IC Chip: Automated Clay Targeted and Scoring System

Project Plan

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28 September 2018

Revision 1.0

CONTENTS

CONTENTS

I. INTRODUCTORY MATERIAL

1.1 Acknowledgement

- Client: Assistant Professor Doctor Henry Duwe
- Advisor: Assistant Professor Doctor Henry Duwe

1.2 Problem Statement

While numerous aspects of clay shooting sports have been automated, specifically target loading and launching, there still remains one notable exception. Scoring for clay shooting sports has been a source of significant difficulty and cost. It requires an individual with good eyesight who is knowledgeable in the rules and procedures of the sport. Finding those who are qualified and willing to score at a reasonable cost has proven increasingly difficult.

The focus of IC Chip is to create a low-cost, fully automated scoring system for clay target shooting sports, primarily Skeet. The project intents to integrate machine learning and computer vision on a dedicated hardware package. The system is intended to be portable, rugged, and easily deployed in order to allow for a one-time cost for the system to replace hiring individual scorers.

1.3 Operating Environment

The IC Chip system is intended to be deployed on a standard skeet shooting range. As such, there exists potential that deployed cameras for recording data may be subject to hazardous conditions. These can include but are not limited to target fragments, accidental damage by shooters, stray shot pellets, and adverse weather conditions.

As such, it is necessary for the system to display a reasonable degree of ruggedness to survive potentially damaging events. This requires that replacement components be low-cost and that the system features protective measures such as hardened cases and protective covers.

1.4 Intended Users and Uses

The project is intended to produce a product which may be utilized by an individual reasonably familiar with the layout of a Skeet range and with limited technical ability. From this, the design for user interfaces and instructions on deployment will remain rudimentary.

The system must fulfill the *plug and play* paradigm. Therefore, integration between the components must be robust and redundant, deployment instructions simple, and user interfaces easily navigated.

1.5 Assumptions and Limitations

IC Chip is not intended to perform beyond human limitations on scoring broken clay targets. It is highly likely that our system will out-perform a human scorer and therefore be in violation of official skeet shooting rules. As such, the system must be designed with the specific limitation of preventing too high of accuracy in scoring targets. All targets that are scored as *hit* must be a human visible *hit*.

1.6 Expected End-Product and Other Deliverables

To begin is the physical system itself. An easily deployable, ruggedized ground system to be placed on a skeet range featuring nodes for video collection and a ground station for computation, video storage, and scoring. This will also feature a trained machine learning model that leverages computer vision to track and identify targets as either *hit* or *lost*.

A supplemental application for use on a smartphone or tablet will also be created. This will allow for the user to replay individual shots as well as review and modify scores for individual shooters. This will allow usage of the system by individuals without notable technical experience.

2.1 Objective of the Task

The goal of this task is to create a low-cost prototype that can be physically taken onto a skeet shooting range. The prototype will consist of multiple components, such as a camera lens for video recording and a hardware component whose function is to perform computations on the video recorded and classify a clay pigeon target as dead, lost with attempt, or lost without attempt. In addition to the physical prototype, this task also includes the development of a mobile application that connects to the physical device. The mobile application will allow users to challenge target classifications, review video footage, and follow along with shooting group scores.

2.2 Functional Requirements

The functional requirements are split into two groups. The first group relates to the physical device itself, while the second group of requirements relates to the mobile application.

2.2.1 Physical Device Requirements

Below is a list of function requirements for the physical device our team will design.

- The physical device should be portable.
- The physical device should connect to a mobile device for use with the corresponding mobile application using WiFi.

- The physical device should able to capture and pr0cess video in real time.
- The physical device should determine and classify whether a clay pigeon target is dead, lost with attempt, or lost without attempt.
- The physical device should be accompanied by a protective, yet removable, casing.
- The device can only be power by an internal battery, no external power sources.
- The physical system will comprise of multiple devices, each at different locations on the field.
- Each device should be able to communicate with the others devices to determine whether a clay pigeon target is dead, lost with attempt, or lost without attempt.

2.2.2 Physical Device Requirements

Below is a list of functional requirements for the mobile application our team will develop. The expected use case of the mobile application is for the user to start a recording session and to monitor and challenge the target classifications if desired. If the user wishes to challenge the target classification, they will request to review that shot's video footage. After footage review, user can then either confirm the software's classification, or manually change the classification.

