Application of Terrestrial 3D Laser Scanning in Cultural Heritage Documentation: Example of "Armenian Bath"

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Abstract. Cultural heritage is the most important bridge of mankind, between past and future which has an enlightening attribute on a society's development and perspective. As long as their values are appreciated, they will continue living as a guide and inspirational resources. Anatolia is one of the leading regions for cultural heritage. Due to its location, many civilizations used it as a homeland and hosted many cultural heritage. However, necessary precautions are not taken for protecting the cultural heritage which is becoming obsolete and worn out day by day. For its protection, restoration is needed and in order to carry the cultural heritage to the future and documentation is needed with modern advanced documentation techniques. The greatest advantage of the recent technological developments enables us to prepare the most precise and accurate documentation. Precise and accurate documentation is not only important for carrying the cultural heritage and historical structures to the future, but also important for evaluating the structures and bring functionality. In this study, the benefits of process for digitizing 3D documentation with laser scanner tools have been discussed for the conservative architecture. Within this context, the sample architectural documentation has been taken from the county of Sivrihisar, which is located in the city of Eskisehir. Today, this sample 'Armenian Bath' is out of use and it was built between 1867 and 1868 by Armenians. At the end of the study, an accurate and precise structured 3D model has been provided.

Keywords. 3D laser scanning, 3D model, cultural heritage, documentation.

1. Introduction

Many communities have been lived on Anatolia geography from past to present. These communities have legated lots of cultural historical and architectural artifact. Cultural objects have been carrying very important information until today. These artifacts have been damaged from both natural and man-made interventions. Because of these interventions, they are imperilment not to be transferred to next generations. Cultural heritage is common property of all nations. Protection and transfer of this heritage is a common task of all nations. Documentation is the most effective way to protect the cultural heritage.

Different laser scanners which have different working principle are used in documentation of cultural heritage. These scanners works according to triangulation, time of flight (TOF) and phase comparison principles [3]. Triangulation short range scanners are suitable for small objects and small sculptures. For the documentation of historical buildings and big cultural heritage sites, time of flight and phase comparison scanners are used [4].

In this study, an Armenian bath, in the Sivrihisar district in Eskisehir city at Turkey was documented. The Bath was scanned from totally 18 different scan positions using terrestrial laser scanner which is working on the TOF principle. Combining all point clouds that were obtained from different scan position, a 3D model of structure was generated. Using point clouds and images an orthophoto of wall was produced. A 2D CAD drawing of walls were produced by the orthophoto. A plan of the bath was generated using profile which is getting on 3D model horizontally. The results showed that terrestrial laser scanners are ideal tools for documentation of cultural heritage.

2. Study area

The historical Armenian bath (hammam) has been built from stacked stones and bricks. The construction date has not been stated in any foundation records; however, written dates found in various parts of the structure indicate the years between 1867 and 1868. We can therefore infer that the bath was built before the church, found nearby, was constructed. The plan of the structure has no difference to the types of plans that we see in Roman and Ottoman baths. When we study the traceable plans, sources indicate that the entrance to the warm room (Tepiderium), is through the opening in the southern end of the bath. Most similar types of mid-sized baths, however, do not have a warm room. The changing room, also known as the Apodyterium, is seen in almost all baths today. For this reason, there is a high chance that this area was in fact an Apodyterium. The entrance to the main area of the bath, the hot room (Caldarium), is from the northern end. In each of the four corners in diagonal axis of the hot room, the private rooms exist. The outward-built section found in the South-west part of the structure, is what is known as the furnace rooms (Praefumium). Some historians claim that the section found on the northern part of the structure was used as a water depot, as it was built at a higher level [5]. This inference makes sense, when we take into account that the water depots in both Roman and Ottoman baths were built in a detached fashion, and how the water was carried into the baths with the help of a slope. This section may therefore be determined as a cold room (Frigidarıum). In fact, unlike Roman baths, the cold rooms in Ottoman baths are located just after the hot room. Hence, the possibility of this structure which is located on the northeast part of the bath, constructed in a North-South axis, is actually a water depot [5], [6], [7]. Today, it is restored by the municipality of Sivrihisar.

