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Internship Report

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Interuniversity Department of Regional and Urban Studies and Planning (DIST)

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Reconstruction of 3D point cloud model based on Agisoft Metashape and CloudCompare - the example of New-Wing Building

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Supervisor:
Piero Boccardo

Candidate:
Tan Xiao

Company Supervisor:
Luigi La Riccia
Vittorio Scolamiero

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Abstract

During the past few years, new developments have occurred in the field of 3D photogrammetric modeling. One of these developments is the expansion of 3D photogrammetric modeling open-source software, such as VisualSfM, and cost-effective licensed software, such as Agisoft Metashape into the practical and affordable world. This type of SfM (Structure from Motion) software offers the world of distorted 3D modeling a powerful tool for restructuring and visualization. On the other hand, low-cost cameras are now available on the market. These cameras are characterized by high resolution and a good-quality lens, which makes them suitable for photogrammetric modeling. This report describes the results of the application of an SfM Photogrammetry system in the 3D modeling of the New-Wing Building in the Politecnico of Turin of Architecture campus. The applied photogrammetric system consists of the iPhone 13 Pro Max, the commercial software Agisoft Metashape, and CloudCompare. Finally, the reconstruction New-Wing building model is integrated into the whole model.

Keywords: *CloudCompare, Metashape, 3D point cloud Model, low-cost photogrammetry, Structure from Motion (SfM)*

Introduction

The mesh model obtained through Unmanned Aerial Vehicle (UAV) photogrammetry methods is typically affected by factors such as weather and building surface materials, leading to a significant decrease in accuracy and ultimately resulting in distortion. Currently, SfM Photogrammetry is the main technique used to reconstruct the distorted 3D point cloud model, in the form of a dense 3D point cloud. SfM Photogrammetry involves acquiring images from several positions relative to the studied object. An algorithm, such as the scale-invariant feature transform (SIFT) identifies distinctive features appearing on multiple images. It establishes the spatial relationships between the original camera positions in an arbitrary and unscaled coordinate system. Using control points, a bundle adjustment is then applied to extract a sparse set of coordinates to represent the object.

SfM Photogrammetry is an important 3D modeling tool due to automated workflows in the new generation of photogrammetric software. These capabilities have significantly helped to reduce the level of knowledge necessary to obtain satisfactory survey results.

New low-cost photogrammetry software based on the SIFT algorithm rapidly expanded to practice due to the advantages of simple automatic processing of image set into a color dense point cloud, which can be used for 3D modeling. For low-price, this type of software can perform both image alignment, dense 3D point cloud generation, and 3D model reconstruction in a fully automated way. Commercial software packages are better than free or open-source ones in 3D modeling, but these software packages can find a lot of applications that do not require high accuracy. Thus, commercial software, together with a standard PC and digital camera, represents an SfM Photogrammetry system that can be used to model cultural heritages in a precise way.

In this report, we deal with SfM photogrammetric 3D modeling of the outside face of the New-Wing building, a new structure in the Politecnico of Turin of Architecture campus.

Metashape

In this report, the software Agisoft Metashape, produced by the Russian company Agisoft LLChas, was used to create 3D products of the distorted New-Wing building. At the first stage, the software reconstructs the virtual positions of the cameras that were used. The next step involves the creation of a 3D dense point cloud. To complete the georferencing task, Agisoft requires some control points that can be used to scale the 3D model and to achieve higher accuracy. After the geometry is constructed, it ca be imported to the CloudCompare, integrating with the whole model. In this report, we use the version of 1.7.5.13229 to run the whole process.

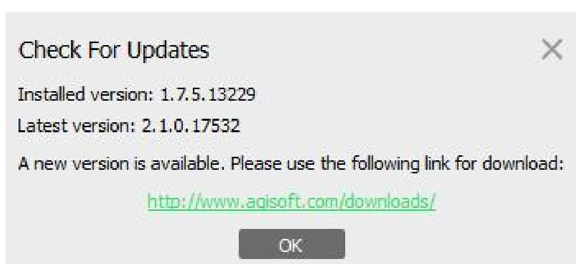


Figure 1 The version information of the Metashape

CloudCompare

CloudCompare is an open source software originally designed to process and compare both 3D point clouds and triangular meshes. Its development began in 2003 and in the last years it evolved into a more generic 3D data processing software, including different kind of algorithms allowing to perform registration, noise filtering, point classification, normal computation and many other functions. In this report, we use the version is 2.12.2 to compute the difference between the original model and restructured model.