- The mobile application should know the rules of skeet shooting.
- The mobile application should track the order of shooters in a squad, and make changes to the order based on skeet shooting rules.
- The mobile application's display screen should turn off automatically after 30 seconds of no interaction.
- The mobile application should connect to the physical device via a wifi signal.

- The mobile application should not store videos that have not been challenged by the user.
- The mobile application should allow users to challenge a target classification.
- The mobile application should display target classification on the screen once the shot classification has been determined.
- The mobile application should keep track of the scores of every shooter in the shooting squad.
- The mobile application should keep track of and display the length (total time) of the shooting session.
- The mobile application should not save a shooting session's scores.

2.3 Constraints and Considerations

This section includes a list of non-functional requirements, constraint considerations, and information about standards that our team will comply with.

2.3.1 Non-Functional Requirements

The non-functional requirements below are related to the performance, reliability, availability, security, and usability of our device and mobile application. Again, the non-functional requirements are split into two groups, the first in regards to the physical device, and the second in regards to the mobile application.

2.3.1.1 Physical Device Requirements

Below is a list of non-functional requirements for the physical device.

Performance:

- The physical device will perform computation and classify the clay target within 2 seconds of when the shot was made.

- **The physical device will notify the mobile application of the shot classification within 1 second after device has classified the shot.**
- **The physical device will send most recent shot’s video footage to mobile application within 3 seconds of the shot being made.**
- **The physical device will classify targets (human-visible breaks) with upwards of a 95% accuracy rate.**

2.3.1.2 Mobile Application Requirements

Below is a list of non-functional requirements for the mobile application.

Performance:

- **The mobile application will receive the target classification from the physical device within 2 seconds after the shot is made.**
- **The mobile application will display the target classification within 1 seconds after the classification is received from the physical device.**
- **The mobile application will display the recording associated with a challenged shot within 3 seconds of the user challenging the target classification.**
- **The mobile application will delete a video from memory within 1 second of a user accepting the target classification.**

Reliability & Availability:

- **If physical device and mobile application connection breaks, the mobile application will save the current shooting session’s statistics until the session is terminated.**
- **The mobile application will not connect to the internet.**

Data Integrity:

- **The mobile application will not store personal data.**

- The mobile application will not require user login information upon startup.

Usability:

- The mobile application will be available to all users who have an android tablet or mobile phone.

2.3.2 Constraints

Below is a list of constraints regarding both the physical device and the mobile application.

The physical device must be small and portable, as users may want to move the device to different locations on the skeet shooting field.

The physical device must be accompanied with a protective covering, or "house," to prevent damage from clay pigeon chips and other materials on the shooting range.

The physical device must be a low-cost device (i.e. < $1,000).

The physical device must not rely on an internet connection to perform its' computations.

They physical device must be battery powered.

The mobile application must not rely on internet to display the target classifications.

The mobile application must not store videos in the mobile device's memory.

2.3.3 Standards

There are a few standards that our project will comply with. Most of these standards are pre-built into the technology and frameworks that we will be using, such as OpenCV and Android Studio. At this point in time, we are unsure of what hardware components specifically we will be using, so we cannot say for sure the exact protocols we will be following. This will become clear once we pick specific hardware components.

2.4 Previous Work and Literature

When we first were introduced to our project concept, our team did research to determine whether there were any similar devices out on the market. The closest device we found was the ShotKam, a small recording device that is attached directly to a gun barrel (ShotKam.com). ShotKam captures footage of the target from the shooter's point of view and stores the video footage via a mobile application for later review and feedback. This device is similar to our project in the sense that ShotKam records the shot, however, there are a few key differences.

First, ShotKam's focus is the target the shooter sees and tracking the path of the gun barrel. We want our device to be stationary and on the ground--not on a gun barrel--and have a wide view of the shooting range. Having a wider view of the range allows our device to have a more accurate computational picture when classifying a target as dead or lost.

Second, the mobile app that accompanies ShotKam shows a live feed of the recording and stores the video at ⅓ the speed on the user's mobile device. While we want our mobile application to have access to the video recordings on our device, we do not want the videos to be stored on the user's phone, as this may cause memory issues. It is noteworthy to think about the slow motion aspect of ShotKam's stored videos. The slow motion feature allows users to watch their shot at a slow speed and determine if they hit their intended target. This might be a feature that our team wishes to include in our design, but will require more discussion with both our team and our client.

