3D Reconstruction and Digital Preservation of Mandaluyong City's San Felipe Neri Parish Interior Using Close-Range Photogrammetry

Fredrik Angelo F. Francisco[1], Adrian Kristian C. Bendicio[1], Alessandra M. Tolentino[1], Janine A. Mendoza[1], Dominic C. Fargas Jr.[1]

[1] Department of Geodetic Engineering, University of the Philippines Diliman, Quezon City, Philippines –
(fffrancisco, acbendicio4, amtolentino6, jamendoza16, dcfargas)@up.edu.ph

Keywords: Cultural Heritage, Places of Worship, Church, Digital Preservation, 3D Modeling, Indoor Photogrammetry

Abstract

This study investigates the application of close-range photogrammetry for digital preservation of cultural heritage, focusing on the interior of San Felipe Neri Parish in Brgy. Poblacion, Mandaluyong City, Philippines. The main objective is to generate a detailed and accurate 3D reconstruction of the church's interior and associated features to showcase modern heritage preservation efforts. The study is oriented towards the 11th Sustainable Development Goal of the United Nations: Sustainable Cities and Communities. In particular, it addresses target 11.4–Strengthen efforts to protect and safeguard the world's cultural and natural heritage. A modified workflow from Bedford's (2017) *Photogrammetric Applications for Cultural Heritage* was implemented, using an iPhone 11 camera, measuring tape, Agisoft Metashape, and MeshLab. A total of 219 images were acquired and processed, and the resulting model was rescaled using field measurements. The final model achieved less than 5% error across all key object measurements, validating the accuracy and potential of accessible photogrammetric tools in indoor heritage documentation. Several challenges were noted, such as mesh distortion from moving objects (e.g., cloth), texture distortion from excessive lighting, and incomplete reconstruction of single-color surfaces (e.g., rugs, screens). Despite these issues, the study demonstrates that low-cost, consumer-grade equipment combined with an optimized workflow can produce reliable 3D models suitable for documentation, visualization, and conservation planning.

1. Introduction

This study investigates the application of close-range photogrammetry for digital preservation of cultural heritage, focusing on the interior of San Felipe Neri Parish in Brgy. Poblacion, Mandaluyong City, Philippines. Close-range photogrammetry has been proven effective in capturing intricate details, particularly in confined or indoor environments where alternative techniques may be limited (El-Din Fawzy, 2019). It serves as the focal point for achieving enhanced accuracy and authenticity in 3D feature documentation (El-Din Fawzy, 2019). This approach is especially relevant for heritage sites where detailed digital records are needed for conservation and public engagement.

Building on previous work, this research highlights the practical value of close-range photogrammetry in conserving the architectural and cultural heritage of a parish interior in the Philippines. By applying and refining existing photogrammetric methodologies, this study establishes a definitive approach as an improved technique for accurate 3D digital documentation. The study demonstrates how close-range photogrammetry can serve as an effective tool for cultural documentation, conservation, and appreciation of historical spaces.

1.1 Background of the Study

The study focuses on the 3D reconstruction of the interior of San Felipe Neri Parish in Brgy. Poblacion, Mandaluyong City, as part of a broader effort to digitally preserve and showcase the legacy of this historically significant religious structure. Established in December 1863, the parish is the oldest and largest church in Mandaluyong (San Felipe Neri Parish, n.d.). Its architectural style harmonizes traditional Filipino and colonial influences. It holds religious and cultural importance to the local community and represents a valuable heritage site.

The study is inspired by a 2015 study conducted in Spain, addressing similar challenges related to virtualizing Gothic churches indoors (Pérez Ramos & Robleda Prieto, 2015). The study underscored the limitations of Terrestrial Laser Scanning and its associated high surveying costs. In response, it proposed a pragmatic and cost-effective photogrammetric approach, utilizing a DSLR camera equipped with an 18-135 mm lens, a tripod, lights, and a total station (Pérez Ramos & Robleda Prieto, 2015). This precedent forms a foundational reference for the current research, adopting a comparable low-cost, image-based approach tailored to indoor heritage environments, contributing to the broader field of heritage preservation.

