

A Study on Three-Dimensional Modeling of the Baitul Ilmi Mosque's Itera Using Terrestrial Laser Scanner Technology

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ABSTRACT

As advancements in three-dimensional (3D) modeling continue to progress, the demand for precise and efficient measurement techniques has led to significant innovations in the methods and tools used for creating 3D models. Among these, the utilization of Terrestrial Laser Scanners (TLS) has become increasingly popular. This study focuses on the integration of TLS and total station technologies for 3D modeling of a mosque. The total station was employed to conduct five sets of perfectly bonded closed polygon measurements, each consisting of five polygon points, from which three marker points were derived. Concurrently, the TLS was used to perform a comprehensive scan of the mosque from 17 different positions. The data obtained from the TLS scan provided a detailed 3D model, while the total station measurements served as control points to ensure the model's global coordinate accuracy. The processing of the closed polygon data was executed using the Bowditch method, and the TLS data was registered using the cloud-to-cloud method. This approach yielded an overall quality assessment, including a bundle error of 0.008 m, an overlap of 27%, a strength of 65%, and a cloud-to-cloud discrepancy of 0.008 m. The integration of point clouds with total station coordinates resulted in an error margin of 0.160 m. Geometric validation of the model was conducted by comparing its dimensions to measurements obtained using a measuring tape, which yielded a Root Mean Square Error (RMSE) of 0.045 m.

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I. Introduction

Modeling is an activity carried out to create an object on a smaller scale which is presented in two-dimensional or 3-dimensional form so that it is easy to understand and communicate [1]. Two-dimensional modeling has two parameters, namely X and Y, while three-dimensional modeling has three parameters, namely X, Y, and Z. Modeling can be used for building reconstruction or archiving activities, as was done by [2] in the *Indonesia Menggugat* Building using TLS technology. As time goes by, three-dimensional modeling in buildings is becoming more sophisticated and diverse. This is due to the demand for measurements to be carried out in an efficient manner without forgetting accuracy, thus encouraging changes in the methods used when making three-dimensional models.

Several tools are commonly used for 3D modeling, including drones, total stations, and TLS [3]. Drones offer the advantage of covering large areas quickly but come with higher data collection costs [4]. Total stations, on the other hand, provide accurate representations of shapes and volumes but require careful distribution of measurement points, which can be time-consuming and costly (Ramadhan et al., 2020). TLS technology stands out for its fast, effective, accurate, and real-time data acquisition process [1]. However, TLS data is typically local, necessitating the integration of TLS and Total Station (TS) measurements to align the models with global coordinates.

In this study, the TS, an electronic digital survey instrument, is employed to measure frame points that connect local coordinates to a global reference system. The TS provides essential field data, including angles, distances, and coordinates [5]. Closed polygon measurements, which rely on two



known reference points to determine the initial azimuth, are used for the frame point measurements in this modeling approach [6]. Meanwhile, TLS operates by emitting a laser beam onto an object and capturing the reflected signal to record horizontal and vertical angles and distances, which are then transformed into 3D visuals [1]. The registration of TLS point cloud data in this study is performed using the cloud-to-cloud method.

II. Method

A. Location and Materials

The present study was carried out at the Baitul Ilmi Mosque located within the campus of the Sumatera Institute of Technology (Itera). The Baitul Ilmi Itera Mosque serves as a key religious facility on the Itera campus, accommodating worship and various Islamic activities conducted by the students of Itera.

B. Stages in Research

The process of creating a three-dimensional model in this study entails a series of steps. A comprehensive outline of the stages involved in this research implementation is depicted in Figure 1 below.

