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Terrestrial Laser Scanning Data Integration in Surveying Engineering

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1. Introduction

In terms of sensitivity and equipment, there are several differences between Close Range Photogrammetry (CRP) which is today often used for documentation of historical and cultural structures, restoration, relievo studies, and Terrestrial Laser Scanner (TLS) technology which is recently started to be used for 3D modelling of every kind of objects and geometric data acquisition.

Terrestrial laser scanning is a new technology that enables easy and fast data acquisition from objects with complex structures such as buildings, machines, etc. In recent years, some manufacturers designed and improved different systems for specific purposes [4]. The combination of terrestrial image photogrammetry and CRP method, which is also a new technology, provides us new opportunities in presentation of 3D photorealistic models, classification of real objects and creation of visual reality [9].

TLSs usage becomes more popular day by day since they present quick and effective solutions in the way of acquiring 3D geometric information on objects.

Some of the significant study areas that benefit from TLS are as follows:

- Archeology,
- Architectural restoration studies,
- Measurement of tunnels and roads,
- Urban modeling,
- Virtual factories, applications of virtual reality,
- Mining and infrastructure projects,
- Manufacturing controls,
- Crime scene investigations,
- Studies of industrial design, etc.

We can consider CRP and TLS as either independent methods or two complementary methods; therefore their area of application broadens day by day.

If TLS and CRP are compared with Laser Scanners;

- 3 dimensional points can be acquired directly
- Intense point cloud data can be obtained within the frequency of millimeters, in a short period
- Smooth data acquisition over difficult surfaces in terms of their form

- Opportunity of real image acquisition

If TLS and CRP are compared with Close Range Photogrammetry;

- High resolution
- Low costs
- Since data acquisition is possible via limning, little time

are the main elements and characteristics.

Terrestrial laser scanners allow the imaging of the object as a point cloud by scanning them as point series in horizontal and vertical directions, under a specific angle. Point cloud data contains polar coordinates (X, Y, Z) which are based on the scanner and a value of reflection density (tons) information for each point measured. These values (polar coordinate, etc.) can be printed in several formats, namely in txt format [10].

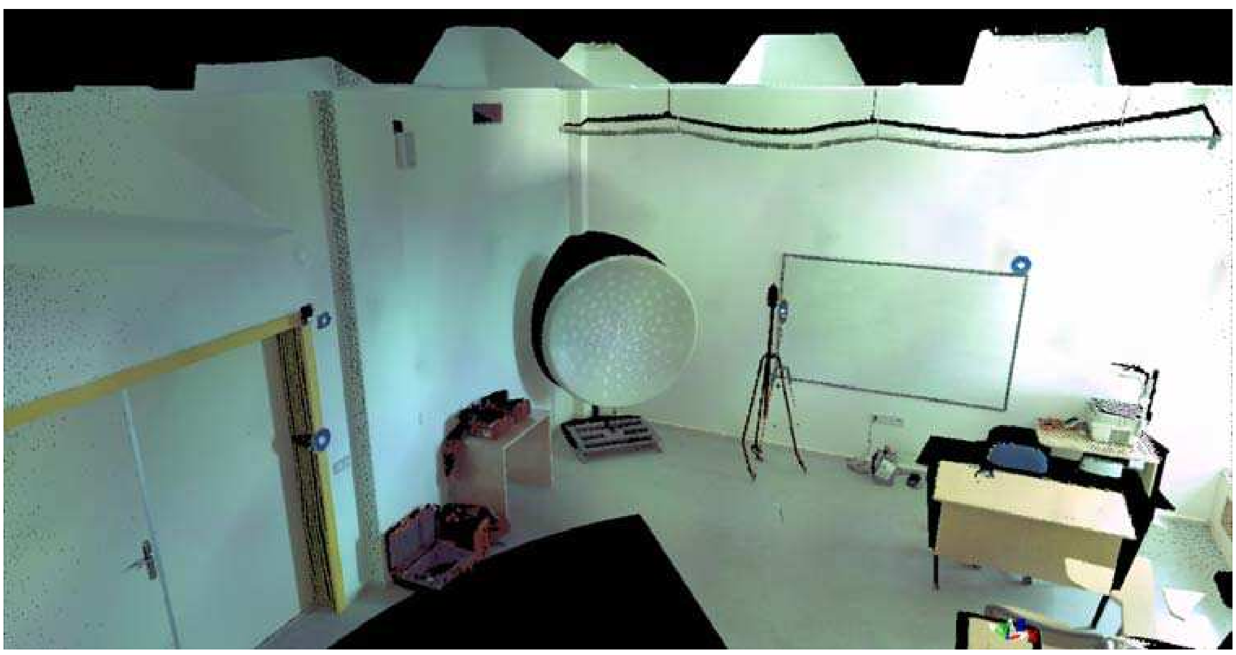


Fig. 1.1. Sample Point Cloud Data from TLS

Integration of scanning data from different station points in a single coordinate system is realized by the help of artificial targets. By coordinating the targets in question by the help of geodesic methods (Total Station etc.) object coordinates are obtained within the desired reference system.

TLS point cloud data is a very intense data set, and making a study with CAD (Microstation, Autocad, etc.) software necessitates computers with very potent hardware and very experienced operators. In order the TLS data to be used in terrestrial photogrammetry, points with known coordinates that will be used in image rectification should be picked up from the whole TLS point cloud data. The sample point cloud data from TLS was shown in Fig. 1.1.

The purpose of this chapter is to provide a filter creation in which surfaces in architectural photogrammetry can be automatically distinguished, so the operator's duty will be reduced under the density of point cloud taken from the surfaces via terrestrial laser scanner. Purpose of the algorithm is to obtain real surface of the scanned object and to reduce the volume of data. In this algorithm, vertical flat surfaces of the structure are auto-selected, irrelevant points are filtered. Depending on the object's surface, different methods should be

performed. These methods are Intersection of Plane Surfaces, Hough Transformation and a new technology based on surface projection etc.
With the improvement of application areas and the advantages mentioned, terrestrial laser technology is academically an interesting topic and continues to be studied.

2. Equipment and data structure of terrestrial laser scanners

Laser technology is an area of research since 1960's; however using laser technology for the sake of making measurements is relatively new concept. As laser scanning systems are innovated, they gain a broader area of application, too. By different companies, depending on their application specifications IQSun, Leica, Optech, Callidus, Trimbe, Riegl, etc. (Table 2.1) and depending on their distance lengths (1m – 1500m) some terrestrial laser scanners which are shown in Fig. 2.1, are manufactured.


Leica -HDS 3000


Leica -HDS 4500


Optech -ILRIS 3D


Trimble- (Mensi) GS200


Riegl LMS-Z210i


Callidus -CP 3200

Fig. 2.1. Terrestrial Laser Scanners of Various Companies

Specifications of several laser scanners currently used are shown in Table 2.1 with respect to their measurement distances and scanning sensitivities. According to this table, TLS system's (Leica HDS 3000) point position accuracy can be acquired [19-23].

Firm	Type	Measurement Range(m)	Meas. Point	Scanning Angle	Distance Accuracy	Position Accuracy	Light Beam
Leica	Scan Station	300m (90% Reflection)	4000 point/sec.	$270^0(V)$ $360^0(H)$	4 mm @ 50 m	6 mm @ 50 m	4 mm @ 50 m
	HDS3000	300m (90% Reflection)	4000 point/sec.	$270^0(V)$ $360^0(H)$	4 mm @ 50 m	6 mm @ 50 m	4 mm @ 50 m
	HDS4500	53.5 m	500000 point/sec.	$310^0(V)$ $360^0(H)$	5mm+120pp m (%100yns. y.)	13.7mm @ 25 m	8.5 mm @ 25 m
	HDS6000	79 m (80% Reflection)	500000 point/sec.	$310^0(V)$ $360^0(H)$	5 mm @ 50 m	10 mm @ 50 m	3 mm + 0.22mrad
Optech	Ilris 3D	3m–1500m (80% Reflection)	2500 point/sec.	$310^0(V)$ $360^0(H)$	7 mm @ 100 m	8 mm @ 100 m	0.00974^0
Riegl	LMS-Z420	2m-1000m (80% Reflection)	12000 point/sec.	$0-80^0(V)$ $0-360^0(H)$	8 mm @ 50 m	10 mm @ 50 m	0.25 mrad
	LMS-Z390	1m-300m (80% Reflection)	11000 point/sec.	$0-80^0(V)$ $0-360^0(H)$	4 mm @ 50 m	6 mm @ 50 m	0.25 mrad
	LMS-Z210	4m-650m (80% Reflection)	12000 point/sec.	$0-80^0(V)$ $0-360^0(H)$	10 mm @ 50 m	15 mm @ 50 m	2.7 mrad
Z – F	Imager 5006	1m – 79 m	500000 point/sec.	$310^0(V)$ $360^0(H)$	mm @ 50 m	1 mm @ 50 m	0.22 mrad
Faro	LS 880	1 m – 80 m	12000 point/sec.	$320^0(V)$ $360^0(H)$	3 mm	5 mm	0.01^0

Table 2.1. Laser Scanners and Their Specifications

2.1 Equipment structure of terrestrial laser scanners

In this section, a Terrestrial Laser Scanner is used and as it is figured out in Fig. 2.2, the components of a Terrestrial Laser Scanner are:

- Scanner,
- Control unit,
- Power source,
- Stand

Fig. 2.2. Terrestrial Laser Scanner Used In This Application and Its Components

Scanning unit is the part that obtains 3D data in TLS system. They can be examined under three groups depending on their distance measuring method.

