SOLUTION FOR THE PROBLEMS ENCOUNTERED DURING THE MODELING OF TERRESTRIAL LASER SCANNER DATA

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Abstract

Terrestrial laser scanners and their applications are becoming very important especially for cultural heritage documentation and modelling purposes. The most important task of this technique is to create an accurate surface model of the data. In this study, a workflow for creating 3D CAD model of historical buildings was given. Pink Mansion which is one of the important monuments of Ottoman Ompire and has been built by Sultan II.Abdulhamit in 1876-1909, has been selected as the study building. In the study, a solution to minimize errors which are occurred during the 3D modeling process of point clouds produced by a terrestrial laser scanner was examined. In addition to, problems of 3D polygonal model transformation that cover the visualization and the modeling the point clouds fitting to real object were investigated and solutions were proposed. Point number of the building used in the study is 4.885.811. During the fitting the points to local coordinate system (geo-referencing) and the period of processing the model trial version of Geomagic Software was used. The results were also presented in the same order as in the steps of 3D modeling data and the solutions were obtained for the problems of surface modeling with the same software. The Surface models which are obtained from the point clouds are saved in suitable formats to be used in CAD systems.

1. INTRODUCTION

3D modelling of the historical monuments is inevitable. Thus, inspecting, monitoring, modelling, restoring and preserving automatic and accurate methods are becoming urgent (Pedersini, et al, 2000). Using terrestrial laser scanners (TLS) is becoming more popular in the field of cultural heritage. Nowadays, the usage of laser scanning systems has an important role for data acquisition and being realized easily (Demir, et all, 2004). Terrestrial laser scanning technology is the best example of technological advances in geomatics techniques for measuring the 3D geometry of the objects without making direct contact with them (Armesto, et, all., 2010). Complete recording of Cultural Heritage is a multidimensional process. It addresses not only the problem of 3D digitization of objects and monuments but involves all the aspects of this new digital content management, representation and reproduction (Pavlidis, et. Al, 2007).

The resulting point cloud can be processed to build a polygonal model consisting of a triangle mesh that faithfully describes the measured surface in shape and dimensions (Lerones et al, 2010) Reconstructing surfaces from scattered point clouds is an omnipresent problem in 3D modeling and has been intensively studied in computational geometry, computer graphics and computer aided design (CAD) (Frank, et.Al, 2007).

The aim of this study is revealing the errors in 3D modeling process of the cultural monuments with TLS data and showing the solution process for the selected monument. Pink Mansion, located on Yildiz Technical University (YTU) campus was scanned with MENSI GS100. All the modeling process was performed on this building. In this study, the criterias which are belonging to substeps of 3D modeling with TLS were proposed.

2. MATERIAL AND METHOD

The monuments selected as the study object is shown in Figure 1. This building is generally known as the Pink Mansion and it is one of the good examples of 19th century of Ottoman Architecture. This mantion is located in the YTU Campus together with two other mansions which are named as Prince Mansions [8].

Figure 1 Pink Mansion

Building was scanned with MENSI-GS100 TLS. This instrument works with class II green laser beam with as wavelength of 532 nm. It is capable of scanning 5000 points per second. Its distance measurement accuracy is 6 mm in 100 m. The scanning resolution was selected as 10 mm and 4.885.811 points were obtained. Evaluation TLS data was performed in three basic steps: (i) pre-processing, (ii) modeling, (iii) visualization.

2.1 Modeling

Before the modeling, point cloud filtering step was performed using four different levels as 25% , 50%, %75 and 100% . It was seen that low level filtering (25%) couldn't eliminate noises. Therefore medium level filtering (50%) was suggested to achieve more successfull result.

There are several algorithms for these processes and they can be classifed into two main categories as follows;

- Algorithms assuming fixed topological type: they usually assume that the topological type of the surface is known a priori (e.g. plane, cylinder or sphere) (Hastie and Stuetzle 1989).

-Algorithms exploiting structure or orientation information: Many surface reconstruction algorithms exploit the structure of the data for the surface reconstruction. For example, in case of multiple scans, they can use the adjacency relationship of the data within each range image (Merrian, 1992). This phase consists of tree major steps; (i) mesh generation (ii) smooth surface creating and (iii) editing.

2.1.1 Mesh generation and filtering

Generation of surface triangular mesh is a convenient and standard method for displaying geometric shapes of the freeform surfaces. Also surfaces created from triangle mesh structures display topology of the triangles. In the study, Delaunay triangulation was applied and 669.273 traingles were produced (Askin, 2009).

