Accuracy Assessment on Detail Survey Plan Using iPhone 13 Pro Max LiDAR Sensor

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Abstract
Total stations, global navigation satellite systems (GNSS) instruments, and laser scanners are common tools used in detailed surveys because of the precision they bring to measurements and data collection. While conventional land surveying methods using total stations and GNSS instruments are widely used for their accuracy, they require a team of at least three people and can be costly. In 2021, Apple introduced the iPhone 13 Pro with a built-in LiDAR sensor that can potentially be used for land surveying. However, it is unclear whether the LiDAR data obtained from the iPhone is accurate and reliable enough to replace the conventional surveying methods. Therefore, a comparison study between the conventional method and the iPhone LiDAR sensor needs to be conducted to evaluate the feasibility and potential benefits of using the iPhone LiDAR sensor in land surveying. The purpose of this study is to evaluate the differences between tacheometry method using total station and laser scanning method using iPhone 13 Pro Max in generating detail survey plan. This study was conducted UiTM Shah Alam Stadium, Shah Alam, Selangor. For scanning method, two device poses (distance of sensor to target) are used which are 5 and 10 cm. Based on results and analysis, the difference between the actual elevation value and the scanning data from the device at 5 cm and 10 cm is relatively small. The lowest values for the device's position at 5 cm and 10 cm are -0.025 m and -0.057 m, respectively, and the highest values are 0.023 m and 0.017 m, respectively. The average deviation at the device's position of 5 cm is 0.023 m, while the average deviation at the device's position of 10 cm is 0.017 m. In conclusion, the LiDAR sensor in the iPhone 13 Pro Max has the potential to be a valuable tool for assessing accuracy in detailed survey plans. Its possible applications in different fields are worth further exploration.

Keywords: Detail Survey Plan, iPhone, LiDAR, Tacheometry, Topographic Survey

1. Introduction

Presently, conventional methods employing a total station or GNSS instruments are used extensively to conduct topographic surveys [1] [2] and [3]. Depending on the observer, a conventional method that utilizing total station may yield slightly varied results in terms of position and height. Traditional methods employing tacheometry require at least three individuals to conduct a survey. GNSS method is now the preferred method for doing topographic surveys since it is more efficient and saves time [4]. However, in order to receive a satellite signal, GNSS equipment demands that there be an unobstructed view of the sky [5] [6] [7] and [8]. The Lidar scanner was initially made available in Apple's iPhone 12 Pro and iPhone 12 Pro Max products in the month of October 2020. Lidar stands for "Light Detection and Ranging" and is a remote sensing technology that uses lasers to measure distance and map the surrounding environment. On the iPhone, lidar is located on the back of the phone and works with the camera to measure the distance between objects and the phone. This technology allows the phone to map the surrounding environment more accurately and quickly than using just a regular camera. Apple claimed that it helped with focusing during low-light photography, and the evidence has supported their claims. It will save so much time, and there is no need to bring survey instruments to the site to do a topographic survey.

The iPhone 13 Pro was released in September 2021 with the same lidar technology, despite the enhanced camera technology. It is conceivable to conduct detail surveys using an iPhone outfitted with a LiDAR sensor if the results are comparable to or almost identical to those obtained using conventional methods.

2. Literature Review

Apple, Inc. produced the first smartphone with innovative built-in Light Detection and Ranging (LiDAR)-based depth sensors and augmented reality (AR) application programming interface (API) in 2020.The device is a relatively inexpensive alternative to existing hardware solutions used in surveying with moderate precision. It does not conduct surface scanning in the sense of TLS devices, but it is capable of obtaining a 1:1 scale colour point cloud. In this paper, the fundamental capabilities of the iPhone 13 Pro LiDAR for conducting typical building surveying tasks are evaluated. Comparing the results of scanning an office room and sample architectural details such as arches in lintels with measurements taken using a precise terrestrial laser scanner. The pros and cons of the tested device were outlined, as well as its capacity for obtaining accurate measurements (1 cm of accuracy) for building inventory.

The project's industry partner Modelar created their own mobile laser scanning application that may improve timing and accuracy. With an iPhone 13 Pro, their application Modelar – 3D LiDAR Scanner offers a chance to explore the sensor's characteristics using a Synchronized Localization and Mapping (SLAM) approach. SLAM is the process of mapping while the location of the moving device is known [9] [10] and [11]. Additionally, a TLS survey will be assessed, comparing industry standard equipment to the performance of the iPhone's sensor. The point clouds produced by both the iPhone and TLS in A-17's reference frame was compared to the total station which surveyed the control network, considering it as ground truth. Recent studies have assessed the iPhone's sensor with other devices such as a TLS or camera. The study by Spreafico et al., [12] assessed the iPhone by comparing it with the TLS. Five ground control points (GCPs) and four check points (CPs) were set up around an area of interest outdoors.

