FAMU-FSU College of Engineering
Department of Electrical and Computer Engineering

PROJECT PROPOSAL AND STATEMENT OF WORK

EEL4911C – ECE Senior Design Project I

Project title: **3D Scanner**

Team #: e10

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EEL4911C – ECE Senior Design Project I

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Project Executive Summary

The purpose of this project is to design a scanner that implements 3D digital images. This design will be used to preserve the artifacts in the *Slavery in the Old South* found in the Meek-Eaton Southeastern Regional Black Archives Research Center and Museum (Black Archives) at FAMU. Because of the easier virtual access to these artifacts, the museum hopes that it will increase the community's engagement in these historical findings.

Team E10's device will take several high resolution photos of the artifacts with overlapping angles covering the entire surface of the object. The photos will be used to generate a 3D point cloud using photogrammetry techniques. The point cloud will then be used to create a solid surface mesh, and the photographs will be used to make a surface texture. This will create a photorealistic re-creation of the object.

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1. Introduction

1.1. *Acknowledgements*

Team E-10 would like to thank Dr. Bernadin for securing a lab space for working as well as for meeting. The team would like to thank Dr. Dawson for establishing the project as well as providing a room at the archives that will be used for scanning the artifacts and data collecting testing.

1.2. *Problem Statement*

The project aims to recreate and preserve historical artifacts from the *Slavery in the Old South* display at the Meek-Eaton Southeastern Regional Black Archives Research Center and Museum (Black Archives) at FAMU. Creating accurate 3D models of the artifacts allows the artifacts to be displayed on the internet for greater access as well as possible replication of the artifacts for display while preserving the originals.

The models will be created from the artifacts by scanning them using photogrammetry. Photogrammetry re-creates 3D scenes by analyzing photographs of the scene. The photographs will be taken of the artifacts by passing them through a frame with cameras that will capture the entire surface area of the artifact. The images will then have a difference image applied which will eliminate the background and only display the artifact. Photogrammetry software will create a point cloud from the collection of images. Mesh modeling software will create a solid surface from the point cloud and generate a texture map from the images. Python programming will be used to automate the steps of each program in the software suite.

1.3. *Operating Environment*

The end product will be designed for being operated indoors in an air conditioned space. The frame will be up to five feet by five feet at the base and up to seven feet tall. The shape of the frame leads to natural stability and should not be prone to falling. The large size of the frame indicates that the device is not likely to be to be handled roughly.

1.4. *Intended Use(s) and Intended User(s)*

The primary users of the device will be computer literate workers with minimal training. While many of the tasks will be automated, some of the tasks will have to be completed by hand. These manual tasks do not require a high degree of education, but at a minimum a technical capacity to use a personal computer and follow guided instructions.

The primary use of the device includes scanning 3 dimensional objects to produce photo-realistic re-creations of the objects. This device is intended to create models with centimeter precision or better. While the device is intended to scan artifacts it has the potential to scan a wide array of objects outside of this scope. This device is not intended to scan live or moving objects as photogrammetry will fail to generate points in the 3D space if the objects move.

1.5. *Assumptions and Limitations*

Assumptions: The best background color is green and will be used for a difference layer. Thirteen cameras will be used to capture the entire surface area with a single pass. Non-rigid objects will be placed on an acrylic surface that will be lifted through the scanner. A single computer will be used to capture input from the 13 cameras as well as process the image data into a 3D model.

Limitations: The final product will not exceed 5’x5’x7’. The scanned objects cannot exceed 3’ in width (though length can potentially be unlimited given enough memory storage and processing power) so as to give the cameras enough standoff to capture the entire surface with some overlap. The cost to produce the final scanner should not exceed $1000. The device should not be used outside or where there is excessive amounts of light interference.

1.6. *Expected End Product and Other Deliverables*

Scanner: A 5’x5’x7’ arch frame containing 13 cameras as well as a PC for control and diffused lighting.
Assembly instructions: The scanner’s construction may be simple to disassemble and reassemble with guided instruction to encourage portability.

User Manual: The operation of the scanner will not be complicated but there are several steps that should be followed in a particular order. This manual may be in video form or short animations.

3D models/animations: 10 artifacts will be scanned to produce 3D models. Given sufficient time, animations will be created for each model that may be used for educational purposes.

2. Concept Generation & Selection

2.1 Technology

The techniques considered were Photogrammetry and LIDAR. LIDAR devices typically have milimeter or better precision while Photogrammetry tends to have centimeter precision at long range. These differences are less apparent at close distances. Photogrammetry allows the use of the analyzed photos to make a texture map. LIDAR detects ranges but not colors while photogrammetry produces both.

2.2 Frame design

Options considered were a cage with multiple cameras, a 3 wall room with rotating objects and a still camera, a free camera and still object, and an arch with multiple cameras.

A cage would limit the sizes that can be scanned to a single size. The 3 wall room may have been a good choice however large objects would make this method impractical and lighting may be more tricky. A free camera is a good option for any size object but requires technical facility to manipulate the camera around the object. A free camera may be best suited for objects that cannot be moved.

The arch was chosen because it allows the objects to be multiple sizes and can allow for very long objects to pass through and is suitable for all of the 10 artifacts required.

2.3 Camera selection

8 megapixels appears to be the minimum resolution required to produce a high accuracy model. The more pixels captured the more points in space that can be compared and analysed by photogrammetry. Tests with 2 megapixels yielded poor point clouds. Tests with 5 megapixels yielded acceptable point clouds but with unacceptable amounts of errors. 8 megapixel tests yielded acceptable results and still allows for the purchase of inexpensive cameras.

2.4 Lighting

Tests in direct sunlight yielded excellent results however the model is then locked in to that set of shadows and cannot be used in scenes with different lighting.Tests in indoor lighting yielded poor point clouds and could not produce a 3D mesh. Diffused or even lighting should allow for a 3D object that is not restricted to a certain angle of light in a 3D scene.

2.5 Software

Photogrammetry software being considered is VisualSFM, Python Photogrammetry Toolbox (PPT), Autodesk PhotoFly, and Autodesk 123D. VisualSFM and PPT are open source and cross platform that can be used with no licensing issues. Autodesk Photofly can be used on Windows only and is currently offered for free as a beta. Autodesk 123D is a free web service but the results tend to be low quality and the rights to the output may be ambiguous. VisualSFM and PPT can be used interchangeably for this project.

3. Proposed Design

3.1 Overview

The overall proposed 3D imaging design, should be able to capture many different images of historic artifacts from the FAMU archives. These images will then be send to a computer where they will be stored in a file for processing. Once the images are saved in a specified folder a python program should start link the different softwares needed to generate the 3D model. This three dimensional representation will then be free to use for any virtual gallery or cinematic motions.

