IC Chip: Automated Clay Target Scoring System

DESIGN DOCUMENT

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1 Introduction

1.1 Acknowledgement

Our team would like to thank Dr. Henry Duwe, Assistant Professor at Iowa State University, for not only letting us pick his brain about the game of skeet shooting, but also for guiding our team throughout our research and encouraging us to continue to ask "why" whenever a design decision was made.

1.2 Problem and Project 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 Operational Environment

The device's environmental setting will be exclusively outside. With an outside environment we have to design a device that can be protected for different types of weather; hot summers, cold winters, and the humidity in the spring. The device wouldn't be used in the event of rain or be left outside for extended amount of time. Along with weather related environments, we have to worry about ballistic related objects hitting the device. Since our device will be operated at a range with weapons being fired, the chance the device being hit with one of pellets or a broken piece from a clay pigeon needs to be considered when designing the device.

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. This project, as noted earlier, consists of a physical device and a mobile application for use on a mobile device, such as a smartphone or tablet. The physical device will record and process video footage to determine whether a clay target was hit (classified as "dead"), or if the shooter missed the target (classified as a "loss"). Thus, the physical device will act as a second pair of eyes for the referee and the shooting squad. The mobile application will allow the referee and shooting squad to review video footage and challenge the target classification for the most recent shot.

Thus, because the project consists of a hardware and a software component, 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

Below is a table that lists the assumptions and limitations of the hardware and the software components of this project.

Assumption	**Justification**
The maximum number of users will be ten per match.	There usually is only a few participants at one time and setting a maximum at 10 would leave enough room.
Users will only use Android Devices	Developing for Android doesn't require any developer licences whereas ios does.
Wifi used for wireless communication	Wifi will be use rather than Bluetooth since Bluetooth has been deemed less reliable than wifi by our team.
Device needs to be small enough to be portable	Client requests
Device needs to be placed in a housing.	Protection from any damage that might occur from debris
All video analysis will be done on the device and must be done in almost real time	Client Requests
Device will be operated with battery power.	This helps with portability and ease of set up.

Limitations	**Justification**
Time of day	Light throughout the day will change.
Cost	The budget final for this project must not exceed the client's budget.
Camera Resolution and framerate	As the resolution and framerate increase, so will the cost which will cut into the project budget as a tradeoff to video quality.
Weather	The device would be used all throughout the year were different weather would cause issues.

1.6 Expected End Product and Deliverables

The project's end product that meets what the client wants is a system that is able to detect whether or not the clay target is dead or gone. It should be able to detect small chips that may be difficult to detect with naked eye and does count as a dead target while at the same time not counting if the surface of the target gets grazed and small particles leave the surface. The system should also be able to differentiate between the target, the shell, and other objects that enter into the cameras view.

Deliverables for hardware include a system with a camera station or multiple camera stations and a ground station. The camera stations pick up video data of the target being shot (or missed). The camera station will determine when the camera needs to record and for how long. The camera station(s) will send its video data to the ground station over wifi. To accommodate all of this, the station will also come with a board and wireless card. The ground station receives the video data from the camera station and analyses it. It will determine if the target is dead or lost along with keeping score for the round.

Another deliverable is an Android app. The app will be used as an interface for the users to use the target scoring system. The users will also be able to contest whether the target is dead or lost by having video to replay the event. If it is determined that the score is wrong after being contested, then the score can be changed.

