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Combination of Terrestrial Laser Scanner and Unmanned Aerial Vehicle Technology in The Manufacture of Building Information Model

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Abstract

The rapid development of the construction world in Indonesia has led to an increase in supporting technology that is more effective and efficient. The Building Information Model (BIM) technology that begins with the creation of an as-built 3D model, this model describes the existing condition of the building. The Terrestrial Laser Scanner (TLS) method can provide a point cloud with a decent point density, but there are still areas of the building that aren't covered, such as the roof. To be more complete and detailed, additional data is needed using an Unmanned Aerial Vehicle (UAV). The results of the combination of TLS and UAV complement each other so that the results of the point cloud can form more detailed buildings. BIM may be built by combining these two data sets, allowing for three-dimensional depiction of assets in buildings. The registration results for TLS point cloud data have a fairly good value where the overlap value is 44.9% (minimum 30%), balance is 41.2% (minimum 20%), points < 6mm is 98.9% (minimum 90%). The measurement results using the UAV have an RMSE GCP value of 0.266m and an RMSE ICP of 0.455m. Merging the results of TLS and UAV measurements is done using 3DReshaper software with four align points. The final result of making the BIM model is obtained level of detail (LOD) 3 where room models such as columns, floors, stairs, and walls are well depicted, while asset models such as furniture are also depicted although they are still simple objects.

Keywords: TLS, UAV, Point Cloud, BIM.

1. Introduction

Buildings are physical forms of construction work that are integrated with their domicile, partially or entirely positioned aboveand/or inlandand/or water, and that serve as a space for humans to carry out their activities, according to Law Number 28 of 2002 governing buildings. Whether for residence or residence, business activities, religious activities, social activities, special activities, or culture. The word building is closely related to construction activities because its implementation requires good construction. The word construction comes from English construction which means putting elements together systematically. Construction activities aim to maintain the integrity of the form so that it is strong and or does not change its shape (Hartiningsih, 2016).

Various kinds of technology are produced to ease the implementation of construction work, be it offices, shopping centers, road construction, or even other public facilities. One of the technologies currently being developed in Indonesia is Building Information Modeling technology or abbreviated as BIM. BIM itself is a digital system that integrates building design with other information about the building itself. Generally, modeling architectural elements that are not included in BIM libraries takes a considerable amount of time (Andriasyan, 2020). This BIM concept allows the stages carried out in development to be carried out more quickly, accurately, effectively, and efficiently starting from the planning, design, construction to operational stages according to needs. Material selection and use of equipment can also be more optimal with this technology so that technical errors that may arise can be minimized (Hutapea, 2019).

The creation of a BIM model begins with the creation of an as-built 3d model, in which the existing building's condition is described. Because of its speed and accuracy, laser scanner technology is extensively used in the creation of this 3d model. Point clouds also provide a very high level of geometric information (Mochtar, 2015). One of the laser scanner technologies that can be used in the process of forming this as-built 3d model is the Terrestrial Laser Scanner (TLS). The scan-to-BIM procedure derives the completed BIM model from the point cloud, which is mainly obtained by surveying terrestrial laser scanners. With 2 to 6 mm precision at 50 m, laser scanning directly acquires three-dimensional (3D) point cloud data at high accuracy level [Muszy´nski and Rybak, 2017]. The scan density representing the average spacing between the points should be selected for the level of information specified in the project requirement (Anil et al, 2013). It deals with some of the most difficult issues, such as the requirement to generalize surveys and create implicit (surface) models from explicit (point cloud) models (Leoni, 2019).

This research was conducted by applying the measurement method using a Terrestrial Laser Scanner in the process of data acquisition for the interior and exterior of the building. In the implementation of data acquisition on the exterior of the building, there is a part that is not formed, namely the roof so that other measurement methods are needed to optimize the manufacture of this three-dimensional model. Another measurement method used to create a more optimal model is to use an unmanned aerial vehicle (UAV). Data is collected using an UAV to create a point cloud for the roof of the building so that the exterior model of the building can be more formed. Due to their ability to produce high-density geometric and radiometric data, laser scanning and photogrammetry are undoubtedly very successful surveying methodologies in terms of application flexibility (Caroti et al. 2015). Terrestrial Laser Scanning (TLS) combines UAV-borne photogrammetry surveys with horizontal flight to create point clouds that documenting geometries mainly on vertical planes (Achille et al., 2015).