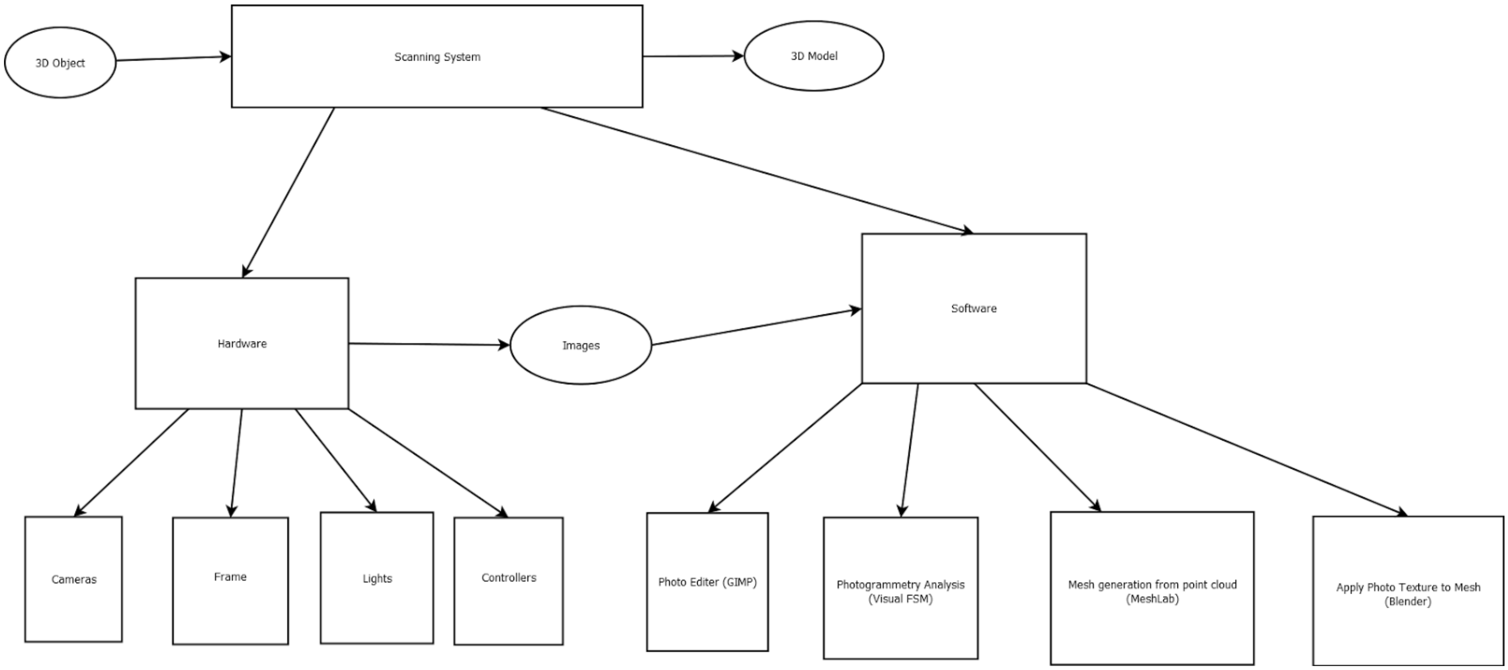


Figure 3.1 - Block diagram of the overall system

The figure above shows what the overall system process will be. The very first row is the most general layer while the further down blocks provide more explanation.

3.2 Hardware Design

3.2.1 Arch Design

3.2.1.1 Design

The arch will be 5'x5'x7' in order to allow for various size object to be passed through. It will be built using PVC pipe and glued together for stability. Green paper will be used to cover gaps in between and for a difference layer to differentiate between the object and background.

3.2.1.2 Benefits

The main reason for an arch is because it allows for multiple camera locations for a better image. The size of the design is necessary for the largest size artifact to successfully pass through. The added advantage is that the cost of PVC is very cheap and easy to obtain. Since PVC pipe is used in construction it should have a high durability.

3.2.1.3 Contingency

If the arch does break, parts are easily bought either at a hardware store or online for very little cost. Since the actual construction is very simple it won't be hard to replace parts.

3.2.2 Cameras

3.2.2.1 Design

The arch will have thirteen cameras on the inside. There will be two rows of three on each of its sides and one of the top in order to collect enough images for a quality 3D model.

3.2.2.2 Benefits

As the object slowly passes through the arc, the object will be taken pictures at fixed all around angles and each picture will have a high resolution of 8 Megapixels.

3.2.2.3 Contingency

The process will only need to be done once per object since the angles at which the data is being collected will have the object of interest constantly taken in all directions with thorough overlapping. As a results, the number of auto-correlated points will be fairly high producing a detailed dense reconstruction cloud.

3.2.3 Lighting

3.2.3.1 Design

The lighting will be diffused with a sheet of fabric between the light source and the object being scanned. Since LEDs are cheap they will be placed systematically through the arch. This is required in order to fully illuminate the object while eliminating unwanted shadows that would hurt the process of capturing accurate images.

3.2.3.2 Benefits

As stated, LEDs are cheap and easy to use. LEDs come in many different sizes and colors giving different options to obtain a perfect lighting area.

3.2.3.3 Contingency

Lighting is one of the most important part so they must be replaced before taking any pictures. If an LED were to break the user would have to cut the tie and order another one. Since there will be a website that lists all of the components used they could easily order a new one.

3.2.4 Acrylic Sheet

3.2.4.1 Benefits

Due to its transparency, the bottom angled cameras will be able to take photographs of the bottom of the artifacts without readjustment.

3.2.4.2 Contingency

The acrylic sheet will be manually pushed through the arc before capturing photos. The distance will possibly be inches at a time to make sure there’s a 60% - 80% overlapping between the images.

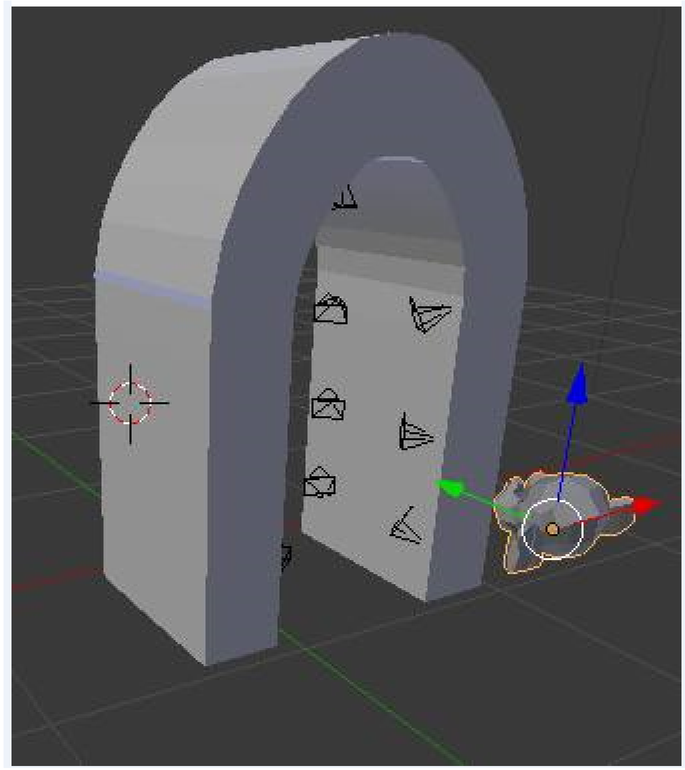


Figure 3.2 - Overall Hardware Design

The figure above shows what the overall hardware system plans to look like. The cameras are the cones set at angles to capture images and the gray arc is what will be constructed with the PVC pipe.

