Optics and Lasers in Engineering 64 (2015) 23–31

Contents lists available at ScienceDirect

Optics and Lasers in Engineering

journal homepage: www.elsevier.com/locate/optlaseng

Planar segmentation of indoor terrestrial laser scanning point clouds via distance function from a point to a plane

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A R T I C L E I N F O

Article history:
Received 7 April 2014
Received in revised form
26 May 2014
Accepted 12 July 2014
Available online 2 August 2014

Keywords:
Segmentation
Terrestrial laser scanning
Computer programming
Integration

A B S T R A C T

Terrestrial laser scanners are frequently used in most of measurement application, particularly in documentation and restoration studies of indoor historical structures, and in acquiring facade reliefs. When compared to a photogrammetric method, terrestrial laser scanners have the ability to give three dimensional point cloud data directly in a fast and detailed way. High data density of point cloud data is a challenging factor in texture-map operations during documentation and restoration of historical artifacts with more indoor spaces. When coordinate information for terrestrial laser scanner point cloud data is documented, it is seen that there is no regular order and classification for the data. The aim of this study is to suggest the mathematical filtering algorithm for segmentation work towards separation of planar surfaces which have different depths and parallel to each other and which can be frequently encountered in the indoor spaces from the data of terrestrial laser scanner. Filtering function for segmentation used, is based on the distance of a point to the plane. This algorithm has been chosen for the advantage of the rapid and easy results for extracting 3D coordinate data in texture mapping process. The MatLAB interface has been developed for using this method and analyzing the results for application which is detected how many different surfaces exist according to the statistical deviation amount. In the application, test data with 21932 points was segmented by separating it into 16 points in total with four different planes and four corner points per plane. Surfaces with four different depths were obtained as the result of the research. Each of them included four points. These segmented surfaces consisting of four points will facilitate integrated data production by integrating vectorial terrestrial laser scanner data into raster camera data, without the need to conventional measurements that accelerate particularly documentation and modeling in the fields of historical indoor areas.

1. Introduction

Terrestrial laser scanners, which are important parts of today's measurement technology, have an area of usage in documentation and restoration studies on historical monuments. When we compare this new method with the previous photogrammetric measurement technique, we can see that the obtained final products have several advantages and disadvantages in terms of architectural usage. When architectural products are examined, geometrical accuracy and image reality of the photographic product are essential factors. Thus, photogrammetric method in architectural studies has not been completely abandoned. It is obvious that when fast geometric measurement speed coming from terrestrial laser scanner is combined with photogrammetry, there will be an effective measurement method. The aim of this study is to produce a filtering function algorithm for the purpose of segmentation of laser data which is the most significant stage for providing integrated data production by integrating vectorial terrestrial laser scanner data into raster camera data, without the need to conventional measurements that accelerate particularly documentation and modeling in the fields of historical indoor areas and also, the aim of the study is to test that algorithm with the sample data.

The digital photogrammetry and laser scanning technique are two of the most frequently used techniques in acquisition of three dimensional digital models [1]. The biggest disadvantage of terrestrial laser scanners is their inability to provide sufficient color precision of the scanned objects for a realistic model. This fact is emphasized frequently in the literature. Laser scanning can produce intense three dimensional point-cloud data which are required to establish high-definition geometric models, but the quality of color information is sometimes lower than the requirement [2]. Because of this scanner inability, in the literature, it is suggested that digital photogrammetry technique and laser scanning technique are combined for a successful three dimensional model. There are also distinctions in terms of accuracy, reliability,

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http://dx.doi.org/10.1016/j.optlaseng.2014.07.007
0143-8166/

and detail acquisition ability and automation level between the techniques. Thus, mostly it is necessary to combine the data from different technologies in order to model complex architectures. Image based approaches and scanner based methods are generally complimentary to each other [3]. Photo-realistic modeling is a technique which produces three dimensional virtual copies of an object in high quality textures, by integrating geometrical data from surface textures of the object and from terrestrial laser scanner [4]. As a result, in most of the cases, the best solution would be a combination of the above mentioned methods considering their benefits [5–7].

Today, there are several studies on indoor areas in the context of combining terrestrial laser scanners and photogrammetry studies. [8] are presenting an accuracy assessment of 3D point clouds of complex interiors produced with a fully automated open source photogrammetric software developed within the IGN (French Mapping Agency) [8]. Laser scanners allow millions of points to be recorded in a few minutes. Because of their practicality and versatility, these kinds of instruments are today widely used in the field of architectural, archeological and environmental surveying [9]. Today, detailed, complete and exact 3D models with photo-realistic textures are increasingly demanded for numerous applications in architecture and archaeology [10]. The integration of several technologies in heritage documentation is discussed every time a new technology appears. Photogrammetry has always been technology driven. TLS technology is more recent and changed the documentation approach from vector based models to point cloud based approaches ([11]). For a long time, laser scanning was the main solution to produce dense 3D point-clouds allowing high resolution geometric models, while photogrammetry was more suited to produce high resolution 3D textured models of small objects [12]. TLS techniques have been widely adopted for cultural heritage documentation and therefore many papers have tried to investigate the advantages and disadvantages of TLS and manual close range photogrammetry ([2,7,13,14]). The general conclusion is that due to the complexity of the scenes and of the materials used the choice of the method is heavily correlated with the scene that has to be modeled and hence a combination of the two methods could be interesting in various cases [8].