1.2 Significance of the Study

The study is oriented towards the 11th Sustainable Development Goal of the United Nations: Sustainable Cities and Communities. In particular, it addresses target 11.4–Strengthen efforts to protect and safeguard the world's cultural and natural heritage. Through the application of close-range photogrammetry, the research underscores the paramount importance of leveraging advanced technologies for the preservation of historical interiors, particularly focusing on the intricate details of the San Felipe Neri Parish. By employing cutting-edge 3D reconstruction techniques, the study showcases the technological strides made in heritage preservation. The use of close-range photogrammetry technology enables a meticulous and precise recreation of the parish interior, emphasizing the potential for innovation in documenting and safeguarding cultural heritage.

Beyond the realm of preservation, the research extends its impact to educational outreach and accessibility. The 3D reconstruction facilitates virtual tours, offering a dynamic and immersive experience that transcends physical boundaries. This accessibility not only broadens the audience but also serves as a platform for educational initiatives, fostering a deeper understanding of the historical and architectural significance of the San Felipe Neri Parish. Furthermore, the study contributes significantly to risk mitigation and future planning. By providing detailed documentation of the interior, it becomes an invaluable resource for conservation planning and lays the groundwork for informed decision-making in future restoration efforts. In essence, this research serves as a pioneering exploration at the intersection of technology and cultural heritage, promising far-reaching implications for the preservation and appreciation of historical spaces.

1.3 Objectives of the Study

The primary objectives of this study are meticulously crafted to ensure a thorough exploration of the preservation and 3D reconstruction of the parish interior. Firstly, the study aims to acquire a comprehensive set of interior images, carefully selected to meet the criteria for creating a high-fidelity 3D reconstruction. Subsequently, utilizing advanced photogrammetric techniques, the goal is to generate a detailed 3D reconstruction of a portion of the church's interior space and associated objects, the main altar to be precise, showcasing the precision and capabilities of modern technology in heritage preservation. Lastly, utilizing Agisoft Metashape's tools, the objective is to cross-reference measurements with the church's actual dimensions. This crucial step ensures the authenticity of the reconstruction, aligning with the research's comprehensive goals.

2. Methodology

2.1 Materials & Data Used

The materials used in the study are the following:

- iPhone 11
    - ➢ Dimensions: 4032 x 3024 pixels
    - ➢ Focal Length: 1.54 mm
    - ➢ Pixel Size: 0.944 x 0.944 µm

  With the following specifications of the iPhone 11 listed above, a total of 219 images had been acquired.

- Measuring Tape
  This tool was used to assess the accuracy of the generated 3D model from the acquired images.

  The following are the objects from the altar and their corresponding measurements in m (L x W x H)
    - ➢ Altar Desk - (2.5 x 0.9 x 1)
    - ➢ Chair - (1.2 x 0.93 x 1.170)
    - ➢ Stand/Podium (0.710 x 0.710 x 1.655)

- Agisoft Metashape & Meshlab
  Metashape played a key role in processing and manipulating images captured from the iPhone 11, facilitating the creation of detailed and accurate 3D model. Also, the generated 3D model undergoes re-scaling using Meshlab to further increase the accuracy.

- HP Pavilion Laptop
  A personal HP Pavilion gaming laptop 15 with an AMD Ryzen 5 processor with 8 GB RAM was used alongside Agisoft & Meshlab to process the images and generate 3D model.

2.2 Study Area & Plan of Acquisition

The San Felipe Neri Parish is located in Mandaluyong City, Philippines with the following coordinates of 14° 35' 9.276" N and 121° 01' 33.348" E, as shown in Figure 1.

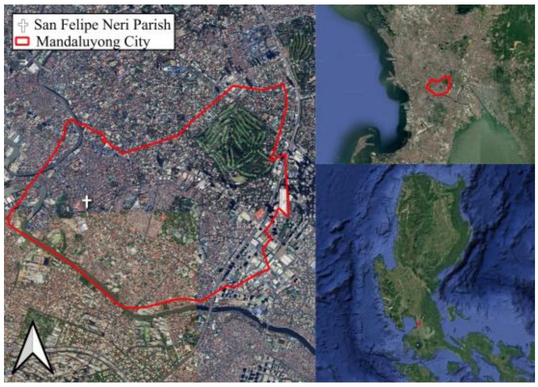

Figure 1. San Felipe Neri Parish Location

Figure 2 shows the actual visualization of the exterior of San Felipe Neri Parish.