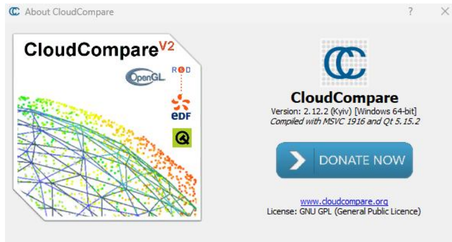


Figure 2 The version information of the CloudCompare

3D Point Cloud Model Restructure

Material Prepared

Device choices

The initial mesh model was generated using images captured by a UAV. However, due to cost and size considerations, for the reconstruction work of the New-Wing building, a personal camera was ultimately used. In this report, images were captured using an iPhone 13 Pro Max.

Route choices

Following the general principle for photogrammetric surveying of the New-Wing, aiming to maintain a consistent distance for each photography spot[1].

Referring to Fig. 3 and 4, we can observe that the distance between the Aloisio Block complex and the New -Wing building is too close to capture the whole New-Wing building in the normal way at position 2. While, from the UAV image in Fig. 4, it is evident that the Aloisio Block complex would obstruct the view of the New-Wing building if photographed from position 1. Consequently, I opted to take the pictures from the grass at position 2, creating two strips (one for the top of the building and another one for the rest part). Meanwhile, I ensured a vertical overlap of approximately 60% and a horizontal overlap of 80% with the tilted camera.

Environment factors

The New-Wing building is predominantly made of glass. Referring to this research paper[2], we know that in sunny conditions, shadows can cause distortion in the glass portions. Therefore, for our photography, we opted for overcast days to mitigate this effect.

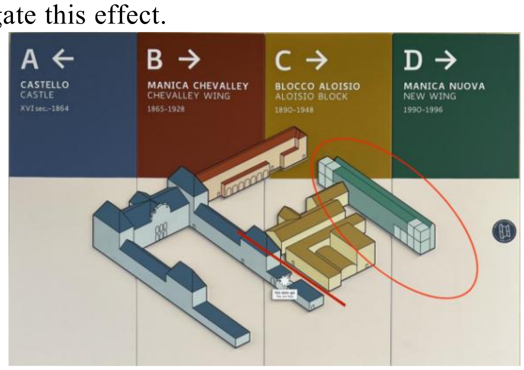
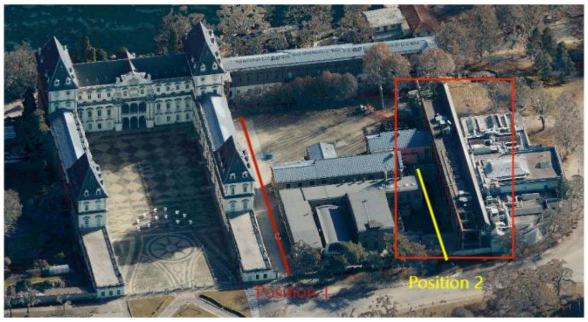


Figure 3 New-Wing Building Location



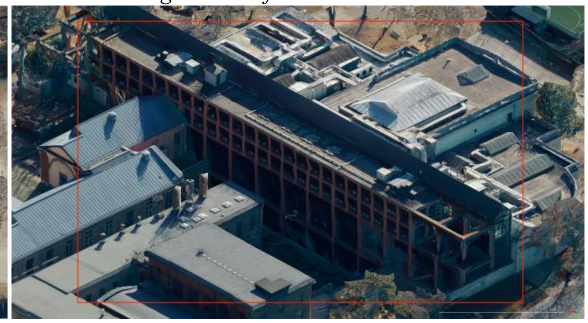


Figure 4 Top View of New-Wing Building *Figure 5 Side View of New-Wing Building (Wall Part)*

