FINAL REPORT

Site Survey, 3D Laser Scanner, and Photogrammetry

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1. Introduction

We conducted a project of producing a 3D model for Malcolm X & Dr. Betty Shabazz Memorial and Educational Center, which belongs to Columbia University. Each of us did the photogrammetry for one bay of the interior wall and did 3D scanning for three bays of the exterior facade. It took us around five weeks to finish the project and use the model to do a building condition assessment.

2. Workflow

a. Site

The first step of our work is collecting data in the fieldwork by taking photos, scanning the building, and sketching the condition. We did the photogrammetry and scanning simultaneously and did the sketch later. During our site visit, there were a couple of challenges. The first and main one was the time. We had to take photogrammetry, scan the building from outside and inside, and do a condition assessment in a limited time.

We start scanning the exterior in order. In the morning the sunlight was perfect to get a good quality scan. We did multiple scans until we reached the entrance. Scanning the Entrance was another challenge since we want to open the doors so the Faro laser scan can capture the interior. However, making the door open was difficult. We managed to open the door but during the scan, some of the doors moved. At noon, the sunlight was very strong and the area got busy because of the lunch break. Therefore we decided to move to scan the interior instead. After finishing that the sun exposure was good to continue the scanning. By the time we needed to do the assessment of the conditions, we had not much time left and we did it very quickly.

The challenge related to photogrammetry is when we took photos, it was a little hard to estimate how much sixty percent or seventy percent overlap is. In order to make sure that there was at least sixty percent overlap, one student took more than nine hundred photos for one bay including the details of a screen and columns. The more photos we take, the more time it will take, but the much clearer the model will be. We need to keep a balance between the time, the number of photos, and the details that should be included.

b. Scene

Using the data we obtained during the site visit using FARO laser scanner, we imported the scan files in FARO SCENE to create a 3d model. The scanner captured a lot of details that are not necessary for our purpose. Therefore, we cleaned the model by removing trees, cars, and humans in the street, in addition to some parts of the interior that we will not use in our final deliverable. Getting rid of the unnecessary details will allow a smaller file and easier control for the rest of the project.

We used a clipping box to delete the unwanted elements, and also to hide some elements instead of deleting them as we were indecisive of which parts should be completely deleted. However, utilizing clipping boxes to hide elements had some errors. The element that was hidden at the beginning kept showing up later when we reopened the file. We decided to delete the entire hidden elements to avoid subsequent issues in the next processes.

After we finished with the cleaning process, we exported the file into e57 format in order to use it in Reality Capture. However, for unknown reasons, the file was too big and was hard to handle and process in reality capture. It took much more time to load, align, mesh, and even save. Therefore, we decided to reclean the model again to the point the file's size was reduced significantly from around 12 GB to 1.5 GB. The new e57 file worked better than the previous one. (Figure.1)

c. Reality Capture

Following this, we imported the e57 file into Reality Capture and aligned the point clouds and images from the 3D laser scanner. At first, some errors occurred, since every time we exported the e57 file and aligned them, the point clouds were fragmented into different components instead of having a complete model of the building. We tried different methods to solve this issue. The first method is to look for common control points among the different components, adding control points as a reference, and re-align the point clouds and images. This method works properly but it took time to be able to make the model perfect as we wanted it to be. The second method we figured out that has a better outcome is by changing the import settings to "exact - use an existing registration".

After the images were aligned successfully, the next step was to create a mesh from the 3D laser scan file by using the tool "Normal Detail".(Figure.2) This process only required waiting, but it took time and required a big drive size. The mesh refused to show on the screen because there was not enough video memory, therefore we used the simplify tool to reduce the mesh size. At some point, we also ran out of the D drive space where the software automatically saved cache. We solved this issue by changing the cache saving location, and eventually, we just deleted the cache completely.