Because of the rapid changes in technology, some new concepts such as indoor space maps and Historic Building Information Modeling (HBIM) are introduced to us. The HBIM process begins with remote collection of survey data using a terrestrial laser scanner combined with digital photo modeling. The final HBIM product is the creation of full 3D models including detail behind the object's surface concerning its methods of construction and material make-up. The resultant HBIM can automatically create cut sections, details and schedules in addition to the orthographic projections and 3D models (wire frame or textured) for both the analysis and conservation of historic objects, structures and environments [15].

Terrestrial laser scanners can be considered as highly automatic motorized total stations. Unlike total stations however, where the operator directly chooses the points to be surveyed, laser scanners randomly acquire a dense set of points. The operator only selects the portion of the object he wishes to acquire and the density of the points he desires in the scan (usually the angular step of the scan in vertical and horizontal planes can be selected by the operator). Once these initial values have been chosen, the acquisition is completely automatic. The result of the laser survey is a very dense points cloud (also called DDSM – Dense Digital Surface Model). For each point of the model the X, Y, and Z coordinates and the reflectivity value are known. As this set of points is acquired in a completely arbitrary way, with the exception of the parameters imposed by the operator, it is necessary to manage this data in a critical and reasonable way. Particular attention must be paid to the quality of the original data [9]. Intense laser point cloud segmentation is one of the most bust academic study areas related to terrestrial laser scanners. The use of terrestrial laser scanners is increasing in the field of cultural heritage recording due to their high data acquisition rate, relatively high accuracy and high spatial data density. The main problem related to this new technique is the treatment of the collected data. [16] describes an automatic approach in laser scanning point clouds for architectural modeling. The aim of the algorithm is to obtain real surfaces of the scanned object and reduce the data volume [16].

Automatic modeling is applicable for buildings with relatively simple structure, such as rectangular solid, but it is not applicable for buildings with intricate structure. The goal is to model Japanese traditional houses and buildings in a district using TLS and photogrammetry for the sake of disaster simulation. In the proposed methodology, users are requested to define the procedure to estimate planes, edges and vertices [17].

Segmentation is the most important step in the feature extraction process. In practice, most segmentation approaches use geometrical information to segment the 3D point cloud [18]. The segmentation process is the essential step in obtaining surfaces, since the extraction of features of the different building elements basically depends on the accuracy of the lsegmentation step ([19]) [18]. As man-made structures are dominated by planar surfaces, many attempts have been made to segment planar surfaces from point clouds [18]. When segmentation is employed as a preprocessing step before the application of filtering algorithms, it is called segmentation-based filtering ([20]). Therefore, the segmentation processes for planar surfaces on man-made objects can be considered as a first step in the creation of 3D model documentation with a best fit to reality directly from 3D point clouds. However, although segmentation is one of the ;main processing steps, it is far from being solved even for planar features ([21]) [18]. In the past decade, many algorithms have been designed to extract planar surfaces from point clouds using segmentation methods. Usually one of three distinct methods is employed for segmenting points: region growing ([22–24]),

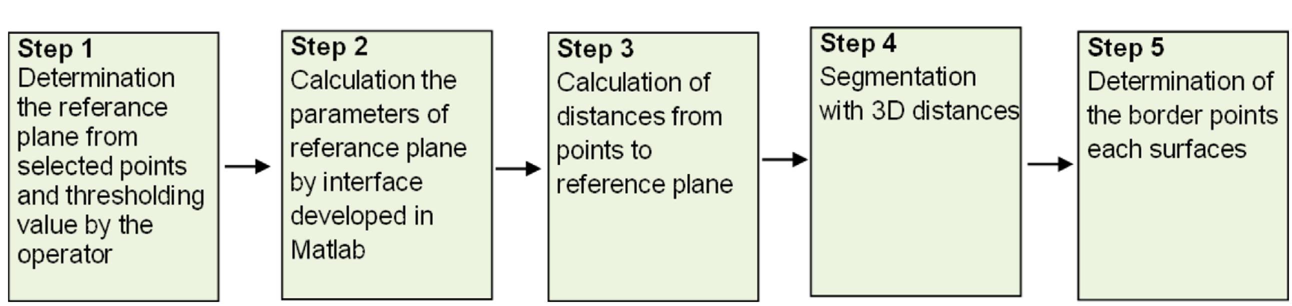

Fig. 1. Segmentation method.