Measurement Model	Range (m)	Accuracy (mm)	Company
Flight Time	<100	<10	Optech, Leica, Mensi, Callidus, Riegl
	<1000	<20	Optech, Riegl
Phase Diff.	<100	<10	IQSun, Leica, Visimage, Z – F
Optical Trian.	<5	<1	Mensi, Minolta

Table 2.2. The Classification of TLSs According to Their Distance Measuring Method

As seen in Table 2.1 and 2.2, it is necessary to choose a scanner relevant to the scanning surface and the desired sensitivity. For instance, for a completed road project, in order to control the suitability of the manufactured product with respect to the project or in the volume measurement of huge excavation fields such as stone pits, sand, gravel, borrowed pits, TLSs like Optech, Riegl can be preferred, because they measure distance with Time of Flight principle (<1000) and a sensitivity of <20mm is more than satisfying in such

applications. However, in a surface with a reduced cross-sectional area, such as a tunnel, a machine of <100 m measurement range should be preferred [3].
The broadest distance measuring method of the scanners, which can be examined under three groups according to their distance measuring principle, is the time of flight method as shown in Table 2.2. The basis of TLS system shown in Fig 2.3, which uses time of flight distance measuring method, is the process of measuring distance by recording the time of flight. That is, it records the time of reflection of laser beam sent by pulse from the object's surface points, the moment of origin of laser beam that leaves the scanner and its time of return, namely the time of flight, so it measures the distance.

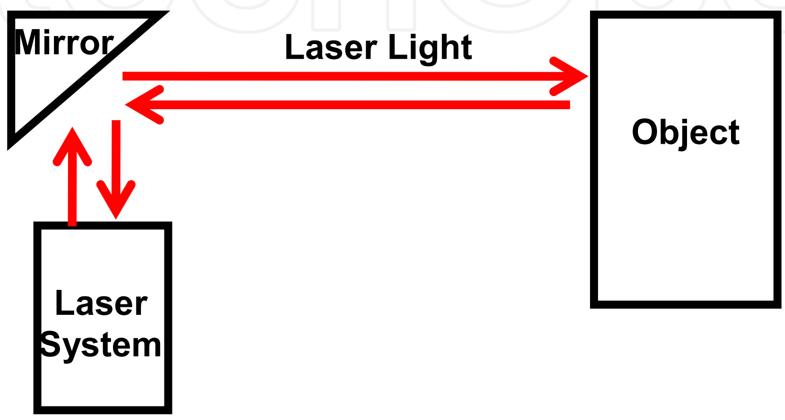


Fig. 2.3. Distance Measuring Method Based on Time of Flight

The second popular distance measuring principles used in TLSs are Phase Difference Method as shown in Fig. 2.4. Laser sent in this method is adjusted with a harmonic wave. The distance is calculated by the phase difference between transmitted and received waves. Most of TLSs, that effectively scans in short distances work under this principle [2].

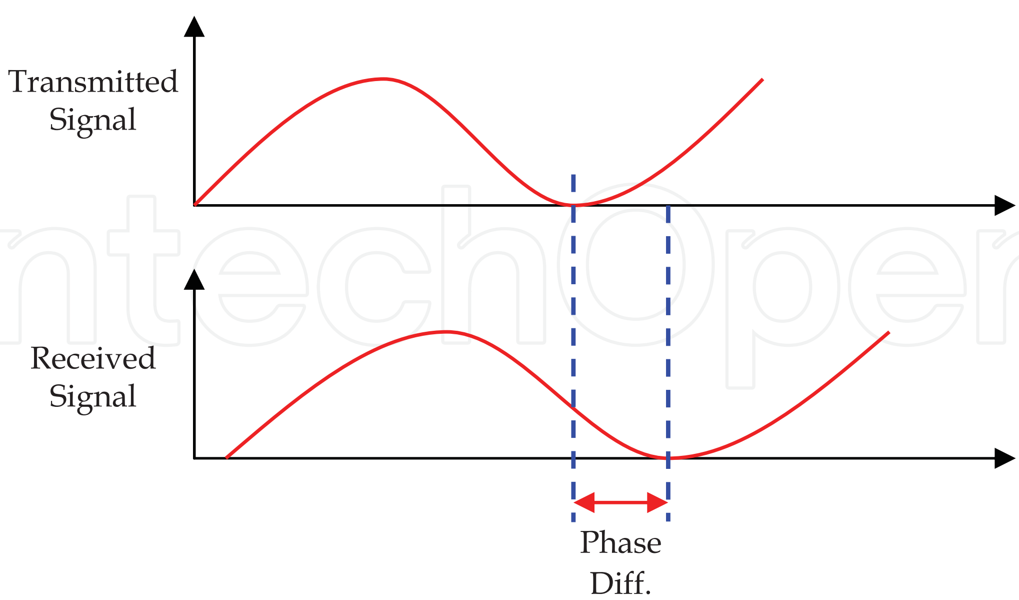


Fig. 2.4. Phase Difference System

Systems that are based on the third principle are systems which work with triangulation method (optical triangulation). Those systems, by performing scans of <1mm sensitivity and

within short distances, work under this principle. They are used in the area of industrial and sensitive applications and for small objects [2].
If scanning unit is inspected generally, the following items can be seen:

- Laser telemetry and
- Laser beam derivation unit.

Laser Telemetry Block Layout includes the following as shown in Fig. 2.5:

- Transistor laser or semi permeable laser diode (Transmitter),
- Detector (AGC) (Receiving Canal),
- Time differentiation, measurement unit (TDC),
- Transmitting and receiving optics

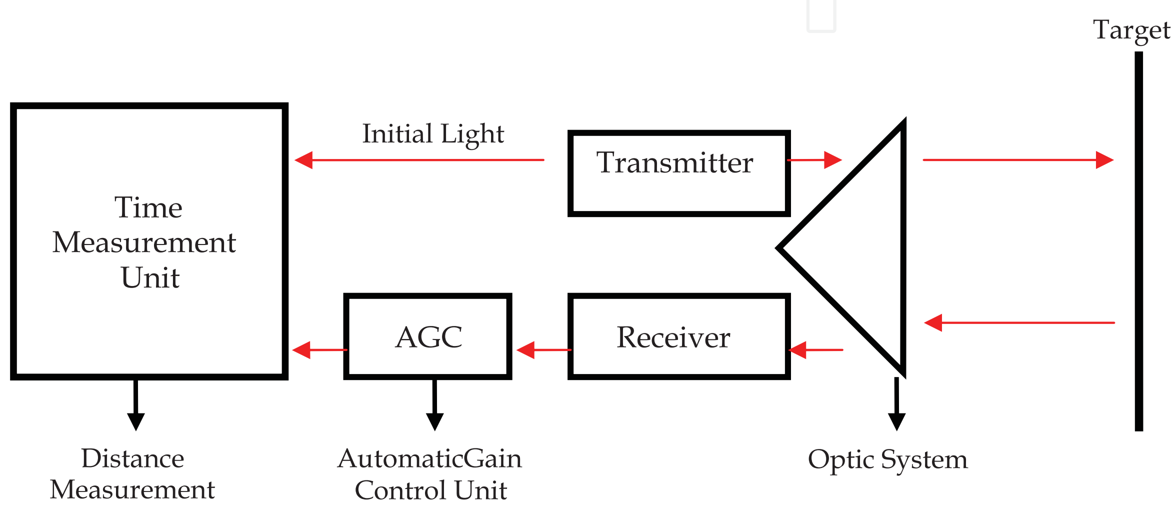


Fig. 2.5. Laser Telemetry Block Layout

Laser transmitter transmits an initial laser pulse which goes to the transmitter and serves to initialize the time measurement unit at the same time. Detector (AGC) is used in the detection of laser signal reflected from the surface and when the signal from measured object is detected by the detector, the time measurement unit initialized by the initial pulse also stops [1].
Distance of the target to the scanner can be calculated with the equation of;

$$R = c\frac{t}{2} \tag{2.1}$$

In equation (2.1), c represents the speed of light, t represents the time that passes during the contact of laser pulse to the measured object and its return.
Laser beam deviation unit is used to deflect the beam in vertical and if necessary horizontal direction and the following items are used in this process:

- Swinging flat mirrors,
- Swinging polygon mirrors,
- Galvanometric mirrors.

