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

EEL4911C – ECE Senior Design Project I

SYSTEM-LEVEL DESIGN REVIEW

Project title: **3D Scanner**

Team #: E10

Student team members:

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Submitted in partial fulfillment of the requirements for

EEL4911C – ECE Senior Design Project I

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Executive Summary

The purpose of this project is to design a scanner that implements 3D digital images. Photogrammetry is the method that will be used to record an overall mapping of the object. To achieve this there will be a hardware and software implementations. The hardware design will be in the form of an arch where an object will be placed inside and sent to software for processing. Inside the arch will be thirteen cameras to take several high resolution photos of the artifacts with overlapping angles covering the entire surface of the object as it is being pushed through. There will be a green background to act as a difference layer to each photo to isolate the object. The photos will be stored in a file where a script will be initiated to run through each software. It will run through a series of stages with creating a point cloud as the first. Then the point cloud will be used to create a solid surface mesh, and the photographs will be used again to make a surface texture. This will finally create a photorealistic re-creation of the object. This design will ultimately 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.

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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.

The team has been working on getting the exact dimensions that would fit all of the hardware and allow the cameras to only have a green view. The main concern is to make the arch big enough for the artifacts and have the acrylic sheet big enough to fit on the rollers. The problem was solved by finding a larger acrylic sheet to fit. Once one of the cameras has been shipped test will be implemented to see the distance and quality of pictures before ordering more. The distance the camera will take pictures at will also factor into the dimension of our arch. Some other problems that are being working on are the type of lights being used. The lights have to be bright, small, and cheap in order to work with the design. LEDs were selected because cheap rolls of them were found and they will provide enough light for the entire arch. There has also been a start to planning the script that will run through all of the software.

1.3 Operating Environment

There is not a concern for weather because the end product will be kept indoors under room temperature. Since this will be stored in an Historical Museum, the conditions they have to preserve the artifacts should be suitable for this product. The structure is made out of PVC and should be stable as long as people do not pull on it. If there are any breaks it should be very easy and cheap to replace the broken PVC. Inside the arch will be heated due to the lights but, should not affect the cultural artifacts.

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

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.

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.

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. A new implementation of the rail will assume the length of the arch will be long enough to fit. This is used for the acrylic sheet in order for smaller object to be scanned through as the user requested.

Limitations: The final product will not exceed 4’x6’x7’. The change is size is due to the new rail and new acrylic sheet. 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’x6’x6.7’ 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 System Design

The current design consists of a frame to collect images of objects and software that processes those images into a 3D model.

2.1 Overview of the System

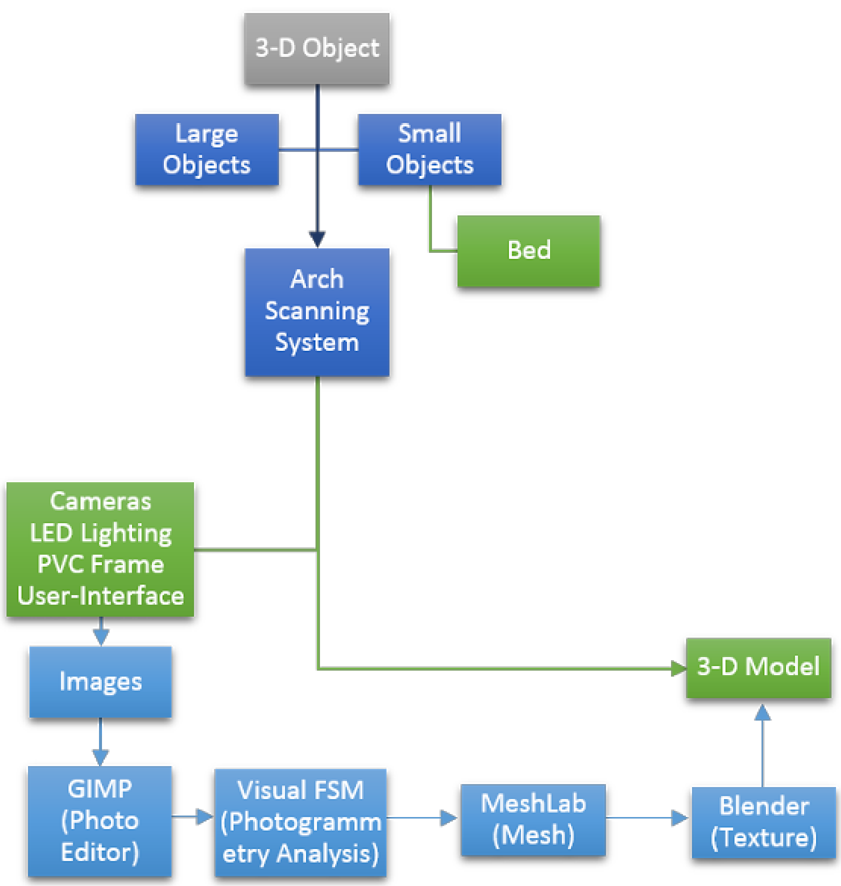


Figure 2.1: A System Overview Block Diagram

2.2 Major Components of the System

Frame:

- The structure will be made from PVC.
- The cover, lights, and cameras will all attach to the frame while the bed will roll on a pair of rails to allow all of the object to be photographed.

Bed:

- The structure will be made from acrylic
- It is a platform to place small objects on for imaging.

Cover:

- The cover will be a "green screen."
- It will cover the inside of the frame to maintain a consistent background in order to isolate the object being scanned.

Lights:

- Lights are 3528 SMD LED strips that will be in two colors to have a more natural lighting effect.
- The strips will be placed in the interior of the frame to illuminate the objects evenly.

Camera:

- The cameras are basic web cameras that will operate through a USB hub.
- There will be 13 cameras in all to photograph the object at many positions.