Using the SiteScape scanning application, the resulting absolute accuracy of the control points from the iPad scans was a root mean square (RMS) error value lower than 2 cm and a standard deviation lower than 1 cm. Razali et al., [13] compared target line distances between a total station and TLS on various materials including wood, aluminum, glass, cement wall, and cotton canvas. The results when comparing the distances produced by each method were centimetric. In the study done by Nagymáté et al., [14], a sub-millimetre triangulation control network was created to determine the absolute accuracy of a motion camera using a total station. The average standard deviation for each measurement was 0.4 mm. After processing, the uncertainty of the control network was 0.75 mm. In a different study performed by Abd-Elmaaboud et al., [15], an accuracy assessment of the TLS was completed and compared to other traditional surveying instruments such as a total station and RTK-GPS.

The results revealed that the TLS's Root Mean Square Error (RMSE) in measuring terrains was approximately 15 cm. In vertical cut measurements, the TLS achieved a RMSE of 6 mm, performing better timewise than other instruments. With a precise control network established in A-17, absolute accuracies of the total station and iPhone can be determined, comparing them to the coordinates produced by the total station, considering it as ground truth. Additionally, this study will also compare the target line distances between different CPs, also using the total station as ground truth when assessing the TLS and iPhone.

3. Study Area

The tachometry method using a total station and an iPhone 13 Pro Max equipped with a LiDAR sensor will be used to conduct a detailed survey and scanning at the same location. The study area measures 35m by 25m, or 875m², and is situated in a parking lot next to the UiTM Shah Alam Stadium. During the detailed survey and scanning, all the site's natural and man-made features, including the buildings, ground level, drainage, road, and other elements were observed. This location was marked with eight (8) ground control points (GCP) (Figure 1).

4. Methodology

This research project's approach and processing involved a total of five (5) stages as shown in Figure 2. The first step is the preparation of the data which are to establish ground control point and preparation of software and hardware. There are two methods during data acquisition which are tacheometry method and scanning method in generating detail survey plan. The application PIX4DCatch will be utilised for the scanning procedure. Next, data scanning will be process using Cloud Compare software to produce detail survey plan. The last phase is to compare all the features based on ground control point, area of building, coordinate of building and drain invert level.

Figure 1: Location of study area that situated in a parking lot next to the UiTM Shah Alam Stadium