Figure 2. San Felipe Neri Parish from the outside

Figure 3 shows the front view of the main altar of the San Felipe Neri Parish.


Figure 3. San Felipe Neri Parish Main Altar

The image in Figure 4 provides an overhead view of the main altar layout. Based on the legend, the shapes in the diagram show where the features that were measured were positioned when the group took the actual photos. The broken lines in the diagram act like a guide, representing the steps that the group has followed during the image acquisition.

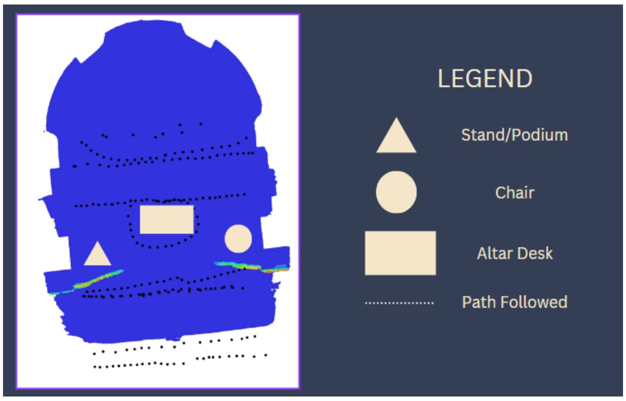

Figure 4. Terrestrial Plan for Image Acquisition

2.3 Data Processing Workflow

The study applied the workflow in Figure 5 for the creation of the model. The overall workflow modified and simplified each process from the General Workflow from "Photogrammetric Applications for Cultural Heritage: Guidance for Good Practice" (Bedford, 2017). The flowchart was further refined through the researchers' careful understanding of Photogrammetric Techniques, knowledge about the study area's environment and structure, and skill in utilizing photogrammetric software.

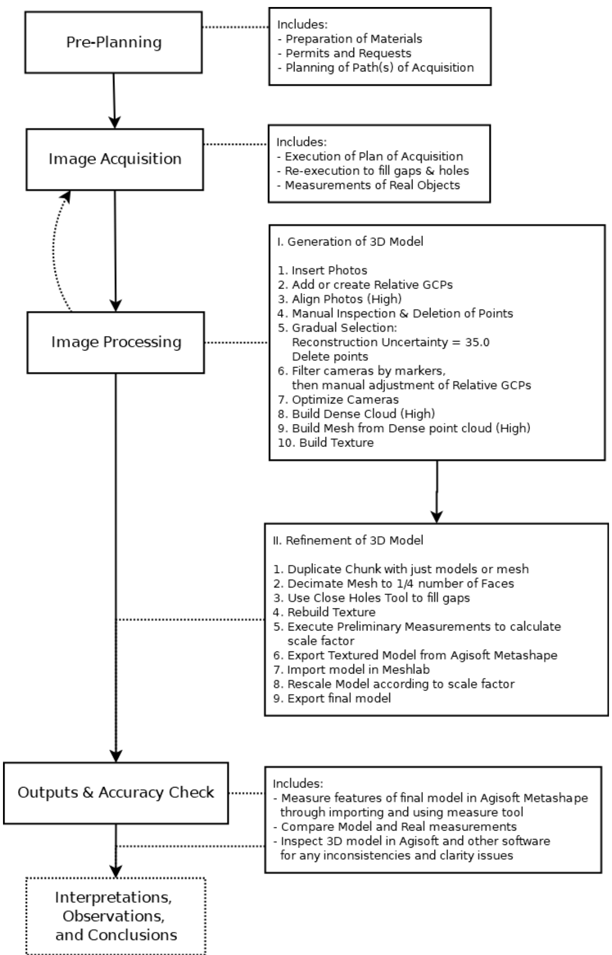

Figure 5. Data Processing Workflow

The flowchart is separated into 4 different stages, with detailed instructions and descriptions for each section.