2. Material and Methods

2.1. Data

The coordinates of the measured polygon net using the Total Station were among the data used in the study. The detailed coordinates of the measurement results using the Total Station for the georeferencing point cloud process of TLS measurement results, and the point cloud of Terrestrial Laser Scanner measurement results for the interior and exterior of the building were obtained through direct measurements in the field using TS.

2.2. Terrestrial Laser Scanner (TLS)

Terrestrial Laser Scanning (TLS) is a method for obtaining spatial data on the earth's surface to scan the surface of objects using laser light (Hendriatiningsih et al, 2014). Besides being located in the speed in data collection and the quality of the measurement results which are much more accurate, the advantages of TLS compared to other conventional measuring instruments lie in the data collection process and measurements can be carried out from a considerable distance so that operator safety can be guaranteed and the point density obtained is very high so as to guarantee a complete and fast topographic survey. (Hutagalung, 2017).

In this study, TLS Leica BLK360 is used, which is one of the TLS series produced by Leica Geosystems. This tool weighs 1kg with a size of 100mm x 165mm and has the ability to capture 360° scans for 3 minutes. The operation of this tool uses an Ipad Pro device and Recap Pro software for the registration process of scanned data.

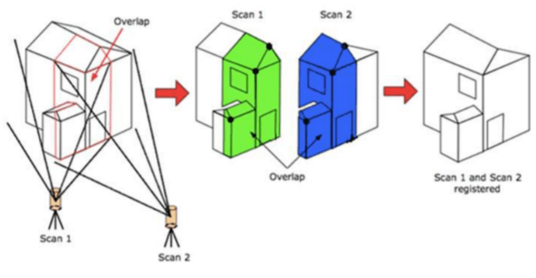
2.3. Unmanned Aerial Vehicle (UAV)

UAV is a powered aerial vehicle that does not carry a human operator, uses aerodynamic forces to create vehicle lift, can fly independently or be piloted remotely, can be disposed of or recovered, and can carry lethal or non-lethal loads, according to the Department of Defense (Yanushevsky, 2011).

2.4. Cloud To Cloud Method

This registration method has the basic principle of combining the same point cloud from several scanned world data. The technique used in this registration method is the Iterative Closed Point technique where the purpose of this concept is to look for the offset or the closest distance repeatedly from the two closest points between the two-point clouds (Mochtar, 2012).

Some of the advantages of this method are that if the accuracy of the registration results is lacking, the data will be repeated with another binding point without having to re-measure, efficient in terms of time and cost because when the measurement is carried out, target identification does not need to be done so that the time required is relatively longer. short. Illustration can be seen in Figure 1.



Source: Pfeider,2007

Figure 1. Illustration of cloud to cloud method

2.5. Model Accuracy Test

Errors are inextricably linked to the process of measuring and processing data. The Root Mean Square Error (RMSE) number indicates the size of the error value. The Root Mean Square Error (RMSE) is a commonly used metric for measuring model error when predicting quantitative data (Moody, 2019). The size of the measurement error against the actual condition can be seen from the RMSE value where the RMSE value is obtained from the process of dividing the value of the total square root of the difference in the size of the square with the number of sizes used. The mathematical definition of RMSE is similar to the standard deviation, which is the square root of the mean of the sum of the squares of the residuals (Soeta'at, 1994 in Hutagalung, 2016). The sum of the squares of the residuals is defined as the standard error. The formula for calculating RMSE is presented by equation (1).

$$RMSE = \sqrt{\frac{\sum (R - R_1)^2}{n}} \qquad (1)$$

where:
R : Value that is considered correct
R1 : value of validation measure result
n : many sizes used

2.6. Stage of Research
1. Preparation Stage
Before carrying out research, there are several things that need to be done so that research can run well, among others, literature study, determination and licensing of measurement locations and procurement of tools.