Figure1: Top and right view of Armenian bath.

3. Methods

In this study, the documentation of Armenian bath was completed into four steps as shown in figure 2.

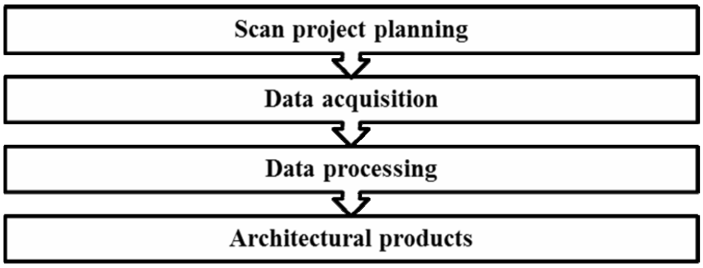

Figure 2: Documentation work steps for Armenian bath.

3.1. Scan project planing

During the step of scan project planning, the location and the number of scan positions, the spatial resolution of scan and the project coordinate system, should be determined [8].

For the documentation of the Armenian bath, the location and the number of scan positions was determined by keeping the number of scans to a minimum and areas of maximum light. Eighteen different scans were performed for all the part of the building which is both internal and external wall of building. Ten of these scans were performed to obtain external wall of building (Figure 3). Also, eight of them were performed to obtain the internal wall of building. Four rooms in the bath were not scanned because of darkness and restrictions in entering the room.

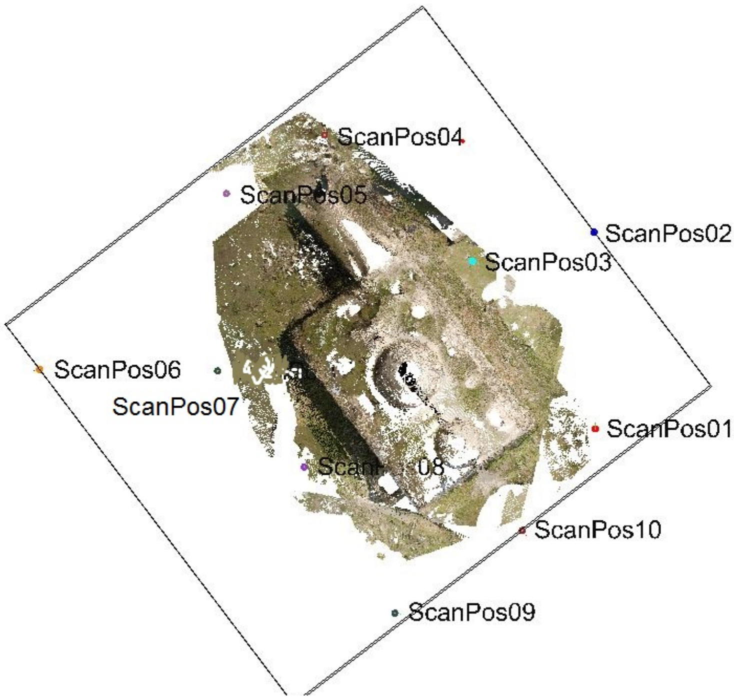

Figure 3: Scan position for external wall of bath.

Spatial resolution depends on angular resolution and the distance measurement accuracy of the scanner. Distance measurement is stable for scanner and it is decreased after a specific distance. Angular resolution is related to the distance between the scanner and the scanning object. If the distance is getting larger, angular resolution should be increased.

Project coordinate system can be a geodetic or a local based coordinate system. If it will be a geodetic coordinate system, reflectors are used to register the point cloud, and measurements by a total station is needed, to the geodetic coordinate system. In this study, the coordinate system of the first scan positions was determined at a project coordinate system.