Software

- Python for scripting which executes instructions to create 3-D model
- GIMP for difference layering to isolate object from background
- Visual SFM for photogrammetry analysis and dense cloud reconstruction
- MeshLab to create a solid mesh from the dense cloud
- Blender to stitch the object's texture to the mesh creating the final product of the 3-D model

2.3 Subsystem Requirements

This section specifies detailed requirements (including quantitative specifications/constraints) on all of the major subsystems. Particularly important to include here are interface specifications (power requirements, digital signal/protocol specs, etc.) that designers of the other subsystems that interact with a given subsystem need to be aware of.

2.3.1 Structure Requirements Specification

PVC Pipes and Joints

The structure is made out of PVC pipes and fittings
The inner dimensions are 4ft x ~6ft x 6.7ft
The outer dimensions are ~5ft x ~6ft x 6.7ft

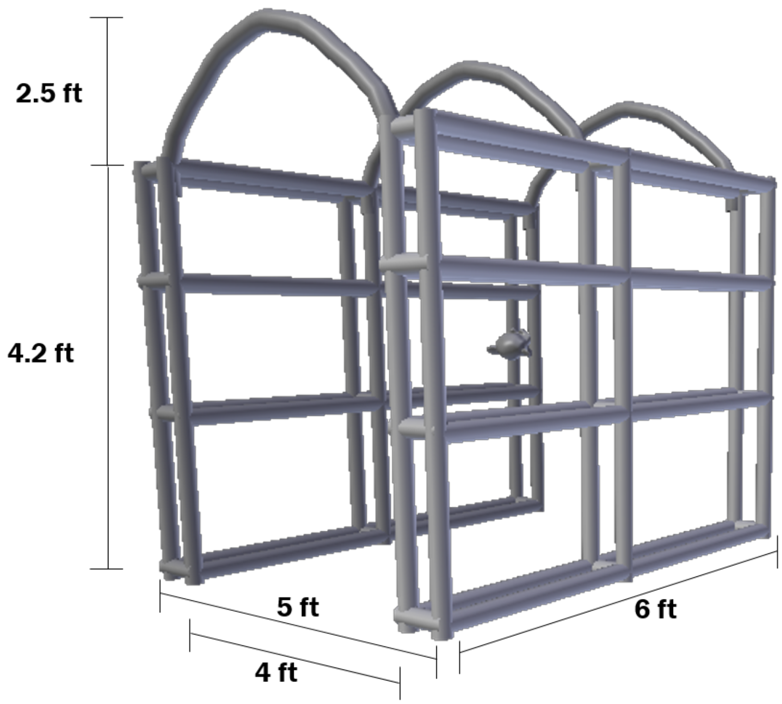


Figure 2.2: The Dimensions of the Arch Frame

2.3.2 Bed Requirements Specification

The idea for scanning smaller objects is to use a bed which the artifacts will lay on. The bed is high enough so the cameras will be able to take pictures above and below the object. Acrylic sheet was chosen because it is very transparent. The bed is 2 ft wide and 4 ft long so two of these will be used to hold making a 4 ft x 8 ft bed. This size will allow small and medium size object to be passed through the scanner easily. To create a fluid direction so that the cameras can take clear pictures, it will be on wheels guided by rails.

- Weight: 10.7 pounds
- Size: 24” x 48”
- Thickness: 0.236”

2.3.3 Cover Requirements Specification

TubeTabe .Chromakey Green Screen Muslin

The final product of the 3-D model has to be a solid figure floating in space. There cannot be any random points floating around the solid figure and the fragments of the background seen in the final product. Therefore, the background has to be properly removed before the point cloud development. The method of choice is using difference layers, but the software needs to easily distinguish the background from the object of interest.

Chroma keying is a technique for compositing two images together based on the color hues. Using a green screen muslin can allow the software to easily detect and remove the background without manual editing.

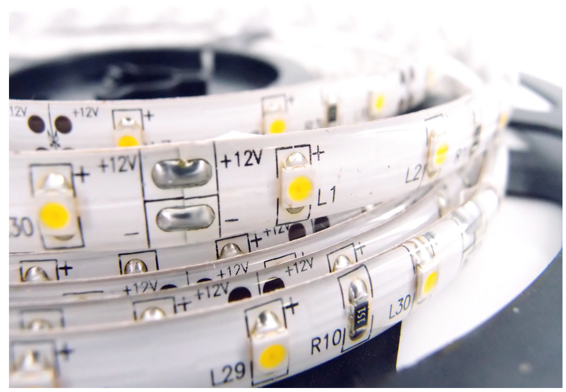
Table 2.1: Green Screen Muslin Specifications

Dimensions (ft)	Weight (lbs)
5 by 7	2

Figure 2.3: The Fabric of the Green Screen

2.3.4 Lights Requirements Specification

Lampux Flexible LED Strip Lights



When collecting data (images) of the artifacts to create the 3D- model, the device must provide its own light source that illuminates the object evenly at every angle with little to no shadows. This can be accomplished using soft light sources or hard light sources with diffusers; however, due to the artifacts sensitivity to temperature, lighting that produces heat in the form of infrared, which can damage fragile objects and fabric. LED light sources do not disperse heat into infrared as well as cheap and easy to find, therefore, this is the preferred choice.

The Lampux Flexible LED Strip Lights use 3528 Surface-Mount-Device (SMD) LEDs. These LED chips have the dimensions of 3.5 [mm] by 2.8 [mm] and a brightness of 5 lm. The LED chips are placed on printed-circuit board (PCB) strip. Per three LED chips, a current limiting resistor is placed to prevent large amounts of power from running through the LED components. Cut markings are available every three chips which provide size adjustments without damaging the rest of the strip. The switching cycle of the LED strip is 25 000 meaning this is the number of times the lights can be turned on and off before burning out due to the rapid heating of the electrodes needed to produce light.