2. Stages of Data Acquisition
a. Preliminary Survey
The implementation of a preliminary survey in the form of a field survey that aims to determine the field conditions, both from the location to be measured and the surrounding environmental conditions, as well as to describe the design of the measuring point polygon.
b. Polygon Measuring
This measurement aims to obtain detail points and detail distances needed for the point cloud georeference stage and validation of the obtained model.
c. TLS Data Acquisition
The implementation of data acquisition using TLS is carried out to obtain point cloud data for the interior and exterior of the building. The scanning process for the interior is carried out in each room from the 1st floor to the 5th floor.

3. Data Processing Stage
a. Polygon Calculation
Closed polygon measurements obtained a number of 7 points. The data obtained from the measurements can be viewed using the Topcon Link software in the form of angles and distances. After getting the data, the data is processed using Microsoft Excel to get the coordinates of the polygons and the accuracy of the linear distance.
b. Calculation of Validation Distance
The placement of the validation distance is taken on the side of the roof, the side of the wall, the side of the window frame and the ends of the roof that are easily identified.
c. Terrestrial Laser Scanner Data Processing
This data processing consists of stages, namely Data Transfer Stage, Merging Projects, Filtering Process, Georeference Process, and Data Export.
d. BIM creation
In making BIM, there are several stages, namely Creating Autodesk Revit Projects, Importing Point Clouds to Autodesk Revit, Floor level division, Creating objects on each floor, Database creation

4. Data Analysis Stage
At this stage, the results of the research data processing in the form of 3D as-built BIM will be displayed and explain the analysis of the results of the data processing. There are 2 analyzes carried out in this study, namely analysis of model accuracy and analysis of BIM optimization.

3. Result and Discussion

3.1. TLS Point Clouds

The overall registration results can be seen in the picture below, where the overall results have a fairly good value. The overall registration results are said to be quite good because of the three parameters required to display the registration quality, it has exceeded the recommended minimum value where the report displayed is as follows:

1. Overlap of 44.9% (minimum 30%)
2. Balance of 41.2% (minimum 20%)
3. Points < 6mm by 98.9% (minimum 90%).

The results of binding model coordinates to soil coordinates in this study have quite good results, where the figure below shows the results of the Root Mean Square (RMS) of each point having a value below 2 cm. The RMS values represent the mean ground truth (GCP) and survey points in each scan with an estimated transformation. The highest RMS value is 18.75 mm and the lowest value is 1.66 mm with an average RMS value of 11.67 mm.

connections

scan location	target	[illegible]
GD.DKT.BR. FSD 13	D94	18.75mm
GD.DKT.BR. FSD 14	D94	18.75mm
GD.DKT.BR. FSD 17	D57	14.95mm
GD.DKT.BR. FSD 19	D57	14.95mm
GD.DKT.BR. FSD 21	D34	14.17mm
GD.DKT.BR. FSD 2	D34	14.17mm
GD.DKT.BR. FSD 17	D56	11.77mm
GD.DKT.BR. FSD 15	D56	11.77mm
GD.DKT. TANGGA 14	D145	8.73mm
GD.DKT.BR. FSD2 3	D145	8.73mm
GD.DKT.BR. FSD 19	D36	1.66mm
GD.DKT.BR. FSD 20	D36	1.66mm

Figure 2. RMS results

Figure 3. is the result of alignment confidence from the georeferenced point cloud results where this parameter shows the difference between ground truth (GCP) and point cloud data. The value of alignment confidence in this study has the highest value of 49.97 mm and the lowest value of 27.28 mm with an average value of 35.62 mm.

target	alignment confidence	RMS (global)
D94	49.97mm	18.75mm
D57	35.46mm	14.95mm
D34	32.59mm	14.17mm
D56	39.63mm	11.77mm
D145	27.28mm	8.73mm
D36	28.77mm	1.66mm