Scanning unit is generally high capacity, often portable computers, in which Terrestrial Laser Scanner software is installed and which is used for recording the whole scanning process and for recording and controlling the data obtained. Power source is composed of one or more batteries. Laser scanner gets its power from these batteries. TLSs are used with an adjustable stand, which can be adjusted depending on the station point used and its purpose of usage.

2.2 Data structure of terrestrial laser scanners

Laser scanners allow the imaging of the object as a point cloud by scanning them as point series in horizontal and vertical directions, under a specific angle. Scanner-centric polar coordinates are measured for each of the laser points. These are; slant distance to measured point P, the angle of measurement line with X-axis and horizontal plane α, and the slope angle of measurement line with horizontal plane φ. Terrestrial laser scanners accept their positioned point as their initial point as shown in Fig. 2.6. They perform a measurement completely based on their local coordinate systems [10].

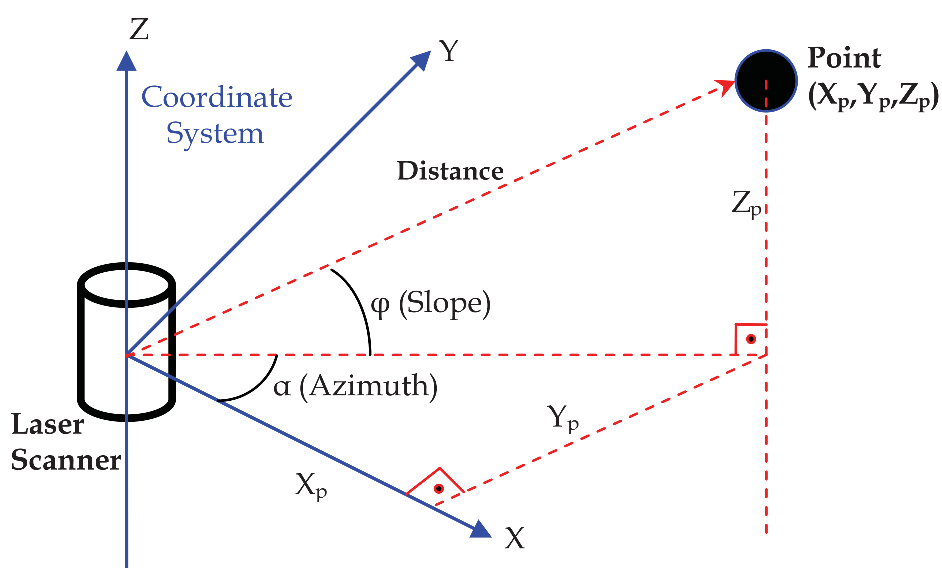


Fig. 2.6. TLS Local Coordinate System

Obtained point cloud data can be processed in various formats as coordinate, angle distance such as DXF for CAD models, ASCII for surface modelling, VRML format for visualization and txt or pts. Point cloud data can be obtained by the software, which varies depending on different TLS models used.

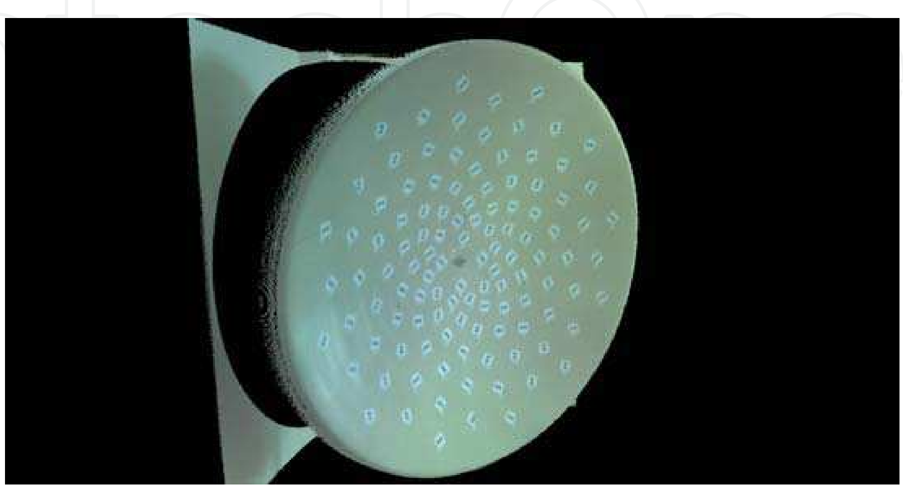


Fig. 2.7. Point Cloud Image from Cyclone 5.2

TLSs scan the surface of object by obtaining X,Y,Z Cartesian coordinates within second in the coordinate system centered on their established station point. Besides three dimensional coordinates, depending on the structure of scanned surface and measuring distance, the obtained data includes the density of returning signal in terms of RGB (Red, Green, Blue). By the help of recorded RGB density values, modeling of scanned object and environment becomes easier. This dense data acquired by scanning is called point cloud. The txt data formation for point cloud data is shown in Table 2.1.

X (m)	**Y (m)**	**Z (m)**	**Color Information**			
0.153229	0.521369	-0.004161	-76	91	115	113
0.270996	0.521319	-0.004880	-75	87	109	107
0.153229	0.467538	-0.009394	41	75	94	98
0.270874	0.467157	-0.006026	-167	81	100	97
0.216461	0.494419	-0.006889	-170	79	98	96

Table 2.1. txt Data Formation

The software exist in goal-oriented modules, in order to obtain raw data, to transform the data into a form that can be worked on, to perform texturing (when necessary) etc. In Fig. 2.7, point cloud data, which is visualized with RGB density values and scanned with Leica HDS – 3000 terrestrial laser scanner.

3. Data integration techniques for TLS in surveying

The use of TLSs in photogrammetric data production is a preferred method today. Points with known coordinates that will be used in image rectification should be picked up from the whole TLS data. Those points are defined as maximum and minimum points over object surfaces. However, because of different scanning angles within TLS data and dense point cloud data, reading and processing of these points over surfaces necessitate a difficult research and it is not time-effective for the operator that produces data. Especially in photogrammetric data creation, in the studies of architectural restoration and the protection of cultural heritage, the data are the images, converted vertically. Taking these images from TLS data, the point cloud set, and using them in photogrammetric image rectification can be done by means of an operator. In order to make this study independent from the operator, differentiating surfaces with different depth over point cloud data can be followed as an integration method [5-8].

As an integration method, in order to determine different surfaces of different depths automatically, a geometric filtering method research is made in this study. Thanks to this integration method, data required for image rectification which is a part of photogrammetric data production can be created automatically without any human factor over the point cloud data which forms TLS data. Data file that constitutes the basis of TLS data format coordinate information and the data that constitutes photogrammetric coordinate information are the same in terms of data coordinate information. However, in order to integrate photogrammetric data automatically, data of vertically converted photographic information should be selected accurately within this point cloud data. They should be classified with a filter algorithm used within this point cloud data. Cyclone 5.2 software is used in forming these TLS point cloud data. When coordinate information of the point cloud data obtained with this software is examined, an orderly processing and classification can not be seen in data contents. In this case, determination of point coordinate from point cloud data can be made by the help of operator, manually, on CAD interface of the software. 3D classification of the data is considered, by applying a filter with the help of a mathematical algorithm over raw data obtained for the classification of point position data of different depth-surfaces. We worked on a mathematical algorithm that would be able to make this classification and the point cloud data is automatically classified under MatLAB environment with an algorithm based on geometric location information. Thus, without any operational interference, it will be possible to obtain information photogrammetrically on point cloud data.

In measurement technology, besides the photogrammetric method, terrestrial laser scanning and modeling technology are intensely used in architectural documentation and cultural heritage studies. In the perception of engineering perspective, these two methods are independent of each other. However, these two methods can be combined with each other in the essential parts of architectural documentation and cultural heritage studies. While one is implementing these applications, the working procedure is so significant that if the amount of data increases, time consumption reaches higher levels. These two methods are compulsorily optimized for working in a collaborative way, especially in the large-scale studies. This necessity leads to the application of two types of integration. One of them is hardware integration, and the other one is data integration. Nevertheless, the laser scanner-measuring algorithm has some problems. The first problem stems from the huge amount of data. The point cloud of a historical building easily contains more than one million measured points. Such a huge amount of data causes problems on CAD documentation. In addition to this significant problem, the huge amount of data also causes problems in photogrammetrical documentation of surfaces, especially in the process of photogrammetric image rectification for building facades [11,12]. There is a variety in the methodology for such studies. Some studies combine laser scanner data and photogrammetry in cultural heritage recording [3,6]. Others apply different techniques for the treatment of laser data. Some of the techniques focus on the object segmentation of architectural facades [8,13,14,15]. In order to solve the above-mentioned confusion, this study presents a specific approach to obtain real surfaces from a scanned object on the one hand and a reduction of the data volume on the other. The algorithm is based on mathematical surface clustering techniques. Using this technique, it manages to extract planar surfaces, including parameters of depth. Additionally, surface points belonging to the designated surfaces are filtered. Once one has the planar surfaces of the buildings, several methods can be proposed to extract the feature bounds.