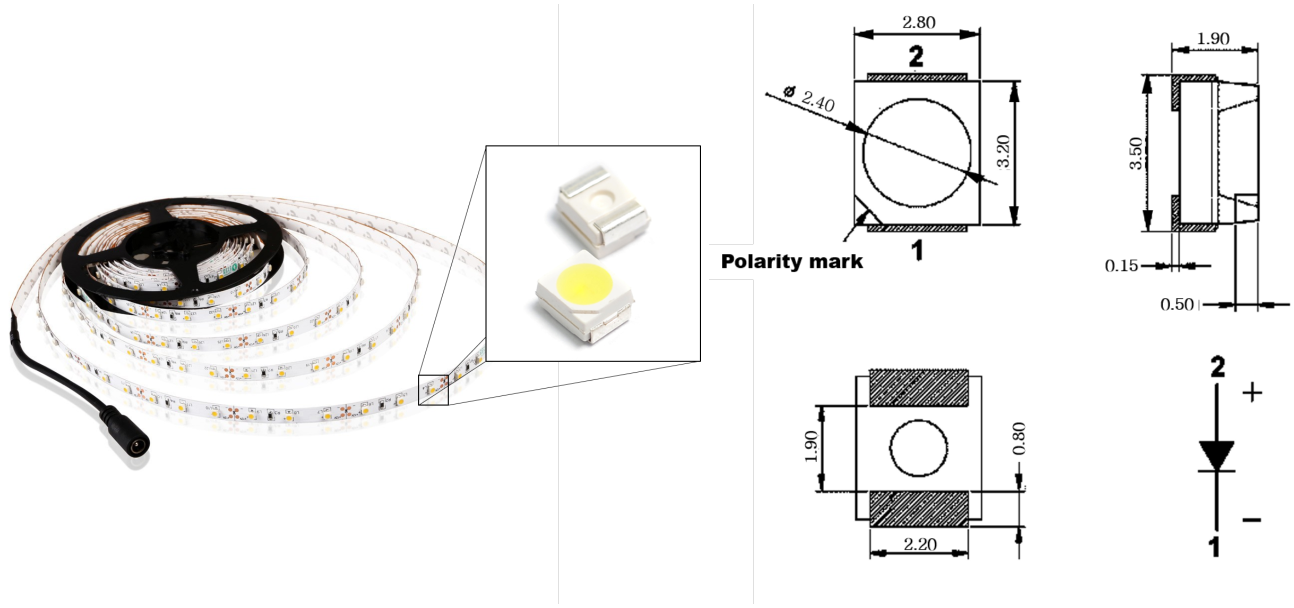


Figure 2.4: The 3528 SMD LED Chips Dimensions

Table 2.2: Lampux Flexible LED Strip Lights Requirement and Specification

Strip Length (m)	5	**Width (cm)**	0.7874
LED Type	3528 SMD LED	**Length (cm)**	500
LED Quantity per meter (Units/m)	60	**Input Voltage (V)**	12
LED Quantity	300	**Power (W)**	24
Switching Cycle	25000	**Lamp Current (mA)**	20
Rated Lifetime (h)	50,000	**Brightness (lm/m)**	300

2.3.5 Camera Requirement Specification

Egg Shaped USB 8MP Webcam Video Camera

Table 2.3.5 Egg Shaped USB 8MP Webcam Video Camera Requirements and Specifications

USB Cable Length (cm)	105
Resolution (MP)	8
Power Supplied	User Interface
Power (mW)	150
OS Compatible	Windows 2000 / XP / Vista / Windows 7 / Windows 8 / Linux

2.3.6 Graphical User Interface Software

The GUI will provide an ordered set of instructions for the user as well as call the functions for capturing from the webcams, eliminate the background with GIMP, create a 3D point cloud with VisualSFM, Generate a surface and texture map with Meshlab, and export the object into other usable formats using Blender.

2.4 Performance Assessment

Needs/Requirements	Subsystem/Major Components
Capture high-resolution images of artifacts at every angle	Cameras/Camera Placement
Create 3-D model of artifacts	Point Cloud-Mesh-Texture Software

Portability	Detachable Framing
Ability to scan objects of a range of sizes	Bed/Framing
Isolating the objects from the background	Chroma key Interior Covering/Software
Illuminating objects evenly at every angle without the product of IR	LED Lighting
Automatically construct a 3-D model with an easy-to-use user interface	Python/GUI

2.5 Design Process

The major design decision that have been made are the arch that will serve as the scanner for all artifacts. The newest addition is the added rail to easily slide the acrylic bed through the scanner for smaller objects. Other major decisions include the using LEDs, 13 cameras, and a green screen to obtain images for the 3D model. Right now the scale on how big the arch should be will rely on the quality of cameras. Once they have been tested the dimensions can be accurately measured so that there won't be cameras expected to take pictures that they might not be able to capture clearly.

The software is the same as mentioned in Milestone 2 which are VisualSFM, MeshLab, Blender, GIMP, and Python. For more information on these programs please look back at the previous report.

3 Design of Major Components/Subsystems

3.1 Structure

PVC is used to create the arch because it is cheap, easily accessible, easy to repair, and easy to take apart. PVC can be found at local hardware stores which makes it very easy to buy which in turn makes repairs easy. Since the design is suppose to be portable PVC would be the best way to take apart joints and reassemble them. There would need to be enough to cover 4ft x 6.7ft x ~6ft for the interior and ~5ft x 6.7ft x ~6ft for the exterior.

3.2 Bed

As stated the bed will be acrylic and used to smaller objects to be easily scanned. Tanning beds for example sometimes use them to allow people to lay on while letting light through. Another option was plexiglass but since acrylic was plastic it would reduce the risk of breaking and harming the artifacts. In order to get quality photos about 92% transparency is what was a criteria when selecting a specific type of bed, which the acrylic has.

