Volume 3, Issue 12, December 2013 ISSN: 2277 128X

International Journal of Advanced Research in Computer Science and Software Engineering

Research Paper

Available online at: www.ijarcsse.com

Interior Renovation of an Urban Building using 3D Terrestrial Laser

Yogesh Rajendra[1], Rajesh Dhumal[2],
[1, 2] Srinivasa Ramanujan Geospatial Chair,
DCSIT, Dr. BAMU, Aurangabad,
(MS), India

Ramesh Manza[3]
[3]Department of Computer Science & IT,
Dr. BAMU, Aurangabad,
(MS), India

Abstract: The need of digital earth for representing information of architecture in three dimensional forms can play very important role in preservation and renovation. Recent development in Terrestrial Laser Scanning (TLS) proves an efficient way to model and analyze this information. This paper evaluates the capability of TLS technology for documenting an urban building in 3D environment. The building of Department of Computer Science & IT (DCSIT) located at the university campus of Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, (MS), India, has been taken as a case study for the purpose. A 3D visualization model based on registered colorized point clouds has been captured using FARO focus 3D laser scanner. The mapping of 3D point clouds data with the RGB value from the digital images was created using the FARO Scene software. The developed visualization model may be used to plan interior renovation and interior decoration purpose.

Keywords: 3D Terrestrial Laser Scanning, Point Cloud, FARO Focus 3D, FARO Scene.

I. INTRODUCTION

Recently lot of interest has been shown to understand a real world object by acquiring its 3D images of using laser scanning technology. A realistic impression of geometric 3D data acquired by laser scanners can be generated by imposing real color textures simultaneously captured by a color camera images. The 3D visualization model, thus created, plays an important role in wide variety of field to support various applications like campus planning, city planning, reverse engineering (Gruen et al., 2004), facility management, Crime Investigation, Cultural heritage documentation (El-Hakim, 2004; Boehler, 2005), and animation (El-Hakim, 2003), and documentation of the historical buildings and sites. 3D modeling is also a new way for data presentation as a final product of measuring and surveying technique.

The scanner records thousands of points per second and each point has intelligence, or location coordinates and elevation information. All of these points are placed into the same local coordinate system to make up a point cloud which represents the area, building, or object being scanned in a 3D space. Most modern scanners are rated to have their best accuracy at distances out to 100-130 meters. The typical scanners (Figure 1) are available that could scan in horizontal and vertical direction which allows us large amount of data to be collected from one location.

Figure 1

Laser scanning systems are used for the rapid acquisition of spatial data, which in turn can be utilized to model terrestrial features such as topography, structures, objects, etc. The 3D laser scanner is also called an active remote sensing system because no additional personnel is required to hold a ranging pole or to place targets for measuring surfaces. This makes the technique more practical for an urban plane sites. Other advantages of laser scanning are (a)better quality of the results in terms of accuracy and precision of final result, (b) survey can be done by only a man (one-man survey), (c) no interference with construction and operations activities and finally (d) simple and easy equipment operating and data processing (Nur Adlina, 2010).

In recent years, the use of 3D terrestrial laser scanning (TLS) seem to be increasing as its effectiveness in recording and documenting cultural heritage is widely documented. This is due to its capability to provide users with better spatial information of structure in complex 3D scenes in a rather short period of time. The 3D colored point clouds data produced by the laser scanner can be used to give a realistic impression of a monument or structure for users to interactively navigate the viewpoint around it, viewing it from all the angles and position desired. TLS technique provides higher efficiency in data collection especially useful in unreachable place as it gives complex and detail 3D point cloud data in a matter of minutes.

In this study, we demonstrate the practical use of 3D TLS in documentation of building structure. The terrestrial laser scanner system used for this project is a phase shift based laser scanner, FARO Focus 3D. This system includes 70 MP color digital camera to capture the high resolution images of the geometric model. This work evaluates the capability of FARO terrestrial laser scanner system for capturing high detailed architectural geometric data. Moreover, we present the combining of 3D point clouds measured by TLS with the RGB information yield by Photogrammetry technique. Lastly, the 3D colored visualization model of Department of Computer Science & IT was produced using FARO Scene. Further, this model may be used to plan effectively and efficiently renovation and interior design of the structure.

II. RELATED WORK

Terrestrial Laser Scanning is an active remote sensing technology that can be used for acquisition of a dense set of three-dimensional (3D) points on a large object or surface (Lichti et al., 2000). The TLS is a surveying instrument that massively captures coordinates of ground points in 3D with high velocity and accuracy. Figure 2 shows working principle of phase based and time of flight laser scanner.