2. Specifications and Analysis

2.1 Proposed Design

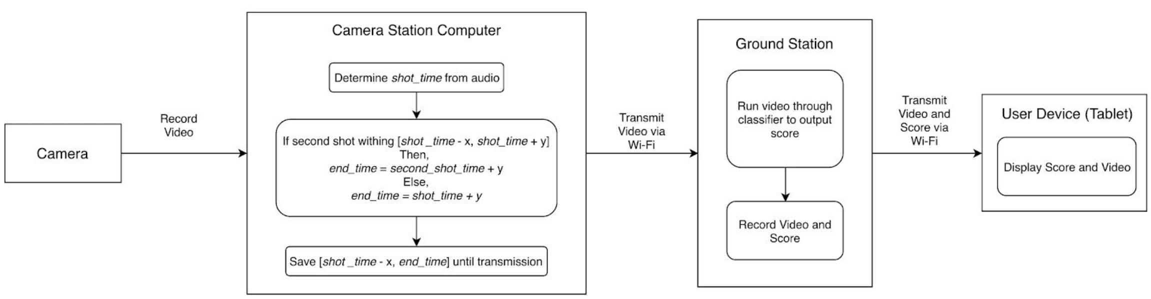

Figure 1. System Block Diagram

The exact configuration of out system has not been fully determine. What we have decided so far is that our system will resemble what is shown in figure 1. To begin with, we have a camera that is placed on a skeet field, the precise location is still an ongoing design decision. That camera will record video which will be spliced into fragments based off of timing of the shots on a connected computer. From there, the video will be transmitted wirelessly to a ground station. This ground station will perform the majority of the computation to classify the shot as a *hit* or a *miss*. The classification is then transmitted wirelessly to a user device, such as a tablet.

Before we can make any further decisions as to the design, we must first ensure that we have a highly accurate computer vision model. To this end we have been recording and classifying video to train the model on from a variety of angles around a traditional Skeet field. The accuracy of the models trained on the various angles also allows us to gain insight into the optimal placement of the camera for recording shots in the field.

2.2 Design Analysis

Collecting a sufficient amount of training information for the classification model proves to be the first weakness of the project. Almost all other components of the project hinge on an effecting classifier. This, in turn, relies upon a sufficient training dataset. If the team manages to provide a large and diverse enough dataset to train on, this hopefully will cease to be a weakness and instead be a strength of the project. To this effect, we have been recording shots in diverse conditions from diverse orientations to prevent over-training and make the model invariant to as many changes as possible.

3 Testing and Implementation

Testing is an **extremely** important component of most projects, whether it involves a circuit, a process, or a software library. In this section, we discuss the tests that our team will perform to ensure our system meets both functional and nonfunctional requirements specified by our client.

3.1 Interface Specifications

Hardware - The hardware will not have a GUI it will just have a CLI.

Software - The software will be an android application which will work as an interface for the hardware.

A majority of our applications logic and processing will be done on our hardware. The hardware will initialize a local WiFi connection that our android application will connect to. From there our hardware will send video and the supposed outcome to the android app. The android app will then allow the user to view the most recent shot, and tell them if a hit or miss was detected.

3.2 Hardware and software

For performing hardware testing on the prototype we can use variety of equipment that is located in the Coover engineering labs for measuring and creating signals.

- Digital Multimeter - A digital multimeter is used to measure voltages and current anywhere on the prototype. This can be used to ensure connections are correct and to verify that that the correct parts of the prototype are active at the create time
- Oscilloscope - An oscilloscope can used to measure and view signals in the prototype. Viewing a signal in the prototype will allow us the verify that the signal isn't being distorted or filtered when it travels through the design.
- Signal Generator - Signal Generator creates artificial signals for the inputs of the prototype. By knowing what signal we put into the prototype and the output signal, we can determine how the prototype response to given inputs.
- Power Supply - Provides a DC signal to input of the device. Using a power supply we allow us to test the prototype without the need of batteries.

Software testing on the prototype differs in that it requires little to no specialized equipment. Instead, it will focus on unit testing, hopefully achieving 100% code coverage for the user application, communication system, and various backend helper programs that may exist on the ground station

The only software aspect that will differ is the testing of the object detection and tracking. This will need to be tested by feeding in pre-scored data that the model has not been trained on previously, and analysing the output score to determine the rate of mis-classification.

3.3 Functional Testing

In this section, we detail the types of tests we will use to validate our system, in addition to the current status of the tests. This section specifically focuses on testing the system to determine whether it meets the functional requirements specified by our client.

3.3.1 Physical Device Functional Testing

In addition to the tests detailed below, our team will also observe our client using the physical device without any instructions beforehand. This way, our team will have a good understanding of how easy and intuitive our device is to use. Then, our team can create an appropriate and descriptive user manual and quick start guide to accompany our system.

Test	Acceptance Criteria	Critical	Test Status
1A: Physical Device is Portable	User is able to move the physical device around without strenuous physical effort.	Yes	Not attempted.
1B: Protective House Protects the Device	Protective House successfully prevents clay target and other debris from damaging the physical device.	Yes	Not attempted.
1C: Protective House is Removable	User is able to easily remove the Protective House without strenuous physical effort and without damaging the physical device.	Yes	Not attempted.
1D: Physical Device WiFi Network	User's mobile device should search for and find the physical device's wifi network.	Yes	Not attempted.
1E: Physical Device Should Capture Video in Real-Time	Video footage recorded on physical device is consistent with the real-time recording environment.	Yes	Not attempted.
1F: Physical Device Should Not Record Video Unless Active Session	The Physical Device should not capture, record, and process video footage until a session shooting session has been created and is active.	No.	Not attempted.