The bed will have wheels attached and use steel railing to move. There will be one rail on each side and 4 wheels per acrylic bed. It will be placed high enough for the bottom cameras to capture images and low enough for the upper cameras to do that same. The railing will be covered in green to match the color of the screen. That is a very important step to eliminate it from the construction of the artifact.

Figure 3.2.1 - Specifications for the Rail

Length	6ft.
Width	2.25in.
Height	1.5 in.
Material	Steel

Figure 3.2.2 - Specifications for the Wheels

Length	1.5 in.
Width	1.69 in.
Color	Black
Material	Plastic

3.3 Cover

The green screen will line the interior of the arch. With loops made of the same material sewn to its edges, the cloth will be fasten firmly to the PVC pipes. The loops help with portability since they can be detached and fasten removing without damaging the cover. The dimensions of the muslin will be exactly the same as the frame, so it can be slightly stretched when tied reducing the amount of wrinkles that could affect the removal of the background during the photo editing. At the location of the frame where the joints can be dislocated for portability, the cover can be split and reattached with a Velcro lining down this location.

3.4 Lights

Four strips will run vertically along the tunnel of the device starting from the base up the frame along the arc and to the base of the frame on the opposite side. The two outer stips will be 1.5 feet inward from the edges, and there will be a 1 foot spacing between each individual strip. To prevent a color temperature imbalance in the photographs, two types of color temperatures 2800-3300K (warm white) and 5000-5500K (daylight white) to prevent a dominating hue. The lights will remain on while the device is active rather than turn on and off when needed for the snapshots because this will reduce the switching cycles of the LEDs, therefore, prolonging the lifespan.

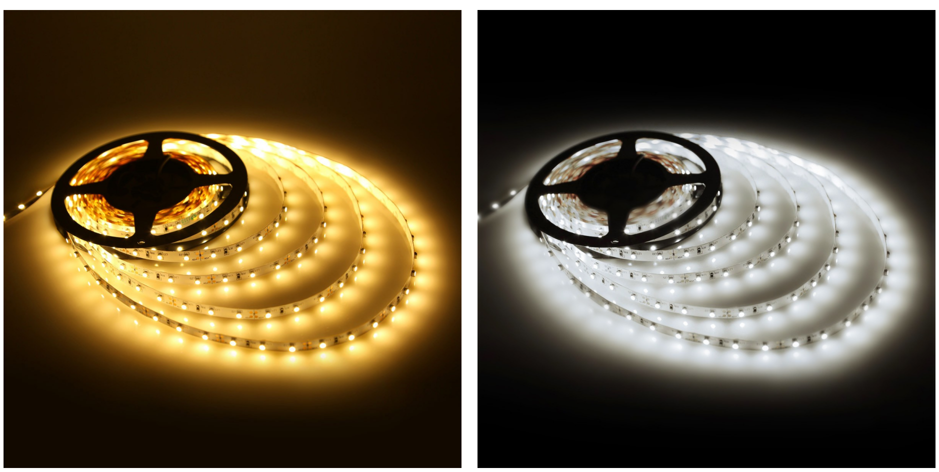


Figure 3.4.1: Chosen color options of strip - White Daylight (left) and Warm White Light (right)