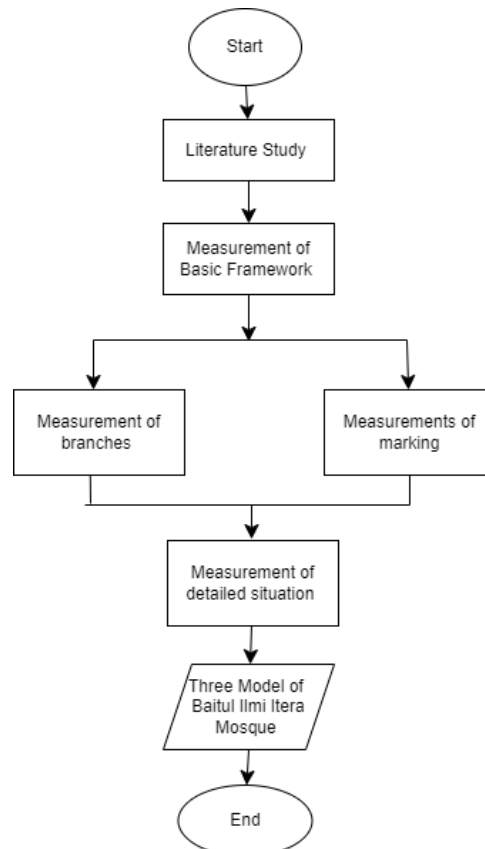


Fig. 1. Flowchart of three-dimensional modeling of the Baitul Ilmi Itera Mosque

Based on the diagram, the steps for 3D modeling can be described as follows:

- The measurement of the polygon framework and marker points

The polygon framework serves as a reference for the measurement of marker points. These marker points are utilized as benchmarks for converting the point cloud data obtained from TLS measurements into global coordinates. The methodology employed involves the use of a closed polygon with a total station instrument. The polygon framework constructed in this research comprises five points, including two control points, ITR021 (BM1) and ITR067 (BM2), and three measured polygon points (P1, P2, and P3). The control points used in this study are two known points at Itera. Fig. 2 illustrates the sketch of the polygon framework measurement. Additionally, three marker points, M1, M2, and M3, were employed in this study. The measurement of these marker points was performed by targeting the markers from the framework points using a non-

prism setting. The shape of the marker can be seen in Figure 2.



Fig. 2. Sketch of closed polygon points

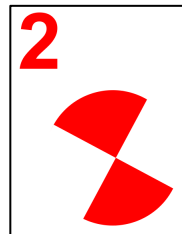


Fig. 3. The shape of the marker points

- The measurement of detailed situations using Terrestrial Laser Scanner (TLS)
The measurement of detailed situations involves the measurement of an object or area by determining significant aspects based on angles and distances in a substantial quantity, which visualizes the object in detail. The measurement of detailed situations is carried out using TLS equipment. The detailed measurement of the research object was conducted using the TLS BLK360. The TLS setup points totaled 17, with 8 points indoor and 9 points outdoor. The quality of the point used during measurement was high, with the measuring time at each point being approximately 6 minutes. The registration of data obtained from the TLS measurement was carried out using the Cyclone Register 360 software. The method used in the data merging process was the cloud-to-cloud method.
- Data processing
Data processing is carried out by combining the same object points between two points. Additionally, there is a filtering process. The purpose of filtering is to focus the data on the modeling of the research object. In the filtering process, there are three marking method options, which include rectangular (F), circular (F), and polygonal (F).
- Modelling.

III. Result and Discussion

A. Results of Polygon Framework Measurement

The processing of the polygon framework is carried out using the Bowditch method. The last processing in the Bowditch method closed polygon calculation is to produce X, Y, and Z coordinates. The Z value is obtained by direct measurement in the field, because at the time of data collection the Z value is directly computed from the total station tool. The following X, Y, and Z coordinates can be seen in Table 1.

Table 1. Closed Polygon Coordinates

<i>Point</i>	<i>X (m)</i>	<i>Y (m)</i>	<i>Z (m)</i>
BM 1	534,682.092	9.407.735.950	108.530
BM 2	534,680.964	9.407.625.817	109.034
P1	534,625.321	9.407.614.395	111.534
P2	534,613.210	9.407.631.559	111.834
P3	534,628.061	9.407.656.989	111.265

Every measurement data will inevitably contain errors; therefore, to eliminate these errors, calculations of angular and distance closure errors are performed. Based on the results of the calculations, the angular closure error obtained is 540, while the total measured angles resulted in 539.9975, with a difference of 0.0029 or 0°0'10.14". The total angular closure error is distributed evenly across each measured angle. Consequently, the angular closure error per point is 0.0005 or 0°0'1.8".

