The Use of Laser Scanning Technology to Survey Building Facades: A Case Study of Camlica Street, Beylerbeyi, Istanbul

Gülhan Benli
Ass.Prof Phd. Istanbul Medipol University
gbenli@medipol.edu.tr (Corresponding Author)

Alper Yiğitoğlu
Lect. Istanbul Medipol University
motifharita@hotmail.com

Yeşim Dolunay Yüksel
Lect. Istanbul Medipol University
ryesimyuksel@gmail.com

ABSTRACT

Today, laser scanning technology has many application areas in areas such as medicine, civil engineering, geodesy engineering and architecture. Photogrammetry, the ability to obtain fast, detailed and accurate information with terrestrial laser scanning and lidar technology, contribute a new dimension to architectural documentation research. Data from terrestrial laser scanners and 3D digital orthoimages provide high speed and accuracy in designing digital surface models. Since it is now possible use 3D precise digital documentation with dimensional accuracy at the millimeter level, it has become essential to support surveying studies with technology in Turkey. This article will describe the learning acquisitions and experience gained by surveying and drawing the front facades of nine wooden buildings in Beylerbeyi's Camlıca Street using laser scanning technology and discuss the use of technology in education.

Keywords: digital surveying, 3D documentation, laser scanning technology, architectural restoration, street silhouette

INTRODUCTION

One of today's most advanced measuring techniques, 3D laser scanning technologies, are very popular because they save time and generate rich content, especially for documenting cultural heritage, urban design projects and surveying and silhouette studies in urban conservation areas. There are many companies working in this field all over the world with measurement and evaluation systems. These systems vary according to the purpose, scope and scale of their work, and single systems or combinations of systems are used. The case area examined in this article will describe the results of students' traditional measurements combined with 3D laser scanning measurements.

THE USE OF LASER SCANNING TO SURVEY BUILDING FACADES

The use of laser scanning technology in architecture education is quite limited in Turkey. There are very few universities with laser scanning devices, and the number of teaching staff in the area of laser scanning and photogrammetry in the architecture discipline is also limited. This is not an issue in undergraduate education, but only in graduate or doctoral programs at universities that support specializations such as in mapping engineering.

This article's case study was valuable in terms of reading the point cloud data obtained from the 3D laser scanning device by the students, evaluating, interpreting and drawing it as digital surveying and presenting it as a survey file at the end of the semester.

The learning acquisitions of the course in which this case study was carried out require not only the determination of the dimensions and form of buildings that are part of our cultural heritage, but also the identification of their materials and analysis of their structure. Within the framework of documentation research on wooden structures, the students also prepared worksheets containing archival information, architectural and art history studies, analysis of their current state, material information, previous repairs, and constructional and structural distortions. In Beylerbeyi, classical (traditional measurement technique) and up-to-date techniques and technologies (laser scanning, photogrammetric measurements) were used together (figure 1). The 18 wooden structures were divided into 2 groups, and 9 groups of students measured their facades using 3D laser scanning. This selection was made by the students in the elective course who learned to read and interpret 3D laser scan point cloud data. The other group used traditional surveying methods. All the students integrated all the theoretical course information that they read within the scope of the architectural restoration program with their field work in Beylerbeyi's Camlıca Street.

Determination of the study area and field survey for the region

İstanbul's Beylerbeyi district has many examples of civil architecture from the Ottoman period. It is fundamental that the students who take the course learn to analyze wooden structure structures, their components and their historical environment. Beylerbeyi's Camlıca Street is an exemplary study area with well-preserved original structure. Camlıca Street was chosen as the study area because of its large number of wooden structures, its accessibility and, most importantly, the fact that the facade heights are accessible to a laser scanning device on the street. The wooden structures that were examined are shown in figure 2.

The students went to Camlıca Street, selected wooden structures to examine and formed groups of two. The 3D laser scanning measurement program was prepared. Digital basemaps of the parcels were obtained from the municipality. At this stage, students experienced establishing communication with public institutions, learning about missing or inaccurate information in the numerical data provided by them, obtaining and verifying data (building block contours, parcel boundaries, zoning lines, registered parcels, suggested parcels for registration or registered building contours). This taught them how to obtain documents from public institutions (e.g., basemaps, diameters, referenced sketch maps, cross-section documents). In addition to the numerical real data, the students learned about the history of the area, its famous residents and studied old maps (Goad, Pervittich, etc.). They prepared a report on its socio-economic profile.

