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The accuracy evaluation of point cloud data generated with iPhone 15 Pro Next Gen LiDAR sensor

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Abstract

Low-cost LiDAR sensors have recently become preferred in many fields by architects, geomatics engineers, industrial design, virtual reality applications, and many other disciplines for rapid 3D model generation. Recently, 3D models created with LiDAR sensors of smartphones (iPhone and iPad LiDAR sensors) have become preferred in many areas for 3D model production. This study discusses the accuracy evaluation of point cloud data automatically generated by the iPhone 15 Pro LiDAR sensor. Therefore, a point cloud was created for the same object with the iPhone 15 Pro LiDAR Sensor, and SiteSCAPE and Scaniverse mobile applications were tested. Our results show that the performance of the iPhone 15 Pro LiDAR Sensor is affected by mobile software technical capabilities. In addition, the results generally concluded that the iPhone 15 Pro LiDAR sensor can be used in many geomatics applications for point cloud generation, but it can be used as auxiliary data for survey studies due to its shortcomings.

1. Introduction

Light Detection and Ranging (LiDAR) is a measurement technique that produces 3D airborne or terrestrial point cloud data. LiDAR systems create a point cloud in 3D space with the intensity values (density value of the reflection energy of the laser reflected from the surface) of the point cloud and RGB values (Kuçak et al.., 2016; Kuçak et al.., 2017; Kuçak et al.., 2020, Kuçak, R. A. 2022, Kuçak et al.., 2023). However, 3D models produced with low-cost LiDAR sensors have recently become preferred for fast 3D model production in many areas.

3D Modeling with point cloud data is essential for archaeologists, architects, or geomatics engineers using smartphones (Such as iPhone Pro sensors). Today's prevalence of smartphones, along with advances in sensor technologies, generation of point clouds, and 3D Modeling, offer new opportunities for scientific applications and low cost. It has been proven that studies can be performed with differences of approximately 10 cm compared to scanning with a hand-held laser scanner (Gollob et al., 2021). Apple Inc., a LiDAR scanner available in consumer-grade devices, will launch the iPad Pro 2020 (11-inch and 12.9-inch displays) on March 25, 2020, and the iPhone 12 Pro and iPhone 12 Pro Max on October 23, 2020 (Luetzenburg et al. 2021). While sensors with the same LiDAR features were preferred in the iPhone 13 and 14 Pro, Apple agreed with SONY for the iPhone 15 Pro and radically changed the LiDAR sensor. While a more efficient ToF (Time of Flight) LiDAR Sensor, first introduced with the iPhone 15 Pro, appeared as Sony IMX591, it was introduced as IMX590 in the iPhone 14 and older series.

Scaniverse and SiteScape programs are mobile applications designed to perform 3D scanning using the LiDAR sensor found in specific iPhone and iPad models. Applications are preferred to produce 3D models by scanning objects and environments with the LiDAR sensor. These apps allow users to create accurate, high-resolution 3D scans directly from compatible iOS devices. Thanks to such applications, Apple iPhone LiDAR is rapidly gaining popularity for the 3D representation of solid objects and surfaces due to its processing capacity, price, size, and versatility (Luetzenburg et al., 2021; Monsalve et al., 2023). Many professional disciplines, including forestry, earth sciences, geology, accident site investigation, documentation of cultural fields, and production of large-scale 3D rapid maps, use point clouds and 3-Dimensional (3D) models created from measurements made using such smartphones, which are

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relatively less expensive than Professional Terrestrial Laser Scanners. (Çakir et al., 2021; Desai et al., 2021; Gollob et al., 2021; Luetzenburg et al., 2021; Mokroš et al., 2021; Murtiyoso et al., 2021; Plaß et al., 2021; Spreafico et al., 2021; Vogt et al., 2021; Wang et al., 2021; Bobrowski et al., 2022; McGlade et al., 2022; Tavani et al., 2022). This kind of hardware is anticipated to grow and be used more frequently in new application areas because of its many benefits, including ease of use, speed, and accuracy.

This study investigated the accuracy of point clouds obtained using the iPhone 15 Pro new generation LiDAR sensor. Free versions of SiteScape and Scaniverse applications were preferred as software. Additionally, to eliminate sources of error in the comparison, the accuracy comparison of LIDAR systems was made relatively using the distance differences of the points selected from the point clouds.

2. Method

Various Apps are available to create a 3D point cloud model of a surface with the iPhone 15 Pro LiDAR sensor (Such as "Scaniverse," "3D ScannerApp", "Pix4d Catch," "SiteScape"). In this study, Scaniverse and SiteScape Apps were used for scanning (Figure 1). The steel tape measure data was also used as a reference for the accuracy evaluation of İPhone 15 Pro data (Table 2).

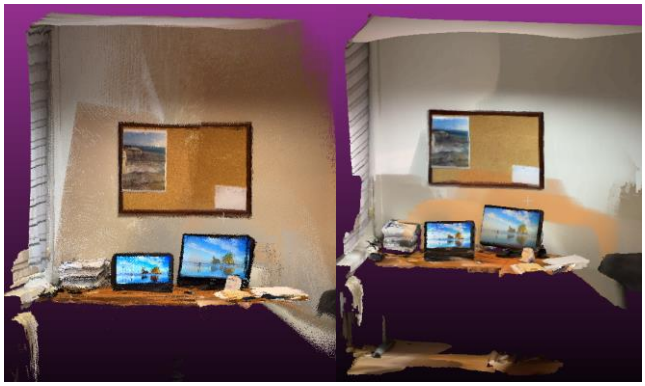

Figure 1. iPad Pro LiDAR sensor SiteScape (Left) and Scanivese (Right) scanning

3. Results

According to the scans obtained, for each point cloud, certain distances were measured with a steel tape measure (Figure 2), and these distances were measured with iPhone 15 Pro (SiteScape, and Scaniverse, software) (Table 1).

