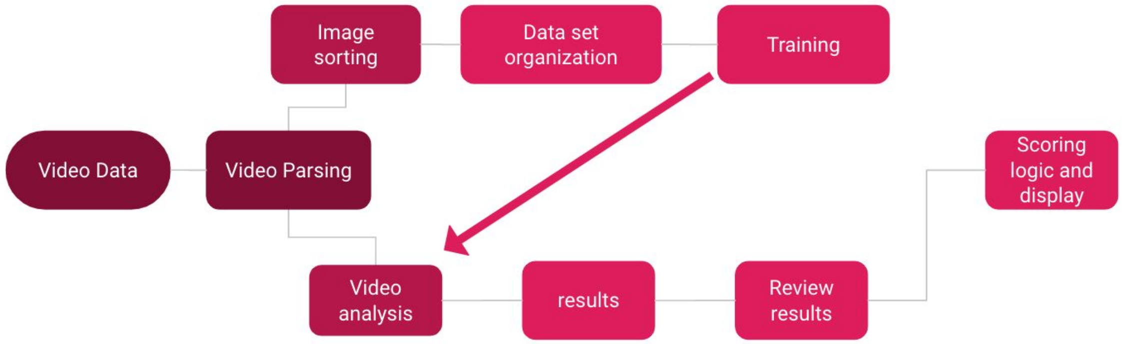
UI was not easily navigated which means the group will have to start from scratch or at the very least use their templating for the new mobile application. The current code also does not include a scoresheet which must be added for requirements. The group will continue to work on areas we thought needed modifications before continuing to the next design element. Gathering data and video from the ISU Skeet team at night will continue to assist us with the Design Analysis.

2.3 Development Process

The team's development process for this project will be Agile which divides the functionality into small parts that can be delivered independently as the team begin to start working on them. We chose Agile because we have been doing weekly sprints with weekly standup meetings to give updates on our parts of the project. This will help to make faster design requirements and get quicker feedback on the groups work from Dr. Duwe.

2.4 Design Plan

The team's design plan is to continue working on respective functionality for the three three sub teams for our project: Mobile Application, Embedded System, and Data pipeline/integration development. As the team continues to work in the Planning and Development stages for IC Chipz we will be working towards a prototype that can track skeet disks and determine if the shot was a hit or miss. Until then, the team will continue to develop and deliver the Functional, Economic, Environmental, and UI requirements to the team's client. Feedback from Dr. Duwe along with data collection from the ISU Skeet Team will allow the team to see what requirements are more crucial and what each smaller team need to focus on more. While the client wants the final design to be able to track any targets under any conditions, the group's first goal is to first have a prototype that can track just one skeet disk and determine if it was hit or not during the night time.



3 Statement of Work

3.1 Previous Work and Literature

While computer vision has been around for a long time and has been used to solve a multitude of problems there are very few applications of computer vision used in a sense like IC Chipz where scoring of a shooting sport is concerned.

One such all in one system that is currently on the market is the Garmin Xero® S1 Trapshooting Trainer. This small camera and display system does almost exactly what our IC Chipz system does and retails for around $1000 (Garmin).

While this product most likely performs well as it has been on the market for some time now, our system offers a sense of user customization. Because our system includes data collection all video is saved and ready for users to review, reference, and assign to data fields for future training of the systems AI.

As this project is a continuation of a previous teams work with the client, we started with the system components already bought and were able to start of integrating parts right away, this saved us what could have possibly been months of research into what hardware would work best.

One of the downsides of continuing a previous teams work is that they failed to document their code properly, so we've been left to figure out what their code is doing which has set us back some. However, despite this setback we're still saving ourselves a lot of time, as it would take much longer to come up with the system from scratch as opposed to simply figuring out undocumented code

3.2 Technological Considerations

We are using an Nvidia jetson TX2 as the mind behind our system. While in reality the power this board supplies is probably much greater than we would need to run our applications, it is helpful to have a system powerful enough do not just run our product, but help develop it too. It is easy to tweak the system internally and process larger data than the end product may require with a board as powerful as this. It also takes the need for external server processing out of the equation.

In addition to that, the camera purchased can get video quality up to 4k which is extremely helpful when testing. While 4k video may be overkill for our given implementations the fact that we have that possibility if needed is extremely helpful.

