

Analysis of Point Density and 3D Mesh Geometry in the Gebouw Van Padangsche Spaarbank Building

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ABSTRACT

Cultural heritage archiving by collecting and managing archives that include documents, archiving using the Close-Range Photogrammetry method by analysing point density and creating a 3D model of the Gebouw Van Padangsche Spaarbank building by taking overlapping photo data from different camera angles. This research aims to analyse point density and 3D mesh geometry to create archives, increasing efficiency in information management. In this research, the results were obtained from 3D modelling of the Gebouw Van Padangsche Spaarbank building using the close-range photogrammetry technique, which resulted in 157 photos being used to create the 3D model. The flying height of the drone is no more than 20 m with the height of each line being different, for Line 1 which is on the top line at the height of 17 m, Line 2 at a height of 10 m, Line 3 at a height of 7 m and for Line 4 at a height of 3m The results obtained from this analysis were a total of 94,869 tie points from 144,764 results, 15,393,722 dense clouds, and 529,237 faces. The results of the comparative calculation of the 3D model building dimension accuracy test against the actual size in the field produce an average distance of 0.1408 m.

Keywords: Close Range, Filing, modeling

1. Introduction

Over time, knowledge of heritage was based on various more or less rudimentary topographical methods, which could design, arrange and construct buildings using simple instruments and drafting techniques. Uses various drafting and cartographic tools well [1]. Cultural heritage must be preserved because there are still many who do not have the awareness to maintain cultural heritage as the nation's cultural heritage [2].

On the other hand, cultural heritage can be preserved by utilizing technology that has developed today, such as Building Information Modeling (BIM). BIM is emerging as a new paradigm for the construction industry, which can facilitate the integration of construction interests. This integration ensures alignment and construction efficiency [3]. Currently, BIM is a digital representation of the physical and functional characteristics of a building, whether in the form of a building or other structure, which contains all information from the design stage to demolition [4]. All these examples show that geometric information is indispensable in the construction of 3D models [5].

Meanwhile, 3-dimensional models can be obtained from several overlapping images using the Structure from Motion (SfM) method with the same basic principles as conventional photogrammetry [6]. SfM is a method that allows the recording of historical heritage in 3D format. Imaging methods based on photogrammetry, 3D laser scanning, video measurements and remote sensing are the most effective tools. Additionally, SfM has undoubtedly changed the way archaeologists and architects model cultural heritage sites in 3D [1]. Meanwhile, knowledge of historic buildings and their components is also enhanced through activities such as preliminary investigations, interpretation of metrological data and material analysis. When it comes to 3D modelling in architecture and archaeology, there is new Structures from Motion/Multi-View-Stereo (SfM/MVS) algorithms

that make modelling easier than photo or video surveys. This research aims to analyse point density and 3D mesh geometry to create archives, increasing efficiency in information management.

2. Research methodology

This research was carried out for archiving using the Close Range method by analysing point density and creating a 3D model of the Gebouw Van Padangsche Spaarbank building by taking overlapping photo data from different camera angles. Close range involves measuring and analyzing objects using two-dimensional photographs taken at close range, aiming to obtain information about the shape, size and position of three-dimensional objects based on their representation in the image [7].

2.1 Research sites

This research is located on Jalan Batang Arau Number 5, Kampung Pondok, West Padang, Padang, West Sumatra at coordinates 0°57'47.2"S 100°21'46.3"E. The research location itself can be seen in **Figure 1**.



Figure 1. Gebouw Van Padangsche Spaarbank

2.2 Research Tools and Data

The tools used in this research can be seen in **Table 1** and **Table 2**.

Table 1. Survey Equipment

No	Tool Name	Tool Function
1	DJI Phantom 4 Pro drone	As a tool for taking building photo data
2	Topcon OTS 102N Total Station	As a tool to obtain ICP coordinate values

Table 2. Software

No	Tool Name	Tool Function
1	Laptops	As data processing hardware
	Agisoft Metashape	Software for Photo Data Processing
2	Microsoft Office Software	Making reports and processing Total Station data

The data used for this research are photo data and independent control point (ICP) coordinate values obtained from data collection in the field which can be seen in **Table 3**.