Aim of this step was, processing smoothness and compactness of triangle meshes. Mesh smoothing were realized using four different levels as 25% , 50%, %75 and 100% and obtained results were presented in Figure 2 (a, b, c and d). It can be seen in the figure, the corruption level of the objects and smoothing level has the linear relationship. Especially, geometric structure was corrupted on the circled corner and the edges of the triangle meshes.

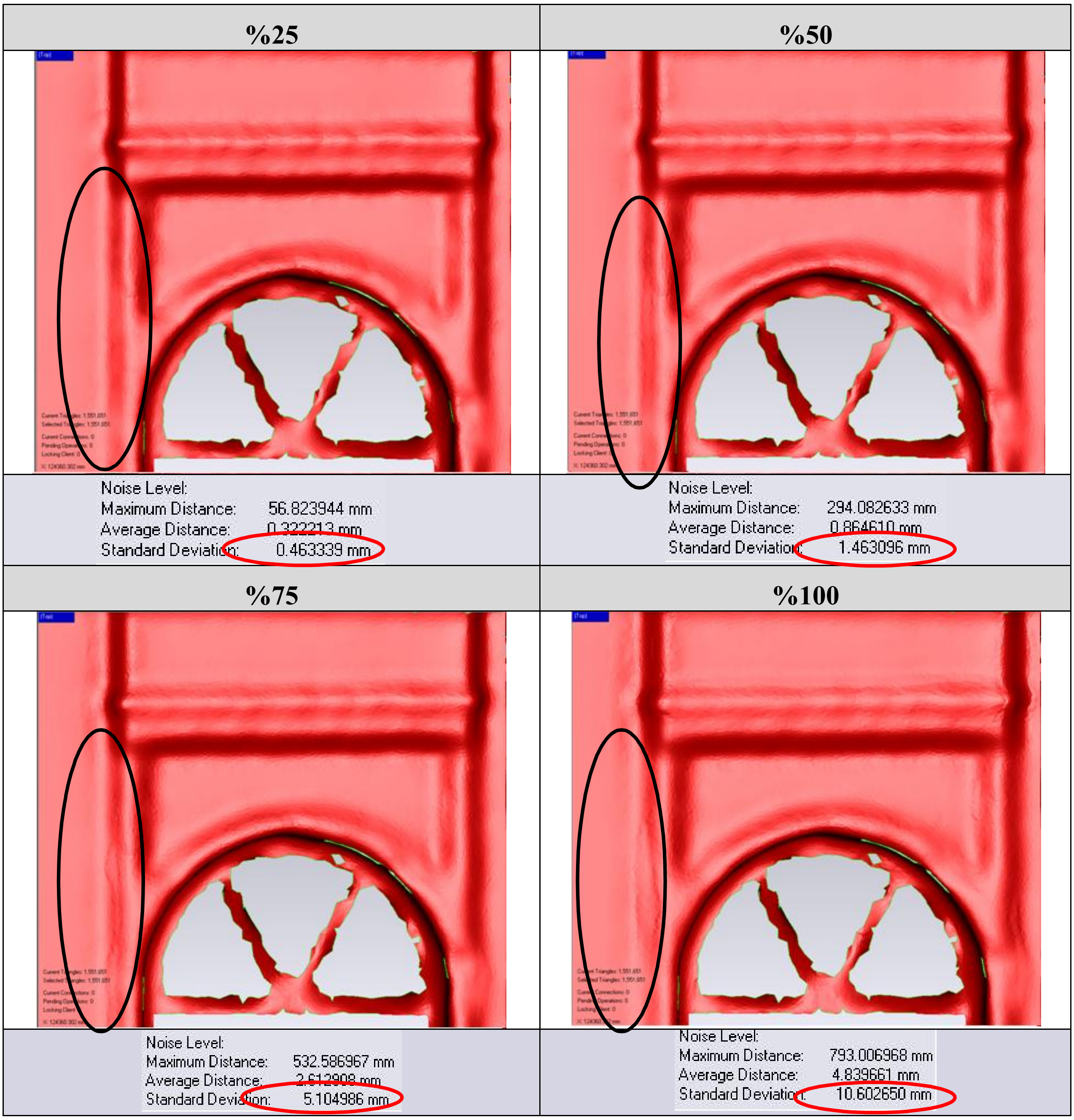


Figure 2 The results of mesh smoothing processes.

As can be seen in Figure 2, standard deviation values increased as a positive function of smoothing levels. Thus, to keep the compactness of mesh model and eliminate vertex errors low level mesh smoothing (25%) was proposed in the mesh filtering step.