3.3 Software Design

3.3.1 VisualSFM

3.3.1.1 Design

Visual SFM is a graphic user interface that creates a 3D point cloud from a group of images that the user selects.

3.3.1.2 Outcome

The output the user will get is a three dimensional image created with points and colors that mapped out what the image should look like.

3.3.1.3 Contingency

This is an open source software which mean anyone can repair any bugs that it might have. Since this is widely used there shouldn't be any major bugs, but if there are the user should download a new version or the same version. If the map does not look correct the user will have to run the test again making sure the pictures are not blurred and the image is well placed in the lighting.

3.3.2 MeshLab

3.3.2.1 Design

MeshLab is used for processing and editing meshes that were created using VisualSFM. They provide different cleaning filters, remeshing filters, colorization, and more to enhance the 3D image.

3.3.2.2 Outcome

The outcome is a solid surface 3D image that is almost a full representation of the given artifact.

3.3.2.3 Contingency

If there is a problem with the image the user may have to reload the mesh to start new. This is an open source software which mean anyone can repair any bugs that it might have. Since this is widely used there shouldn't be any major bugs, but if there are the user should download a new version or the same version. There is a bug in version 1.3.3 that is fixed in 1.3.4 beta that is necessary for the certain embedded graphics cards.

3.3.3 Blender

3.3.3.1 Design

Blender will be used to add detail onto the given 3D image. This is where color and scratches of the different artifacts will stand out. With this software the consumer can create with own virtual gallery or any animation they choose.

3.3.3.2 Outcome

This is where the final product of our 3D system ends. The image should be a very good representation and can be viewed 360 degrees.

3.3.3.3 Contingency

If there is a problem with the software the user should redownload it. Ensure the .obj file output from Meshlab is in the proper format and contains the texture map. If the texture map is missing generate it in Meshlab and re-export the .obj file with the map included.

3.3.4 GIMP

3.3.4.1 Design

Gnu Image Manipulation Program (GIMP) is used to capture the background in order to discard it when forming the three dimensional image. It is necessary to easily determine the difference between them so MeshLab will not have to check for unwanted particles. Applying a difference layer of the scanner images without objects to images with objects will yield a new image without the background.

3.3.4.2 Benefits

This simplifies the automated construction of the 3D image because it reduces the step of manually deleting unwanted parts. VisualSFM will produce less noise and errors and process faster if it is only tracking the scanned object and not the background.

3.3.4.3 Contingency

This can alternatively be done with Adobe Photoshop or Paint.net or may be skipped all together. This step only eases the burden on motion tracking in VisualSFM and noise generated from the background can be filtered out by scripts in the Meshlab steps. Applying a difference layer is significantly easier than attempting to script a noise filter in Meshlab.

3.3.5 Python Code

3.3.5.1 Design

Each of the softwares needed to complete a 3D imaging system has a python handle that can be written to. The python code is designed so that the comsure won't have to use each of the previously stated softwares. It will simply start running and automate the process of creating a 3D image.

3.3.5.2 Benefits

The main benefit is that it significantly simplifies the process of creating the dimensional object. Only a command telling the script to run and the 3D image should be produced.

3.3.5.3 Contingency

If a problem occurs there will be a detailed manual on how the code works so that it can be easily interpreted for any future repairs. Software updates may change the python handles within the suite and break the automation. In this instance revert to the supported software versions or update they python code to support the new handles.

4. Statement of Work (SOW)

4.1. Task 1: Project Management

Aubrey Tharpe, Project Manager, will ensure the completion of this project by keeping the team on track with the use of the statement of work, Gantt chart, and overseeing tasks in order to meet milestone deadlines and sponsor requests where possible.

The project is broken down into 10 tasks. Team members are assigned tasks based on a combination of preference, skill, and experience. Nick Cardenas is responsible for all script work and if time allows works on other tasks. Taylor Wagner will be working on the frame, camera placement, as a reference for all programming, user interface, and possibly lighting. Rachelle Dauphin will be working on lighting, cover, and parts of scripting. Aubrey Tharpe will be responsible for work on the frame, management, coding, user interface, and possibly lighting. Every member is expected to contribute to the technical manual and user manual. Each member is required for scanning in the spring as each member will take turns operating the scanner to obtain the 3D model. This will allow the team to better write the technical manual and user manual.

4.2. Task 2: Scripting

4.2.1. Objective

During this task the goal is to automate the process of converting the jpeg images into 3D models.

4.2.2. Approach

4.2.2.1. Subtask: Gimp Script

4.2.2.1.1. Objectives

Reduce the workload of the photogrammetry process and also reduce the noise and error possibilities.

4.2.2.1.2. Approach

Apply a difference layer to the scans. This layer will be an image of the scanning environment prior to the object being scanned being placed in the device.

4.2.2.1.3. Test/Verification Plan

Each image can be viewed after being processed to determine if the background has been successfully removed.

4.2.2.1.4. Outcomes of Task

Remove background from images of scanned objects. And pipe the new input into VisualSFM.

4.2.2.2. Subtask: VisualSFM Script

4.2.2.2.1. Objectives

Generate a point cloud from a set of images that accurately outlines the surface of a 3D object.

4.2.2.2.2. Approach

Calculate mismatches between photos, generate a sparse 3D point cloud, eliminate errors, generate a dense 3D point cloud.

4.2.2.2.3. Test/Verification Plan

Verify that the point cloud resembles the 3D object

4.2.2.2.4. Outcomes of Task

Create a bundle-d.out file and a list.txt file that will be used in meslab to generate a solid surface.

4.2.2.3. Subtask: Meshlab Script

4.2.2.3.1. Objectives

Generate a solid surface of the 3D object as well as a texture map to be used in Blender

4.2.2.3.2. Approach

Eliminate any noise and errors by deleting erroneous vertices. This will be determined by eliminating vertices that are separated by a certain threshold. Generate a solid surface using the Poisson tool. Generate a surface texture map from registered rasters. Export the completed mesh as an .obj file that can be imported into Blender.

4.2.2.3.3. Test/Verification Plan

The output model should be free of background noise and be free of holes or missing data. The parameters can be tested by scanning a range of different sized objects with a variety of geometrical properties.

4.2.2.3.4. Outcomes of Task

Generate an .obj file that can be imported into Blender for animation and rendering.

4.2.2.4. Subtask: Blender Script

4.2.2.4.1. Objectives

At a minimum apply the texture map to the mesh to generate a photo realistic object. Scripts can be generated to make a generic animation of each object that can be narrated for educational purposes.

4.2.2.4.2. Approach

Apply the texture map generated from Meshlab as a new texture on the object and remove any rendered shading.

4.2.2.4.3. Test/Verification Plan

The output should be an animatable object that represents an accurate re-creation of the scanned object.

4.2.2.4.4. Outcomes of Task

Produce accurate 3D animations.

