Requirements Specification

Version 1.3 - 5/3/2024

CRAFT (Ceramic Recording Automation and classiFication Team)

Project Sponsor:
Dr. Leszek Pawlowicz

Faculty Mentor:
Vahid Nikoonejad Fard

Course Organizer:
Dr. Michael Leverington

Team Members:
Kimberly Allison
Aadarsha Bastola
Alan Hakala
Nicholas Wiley

Accepted as baseline requirements for project:

For the Client: ______________ For the Team: ______________

Table of Contents

1. Introduction

The rapid progression of modern technology has brought with it the modernization of many long existing scientific fields. While most areas of science have seen rapid increases in progress, reliability, and efficiency in their field, archeology has fallen behind due to the uniquely human decisions involved in the field. In archeology, a sherd is a broken piece of a ceramic vessel. Did you know that up to 50% of archeologists can disagree with each other on the classifications of these sherds? Discrepancies in the lab and the field are not the only issues archeologists face, the tedious nature of collecting those sherds makes data collection slow. Team CRAFT hopes to reduce inefficiency and improve accuracy in archeology by addressing long existing problems in the field.

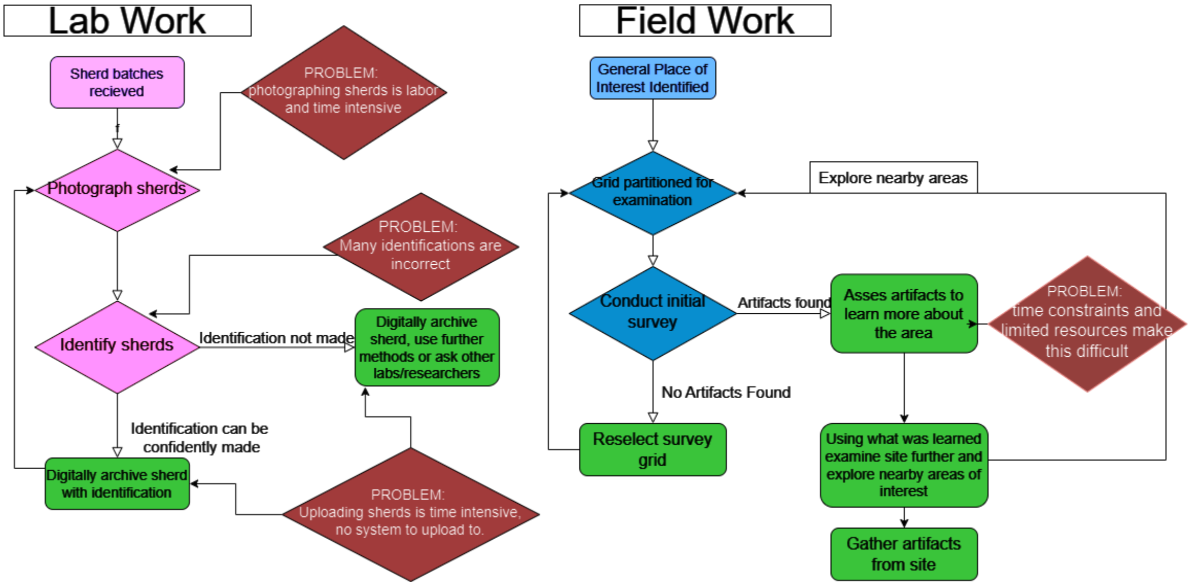
Our sponsor, Dr. Pawlowicz, is a veteran archeologist and researcher currently working as a Research Professor in the Department of Anthropology in Flagstaff, AZ. Dr. Pawlowicz has a unique perspective as he has seen both sides of the field, hands on survey work examining sherds in remote locations and research experience evaluating sherds in the lab. Archeological surveys may be the most labor intensive and tedious part of the field. A common question non archeologists have about the field is how archeologists know where to find archeological sites. Typically, this can be a rather large problem for archeologists themselves. Before excavation or further examination of a site can begin, a pedestrian/foot survey must take place. Pedestrian surveys consist of teams of field archeologists walking straight lines at a constant spacing, looking for artifacts Pedestrian surveys are labor and time intensive, leaving individuals in the field with little to no time to archive, assess, or catalog sherds. Field technicians can often have limited experience with the ceramic artifacts in the area they are working, which can seriously impact the accuracy of their classifications.