3.2. Data acquisition

Data acquisition was performed with a Riegl LMS Z-390i 3D laser scanner. This scanner collects 3D coordinate data of object with the time of flight principle. It measures distance between "1.5-400" meters. It has 6 mm distance measurement accuracy in 50 meter in normal condition. After 50 meter the measurement accuracy is decreased. The viewing field has 80° vertical amplitude and 360° horizontally. The point acquisition rate ranges between 8 000 and 11 000 points per second. The beam divergence is 0.3 mrad, this means 30 mm per 100 m range. The scanner was used in combination with a calibrated Nikon D200 camera to register real colour information. This camera is equipped with a CCD sensor (Charged Coupled Device), DX format 10.2 megapixels. The scanner is controlled by Riscan Pro software. This software was used for many tasks such as controlling the scanner and the camera, data acquisition, data visualization and data processing [8], [9]. Before the scanning process, reflectors were distributed the scanning area in order to register the point cloud data.

For the documentation of the Armenian bath, three different scans were performed for each area of the bath. These are overview scan, tie-point scan and panorama scan. Overview scan was performed to determine field of view of scanner with a minimum angular resolution. Overview scan was used to select reflectors and panorama the whole scan area. Tie-point scan was performed to determine the coordinates of reflector center with maximum angular resolution. Scanning reflectors were used for the registration of point cloud which was obtained by the different scan positions. Panorama scan was performed to scan the main area from the current scan position with higher resolution than the overview scan. Detailed information for each panorama scan is shown in table 1.

Table 1. Detailed information for each panorama scan.

Scan Position	Number of Scanned Points	Scan Resolution (^{0})	Average Distance(m)	Scan Time
1	410 550	0.120	6.040	1' 37"
2	436 667	0.080	15.872	2' 26"
3	991 107	0.090	4.459	3' 16"
4	643 037	0.070	4.607	2' 29"
5	611 040	0.070	6.098	3' 10"
6	208 362	0.070	23.361	2' 02"
7	398 696	0.100	7.236	1' 55"
8	762 190	0.090	6.071	2' 38"
9	603 288	0.060	10.045	2' 56"
10	819 400	0.080	6.928	2' 30"
11	2 378 744	0.110	2.242	4' 56"
12	1 998 000	0.120	2.242	4' 08"
13	1 051 392	0.100	2.242	2' 56"
14	942 877	0.100	1.350	1' 58"
15	1 136 000	0.100	1.052	2' 39"
16	2 880 000	0.100	2.580	5' 58"
17	1 507 275	0.100	2.580	3' 27"
18	1 998 000	0.120	2.580	4' 08"

3.3. Data processing

Data processing of the documentation of the Armenian bath consisted of the registration of the point cloud data along with colouring information in order to generate a 3D model of the bath.

Data processing was performed by Riscan Pro Software. Riscan Pro software has three coordinate systems. First one of them is scanner own coordinate system (SOCS). Second one of them is project coordinate system (PRCS). Third one is global coordinate system (GLCS). The transformation point cloud from SOCS to PRCS or GLCS called registration. In this study, the scanner's own coordinate system of first point cloud was determined as a project coordinate system. Other point clouds that were obtained from other scan positions were registered at the project coordinate system. During the registration process, the rotation and translation parameters were automatically calculated by Riscan Pro by using common reflectors between point clouds. The images taken after scanning in each scan position were used to colour the related point cloud. This process was also made automatically by Riscan Pro. After the colouring and registration of point cloud, the point cloud was combined which in PRCS and a 3D model of Armenian bath was generated (Figure 4).