3.1 Mathematical models of data integration with filtering

In this section, a new data integration model is suggested for the operating processes in architectural documentation and cultural heritage studies, with the terrestrial laser scanning that uses new data production methods of photogrammetry and surveying. The mathematical model and algorithm in the presented integration model is programmed in MatLAB 7.0 and is tested with the original data set. The functional model is explained, benefiting from the object oriented programming languages in MS Windows system [8,13,18].

The point cloud data that is shown in Fig.3.1. is defined by distinct surfaces. Indoor areas are usually defined by plane surfaces such as walls. Figure 3.1 shows that point cloud data and different surface construction in three dimensional coordinate system [18].

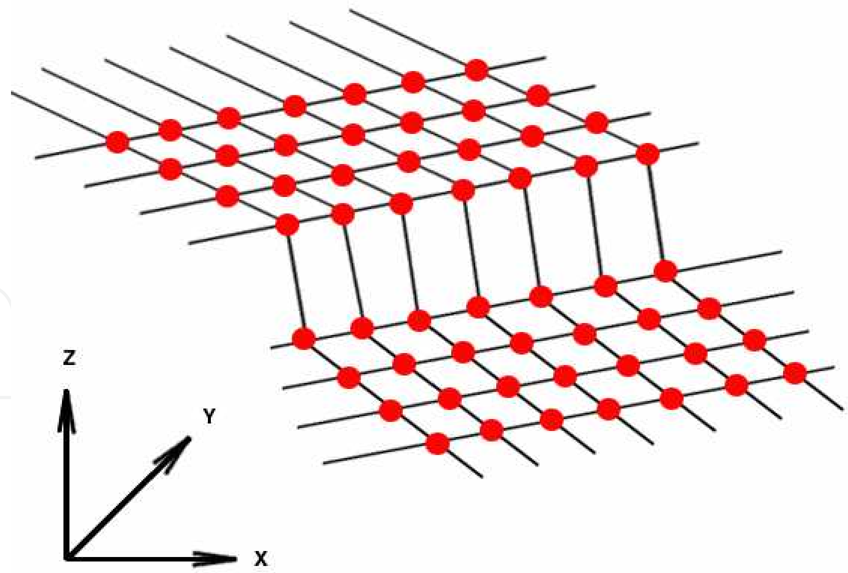


Fig. 3.1. Data Structure in 3D Coordinate System.

The algorithm used in this section was constructed by using the mathematical model of the surface. This surface function has four parameters:

$$\begin{aligned} ax_1 + by_1 + cz_1 + d_1 &= 0 \\ ax_2 + by_2 + cz_2 + d_2 &= 0 \\ &\dots \\ ax_n + by_n + cz_n + d_n &= 0 \end{aligned} \tag{3.1}$$

The first step of the algorithm was to define the reference surface. The reference surface was created by an operator by determining at least five points that belonged to same surface. This process was called adjustment computation for surface parameters in Eq. 3.1. After the process, Δz_i values were calculated separately for each point in the data set. The adjusted reference plane and the elevation coordinate system are explained in Fig. 3.2.

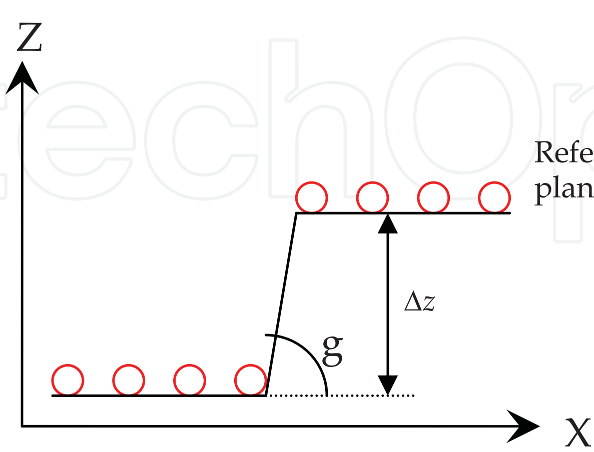


Fig. 3.2. Reference and Elevation Coordinate System for Point Cloud Data

These values were added to the data set for the column matrix. The second step of the algorithm was the determination process of the slopes of the points in reference to the

surface. These values were also embodied to the data set matrix as a column. In this case, the data set matrix was composed of five columns.
The suggested filtering function are shown as below [18].

$$f(p) = e^{\frac{\Delta z^2 . Cosg}{\sqrt{x^2 + y^2}}} \tag{3.2}$$

x_i : x coordinate of a point.
y_i : y coordinate of a point.
g : Slope angle from the reference surface.
The mathematical model for the filtering function is based on the slope angle of the points, Δz_i by the reference plane and is parallel to the distance of the points from origin. In this filtering algorithm, the origin point of the coordinate system has to be on the reference plane. This algorithm has mathematical model such as in Eq.3.2. This obligation is basically set up by affine transformation [7, 8]. In this case, Δz_i points get closer to zero. Therefore, the result of the filtering function of the points, which appears on the reference plane, gets closer to 1. Thus, with this filter function one can select the points on the reference plane easily.

3.2 Application

In order to facilitate CRP and TLS integration, data of TLS is simplified by a filter in this dissertation study. For this reason, a 3D, object-based filter, based on point weights, which has a mathematical algorithm is developed and is applied in two different data sets under two stages. The dissertation includes the obtained results and used data sets and their accuracy analysis has been made. For the purpose of obtaining TLS point cloud data that will be used in the chapter, scanning's made with Leica HDS 3000 Laser Scanner in the classroom of GYTE Geodetic and Photogrammetric Engineering Department.
The developed filter has been coded in Matlab 7.0 software as the base programming language via the flowchart in Fig.3.3. A plane is made with the points determined by an operator in the first step and after balancing, plane equation parameters are obtained [18].
In the second step, depth differences Δz in all points are calculated with the obtained parameters. Surfaces are differentiated from each other by a filter containing the geometric surface model and Δz parameters which are determined according to the average surface parameters calculated. The filter matrix (T) which is manipulated by the filter created under the scope of this dissertation study helps us to compare the results, by the applying it to all of the points.
This algorithm was tested with an application in indoor planar surfaces that were placed in the classroom of GIT. The application is provided in the Fig.3.4. below.
At first, each data set was obtained with Leica HDS 3000 scanner identically because of the point density and plane area wideness [9,10]. A data set of two distinct surfaces with 232 points was chosen, which had an approximate difference of depth between the designated surfaces. This data set is shown in Fig.3.5.
The first surface was selected as a blackboard, and the second one was a wall surface. The difference of depth between the board and the wall was approximately 3 cm. The wall surface was determined as the reference surface and 5 significant points that were necessary for the calculation of the parameters of plane equation were chosen from the mentioned