Once batches of sherds are discovered, archeologists examine things like craftsmanship, material used, and artistic design features to identify the sherd. In an effort to preserve history, make reassessments, and share data conveniently, archeologists often wish to photograph sherds and digitally archive them, but due to constraints on time and manpower, this is often not practical. Having experience in both areas, Dr. Pawlowicz hopes to tackle problems in the lab and the field. Working with him, team CRAFT aims to reduce inaccuracy in identification, speed up the archival process in the lab, and make survey work easier and more efficient. This document will detail the specific issues we plan to solve, the requirements our solutions should have, risks we may encounter, and milestones we hope to achieve.

2. Problem Statement

The problems Leszek hopes to resolve span across multiple areas in the field. To better understand where problems arise in the workflow, and how the two sides of the field connect, the flowchart below has been created.

Figure 1.



As mentioned above, up to 50% of sherd identifications may be disputed by archeologists. Even worse, archeologists disagree more with themselves. It is not uncommon for veteran archeologists to change their minds over half of the time on sherd classifications. These visual assessments, which originate from years of experience and extensive knowledge of art, history, culture, and many other subjects, can be aided by computers.

Unfortunately, many archeologists do not get the opportunity to reassess their work. Many sherds are historically, culturally, and religiously significant to the indigenous groups they originate from. Since these indigenous groups expect to have their property returned to them researchers have a limited window of time to make their assessments. Losing the ability to reassess sherds makes the already present identification issues even more problematic. If researchers have tens of thousands of sherds archiving all of them poses a significant challenge. This can also be seen in the lab work section of the flowchart.

3. Solution Vision

To provide an accessible and consistent baseline for sherd classification, team CRAFT will build upon preliminary deep learning models for sherd identification for mobile and desktop applications already developed by our sponsor. The current CNN model utilized by the mobile application will be redone and implemented into a physical conveyor belt and an expanded version of the current mobile application.

In the field, researchers will be able to open the mobile application and take a photo of a sherd. After the photo is taken, the improved CNN will classify the sherd and display the information to the user. After a classification, the user will have a chance to manually update it if desired. Then, the classification data, along with a photograph and associated metadata for the sherd will be saved in the cache until the user is within range of cellular service. The app's development should increase the number of sherds a field archaeologist can process and classify and improve the accuracy and consistency of sherd classification.

For laboratory-based documentation and analysis, the user will place a sherd onto a moving conveyor belt. The application will detect when a sherd passes underneath a webcam and take a photograph of the sherd. Once the photo has been taken, the improved CNN will classify it and save the data in a similar form to the app. The data will be uploaded directly to a database.

Listed below are the main features to be implemented in each of our team's developed solutions, along with Figure 2, that describes how both the mobile application and conveyor belt operate.

3.1 Artificial Intelligence

- The model will have an improved accuracy rate compared to the previously developed model.