4.2.3. Test/Verification Plan

Perform each of the modules of the script manually and verify that the scripted module produces the same result or with negligible differences.

4.2.4. Outcomes of Task
Convert captured images into a 3D object with a photo texture that can be used in animation.

4.3. Task 3: Lighting

4.3.1. Objectives
The arch will provide diffused white lighting while the object is being passed through to prevent shadows and discoloration.

4.3.2. Approach
The lights will be installed between the cameras throughout the arch with a diffuser attached to each one.

4.3.2.1. Subtask: Review Options and Order parts

4.3.2.1.1. Objectives
Find lighting that does not saturate the object and still provides light to recessed areas.

4.3.2.1.2. Approach
Observe samples if available and select appropriate lighting

4.3.2.1.3. Test/Verification Plan
Attempt a reconstruction with selected light.

4.3.2.1.4. Outcomes of Task
Provides an even light source throughout the 3D model, and minimize to eliminating shadows

4.3.2.2. Subtask: Ensure Optimal Lighting

4.3.2.2.1. Objectives
Ensure lighting is evenly distributed across the object and does not saturate individual locations or fail to illuminate recesses.

4.3.2.2.2. Approach
Use diffused lighting to illuminate the entire object and not produce bright spots.

4.3.2.2.3. Test/Verification Plan
Apply lighting in the frame and visually determine if an area is being over saturated or there is not enough light.

4.3.2.2.4. Outcomes of Task
Produce a neutral light representation of the object that can be used in an animation and not restrict the lighting to a certain direction.

4.3.3. Test/Verification Plan

Capture images with diffused lighting and ensure that the object is illuminated without being over saturated or too dark in recesses.

4.3.4. Outcomes of Task

Illuminate the object sufficiently so that the photo sensors can capture the entire surface of the object

4.4. Task 4: Cover

4.4.1. Objectives

A solid colored material that will cover the frame of the arch to provide a consistent background as the objects is captured when passing through.

4.4.2. Approach

4.4.2.1. Subtask: Review Options and Order parts

4.4.2.1.1. Objectives

Find the most cost effective material that still serves optimally

4.4.2.1.2. Approach

Once the best type of material has been determined test different vendors to find the most appropriate one.

4.4.2.1.3. Test/Verification Plan

Briefly test backgrounds with a couple of snapshots and see how it behaves in VisualSFM. Material that tracks the least amount of points should be selected.

4.4.2.1.4. Outcomes of Task

Find the best material that is still cost effective.

4.4.2.2. Subtask: Ensure Quality and Color are appropriate

4.4.2.2.1. Objectives

Determine which color(s) and materials produce the least amount of motion tracking in VisualSFM

4.4.2.2.2. Approach

Test several colors and materials with snapshots and process them in visualSFM

4.4.2.2.3. Test/Verification Plan

The color and material combination that tracks the least will be selected for use. A secondary color will be chosen in the event that a scanned object is predominantly the same color as the background.

4.4.2.2.4. Outcomes of Task

Find the best material for the cover

4.4.3. Test/Verification Plan

Test shots of the cover in VisualSFM and determine if the noise is low enough that it can be filtered out with a difference layer.

4.4.4. Outcomes of Task

Provide a background that can easily be filtered out before being processed in VisualSFM

4.5. Task 5: Frame

4.5.1. Objectives

Provide a stable structure that supports the cameras at angles that can capture the entire surface of the objects

4.5.2. Approach

An Arch/tunnel will be used to allow for angles all the way around the objects and provide a constant background.

4.5.2.1. Subtask: Review Options and Order parts

4.5.2.1.1. Objectives

Find material sturdy enough to support the cameras, lighting, and cover

4.5.2.1.2. Approach

The system should be sufficiently lightweight that a PVC frame should be strong enough to support it.

4.5.2.1.3. Test/Verification Plan

Construct the frame and ensure it can support the weight of 13 small cameras.

4.5.2.1.4. Outcomes of Task

Select materials that are appropriate for the frame

4.5.2.2. Subtask: Build Skeleton Frame

4.5.2.2.1. Objectives

Provide a solid base for mounting of cameras, lights, and cover

4.5.2.2.2. Approach

PVC can be easily assembled and disassembled and provide sufficient strength and stability to support the weight.

4.5.2.2.3. Test/Verification Plan

Assemble the frame using PVC parts and ensure that it can support the weight.

4.5.2.2.3.1. Outcomes of Task

Produce a stable base for the rest of the system

4.5.2.2.4. Subtask: Add Acrylic Bed

4.5.2.2.4.1. Objectives

Provide a transparent layer that allows the underside of the objects to be captured

4.5.2.2.4.2. Approach

This provides stability for the scanned objects to minimize motion during capture

4.5.2.2.4.3. Test/Verification Plan

Ensure the acrylic plate can support the weight of the heaviest non-rigid object and not distort the images

4.5.2.2.4.4. Outcomes of Task

Allow for the scanning of the underside of the objects

4.5.3. Test/Verification Plan

Scan objects and observe that the entire surfaces are captured

4.5.4. Outcomes of Task

Produce photographs of the entire surface area of the scanned objects to be processed.

4.6. Task 6: Camera Placement

4.6.1. Objectives

Capture the entire surface area of the scanned objects with photographs

4.6.2. Approach

Place 13 cameras as follows: 4 at the base pointing upward and inward, 4 at mid-level pointing straight on and inward, two near the top pointing downward and inward, 1 at the apex pointing downward.

4.6.2.1. Subtask: Review Options and Order parts

4.6.2.1.1. Objectives

Find cameras that produce satisfactory images to be used for photogrammetry

4.6.2.1.2. Approach

Cameras need to be at a minimum 8 megapixels

4.6.2.1.3. Test/Verification Plan

Manually capture images with a single camera at multiple angles and attempt photogrammetry processing

4.6.2.1.4. Outcomes of Task

Find cameras that meet the criteria at a low cost.

4.6.2.2. Subtask: Determine optimal position of cameras

4.6.2.2.1. Objectives

Find camera positioning that covers the entire surface of the objects with some overlap

4.6.2.2.2. Approach

Cameras should capture from above, the front, back, sides, and below.

4.6.2.2.3. Test/Verification Plan

Place cameras and observe the surface area captured, ensure the entire surface area is captured on a single pass

4.6.2.2.4. Outcomes of Task

Find proper placement of cameras

4.6.3. Test/Verification Plan

Capture images with the placement and camera type selected and ensure that photogrammetry software is able to produce an accurate point cloud.

4.6.4. Outcomes of Task

Capture the entire surface area of the object for re-creation as a 3D model.

4.7. Task 7: Scanning Sample Collection

4.7.1. Objectives

Scan a diverse set of objects that range in size and geometry

4.7.2. Approach

Scan small and large objects as well as different shaped objects

4.7.2.1. Subtask: Scan small objects

4.7.2.1.1. Objectives

Ensure the device is capable of accurately scanning smaller objects

4.7.2.1.2. Approach

Pass a small object through the scanner on the acrylic bed

4.7.2.1.3. Test/Verification Plan

process the output and determine if an accurate 3D chart has been created

4.7.2.1.4. Outcomes of Task

Ensure the scanner can process small objects.