The finished mesh still requires a thorough cleaning, since many unwanted polygons showed up in the file. We used the tools "lasso" and "rect" to select the unwanted polygons and use "filter selection" to clean the model. The cleaning process is very

time-consuming as well, as we need to be careful that the necessary parts will not be deleted by accident. Thankfully there was no significant issue during this step. (Figure.3) Then we textured the model with the photos taken by the scanning model so that the model has colors. (Figures. 4&5)

d. Photogrammetry

To create a texture model that is very close to reality where conditions and texture are shown, we imported all photographs taken on-site into reality capture and let the software align the image, before adding control points to reference some images that were not aligned properly. Since the interior part of this building has very similar repetitive bays, we imported the photographs in sequence by bays to avoid confusion. Later, each bays' images were aligned and imported into the Reality Capture Alignment Component. To give a better georeference, some control points were also created in photographs taken by a 3D laser scanner.

Creating a mesh after the photographs were aligned was challenging, as it needed big drive space and a very long time. Even after letting the mesh be created for the whole night, there are still some errors found, especially in Kemuning and Jerry's walls, where it has a hole in between. We thought that this error might happen because of two possibilities: 1.) The mesh creating process was not thoroughly conducted as at some point it has an error notification, or 2.) More control points are needed. To prove the second hypothesis, we tried adding control points but it still has the same result; hence this issue is still not resolved yet. Fortunately, the mesh works when we process our respective bays individually. After the mesh model was created, we unwrapped the model and textured it with the photos to make the model look like the real building. Then we used "Ortho Projection" or "Render Image" to export images. (Figure.6)

An alternative way of creating a mesh model and then texturing it is by clicking the "Start" button under the "WORKFLOW" tab. It is also time-consuming but it simplifies the processing steps.

3. Challenges and Solution

a. Group Work and accessibility to computers and accounts

- **File Accessibility** (Had to use one UNI and password to open one particular computer and file, sometimes the computer was in use). The solution was to share each other's UNI and password.
- **Out of disk space**. The solution to this problem was to move the cache saving drive to C, which was relatively empty during the process, and even delete the whole cache since we decided we do not actually need it.
- **Out of video card memory.** The solution to this problem was to simplify the mesh to make it under four million.
- **Remote access ended during the reconstruction process.** The solution to this was to make sure the computer is on all the time and keep logging back in if it

enters sleep mode. We also decided to work in the lab to avoid recurring issues in regard to this.

b. Scene - Reality capture - Photogrammetry

- **Clipping box issue in FARO SCENE**. We just decided to not hide any elements and delete them instead if we were sure they are unnecessary. As we cannot recover what we have deleted with the clipping box, we were very careful to clean the model and save it occasionally.
- **Big E57 file resulted in very slow processing in Reality Capture**. The solution to this was to redo the cleaning process, especially the additional point clouds created behind the exterior walls.
- **Point clouds and images did not align properly when the e57 file was imported**. We tried two different methods to solve this issue: put control points, which were working but took time, and to export the e57 file with "exact - use an existing registration" option chosen at the beginning.
- **Hole in between Kemuning and Jerry's wall while processing the entire interior.** Unfortunately still not resolved yet. We decided to make mesh and texture our individual works due to the limited time.

4. Pros and Cons of Each Tool

Traditional

Pros:

- Relatively cheaper
- Does not require specific training to use particular software
- Could be more accurate if the work were done perfectly
- After the survey was finished completely, the following process including the drawing and data processing is relatively simple
- Able to survey some parts of the building that cannot be captured by other tools (therefore this method has the biggest potential to be utilized as a secondary survey method to support data from other tools)

Cons:

- Require big numbers of workers on the site
- More time consuming and physical-demanding if the scale of buildings is large - Possible human-error (relatively big possibility than the other methods especially if this is the only method conducted without support from other tools)

3D Laser Scan

Pros:

- Having one of the best accuracy of dimension and scale.
- Very quick on-site process, a very good solution for projects with limited time-on-site
- Less labor is required on-site

- Progressing technology, the software keeps being updated and getting easier to use
- Can use ariel scanning to include the roof or other part that is hard to be captured by taking photos on the ground.