Table 3. Data Used for Research

No	Name	Use	Source
1	DJI Phantom Drone Closerange	Used to maintain shape and color	Field Acquisition Year 2024
2	ICP coordinates	Used to maintain size	Field Acquisition Year 2024

2.3 Research Stages

1. Preparation

The aim of the literature study is to strengthen theory in solving the problems being researched regarding point density and 3D mesh geometry so that they can be solved well and perfectly. What is

done next is the preparation of tools and materials, equipment that will be used to support the implementation of research objectives. The tools used in this research were one DJI Phantom 4 Pro Drone unit and one OTS 102N Total Station package. Before collecting information, the thing that must be considered is the information collection scheme. The information collection scheme is an activity to find out a systematic plan for collecting information or information in research to make it easier for us to combine the location to be measured, what the condition of the location is, the position and shape of the building, the data collection scheme can be seen in **Figure 3** in picture a. that is a measurement using a Total Station tool, b. distribution of ICP points on the building facade and c. distribution of Drone trajectories.

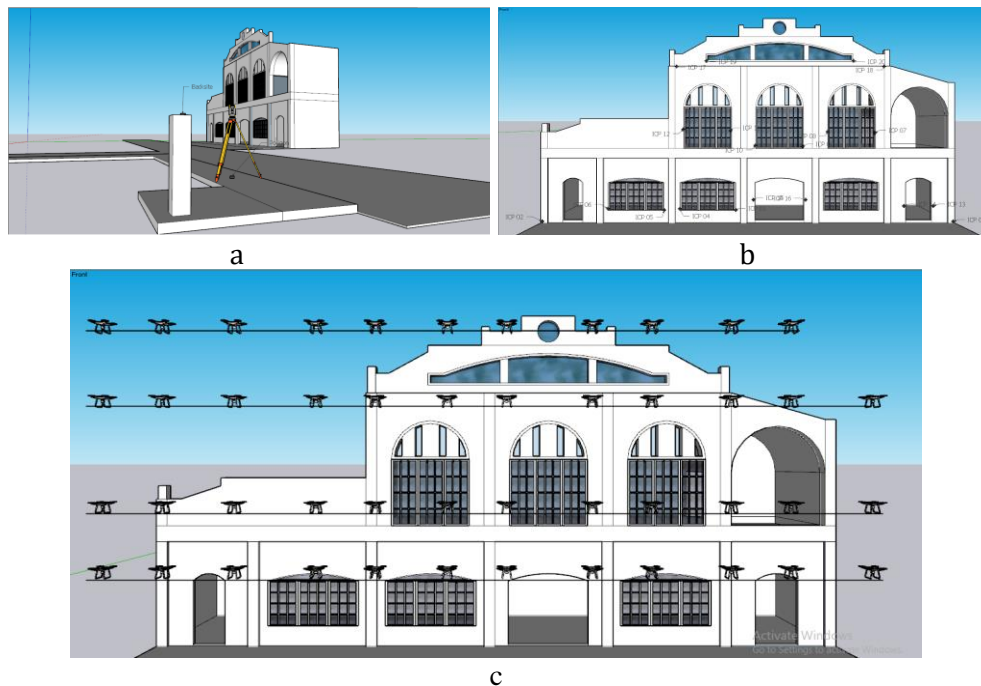


Figure 3. a. Measurement using Total Station, b. ICP point distribution, c. Distribution of Drone trajectories

2. Data collection

In the research, there are two methods of collecting information. The first is taking Independent Control Point (ICP) coordinates using a Total Station tool. The methodology is based on calculating the distance between the laser and the object. This method sweeps the entire surface by capturing several points in a coordinate system (x,y,z) to obtain a range cloud. Second, using the close-range method using drone instruments. The methodology when collecting information uses drone instruments by taking photo information at a distance of 5-6 meters in front of the building to be studied.