3.3 Task Decomposition

Our main tasks for the full development of the system are…

1. System integration (hardware, application, and mobile all connected)
    a. Create embedded application
    b. Create mobile application
    c. Set up video collection
    d. Connect mobile app to embedded app
2. Automated Data labeling
    a. Create script to label data from video footage
    b. Successfully label data
    c. Run the test data through the machine vision algorithm to further test labeling
3. Algorithm Training
    a. Gather night data
    b. Train algorithm based on night data
    c. Gather day data
    d. Train algorithm based on day data
    e. Gather poor weather condition data
    f. Train algorithm based on poor weather condition data
4. Algorithm testing
    a. Take night footage results from algorithm and check accuracy
    b. Take day footage results from algorithm and check accuracy
    c. Take poor weather footage from algorithm and check accuracy
5. Data/algorithm tweaking
    a. Refine algorithm for night conditions based on testing
    b. Refine algorithm for day conditions based on testing
    c. Refine algorithm for poor weather conditions based on testing

3.4 Possible Risks and Risk Management

The team is concerned that the weather may slow down our plan, as the team needs to gather data outside at the shotgun range, and if it is snowing/raining this can hinder our progress, as we can’t gather the data to train the model.

The team also has little experience with computer vision algorithms, so there will be a slow patch while the team learns how computer vision algorithms work and how to write them.

3.5 Project Proposed Milestones and Evaluation Criteria

A key milestone we are looking forward to is data collection automation. With that we can start to gather data to train our computer vision with. After our model is trained then we can integrate the trained model into our data collection schema and thus evaluate the accuracy of the algorithms reading on data as it is labeled by a user. a success rate of 99% is what we are looking for given that a success is when the users input of the data matches the algorithms guess on if a pigeon was broken or not.

Our specific milestones are as follows:

1. Full System Integration
2. Data labeling completed and fully automated
3. Algorithm is fully trained
4. Algorithm is fully tested
5. Data/Algorithm tweaked as needed
6. Loop back through the milestones as needed

3.6 Project Tracking Procedures

The group will utilize GitLab milestones in order to track progress throughout the course. The group will also utilize Google Drive and a schedule/progress document to help track progress.

3.7 Expected Results and Validation

Our end goal is to have a scoring application that reads destruction of pigeons at a 99%+ success rate. Once the application can denote whether pigeons are destroyed or not, implementing the scoring system based on vision data should be fairly simple. To test the success of our system we will simply have to relate human visualised input to the data and input provided by our application. A key to streamlining this is to make sure the Computer vision works flawlessly and is tested extensively before integrating into the final application.

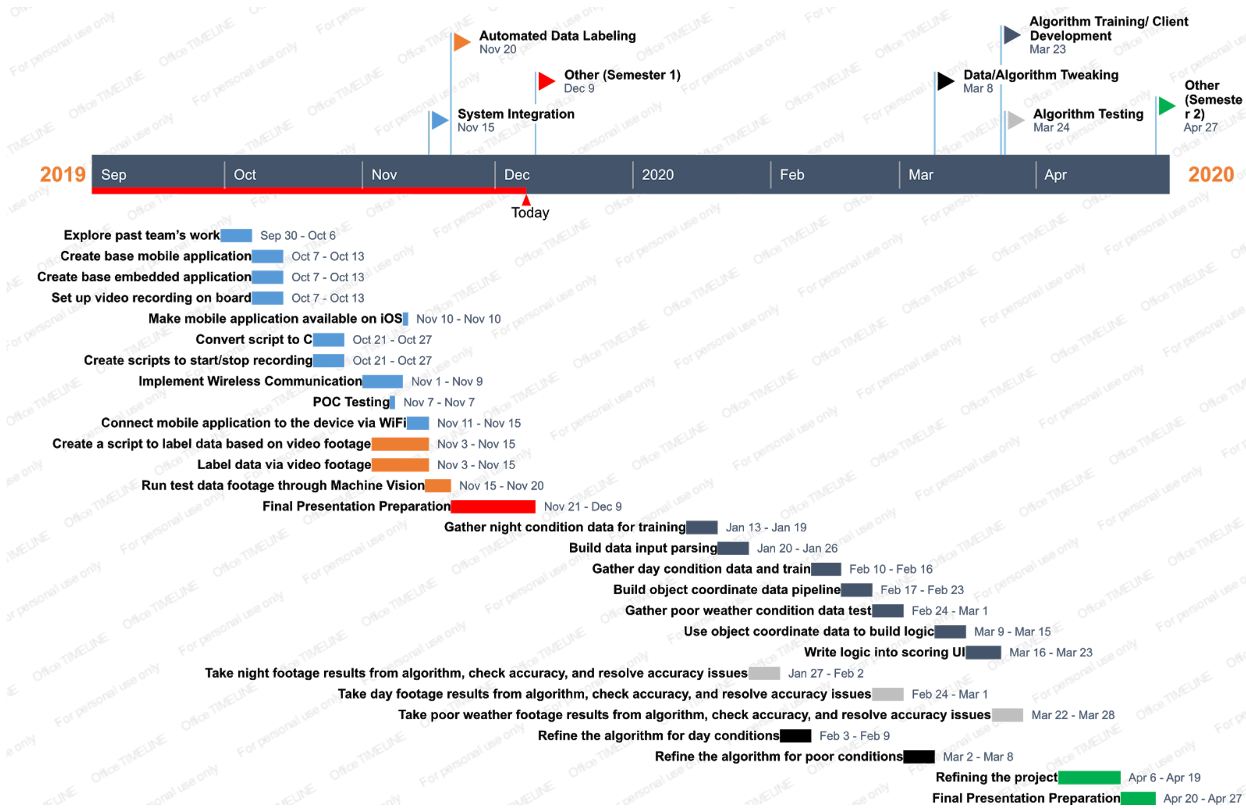
4 Project Timeline, Estimated Resources, and Challenges