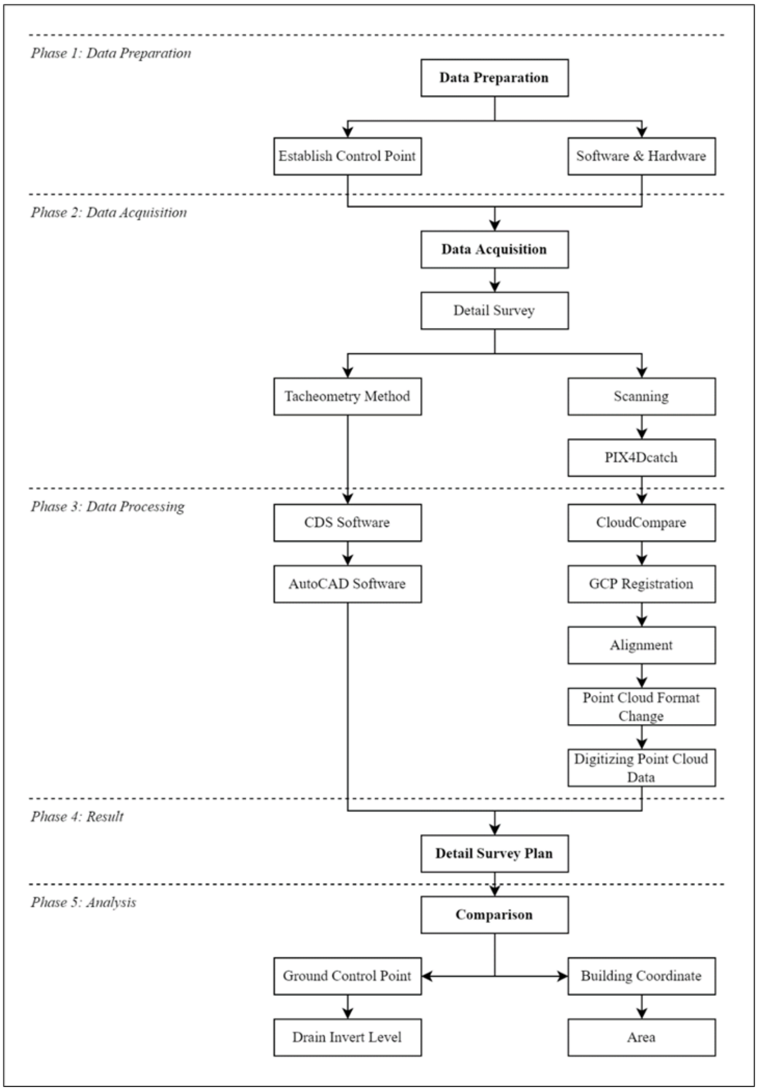

Figure 2: Workflow of study process

5. Result and Analysis

The outcomes of this study are presented in four sections. Tacheometry allows for the comparison of GCP coordinate values, area of building, coordinate of building and drain invert levels with the dataset using scanning from the iPhone 13 Pro Max LiDAR Sensor.

5.1 Comparison of the GCP Coordinate Value

All the coordinates from the scanning will be compared with the GCP that was generated using the tacheometry approach, which is regarded to be the true value. This investigation included two (2) scanning methods which are devise pose in 5cm and 10 cm using pix4D Catch application. There are variations in the results of measurements conducted with the iPhone 13 Pro Max LiDAR Sensor and tacheometry methods as shown in Table 1 and Table 2 respectively. All the units are in meters. Based on Table 1 and Table 2, the discrepancies in the measurements produced by the two approaches have been determined to facilitate an investigation into the errors produced by each measurement.

5.2 Comparison of the Coordinate of Building

Building and drainage are the two (2) features that are going to be evaluated and analyzed in this process. The tacheometry coordinate and the scanning coordinate will be compared in terms of X, Y, and Z. As shown in Figure 3, the four corners of the building are chosen based on the results of a data scan performed with Cloud Compare software. Using the tacheometry approach, all the scanning results from the device posed at 5 cm and 10 cm will be compared with their actual coordinates as shown in Figure 3. The data have been summarized in Table 3 and Table 4, and all values are given in meters.

5.3 Comparison of the Area of Building

Using AutoCAD software, it is possible to establish the percentage of data overlap between the conventional approach and the LiDAR scan as tabulated in Table 5. The percentage of the building's area that differs between iPhone LiDAR point cloud with 5cm device pose distance and iPhone LiDAR point cloud with 10cm device pose distance is 6.06% and 0.03%, respectively.

Table 1: Different Coordinate using device pose distance 5 cm

No. of GCP	**Tacheometry**			**iPhone 13 Pro Max (5cm)**			**Different**		
	X	Y	Z	X	Y	Z	X	Y	Z
1	-1100.015	-68023.043	21.547	-1100.039	-68022.982	21.547	0.024	-0.061	0.000
2	-1115.994	-68024.822	20.076	-1115.971	-68024.785	20.079	-0.023	-0.037	-0.003
3	-1109.071	-68013.645	21.038	-1109.105	-68013.693	21.042	0.034	0.048	-0.004
4	-1100.034	-68006.125	21.514	-1100.071	-68006.076	21.516	0.037	-0.049	-0.002
5	-1115.795	-68006.017	21.422	-1115.795	-68006.017	21.422	0.000	0.000	0.000
6	-1108.904	-67999.467	21.565	-1108.956	-67999.469	21.612	0.052	0.002	-0.047
7	-1100.252	-67993.225	21.582	-1100.202	-67993.211	21.570	-0.050	-0.014	0.012
8	-1115.625	-67992.932	21.662	-1115.612	-67992.977	21.626	-0.013	0.045	0.036
						Total	0.061	-0.066	-0.008
						Mean	0.008	-0.008	-0.001
						RMSE	0.022	0.023	0.003

Table 2: Different Coordinate using device pose distance 10 cm

No. of GCP	**Tacheometry**			**iPhone 13 Pro Max (10cm)**			**Different**		
	X	Y	Z	X	Y	Z	X	Y	Z
1	-1100.015	-68023.043	21.547	-1100.072	-68022.958	21.622	0.057	-0.085	-0.075
2	-1115.994	-68024.822	20.076	-1115.932	-68024.785	20.061	-0.062	-0.037	0.015
3	-1109.071	-68013.645	21.038	-1108.999	-68013.750	20.989	-0.072	0.105	0.049
4	-1100.034	-68006.125	21.514	-1100.075	-68006.085	21.512	0.041	-0.040	0.002
5	-1115.795	-68006.017	21.422	-1115.810	-68006.070	21.431	0.015	0.053	-0.009
6	-1108.904	-67999.467	21.565	-1108.867	-67999.517	21.601	-0.037	0.050	-0.036
7	-1100.252	-67993.225	21.582	-1100.159	-67993.202	21.535	-0.093	-0.023	0.047
8	-1115.625	-67992.932	21.662	-1115.664	-67992.885	21.676	0.039	-0.047	-0.014
						Total	-0.112	-0.024	-0.021
						Mean	-0.014	-0.003	-0.003
						RMSE	0.040	0.008	0.007