2.5 Proposed Design

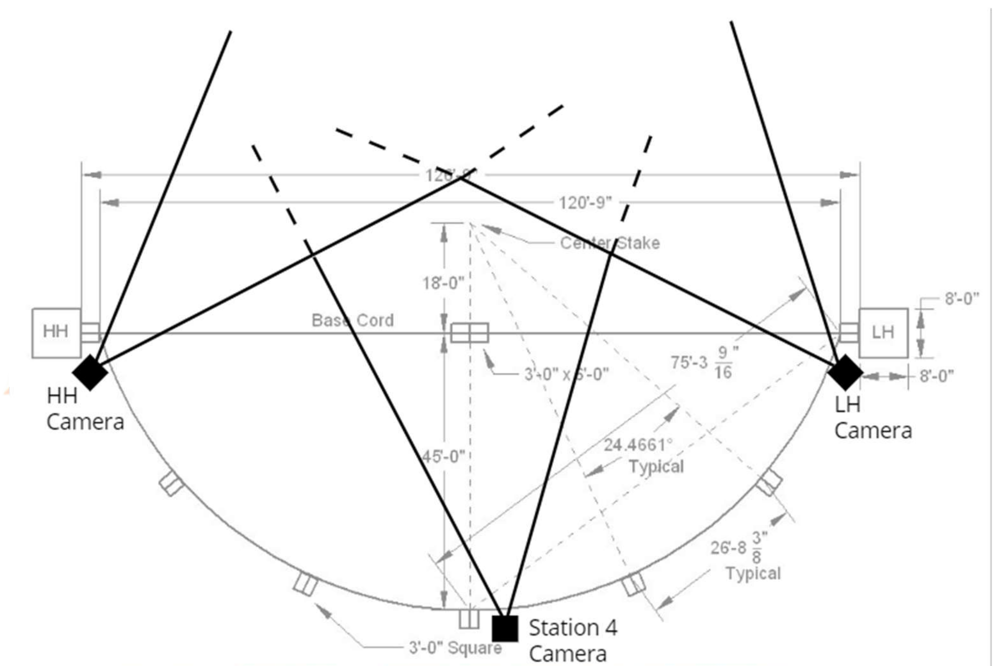

Figure 1. Camera Locations on a Skeet Range

Our proposed design features three individual cameras stationed at positions one, four, and seven around a skeet range, as shown above in *Table 1.* This will allow us to capture multiple, overlapping angles of targets and ensure that they are at no point out of visible range. This will also allow us redundancy in scoring information to produce more accurate results.

Furthermore, we intend to have a ground station located behind the field. This will feature the bulk of the computational hardware and will connect with the individual cameras wirelessly to reduce tripping hazards and improve ease of use. Additionally, we intend for the entire system to be powered off of individual and separate battery systems, though this may not be feasibly for the ground station due to the high power use of large computations.

2.6 Technological Considerations

Capturing, processing, and transmitting video of a high speed object imposes a couple challenges that we had to solve and implement solutions for. For capturing the object, a single camera doesn't effectively cover the entire field in a stationary point. If the shooter hits the target early or later in its path, then the camera will not see. Using a single very high resolution camera with a very high frame rate would be exceed the total cost of the budget. We had to decide on a cost-efficient solution that involves multiple low cost cameras that would cover the entire field. This multiple camera system will allow the device to have a constant view of the object in flight. This would also allow the system to view the object at different angles; if one camera didn't see a hit, another camera could.

Processing video and transmitting at almost real time would need dedicated hardware. Most single-board computers (i.g. Raspberry Pi, Arduino) lack the hardware and the necessary connections to accomplish this. We decide that creating our own single-board computer would be beneficial because it would allow us to have control on the specifications of the hardware. in the custom single-board computer, we will have a microprocessor that will be able to process video in real time, memory to store the video, and WiFi chip capable of transmitting the length of the field.

2.7 Safety Considerations

The major safety concern of our project is the safety of device users and our team members when we test the device on the shooting range. It is extremely important, on any shooting range, to be aware of one's surroundings, as shotgun shells or clay pigeon chips, for example, may come flying towards a person. Because of this, most ranges require participants to have eye and face protection (i.e. baseball cap to protect forehead). Range participants and onlookers also have to protect their hearing, as the sound level of a shotgun blast can permanently damage a person's hearing (Stewart).