3.2 Mobile Application

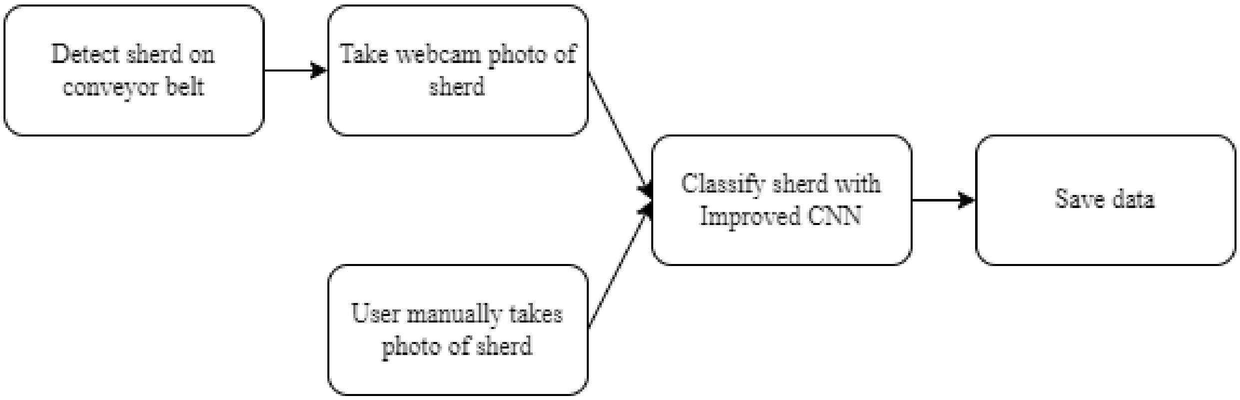
- The mobile application will be capable of saving associated metadata for each sherd, including geographic data and CNN-determined classification information
- When the user has cellular service, data will be uploaded to a database
- The application will be available on both iOS and Android devices

3.3 Conveyor Belt

- The conveyor belt will be able to detect each sherd as it passes over a conveyor belt and under a web camera

- Where appropriate, classifications will be made for each sherd, and the data will be saved to a database for later access

Figure 2.



4.0 Project Requirements

4.1 Functional Requirements

Team CRAFT has determined various functional requirements to ensure the development of an optimum solution that meets our sponsor, Dr. Leszek Pawlowicz's requirements. These functional requirements are divided into three sections, each with different development requirements and goals but are integrated at some level.

4.1.1 Mobile Application

1. **Image Classification**
   The application should be able to classify the images provided by the user via camera/local storage using an Image Classification Model.
2. **Offline Functionality**
   The application should be able to perform image classification without an active internet connection. The application should be able to perform all the functions except uploading data to the Database without an internet connection.
3. **Save Results in a Database**
   The application should be able to save the classified results into a Database.
4. **Location Services**
   The application should be able to record the obscured geolocation of the device where the classification is performed to record where the sherd was found. The user should be able to edit the location if the found location and classified locations are different.
5. **Edit Classification**

The application should be able to edit the classification if a user believes that the classification results produced by the Classification Model are incorrect.

6. **Feedback Mechanism**
   Once the model has classified the provided image, the application should be able to show the results with respective confidence levels.
7. **Offline Data Buffer**
   The application should be able to classify images. Then, if there is no active internet connection, the application should hold the classified data in a buffer until there is an active internet connection. Once the application detects an active internet connection, the application should be able to upload the results to a database.

4.1.2 Conveyor Belt

1. **Image Classification**
   The application should be able to use an image classification model to classify sherds that are passing through a conveyor belt.
2. **Bulk Image Processing**
   The application should be able to process multiple pieces of sherds passing through a conveyor belt.
3. **Real-Time Processing**
   The application should be able to process images of sherds passing through the conveyor belt in real time to keep up with objects moving in the conveyor belt continuously.
4. **Bulk Data Output**
   The application should be able to output all the results of sherds classified in one session into an appropriate data file format.
5. **Image Pre Processing**
   The application should be able to pre-process the images before classification to ensure improved accuracy and consistency.

4.1.3 Image Classification Model

1. **Sherd classification with highest possible practical accuracy**
   The image classification model needs to accurately identify sherds from images. To do this, each potential model needs to be trained on images of sherds. These images need to be modified to suit the specific model requirements. For example, CNN models need the training data to be a set resolution usually much smaller than modern resolutions or else training fails.learning
   rate, and batch size to name a few.