4.1 Project Timeline

Task Name	Start Date	End Date
Semester 1		
System Integration		
Explore past team's work	September 30, 2019	October 6, 2019
Create base mobile application	October 7, 2019	October 13, 2019
Create base embedded application	October 7, 2019	October 13, 2019
Set up video recording on board	October 7, 2019	October 13, 2019
Make mobile application available on iOS	October 21, 2019	November 10, 2019
Convert script to C	October 21, 2019	October 27, 2019
Create scripts to start/stop recording	October 21, 2019	October 27, 2019
Implement Wireless Communication	November 1, 2019	November 9, 2019
POC Testing	November 7, 2019	November 7, 2019
Connect mobile application to the device via WiFi	November 11, 2019	November 15, 2019
Automated Data Labeling		
Create a script to label data based on video footage	November 3, 2019	November 15, 2019
Label data via video footage	November 3, 2019	November 15, 2019
Run test data footage through Machine Vision	November 15, 2019	November 20, 2019
Other		
Final Presentation Preparation	November 21, 2019	December 9, 2019

Semester 2		
Algorithm Training/ Client Development		
Gather night condition data for training	January 13, 2020	January 19, 2020
Build data input parsing	January 20, 2020	January 26, 2020
Gather day condition data and train	February 10, 2020	February 16, 2020
Build object coordinate data pipeline	February 17, 2020	February 23, 2020
Gather poor weather condition data test	February 24, 2020	March 1, 2020
Use object coordinate data to build logic	March 9, 2020	March 15, 2020
Write logic into scoring UI	March 16, 2020	March 23, 2020
Algorithm Testing		
Take night footage results from algorithm, check accuracy, and resolve accuracy issues	January 27, 2020	February 2, 2020
Take day footage results from algorithm, check accuracy, and resolve accuracy issues	February 24, 2020	March 1, 2020
Take poor weather footage results from algorithm, check accuracy, and resolve accuracy issues	March 22, 2020	March 28, 2020
Data/Algorithm Tweaking		
Refine the algorithm for day conditions	February 3, 2020	February 9, 2020
Refine the algorithm for poor conditions	March 2, 2020	March 8, 2020
Other		
Refining the project	April 6, 2019	April 19, 2019
Final Presentation Preparation	April 20, 2019	April 27, 2019

Gantt Chart



This semester we covered what we have already done, as well as a tentative schedule for our schedule the rest of the semester in order to completely finish the system integration. System integration is one of the longest tasks we have to do, and our plan is to get that finished by the end of the semester, along with automatically labeling data from a video. We're giving ourselves a week for each task, as we have our weekly standup with our client/advisor every Monday and this makes the project compatible with Agile (weekly sprints).