1) 3D Model CreationManajemen Foto

Photo management is arranging or sorting photos that will be processed in the Agisoft Metashape computer program. Its use is to make it easier for researchers to process information. If there are missing photos when taking information, they will be added back to the photo scene itself, so its use is to make it easier for researchers to see which photos are suitable for processing and which are not suitable for processing.

2) Add Photos

This stage is the earliest stage in starting processing, where here the photos taken are imported into the Agisoft Metashape software.

3) Align Photos

The photo adjustment process in Agisoft Metashape integrates 2D images into a 3D display. After importing images, Metashape automatically matches visual features across images, arranging them

in the same time frame. Can adjust settings and utilize Global Positioning System (GPS) information. Once the adjustment process is complete, you can optimize and check the results before creating a 3D model. This process is crucial to the accuracy and detail of the resulting display, and Metashape provides the ability to create textured displays.

4) Build Dense Cloud

The cloud build process in Agisoft Metashape involves the construction of a 3D dense cloud model that is more detailed than the initial photo-based model. Metashape uses the alignment information to generate dense 3D points and details of the reconstructed object. It involves estimating the position and orientation of points in 3D space. Users can set the density of dense clouds, the level of detail, and the processing method used, such as stereo calculations or multi-view photogrammetry. This process is important to increase the accuracy and detail of 3D models produced from 2D images.

5) Build Mesh

The mesh build process in Agisoft Metashape is a critical stage in creating a 3D model. Metashape uses points obtained from dense clouds to create dense, detailed surfaces. Once the process is complete, the mesh can be viewed visually and used for further analysis or processing, such as texturing. This process is important because it converts 3D points into an accurate surface representation of the reconstructed object.

6) Import Independent Control Point (ICP) Coordinates

The Independent Control Point coordinate import process in Agisoft Metashape involves updating independent control point positions obtained from other sources into the Metashape project. This is useful for improving the registration and orientation accuracy of 3D models. By importing independent control coordinates, Metashape can use this additional information to improve modeling and mapping results, as well as ensure positional consistency between the 3D model and known control points.

3. Analysis

Accuracy analysis of 3D model coordinate accuracy using ICP points from total station measurement results and comparison with 3D model coordinates. The total station results are reduced to the 3D model coordinate results. Compare and analyze the front elevation dimensions of the building from the 3D model with the actual dimensions in the field. This comparison is intended to show the dimensional error value of the 3D model when compared from several distances.

3. Results and Discussion

3.1 Photo Results of the Close-Range Photogrammetry Method

Photos taken with the DJI Phantom 4 Pro drone camera were taken using the close-up method shown in **Figure 4**. Although there were only four photo samples, the total number of aerial photos used for processing was 157.



Figure 4. Photo Results of the Gebeouw Van Padangsche Spaarbank Building

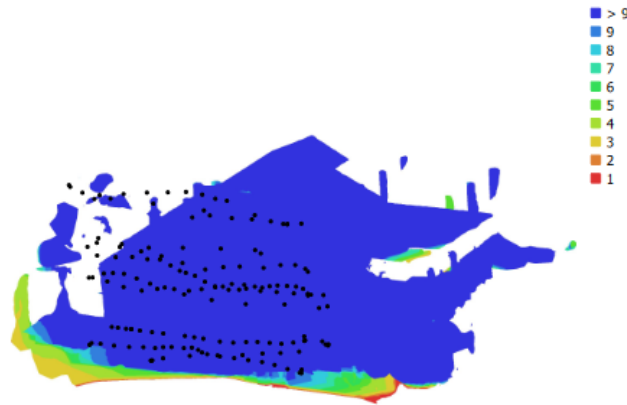


Figure 5. Distribution of Camera Locations and Appearances

Figure 5 is a distribution of drone photography locations for the Gebouw Van Padansche Sparkbank building. When taking photos, the drone has a horizontal trajectory that directly photographs objects at different heights divided into several flight paths. This path is divided into four paths as drone paths: Path 1 is 17 m above ground level, Path 2 is 10 m above ground level, and Path 3 is 7 m above ground level. Path 4 has a flight height of 3 meters above ground level. The distance when photographing a building is $\pm 5\text{m}$ from the front of the building. Photo overlays of objects that are more than 90% formed are marked with >9 , thus allowing good object modelling.