2.3.1 Pre-Planning: Indoor mapping presents different challenges in 3D reconstruction compared to capturing photos from an object's or building's exterior. In line with this, at this stage, the researchers best followed principles found in "Indoor Mapping using 3D Photogrammetry Software" (Pix4D, 2017) and adjusted the plan of acquisition according to the indoor structure of the church, as shown before in Figure 4.

The optimal path could not be planned and followed upon initial observation due to obstructions from existing church artifacts, like chairs or even the altar itself. The final plan of acquisition, as seen in Figure 4, was decided upon by figuring out which paths lead to the least obstruction and consistent coverage throughout the project area, still following the best principles in the referenced article from Pix4D.

Additionally, the other materials and permits for capturing photos and conducting the study on the premises of the church were secured in this section.

2.3.2 Image Acquisition: At this stage, images were captured in the project area using the designated camera, following a pre-planned capture path. Camera settings and lighting conditions were carefully considered during image acquisition. Each image was taken around 2 to 4 steps of each other along the dotted paths in Figure 4. Besides neutral or level shots, additional oblique camera angle shots were used to ensure coverage for more complex details and geometry, such as the ceiling and each indoor object of highlight (Chair, Stand/Podium, Altar Desk). Only natural and recreational lighting for the church was used. Additionally, clear measurements of indoor objects are also made for later accuracy checks. These measurements were done at a millimeter level. Three (3) objects were measured in length, width, and height: the podium, the altar desk, and a chair.

Furthermore, upon the creation of a low-quality processed model in the image processing stage, gaps are inspected in the reconstruction. After a quick assessment of these gaps, the researchers return to the Image Acquisition stage to fill in the gaps with more images for better reconstruction.

2.3.3 Image Processing: At this stage, after compiling and importing all obtained images in Agisoft Metashape, photos were aligned with Natural Relative GCPs in overlapping images, which would help achieve better & quicker processing and results. The relative natural GCPs were chosen due to their point-like structures and spatial distribution. By denoting these GCPs as the same among multiple images, the computational process for image matching became easier and minimized distortion and mismatching, rather than if no GCPs were chosen at all. Within the overlapping images, four (4) GCPs were chosen as seen in Figure 6.

Figure 6. Natural Relative GCPs chosen.

Within this stage in the workflow, two substages occur: (I) Generation of the 3D Model; and (II) Refinement of the 3D Model.

In (I) Generation of the 3D Model, after photo alignment, low confidence points in reconstruction and points outside the project area from the point cloud were removed. Each GCP was then inspected and manually adjusted in each image to optimize camera positions and photo alignment for cleanup. Afterwards, the dense cloud and mesh were generated. Figures 7, 8, and 9 all show the point cloud before cleanup, dense cloud, and mesh for visualization purposes.

Figure 7. Raw Point Cloud.

Figure 8. Dense Cloud.

Figure 9. Textured Unrefined Model or Mesh.

For (II) Refinement of the 3D Model, the mesh was duplicated and decimated to a quarter of its original number of faces. Holes in the mesh were also filled using the Close Holes tool and then retextured. This process was done for quicker and lighter sharing of the model. After retexturing, objects in the model that had measurements taken during the image acquisition stage were measured in each dimension (or length, width, and height) to obtain a preliminary accuracy assessment and to calculate the scale factor of the model. The overall scale factor of the model was calculated by averaging the scale factors obtained from one measurement of an object in each of the three dimensions. For example, the overall scale factor can be computed from the scale factor from the length of the podium, the scale factor from the width of the altar desk, and the scale factor from the height of the chair. The measurement was chosen based on the object's clarity of measurement as observed in the model. If one dimension of the object had more clearly defined endpoints for the measuring tool, that measurement was used to calculate the scale factor. Equation 1 shows a concise representation to calculate the scale factor of an object.

$$S_n = \frac{Rd_n}{Md_n} \tag{1}$$

where S_n is the scale factor of object n
Rd_n is the real measurement of dimension d of object n
Md_n is the model measurement of dimension d of object n

After calculating the overall scale factor of the model, the model was imported into MeshLab and rescaled with the overall scale factor uniformly, using the barycenter as the basis for rescaling. Figure 10 demonstrates this in a screenshot from Meshlab. After rescaling, the final model was reimported into Agisoft for accuracy assessment, the next stage in the workflow.