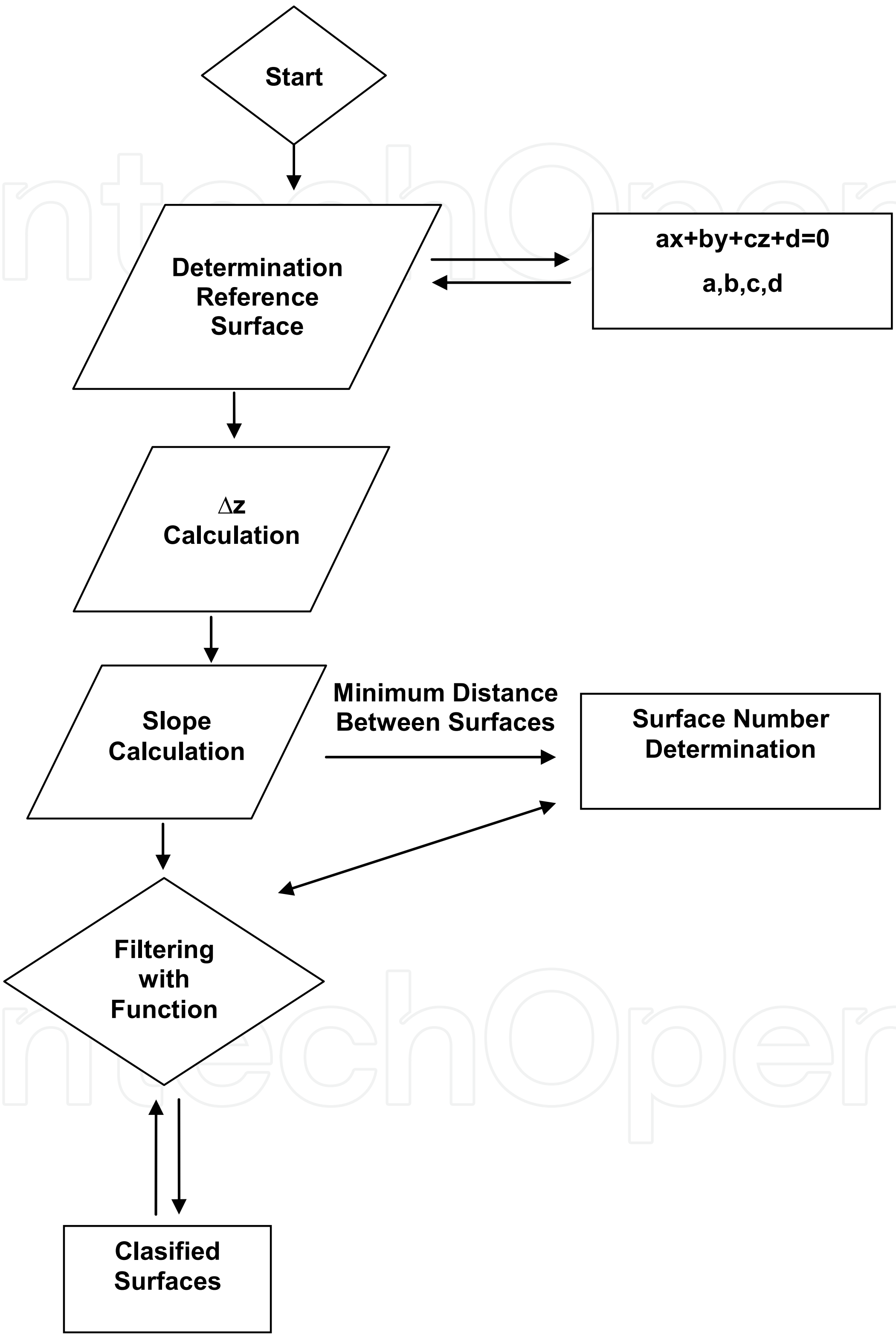


Fig. 3.3. Flowchart of The Filtering Code

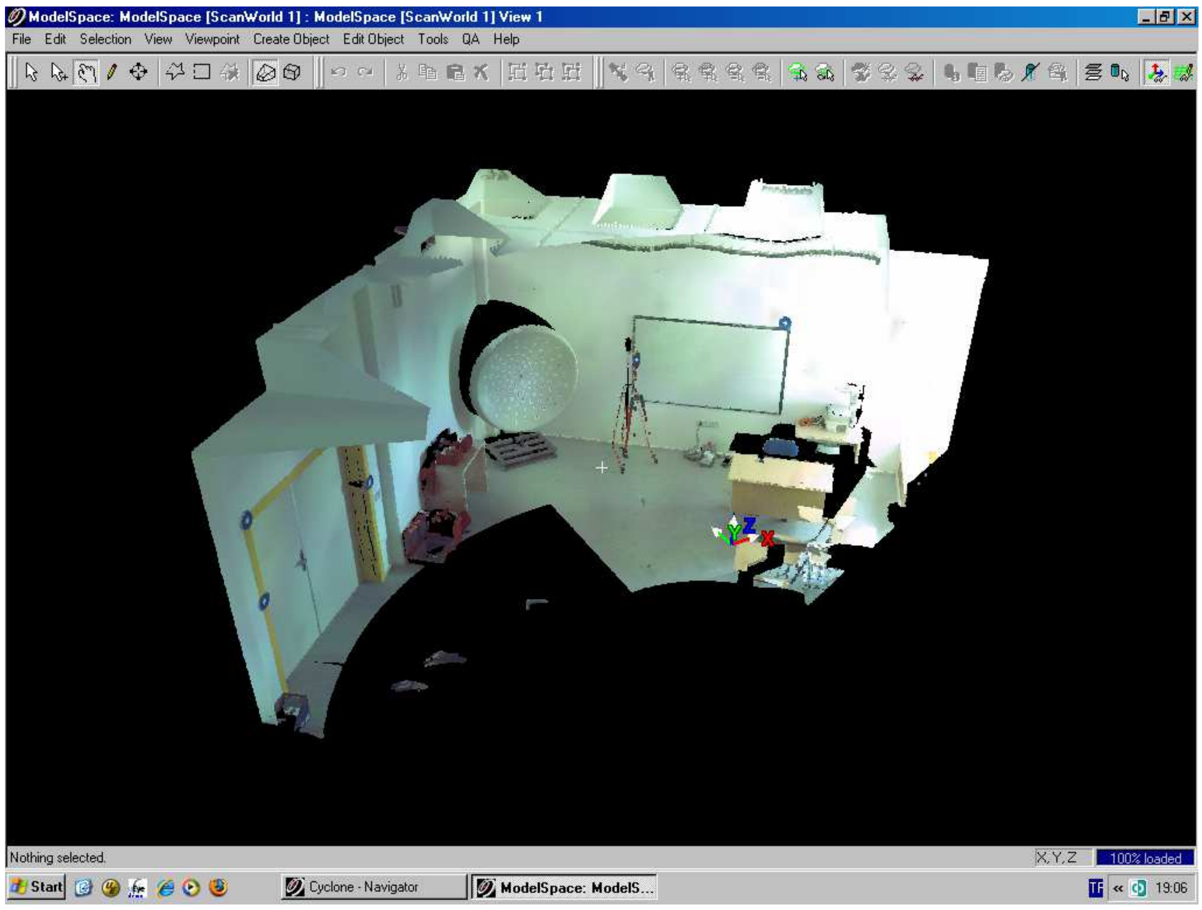


Fig. 3.4. Application Room within Point Cloud Data

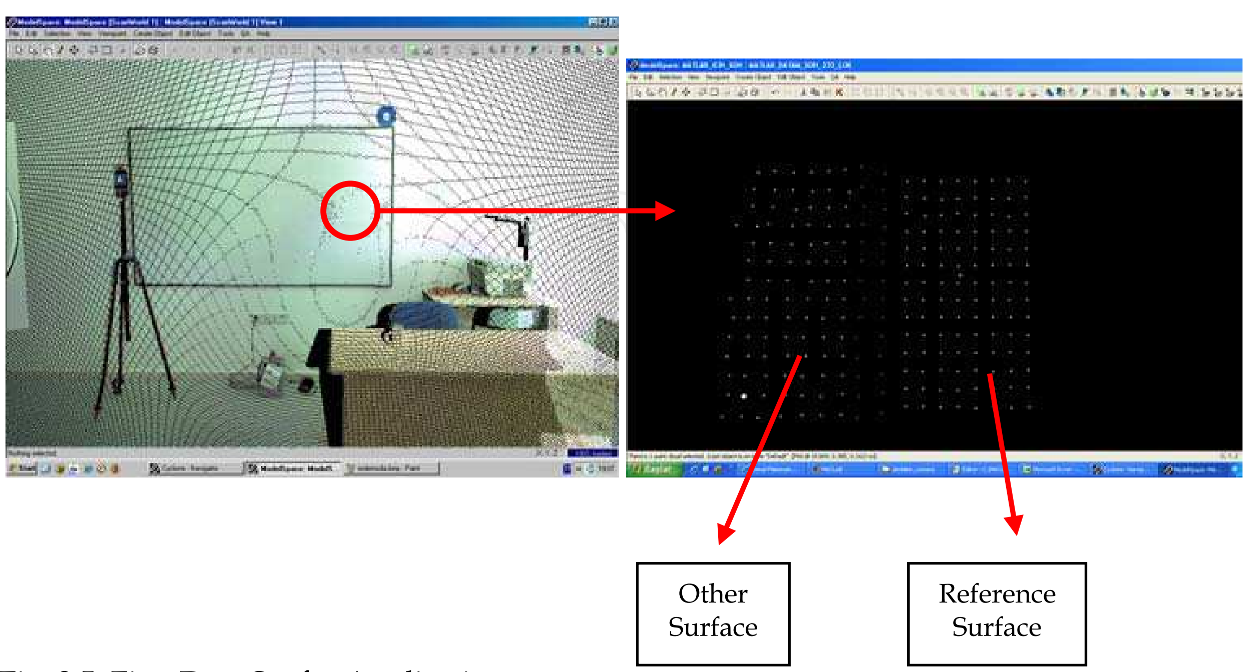
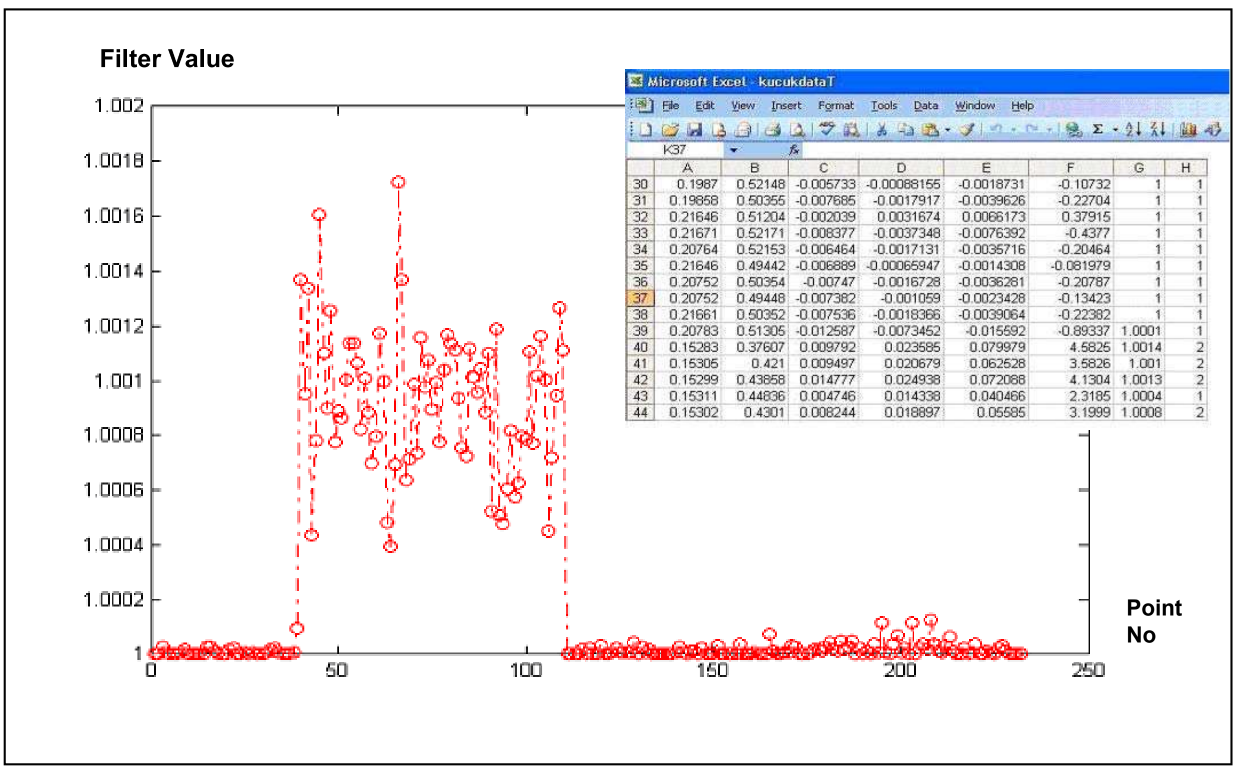