4.7.2.2. Subtask: Scan Large Objects

4.7.2.2.1. Objectives

4.7.2.2.2. Determine if the scanner can handle the largest objects in the collection

4.7.2.2.3. Approach

Scan the largest objects in the collection and observe the output

4.7.2.2.4. Test/Verification Plan

Pass a large object through the scanner without the acrylic bed and observe the rendered output.

4.7.2.2.5. Outcomes of Task

Ensure the scanner can process large objects

4.7.3. Test/Verification Plan

Pass large and small objects through the scanner and verify that the depth of field and camera distance is appropriate

4.7.4. Outcomes of Task

Ensure the scanner can handle objects of any size

4.8. Task 8: User Manual

4.8.1. Objectives

Produce a simple guide that a non-technical user can follow to produce 3D re-creations of objects as well as technical documentation so that advanced users can tweak their settings and improve results.

4.8.2. Approach

Document the process as it is developed and produce verbose summaries of each of the components for the advanced documentation

4.8.2.1. Subtask: Provide simple non-technical guidelines

4.8.2.1.1. Objectives

Provide easy to follow steps for non-technical users

4.8.2.1.2. Approach

Provide simple steps for a user to follow that allows the user to complete the entire process whether or not the user understands what is happening in each process

4.8.2.1.3. Test/Verification Plan

Ask non-technical users to attempt to use the device with only the manual as guidance, if the user fails or has questions the manual can be updated.

4.8.2.1.4. Outcomes of Task

Provide a simple guide for non-technical users to use the scanner

4.8.2.2. Subtask: Advanced documentation for technical users

4.8.2.2.1. Objectives

Provide advanced documentation so a technical user can tweak settings and produce better results or improve performance

4.8.2.2.2. Approach

Verbosely describe each of the steps in the process as well as the purpose of each component of the design

4.8.2.2.3. Test/Verification Plan

Provide the manual to a technical user and ask them to perform an advanced concept

4.8.2.2.4. Outcomes of Task

Allow technical users to modify the settings or replace components to fit their needs

4.8.3. Test/Verification Plan

Provide the manual to a diverse group of users and ensure the documentation is clear enough for the steps to be followed.

4.8.4. Outcomes of Task

Ensure a range of users can follow the documentation and use the device to fit their needs.

4.9. Task 9: Technical Manual

4.9.1. Objectives

Provide technical specifications of the device that demonstrates the capabilities as well as the limitations of the device

4.9.2. Approach

Document the components used as well as the technical specifications of each and compile them all into a single document

4.9.2.1. Subtask: Technical documentation for Hardware

4.9.2.1.1. Objectives

Provide technical documentation for each hardware component

4.9.2.1.2. Approach

Record technical manufacturer specifications for each component and compile them into a single document

4.9.2.1.3. Subtask: Technical Documentation for Software

4.9.2.1.4. Objectives

Provide documentation for the script that controls the software as well as references for each program in the suite

4.9.2.1.5. Approach

Open source the script and maintain clear and concise comments throughout the souce. Compile a summary of the comments for each module in the technical manual

4.9.3. Outcomes of Task

Provide technical documentation of both the hardware and software aspects of the system.

4.10. Task 10: GUI

4.10.1. Objectives

Provide a simple interface for a non-technical user to be able to use the suite and capture scans

4.10.2. Approach

Script each step in the process using python and use tkiner or wxwidgets to provide a graphical front end to the scripts.

4.10.2.1. Subtask: Script the steps of using the software suite

4.10.2.1.1. Objectives

automate the tasks required in each step of using the suite

4.10.2.1.2. Approach

Use python handles provided by each program in the suite to control each program and complete the tasks.

4.10.2.1.3. Test/Verification Plan

Complete each step manually and then complete each step as a module of the script, ensure the output is the same for manual and scripted steps

4.10.2.1.4. Outcomes of Task

Automate the process of each step in the suite.

4.10.2.2. Subtask: Provide a graphical front end to the script

4.10.2.2.1. Objectives

Provide a user friendly interface that is intuitive and simple for non-technical users to use.

4.10.2.2.2. Approach

Use Tkinter or wxwidgets to produce graphical contexts that call the modules of the script

4.10.2.2.3. Test/Verification Plan

Ensure each step of the GUI properly calls each module of the script and the output mirrors that of manually completing each task.

4.10.2.2.4. Outcomes of Task

User friendly interface to operate the scanner

4.10.3. Outcomes of Task

Completely automated process from capturing the images and processing the data in graphical form so the user simply has to operate the device with intuitive controls.

4.11. *Test Plan/Verification Plan*

The test will be in numerous stages starting with the basics and ending with the overall approval of the customer. The first step is to test each software before running a python script. This will be done by taking pictures of random objects and going through the process step by step. Next, the python script will be loaded and test to make sure it is working. If there are any bugs the code will be corrected and retested until perfect. Once all of the software is running smoothly it will be time to test the hardware. The first test will be to see if the arc will hold all of the cameras and lights needed to capture crisp images. There needed to be a balance for the bendiness and thickness of the needed to hold the accessories. Once the arch is sturdy and all set up it will be time for actual artifacts to be tested. This is where handling of precious items is a risk. They will be carefully placed in different locations under the arch to test lighting and the type of images that will be rendered. This may take some time to in order to meet the consumer's approval. Once the software and hardware is completed the rest of the items should be ready to be processed for 3D imaging. After each item has been created the consumer will analyze it before moving onto the next one. This will make sure the overall product is correct and conclude the 3D system.

5. Risk Assessment

5.1. Administrate Risks

This project is going to be broken up into separate task for the individual team members and the final product is going to be divided up into smaller results with earlier deadlines. With this, there can be risks of falling behind of the schedule of construction and not meeting our final deadline due to the failure of members meeting their deadlines, exceeding the maximum budget for the necessary parts for the design proposed, and not meeting the requirements of the project.

5.1.1. Failure of Meeting Deadlines

Each member is assigned a task needed for every deadline, and some of these task are independent from another while others are not. If a team member does not meet their deadline when expected, the project is as risk of being set back. If the task that was not completed is needed for another task to be finished, this can prevent a further stall in the project's progression while preventing other team members from starting or finishing their tasks. To prevent this issue from happening, a member that is ahead of schedule with their assignments and is working on an independent task could take up assist or take up the unfinished task, so the project can continue to progress.

5.1.2. Exceeding the Maximum Budget

The maximum budget for this project is $1000. This customer designs the entire work station including the ios system to be included in this budget. Although, the budget will be estimated by the financial advisor throughout the project's progression, components may not meet expectations needed for the design, or broken materials during testing may not be able to be fixed but only replaced. These conditions can lead to exceeding the budget which can lead to altering parts of the design to lower cost and less efficient material to continue the project. The need to redesign the device with the alterations could lead to a great standstill in production. Unfortunately, some scenarios which could lead to this cannot be assumed, therefore, prevented; however, the processes of purchasing components will not be in bulks. If multiple of the same component is needed for the design, a sample will be purchased first and tested before buying additional ones, so if the considered material is faulty, less money is wasted.