Figure 3. Alignment confidence results

3.2. UAV Point Clouds

The RMSE GCP and ICP values in UAV data processing need to be considered because GCP is a known coordinate point and is used for georeferencing, while ICP is a known coordinate point to indicate the georeferenced quality of the GCP made where the smaller the RMSE value, the better the georeferenced results. . Careful GCP picking process can determine the value of RMSE GCP and ICP. In **Figure 4**, the RMSE GCP value is shown to be 2.66366 cm or 0.266 m, while the RMSE ICP in **Figure 5** is 4.5503 cm or 0.455 m. The RMSE GCP value shows the accuracy of GCP binding to other GCPs, while the RMSE ICP value shows the georeferenced quality of the GCP used. The value obtained in the processing process in this study reached an accuracy of cm so that this study obtained a fairly good accuracy.

Count	X error (cm)	Y error (cm)	Z error (cm)	XY error (cm)	Total (cm)
3	2.08919	1.26919	1.05807	2.44449	2.66366

Table 4. Control points RMSE.
X - Easting, Y - Northing, Z - Altitude.

Figure 4. Control Point RMSE

Count	X error (cm)	Y error (cm)	Z error (cm)	XY error (cm)	Total (cm)
1	3.30992	1.89287	2.48329	3.81294	4.5503

Table 5. Check points RMSE.
X - Easting, Y - Northing, Z - Altitude.

Figure 5. Check Point RMSE

3.3. TLS and UAV Combination

The merging of the two-point cloud data was done because the TLS measurement results showed that the research object was not covered perfectly (there was a hole in the wall leading to the roof) so data was collected using a UAV which can be seen in the image below.

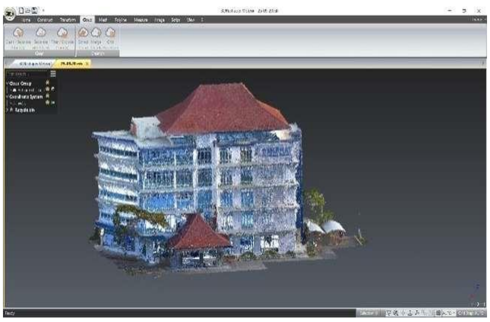


Figure 6. Combination of TLS and UAV Point Clouds

The process of combining two-point cloud data measured by UAV and TLS is carried out using 3D Reshapher software and four align points, with the point cloud measured by TLS serving as a reference in this align process.

3.4. Validation Test

In this study, a total station was used to measure the validation distance, and Autodesk ReCap was used to measure the results of the point cloud measurement. The results of the RMSE calculation of the comparison of field distances with distances in point cloud data can be seen in **Table 1**.

The RMSE value from the calculation result is 0.0115 m. When compared to Sekar Melati Ramadhani's research (2020) on the analysis of point cloud accuracy using a combination of terrestrial laser scanner and unmanned aerial vehicle technology, the results of this study are better. The RMSE value in Sekar Melati Ramadhani's research (2020) is 0.036, while the RMSE value in this study is 0.0115 m.

Table 1. Distance Validation Test

No	Point	Xerror	Yerror	Zerror	XYZerror
1	D1	0,004218	0,002314	0,007207	0,013739
2	D2	0,000082	0,000319	0,000306	0,000707
3	D3	0,000023	0,000079	0,005110	0,005212
4	D5	0,000001	0,000191	0,000354	0,000547
			⋮		
136	D172	0,00002	0,00174	0,00013	0,00190
137	D173	0,00001	0,00181	0,00114	0,00297
138	D174	0,00000	0,00026	0,00020	0,00046
139	D175	0,00003	0,00114	0,00062	0,00179
	RMSE	0,02029	0,02418	0,02564	0,04067

3.5. BIM Result

Figure 8 shows a comparison between the BIM model made and the architectural form of the building in the field. Based on the level of detail class, this study belongs to the LoD 3 class. In **Figure 8** it can be seen that the room models such as columns, floors, stairs, and walls are well described, while the asset models such as furniture are also depicted although they are still simple objects. **Figure 9** shows the results of making BIM with a floor plan display and shop drawings (design) from the ground floor. Parts marked with a red circle are parts that are not in accordance with the initial design.