Figure 1. Camlıca Street, the surveyed buildings are marked with red circles (source: Sibel Eryılmaz, student at Istanbul Medipol University Vocational School of Architectural Restoration)

SURVEYING AND WORK METHODOLOGY

Laser scanning technology obtains 3-D point cloud data and reflection density data. The beam that is sent to the object or surface facing it returns to the computer environment as millions of point clouds (point data). Each of the points in this set has 3D coordinates (x, y and z values). The scanned surface can be identified with millions of 3-D coordinates within a few minutes. The surface created by the point cloud is represented digitally in its actual dimensions and very accurately.

FIELD WORK

The Camlıca street structures to be surveyed were selected and a 3D laser scanning program was prepared. The 3D point cloud data were simplified by the partner company that supported our course and distributed to the students as digital basemaps. The data gathered in the field was recorded and uploaded to computers. Each building facade was turned into a 3D colored point cloud.

Equipment and Software

A Faro Focus 3Dx130 laser scanning device is used for point cloud scanning. Processing and optimizing the point clouds and transferring them to other programs were done using Faro Scene 6.2 software. The color and grayscale orthophotos prepared in PonitCab software were transferred to the student version of AutoCAD. The orthophotos created by combining high resolution point cloud orthophotos and the orthophotos taken with external metric camera in AutoCad were used as drawing bases in CAD. Easily and with high accuracy, plans, sections and views were formed with them. A Sony DSC HX400v metric camera with a 24 mm Zeiss Lens was used to calibrate photographs of the structures.

Measurement with 3D Laser Scanning

The main criterion of the scanning program was to obtain the maximum amount of data as quickly as possible, since the device used for the point cloud data of Camlıca Street was provided by the project's partner company. For this reason, the proximity of wooden structures to each other was important. The work hours, the work conditions and the location of the equipment were determined by the students. The number of sessions for nine buildings were determined according to their position and surface areas. The scanning program was prepared in class using these calculations and is shown in table 1. Since Camlıca Street is very busy with vehicle and pedestrian traffic, scanning stations were installed where traffic flow was low.

Table 1. Scanning program

Device	Faro Focus 3Dx130
Duration of field work	Two five-hour days
Number of structures	9
Number of sessions	61

Scanning was carried out at 61 different stations (figure 2) with 6mm/10m (6mm in each 10m) and 6 minutes of measuring duration with color scanning as the settings. External photos were taken immediately after the scanning. All these activities took 2 five-hour days of field work. Factors such as ambient light, direction and quality of light for reflective images, transparent and reflective surfaces, problems on the surfaces, light coming directly to the laser scanning device are known to be very fundamental for quality photography; however, due to the schedule, sometimes the students had to take pictures when light was not optimal.

Figure 2. Camlıca Street field research (source: Alper Yiğitoğlu)

CLASS WORKS

ORTHOPHOTOGRAPHY

At this stage, the students learned about the use of the Faro Focus 3Dx130 laser scanner and its settings. In addition, they learned about the problems with making measurements in open areas with human and vehicle traffic and the precautions to be taken. They also learned that, during static measurements, noise, excess data caused by motion, affects point cloud orthophotos. This noise is removed from the point clouds. Due the inability to modify photographs in the laser scanning devices that measure with the internal camera, inadequate or poor light and shadows caused negative results in the orthophoto production and drawing phases. In order to avoid this, except for the points noted in the field studies, photogrammetry was used. The photographs of the facades of the buildings taken high points and matched with the point cloud models using evaluation software (Faro, Scene, etc.) to generate high resolution orthophotos. Then, they were prepared for the drawing stage in CAD by having them scaled to the point cloud data orthophotos.

DATA SIMPLIFICATION

The point cloud data includes environmental data related to the wooden facades and their surroundings. The unnecessary data needs to be removed before arranging the data and starting the drawing. Images of passing vehicles and pedestrians were seen on the point clouds, at time obscuring the facades. For this reason, the point clouds obtained from different angles from the 3D laser scanning device were combined and unnecessary images removed. However, doing this to overlapping areas of aggregated point cloud data can make it hard to read architectural details, so it needs to be done very carefully and precisely. This process was carried out in the classroom by the course instructors using a video projector because of time constraints and the students' lack of experience. All the scanning data and topographic coordinates from different stations were combined into a single coordinate system using in the Faro Scene 6.2 point cloud software. This was done by defining the common points and target points between scanning stations and using them as connection points or overlapping point clouds. Figures 3 and 4 show the merged data from the different screening stations for silhouette data of Camlıca Street. Figures 5, 6 and 7 show the stage and screen views of the 3D textured model produced from the point cloud with orthophotos and external camera support.