4.2 Performance

4.2.1 Mobile Application

1. **Resource Efficiency**
   Since the application needs to run on many phone models, some of which lack the processing power of newer phones, resource efficiency is critical.
2. **Usability**
   The application should be easy to use, and should have a very clean and simple UI and UX.
3. **Compatibility**
   The application should be compatible with IOS and Android, as these are two of the most widely used operating systems in smartphones.
4. **Error Handling**
   The application should be able to handle any runtime errors without breaking the app, this means catching potential runtime errors and successfully handling them so that the flow of the app does not break.
5. **Scalability**
   The application should be easily scalable. There should not be any issues arising when the app is used by many users simultaneously.

4.1.2 Conveyor Belt

1. **Usability**
   The conveyor belt system must be user-friendly as everyone using this will have a non-technical background.

4.2.3 Image Classification Model

1. **Accuracy**
   The model must be accurate as this is the main requirement for it.

4.3 Environmental Requirements

4.3.1 Mobile Application

1. **Flutter**
   The client wrote the prototype mobile app with Flutter. As such, we will continue to use Flutter for the finished product, as Flutter is a multi-platform framework for app development, which means the same code can be used for IOS and Android platforms with only slight changes.
2. **IOS and Android**
   To be useful to archaeologists, the app needs to be available on all major phones, specifically IOS and Android.

4.3.2 Conveyor Belt

3. **Hardware**
   The hardware for the conveyor belt system is provided by our client and is a requirement

for the system. A camera will be used to capture images of sherds and a conveyor belt moves the sherds under the camera.

4.3.3 Image Classification Model

1. **Tensorflow and Keras**
   AI researchers around the world use Tensorflow and Keras, which results in a wealth of online support. These libraries also support the use of CUDA, a library required to utilize Nvidia GPUs for processing. Without a GPU, training a single AI model would take days at a minimum and is impractical.

5.0 Potential Risks

While we are still in the design phase of this project, it is important that we identify potential risks that could negatively impact the project in later phases.

5.1 Mobile Application Too Computationally Expensive

Due to the limited computational power available on phones, if the app is inefficient, it can lead to slow response times invalidating the usability of the app.

5.2 Image Classification Model Lacks Accuracy

For the image classification model to be a viable improvement over the client's current model, it needs to be more accurate. If we cannot properly tune the hyperparameters on the model, it will not improve accuracy, resulting in an undesired finished product.

5.3 Poor Conveyor Belt Performance

There will be multiple different moving pieces in the conveyor belt system. It is crucial that the system is able to handle detecting sherds, taking a clear photo, processing the photo, and classifying the sherd in an efficient manner.

5.4 Conveyor Belt is Difficult to Use

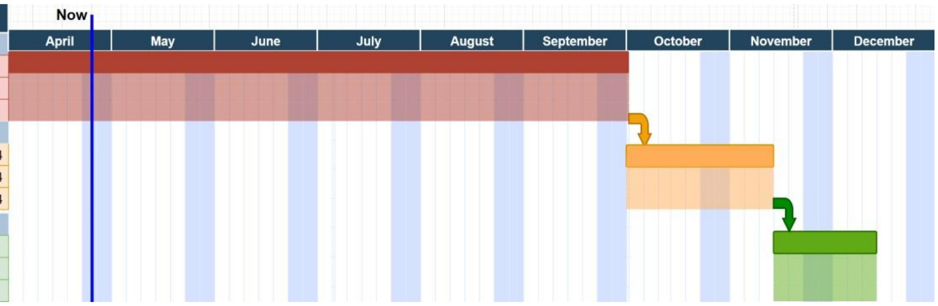
The conveyor belt system will require multiple different pieces of equipment to function, introducing the risk of the system being too difficult to set up or use. The users of the conveyor belt system are archeological researchers, not computer scientists, meaning that the system should be intuitive to set up and run for a general audience, with minimal troubleshooting required.

6.0 Project Plan

Due to our sponsor's experience in the field team, CRAFT hopes to solve problems in several different but related areas of the field. We have chosen to partition our plan for next semester into

3 phases, a “MVP” or bare minimum each component, finishing each component into a near final product, and the last phase will be allocated for testing, fixing bugs, and handling unexpected issues we will encounter. This is why we have three solutions to problems that span from work in the lab to work in the field. Our current estimated plans for our solutions are as follows.