Fig. 3.5. First Data Set for Application.

surface. In line with those five points, the parameters of the plane and the height of reference surface were determined. The scanning frequency for the data set was 1 cm.

Once the group of points belonging to planar surfaces was obtained, different planes existing in our data were observed. With the filtering algorithm, separation of the planes from each other became possible. In this case, this algorithm was some kind of modification of the geometric method based on the plane theory, which enabled location of the data structure. Thus, it was not obligatory to specify the number of classes existing in the data. It was essential because the number of different plane orientations in a data set were unknown. Due to the algorithm, the points were obtained in separated groups that represented planes with a determined weight, by the Δz_i distance from the reference surface. Two points in parallel planes were still in the same group, but they were separated with the weightiness of the T Matrix. The reason for this process was to differentiate the points of different parallel planes and to ascertain the groups of points that were represented in T Matrix within the last column. The calculation of the weight of the points was done with formulation of Eq.3.2. The weights of the points were distributed between 0 and 1. This was the mathematical exponential function of distribution. The result for the classification of the first data set is shown in a Fig.3.6. below.



	A	B	C	D	E	F	G	H
30	0.1987	0.52148	-0.005733	-0.00088155	-0.0018731	-0.10732	1	1
31	0.19858	0.50355	-0.007685	-0.0017917	-0.0039626	-0.22704	1	1
32	0.21646	0.51204	-0.002039	0.0031674	0.0066173	0.37915	1	1
33	0.21671	0.52171	-0.008377	-0.0037348	-0.0076392	-0.4377	1	1
34	0.20764	0.52153	-0.006464	-0.0017131	-0.0035716	-0.20464	1	1
35	0.21646	0.49442	-0.006889	-0.00065947	-0.0014308	-0.081979	1	1
36	0.20752	0.50354	-0.00747	-0.0016728	-0.0036281	-0.20787	1	1
37	0.20752	0.49448	-0.007382	-0.001059	-0.0023428	-0.13423	1	1
38	0.21661	0.50352	-0.007536	-0.0018366	-0.0039064	-0.22382	1	1
39	0.20783	0.51305	-0.012587	-0.0073452	-0.015592	-0.89337	1.0001	1
40	0.15283	0.37607	0.009792	0.023585	0.079979	4.5825	1.0014	2
41	0.15305	0.421	0.009497	0.020679	0.062528	3.5826	1.001	2
42	0.15299	0.43858	0.014777	0.024938	0.072088	4.1304	1.0013	2
43	0.15311	0.44836	0.004746	0.014338	0.040466	2.3185	1.0004	1
44	0.15302	0.4301	0.008244	0.018897	0.05585	3.1999	1.0008	2

Fig. 3.6. The Classification for The First Data Set with Filtering Method

Secondly, an original data set containing four different surfaces and 3807 points was selected, and the difference of depth between the surfaces of the doors, borders, wall, and columns was changing from 7 cm. to 20 cm. Fig.3.7 shows that data set within four different surfaces.