3.2 Align Photos Results

In alignment photo processing, processing results were obtained from photos taken with drone instruments, so that a total of 157 photo scenes were obtained. When making these edits, it is important to ensure each photo is positioned correctly relative to the other photos. The result is tie points that form an accurate and detailed 3D model which can be seen in **Figure 6**.



Figure 6. Align Photos Results

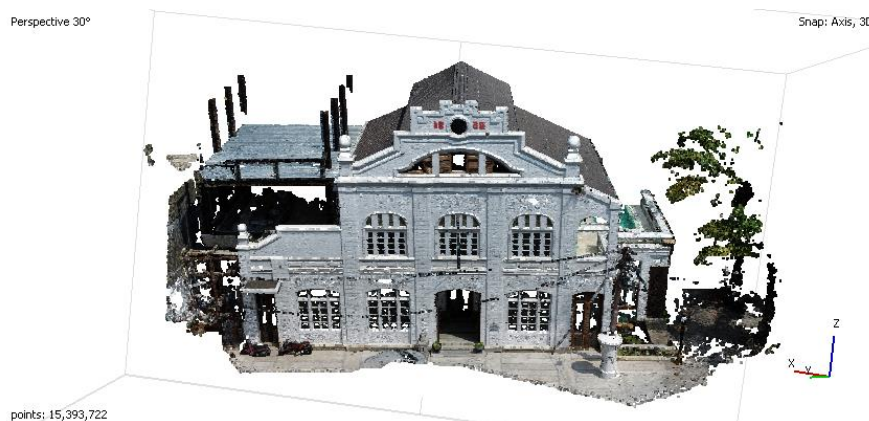
Table 4. Align Photos Information Display

Properties	Value
Points	94.869 of 144.764
Point Colors	3 bands, uint 8
Key Points	No
RMS reprojection error	0,155762 (1,63905 pix)
Max reprojection error	0,501019 (74,7473 pix)
Mean Key Point Size	8,24078 pix
Average tie point multiplicity	3,30911 point
Accuracy	Medium
Reference Preselection	Source
Key Point Limit per Mpx	1000
Alignment Time	36 second

In the Align Photos section there are several important sections. Firstly, the number of points produced during the align photos process is 94,869 out of 144,764 points and for point colors there are 3 bands of 8 units. Second, the RMS projection error is 0.155762 (1.63905 pix). Meanwhile, the MAX projection error is 0.501019 (74.7473 pix) and the mean key point size at the align photos stage is 8.24078 pix. And finally the average multiplicity tie point is 3.30911. For alignment, the accuracy parameters used are medium and initial selection reference with source type and a key point limit per MPX of 1000, with an alignment time of 36 seconds, the results can be seen in **Table 4**.

3.3 Dense Cloud Build Results

When processing the dense cloud build, the results used to continue processing are the align photos and can be seen in **Figure 7**, the results of the dense cloud build. The advantage of the dense cloud construction process is that it produces 3D models or objects that are accurate and easy to map, this is useful for architectural mapping.



Gambar 7. Dense Cloud Build Results

After carrying out the Dense Cloud process, there were additional points, initially 94,869 to become 15,393,722 points. Meanwhile, point colors still have 3 bands of 8 unit and medium quality and a mild filter mode with a max neighbor value of 16 with a processing time of 1 minute 32 seconds for the Depth maps section, while the processing time for Dense cloud is 3 minutes 2 seconds, the results can be seen in **Table 5**.

Tabel 5. Build Dense Cloud Information Display

Properties	Value
Points	15.393.722
Point Colors	3 bands, uint 8
Quality	Medium
Filtering Mode	Mild
Max Neighbors	16
Processing Time	1 minute 32 second

3.4 Mesh Build Results

The build mesh results are shown in **Figure 8**. The build mesh is created from the results of dense dense cloud build processing. The build mesh itself is used to archive and document the 3D model of the Gebouw Van Padangsche Spaarbank building. This process allows the creation of more realistic 3D models of mapped objects. Build mesh provides a frame for adding texture, color, and other visual details.