1G: Physical Device is Now Powered by an External Source	The Physical Device turns on and stays on without needs an external power source.	Yes.	Not attempted.

3.3.2 Mobile Application Functional Testing

Below is a table of the functional tests our team will use to validate the mobile application that accompanies the physical device. Similar to the physical device functional testing, our team will first observe our client using the mobile application without prior instruction. Again, this is so we understand how easy and intuitive our system is to use. Once we have made observations, we can then create a more effective user manual and quick start guide.

Test	**Acceptance Criteria**	**Critical**	**Test Status**
2A: Mobile Application Connects to Physical Device's WiFi Network	Upon opening of the mobile application, the mobile device should successfully find and connect to the physical device's wifi network.	Yes.	Not attempted.
2B: Mobile Application Knows Skeet Shooting Rules	When the rules of skeet shooting dictate that the shooters change order in an active shooting session, the mobile application updates the order of the shooting squad members to accurately reflect the rules.	No.	Not attempted.
2C: Mobile Application Knows Shooting Squad's Scores.	The mobile application updates the scores of members of a shooting squad as per rules of skeet shooting during an active shooting session.	No.	Not attempted.
2D: Mobile Application Displays	Mobile Application receives data from the	Yes.	Not attempted.

the Correct Target Classification	physical ground station and displays the target classification as determined by the computations from the ground station.		
2E: Mobile Application Allows for Classification Challenge	If User challenges the target classification determined by the ground station, mobile application will allow user to review and manually enter the target classification, followed by updating the squad member's score appropriately.	Yes.	Not attempted.
2F: Mobile Application Should Not Save Shooting Session	Upon termination of a shooting session, the mobile application will not save any data from the shooting session on the user's mobile device.	Yes.	Not attempted.
2G: Mobile Application Displays Classification	Upon receiving target classification data from the physical ground device, the mobile application will display the classification on the screen for the user to view. The mobile device will also display a choice to either confirm or challenge the target classification.	Yes.	Not attempted.

3.4 Non-Functional Testing

In this section, we detail the types of tests we will use to validate our systems performance, usability, compatibility and security . In addition to the current status of the tests. This section specifically focuses on testing the system to determine whether it meets the non-functional requirements specified by our client.

3.4.1 Physical Device Non-Functional Testing

The below table contains tests for non-functional aspects of the physical device and the relevant acceptance criteria for them.

Test	Acceptance Criteria	Critical	Test Status
1A: Device will classify shots with a 95% accuracy.	The device will identify a hit or miss correctly.	Yes.	Not Attempted
1B: Device shall compute classification of shot with 2 seconds of shot.	The shot classification is performed within 2 seconds of the shot being taken.	Yes.	Not Attempted
1C: Device shall send shot classification within a second of classification	The device will make a request to the application with the notification within a second of the shot classification	Yes.	Not Attempted
1D: Device will transmit shot video within 3 seconds of shot	The physical device will begin sending the video to the mobile application once the shot is classified and will have the video clip transmitted to the device within 3 seconds of the classification.	Yes.	Not Attempted

3.4.2 Mobile Application Non-Functional Testing

The below table contains tests for non-functional aspects of the mobile application and the relevant acceptance criteria for them.

Test	Acceptance Criteria	Critical	Test Status
2A: Application receives the classification from the physical device within 2 seconds after the shot is made.	The application will receive a request from the physical device. With the shot classification within 2 seconds of the shot is	Yes.	Not Attempted

	made.		
2B: Application will display the target classification within 1 second.	The application will display the shot classification to the user within a second of receiving it from the device.	Yes.	Not Attempted
2C: Application will display a challenged shot within 3 seconds of the user challenge.	When a user challenges a shot classification the video will be displayed within 3 seconds	Yes.	Not Attempted
2D: Application will deletes video from memory within a second of classification.	When a user re/classifies a shot the video will be deleted from the devices memory	Yes.	Not Attempted
2E: In case of connection breaking, application will save current session until session is reinstated	When application detects a broken connection the session information will be saved.	Yes.	Not Attempted
2F: The mobile application will not connect to the internet.	The application will work in an offline setting.	Yes.	Not Attempted
2H: The mobile application will not require user login information upon startup.	The application will open without any login credentials.	Yes.	Not Attempted
2I: Application will be available to all users who have an android tablet or mobile phone.	Android SDK used will make app available to > 95% of android users.	Yes.	Not Attempted

