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THE EFFECT OF OBJECT SURFACE COLORS ON TERRESTRIAL LASER SCANNERS

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ABSTRACT: Terrestrial laser scanning systems are a relatively new measurement technology. With the advances in technology, these systems have gained more popularity and have been increasingly used in many different fields. With the terrestrial laser scanning technology, three- dimensional (3D) information and images of objects can be obtained in a more practical and easier manner and with higher accuracy compared to the conventional methods. Additionally, the measurement of an object is performed without being in physical contact. In this study, a test area of 2.10 meters ×2.80 meters in a vertical position was scanned at a 35 meters distance using different object colors (white, red, blue and green) with a Topcon laser scanner to determine the position accuracy of the scanner according to the colors. Then, by switching the Y and Z coordinates obtained from laser scanning, the test area was placed in a horizontal position, which resulted in a half rectangular prism. Then, the volume of this prism and the volumes obtained from laser scanning were calculated and compared. Based on the differences in this values, it was found that within a scanning distance of 35 meters, the position accuracy of the laser scanner varied between 5.7 mm and 12.2 mm. In addition, the best result was obtained by scanning the test area in white color.

Keywords: *Laser Scanning Technology, Object Color, Position Accuracy, Volume.*

1. INTRODUCTION

In recent years, three dimensional terrestrial laser scanning systems have been employed very successfully in many engineering applications. These systems allow the user to survey structural surfaces and 3D bodies. The data is then transferred to a computer where it is converted into accurate 3D models. The high quantity and precision of the measured points enable the user to generate realistic, 3D illustrations of complex structures (Shulz and Ingesand, 2004; Yılmaz at al., 2009). 3D terrestrial laser scanning techniques are an effective method of creating a complete 3D documentation of the spatial geometries of an object. They yield maximum information and have unsurpassed accuracy within a few millimeters. The recording techniques are hands-free allowing hazardous sites to be easily documented from a distance of greater than 100 m (Demir at al., 2004; Yılmaz at al., 2009). In terrestrial laser scanning, 3D coordinates are obtained as point clouds. Several 3D coordinates on an object's surface can be measured in a very short time (Ingesand at al., 2003; Yılmaz at al.,2009). Thus, terrestrial laser scanners present as a very promising alternative for various types of surveying applications. They allow acquiring a huge amount of 3D data in a fast manner and can be often profitably combined with colored high resolution digital images to provide an accurate 3D representation of the environment. Another major advantage of this technique is providing a higher level of detail with good metric accuracy which results in the representation of real objects more adequately than using a single picture or a collection of pictures. The 3D models generated with these scanners are now widely used for cultural heritage, industrial, land management and medical applications (El-Hakim, 2001; Yılmaz at al., 2009).

Today, terrestrial laser scanning technology is used more than classical measuring methods. This technology provides the users with direct 3D position information and performs measurements faster and more accurately compared to the conventional methods. Therefore, particularly studies that would be time consuming and cost intensive using classical measuring techniques can be easily performed with laser scanning techniques to overcome these disadvantages.

Terrestrial laser scanning technology has significant advantages in terms of cost, time, and convenience in a wide variety of applications. Using this technology, 3D and high-resolution data can be obtained with high precision.

As with all measurement techniques, the results of laser scanning can be misleading due to different factors such as environmental factors and the characteristics (e.g., permeability and roughness) of the object surface to be measured and roughness. Therefore, the determination of the error sources is extremely important and necessary to maintain the quality of data. It is also crucial to know the accuracy of the measurements made with this type of equipment (Karşıdağ and Alkan, 2012).

In this study, the test area surface was covered by glossy foil paper of different colors (white, red, blue, and green) and scanned using a Topcon GLS-1000 terrestrial laser scanner from a distance of 35 meters. Then, the effects of the object surface color on the accuracy of the scanner were investigated.