In the Build Mesh results there are a total of 529,237 faces and 265,724 vertices and a vertex color of 3 bands of 8 uint. With medium quality and mild filtering mode with a MAX neighbor value of 16 with a processing time of 1 minute 32 seconds in the depth maps section. For reconstruction parameters using an arbitrary type surface with source data using the Depth Maps type and interpolation enabled, for a processing time of 1 minute 0 seconds, the results can be seen in **Table 6**.



Gambar 8. Mesh Build Results

Table 6. Mesh Build Information Display

Properties	Value
Faces	529.237
Vertices	265.724
Vertex Colors	3 bands, 8 uint
Depth Maps	
Quality	Medium
Filtering Mode	Mild
Max Neighbors	16
Processing Time	1 minute 32 second
Surface Type	Arbitrary
Source Data	Depth Maps
Interpolation	Enabled
Processing Time	1 minute 0 second

3.5 Independent Control Point (ICP) Acquisition Results using Total Station

The results of ICP acquisition using total station equipment can be seen in **Table 7**.

Table 7. ICP acquisition using total station

Point number	Y	X	Z	Information
P1	9893514	651606	0.2	Polygon
BS	9893514.664	651603.339	0.352	Polygon
1	9893515.286	651632.39	1.529	Building Width
2	9893525.352	651652.176	1.437	Building Width
3	9893520.802	651643.498	2.011	Window
4	9893521.669	651645.184	2.027	Window
5	9893522.688	651647.105	2.047	Window
6	9893520.792	651643.48	2.028	Window
7	9893520.716	651643.376	7.523	Window
8	9893521.699	651644.997	7.797	Window
9	9893518.822	651639.74	6.92	Window
10	9893519.878	651641.374	7.195	Window
11	9893517.725	651637.455	11.341	Window
12	9893520.734	651643.279	11.449	Window
13	9893515.532	651633.618	1.881	Door
14	9893516.063	651634.44	1.888	Door
15	9893519.769	651646.809	4.39	Door
16	9893519.87	651641.505	4.042	Door
17	9893516.309	651634.279	10.712	Building Top
18	9893522.592	651646.136	10.97	Building Top
19	9893518.081	651637.987	14.919	Building Top
20	9893522.462	651646.008	12.166	Building Top

The Independent Control Point (ICP) measurement results were obtained from data collection in the field using a total station tool which is used to control the quality of 3D model building objects. The method for taking ICP points is to use two polygon points with reference coordinates from UTM. The ICP positions that are targeted include several parts such as windows, doors, building width, building height. For details of the door parts taken, namely the main door with point numbers 16 and 15 and the door with point numbers 13 and 14. For detail of the window parts, around 5 window parts were taken with 2 windows on the first floor and 3 windows on the second floor. For further details, it is on the width of the building with point numbers 1 and 2. For details of the top of the building, 4 points were taken with point numbers 17, 18, 19, 20. The way to get the results in the table above is by standing the tool at the polygon point that has been on the previous backsite, then aim at the object on the building facade. The aim of aiming at this section is to make it easier to analyze the distance in the field and the distance in the application to see how big the distance error is caused when comparing the distance in the field with the distance in the application. The distribution of ICP points on the 3D mesh can be seen in **Figure 9**.



Figure 9. ICP Coordinate Distribution

Taking the ICP coordinate points in the image above has important things, such as when using ICP points you can make geometry and scale corrections to the building model. It is important to ensure that the resulting model is geometrically accurate and corresponds to actual dimensions.

3.6 Building Dimension Comparison Results

The results of the comparison of building dimensions can be seen in **Table 8**. for distance comparison results, **Table 9**. for height comparison results, **Table 10**. for horizontal camera position results and **Table 11** for vertical camera position results. By using close-range photogrammetry techniques using the Agisoft Metashape application, dimensional analysis was carried out to find out how much the 3D model results matched the actual size results at the location. The analysis was carried out by taking several samples of building dimensions including distance, length and width, and building height from the 3D model.