Cons:

- Very expensive tools and software, not a good option for projects with a limited budget
- Might be unfamiliar for many people, hence a training for the tool and software is required
- Require time for the cleaning and processing stage
- Cannot get texture with high resolution and cannot clearly present the details of the deterioration as it only relies on the photos taken by the scanning machine

Photogrammetry

Pros:

- Relatively quicker on-site works than the traditional process
- Taking photographs will not require highly-skilled labor (but still require initial training to conduct the on-site survey properly, including the requirements of taking photos and the way to put “target points”)
- Capture Reality can automatically generate a new model after each step, which is more tolerant to the mistakes we made in the data processing.

Cons:

- The accuracy of scale might be relatively lower than the other methods, as the software cannot regenerate the actual scale by itself. Hence an on-site scale reference is required
- Require software skills for aligning and processing the photographs - Might have human-error as well during the photograph-taking process - Require time for the cleaning and processing stage, possibly even longer than a 3D laser scan since it also requires more control points.
- It is hard to take photos of the top, like the roof. When there is no image, the software does not know what happened between the point cloud. As a result, the top surface of the sculpture and the screen would not be clear. (Figure.7&8)

When to use which method?

To decide which method to use, there are three significant parameters to be considered: money, time, and human. Depending on how much the project’s budget is when a project has a more flexible schedule, photogrammetry might be a good option to choose, since it costs less. However, if the schedule is tighter, a 3D laser scan might be a better solution, of course with higher requirements of funds and human resources. If the project has a big number of human resources and a more flexible timeline but has limited funding, traditional methods can be utilized.

Another suggestion is to combine different methods, for example, the traditional method with photogrammetry, or the traditional method with 3D laser scan. Here, the traditional

method will act as a data supporting tool when a certain part of the building is impossible
to document by other methods. This hybrid approach can also be a solution for tight schedules or tight funding.

This diagram below shows a rough idea of how these three considerations can be a tool to determine which methods to use.

Money, Human, and Time Element as a Consideration to Choose Methods
(Diagram by Kemuning Adiputri)

Besides the three factors mentioned above, the expected result, the aim of doing the project, and the usage of the model also need to be asked before we can decide which method can be used. For example, if the aim of doing the model is documenting the heritage for a virtual museum or recording the heritage condition online, photogrammetry may be preferred for its high resolution and many details it can include. If the model is used to do building condition assessment in order to find the conservation methods, photogrammetry, and the traditional way can be combined so that the deterioration condition can be recorded and studied thoroughly. If the model will be used for an architectural company to facilitate the adaptive reuse design of the original building, 3D scanning will be more suitable, as it can include the whole structure, the scale of the building, and the context around the building. The traditional way can also be used if architects have time to do the fieldwork and do measurements by themselves.

5. Conclusion and Suggestions

This entire process was very educational and we perceive this experience as an excellent opportunity for us to learn new software and methods for digital documentation. We were proud to be able to overcome the issue and produce a relatively good result, even if it was not entirely perfect. We hope we can explore further on topics we learned during this study and apply them in our future professional works.

We recommend that the site visit will be more than one day since we are learning we

need time to adjust and learn without the pressure of time in order to have a more enjoyable experience. We also suggest we take more classes in photogrammetry since it
is time-consuming and complicated. Maybe two courses can be taught expertly. One for GIS and another one for 3d scanning instead of combining them into one course.