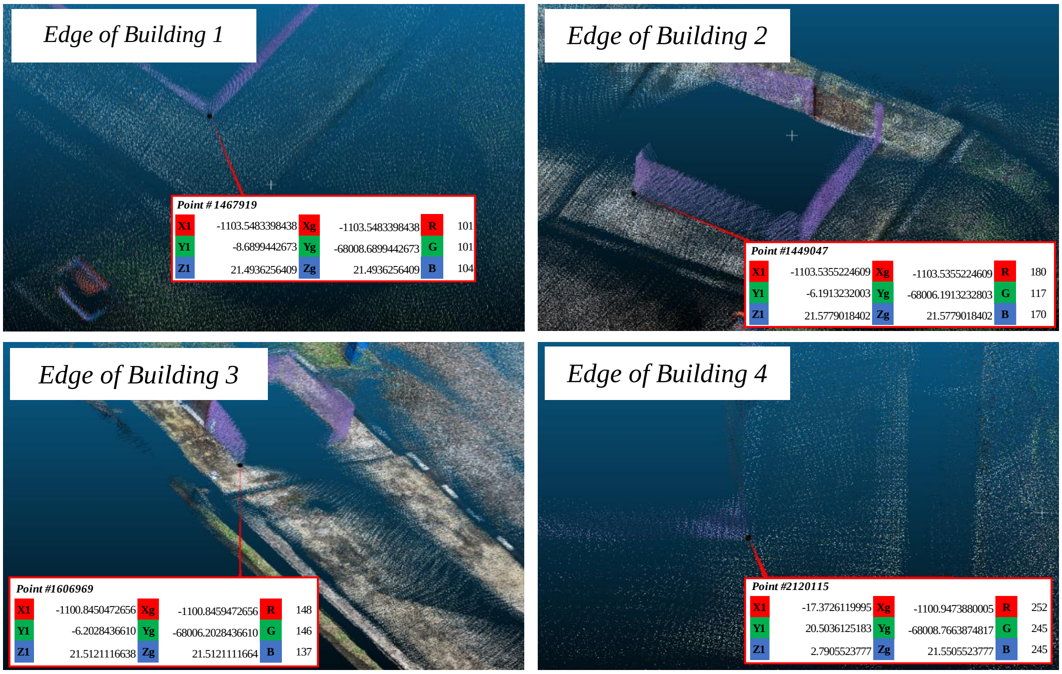

Figure 3: Features identification (coordinates for edge of building)

Table 3: Different Coordinate using device pose distance 5 cm

Edge of Building	Tacheometry			iPhone 13 Pro Max (5cm)			Different		
	X	Y	Z	X	Y	Z	X	Y	Z
1	-1103.452	-68008.839	21.550	-1103.528	-68008.689	21.501	0.077	-0.150	0.049
2	-1103.458	-68006.243	21.574	-1103.533	-68006.192	21.577	0.075	-0.051	-0.003
3	-1100.768	-68006.216	21.542	-1100.843	-68006.208	21.512	0.075	-0.008	0.030
4	-1100.899	-68008.759	21.594	-1100.947	-68008.766	21.550	0.048	0.007	0.044
						Total	0.275	-0.202	0.120
						Mean	0.069	-0.051	0.030
						RMSE	0.019	0.010	0.004

Table 4: Different Coordinate using device pose distance 10 cm

Edge of Building	Tacheometry			iPhone 13 Pro Max (10cm)			Different		
	X	Y	Z	X	Y	Z	X	Y	Z
1	-1103.452	-68008.839	21.550	-1103.518	-68008.799	21.539	0.067	-0.040	0.011
2	-1103.458	-68006.243	21.574	-1103.531	-68006.204	21.622	0.073	-0.039	-0.048
3	-1100.768	-68006.216	21.542	-1100.801	-68006.242	21.596	0.033	0.026	-0.054
4	-1100.899	-68008.759	21.594	-1100.952	-68008.795	21.531	0.053	0.036	0.063
						Total	0.226	-0.017	-0.028
						Mean	0.056	-0.004	-0.007
						RMSE	0.013	0.000	0.000