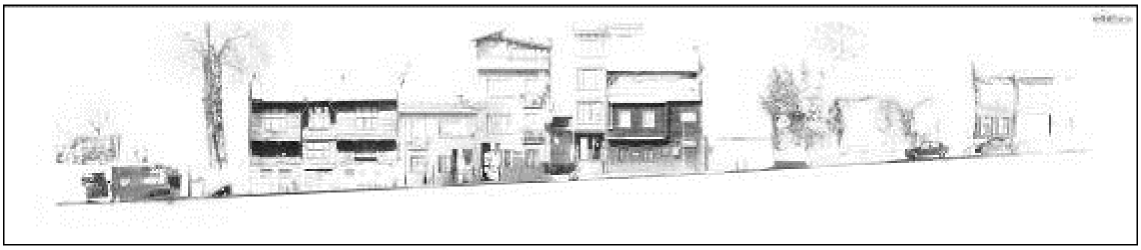

Figure 3. Camlıca Street left side silhouette, orthophoto data (source: Sibel Eryılmaz, Hülya Kakşi and Gülsüm Köse, student at Istanbul Medipol University Vocational School of Architectural Restoration)

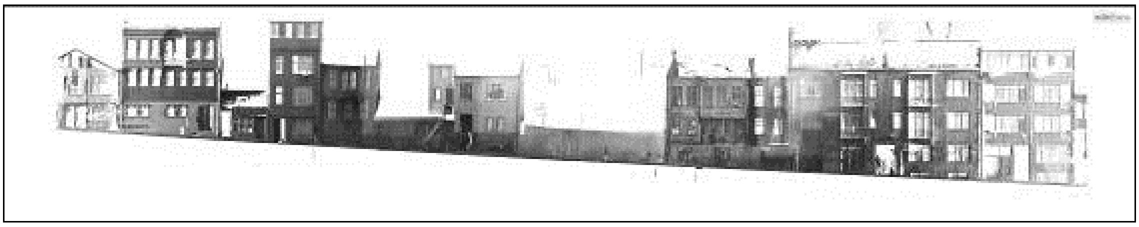

Figure 4. Camlıca Street right side silhouette, orthophoto data (source: Esmanur Guguk and Dürdane Karabul, student at Istanbul Medipol University Vocational School of Architectural Restoration)

Figure 5. Orthophoto from a 3D point cloud (source: İlyas Keskin and Nazım Keskin, student at Istanbul Medipol University Vocational School of Architectural Restoration)

Figure 6. Screen view of 3D textured model produced with a point cloud and external camera support (source: Alper Yiğitoğlu)

Figure 7. High resolution orthophoto of 3D textured model produced with a point cloud and external camera support (source: Alper Yiğitoğlu)

CAD DRAWINGS (SUPPORTED BY ORTHOPHOTO AND PHOTOGRAPHY)

Since the data obtained from the 3D laser scanning device is an image consisting of millions of points, surfaces, curves, indentations and bulges are seen as sharp lines formed by points. Since each point in this space has its own coordinate value, the lines formed by these points can be captured and combined to become vectors. However, the image, which is a dense point cloud, now has a large number of points and is saturated data. Using this data requires special knowledge and is a long-lasting learning process. For this reason, the scanned files were distributed to the students only for the facades of their own wooden buildings and neighboring buildings. In addition, in order to support their drawings, orthophotos were created and put into CAD (figure 8). This method is shown in figure 9.