The measured distances "a,b,c" are selected as horizontal distances, and "d,e,f" are selected as vertical distances (Figure 2). By taking the differences between these values given in Table 1, standard deviation values were calculated from the distance differences (Table 2).

According to the calculated difference values, it has been observed that Sitescape and Scaniverse values are very close. However, since the steel tape measure is used as a reference in this application, the difference values in Table 2 are calculated according to the steel tape measure values. As can be seen from Table 2, the values obtained from the Scaniverse program were close to the steel tape measure distances, and the most enormous differences were observed to be those obtained from the SiteScape program.

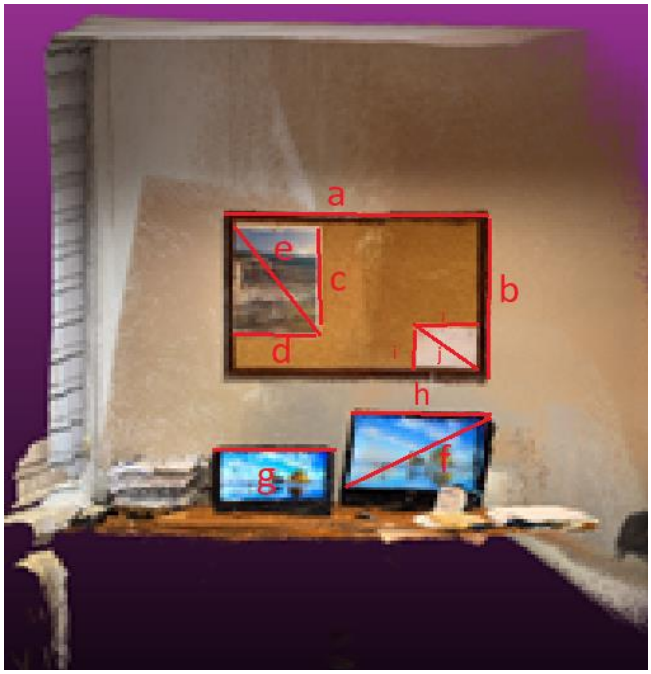

Figure 2. Distances measured with a steel tape

Table 1. Measured distances

(m)	Steel tape measure	SiteScape	Scaniverse
a	0.900	0.904	0.906
b	0.600	0.606	0.601
c	0.420	0.414	0.420
d	0.297	0.295	0.293
e	0.514	0.511	0.510
f	0.558	0.554	0.556
g	0.374	0.375	0.373

Table 2. Calculated differences

(m)	SiteScape	Scaniverse
a	0.004	0.006
b	0.006	0.001
c	-0.006	0.000
d	-0.002	-0.003
e	-0.003	-0.004
f	-0.004	-0.002
g	0.001	-0.001
Std.	0.004	0.003

Overall, the first results from the study showed that LiDAR sensors integrated into portable mobile devices showed promising performance indoors. This study has evaluated that this type of sensor can be an essential alternative to expensive professional-type scanners in many applications with their low cost, portability, speed, and easy usability. However, despite the system's many advantages, it has some disadvantages. The most prominent is that LiDAR sensors integrated into the tablet/phone generally have a limited scanning range. For example, the maximum measurement distance for the iPad Pro used in the study is given as 5 m (Wang et al., 2021). Another issue is that the accuracy of the point clouds obtained as a result of scanning depends on the software used during scanning and the options preferred in the software.

4. Conclusion

According to the calculated values, Scaniverse gave results closer to the steel tape measure with a standard deviation value of 0.003 m. According to this study, SiteScape iPhone 15 Pro data can easily be used in surveying tasks with a standard deviation of 0.004 m. These standard deviations were obtained from approximately 1 meter. When the results obtained according to SiteScape data were examined, it was observed that there may be a need for more detail in obtaining the 3D model of objects with details of up to 2 cm. As seen in Figure 1 from both data sets, it has been observed that although data with sufficient numerical accuracy can be obtained to obtain 3D models, data with the same precision cannot be obtained for all surfaces. The data obtained for SiteScape and Sacaniverse can be collected up to 5 meters indoors, as stated in the user manual of the iPhone 15 Pro and explained in the literature. However, it has been observed that the iPhone 15 Pro LiDAR sensor can collect better data at distances of 3 meters and closer.

When evaluated according to these results, it has been observed that the iPhone 15 Pro LiDAR data can be used in many surveying operations by subjecting it to a proper registration (fine registration) process in areas where terrestrial laser data is incomplete. It can be preferred in projects where an accuracy of approximately 3 cm or more is sufficient, especially in areas such as BIM applications. However, as stated in the literature, it is mentioned that scanning can be done from a distance of 2-3 meters in many applications. In our application, healthy results can be obtained in indoor scanning up to 1-3 meters; A very noisy point cloud could be obtained at distances of 4-5 meters. This situation prevented the data from being used in 3D modeling. However, as seen from the Scaniverse and SiteScape data set, this study has again shown that 3D model data, which can be used as a basis for many applications, can be obtained easily.

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