3.5 Process

Our process so far for collecting data first come up with criteria on how data is going to be collected which will be the action plan for going out to the field and collecting data. Then we go out to the field and record the targets being hit or missed from different angles. The videos are then split into shorter segments that include the shooter saying “pull” as a voice cue and the target within cameras view to determine a hit or miss. The videos segments will be labeled and archived for later usage. Each video segment will have a raw and labeled copy. Each video segment will then be evaluated to determine how sufficient it is to be used for the training model. The video data set will also be evaluated based on what worked, what didn’t work, and what we could do for future data collection. Once the data has been analysed, the team members in charge of computer vision and machine learning will work with the video segments and model while the members in charge data collection will go back out into the field to collect more data which repeats the process. For the most part, data collection will be an ongoing process because more variety of data will improve the model and will avoid over-training.

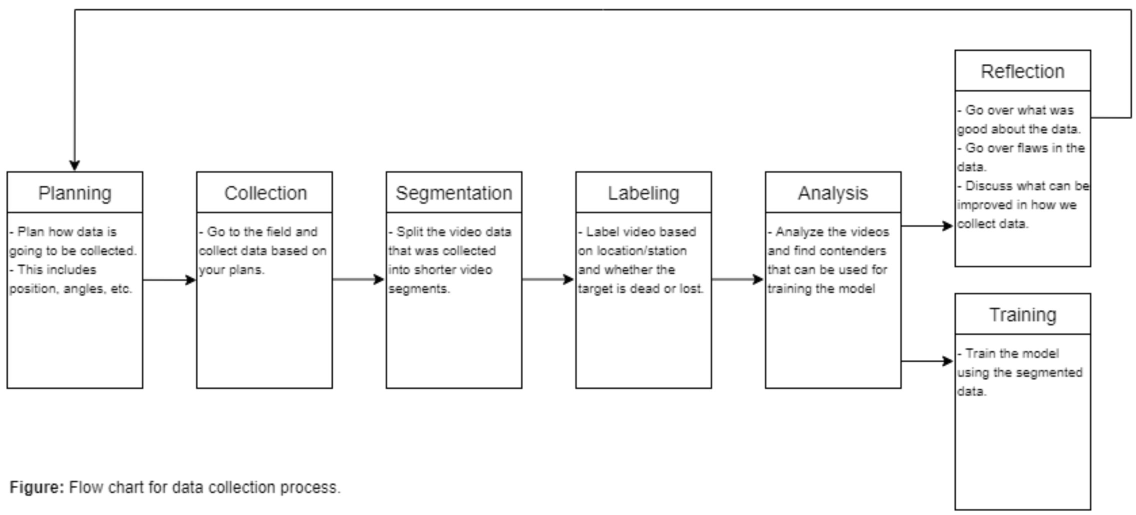

Figure: Flow chart for data collection process.

3.6 Results

Most tests are unable to be performed as of the current date, we are in the midst of finalizing some of our research so that we may start some of the initial testing phases of both our hardware and software capabilities. We have begun to setup our android software application and have attempted to connect our android application to a local Wi-Fi signal initialized from our own hardware. This process is still ongoing as we have not yet been able to reliably connect our application to a local hardware Wi-Fi signal.

An initial round of data collection has taken place on the field. Although at this point it may be extremely difficult to analyze some of our data due to the small, fast moving clay pigeon targets. We have been able to successfully label and identify most of our data and determine if the clay target is dead or lost. There are some videos that have failed to provide us with useful results, as sometimes you may not see the clay pigeon at all during its flight. In the future we hope to gain access to better cameras which will make it easier to clearly see if the clay pigeon has been hit.

One challenge that we will face over the duration of our project is finding a camera that is good enough to be able to provide us with an image that we may use to accurately identify if the clay pigeon has been destroyed or only chipped. We also need to find the best location to place our camera so that we may capture most of the flight of each clay pigeon or decide if multiple cameras are needed, while also finding a way to fit this into our budget.

4 Closing Material

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