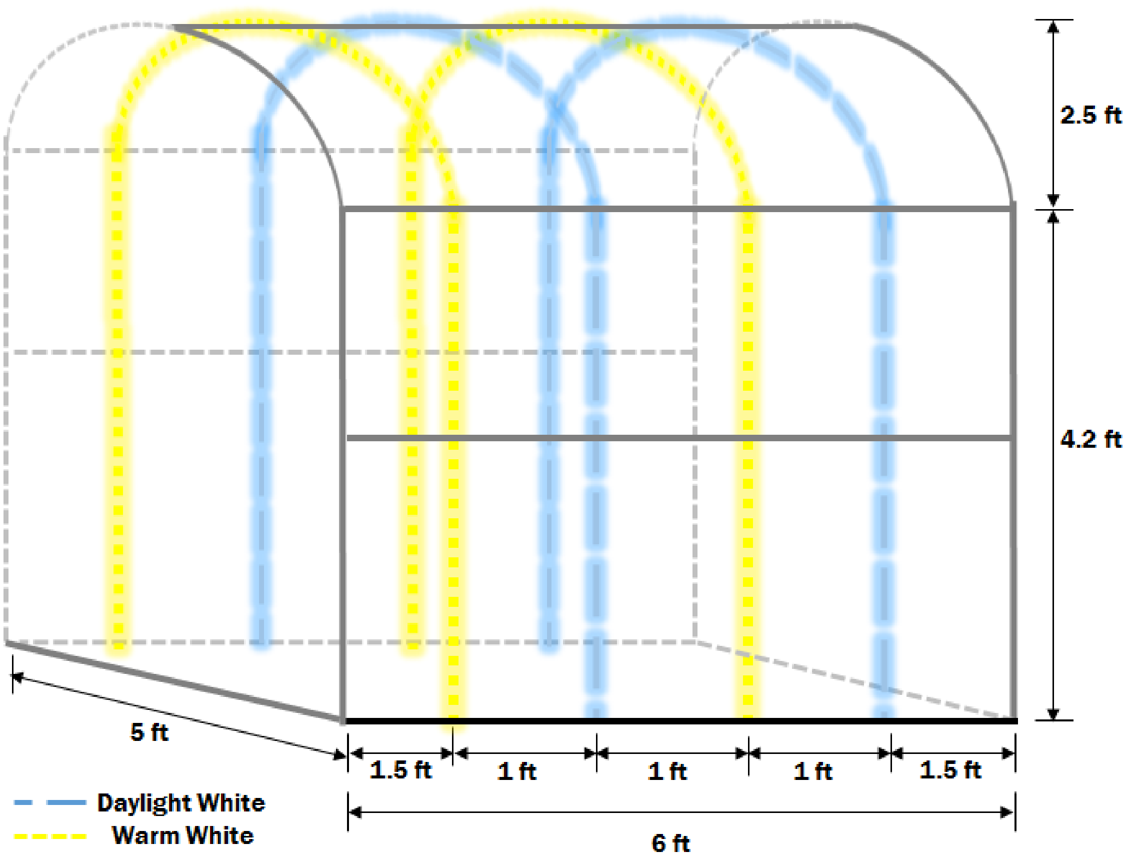


Figure 3.4.2: The Lighting Placement

3.5 Camera

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

3.6 Software

GUI prompts the user for the working directory and allows user to select where to continue in the process. The path to the working directory is saved in a python variable called “thePath” that will be passed to each respective script. The capture script will store the images from the webcams in respective folders within the path. The GIMP script will remove the background from the images for each folder in the path. The VisualSFM script will import the pictures with the background removed and generate a 3D point cloud. The path will then be passed to the Meshlab script which will generate a solid surface and a texture map as well as export an .obj file which will be imported into Blender. The Blender script will apply the texture map to the object and export the final product into a desired format.

Pseudo Code:

```
prompt_for_path();
detect_available_steps(); /*if working dir is empty only capture
is available, if obj file exists all steps available, etc*/
enable_available_step_buttons();
//Clean background selected
for each in thePath{
     fuzzy_select_green(); //threshold from fuzzy select tool
may be tweaked
     delete_selected();
     export_jpg();
}
//generate cloud selected
import_from_thePath();
calculate_mismatches();
generate_sparse_cloud();
generate_dense_cloud();
//construct surface & texture map is selected
import_cloud();
select_list(); //select list.txt file
delete_sparse(); //remove sparse cloud from current view
import_dense();
poisson_reconstruction();
texture_map_from_registered_rasters();
export_obj();
//open with Blender
import_obj();
```

4 Schedule

ID		Task Mode	Task Name	Duration	Start	Finish
35			PP&SOW	0 days	Fri 10/17/14	Fri 10/17/14
5			Arc Path	1 wk?	Mon 10/20/1	Fri 10/24/14
6			**Lighting Design**	**10 days?**	**Mon 10/27/1**	**Fri 11/7/14**
8			Consider all lighting solutions and order	1 wk	Mon 10/27/14	Fri 10/31/14
7			Test Lighting to ensure lighting is optimal for 3D model	1 wk?	Mon 11/3/14	Fri 11/7/14
36			System Level Design Review	0 days	Thu 11/13/14	Thu 11/13/14
9			**Script Software together**	**25 days?**	**Mon 10/20/14**	**Fri 11/21/14**
13			Script Gimp	1 wk?	Mon 10/20/1	Fri 10/24/14
12			Script VisualSFM	1 wk?	Mon 10/27/1	Fri 10/31/14
11			Script MeshLab	1 wk?	Mon 11/3/14	Fri 11/7/14
10			Script Blender	1 wk?	Mon 11/17/1	Fri 11/21/14

ID		Task Mode	Task Name	Duration	Start	Finish
14			**Cover Design**	**10 days?**	**Mon 11/10/1**	**Fri 11/21/14**
16			Consider Alternatives and order	1 wk?	Mon 11/10/14	Fri 11/14/14
15			Test choice	1 wk?	Mon 11/17/1	Fri 11/21/14
1			**Build Frame**	**15 days?**	**Mon 11/10/1**	**Fri 11/28/14**
2			List parts and Order	1 wk?	Mon 11/10/14	Fri 11/14/14
4			Build Skeleton Frame	1 wk?	Mon 11/17/14	Fri 11/21/14
3			Acrylic Bed	1 wk?	Mon 11/24/1	Fri 11/28/14
37			Build Desktop User Interface	4 wks	Mon 2/9/15	Fri 3/6/15
17			**Camera Placement**	**115 days?**	**Mon 10/27/1**	**Fri 4/3/15**
34			Consider options and order	1 wk	Mon 11/24/14	Fri 11/28/14
18			Test choice, find optimal placement	1 wk?	Mon 12/1/14	Fri 12/5/14
19			Add information to Technical Manual	19.2 wks	Mon 10/27/14	Mon 3/9/15

ID		Task Mode	Task Name	Duration	Start	Finish
20			**Scan Sample Collection**	**60 days**	**Mon 1/12/15**	**Fri 4/3/15**
33			Prioritize Artifacts	1 wk	Mon 1/12/15	Fri 1/16/15
21			**Scan**	**55 days**	**Mon 1/19/15**	**Fri 4/3/15**
32			Revise Arch	55 days	Mon 1/19/15	Fri 4/3/15
38			User manual	3 wks?	Mon 3/16/15	Fri 4/3/15
39			Project Management	160 days	Mon 9/8/14	Fri 4/17/15
40			Website	151 days	Sun 9/21/14	Fri 4/17/15

Figure 4.1: The schedule from the Project Proposal.