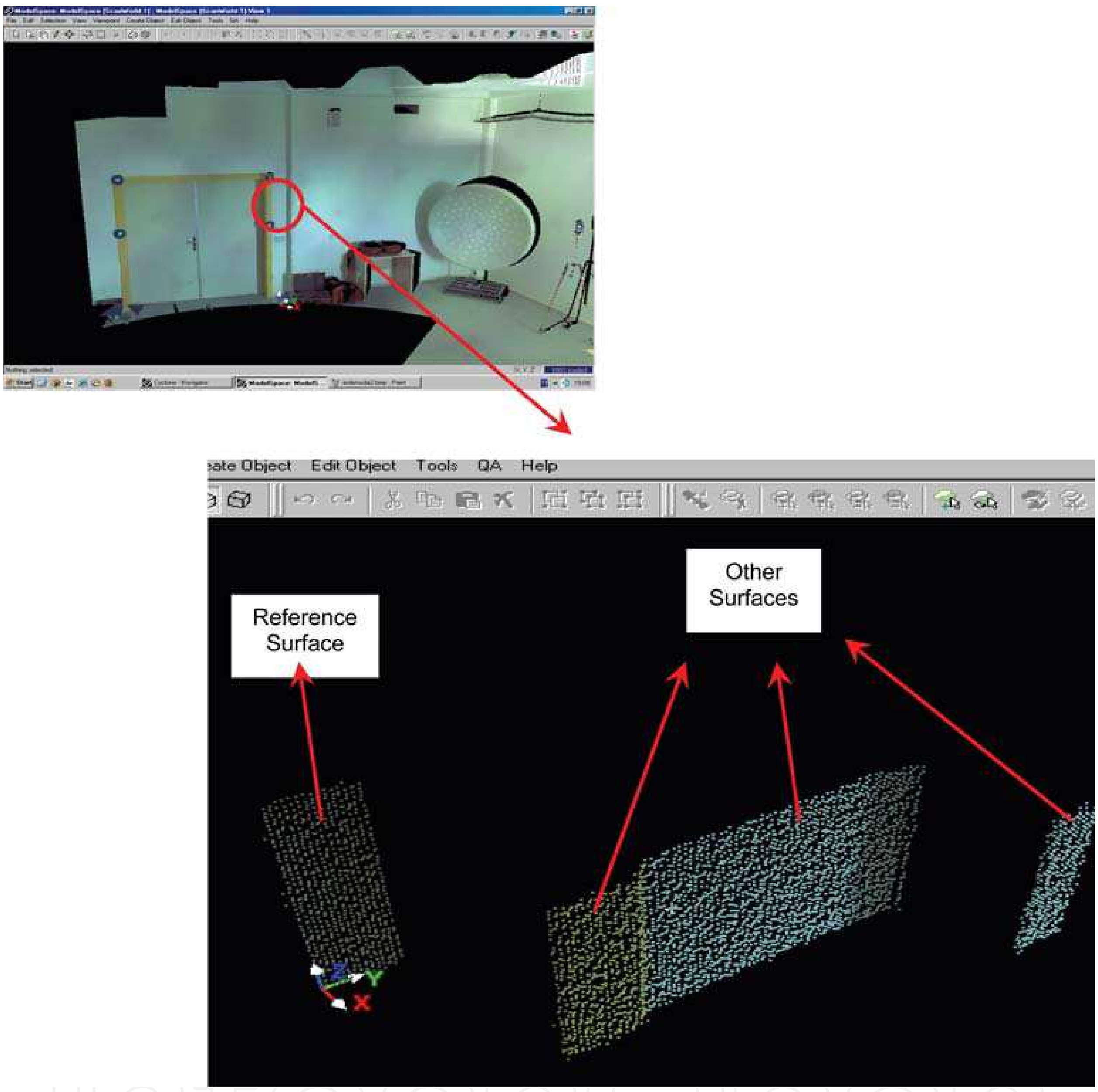
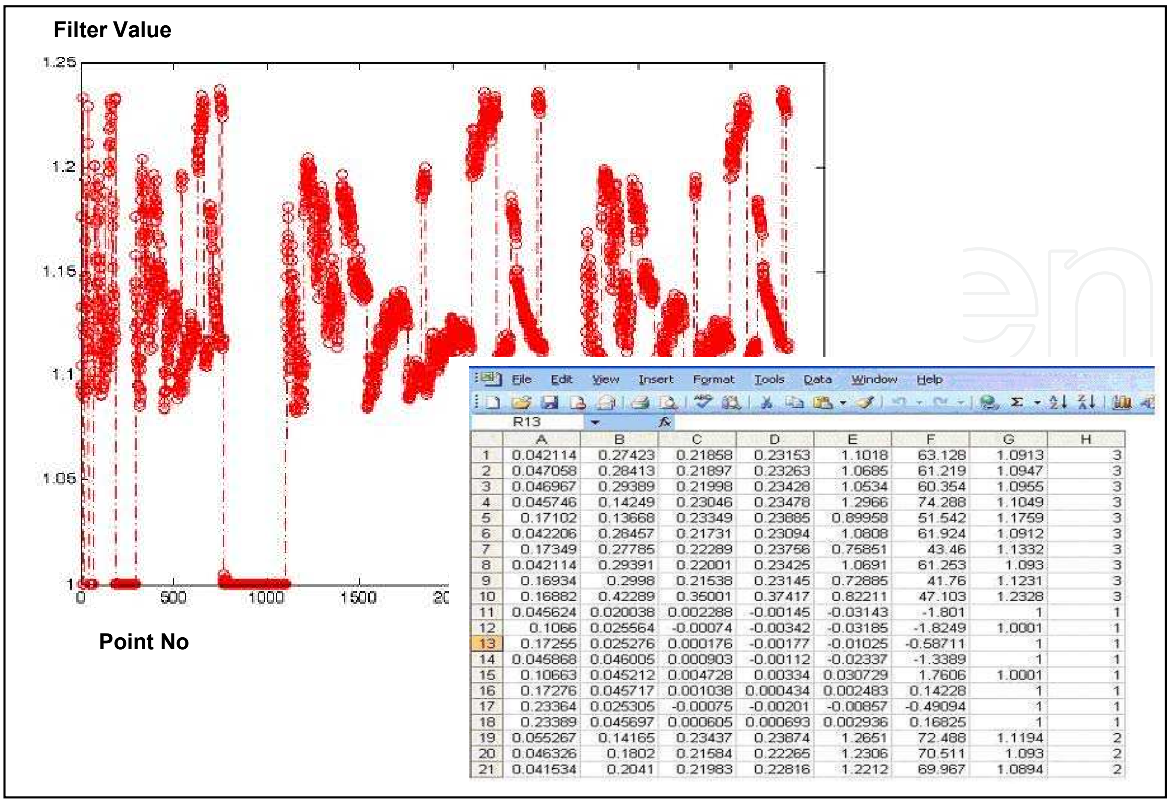


Fig. 3.7. Second Data Set From 4 Distinct Surfaces.

The result for the classification of the second data set is shown in Fig.3.8 above. Hence, the ASCII file was randomly composed with the coordinates of the surface. In this case, affine coordinate transformation was considered necessary. The Cyclone 5.2 software randomly collected the X, Y, Z data to the txt format. Therefore, the operator manually selected the points that were used in the rectification for all surfaces. This process caused extra time consumption and resulted in mismatching surface points when the deepness of the surfaces was in close proximity. With this algorithm, the operator was able to find the right coordinates automatically for image rectification from X, Y, Z ASCII file, whose points belonged to the surface for photogrammetric image rectification, without any additional coordinate transformation [14,17,18]. The data was collected from the hardware in accordance with the time, and the filtering algorithm could be applied directly [18].



	A	B	C	D	E	F	G	H
1	0.042114	0.27423	0.21858	0.23153	1.1018	63.128	1.0913	3
2	0.047058	0.28413	0.21897	0.23263	1.0685	61.219	1.0947	3
3	0.046967	0.29389	0.21998	0.23428	1.0534	60.354	1.0955	3
4	0.045746	0.14249	0.23046	0.23478	1.2966	74.288	1.1049	3
5	0.17102	0.13668	0.23349	0.23885	0.89958	51.542	1.1759	3
6	0.042206	0.28457	0.21731	0.23094	1.0808	61.924	1.0912	3
7	0.17349	0.27785	0.22289	0.23756	0.75851	43.46	1.1332	3
8	0.042114	0.29391	0.22001	0.23425	1.0691	61.253	1.093	3
9	0.16934	0.2998	0.21538	0.23145	0.72885	41.76	1.1231	3
10	0.16882	0.42289	0.35001	0.37417	0.82211	47.103	1.2328	3
11	0.045624	0.020038	0.002288	-0.00145	-0.03143	-1.801	1	1
12	0.1066	0.025564	-0.00074	-0.00342	-0.03185	-1.8249	1.0001	1
13	0.17255	0.025276	0.000176	-0.00177	-0.01025	-0.58711	1	1
14	0.045868	0.046005	0.000903	-0.00112	-0.02337	-1.3389	1	1
15	0.10663	0.045212	0.004728	0.00334	0.030729	1.7606	1.0001	1
16	0.17276	0.045717	0.001038	0.000434	0.002483	0.14228	1	1
17	0.23364	0.025305	-0.00075	-0.00201	-0.00857	-0.49094	1	1
18	0.23389	0.045697	0.000605	0.000693	0.002936	0.16825	1	1
19	0.055267	0.14165	0.23437	0.23874	1.2651	72.488	1.1194	2
20	0.046326	0.1802	0.21584	0.22265	1.2306	70.511	1.093	2
21	0.041534	0.2041	0.21983	0.22816	1.2212	69.967	1.0894	2

Fig. 3.8. The Classification for The Second Data Set with Filtering Method

3.3 Accuracy analysis

The analysis of the filter program coded and accuracy given by the function necessitates a real effort and relatively long time. Since data sets contain data structure, a comparison between operational and visual differentiation is necessary for determining true accuracy. Because of that, accuracy ratios obtained in the application are obtained over two data sets and the resultant accuracies are determined. First data set and second data set point clouds are analyzed individually by the operator under CAD environment and for each point coordinate information, whether they belong to a surface or not are visually inspected and recorded. Those recordings and surface results obtained with the filter are compared. In these comparisons, for the two surfaces used and classified in the first data set, 2 of total 232 points are classified under different surfaces. In the classification of two surfaces with total 352 points, 17 points are seen to be on different surfaces. This accuracy represents approximately 90-98% accuracy for the first data set. The second data set is composed of total 3807 points and belongs to 4 surfaces. With the evaluation on this data set, 279 points are determined to be classified in different surfaces. This ratio is again approximately 92%. When these misclassified positions of the points are examined, the errors generally occur on the points which are most close to the surface limit in the surface transitions. This means the necessity of using the skewed parameters used in this filter model by the help of a better method. These skewed parameters should be optimized and their significance should be increased in the function [11-18].

Filtering Result					Raw Data for Surface 1			
X(m)	Y(m)	Z(m)	S.N.		X(m)	Y(m)	Z(m)	Control (m)
0,0785220	0,40471	-0,002459	1		0,0785217	0,404715	-0,024586	-0,0000003
0,0786130	0,37763	-0,002509	1		0,0786133	0,377631	-0,025091	0,0000003
0,0786440	0,38669	-0,00248	1		0,0786438	0,38669	-0,024799	-0,0000002
0,0788880	0,33255	-0,002592	1		0,0788879	0,350549	-0,025142	-0,0000001
0,0788880	0,35055	-0,002514	1		0,0788879	0,332547	-0,025916	-0,0000001
0,0984800	0,32326	-0,002011	1	*	0,078949	0,368543	-0,023656	-0,0195310
0,0789490	0,35953	-0,002412	1		0,078949	0,359534	-0,024119	0,0000000
0,0791320	0,34151	-0,002425	1		0,0791321	0,341505	-0,024246	0,0000001
0,0792850	0,39549	-0,0021	1		0,0792847	0,395494	-0,020997	-0,0000003
0,0875550	0,40479	-0,002581	1		0,0875549	0,404788	-0,025814	-0,0000001
0,2014800	0,32273	-0,001071	1		0,0877075	0,332633	-0,028482	-0,1137725
0,0877690	0,37766	-0,002582	1		0,0877686	0,377661	-0,025824	-0,0000004
0,0880740	0,36855	-0,002437	1		0,0880737	0,368551	-0,024369	-0,0000003
0,0984800	0,32326	-0,002011	1		0,0882568	0,395582	-0,02311	-0,0102232
0,0883790	0,35945	-0,002268	1		0,0883789	0,359452	-0,022675	-0,0000001
0,0888060	0,35038	-0,002105	1		0,0888062	0,350378	-0,021046	0,0000002
0,0972600	0,40465	-0,002362	1		0,0972595	0,404653	-0,023617	0,0000005
.	.	.	1		.	.	.	.
.	.	.	1		.	.	.	.