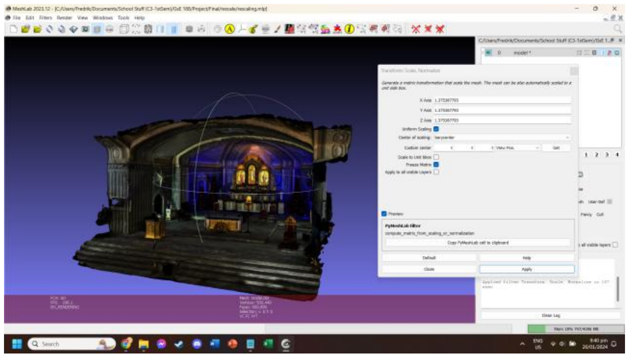

Figure 10. Rescaling the model in Meshlab.

2.3.4 Outputs & Accuracy Check: After creating the final model, absolute measurement differences were measured and inspected for model inconsistencies and clarity issues. Equation 2 was applied for the absolute measurement differences. Figure 11 demonstrates the measurement tool in Agisoft using the final model.

$$\%\,diff = \left(\frac{Rd_n - Md_n}{Rd_n}\right) \times 100\% \tag{2}$$

where $\%\,diff$ is the percent difference between the real measurement and model measurement
Rd_n is the real measurement of dimension d of object n
Md_n is the model measurement of dimension d of object n

Figure 11. Measuring the altar desk in Agisoft Metashape.

3. Results and Discussion

Overall, a 3D Model of the interior of San Felipe Neri Parish was successfully reconstructed using Agisoft Metashape and MeshLab. The full model can be seen in Figures 12 and 13, showing the exterior of the mesh and interior structure, respectively.

Figure 12. Exterior view of the Model

Figure 13. Interior view of the Model

3.1 Preliminary Accuracy Assessment & Scale Factor

Measurement of the unscaled model validates the scale issue during reconstruction, as the percent difference between measurements consistently fluctuates around 25 to 30%, as seen in Table 1. The chosen measurements from each object to be used for calculating the scale factor would be the altar desk height, podium width, and chair length. These particular dimensions were chosen over others because of their rigidity among each object in consideration of each object's existing structure and position in the study area to minimize distortion effects throughout the whole study area after rescaling. From Table 2, the average or overall scale factor applied for the final model is 1.375387793, scaling up the measurements.

Object	Dimension	Measurement (m)	Model (m)	% difference
Altar Desk	Length	2.500	1.870	25.200
	Width	0.900	0.647	28.111
	Height	1.000	0.715	28.500
Podium	Length	1.200	0.904	24.667
	Width	0.930	0.695	25.269
	Height	1.170	0.846	27.692
Chair	Length	0.710	0.511	28.028
	Width	0.710	0.496	30.141
	Height	1.655	1.190	28.097

Table 1. Preliminary Measurement Comparison

Object	Dimension	Scale Factor	Average Scale Factor
Altar Desk	Length	[redacted]	1.375387793
	Width	[redacted]	
	Height	1.398601399	
Podium	Length	[redacted]	
	Width	1.338129496	
	Height	[redacted]	
Chair	Length	1.389432485	
	Width	[redacted]	
	Height	[redacted]	

Table 2. Scale Factor Calculation

3.2 Accuracy Assessment

Based on the differences found in Table 3, the model is very accurate, boasting percent differences of less than 5% for all model object measurements. The percent difference varies from 0 to 3.6% overall. From these measurements, the model was correctly reconstructed and can be applied to other applications and purposes when it comes to obtaining precise measurements indoors.

Object	Dimension	Measurement (m)	Model (m)	% difference
Altar Desk	Length	2.500	2.590	3.600
	Width	0.900	0.904	0.444
	Height	1.000	1.000	0.000
Podium	Length	1.200	1.240	3.333
	Width	0.930	0.916	1.505
	Height	1.170	1.190	1.709
Chair	Length	0.710	0.705	0.704
	Width	0.710	0.720	1.408
	Height	1.655	1.690	2.115

Table 3. Absolute Measurement Comparison

3.3 Clarity Assessment

Some clarity issues have been noted upon inspection: (1) broken features; (2) ghost or duplicate features; and (3) inconsistent meshes.