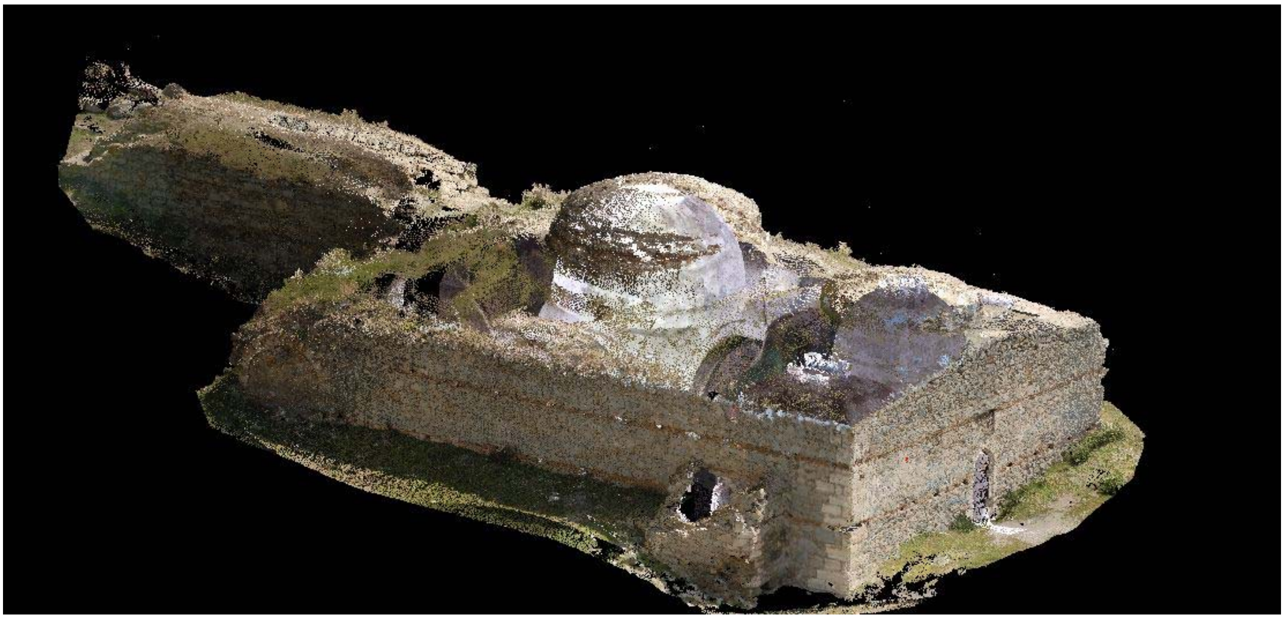

Figure 4: 3D model of Armenian church.

3.4. Architectural products

For the documentation of the Armenian bath, architectural products were produced. These products are orthophotos of bath walls, 2D CAD drawing of wall and plan of the bath.

In this study, using point clouds and images, orthophoto images of walls was produced with Riscan Pro. Figure 5a shows orthophoto images of front wall. 2D CAD drawings of walls were drawn using the AutoCAD software. For transferring orthophoto images from Riscan Pro to AutoCAD, the Pointcloud software was used. Figure 5b shows a 2D CAD drawing of the front wall in orthophoto.