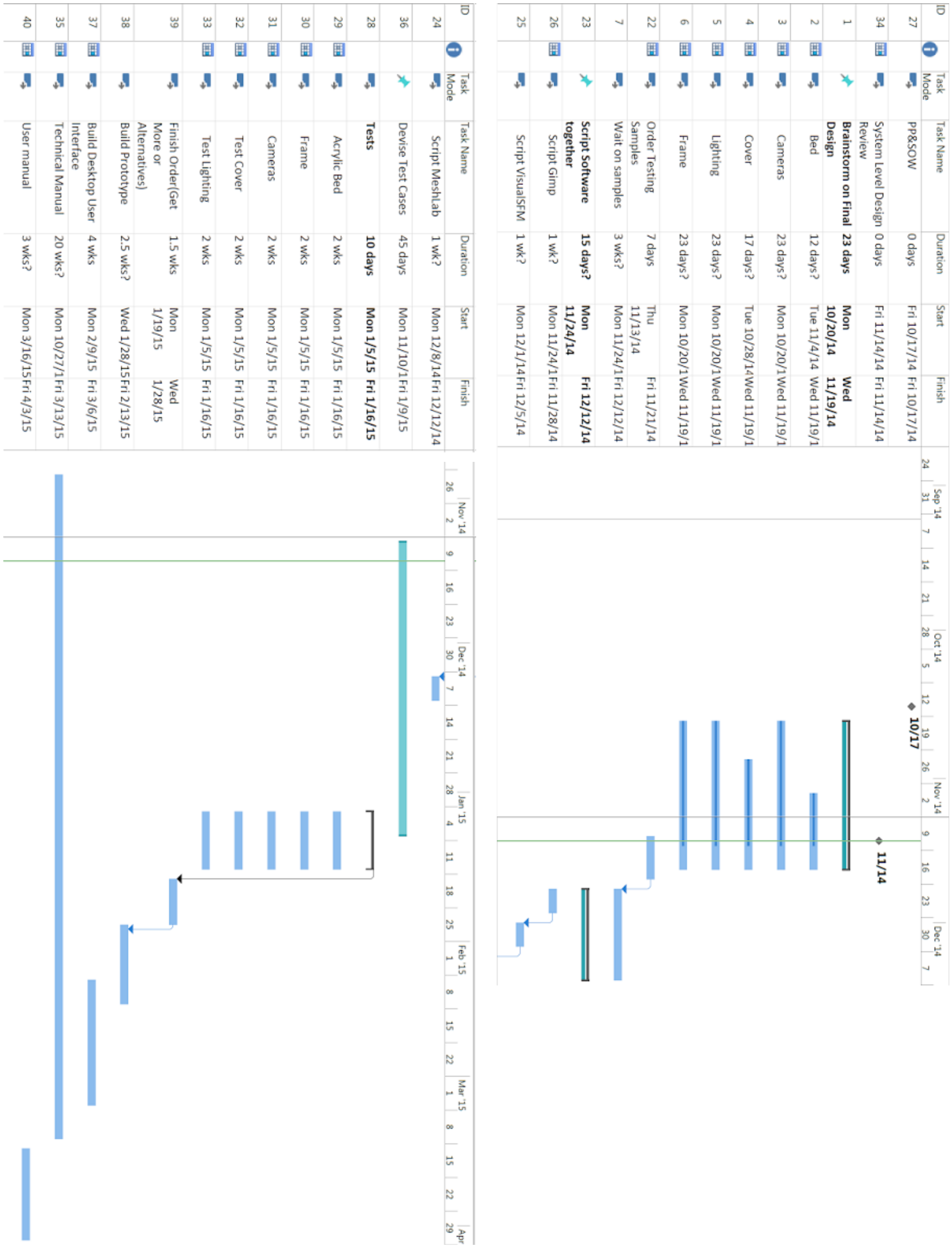
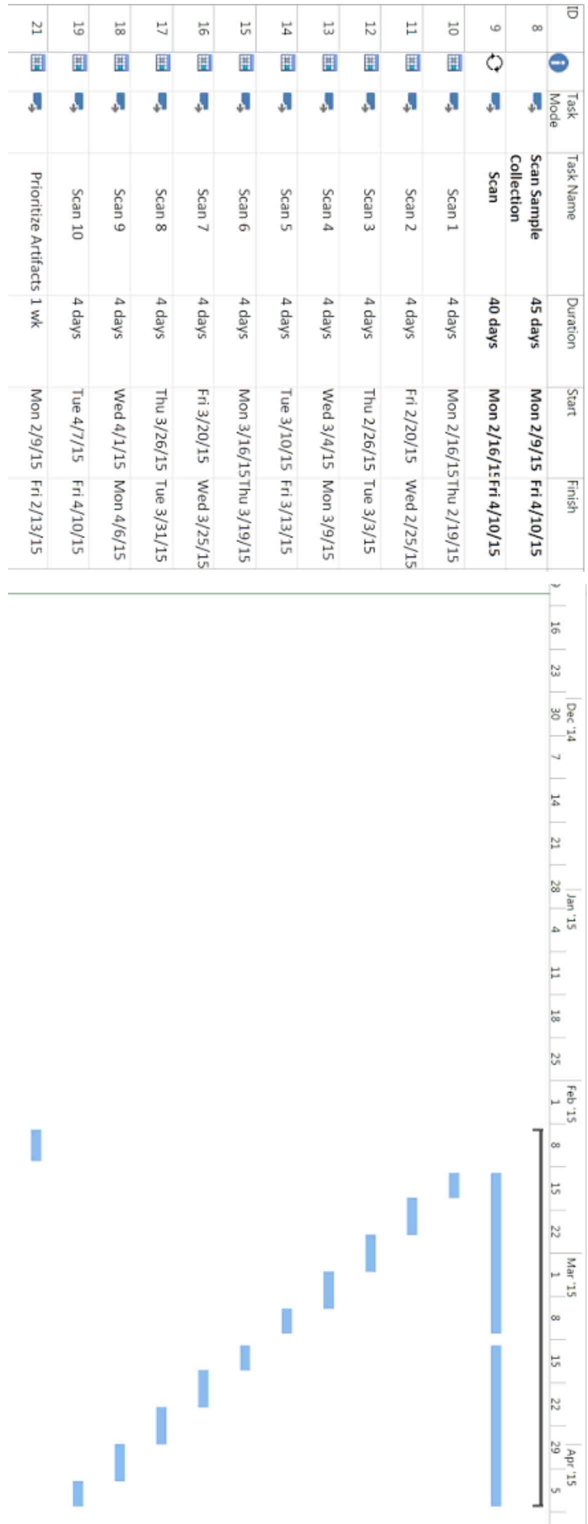