When it came to broken features, some artifacts or objects could have been split into multiple segments or meshes during reconstruction, as seen in Figure 14. The artifact was broken into two parts rather than one full pole or cross. This issue is best fixed by adding more photos encircling the broken object to ensure precise reconstruction.

Figure 14. Broken Feature

For ghost or duplicate features, some objects could have moved during the image acquisition process, causing duplicate reconstructions seen in the chair in Figure 15. The chair was duplicated as it was moved from one place to another while the researchers were capturing photos. This problem could be fixed through removal in 3D Modeling software; Usually, this issue is fixed through deletion in the point cloud during image processing. However, since the reconstructed model is indoors, the selection of duplicate points would have been more difficult and tedious than simply post-processing the 3D model in other software.

Figure 15. Ghost or Duplicate Feature

In the case of inconsistent meshes, some thin and easily moved objects such as cloth could cause incorrect reconstructed meshes or faces, as seen beside the altar desk in Figure 16. A random floating mesh was made near the table, possibly due to the cloth around the table moving during photo capture. This problem could be fixed through removal in 3D Modeling software or affixing light objects during photo capture in the image acquisition stage.

Figure 16. Inconsistent Mesh beside Altar Desk

Despite these clarity issues, overall, many features have been successfully reconstructed with great detail and clarity, including the ceiling of the interior of the main altar as seen in Figure 17. Smaller and more complex features are less detailed but still surprisingly are well-represented in the reconstructed model. Such is the case of Figures 18 and 19, where the saints' poses and larger details like color and outfits are well captured but to acquire more detail on the smaller body parts like the arms or faces require more images.

Figure 17. Main Altar Ceiling

Figure 18. Left side Saint model

Figure 19. Right side Saint model

Additionally, there are novel challenges found that were not initially expected in the study, such as strong light distorting reconstruction, moving cloth causing inconsistencies as mentioned before for Figure 16, and single color objects like rugs or TV screens causing holes in the mesh.

In the case of strong light distorting reconstruction, this is best seen in Figure 20, where the main altar saints' faces become completely yellow or white due to the strong amount of light reflected on their faces' surface from the nearby altar frame lights. The details on their outfits are more clarified than the previous saints due to their size, but the skin and lighter features like facial shape or cheeks are distorted due to the strong light. The distortion is most pronounced in the saint's face at the left of the main altar.

Figure 20. Main Altar Saints

https://doi.org/10.5194/isprs-archives-XLVIII-5-W4-2025-103-2026 | © Author(s) 2026. CC BY 4.0 License.

In the case of single-color objects causing holes in the mesh, this is best seen in Figures 21 & 22, and 23 & 24, which collectively showcase the dense clouds and captured pictures of a wall rug and TV screen respectively, found at the edges of the project area.

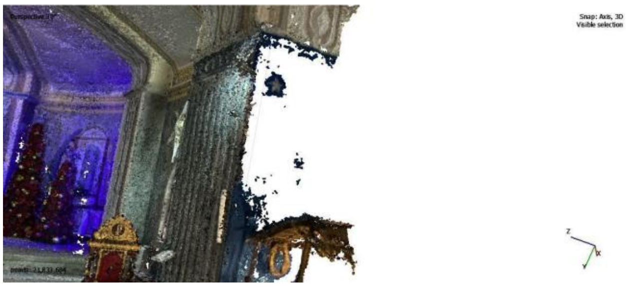

Figure 21. Wallrug Dense Cloud

Figure 22. Wallrug Captured Photo

The wall rug was not even reconstructed in the final model due to how much of its surface area was missing. On the other hand, the TV screen was missing most of its points that would have reconstructed its screen surface, only keeping the extent of the actual screen.