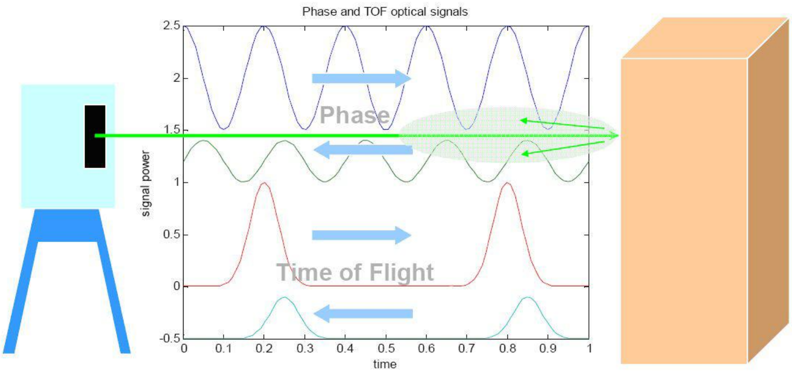


Figure 2 *Image courtesy of the UC Davis AHMCT Research Center: http://www.ahmct.ucdavis.edu*

Laser scanning technology and digital close-range Photogrammetry are two types of technology that can produce 3D model. The main difference between these two technologies is that the equipment that is used and the work procedure. Close range Photogrammetry is a visual method where the camera orientations need to be solved first before capturing an image (Ordóñez et al., 2010). Meanwhile, like most of surveying devices, TLS need to be calibrated periodically (Santala and Joala, 2010).

TLS has become popular in the 1990s for mobile robot navigation (Singh and West, 1991), in the construction of metric scale 3D models, such as sculptures (Beraldin et al., 2000) and industrial applications (Sequeira et al., 2003). There are three types of laser scanner systems based on principles of (i) time of flight, (ii)triangulation (iii) and phase shift measurement system (Anne, 2009). Time of flight measurement system has a laser diode that sends a pulsed laser beam to the scanned object. The pulse is reflected by the surfaces and part of the light will return to the receiver. The time that light travel from laser diode to the object surface and back is calculated. Therefore, the distance to object using assumed speed of light can be calculated from the time that the beam travels. (Boehler et al., 2001).

The triangulation system is an active system that uses laser light to probe the environment. Phase shift measurement is a technique for measuring distances that uses a laser beam with sinusoidal modulated optical power being sent to a target. A reflected beam is monitored, and the phase of the power modulation is compared with the emitted beam (Nur Adlina, 2009). Digital Photogrammetry techniques for object capturing are already well established (Remondinho and El-Hakim, 2006). Image-based technique has a simple data acquisition procedure but it has the limitation on capturing complex surface. In contrast, laser scanning technique does not bother with the surface shape (Boehler and Marbs, 2004). It also accomplishes the needs of high density of data, speed of capturing and accuracy in different field (Biosca and Lerma, 2008). Unfortunately, the laser ray cannot identify the color of the measured surface. As the result, the obtained 3D point clouds from the laser scanner are colorless. Thus, in most cases, a proper combination of both laser scanning and Photogrammetry technique able to produce better 3D textured model when the characteristics of the study area are complex and with large dimensions (Remondino and Campana, 2007).

According to (EL-Hakim et al, 2002), the generation of detailed 3D models of buildings and artifacts have to accomplish some specifications and requirements in term of geometric accuracy and level of details. In order to get an accurate 3D point cloud data of the whole object surface there are two factors that need to be concerned such as distance accuracy and space resolution of the laser scanner (Boehler and Marbs, 2005). Another important issue is about the quality of the intensity value and a feasible influence on distance measurement using laser scanner (Pfeifer et al, 2007). The latest developments in sensor technology, laser scanning, offers a new efficient data collection method for measuring an objects. The use of TLS for architectural recording and documentation is becoming increasingly popular (Yastikli, 2007). Since the development of the first generation of terrestrial laser scanner in 1999, laser scanning technology undergoes continued phase of product development, growth and expansion into many areas of survey (Bellian et al., 2005). In the review research study conducted by Xiao et al (2007) from Wuhan University, the use of terrestrial laser scanners for architectural surveying is a promising technique to produce 3D measurable models and efficient in documentation of historical heritage. A plenty of cultural heritage projects used TLS technique for data capturing such as the Digital Michelangelo Project (Levoy et al, 2000), the acquisition of Michelangelo's Pietà in Florence (Bernardini et al, 2002), and the acquisition of a portion of the Coliseum in Rome (Gaiani et al, 2000). Besides, the 3D reconstruction of Petra, Jordan was carried out by Alshawabkeh (2005) using terrestrial laser scanner, GS100 manufactured by Mensi. Furthermore, recent research work emphasizes on the capability and reliability of scanning sensor to record paintings, artifacts, and archaeological sites by member of the National Research Council of Canada. In recent years, many researchers have combined both Photogrammetry and TLS in different ways (Yastikli, 2007; Grussenmeyer et al, 2008; Alkheder et al, 2009; Cabrelles et al, 2009; Lerma et al, 2010). Laser scanning technology also improves the efficiency and quality of construction projects as described by Arayici (2007).