Figure 6 Side View of New-Wing Building (Grass Part)

Model Generated

Images were taken in maximum resolution as possible (4032x3024 pixel), with good overlapping between images, and the presence of points on as many images as possible. Given that the grass part cannot be captured manually due to site constraints, we will only reconstruct the wall part. The report involved a total of three reconstruction works. 97 photos were used to generate the dense model for Chunk 1. However, it was observed that the right side of the model had sparse points, leading to an incomplete final model. In the second attempt, reconstruction work was carried out using 110 photos. It was found that distortion still existed in the glass portion of the building, possibly due to the presence of some shadows. In the third attempt, a complete dense model was constructed using 165 photos, with no observed distortions. We selected the third attempt as the final model.

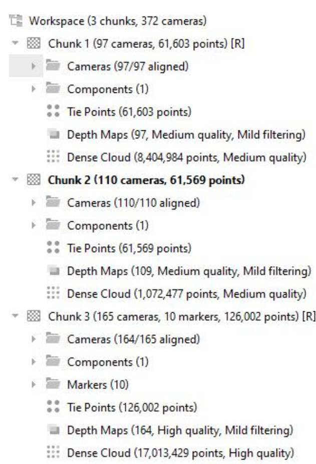
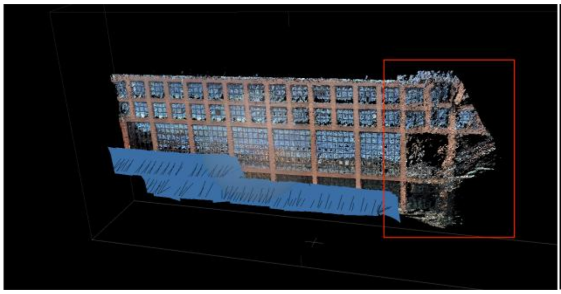


Figure 7 Chunks Information



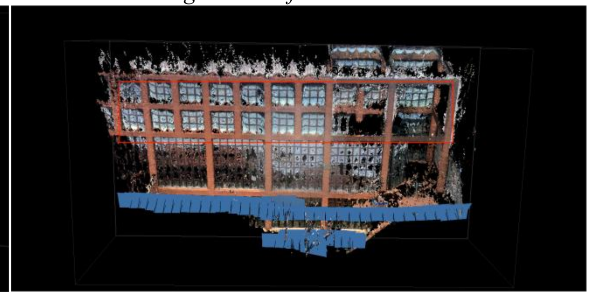


Figure 8 Chunk 1 Dense model and camera locations *Figure 9 Chunk 2 Dense model and camera locations*

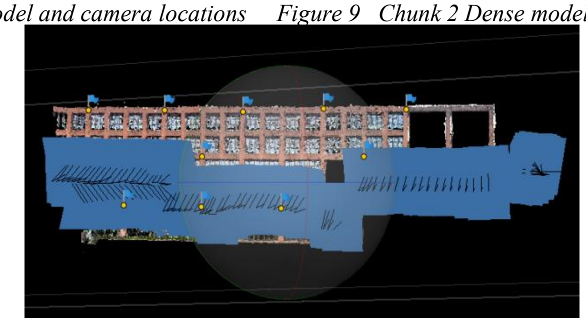


Figure 10 Chunk 3 Dense model and camera locations

3D Point Cloud Model Registration

The Point Registration

In Metashape there are 2 types of markers. They are control and check points: Control points are used to reference the model. While check points are used to validate the accuracy of the camera alignment and optimization procedures results.

In this part, we uniformly extracted 13 coordinate points from the new dense model to scale it with the original model (as shown in Fig. 11 and 12). However, considering the final error values, we omitted points 1, 9, and 10, as they exhibited significant errors. Points 2, 4, 3, 5, 6, 7, 11, and 12 were selected as control points, while the remaining points 8 and 13 were designated as check points (as shown in Fig. 13). Comparing their differences in the "Total Error" section, we found that the difference between 0.357361 and 0.318789 was insignificant, indicating that the new dense model had been scaled to match the scale of the original model. Therefore, we proceeded with the next step of importing the model.