5.1.3. Not Meeting Requirements

The requirements of the project consist of producing 3D models of historical artifacts that can be animated to reenact their uses during slavery. If the device does not meet the requirements given by the costumer's proposal, as the first pilot case study of this project, the project is at risk for being continued in the future.

5.2. Software Risks

The project will be using four software programs: GIMP, VisualSFM, MeshLab, and Blender. The commands needed to implement a 3D model while using these softwares will be scripted in Python creating a user-interface that needs less software interaction. Since there are four different softwares being tied together to produce the final result, one of the softwares could crash or run incorrectly while the script is being ran. This could cause inaccurate results without the user being able to find the problem. To resolve this problem, flags should be placed throughout the script, so if the system runs into a bug, the program can terminate properly while stating the type of error that caused the system to crash.

VisualSFM is a crucial program to this project design because it converts the photographs into a dense reconstructed cloud that can be used to create the mesh. The software requirements need to be met for the optimal results. The SiftGPU feature detection used by VisualSFM is responsible for point matching. This feature requires a large amount of GPU memory (minimum of 1 GB). If the GPU memory is too small, the results will have less features leading to different results on different machines. As a solution, VisualSFM could be ran on a CUDA-capable Linux server, or the CPU can be used as a replacement for the GPU during this process; however, the time is significantly longer when producing the results [3].

5.3.Hardware Risks

The device is going to be shaped as an arch. PVC pipes will be the material used to create the frame skeleton since PVC pipes are bendable and inexpensive. If we purchase pipes with too big of a diameter, its flexibility will be reduced losing the arc shape, so pipes with a small diameter is considered. Using PVC pipes with smaller diameters, however, have a higher risk of breakage. The sides which is needed to hold the weight of the arc and cameras cannot bend or the frame will collapse; therefore, there is a range of diameter sizes that can be supportive and bendable enough to construct the desired frame.

5.4. Data Collection Risks

*5.4.1.*Poor Photograph Collecting

For close-range photogrammetry, the camera, lens, and placement are crucial when achieving a high definition 3D model. The minimum resolution requirement should be at least 8 Megapixels. Using a camera with a lower resolution can lead to distorted mesh models and poorly detailed textures. Having a design that requires 13 cameras, the design will become costly if cameras with resolution higher than 8 Megapixels were to be chosen [2].

The depth of field (DOF) is the distance between the nearest and furthest object in view that appears to be the sharpest. While collecting photos of the object of interest, the entire object must remain within this field; therefore, the camera focus ring must remain in consistent range and the aperture setting of the camera (if applicable) must be between f8 and f16, or some parts of the object will come out blurry. Blurry photos can lead to a fairly low number of auto-correlated points which cannot be reconstructed. Since the photos will be captured from less than 5 meters, autofocus can be used for all the images taken, so this is not a severe concern. A wired or wireless shutter release is also needed to minimize blur. To achieve the greatest number of auto-correlated points, photos must maintain a 60% to 80% overlap, and all import areas of the object must be visual in at least three images [2].

*5.4.2.*Artifact Handling Risks

The objects of interest are historical artifacts that comes from the years of slavery in America, so they are roughly 400 – 600 years old. These relics are fragile and can be damaged by moisture, sunlight, temperature, and careless handling. When handling these objects, the handler must wear gloves since the natural oils from a person's hands can damage the artifact. Tweezers and Q tips are required to manipulate the rigid objects (i.e. dolls, rags, books) when collecting data. Since the artifacts are located in the Black Archives Museum at FAMU, the museum would prefer to personally transport the objects to the college of engineering and back. It will become essential to give the museum director weeks' notice to prevent delays in the deliveries; also, there is a chance of damaging the artifacts during the transportation. As a solution, part of a media room is going to be reserved for this project on the top floor of the museum when data collecting; therefore, the team has more control on accessing the objects, and the artifacts won't be manipulated as much.

6. Qualifications and Responsibilities of Project Team

6.1 Qualifications

6.1.1 Aubrey Tharpe

Project Leader

Currently a senior at Florida State University pursuing a dual bachelors degree in Computer and Electrical Engineering. Aubrey has experience programming in c++,java, and some python. Aubrey is experienced using blender software which will aid in the 3D modelling part of the project. Aubrey's work experience includes entrepreneurship. This experience qualifies him to be the Project Leader because creating a business takes meticulous management practice.

6.1.2 Taylor Wagner

Lead Programmer

Currently a senior at Florida State University pursuing a bachelors degree in Computer Engineering. Taylor has experience programming in C++, python, tkinter, VHDL, assembly, and shell scripting. Taylor has experience modeling and animating with Blender and is familiar with the python interface which will greatly help with automation of the project. He currently works as an IT Support Specialist at the College of Medicine at Florida State University. This IT experience provides Taylor with extensive knowledge of computer hardware which will aid in determining an appropriate system for the software suite.

6.1.3 Rachelle Dauphin

Secretary

Currently a senior at Florida State University pursuing a bachelors degree in computer engineering. Rachelle has knowledge in some software programming languages such as VHDL, Verilog, C++, MIPS assembly, and Python. She also has experience in using Multisim, Altra 12.1 (Quartus, Modelsim, Altera U. P. Simulator), and Microsoft Visual Studio 2010. These skills can be used in scripting the user interface and working with the open source software chosen for this project. She has been working as a math peer tutor at Florida State ACE Learning Center since February 2013. She helps peers with course material, time management, and note organization. This helps qualifies her as the Secretary who keeps the meeting minutes organized and team members informed with alterations in the decided schedules.

6.1.4 Nicolas Cardenas

Financial Advisor

Currently a senior studying computer engineering at Florida State University. Nicolas has taken many classes in different programming languages such as C++, VHDL, and microcontroller programming. Other classes that may provide useful for different design options include circuits, electronics, digital logic, signals and linear system analysis. These skills can help in when designing code needed to run the different open source software. Previous work experience would be a job at Walgreens and volunteering at different organizations like Kids Against Hunger. At Walgreens he worked as a cashier handling money, customers, and inventory. This helps qualify him to be our Financial Advisor to keep track of the money flow to make sure the project stays within budget. Volunteering provides useful skills when working in a group setting to interact with many different people.