III. METHODOLOGY

A. Project Plan and Site Information.

Project plan is designed after, preliminary works are done. Site visit was done in order to decide on where to establish the scan stations and scan targets. It is very crucial to plan the location of the scan stations in order to ensure that the object and also the spherical target are visible and clearly seen from the various stations. Four stations were established to cover from all dimensions around the room in the scanning sessions. Hence, the spherical scan target should be used wisely as a link. Digital camera included in FARO focus 3D was used in order to capture the images of the scene that we can map the scanned objects with the objects in the real world (Suhaib, 2009).

The object selected for our study was the building of the department of Computer Science & IT (DCSIT)located at the University campus of Dr. Babasaheb Ambedkar Marathwada University , Aurangabad (MS), India. The building has an area of about 200 m^2, and height of 20 m.

B. Data Acquisition.

Laser Scanner FARO Focus 3D system (see Figure 1), which uses laser, capable of capturing up to 976,000 points per second. The maximum captured range for this scanner is 153 meters with low ambient light on 90 percent reflective surface. This system is based on phase shift measuring principle and it

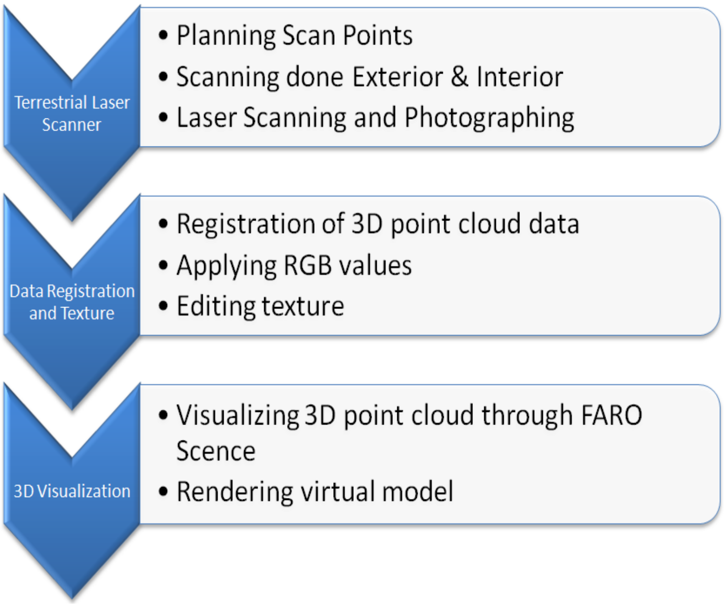


Figure 3: Methodology

Provides a larger field of view of 360 degrees in horizontal direction and 300 degrees in vertical direction with 0.009 degrees accuracy, and allows the collection of full panoramic views, including color camera of 70 megapixels.

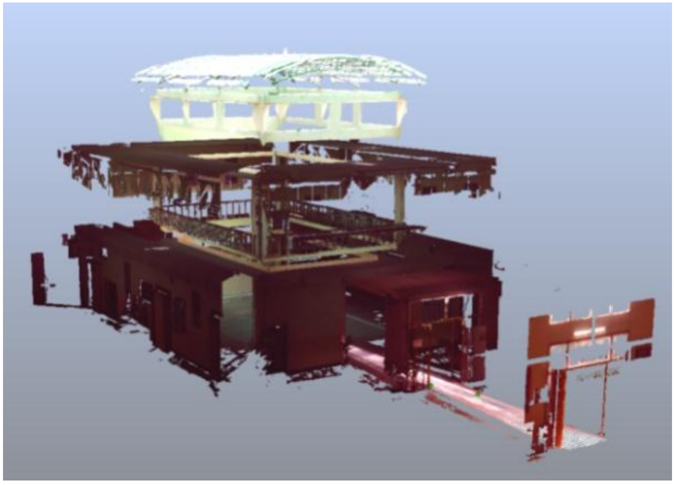
The TLS data acquisition at the DCSIT was carried out with the phase-shift based scanner, FARO Focus 3D. The data capturing procedure was executed in two steps, laser scanning and photographing (see Figure 3). The geometry and the intensity of frontage data were captured by the terrestrial laser scanner while the RGB values of the geometric object were captured by a high resolution digital camera. The DCSIT has very complex features for its inner and outer shape. Hence, an appropriate scanning positions need to be established to capture the full coverage of the façade data.