B. Three-Dimensional Model of Baitul Ilmi Mosque

The registration process for three-dimensional modeling in this study utilizes the cloud-to-cloud method, which concentrates on merging point clouds corresponding to the same object. The registration phase of this method involves combining all the standing points of the TLS instrument, with merging based on the closest point to influence the overlap value. A challenge in this registration process is the need for patience and precision during the merging stage. The outcomes of this method's registration are depicted in Figure 4, where it is evident that the Baitul Ilmi Itera Mosque is surrounded by numerous trees.

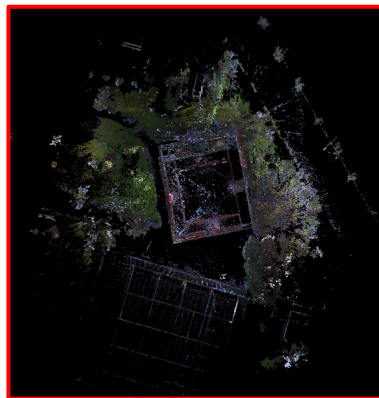


Fig. 4. Registered point cloud data

From the image, it is observable that there are some objects scanned that are not required for three-dimensional modeling, such as trees, vehicles, people, and other unnecessary objects. Consequently, it is essential to remove the point cloud of these objects by executing a filtering process. In the filtering process, unwanted objects are manually selected and then deleted. The point cloud results after the filtering process are illustrated in Figure 5.

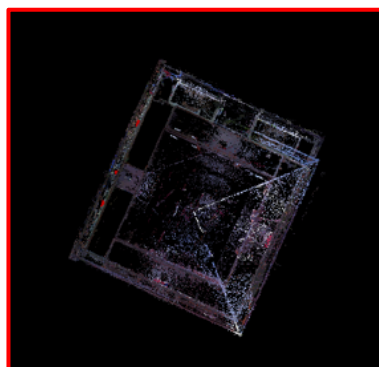


Fig. 5. Filtering Result

The image above displays the residual point cloud following the filtering process, which is now solely concentrated on constructing the mosque building's modeling form. However, the coordinates derived from the point cloud registration process remain in the form of local coordinates. Consequently, the subsequent step involves assigning ground coordinates at the marker points to ensure the point cloud aligns with the earth's original state; these coordinates can be observed in Table 2. During the processing phase, the installed markers are not automatically recognized by the software, thus manual pinning of the markers is required. The pinpointing of the markers is carried out at points 1 and 2 of the TLS instrument's stand. In Fig.6, it is evident that the point cloud now possesses ground coordinates. The error value encountered in assigning coordinates to the point cloud is 0.160m. Several factors contribute to this error value, including the minimum distance from the TLS to the marker point, environmental conditions, and light bias.

Table 2. Marker coordinates

Marker	X (m)	Y (m)	Z (m)
M1	534621,586	9407631,553	111,742
M2	534623,44	9407635,686	111,638
M3	534625,276	9407639,68	111,7

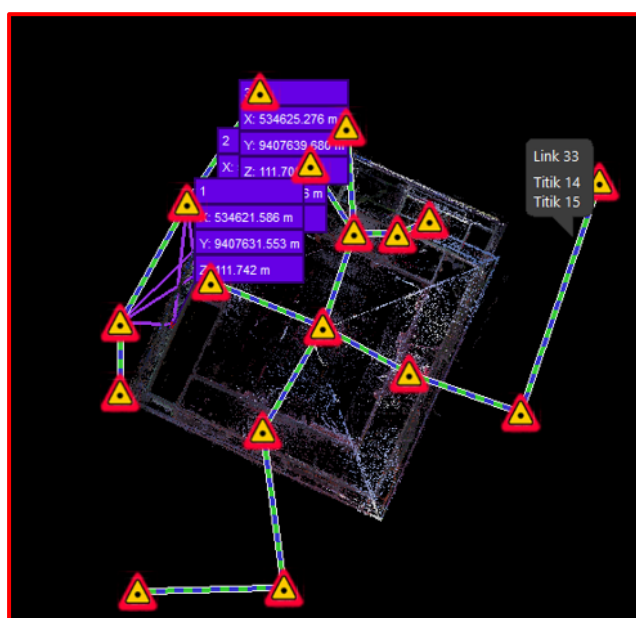


Fig. 6. Point cloud results that have ground coordinates

Figure 6 shows a point cloud that has been assigned ground coordinates. The triangles in the image indicate the positions of the TLS instrument stands, and the blue-green lines represent the connections between points during the registration process. Before the filtering process, the point cloud in the three-dimensional modeling of the Baitul Ilmi Mosque contained 645,379,107 points. After the filtering process, the number of points in the point cloud was reduced to 434,483,602 points. This reduction represents a 32.68% decrease in the number of points, indicating that many unnecessary points were scanned. The registration process achieved an overall quality that includes a bundle error of 0.008 m, an overlap of 27%, a strength of 65%, and a cloud-to-cloud distance of 0.008 m. The overlap value is attributed to the high overlap occurring in trees that were removed during the filtering process.