6.2 Individual Responsibilities

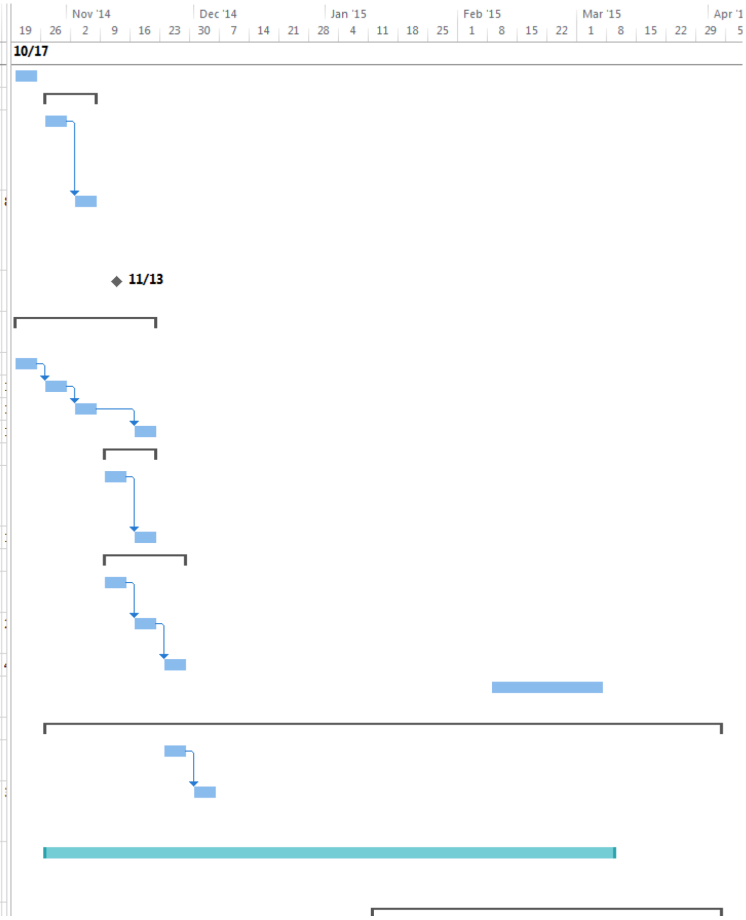
Task	Task	Assignment	Skills and Knowledge
1	Project Management	AT	Leadership
2	Scripting	NC, TW, RD	Python
3	Lighting	RD, AT/TW	Research photography
4	Cover	RD	Research green screen
5	Frame	AT, TW	Physics
6	Camera Placement	TW	Depth of field and focus
7	Scanning Collection Sample	All - Rotating	
8	User Manual	ALL	
9	Technical Manual	ALL	
10	Desktop User Interface	AT, TW	Python, TKinter or wXwigits

AT = Aubrey Tharpe, TW = Taylor Wagner, RD = Rachelle Dauphin, NC = Nicolas Cardenas, ALL = All Team Members

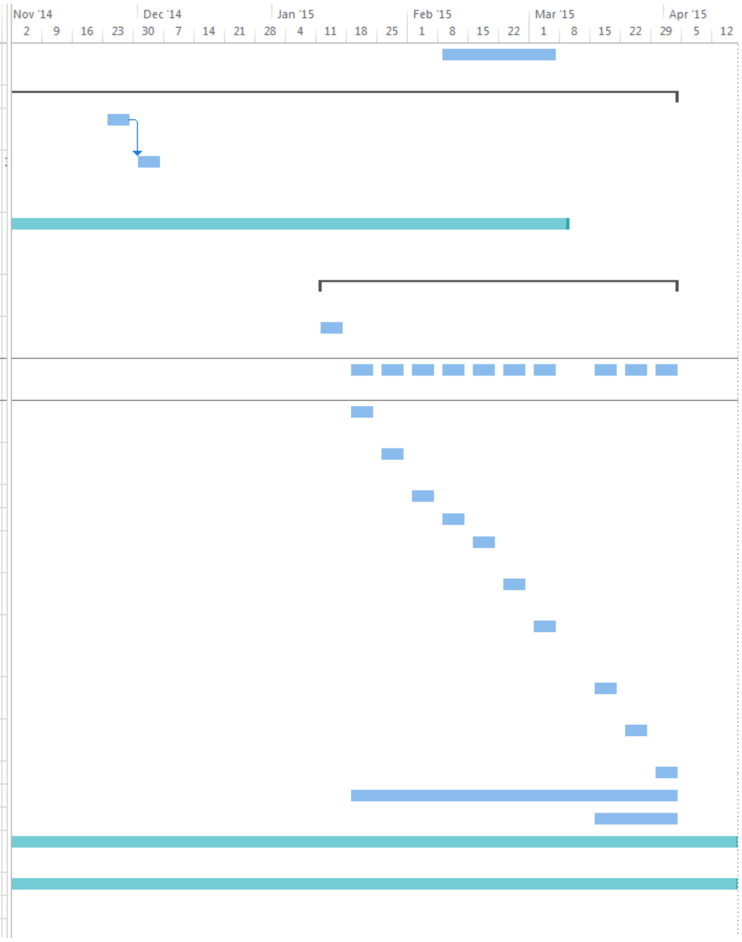
Finally, you need to back this section up with some form of resume for each team member. In actual proposals, these can include one or more of the following: 1-paragraph description of expertise, 1- or 2-page biosketch, or full resume. Biosketches and resumes are typically included in the appendices for the proposal. For this proposal, include a 1-paragraph description of each team member including the student's degree program, related classes, experience, etc. that make the student qualified for the tasks to which the student has been assigned.

7. Schedule

Task Mode	Task Name	Duration	Start	Finish
	PP&SOW	0 days	Fri 10/17/14	Fri 10/17/14
	Arc Path	1 wk?	Mon 10/20/1	Fri 10/24/14
	Lighting Design	**10 days?**	**Mon 10/27/1**	**Fri 11/7/14**
	Consider all lighting solutions and order	1 wk	Mon 10/27/14	Fri 10/31/14
	Test Lighting to ensure lighting is optimal for 3D model	1 wk?	Mon 11/3/14	Fri 11/7/14
	System Level Design Review	0 days	Thu 11/13/14	Thu 11/13/14
	Script Software together	**25 days?**	**Mon 10/20/14**	**Fri 11/21/14**
	Script Gimp	1 wk?	Mon 10/20/1	Fri 10/24/14
	Script VisualSFM	1 wk?	Mon 10/27/1	Fri 10/31/14
	Script MeshLab	1 wk?	Mon 11/3/14	Fri 11/7/14
	Script Blender	1 wk?	Mon 11/17/1	Fri 11/21/14
	Cover Design	**10 days?**	**Mon 11/10/1**	**Fri 11/21/14**
	Consider Alternatives and order	1 wk?	Mon 11/10/14	Fri 11/14/14
	Test choice	1 wk?	Mon 11/17/1	Fri 11/21/14
	Build Frame	**15 days?**	**Mon 11/10/1**	**Fri 11/28/14**
	List parts and Order	1 wk?	Mon 11/10/14	Fri 11/14/14
	Build Skeleton Frame	1 wk?	Mon 11/17/14	Fri 11/21/14
	Acrylic Bed	1 wk?	Mon 11/24/1	Fri 11/28/14
	Build Desktop User Interface	4 wks	Mon 2/9/15	Fri 3/6/15
	Camera Placement	**115 days?**	**Mon 10/27/1**	**Fri 4/3/15**
	Consider options and order	1 wk	Mon 11/24/14	Fri 11/28/14
	Test choice, find optimal placement	1 wk?	Mon 12/1/14	Fri 12/5/14
	Add information to Technical Manual	19.2 wks	Mon 10/27/14	Mon 3/9/15
	Scan Sample	**60 days**	**Mon**	**Fri 4/3/15**