2. MATERIAL AND METHOD

2.1 The Test Area

For this study, a test area of 2.10 meters × 2.80 meters was constructed and placed in a vertical position. The inside of this test area was covered with steel and the outer surface was covered with hardboard. Figure 1 shows that the test area is mounted on special metal feet and is fixed.

Figure.1 The test area

To ensure that the test area was exactly vertical, level screws were placed on the feet and on the back. The hardboard surface was white because this color reflects the most light.

2.2 Topcon GLS-1000 Terrestrial Laser Scanner

In this study, a Topcon GLS-1000 terrestrial laser scanner was used as shown in Figure 2.

Figure.2 Topcon GLS-1000 terrestrial laser scanner

The Topcon terrestrial laser scanner has the ability to quickly collect and store data. It has precise scanning technology, a 2 megapixel digital camera, 3000 dots per second scan rate, 90% reflection up to a range of 330 meters, 4 mm accuracy from 1 meter to 150 meters, 6″ angle accuracy horizontally and vertically and horizontal and vertical movement. There is less noise in the point clouds in the scans made with the Topcon terrestrial laser scanner, and even at distances above 100 meters, it possesses sufficient accuracy.

2.3. The Method

In this study, glossy foil paper in different colors of white, red, blue, and green were pasted on the test area surface. Then, by scanning the test area with a Topcon GLS-1000 terrestrial laser scanner at a distance of 35 meters, the effects of object surface colors on the terrestrial laser scanner were investigated.
To achieve this aim, the test area was scanned with different surface colors and after the test area was placed in a horizontal position with the help of the obtained point clouds, the volumes that were obtained were calculated. It is necessary to determine the most appropriate scanning color by comparing the calculated volumes with known volumes. Verticality was provided using the levels at the feet and behind the test area. The verticality was checked again using a square grid network of 10 cm created in an area of 2.70 × 2.00 meters using the Total Station in local system. The coordinates of the 588 points obtained were recorded as shown in figure 3.

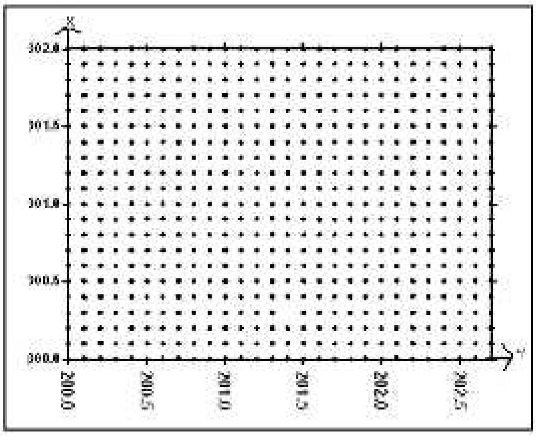

Figure.3 The grid network created on the test area.

The Y and Z coordinates were displaced to obtain a 3D image of the test area as shown in Figure 4.

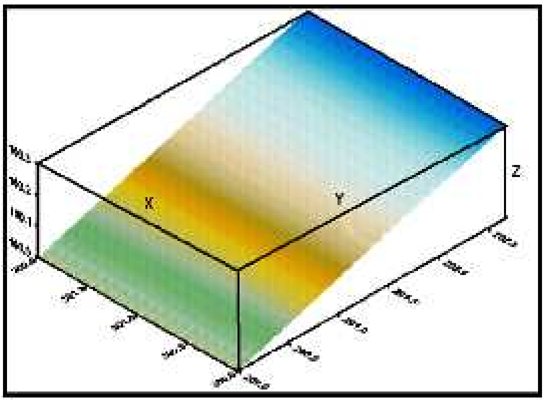

Figure.4 A 3D image of the grid network on the test area

Since the system that coordinates the grid network was not perpendicular to the test area, a surface that was a half a rectangular prism was obtained. This surface should have a volume of 0.8154 m3 and it was calculated by the obtained coordinates as 0.8165 m3 according to the volume calculation method of the rectangular prism. This very close result is numerical proof of the verticality of the test area. It is also necessary to have systematicity between the coordinates on the test area and this was visually checked for the three axes. Figures 5 to 7 show the systematicity between the X, Y and Z coordinates of the axes, respectively.