Figure 4.2a: Revised Fall Semester Gantt Chart Up Until February



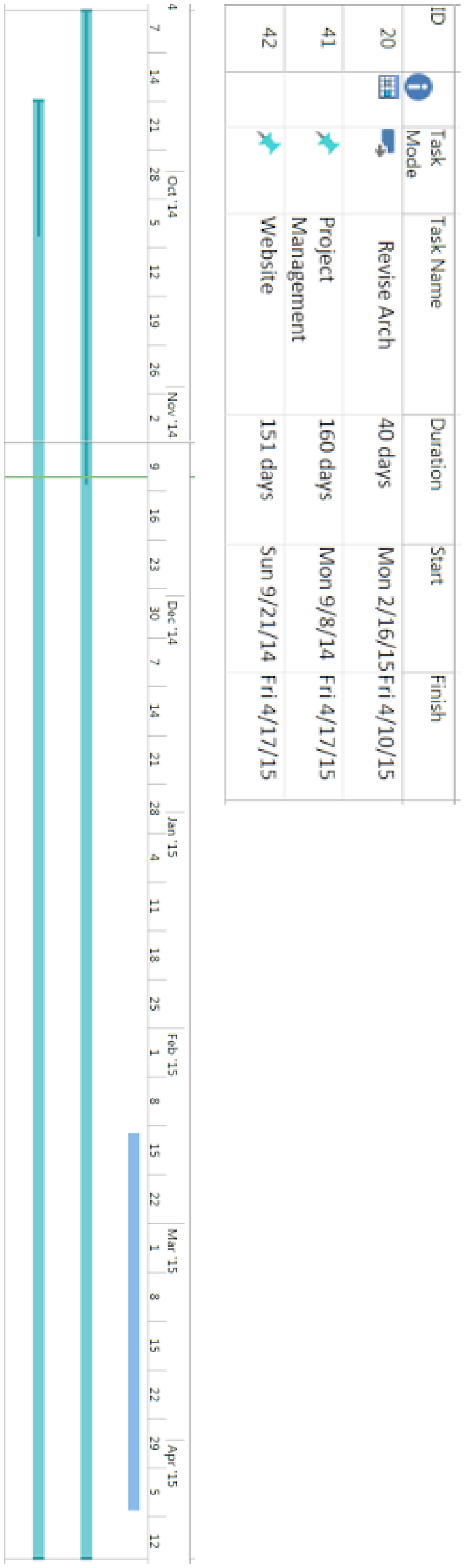


Figure 4.2b: Revised Gantt Chart for Remaining Spring Semester. February to April

Contrasting the two schedules, Figure 4.1 and Figures 4.2a, 4.2b, shows that the fall schedule has been majorly rewritten as well as the first part of the spring. The scanning of the artifacts has also been condensed from 55 days down to 40 days. This, however, will put more slightly more pressure on completing this section due to the shrinkage. The reason for this revision from the project proposal was to account for adding vendors and receiving deliveries. As seen in 4.2a, under Wait on Samples it is assumed it will take at most 3 weeks to receive items order accounting for adding the vendors and shipping. Due to this constraint on the schedule, building the prototype arc will be placed on hold until the spring. This will be done after testing the sample parts for quality and correctness of choice.

Table 4.1: Summary of Gantt Chart Tasks

ID	Task	Description	Completion Status
1	Brainstorm on Final Design	This task requires the whole team to come together to discuss option on how to construct the frame, how the lighting system needs to be set up, how the cameras are placed, and how the bed that artifacts are scanned on is connected to the frame.	85%
23	Script Software Together	This task uses python to script together taking photos from webcams, using a magic selection tool in gimp to take away the background for processing, linking those difference photos to VisualSFM, taking the dense point cloud from VisualSFM into MeshLab to generate a mesh model with a texture overlayed onto it.	5%
22	Order Testing Samples	After the brainstorming is complete, the purpose of this task is to order sample parts that will be used in testing the viability of those components. If those components are viable then the remaining parts will be ordered to complete the prototype.	Not Started
7	Wait on Samples	This is a period of waiting for the parts to arrive and for vendors to get into the ordering system if necessary.	Not Started
27	Devise Tests	This will be when the team devises test cases for their sections in order to test the viability of the samples.	Not Started
28	Tests	This take is where the tests will be performed on lighting,cover, frame, bed, and cameras	Not Started

39	Finish Order	When the tests are finished more parts will be ordered. If the parts did not work properly then new replacements will be ordered with the test knowledge in mind.	Not Started
38	Build Prototype	After waiting roughly a week for the new parts to arrive, the prototype will be built and tested.	Not started
37	Build Desktop User Interface	This is a graphical user interface for the end user to essentially just click and scan.	Not Started
35	Technical Manual	The technical manual is a manual that will be passed down to people who need to work on the arc design such as future teams and personnel.	Not Started
40	User Manual	The user manual is a manual for how to operate the scanner	Not Started
8	Scan	The scanning period is a period of 45 days where the first week is used to prioritize the artifacts based on their delicateness. The remaining 40 days are used to scan the 10 artifacts from least delicate to the most while adding to the user manual and technical manual and making adjustments to the design as needed.	Not Started
41	Project Management	This task is essentially ensuring that the project is completed on time and within budget.	Ongoing
42	Website	The website is a team site that will be built on the team leader's public web space at the College of Engineering.	10%

5 Budget Estimate

Proposed Budget

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

Updated Budget

D. Expenses				
Item	Distributer	Costs ($)	Quantity	Total ($)
USB 8MP Webcam	TVC-Mall	2.50	13	32.50
Acrylic Sheet	Amazon	52.00	2	104.00

PVC Pipe	Home Depot	3.00	8	24.00
PVC Joints	Home Depot	0.50	8	4.00
USB Hub	Amazon	4.00	2	8.00
Green Screen Muslin 5 x 7	TubeTape	17.95	2	35.90
Zinc-Plated Steel Slotted Angle	Home Depot	$22.00	2	$44.00
Polypropylene Wheel Rigid Caster	Home Depot	$3.00	8	$24.00
LED Strip Lights	Lighting Ever	$10.00	2	$20.00
LE Power Adaptor	Amazon	$10.00	2	$20.00
Computer	Walmart	500.00	1	$500.00
Other	-	-	-	$150.00
Total Cost:	-	-	-	$966.40

6 Overall Risk Assessment

6.1 Technical Risks

6.1.1 Software Risks

6.1.1.1 Processing Dependency

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 programs in the sequence to produce the final result, one of the programs could crash or produce erroneous results while continuing to execute the script. This could cause inaccurate results without the user being able to find the problem.