Table 8. Distance Comparison Results

Point number	Point code	Measurement Results (meters)		Difference (meters)
		Field Distance (m)	Distance in Software (m)	
1 dan 2	Building Width	22.22	22.10	0.12
3 dan 4	Window Width	2.304	2.19	0.11
5 dan 6	Window Width	3.384	3.27	0.11
7 dan 8	Window Width	1.9	2.05	0.15
9 dan 10	Window Width	1.95	2.16	0.21
11 dan 12	Window Width	6.56	6.69	0.13
13 dan 14	Door Width	1.10	1.28	0.18
15 dan 16	Door Width	3.20	3.05	0.15
17 dan 18	Peak Width	13.42	13.20	0.22
19 dan 20	Peak Width	9.14	9.16	0.02
Amount of Difference (m)				1.408
RMSE (m)				0.1408

The formula for finding the difference between the two measurement results is to subtract the distance in the field from the distance in the software. Based on the quality control results, the difference between the distance between the photo and the ICP, Selisish, was found at points 1 and 2, namely the width of the building with a distance of 22.22 m on the ground and a distance on the software of 22.10 m with a difference of 0.12 m. At points 3 and 4, namely the window code on the 1st floor with a distance of 2.304 m in the field and a distance in the software of 2.19 m with a difference of 0.11 m. At points 5 and 6 with the window code which is also on the 1st floor, the distance in the field is 3.384 m and the distance in the software is 3.27 m with the difference between the two distances being 0.11 m. At points 7 and 8, the biggest difference is at the window on the 2nd floor of the building with a distance of 1.90 m on the ground and a distance of 2.05 m on the software with a difference of 0.15 m. At points 9 and 10, namely at the window on the 2nd floor of the building with a distance of 1.95 m on the ground and a distance of 2.16 m on the software with a difference of 0.21 m. At points 11 and 12, namely at the window on the 2nd floor of the building with a distance of 6.56 m on the ground and a distance of 6.69 m on the software with a difference of 0.13 m. At points 13 and 14, namely at the door on the right side of the building, the distance on the ground is 1.10 m and the distance on the software is 1.28 m with a difference of 0.18 m. At points 15 and 16, namely at the main door of the building, the distance on the ground is 3.20 m and the distance on the software is 3.05 m with a difference of 0.15 m. At points 17 and 18, namely at the top of the building, the distance in the field is 13.42 m and the distance in the software is 13.20 m with a difference of 0.22 m. At points 19 and 20, namely at the top of the building, the distance in the field is 9.14 m and the distance in the software is 9.16 m with a difference of 0.02 m. Of all the differences obtained, the formula used to obtain the differences is the largest distance minus the smallest distance and then the difference between the two distances is obtained. And the total difference for the entire building detail is 1.408 m. The way to get this value is to add up the total value of the differences obtained then divide it by 10 and get the result, namely 0.1408 m.

Table 9. Height Comparison Results

Point number	Point code	Measurement Results (meters)		Difference (meters)
		Field Distance (m)	Distance in Software (m)	
19	Building Top	14.919	14.70	0.219

Based on the quality control results, the difference between the building height in the field and the building height in the software was obtained, with a difference at point 19 at the top of the building with a distance of 14.919 m in the field and a distance in the software of 14.70 m with a difference of 0.219 m.

Table 10. Horizontal Camera Position Results

Mission	Number of Photos	Position	Height (m)
Line 1	11	Horizontal	17
Line 2	13	Horizontal	10
Line 3	74	Horizontal	7
Line 4	59	Horizontal	3
Total Photos			157

Based on the quality control results, quality control was obtained to see how dense the photos were horizontally, the highest density was on line 3 with a total of 74 photos and the smallest was on line 1 with a total of 11 photos. In Figure 8, you can see the display of the distribution of photos when taking data using the DJI Phantom 4 Pro Drone, by taking photos horizontally at 2-second intervals. In **Figure 10** you can see the results of the horizontal distribution of photos with a total of four lines with a height of one line of 17 m, line two 10 m, line three 7 m, line four 3 m.