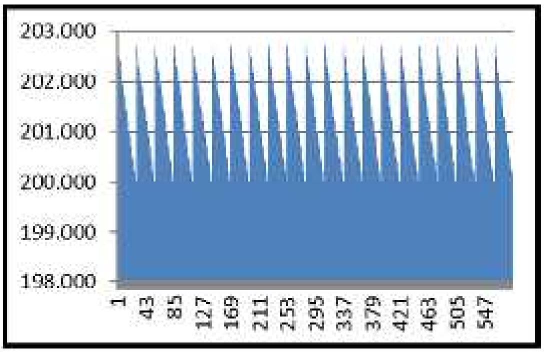

Figure.5 Systematicity between the X coordinates

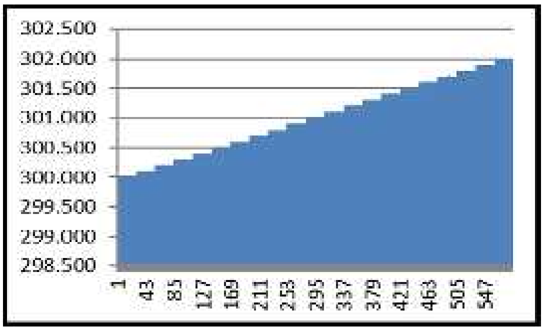

Figure.6 Systematicity between the Y coordinates

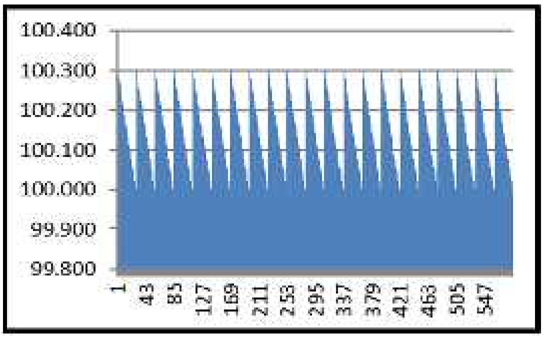

Figure.7 Systematicity between the Z coordinates

Each scan was performed at a fixed point 35 meters from the test area. The test area was first scanned in white color as shown in Figure 8.

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Figure.8 Scanning of the test area in white color.

Then, the test area was scanned in red, blue, and green as shown in Figures 9 to 11, respectively.

Figure.9 Scanning of the test area covered with red foil.

Figure.10 Scanning of the test area covered with blue foil.

Figure.11 Scanning of the test area covered with green foil.

The color values of each glossy foil paper were measured and recorded as shown in Table 1. A Datacolor SF600+CT device was used for color measurement. The parameters were chosen as follows: eye size 30 mm, enlightening CIE-D65 and the observation angle 100.

Table 1. Results of color measurement (CIE color parameters)

Color Parameters	Color Name			
	White	Red	Green	Blue
CIE L*	91.05	37.81	42.49	33.15
CIE a*	-2.36	58.84	-59.45	21.52
CIE b*	-3.42	38.85	21.36	-60.57
CIE Y	78.60	9.98	12.82	7.61
CIE x	0.3040	0.6066	0.2172	0.1652
CIE y	0.3260	0.3250	0.5134	0.1302

The scans were undertaken in an indoor space to reduce the effects of the external environment. Once the scanning was complete, the data was transferred to Scanmaster software to remove any unnecessary point clouds. The remaining point clouds were recorded in Microsoft Excel to calculate the expected volumes for each scan. For the red and green foil, the raw data and the processed images (unnecessary point clouds removed) are shown in Figures 12 to 15.