When our team first collected video data at the Boone County Sportsmen's Club with Dr. Henry Duwe, we wore eye protection, baseball caps, and ear protection. It was

made clear to us by Dr. Duwe that whenever we are on or near the shooting range, hearing, eye, and face protection are required. So, when we go on to test our physical device, we will ensure all team members have the appropriate protection.

Unfortunately, we cannot ensure that our device users will wear the proper eye and hearing protection equipment. Although most shooting ranges do require these methods of protection, users may decide not to use protection. So, we will provide safety recommendations along with our device instructions in the hopes users will take the safety precautions seriously.

2.8 Task Approach

For capturing the video of the clay pigeon, the solution was found that using a two or three camera system would be the better then using a single camera, as shown previously in *Table 1*. The multiple camera system would cover the entire field, a camera placed near the high house would cover the left side of the field and a camera place at the low house would cover the left side of the field. A third camera could be placed in the middle if the right next to station 4 that would cover the middle section of the field (the camera locations related to the field are shown in the diagram below). The multiple camera system has the added benefit of seeing the object in multiple angles. Having multiple angles help with determining if the clay pigeon has been hit or not.

2.9 Possible Risks and Risk Management

This project will be completed using Android Studio framework for the mobile application and Python for the software on the hardware component. Only two of our team members, Cole Huinker and Keith Snider, have experience with designing and developing a mobile application using Android Studio. This poses a challenge as our software architect lead, Eva Kuntz, does not have a lot of experience with this particular technology stack. Fortunately, there are three team members working on the mobile application, so they will work together to overcome problems that arise from the lack of knowledge surrounding Android Studio.

Another risk is the limited experience with machine learning and OpenCV. Only one team member, Steven Sleder, has previous work experience with machine learning algorithms and techniques. Instead of teaching the entire team about machine learning theories, Steven will work with Cole on the OpenCV component of our project and reach out to other team members for help as needed.

Since the mobile application will be developed using Android Studio and the target classification and video analysis will be done in Python, this may pose a challenge in communication between the two systems. Our team will have to research and experiment to determine the best course of action if issues arise.

Another problem our team may run into is the hardware component assembly and connection to mobile devices. After completing research regarding connectivity, Mike Ruden concluded that installing a WiFi chip on one of the hardware components would be the best way to transfer data reliably and accurately to the connected mobile device. However, Mike is the only team member who has had experience installing WiFi chips, so if he runs into an issue, other team members can only provide limited help.

In addition to the limited knowledge of technologies, our team still is deciding which hardware components to use. This is a risk because we need to start designing our prototype soon, and in order to do so, we need to know the hardware component specifics so we can make informed design decisions.

2.10 Project Proposed Milestones and Evaluation Criteria

The milestones listed below will be used to determine the progress being made on the project.

- Project Requirements and planning: This includes having a project plan for the entire project. Have a design document for the mobile application. Design specifications and document for the hardware.

- Data collection and analysis: Collect video data out in the field. Organize and label video clips. Analyze the clips and have them ready for CV analysis.
- Clay target movement detection (moderate accuracy): Based on our video data, detecting the clay target movement should be around 90% accurate.
- Clay target object recognition (moderate accuracy): Based on our video data, the program should be able to detect the clay target when not hit, the clay target when hit, and the shell casing. Detecting other objects as clay targets should be minimal at this stage.
- Mobile app prototype. A simple Android application that sets up simple communication between the mobile devices and another device.
- Camera device prototype: The camera device is implemented and tested to gather video data, communicate over WIFI, and do computer vision computations.
- Mobile app and camera device communication prototype: Mobile devices are able to connect to camera device(s), get video, and keep score.
- Client prototype test: have the client(s) test the prototype.
- Clay target movement detection (high accuracy): Based on our video data and video captured while in the field, detecting the clay target movement should be over 99% accurate.
- Clay target object recognition (high accuracy): Based on our video data and video captured in the field, the program should be able to detect the clay target when not hit, the clay target when hit, and the shell casing. Detecting other objects as clay targets should be almost null at this stage. Detecting the objects should be over 99% accurate.