Common artifacts (triangle errors) faced in the triangulation stage were: Triangle intersections, overlaps, holes, the singular corners, gaps and the complex edges. In this study, the objects were defined as open-manifold for they contained boundry element.

2.1.2 Determination of edges from mesh

Irregular edges of the triangles prevent the creation of a smooth boundary. Sharp corners may give Manifold errors. So these edges must be precisely defined in order to obtain a surface model. Irregular edges have a negative impact on the process of edge line extraction from the model surface. Dashed edges in the model made it difficult to create surface patchs.

In the study, identification of these irregular edge structures was edited semi-automatically. For extreme edges refinement process and boundary identification, initially a datum plane was defined by taking three aligned points on the same plane on the model (Figure 3) and with reference to this datum, a plane was aligned as shown in Figure 4.

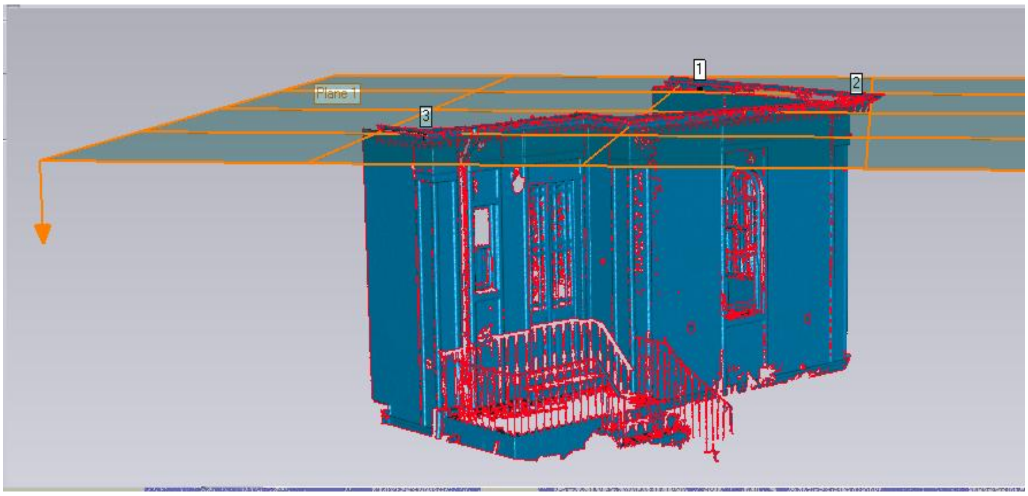


Figure 3 Defining horizontal Datum Plane

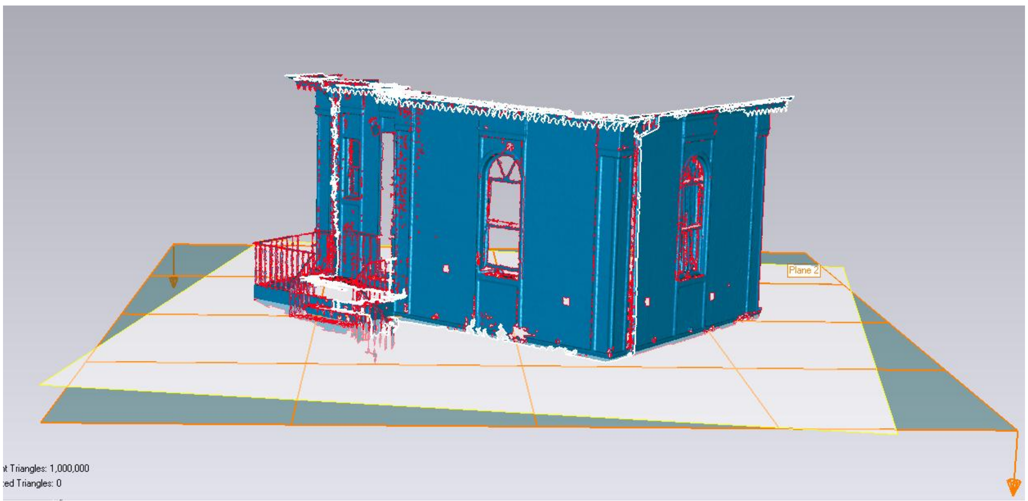
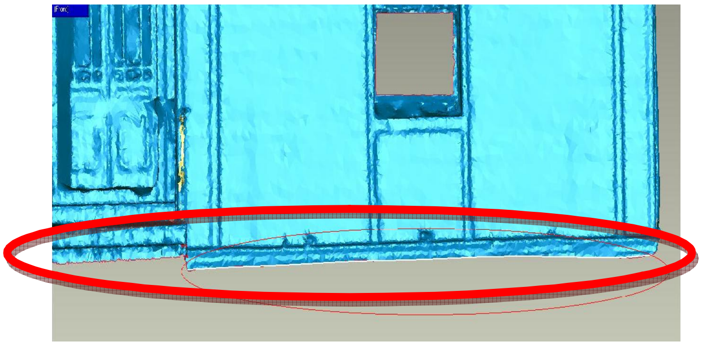


Figure 4 Result of datum process

The triangle mesh with the defined border model is presented in Figure 5 (a, b).