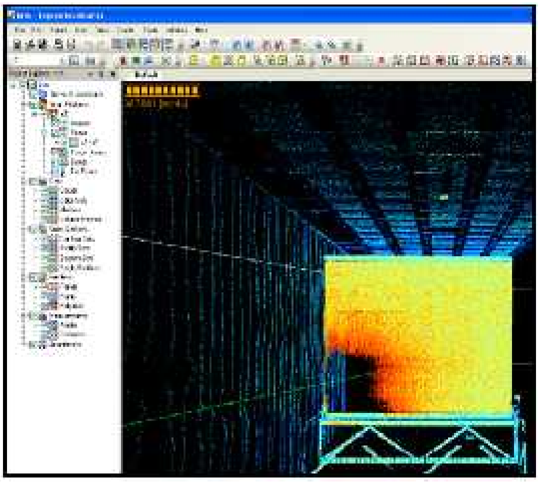

Figure.12 A Scanmaster image of the test area based on raw data from the scan of the red foil.

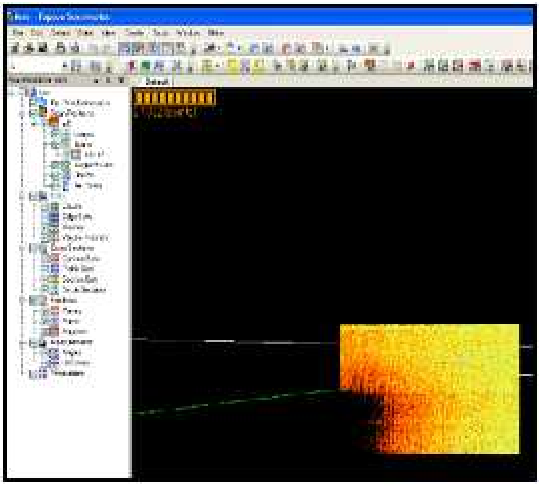

Figure.13 A Scanmaster image of the test area based on the processed data from the scan of the red foil.

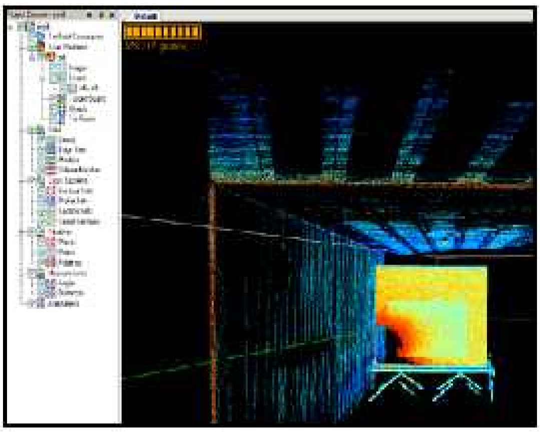

Figure.14 A Scanmaster image of the test area based on raw data from the scan of the green foil.

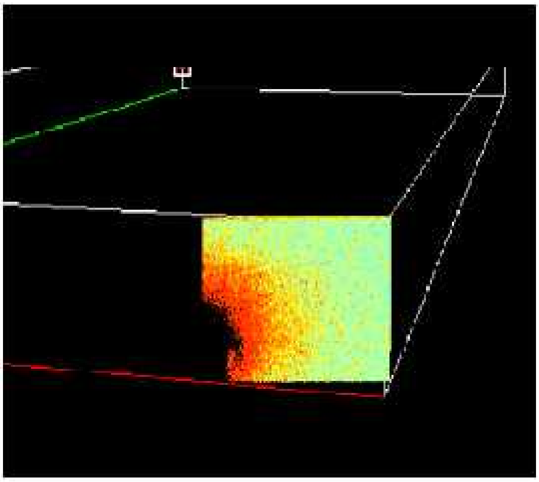

Figure.15 A Scanmaster image of the test area based on processed data from the scan of the green foil.