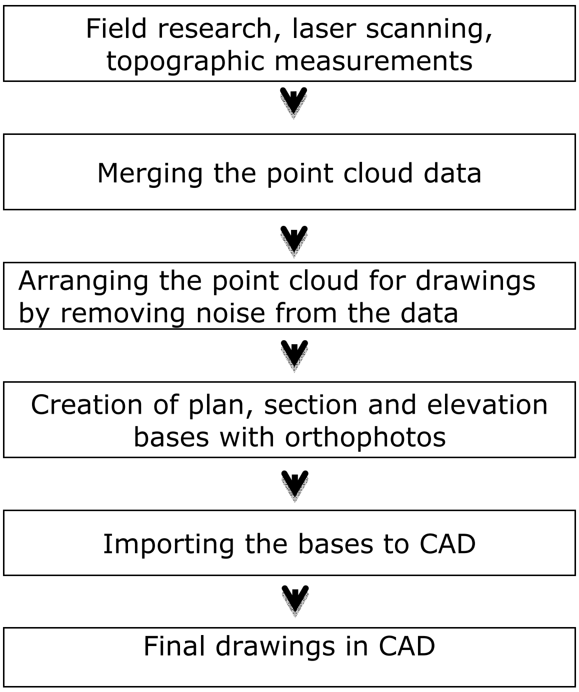

Figure 8. Research Methodology

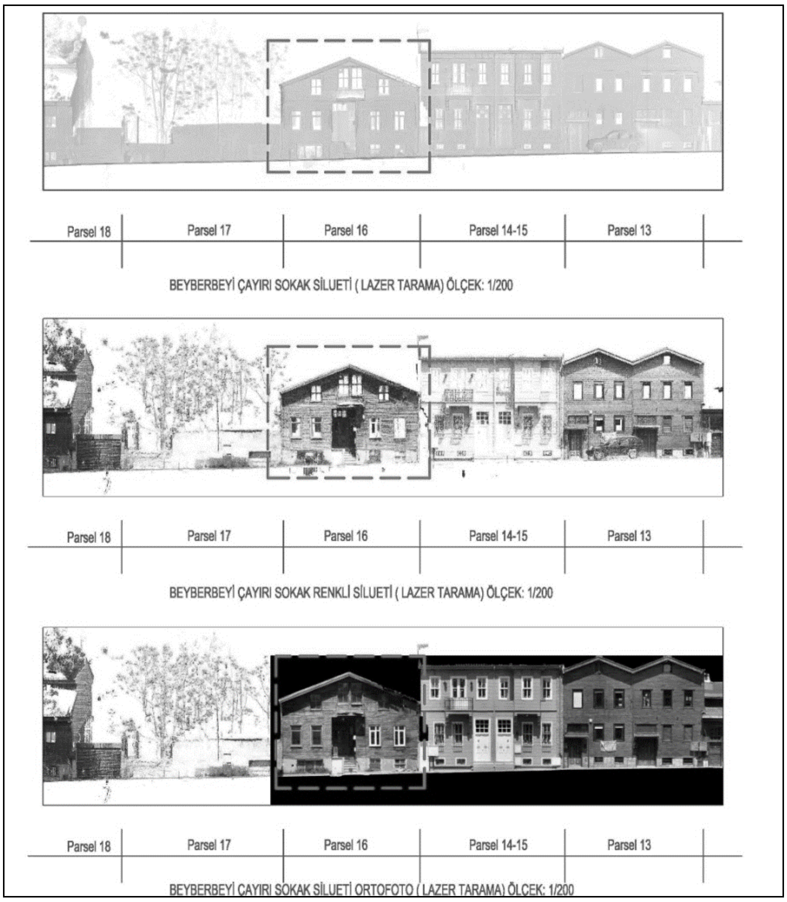

Figure 9. Çayırı Street silhouette orthophotos and point clouds (black and white and color) (source: Seyda Yılmaz and Elif Akkurt, student at Istanbul Medipol University Vocational School of Architectural Restoration)

EVALUATION

In Turkey, which has a very rich architectural and cultural heritage, it is extremely significant for laser scanning technologies to be used in education about of documentation and conservation projects. Laser scanning technology is faster, more reliable and more precise than conventional or photogrammetric measurements, and it can provide easily processable and accurate data with fewer personnel. When the digital photogrammetric products used for architectural documentation and laser scanning data are used in combination, more meaningful and superior results can be obtained.

DISCUSSION

As part of this course, we used laser scanning technology for architectural documentation. The results of this study are extremely significant because they concern the adaptation of technology to a course that uses conventional methods. The students, who got the opportunity to practice and experience a course with real data that they study theoretically and benefited from the latest technology in their field. The students mastered point cloud technology, processed the data, transferred them to diagrams and expressed them as architectural documentation. This experience will make a difference in their professional lives.

In the case study presented in this article, students were given the opportunity to prepare their drawings by asking their supervisor even in outside of class hours. During course hours, the course instructors ensured that the drawings were rendered in the common architectural language for analytical surveying (material, damage detection and intervention analysis). The semester's methodology and experience were successful.

CONCLUSION

It is clear that laser scanning technology is a significant contribution to architectural documentation and conservation. This technology is more than just a measurement method, it is a technique that enables the study area to be documented on a comprehensively and holistically. Since the laser scanning data from Beylerbeyi's Camlıca Street were obtained more quickly and in more detail than traditional methods, the students have saved a considerable amount of time. In addition to these benefits, point cloud technology enables the documentation and mapping of deformations and the most important details on the wooden facades. The curvatures and breaks in the roof and the eaves, the seats and deformations in the oriels and the facades can easily be seen, and the students can discuss them. It makes it possible to collect data from surfaces that are physically difficult to reach such as roofs and eaves. It makes documentation easier for the areas that is not possible to gather information without entering the building such as from the upper side of an oriel.

Using advanced technology for building surveying research, which takes considerable self-sacrifice, saved the students a significant amount of time and contributed to their productivity, so that they embraced their work even more. Easily and simultaneously sharing data and information by internet among the workgroups ensured that the students could do the drawing quickly.

Importing laser scan data into CAD and drawing it in a vector environment makes it easy to process the data in an architecturally meaningful way. Point cloud data and orthophoto images can be directly superimposed in CAD, and all architectural projects can be easily generated in CAD without any other software. This enabled the students to manage the information in the digital environment.

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