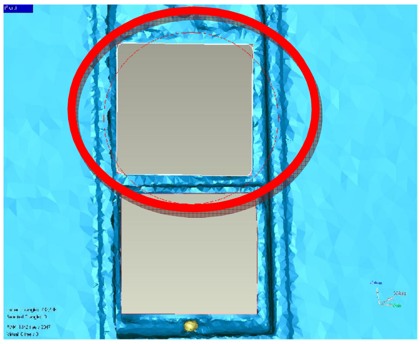


Figure 5 a) Result of boundary identification process **b)** Result of boundary identification process

3. VISUALIZATION

While processing irregular triangle meshes that consist of these elements, it is very difficult to displaying, storing and exporting into CAD enviroment. Remeshing process was necessary for elimination of complexity in the triangle mesh. This process reduces the density of the triangle by preserving model's geometric structures at minumum level [10]. In presented study, model geometry preservation and triangle mesh count minimization was taken into consideration, then the most suitable decimation level was determined as 16 %. Thus triangle reduction in mesh count number has minimized for the solving memory problem in modelling phase. After all necessary editings were implemented on the model surface, polygons intersections were validated and the result errors were repaired. End of the whole intersection controls, corrected 3D polygonal model was obtained and displayed in Figure 6.

Figure 6. Edited mesh model

After mesh editing, the created mesh models were segmented into the surface patches in order to reveal model's geometric details. Each patch contains an interrelated, coordinated and determined topolojical structure. This stage is required in order to create appropriate Nurbs Models. Moreover, in this stage curvature details from the model surface were converted into 2D conture lines. The curvature level analysis results is given in Figure 7.

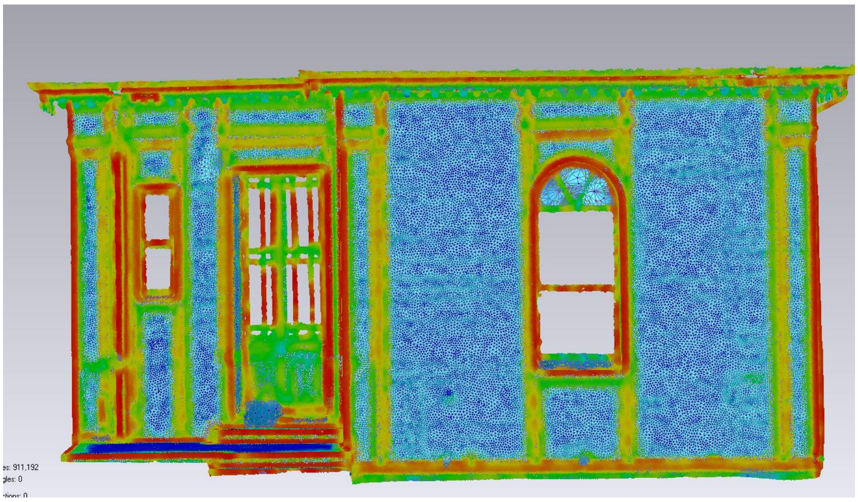


Figure 7 Curvature Level Analyze

According to the curvature analysis, model was segmented (Figure 8) into different regions and their contour lines were extracted automatically (Figure 9) and CAD model of the monument was presented in the Figure 10.