We're giving ourselves the entire semester for the algorithm training, testing, and refining because it takes a full week for the computer vision algorithm to be trained on a computer as we do not have access to a super computer. We also anticipate various weather delays in collecting data, so we're taking that into account as well. Our client wants our device to work in all conditions, so we have time set aside for the three major conditions that will affect the device (a day background, a night background, and a poor weather background), as each condition has a different background that the clay pigeon will have to stand out against. We have also given a week for our team to refine the algorithm that will determine the shot result since the algorithm that we will design for automating the result will also need to adjust depending on the conditions present.

The schedule above is split into 5 major tasks, with 2 being done in the first semester and 3 being done in the second semester. The first semester has more planning to it than the second semester, hence the less tasks. We also have a section for other tasks that need to be done that don't fall into the major tasks, this mainly consists of presentation preparation.

4.2 Feasibility Assessment

Our realistic projection of this project will include a mobile app that sends data to the embedded board when a button is pressed. The embedded board will then begin recording video of a clay pigeon. This video will then be sent to the machine vision algorithm, where it will determine if the clay pigeon was shot in the video or not. If it has, then it will score points and return the result to the user. If the machine vision determined that the user missed a shot, then the user will be notified that they missed the clay pigeon and their score will not be updated. Our group would like to have this project work in all conditions, but realistically, our goal is to get it working with high accuracy in night conditions.

Some of the challenges that may make these objectives difficult to complete is the weather, especially with winter weather in Iowa. There may be a week or two where we can not gather data due to a blizzard or it being too cold. Another challenge is the training of the algorithm. The group has planned on one week for training the algorithm and then one week for fixing any bugs. Depending on the conditions that we are testing and the accuracy desired, it may take longer for the algorithm to be trained and debugged then the two weeks that the group has allotted. This could be an issue if this deadline is missed as it would put the group behind schedule. Lastly, another challenge that will make these objectives difficult is the debugging of the current machine vision algorithm. The group has made progress in debugging the previous team's machine vision algorithm, but if there are any issues that arise with this algorithm, then the team may have difficulty keeping up with the current schedule since this algorithm is poorly documented.

4.3 Personnel Effort Requirements

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Task	Personnel Effort
System Integration	All groups members will conduct research into the previous teams work. Group members will also communicate with Client to gain an understanding of the objectives. The group will then be split into smaller teams that will focus on one of the pieces of the application. Each member of a team will work on setting up their part so that video recording of skeet shots can begin.
Automated Data Labeling	All team members will focus on sending video data into a data pipeline where the data can be labeled. All members will also run test samples through the machine vision algorithm to determine accuracy, and what work needs to be done in Algorithm Training.
Algorithm Training	All team members will work on fixing the issues that were found in Automated Data Labeling. Team members will also collect video samples in various conditions in order to train this algorithm. The samples being used in Algorithm Testing to help the machine vision learn.
Algorithm Testing	All team members will check the results that were obtained by the machine vision algorithm and make the necessary tweaks to fix them. The team members may also collect new video recordings to test the Algorithm's accuracy, and make changes if needed. Any small bugs that are present will be recorded to be fixed

	in Data/Algorithm Tweaking.
Data/Algorithm Tweaking	All team members will work on increasing the accuracy of the algorithm by fixing the small bugs that were not fixed in Algorithm Testing. The team will refine all conditions in order to increase the accuracy of the machine vision algorithm. The team should have a workable product that obtains the correct outcome 99 percent of the time.

4.4 Other Resource Requirements

Other resources for the project are as follows:

- Xamarin Forms
- Nvidia Jetson TX2 board
- A new camera lens for the TX2 board
- Shotgun ammunition for gathering data at the skeet range
- Clay pigeons

4.5 Financial Requirements

N/A

5 Testing and Implementation

With our project being spread across multiple systems, the majority of our tests will consist of integration and individual modular testing of each system. We have multiple items for each system that we've identified which need to be tested. These items include:

1. eCon's TX130 camera integration
2. Wifi/Bluetooth communication between camera system and mobile device
3. Mobile device integration with user interface
4. Machine vision neural network accuracy testing

5.1 Interface Specifications

We have two different hardware devices, an "embedded" Nvidia Jetson board with a mobile device (iOS or Android). These two devices are connected via our SkeetRecord program over either a bluetooth or Wifi wireless system, depending on the mobile device's preference and available hardware.