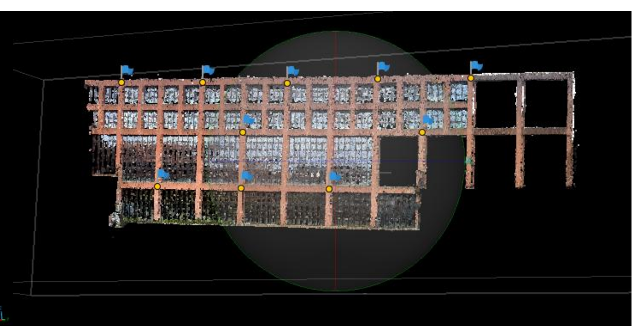
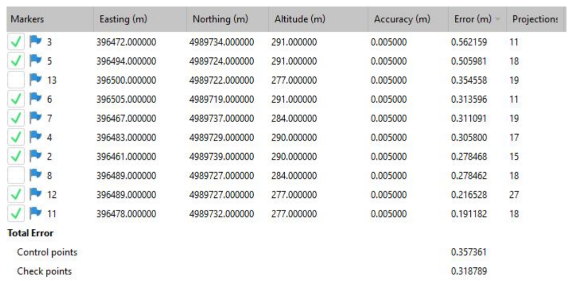


Figure 11 Control points information *Figure 12 Control points distribution (Chunk 3)*

Table 1 Control points coordinate information

POINTS	X	Y	Z
1	396467.570577	4989737.153477	284.883744
2	396461.806577	4989739.787449	290.918744
3	396472.801577	4989734.605450	291.163744
4	396483.488577	4989729.669445	290.980744
5	396494.656577	4989724.489449	291.049744

POINTS	X	Y	Z
6	396505.680577	4989719.368447	291.136744
7	396467.570577	4989737.153447	284.883744
8	396489.462577	4989727.118447	284.943744
9	396505.161576	4989720.163449	284.115744
10	396467.461577	4989738.413449	279.088744
11	396478.450577	4989732.064450	277.772744
12	396489.166577	4989727.100449	277.648744
13	396500.113578	4989722.941449	277.463744



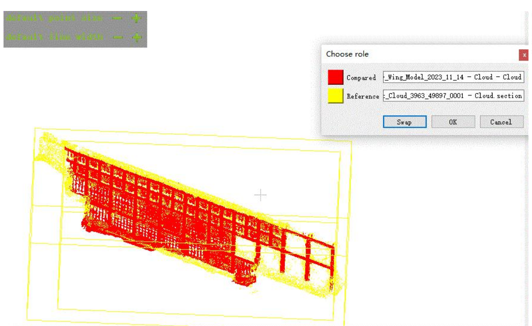
Markers	Easting (m)	Northing (m)	Altitude (m)	Accuracy (m)	Error (m)	Projections
3	396472.000000	4989734.000000	291.000000	0.005000	0.562159	11
5	396494.000000	4989724.000000	291.000000	0.005000	0.505981	18
13	396500.000000	4989722.000000	277.000000	0.005000	0.354558	19
6	396505.000000	4989719.000000	291.000000	0.005000	0.313596	11
7	396467.000000	4989737.000000	284.000000	0.005000	0.311091	19
4	396483.000000	4989729.000000	290.000000	0.005000	0.305800	17
2	396461.000000	4989739.000000	290.000000	0.005000	0.278468	15
8	396489.000000	4989727.000000	284.000000	0.005000	0.278462	18
12	396489.000000	4989727.000000	277.000000	0.005000	0.216528	27
11	396478.000000	4989732.000000	277.000000	0.005000	0.191182	18
Total Error						
Control points					0.357361	
Check points					0.318789	

Figure 13 The Error accuracy report

Integrate to the whole Model

First, we import the newly created model and the original model into the CloudCompare software. Use the tool in CloudCompare named Cloud/Cloud Distance to compute the difference between the original model and the restructured model.