Probability <moderate>

It is moderately probable that a step in the process will produce erroneous results. There is a low probability that a program will crash.

Severity<low>
The consequence of the script failing is that a part of the script may need to be redone.

Strategy
To resolve this problem the script will be broken into sub scripts that will be called from the GUI. In this way the output from each task can be reviewed before moving on to the next step in the sequence. This way only the erroneous task will need to be repeated instead of the whole process.

6.1.1.2 VisualSFM Hardware Requirements

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.

Probability <low>
There is a low probability that a modern computer system will have less than 1GB of ram. There is a high probability that the system does not contain CUDA processors.

Severity<low>
The overall impact on the design is that VisualSFM will take significantly longer to process using a CPU rather than GPUs. This extended amount of time is typically still a reasonable duration.

Strategy
Select a system that has more than 1GB of ram and if possible a CUDA graphics card [3].

6.1.2 Hardware Risks

6.1.2.1 Unsturdy Framing

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.

Probability<moderate>
Some of the objects may have a significant amount of weight.

Severity<high>
Breaking the frame of the scanner will effectively render the system useless.

Strategy
Use shorter runs in the design of the frame and thicker pipes for the walls. Only use thin pipe for the top part of the arch which will only be supporting part of the cover and a single camera.

6.1.2.2 Lighting Risk

6.1.2.2.1 Inefficient Internal Heating Removal

Although the LED lights do not have product of IR radiation, which is harmful for the artifact during scanning, LEDs' efficiency is highly depend on the operating environment's ambient temperature. During long term usage, the SMD LED chips can exceed their junction temperature, the highest operating temperature of the component, as the ambient temperature increases and can lead to damage and component failure. This situation can also reduce their lifetime by 80 % meaning the 50,000 hours the manufacture proclaim could lead to being 10,000 hours instead. The temperature juncture was not specified on the provider's online catalog page, so the maximum ambient temperature is unknown until purchasing one of the LED strips and testing. The tests will consist of measuring the temperature after a period of time. The temperature and time correlation will be compared to the average time needed to have a successful 3-D scan of objects using the acrylic bed and without.

Probability<low>
Due to the large dimensions of the arch, it is possible that there is enough air flowing through the tunnel that the ambient temperature will not reach to this point; however, since heat rises and the roof of the arch is enclosed, it is possible that the LEDs lining the arc can reach high temperatures.

Severity<low>
If the LED strips reached high temperatures, the LEDs can become defective causing them to dim. This could to lead to producing shadows on the objects if enough are damaged. Also, the glue on the back of the strip which attaches it to the muslin can warm up and detach.

Strategy

Due to the cutting option of the light strips, a part of the lights could be replaced rather than the entire strip, and these lights are not expensive and can be easily replaced if needed.

6.1.2.2.2 Overexposure
From the design, the four LED strips will be extend around the frame vertically approximately 1 foot apart. Each strip has a brightness of 300 lumens per meter (see), therefore, 1500 lumens per

strip. This mean the entire lighting system will have a brightness of 6000 lumens. If the brightness is too high the photographs will become washed out and unusable for making the point cloud.

Figure 3.1 Good Brightness (left) Overexposure (right)

6.1.3 Data Collection Risks

6.1.3.1 Poor Photograph Collecting

6.1.3.1.1 High-Resolution

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].

6.1.3.1.2 Depth of Field

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].

6.1.3.1.3 Object Placement

The method for capturing images for photogrammetry typically involves moving a camera around the object and capturing images. This design will move the objects through the field of view of the cameras instead of moving the cameras around the object. Photogrammetry software should be able to process the data in the same manner, however there is a chance that this innovative approach may be too different for autocorrelation of points.

6.1.3.2 *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.

6.2 Schedule Risks

6.2.1 Task Dependency

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.

6.3 Budget Risks

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.

6.4 Summary of Risk Status

In any type of project there will always be some type of risk. The only way to reduce the risk is to keep planning and improving. Overall, there risk needed to be considered in both hardware and software aspects of the project. The major concerns for the software are the requirements of the VisualSFM and the program I/O dependency from the scripting. For hardware, it is mainly the lighting and the frame.

7 Conclusion

Overall the design is coming along great. The scanner will be constructed with PVC for the frame generally forming an arch. A green screen will be used to assist with removing the background from each image for maximum point autocorrelation. 13 cameras will be strategically placed to capture the entire surface area with at least 60% overlap. An acrylic sheet will be used as a scanning bed for smaller and non-rigid objects that cannot be flipped without changing their shape. The clear colorless sheet should allow for cameras below the sheet to scan the underside of the objects. A track and wheels will be added to the frame to allow the bed to be moved in the scanner without adding additional artifacts (such as hands) to the captured images. LED strips will provide an even amount of lighting by being evenly spaced in the arch. The captured images will be processed GIMP to eliminate the background from each image. The images will then be processed by VisualSFM to generate a sparse and later a dense 3D point cloud. Meshlab will use the dense 3D point cloud to generate a solid surface as well as use the list.txt of picture files generated by VisualSFM to generate a texture map. Blender will import the .obj file generated by Meshlab where modifications can be made to the object or it can be exported to more desirable formats.

8 References

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Appendices

1.

2.

3.