Table 5: Area percentage comparison between tacheometry and iPhone LiDAR scanning

Tacheometry (m²)	iPhone Lidar (m²)		Different (m²)		Different Percentage (%)	
	5cm	10cm	5cm	10cm	5cm	10cm
6.982	6.559	6.98	0.423	0.002	6.06	0.03

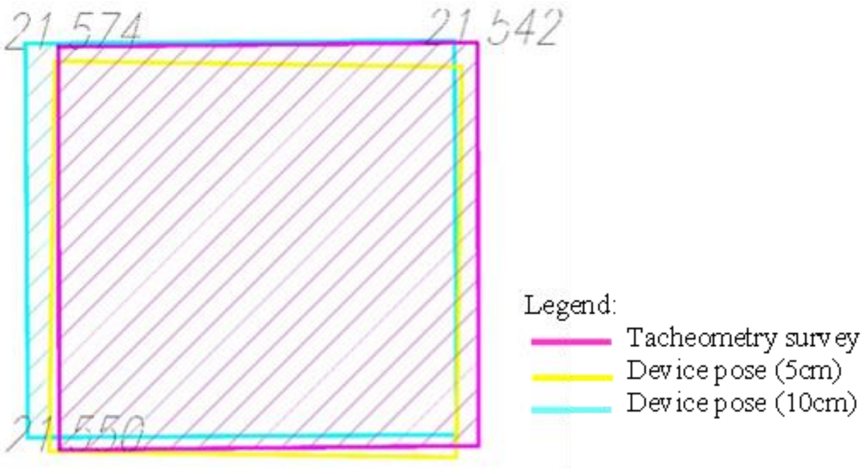

Figure 4: Building overlay from iPhone LiDAR scans and tacheometry

Table 6: Different coordinate using device pose distance at 5 cm and 10cm

Point of Invert Level	Tacheometry	iPhone Lidar		Different	
	Elevation (Z)	5cm	10cm	5cm	10cm
		Z	Z	Z	Z
1	20.976	20.955	20.959	0.021	0.017
2	20.804	20.809	20.815	-0.005	-0.011
3	20.742	20.722	20.734	0.020	0.008
4	20.688	20.696	20.702	-0.008	-0.014
5	20.630	20.655	20.654	-0.025	-0.024
6	20.418	20.395	20.422	0.023	-0.004
7	20.160	20.183	20.189	-0.023	-0.029
			Total	0.003	-0.057
			Mean	0.000	-0.008
			Max	0.023	0.017
			Min	-0.025	-0.057
			RMSE	0.000001	0.0005

Figure 4 depicts the building overlay from iPhone LiDAR scans and tacheometry. It may be observed that the shape resembles the same pattern but is oriented slightly differently. Magenta is the color of the building that was derived from the tachometric survey, while yellow and cyan were generated from 5cm device pose distance and 10cm device pose distance, respectively.

5.4 Comparison of the Invert Level

The drainage invert level is the elevation or height of a drain's bottom relative to a benchmark. Typically, the invert level of a drain is used to determine its slope and verify that it has sufficient gradient to allow water to flow properly. In this study, the results from actual coordinates were compared with the coordinates generated from scanning using device poses of 5 cm and 10 cm, respectively. All the results were tabulated in Table 6 and all units are in meters.

According to the findings in Table 6, it was discovered that the discrepancy between the real value of the elevation and the scanning data from device pose at 5 cm and 10 cm is not very significant. The minimum values for device pose at 5 cm and 10 cm are -0.025 m and -0.057 m, while the maximum values for device pose at 5 cm and 10 cm are 0.023 m and 0.017 m, respectively. The average error at device pose at 5 cm is 0.023 m, while the average error at device pose at 10 cm is 0.017 m.

6. Conclusion

In conclusion, the iPhone 13 Pro Max LiDAR sensor can be used for accuracy assessment on detail survey plans for small areas only. With its advanced technology, it can measure distance, create 3D maps, and detect objects with high precision. This feature can be particularly useful for professionals in the architecture, engineering, and construction industry, as well as for land surveyors and geospatial analysts. However, it is important to note that the accuracy of the LiDAR sensor may be affected by external factors such as lighting conditions and weather. Therefore, it is crucial to perform rigorous testing and validation of the data collected using this technology to ensure the accuracy and reliability of the results. Overall, the iPhone 13 Pro Max LiDAR sensor presents a promising tool for accuracy assessment on detail survey plans, and its potential applications in various fields are worth exploring further.

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