Figure 23. TV Screen Dense Cloud

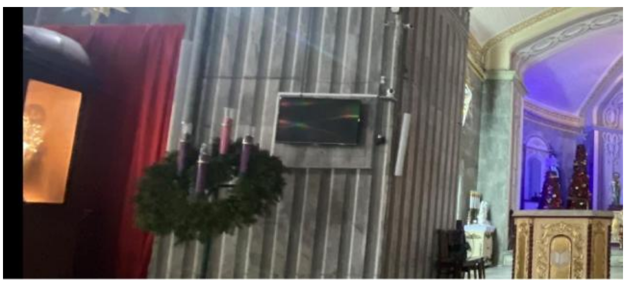

Figure 24. TV Screen Captured Photo

4. Conclusions

The application of close-range photogrammetric techniques for the 3D reconstruction of San Felipe Neri Parish's interior is successful, albeit with a few minor caveats. The process requires thorough planning and execution of an image-processing workflow in Agisoft, resulting in a 3D model that captures the overall structure of the project area with an adequate level of detail and accuracy. However, there are limitations in accurately representing every feature within the church.

Novel challenges surfaced during the process, such as the mesh distortion caused by slight movements of the cloths around the table. To address this issue, it is important to ensure the consistency and rigidity of object movement during the image acquisition phase. Only natural and recreational lighting for the church was used during image acquisition, thus features with harsher or intense lighting become distorted or even outright blank after applying textures. In the case of indoor churches such as this with no large windows for natural light to enter, it is recommended for future application and studies that neutral lights (such as white light) and balanced intensity for lights must be adjusted whenever possible for the best results. Additionally, numerous holes in the mesh were observed, attributed to features with a single, unchanging color, such as the wall rug and TV Screen. To enhance hole-filling, it is recommended to explore advanced methods that involve implementing algorithms capable of effectively interpolating missing data, addressing both simple and complex holes. Furthermore, areas with excessive light impacted the clarity and reconstruction of intricate artifacts, notably the Saints on the altar. To optimize results, the study recommends experimenting with alterations in the plan of acquisition for capturing images. Exploring different angles and perspectives can minimize potential blind spots. Utilizing higher-resolution cameras mounted on tripods is essential to prevent camera shake and ensure sharpness and clarity in images. Stability is a factor in achieving a more accurate 3D representation. Lastly, improving the processing method by exploring more advanced processing techniques or software can provide better optimization of mesh. These recommendations suggest refining the overall workflow for better 3D reconstructions of the interior of cultural heritage sites.

Despite encountering these challenges, the successful reconstruction enables the preservation of cultural heritage, as exemplified by the San Felipe Neri Parish. The next crucial step involves delivering the 3D model to relevant authorities responsible for cultural heritage preservation, ensuring broader access to digital documentation, and allowing for collaborative efforts in its proper management. Providing the 3D model facilitates the establishment of a comprehensive database dedicated to preserving cultural artifacts and architectural elements. Moreover, this lays the foundation for informed decision-making regarding conservation efforts, restoration projects, and future planning, ensuring the church's lasting cultural significance. In conclusion, this study underscores the potential and significance of close-range photogrammetry in cultural heritage preservation.

References

Bedford, J., 2017: Photogrammetric applications for cultural heritage: Guidance for good practice. Historic England.

El-Din Fawzy, H., 2019: 3D laser scanning and close-range photogrammetry for buildings documentation: A hybrid technique towards a better accuracy. *Alexandria Engineering Journal*, *58*(4), 1191–1204. https://doi.org/10.1016/j.aej.2019.10.003

Pix4D., 2017: Indoor mapping in 3D using photogrammetry software. https://www.pix4d.com/blog/indoor-mapping-game-plan/ (24 January 2024).

Pérez Ramos, A., Robleda Prieto, G., 2015: 3d Virtualization By Close Range Photogrammetry Indoor Gothic Church Apses. The Case Study Of Church Of San Francisco In Betanzos (La Coruña, Spain). *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XL-5/W4*, 201–206. https://doi.org/10.5194/isprsarchives-xl-5-w4-201-2015

Philippine Faith and Heritage Tours., 2022: San Felipe Neri Parish, Mandaluyong City - Philippine Faith and Heritage Tours. https://philippinefaithandheritagetours.com/san-felipe-neri-parish-mandaluyong-city/ (24 January 2024).

San Felipe Neri Parish., n. d. About Us. https://www.rcam.org/sanfelipeneriparish/about-us/ (24 January 2024).

Mary Help of Christians., 2020: San Felipe Neri Parish – Mandaluyong City. https://maryhelpjorizchapel.wordpress.com/san-felipe-neri-parish-mandaluyong-city/ (24 January 2024)