	Task Name	Duration	Start	ETA
1	Barebones Component			
2	Image Model	34 days	8/28/24	10/1/24
3	Mobile Application	34 days	8/28/24	10/1/24
4	Conveyor belt Application	34 days	8/28/24	10/1/24
1	Finished Product			
2	Image Model	40 days	10/1/24	11/10/24
3	Mobile Application	40 days	10/1/24	11/10/24
4	Conveyor belt Application	40 days	10/1/24	11/10/24
1	Make final tweaks & handle bugs			
2	Image Model	21 days	11/10/24	12/1/24
3	Mobile Application	21 days	11/10/24	12/1/24
4	Conveyor belt Application	21 days	11/10/24	12/1/24



6.1 Mobile Application

October 1st: Mobile application should be downloadable and able to capture sherds, and forward data in batch or individually to a server.

November 10th or by thanksgiving break: Application should be in a completed state, should receive an identification(s) for individual or batch uploads from image classification model server.

November 10th-end of semester: Any issues we encounter with the finished product or issues that prevent us from creating the finished product should be resolved. Additional stretch goals should be worked towards if possible.

6.2 Conveyor belt application

October 1st: Conveyor belt should photograph sherds, use OpenCV to properly format images, forward that data to the server, and store sherd data to a database.

November 10th or by thanksgiving break: Application should be in a completed state, should receive an identification(s) for individual or batch uploads from image classification model server. Database, even if only for testing, should exist and be capable of receiving data from conveyor belt application.

November 10th-end of semester: Any issues we encounter with the finished product or issues that prevent us from creating the finished product should be resolved. Additional stretch goals should be worked towards if possible. Potential goals for this application involve adding an additional camera and potentially altering the program to function with an enhanced camera.

6.3 Image Classification Model

October 1st: Current model should be converted into a Deep Learning model, such as a CNN or ViT, uploaded to Monsoon. Training and testing data should be uploaded to the monsoon cluster as well.

November 10th or by thanksgiving break: Image classification model should accurately and reliably identify sherds.

November 10th-end of semester: Any issues we encounter with the finished product, or issues that prevent us from creating the finished product, should be resolved. Additional stretch goals should be worked towards if possible. Stretch goals include adapting the model to work with sherds from different states and tribes. Optimizing the model to reduce identification time to make use more convenient would also be a possible stretch goal given enough time.

Conclusion

Currently, there is a lack of ease and consistency when it comes to classifying prehistoric decorated sherds. Archeological surveys that are done in the field are time and labor intensive, often
leaving researchers little time to make assessments and catalog sherds. Laboratory analysis of extant or new collections can be difficult and expensive due to lack of automation. Team CRAFT aims to streamline the process of identifying and cataloging sherds by utilizing AI, specifically deep learning models.

Team CRAFT plans to first re-develop our client's current deep learning model, creating a model with an increased level of accuracy. Once completed, the model will be implemented into both a conveyor belt and a mobile application. The mobile application will be available on both iOS and Android, allowing researchers to save relevant information on a sherd by just snapping a photo. With the development of this application, team CRAFT will both speed up the process of cataloging sherds, and reduce the number of sherds that need to be removed from the field.
Unlike the mobile application, the conveyor belt system will be used in a laboratory setting. Researchers will load sherds onto the conveyor belt, where computer vision tools will be used to detect a sherd passing underneath a webcam. Afterwards, a photo will be taken, the sherd will be classified, and all the information will be saved for later retrieval. With this technology, archeological researchers will be able to process a large number of sherds in a time efficient manner.

With team CRAFT's implementation, archeologists will be able to harness the power of artificial intelligence to provide a consistent baseline for classifying ancient ceramics. Researchers will have options for utilizing this technology in multiple settings, allowing archeologists to complete their work efficiently in both the field and back in the lab.