6. Figures

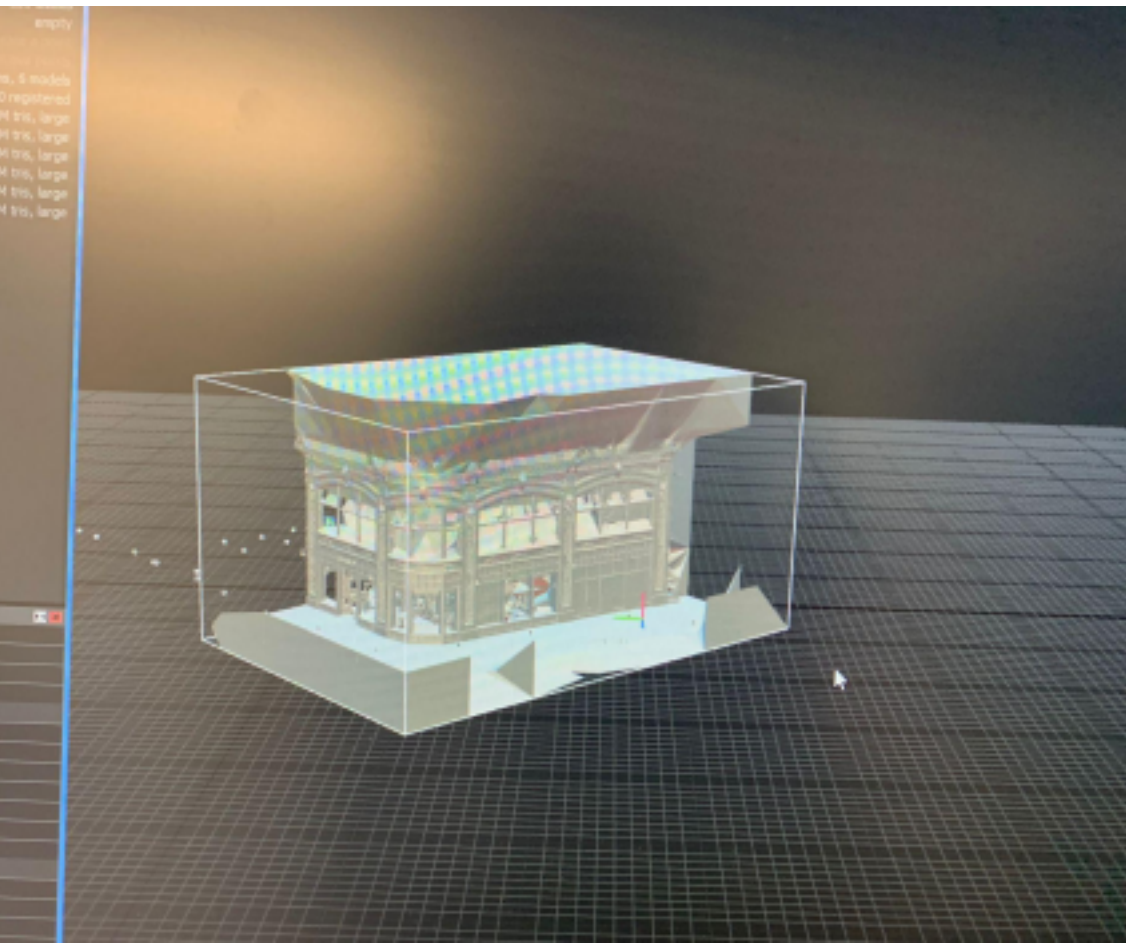

Figure 1. 3D model in FARO SCENE

Figure.2. The model converted to mesh

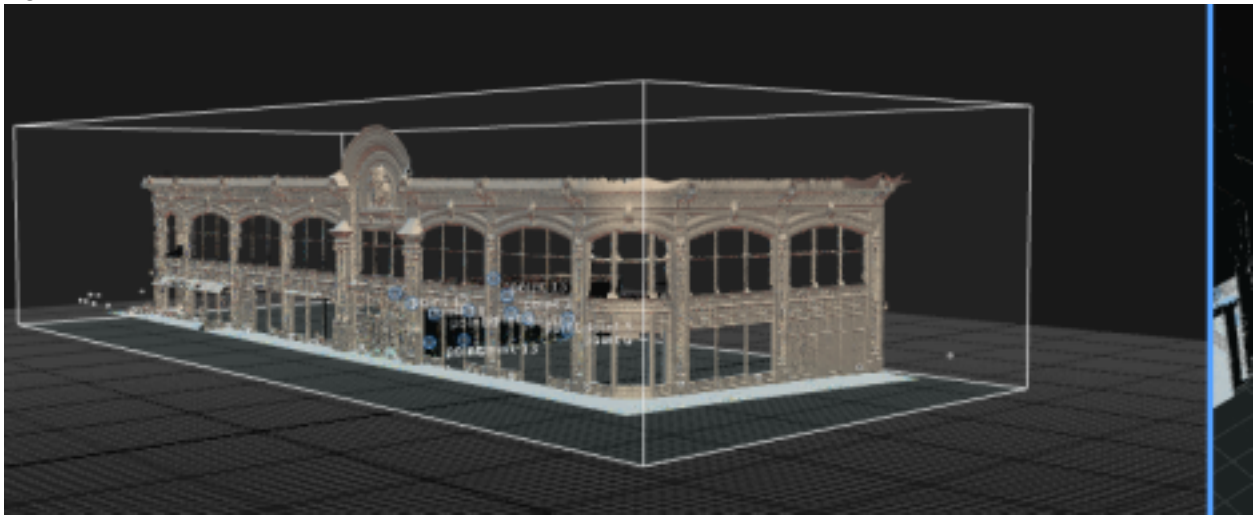

Figure.3. The cleaned model

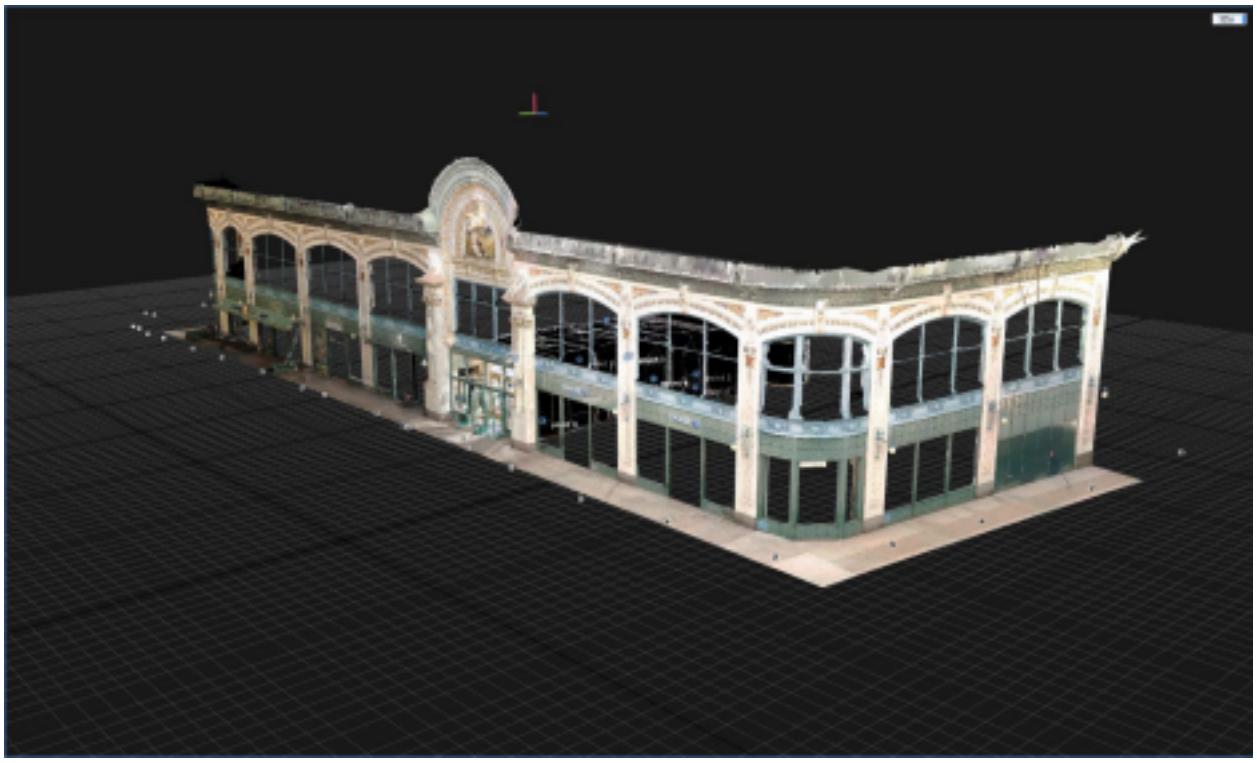

Figure. 4. The exterior of the rendered model

Figure. 5. The interior of the rendered model

Figure. 6. Photogrammetry: the orthodox projection of the south wall after texturing


Figure 7. Photogrammetry cannot include the top part

Figure. 8. Photogrammetry cannot include the top part