Finally, in the 'Properties' menu, under the 'Display Ranges' section, we observe the values. Setting saturation to 1, the minimum difference displayed is 0.00119828 m, and the maximum difference is 0.99973825 m.



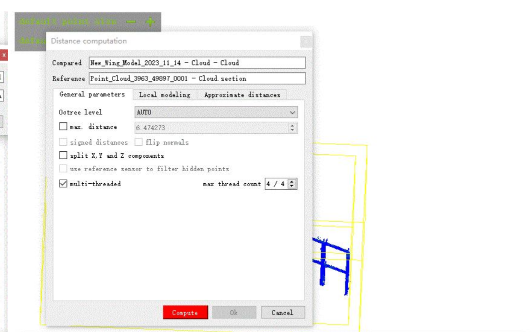


Figure 14 Roles choice

Figure 15 Parameters choice

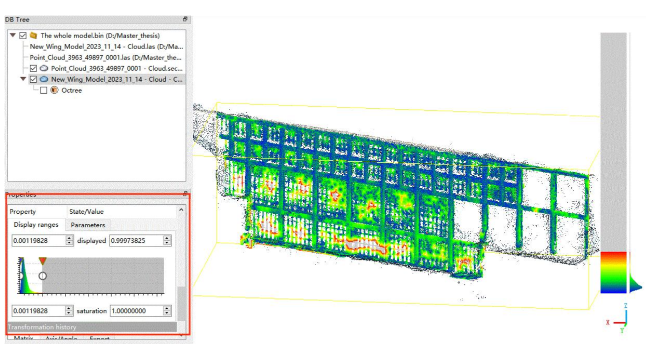


Figure 16 The difference between the original and reconstructed model

We found significant discrepancies in the glass portion due to shading, so we removed the glass portion and recalculated the absolute distance between the original model and the reconstructed model (as shown in Figure 17). We output Histogram (as shown in Figure 18) and found that the majority of the differences are within 0.5 meters. Thus, we concluded that the new reconstructed model has been successfully aligned with the position of the original model with high accuracy.

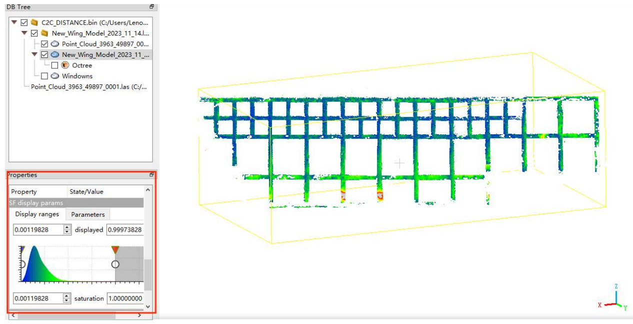


Figure 17 The difference between the original and reconstructed model without the Windows Part

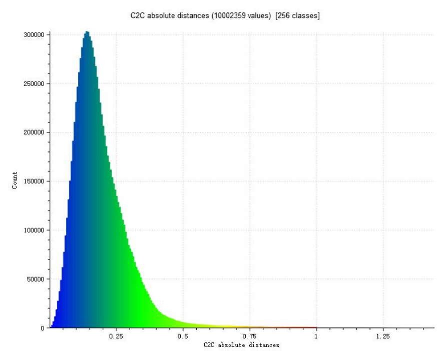


Figure 18 The Histogram of C2C absolute distance

Conclusion

In conclusion, this study demonstrates the efficacy of SfM Photogrammetry in reconstructing 3D models, exemplified by the New-Wing building at the Politecnico of Turin Architecture campus. Leveraging affordable software such as Agisoft Metashape and tools like CloudCompare, we successfully generated accurate models from iPhone 13 Pro Max images. Integration of technologies like control point registration and 3D point cloud restructuring was pivotal, mitigating challenges such as weather and building materials. Our approach, informed by careful route planning and consideration of environmental factors, minimized distortion. This research underscores the value of an integrated approach in 3D modeling, with broad implications for architecture, urban planning, and cultural heritage preservation.

References

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