Table 3.1. Control Table for The First Data Set

Filtering Result					Raw Data for Surface 2			
X(m)	Y(m)	Z(m)	S.N.		X(m)	Y(m)	Z(m)	Control (m)
0,0328369	0,3457570	0,2140753	2		0,0328369	0,3457570	0,2140753	0,00000
0,0328674	0,3558072	0,2144537	2		0,0328674	0,3558072	0,2144537	0,00000
0,0328979	0,3607536	0,2148979	2		0,0328979	0,3607536	0,2148979	0,00000
0,0329285	0,3704611	0,2164029	2		0,0329285	0,3704611	0,2164029	0,00000
0,0329895	0,3659124	0,2146190	2		0,0329895	0,3905043	0,2174159	0,00000
0,0329895	0,3805984	0,2163755	2		0,0329895	0,3805984	0,2163755	0,00000
0,0329895	0,3905043	0,2174159	2		0,0329895	0,3659124	0,2146190	0,00000
0,0744934	0,1364970	0,2352521	2		0,0330200	0,3858122	0,2158834	-0,04147
0,0330811	0,3958577	0,2163480	2		0,0330811	0,3958577	0,2163480	0,00000
0,0330811	0,4009570	0,2163684	2		0,0330811	0,4009570	0,2163684	0,00000
0,0331726	0,4108378	0,2174723	2		0,0331726	0,4108378	0,2174723	0,00000
0,0332336	0,4069457	0,2131742	2		0,0332336	0,4166092	0,2150874	0,00000
0,0332336	0,4166092	0,2150874	2		0,0332336	0,4069457	0,2131742	0,00000
0,0364075	0,1546124	0,2197993	2		0,0364075	0,1546124	0,2197993	0,00000
0,0364990	0,1600594	0,2174183	2		0,0364990	0,1600594	0,2174183	0,00000
0,0408630	0,1320048	0,2336225	2		0,0365601	0,1745574	0,2190564	-0,00430
0,0365906	0,1699335	0,2174628	2		0,0365906	0,1699335	0,2174628	0,00000
0,0366211	0,1653550	0,2158285	2		0,0366211	0,1653550	0,2158285	0,00000
0,0746460	0,1325353	0,2306476	2		0,0366211	0,1795070	0,2190469	-0,03802
0,0366821	0,1897474	0,2175339	2		0,0366821	0,2040320	0,2203057	0,00000
0,0366821	0,2040320	0,2203057	2		0,0366821	0,1897474	0,2175339	0,00000
..	..	..	2		..	..	..	..

Table 3.2. Control Table for The Second Data Set

In Table 3.1 and 3.2, there are some samples from the tables created in Excel software, for the accuracy analysis of data sets that enters into the filter. In these tables, the first part is T analysis matrix outputs; the second part is the true values differentiated from the raw data, depending on the surface that they belong to. The column of difference represents differences of Coordinate X. When the column of difference gets the value of zero, the points are the same and in that line, the point is on the right surface [18].

4. Conclusion

The analysis of the developed software and determination of the surfaces has been made as a result of the analysis matrix obtained by the application made with the recommended filtering model and selected sample data.

In consideration of these data, feasibility and accuracy of the selected model is detected. With the statistical analysis, it has been determined that the model gives an accurate result for data under 9 mm scanning frequency with approximately 90% accuracy. However, since the applied model and filtering technology operates based on point data, the greater the point data, the higher the processing time and the lower the program speed. Additionally, local data and especially Lidar originated data should be inspected and the analysis of results should be performed in surveying engineering.

With this chapter, we observe that terrestrial laser scanners (TLS) and photogrammetric technologies need equipment (hardware) and data based integration as the first step of the process. Obviously, TLSs are independent equipments which depend on their own algorithm and optical (Laser) structures. Photogrammetric technologies are methods based on seen light and used with independent equipment (camera). When these two independents are used in measurement equipment, there is definitely a need for integration. When the equipment integration is not fulfilled, an integration of data is crucial at least. Current TLS equipment and some of the sub-software satisfy some parts of this integration; however this integration is not used completely independent from operators. The processes and difficulties are determined in this chapter, which is made for a kind of data integration, and an approach to solve these issues is presented [18].

Generaly, made on terrestrial laser scanner coordinate system does not use affine transformation. Thus, point cloud data listed disorderly by Cyclone 5.2 software are classified in a surface-based way, so it passes through a filter.

Considering the core software as the result of the research, a general advantage-disadvantage list is shown below for the functional model:

Advantages;

- It can differentiate the surfaces with two distinct depth by the accuracy of 90%
- It is a function designed for the MatLAB environment.
- It has an object-oriented structure that can be developed under Windows.
- It can give faster and more accurate results for limited data intensity and for quick, small scale experiments.
- It provides hardware data integration.
- The extremes of the filter function can be defined and always are positive because of the exponential filtering technique.

Disadvantages;

- When the data density is increased, time of the operation gets longer.
- The credibility is an issue of question for various types of data and in terms of data intensity.
- It is sensible to the limitations deriving from the hardware and the processor.
- It does not have the structure of an object-oriented function.
- It has not yet been applied to wide range photogrammetric studies.

This approach for planar segmentation is valid for monuments with planar surfaces. It drastically reduces the huge amount of laser data and adds information about the nature of the data. Thus, this data can be treated easily with most of the existing CAD software for 3D modeling or other applications. Some precautions in data acquisition should be taken for future works in surveying engineering. First, the location of the stations should ensure both the complete covering of the object and the most possible homogeneity along each single scan in surveying. Another precaution is to perform the image rectification in the close range photogrammetric and surveying applications at the end.
Consequently, it is seen that TLS data can be used in photogrammetric, three dimensional modeling, in reducing the work steps that depend on operator and in point analysis research with the combination of software and hardware integration methods.

Abbreviation list

TLS **:** Terrestrial Laser Scanner
CRP **:** Close Range Photogrammetry
RGB **:** Red, Green, Blue
T **:** Filtering Matrix
MS : Microsoft

Biography of author

Bahadır Ergün, born in 1974. He graduated his bachelor's degree in 1996 in Istanbul Technical University in Turkey. He graduated in 1999 as master of science in Geodesy and Photogrammetry Engineering and obtained his doctorate in 2003 in Photogrammetry Engineering, all of from Istanbul Technical University. He worked as Research Assistant between 1997-2003 in Istanbul Technical University Photogrammetry Department. He has been since 2003 Associate Professor in Gebze Institute of Technology, Geodesy and Photogrammetry Department in Turkey. He has held research assignments in TU Berlin Photogrammetry Department in 2001.

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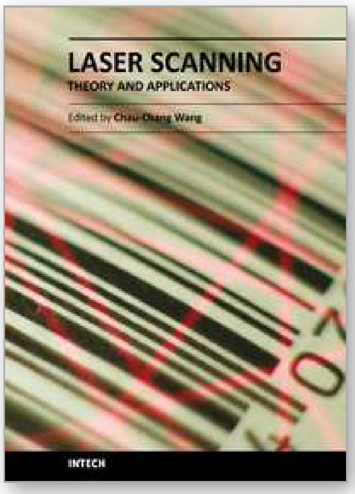

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Ever since the invention of laser by Schawlow and Townes in 1958, various innovative ideas of laser-based applications emerge very year. At the same time, scientists and engineers keep on improving laser's power density, size, and cost which patch up the gap between theories and implementations. More importantly, our everyday life is changed and influenced by lasers even though we may not be fully aware of its existence. For example, it is there in cross-continent phone calls, price tag scanning in supermarkets, pointers in the classrooms, printers in the offices, accurate metal cutting in machine shops, etc. In this volume, we focus the recent developments related to laser scanning, a very powerful technique used in features detection and measurement. We invited researchers who do fundamental works in laser scanning theories or apply the principles of laser scanning to tackle problems encountered in medicine, geodesic survey, biology and archaeology. Twenty-eight chapters contributed by authors around the world to constitute this comprehensive book.