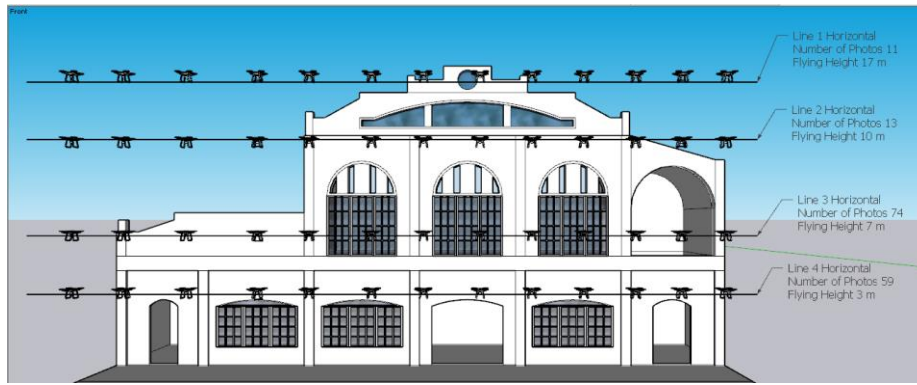


Figure 10. Horizontal Photo Spread

Based on the quality control results, quality control was obtained to see how dense the photos were vertical, the highest density was on line 7 with a total of 17 photos and the smallest was on line 1 with a total of 6 photos.

Table 11 Vertical Camera Position Results

Mission	Number of Photos	Position
Line 1	6	Vertical
Line 2	9	Vertical
Line 3	12	Vertical
Line 4	14	Vertical
Line 5	14	Vertical
Line 6	16	Vertical
Line 7	17	Vertical
Line 8	14	Vertical
Line 9	14	Vertical
Line 10	14	Vertical
Line 11	10	Vertical
Line 12	9	Vertical
Line 13	8	Vertical
Total Photos	157	

In Figure 11, you can see the display of the distribution of photos when taking data using the DJI Phantom 4 Pro Drone, by taking photos using 13 lines vertically at 2-second intervals.

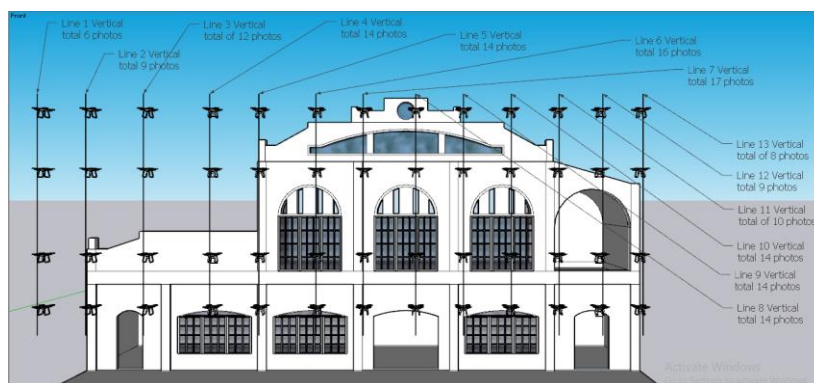


Figure 11. Vertical Photo Distribution

4. Conclusion

Based on the research that has been carried out, you can apply the Close-Range Photogrammetry method for 3D modelling of the Gebouw Van Padangsche Spaarbank building so that this method can be used to document the three-dimensional shape of the building by producing good detail and more efficiently. The implementation of this research has resulted in the conclusion that the results of 3D modelling of the Gebouw Van Padangsche Spaarbank Building using the close-range photogrammetry technique from data from 157 photos used for the

building produced a total of 94,869 tie points from 144,764 results, 15,393,722 dense clouds, and 529,237 faces. The results of the comparative calculation of the 3D model building dimension accuracy test against the actual size in the field produce an average distance of 0.1408 m. In the quality control section, the camera positions for aircraft flying heights vary, in Line 1 which is on the top line at a height of 17 m, Line 2 at a height of 10 m, Line 3 at a height of 7 m and for Line 4 at a height of 3 m.

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