2.11 Project Tracking Procedures

Our team is using a variety of methods to track our progress. Below is a list of the methods we are using and why we decided to use the particular method.

2.11.1 Regular Meetings

Our team holds regular meetings on Mondays and Wednesdays of every week. We also have a regular client meeting with Dr. Duwe on Thursdays. These meetings allow us to check in with each other face-to-face and carve out a set time for everyone to work on our project. Since all team members are in the same physical location, the meetings allow us to determine what progress has been made since the last meeting and to discuss any concerns or issues team members may be having. If, for example, a team member has hit a roadblock on a certain task they are working on, they can brainstorm with the entire team and receive help to overcome the issue if needed.

Our regular client meetings allow us to share what progress we have made with our client. These meetings also allow us to clarify any unknowns or questions regarding projects requirements and elicit any information we need from Dr. Duwe. In addition, these meetings also hold our team accountable for those tasks we said we would accomplish.

2.11.2 Slack

Our team uses Slack as a way to communicate quickly and efficiently with other team members. If one team member has a question regarding a task they are working on, they can easily post the question in Slack and get an immediate response.

Slack provides our team with an easy way to plan meetings and clarify task assignments.

2.11.3 GitLab

Not only does our team use GitLab as a place to place our project code, but we also use GitLab as a way to document tasks and issues that need to be completed. Of all the methods used to track project progress, GitLab is the most important. Our team can follow our project progress based on the number of tasks completed and the number of commits made. GitLab will become more of a priority once we start developing the mobile application and the software that will be on the physical device.

2.11.4 GoogleDocs and Meeting Notes

In addition to the above methods for tracking our project progress, we also use GoogleDocs as a way to list "Action Items" and keep them in one place. At every team meeting, meeting notes are taken to record topics discussed, any current or pending issues and their solutions, and upcoming, or action, items that need to be done. These action items are reviewed at the next team meeting and either reassign, troubleshoot, or close.

2.12 Expected Results and Validation

The end goal is a fully functioning, portable, clay pigeon target classification system, complete with a mobile application that allows users to confirm or challenge the device's target classification. In order to validate our system, we will take the physical device, along with the mobile application, to a shooting range and determine the classification accuracy rate. We will confirm the device's accuracy by using a human referee's classification as reference. Our goal is to have a system that classifies human-visible breaks with a 95% or higher accuracy rate.

2.13 Test Plan

Our test plan consists of two main components: the physical device and the mobile application. The physical device will be the focus of the first tests, and we will add tests for the mobile application later on into the project.

The main testing plan for the physical device will consist of taking the device out to the shooting range and comparing the device's target classifications to those of a human referee. Our team will keep track of those shots the device scored successfully, in addition to keeping video footage of the shots the device did not score the same as the human referee. That way, we can review the video footage later and make adjustments to our software and machine learning model as needed. Our goal is to achieve an accuracy of 95% or better. This phase of testing will require multiple rounds.

3. PROJECTED TIMELINE, RESOURCES, AND CHALLENGES

The main testing plan for the mobile application will start once our physical device has an accuracy of 85% or better. The mobile application will be downloaded onto a mobile device and taken out onto a shooting range. Then, we will observe a game of skeet shooting with multiple shooters in the shooting squad to ensure the application performs as desired. We are hoping to have Dr. Duwe, our client, use the application while we observe what he did and did not like, in addition to noting any performance or functional requirement failures.