The minimum and maximum values of the coordinates of the required point clouds were calculated in Microsoft Excel. In order to avoid a possible conversion error, the local coordinates obtained from the scanner were used directly. From the obtained coordinates, the values of “Y” and “Z” were replaced and the test area was made horizontal. If the scans had been made exactly perpendicular to the test area, the volume of the rectangular prism would have been zero. However, since the scanner was not completely perpendicular to the object and was not leveled, this was not possible. In this case, a half rectangular prism is expected to be formed with a base which is the difference between the minimum and maximum X coordinates and the difference between the minimum and maximum Y coordinates, and the height of the rectangular prism is the difference between the minimum and maximum Z coordinates. The calculated difference values were multiplied (base area × height) and divided by two (half rectangular prism) and the expected volume values were calculated for each color. The calculation of the volume value obtained from scanning the white test area is shown in Figure 16.

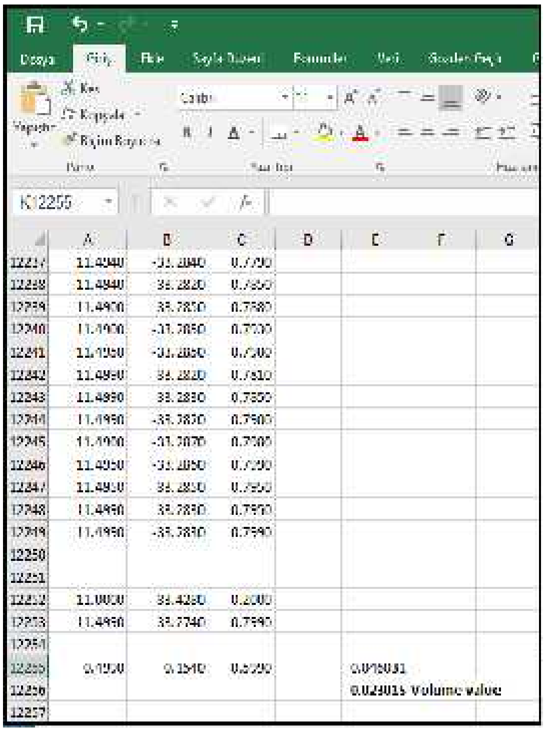

Figure. 16 The expected volume obtained by scanning the test area in white color.

After determining the difference between the minimum and maximum values of the coordinates of the four scanning stations, these values were transferred to Surfer software to calculate the volume for each station. Figure 17 shows the volume values calculated using the point clouds obtained by scanning the test area in white color.

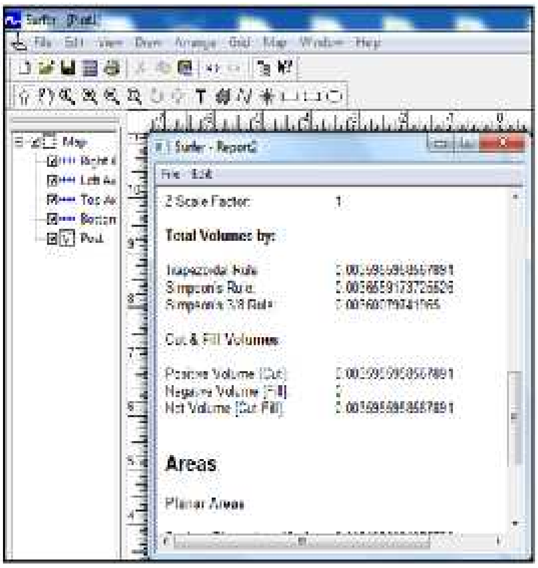

Figure.17 Volumes calculated from the point clouds obtained by scanning the test area in white color.

As the surface of the object was flat, a linear interpolation method was used in the volume calculations for the best result (Yılmaz, 2007). In addition, the volume values obtained from the coordinates for each color were calculated. This allowed determining the differences between the volumes.