There were 13 captured scans to cover the whole DCSIT structure. There were 4 artificial spheres (act as control point) placed around the 3D space. The placing of the spheres must meet the requirement of minimum 3 corresponding points in two different stations. This necessity was needed to smooth the post processing work. Besides, the numbers of total scan station depends on the size and complexity of the structure. Hence, appropriate scan station needs to be established for better coverage to cover all the details of the building. The distribution of the artificial sphere has to be fairly located at a distance around 2 meters to 5 meters from the scanner to obtain a good geometry network. The distribution of the spheres is very crucial in merging all images properly. The spheres need to set in a position that could be seen and corresponded between two scan stations which require minimum 3 common targets. The high resolution color image acquisition was done by 70 megapixels camera contained in the FARO focus 3D laser scanner.

C. Processing.

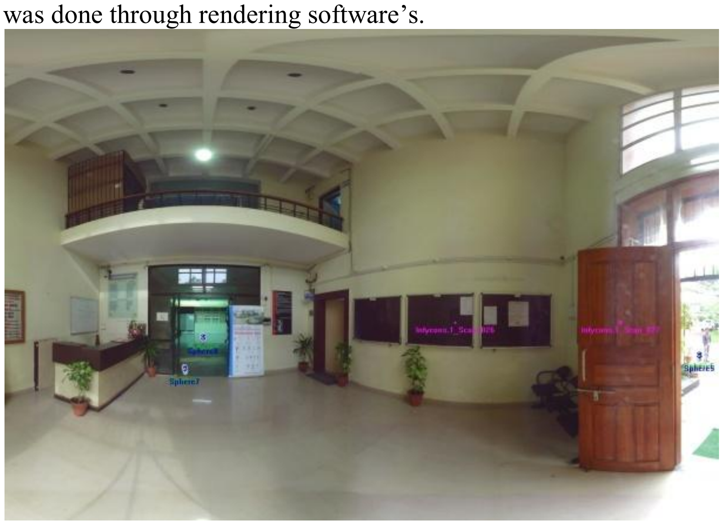
The point cloud processing stage involves the basic checking of data, removal of bad point cloud caused by blocking object or false returns. FARO Scene was used to mesh the point clouds. The registration involved point clouds from a total of 13 scans location covered the whole DCSIT structure with planned scan direction. There were 4 scans positions at the exterior part and 9 scans in the interior part of the DCSIT. These point clouds have to be registered into one coordinate system in order to achieve a complete visualization model of the Department. Millions of points have been merged to get an integrated view. Before starting to mesh the point clouds, data filtering process need to be done to correct or remove the selected scan point from the raw data. This was determined by the selection criteria. The filters differ according to which method they identify an inaccurate scan point and which counter measure was then taken.

The FARO Scene software was used to register the range data and produce a 3D visualization model based on registered colorized point clouds. The registration of all scans were performed pair by pair by means of minimum 3 control points required to match two different datasets in one common coordinate system. Once the scan registration was completed, a partial 3D model view of the Department was loaded in 3D form to check whether the two scans were correctly registered. The color information from the high resolution digital images would be fused with the 3D registered point clouds after the geometric object had correctly meshed.



D. 3D Visualization.

3D visualization and creation of walkthrough animation is followed by rendering of animation of the complete 3D registered colorized model was done through rendering software's.



IV. RESULT AND DISCUSSION

The use of terrestrial laser scanner has proven to be fastest in reconstructing the 3D buildings. Added advantage of this method is the fact that not only buildings, but also others bodies, that would have been impossible to get their real shape using other methods can be scanned. It is important to note that during the scanning process, moving objects like vehicles and people can affect the real color of certain stationary and/or needed objects. This needs to be removed from the final data. The model provided very beneficial way for planning renovation of the building and depicting idea for applying interior decoration. This has proved efficient way for rendering large information into 3D model.

ACKNOWLEDGEMENT

The authors would like to thank all involved in this project. Specially, to the Head of Department for his endless encouragement towards this work. Srinivasa Ramanujan Geospatial Chair Professor, and Department of Science and Technology for providing appropriate support.

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