With this cross-platform system, many interfaces open up with regards to testing. Specifically, we are going to target:

1. Commands must be successfully transferred and interpreted across a wireless medium.
2. Video footage can be taken and recorded on the Jetson Board
3. Mobile device can interpret user input and translate it to an underlying action
4. Nvidia Jetson board can transfer files, usually large, over a wireless medium
5. Transferred files can be successfully viewed and results can be challenged

5.2 Hardware and Software

For the Embedded part of the system, there are a couple pieces of hardware/software that need (or have) been tested in the testing phase. The main piece of hardware that the embedded team tested was the Econ-systems camera. This camera (and the software associated with it) was tested because the camera is being used to record the clay pigeons being shot out of the air. If the camera on the board was not working, then we would not be able to use the software to record footage, and thus the automated scoring cannot be done. Since the rest of the hardware was implemented, there was no other hardware to test. In terms of software, there is a couple pieces of software to test. The first piece of software that has already been tested is the scripts that were created to start/stop recording video footage. This needed to be tested because if these scripts did not work, then the video would need to be manually started/stopped for every shot, which would be inefficient. The second piece of software that needed to be tested is the program that starts the previous scripts when a user on the mobile devices specifies it to do so. This needed to be tested because this would meet the requirement of the mobile application keeping records and scoring.

To handle the machine vision aspect of the system we decided to use a library called Darknet. This library builds out a neural network based on a training dataset. We will be continuously testing the underlying neural network using a parallel testing dataset. This verifies the accuracy of the neural network and help achieve our 95% accuracy requirement.

The mobile application acts as a middle man between the user and the underlying commands the Jetson board can handle. This portion of the project will house typical unit tests.

5.3 Functional Testing

Testing the mobile app will require unit testing to make sure our methods for connection with the Jetson board and tracking the players score during a round are accurate and have the results needed. This will make sure the commands sent by the mobile app are correctly receiving the right data from the board when it takes a video. More unit testing will be required to test other important functionalities and commands as they are added or deemed necessary. System testing will also be required to make sure the system complies with specified requirements from the client and that the jetson board is successfully transferring files and that these files are accessible via the mobile application.

5.4 Non-Functional Testing

Non-Functional Testing so far has focused on the video and file transfer speed, security of the connection between mobile and board, and the compatibility of mobile app. The mobile app is intended to work on both Android and iOS which required testing to make sure both applications run the same and outputs the same results. This ensures constant user experiences and results between the two apps. Testing of the video and file transfer speed is important as it will determine the speed of the results to get to the user from the clay pigeon being hit or not. Security of our connection and mobile app is vital as it will make sure a third party is not able to change or modify the results.

5.5 Process

Unit testing was used to test the mobile application, along with checking the physical Wifi/Bluetooth connection manually. The Jetson board was tested via system testing. Darknet will be tested using a method called confusion matrices. Our non-functional testing covered video and file transfer speed, security of the connection between mobile and board, and the compatibility of mobile app.

5.6 Results

Through our testing process this semester, we have been able to successfully implemented the eCon's camera integration and Wifi/Bluetooth communication between the mobile app and the Nvidia Jetson board. We are able to send commands through the mobile app using Wifi/Bluetooth to activate the camera commands to record video footage and transfer a video file to the mobile app. In addition, we are able to mark the video as a hit or miss for testing purposes.

When testing, we ran into an issue of initially implementing the Wifi/Bluetooth connectivity. At first, we tried using a USB Wifi adapter to create a peer-to-peer Wifi connection. Through this, we determined that this would not be possible due to the limitations of the eCon camera drivers. Therefore, we decided to implement Wifi by using the on-board Wifi connection as a hotspot.

6 Closing Material

6.1 Conclusion

This project so far has been a slow but steady progression into multiple areas our team has never dealt with before. While there is still a lot to do in the long term, I think each individual team has been satisfied with their successes thus far. We have a working and reliable way to take video directly on the TX2 board. The mobile application is at the point where it should be ready for data collection. Lastly the Computer Vision team has worked on integrating the system together for data collection. From here it will be on to the merger of computer vision and embedded systems team to create a reliable computer vision implementation and train it accordingly. We aim to get the data collection finished in the next week so the client can start working on getting data for us. After that our goals are a 99% success rate of object recognition in our algorithm and then build an accurate scoring system. While progress thus far has been steady and successful, it hasn't been the fastest. To combat this in the future and next semester as development continues we will most likely build weekly meeting times into our schedules that are just meant for development time. Overall the project is progressing well and we are meeting the vast majority of deadlines we set for ourselves.

6.2 References

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6.3 Appendices

N/A