2.4. Results

Table 2 presents all the calculated volumes and the differences between the values by scanning color.

Table 2. A comparison of the calculated volumes between the scanning colors.

Object Surface Color	Volumes Calculated From Point Clouds (m3)	Expected Volumes (m3)	Differences (m3)
White	0.0036	0.0230	0.0194
Red	0.0033	0.0440	0.0407
Blue	0.0027	0.0312	0.0285
Green	0.0033	0.0451	0.0418

A 1.0 meters × 2.0 meters portion of the test area was assessed in the study. The laser scanner was not completely perpendicular to the test area and there was a 30 cm slip on the Y axis. This resulted in a half rectangular prism of 2.7×2.0×0.3 meters in dimensions for each scan. The volume of this half rectangular prism was calculated as 0.810 m3. The volumes were recalculated by increasing each edge of the prism from 1 mm to 15 mm and the values obtained are shown in Table 3.

Table3. The volume values obtained by increasing each edge of the prism from 1 mm to 15 mm.

Y (m)	X (m)	Z (m)	Error (mm)	Calculated Volume (m^3)	Known Volume (m^3)	Differences (m^3)
0.301	2.701	2.001	1	0.81341		0.00341
0.302	2.702	2.002	2	0.81682		0.00682
0.303	2.703	2.003	3	0.82024		0.01024
0.304	2.704	2.004	4	0.82366		0.01365
0.305	2.705	2.005	5	0.82709		0.01709
0.306	2.706	2.006	6	0.83052		0.02052
0.307	2.707	2.007	7	0.83395	0.81000	0.02395
0.308	2.708	2.008	8	0.83740		0.02740
0.309	2.709	2.009	9	0.84085		0.03085
0.310	2.710	2.010	10	0.84430		0.03430
0.311	2.711	2.011	11	0.84776		0.03776
0.312	2.712	2.012	12	0.85122		0.04122
0.313	2.713	2.013	13	0.85469		0.04469
0.314	2.714	2.014	14	0.85816		0.04816
0.315	2.715	2.015	15	0.86164		0.05164

The differences in the volume values shown in Tables 2 and 3 were compared. According to the data in Table 3, if the volume difference was 0.02740 m3, it was assumed that scans had been performed with an error of 8 mm. Then, the difference values given in Table 2 were compared to those in Table 3 to obtain the scanning sensitivity/precision of the four applications (Table 4).

Table 4. Scanning precisions by object surface color.

Object Surface Color	Scanning Precision (mm)
White	5.7
Red	11.8
Blue	8.3
Green	12.2

3. CONCLUSION

In recent years, the scanning precision and field of use of terrestrial laser scanners have been steadily increasing. These scanners have been successfully applied in many engineering applications. The most important factor in obtaining 3D positional data of an object is the sensitivity of this data. The acquisition of this data in the shortest time is another important factor. In addition to 3D modeling, which is one of the most common uses of terrestrial laser scanning technology, there are various applications such as deformation measurements, in which data precision is very important.

In terrestrial laser scanners, the radial resolution is defined by the scan range. In this study, the test area was covered with glossy foil papers in different colors (white, red, blue, and green) and scanned with a Topcon GLS-1000 terrestrial laser scanner from a distance of 35 m. Then, the effects of the object surface colors on the precision of scanning were investigated. The results demonstrated a scanning accuracy of 5.7 mm to 12.2 mm. As known, the 5 mm scan range for each scan somewhat varies. Accordingly, the number of points obtained for each scan was also different, which resulted in variations in the results. On the other hand, there is more reflection of a certain region on the test area than the other regions that causes the lack of data in this region. Based on the results, it can be concluded that the Topcon terrestrial laser scanner used in this study has a scanning sensitivity of 5.7 mm to 12.2 mm for the given colors at a 35 m distance and scans with minimum errors when the object has a white color.

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