Task Mode	Task Name	Duration	Start	Finish
	Build Desktop User Interface	4 wks	Mon 2/9/15	Fri 3/6/15
	Camera Placement	**115 days?**	**Mon 10/27/1**	**Fri 4/3/15**
	Consider options and order	1 wk	Mon 11/24/14	Fri 11/28/14
	Test choice, find optimal placement	1 wk?	Mon 12/1/14	Fri 12/5/14
	Add information to Technical Manual	19.2 wks	Mon 10/27/14	Mon 3/9/15
	Scan Sample Collection	**60 days**	**Mon 1/12/15**	**Fri 4/3/15**
	Prioritize Artifacts	1 wk	Mon 1/12/15	Fri 1/16/15
	Scan	**55 days**	**Mon 1/19/15**	**Fri 4/3/15**
	Scan 1	1 wk	Mon 1/19/15	Fri 1/23/15
	Scan 2	1 wk	Mon 1/26/15	Fri 1/30/15
	Scan 3	1 wk	Mon 2/2/15	Fri 2/6/15
	Scan 4	1 wk	Mon 2/9/15	Fri 2/13/15
	Scan 5	1 wk	Mon 2/16/15	Fri 2/20/15
	Scan 6	1 wk	Mon 2/23/15	Fri 2/27/15
	Scan 7	1 wk	Mon 3/2/15	Fri 3/6/15
	Scan 8	1 wk	Mon 3/16/15	Fri 3/20/15
	Scan 9	1 wk	Mon 3/23/15	Fri 3/27/15
	Scan 10	1 wk	Mon 3/30/15	Fri 4/3/15
	Revise Arch	55 days	Mon 1/19/15	Fri 4/3/15
	User manual	3 wks?	Mon 3/16/15	Fri 4/3/15
	Project Management	160 days	Mon 9/8/14	Fri 4/17/15
	Website	151 days	Sun 9/21/14	Fri 4/17/15



8. Budget Estimate

- **<u>Personnel:</u>** Estimated cost needed to pay each engineer for the entire project
- **<u>Fringe benefits:</u>** Extra payments needed for insurance, company car, etc. The assumption is 29% of the total payment to the engineers.
- **<u>Expense:</u>** Costs for the materials needed to complete the overall hardware system
- **<u>Overhead costs:</u>** Estimated cost needed to keep this system running after completion. The assumption is 45% of the personnel plus the expense cost.
- **<u>Equipment:</u>** Includes all hardware over $1,000.
- **<u>Total Project Cost:</u>** This includes all possible charges needed to this system to start and continue to run.

A. Engineers	Total Hours	Base Pay	Total Pay
Aubrey Tharpe	360	$30.00	$10,800.00
Taylor Wagner	360	$30.00	$10,800.00
Rachelle Dauphin	360	$30.00	$10,800.00
Nicolas Cardenas	360	$30.00	$10,800.00
Total:			$43,200.00
B. Fringe benefits		29% rate of A	$12,528.00
C. Total Personnel Costs			$55,728.00

D. Expenses				
Item	Distributer	Costs ($)	Quantity	Total ($)
USB 8MP Webcam	TVC-Mall	2.50	13	32.50
Acrylic Sheet	Amazon	15.00	1	15.00
PVC Pipe	Home Depot	3.00	8	24.00
PVC Joints	Home Depot	0.50	8	4.00
Green Wrapping Paper	Amazon	15.00	4	60.00
USB Hub	Amazon	4.00	2	8.00
Computer	Walmart	500.00	1	500.00
Other	-	-	-	150.00
Total Cost:	-	-	-	793.50

E. Overhead costs	45% rate of C+D	$25,434.70
F. Equipment	-	$0

G. Total Project Cost	C+D+E	$81,956.20

The wrapping paper might be too reflective, so green construction paper might be an alternative option. The cost for other is set at $150 to cover the tax, shipping, and other possible add ons to enhance the quality of the pictures.

Item	**Distributer**	**Costs ($)**	**Quantity**	**Total ($)**
Image Sensor	Uctronics	20.00	13	260.00
Arduino	Amazon	18.00	1	18.00
Bluetooth	Adafruit	20.00	1	20.00

The table above is an optional hardware solution to obtain the images. The image sensor plus arduino will capture the image while the bluetooth can wirelessly send them to the computer. This can simplify the hardware configuration by having less wires laying around for potential hazards.

9. Deliverables

The final product will be a system that can create 3D images for future animations or some type virtual gallery given the specified budget. The device will be a combined hardware system to take pictures and a software system to convert the images into a visual model. The consumer will have to place the objects through an arc with cameras attached that will be sent to a computer. The user will then use a python program to run through the software suite needed to make the model. There will be a user friendly manual provided so that the system can be even easier to use in the future.

All of the group meeting talks and presentations will be posted on the website that will be created soon. Users can use this to go through the process and understand how the system was built. This project has a deadline in March so the planning part will be completed by the end of this semester and final product before the deadline.

9.1 Hardware

As stated, the overall hardware goal is to build an arc that will capture images and be sent to a computer to create a 3D image. PVC pipe will be used to construct a 5’x5’x7’ arc with cameras attached. The arc will contain two rows with three cameras on each side and one on the top, equaling thirteen cameras in total. The cameras will be connected to the computer with will run the software.

9.2 Software

After the images have been taken and saved in a file there will be a python code to run through the different softwares needed to construct the 3D images. It will first run through Visual SFM, then meshlab, and finally blender. Visual SFM will take the different images and create points that will outline the overall 3D image. It will then be sent to meshlab where the points will be molded into one solid figure and unnecessary particles can be erased. Then blender will be used to add cosmetics to make the 3D image capture the details and colors.

9.3 Reports

As stated, documents from throughout this project will be uploaded to a website for future reference. Meeting minutes will be posted so one can follow through the process on how the project was created from start to finish. The needs analysis and requirements contain the original goal and can be modified for any other alterations. This system will come with a step by step user friendly manual to make it even easier to use the 3D imaging system.

10. References

[1] J.A. Marin, J.E. Armstrong, and J.L. Kays, "Elements of an Optimal Capstone Design Experience," Journal of Engineering Education, January 1999, pp. 19-22.

[2] Barnes, Adam. 2013. "Good Photos vs. Bad Photos for Close-range Photogrammetry".*Geospatial Modeling & Visualization*. CAST Technical Publications Series. Number 12144. 7 August 2013. 10 October 2014.

[3] Changchang Wu, "Basic Usage", *VisualSFM : A Visual Structure from Motion System.* Copyright 2006-2012 Changchang Wu. 08 October 2014.

[4] Changchang Wu, "Limitations and Issues", *VisualSFM : A Visual Structure from Motion System.* Copyright 2006-2012 Changchang Wu. 08 October 2014.

[5] P. Cignoni and G. Ranzuglia, "Features", *MeshLab*. Copyright 2014 Dice. All Rights Reserved. SourceForge is a Dice Holdings, Inc. service. 14 October 2014.

[6] "User Manual", *Blender.* Creative Commons Attribution ShareAlike. 11 October 2014.

[7] "Documentation" *GIMP* - The *GNU Image Manipulation Program.* GIMP Team. 2001-2014. 16 October 2014.

Appendices

1.

2.

3.