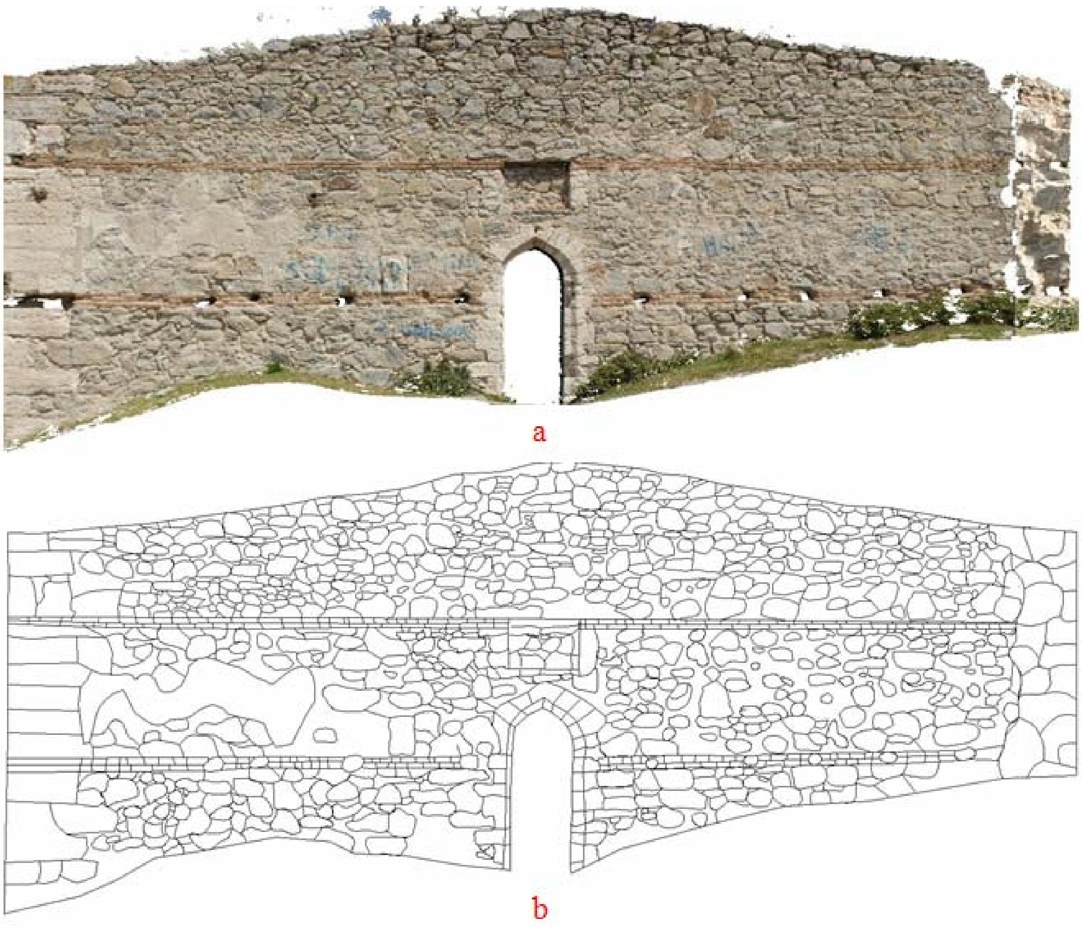

Figure 5: a: orthophoto image of front wall of the bath; b: 2D CAD drawing of front wall on orthophoto image.

For producing a plan of the bath, a horizontal profile was taken on the 3D model of the Armenian bath (Figure 6a). Using this profile, a 2D CAD drawing of the plan of the bath was produced (figure 6b).