3.1 Project Timeline

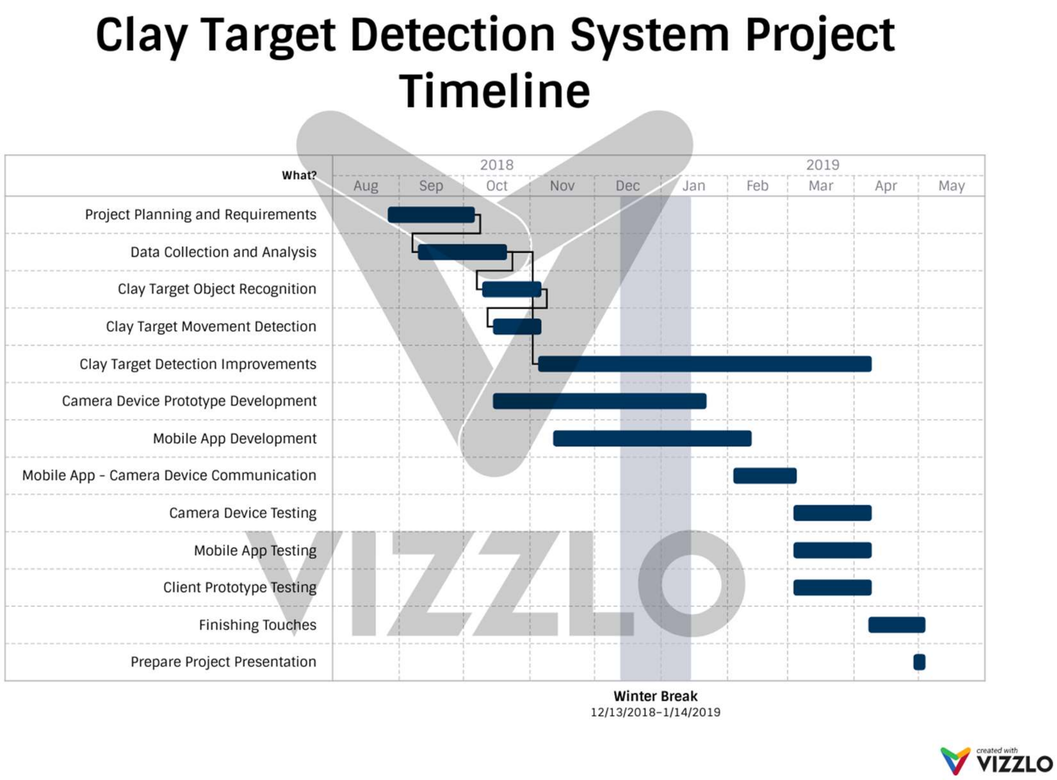

Figure 2. Timeline for the Project

During the first semester, our team will spend a large chunk of our time collecting video of clay target shooting and analyzing it to fit our machine learning model, we plan to have a working model that can detect a clay target by the start of November, in this time we will also be working on tracking the clay target as it moves across the frame of view in the video. Once our model is able to detect the clay target and its movement we will start training it to improve its ability to do so. While we are training our model to detect the target, we will begin development of our camera device prototype and our mobile application.

During the second semester our team will continue improvements on our clay target detection and motion tracking. We will also complete the camera device prototype, the prototype for our mobile app and begin working on making them work together. Once our application and camera device are working together we will begin testing on the prototypes. Towards the end of the second semester we will begin working on the final presentation of our project.

3.2 Feasibility Assessment

The goal of our project is to devise a camera system for our client that will enable us to identify if a clay target has been struck. This camera system may be used for skeet competitions to help determine the type of hit on the clay target, or whether the clay target was struck at all. Multiple cameras will be facing the field of view where clay targets can clearly be seen from all angles and by all cameras. Data will be captured and processed to be used within our program. Our program will render the video data and we will use image processing and machine learning to identify a clear break in the target. A signal will be given by our system that will indicate if the target has been hit, the type of hit, or if that target was missed completely. We must determine the best camera system to purchase that will enable us to obtain the most accurate results.

One of our greatest challenges is programming the camera system and using signal processing to capture the movements of the clay target and determining if any changes were made to the target mid-flight to indicate a hit or a miss. There is also the challenge of the camera system detecting and object other than the clay target in the field of view, two such examples are birds that could cause the camera system to indicate a false miss, or the possibility of a bug flying in front of the camera and being mistaken for a clay target. One possible solution to this problem is the fact that we will be using multiple cameras, this will eliminate the bug problem since we can determine if the bug is only seen on one of the cameras. Another challenge we will be facing is the speed at which the data can be obtained and processed to reveal a clear and reliable result to our client.