The three-dimensional modeling of the Baitul Ilmi Itera Mosque using TLS technology does not necessarily guarantee an exact match with the original state of the object. To verify the quality of size data in the three-dimensional model created with TLS, geometric validation can be conducted using a measuring tape on several samples of the object. Subsequently, the Root Mean Square Error (RMSE) calculation is performed, with the results presented in Table 3.

Table 3. Modeling accuracy test

No.	Objects	Tape Size (m)	3D Model (m)	Difference (m)	Difference (^2)
1	Mosque's Door	1,80	1,639	0,161	0,0259
2	Length of Women's Restroom	8,00	8,184	-0,184	0,0339
3	Length of Mosque	24,50	24,542	-0,042	0,0018
4	Length of Men's Restroom	8,00	8,101	-0,101	0,0102
5	Width of the Pillar	0,30	0,277	0,023	0,0005
6	Mimbar	2,90	2,862	0,038	0,0014
7	Mosque Corridor	3,00	2,835	0,165	0,0272
Total					0,1009
RMSE					0,045

The modeling conducted in the mesh process using Cyclone software yields a model that lacks detailed features. Consequently, the point cloud results are fully modeled in three-dimensional software to enhance detail. The resulting three-dimensional model, created using three-dimensional tools, can be seen in Figure 7.

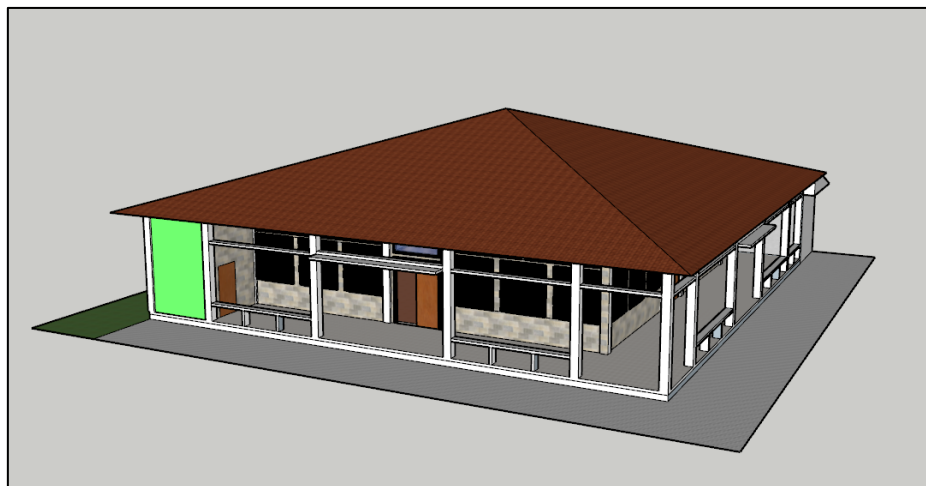


Fig. 7. Three-dimensional of Baitul Ilmi Itera Mosque

IV. Conclusion

Based on the findings from the final project research conducted, the following conclusions can be drawn:

1. The resulting model is not entirely accurate, particularly in the roofing area of the mosque. This inaccuracy is attributed to obstructions caused by trees during scanning and the lack of a sufficiently elevated position for scanning.
2. The cloud-to-cloud registration method used for the Baitul Ilmi Mosque achieved an overall quality that includes a bundle error of 0.008 m, an overlap of 27%, a strength of 65%, and a cloud-to-cloud discrepancy of 0.008 m. Moreover, the merging process between the point cloud and the total station coordinates resulted in an error value of 0.160 m. Geometric validation was conducted by comparing the model size results with actual distance measurements using a measuring tape, yielding an RMSE value of 0.045 m..

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