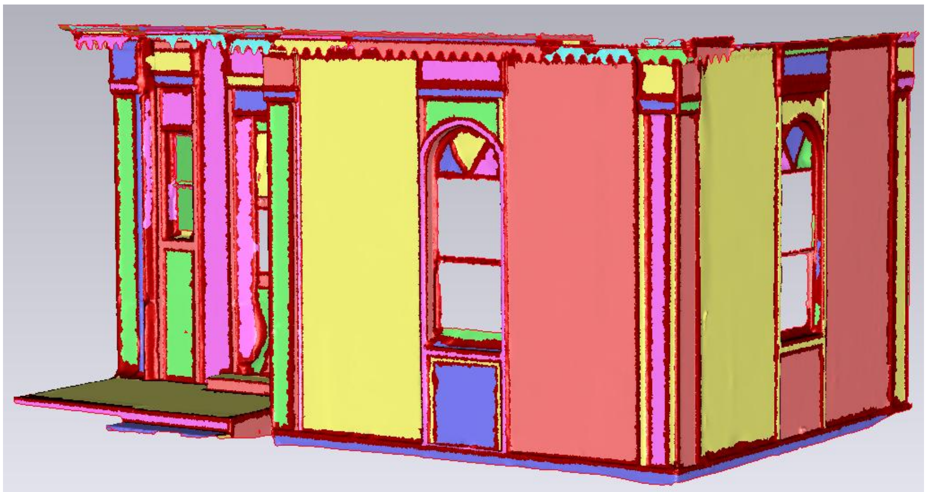


Figure 8 The segmented model

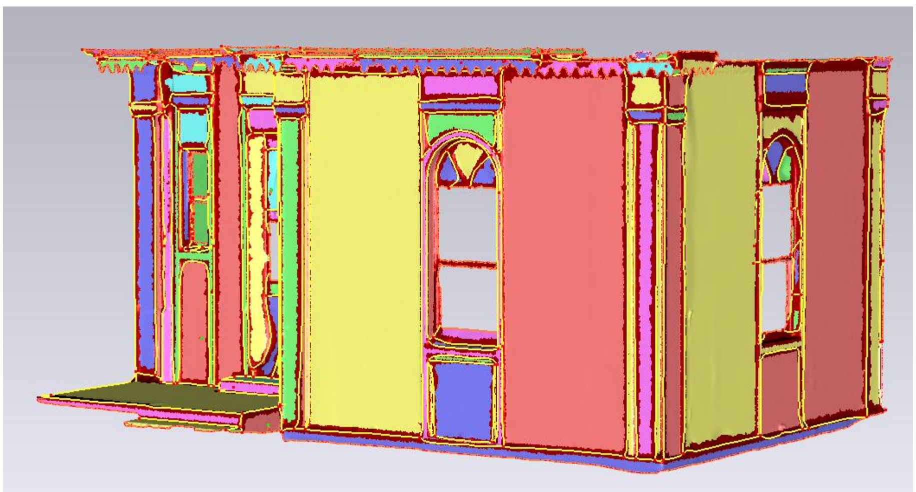


Figure 9 Contuer Lines from Polygonal Model

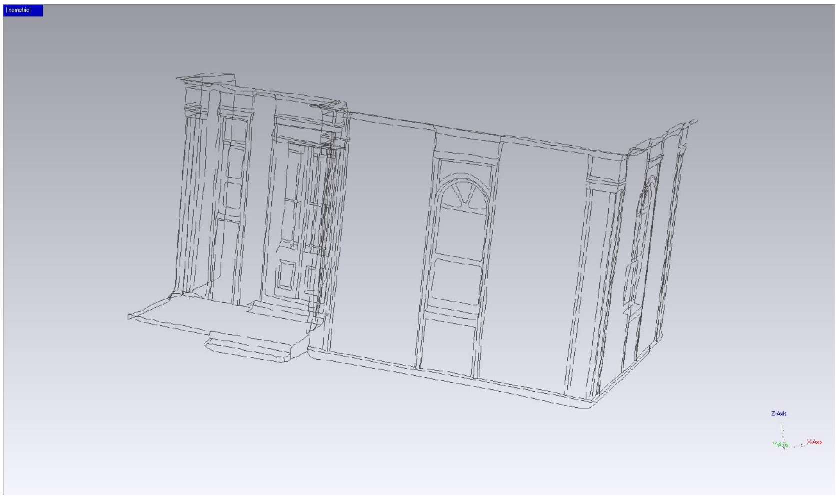


Figure 10 CAD model of Pink Mansion Building

6.CONCLUSIONS

In this study common processing steps required for modeling phase and generation of CAD model from the mesh were examined in details. Mesh filtering, edge determination and curvature analysis steps were realized for modelling of historical monuments and reliable results were obtained. Even though medium level mesh filtering was applied in the study, it is obvious that structural aftributes of objects has significant effects on the data processing, thus each object structure type requires different filtering level. It was observed that the gap filling operation over the mesh reduced the errors that commonly occur during the triangulation.

In modeling step, curvature levels were analysed on 3D model surface of the Pink Mansion Building and subsequently counter lines (3D polylines) were extracted from this model. As a result, it was presented that successful results can be obtained when appropriate modeling technics were used for the historical monuments modeling and producing 3D CAD data.

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