3.3 Personnel Effort Requirements

Personnel Effort Requirements Table		
Task Title	**Task Description**	**Effort**
Weekly report	Every week a report needs to be submitted.	~2 hrs/week
Project plan and design document updates	A project plan must be created and updated throughout the project lifetime. Create design and specification documents for hardware/camera device and mobile app.	Initial draft of documents should take ~4 hours to draft. Update ~0.5hrs/week
Data Collection	Collect video data for CV analysis and training on the field.	~3hrs per collection session
Video Editing	Cut and edit videos so they can be used for CV training.	10+ hours after collection session
CV analysis and training	Implement a solution for detecting clay target movement and object detection. Train using video data.	10+ hours per week

Hardware requirements/Design	Create design and specification documents for hardware/camera device.	Initial draft of documents should take ~2 hours to draft. Update ~0.5hrs/week
Camera device casing design.	Design the housing unit for the camera device.	3 hours
Mobile app requirements/design	Create design and specification documents for mobile app.	Initial draft of documents should take ~4 hours to draft. Update ~0.5hrs/week
Device communication	Work on communication between camera devices and mobile devices.	7+ hours per week
Android app prototyping	Build a mobile app prototype that is able to connect to the camera devices, get data, and keep score.	8+ hours per week
Android app testing	Test functionality of mobile app.	1+ hours per week
Camera device prototyping	Build camera device prototype that is able to communicate over WIFI and collect and analyze video data.	8+ hours per week
Camera device testing	Test camera device.	1+ hours per week
CV movement testing	Test accuracy of clay target movement accuracy.	2+ hours per week
CV object detection testing	Test accuracy of clay target movement accuracy.	2+ hours per week

Camera device, mobile app, and communication integration and testing.	Integrate camera device and mobile app prototypes and test after integration.	20+ hours
User acceptance testing	Have the users test the prototype. Observe the user's processes and get feedback from them	6+ hours
Deployment	Get final version of project deliverables ready.	10+ hours

Table 1. Personnel Effort Requirements

3.4 Other Resource Requirements

For the hardware and camera, we'll need access to labs in order to work with the board and camera. For creating the housing unit for the camera device and hardware, our team will need access to a 3D printer to print the case.

For the mobile application we will need Android devices to test the app on. For the most part, I believe most of the team have Android phones that can be used, but an Android tablet may be useful for testing on different types of devices.

We need access to the field along with cameras in order to collect video data of shooting clay targets. We also need access to know how and where we are going to setup the camera housing stations.

3.5 Financial Requirements

Total Budget	$1,000 - $1,300
Cost of Materials	
Device Components	($125-$175)
Cameras	($500)
Cost of Assembly	
PCB Manufacturing	($-)
PCB Assembly	($-)
House Manufacturing	($0)
Cost of Testing	
Field Fees	($18)
Transportation	($3)
	$300

The total budget of the project is around $1,000 - $1,300, with the physical device taking up majority of the cost of the total project. The cost of the device can be broken up into couple different parts; cost of materials, cost of assembly & manufacture, and the cost of testing.

The cost of the materials of the device will take up the majority of the budget. The design requirements need to have multiple cameras that can capture high resolution. These cameras will be off the shelf with a cost of around $100-$200, the cost could very on the specifications needed for the camera. The computing device will either be a stock single-board computer with a cost of around $35. If no single-board computer is found that could meet the specifications, we will make our own. A custom made single-board computer will have the cost of around $125-$175 in components.

The cost of assembly and manufacture will depend on the on either the project will require a custom single-board computer. If it is required, the cost of board will depend number of layers and the total size of the board. Since that most microprocessors have ball-grid arrays (BGA) the only way to assembly is through pick-and-place machine. The cost of using this depends on what company we get our board manufactured. The house can be made using one of the Iowa State 3D printers, which would eliminate the cost of the manufacturing cost of the house.

4. CLOSURE MATERIALS

Testing will need to take up a small portion of the budget with going out to the field and collecting data samples. It can be broken up into the cost of transportation to getting and from the field and the cost of renting out the field. The total cost is around $21 per sample collection.

4.1 Conclusion

In summary, *IC Chip* intends to provide a solution to the problem of human involvement in the scoring of clay target sports. It is to be a rugged and easily deployed autonomous system utilizing current machine learning and computer vision algorithms to integrate seamlessly with readily available user devices such as tablets. The project also intends to minimize our reliance on expensive computational equipment through the production of our own printed circuits and use of open source packages.

4.2 Appendices

4.2.1 List of Figures

Figure 1. Camera Locations on a Skeet Range

- This figure shows the tentative location of cameras around a standard skeet range for recording individual shots for processing.

Figure 2. Timeline for the Project

- This figure features an approximation of our time distribution and frame for expected results on the project.

4.2.2 List of Tables

Table 1. Personnel Effort Requirements

- This table features our required effort for the project in time commitments.