Each asset model that has been made in three-dimensional form can be assigned information attributes so that each asset model not only represents the shape and dimensions of the asset but also contains additional information in it. **Figure 7** shows the results of the database creation in this study.

Cabinet 2: 800mm Wide 7	2	FT UNDIP	Level 3
Cabinet 9: Cabinet 9	1	FT UNDIP	Level 3
Dispenser: Dispenser	1	FT UNDIP	Level 3
Furniture_Chairs-Stools-Benches_Sw	2	FT UNDIP	Level 3
Kursi Kerja 2: Kursi Kerja 2	2	FT UNDIP	Level 3
Meja Kayu 9: Meja Kayu 9	1	FT UNDIP	Level 3
Meja Kayu 14: Meja Kayu 14	1	FT UNDIP	Level 3
Meja Kayu 21: Meja Kayu 21	1	FT UNDIP	Level 3
Meja Kayu 27: Meja Kayu 27	1	FT UNDIP	Level 3

Figure 7. Asset database

In this study, the creation of an asset database is separated by room and floor level so that it can be seen what types of assets and how many assets are in one room. Making the database in this research is useful in asset management activities.

(a) Outside view

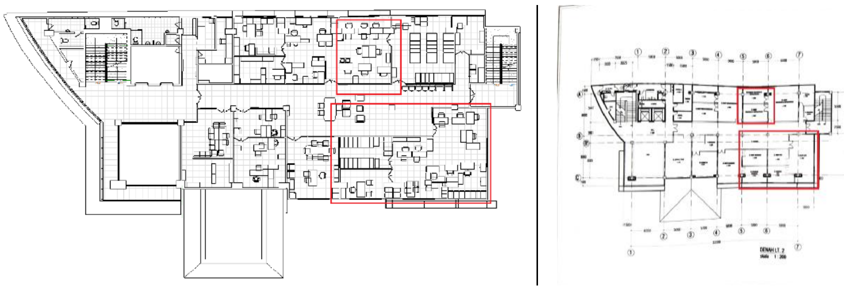
(b) Inside View

Figure 8. Comparison between BIM and the field

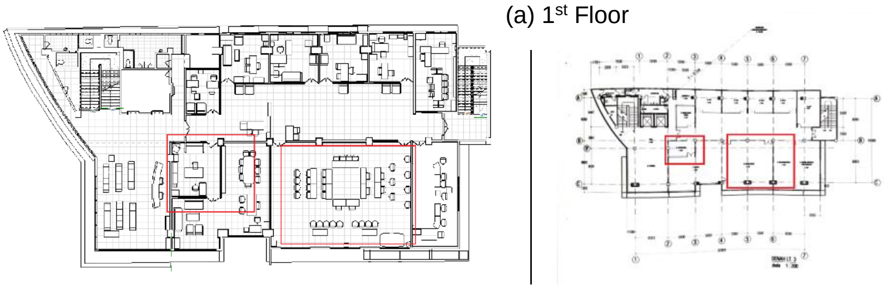
Parts marked with a red circle are parts that are not in accordance with the initial design. The discrepancy of some of these parts is only found on (a) 1st floor (b) 2nd floor in **Figure 9**.

BIM

Shop Drawing



(a) 1st Floor



(b) 2nd Floor

Figure 9. BIM Result (left), Shop Drawing (Right)

4. Conclusion

According to the results of this study, it can be concluded that overall registration results for point cloud data have a fairly good value where the Overlap value is 44.9% (minimum 30%), Balance is 41.2% (minimum 20%), Points < 6mm is 98.9% (minimum 90%). The final result of making this BIM model has a level of detail (LOD) 3 where room models such as columns, floors, stairs, and walls are well described, while asset models such as furniture are also depicted although they are still simple objects.

The results of the combination of TLS and UAV complement each other so that the results of point clouds can form buildings in more detail. Based on the combination of the two data, BIM can be created which can help provide three-dimensional visualization of assets in the building, besides that BIM also provides convenience in tracking asset locations, updating information and planning for building development.

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