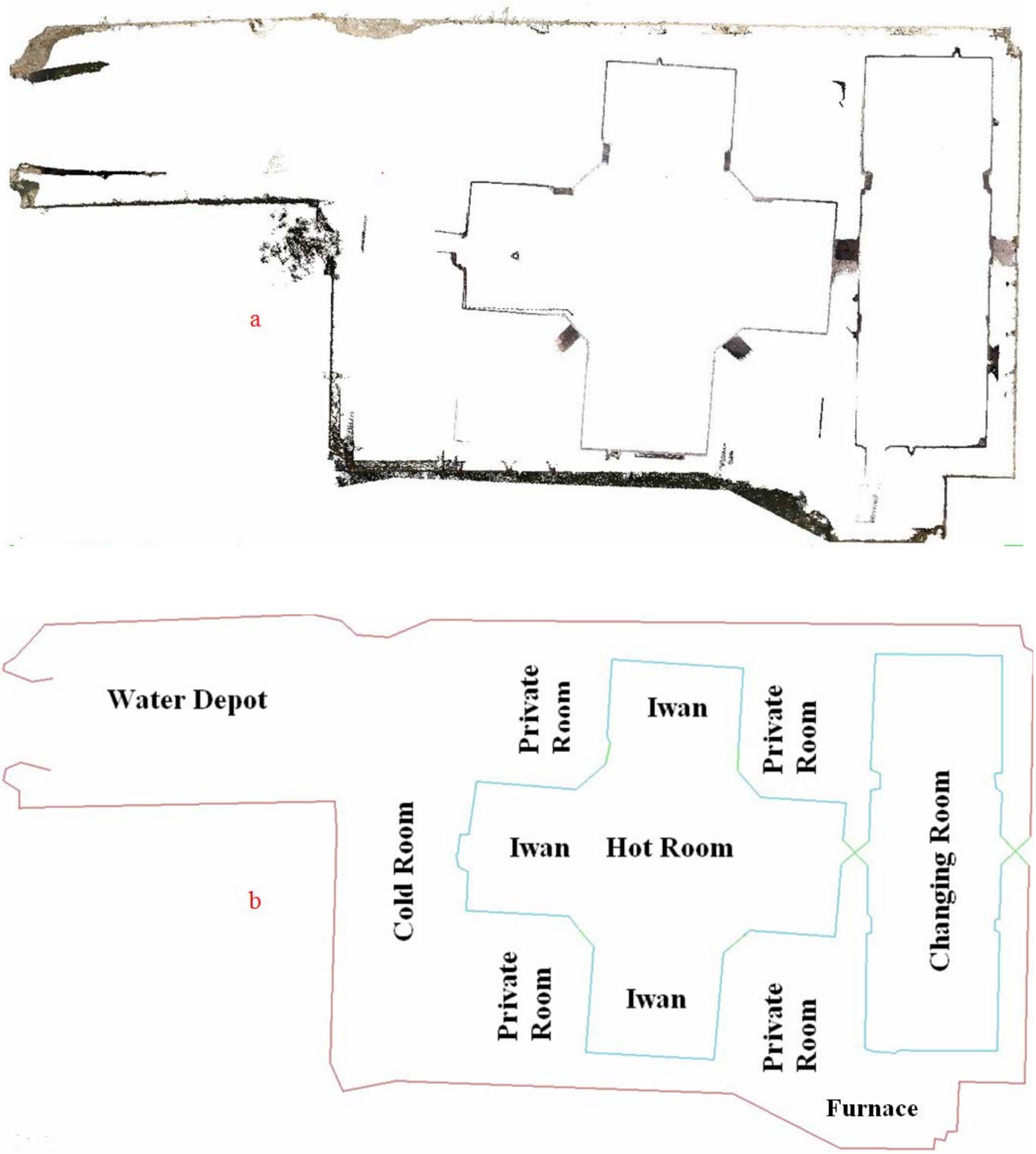

Figure 6: a: Plan view of point cloud bath; b: 2D plan drawing of bath on point cloud.

4. Results

The results of the documentation of Armenian bath showed that terrestrial laser scanners are usable instruments for getting fast and accurate 3D information about cultural heritage objects. They are also effective tools for scanning more complex structures. Using point clouds and images that are obtained from laser scanner, orthophotos can be generated. Also 2D CAD drawing can be produced by the orthophoto images. Finally, plans of the scanning objects can be obtained at various profiles using a 3D point cloud model.

5. Conclusions

In this study, a historical Armenian bath was documented with terrestrial laser scanning. The structure was scanned both inside and outside of the building. Eighteen scan positions were performed to obtain a full coverage of the building. Using point clouds obtained by different scan positions, a 3D point cloud of the building was produced. Also orthophoto images, 2D wall drawing and 2D plan drawing of bath was produced as architectural products. As a result of this study, it van be inferred that terrestrial scanning methods are very useful for the documentation of cultural heritage.

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