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*Full Length Research Paper*

# Advanced technologies for archaeological documentation: Patara case

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**The documentation of cultural heritage has been ongoing for several decades. In parallel with the progress of technology, the conventional techniques are slowly being replaced with more advanced ones. In particular, the advances in digital photogrammetry and laser scanning systems present significant improvements and opportunities for those working in this field. Hurmalik Bath and Palestra Complex reside in Patara Archeological Site within Kalkan County of Antalya province. This article presents brief information about the Hurmalik Bath of the site, and the advanced technologies used in the documentation.**

**Key words:** Archaeological documentation, cultural heritage management, geographical information system, laser scanning, Patara, photogrammetry.

## INTRODUCTION

Advanced surveying technologies offer rapid, accurate and detailed documentation solutions on the physical characteristics of objects and their surroundings provided that highly trained expert personnel are available to collect and evaluate the data supplied by the hi-tech equipment. Turkey is a unique country with its rich archaeological and cultural heritage. However, inadequate documentation poses a great threat to the survival of this heritage for the next generations. In spite of the attempts to improve the documentation, technical deficiencies combined with the lack of qualified personnel in terrestrial surveys reduce the quality of the survey results. Furthermore, improperly executed terrestrial survey, restoration, documentation or reconstruction projects may even cause harm to the cultural heritage. Laser-scanning technology was introduced commercially in 1998 when field and office tools and technologies were still in the early stages of development.

Laser scanning collects spatial data consisting of numerous points clouds and scans these objects three-dimensionally without any physical contact. Laser scanning was used to create 3D models and then extract 2D drawings from these models, but this was more expensive and time consuming than traditional office methods (Jacobs, 2004). For this reason, laser scanning was initially considered advantageous only for use in large-scale, complex projects. Today, however, there are many advantages to using laser scanning over traditional methods. Traditional topographic and planimetric surveys are typically done at a stationing or grid density of 50 or 25 m.

Surveyors traditionally collect points at corners, intersections, edges, features, or in areas of sharp changes in geometry. But blanketing the site with points using laser scanning saves the surveyor from having to return to the site if surveyor needs to recheck a point in question (thus reducing potential errors), if something might have been missed (thus reducing potential omissions), if the project scope changes, or if other clients require different data from the same site (Jacobs, 2005)).

Laser scanning can be used in several areas such as

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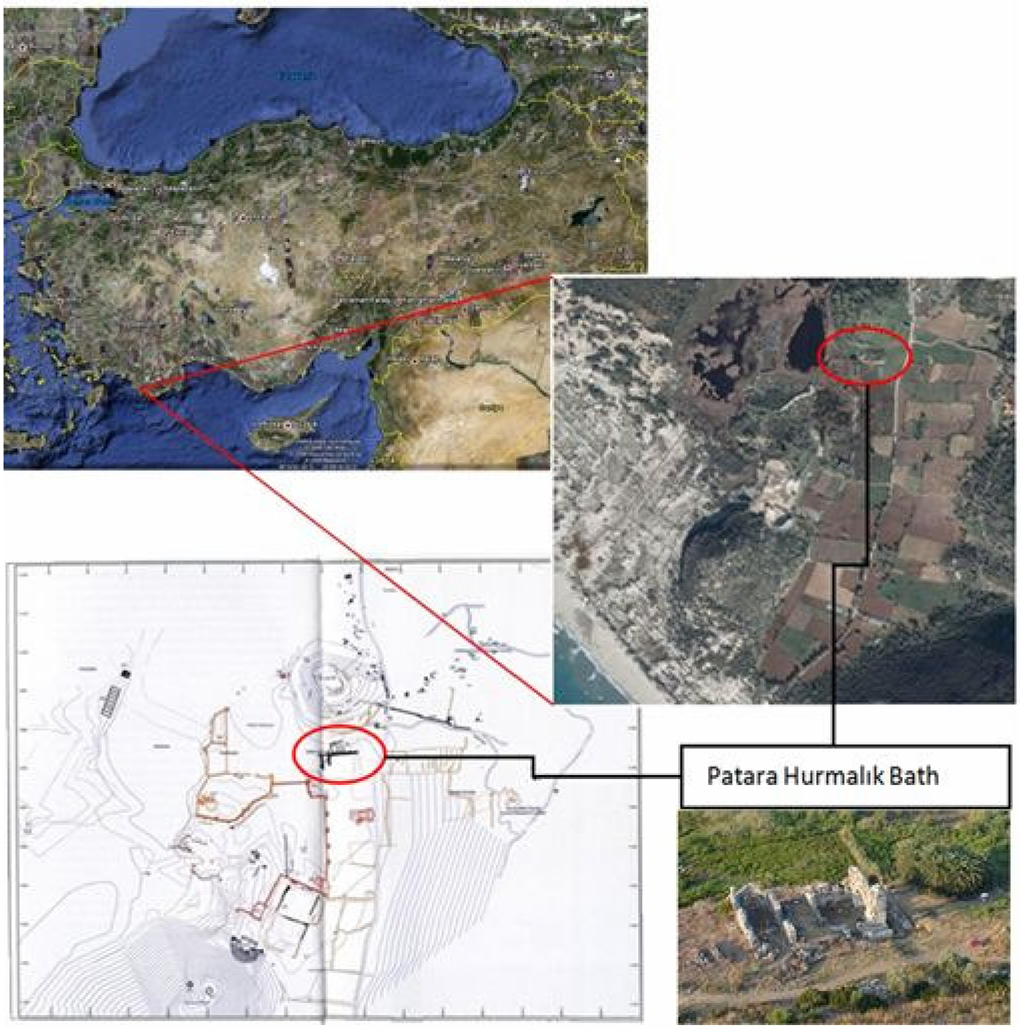

**Figure 1.** Satellite photo of the work site (from Google Earth) and city plan.

documentation of the cultural heritage, reverse engineering applications, rapid prototyping, deformation measurement/calculation, direct production from scanning data, digital archiving of unmovable objects (fossils, antiques, historic items).

This article presents a new method successfully used to document Hurmalik Bath and Palestra complex (Figure 1). The new method significantly reduces the number of personnel as well as the time spent on-site to document the cultural heritage.

## Patara and the hurmalik bath

Just as Patara was an important city in the ancient state of Western Lycia, Hurmalik Bath was important in Lycia and in Roman Empire-period bath architecture. Consequently, much research exists on the bath (Farrington, 1995; Işik, 1990, 1991, 1999, 2000; Korkut, 2003; Yegül, 1992; Bulba-Kizgut, 1993; Çevik, 1992; Çevik and Kizgut, 1994; Kizgut, 1999; kizgut and Özhanli, 1996; Kizgut et al., 1997).

As a port on the Mediterranean Sea, Patara was a very important city in ancient Lycia. Hurmalik Bath was the harbor bath of the city and so was of special importance for visiting merchants and sailors. Hurmalik Bath, also known as Little Bath, North Bath, and Harbour Bath (Farrington, 1995; Işik, 1999, 2000; Korkut, 2003; Yegül, 1992), was named after the North African palm trees planted in its western part. Along with Hurmalik Bath, three other Roman-period baths made up an important construction group in ancient Patara: Vespasian Bath, Central or Southwest Bath, and Little Bath (Farrington, 1995; Işik, 2000; Korkut, 2003).

As Hurmalik Bath lies 60 m southwest of the Modestus Gate, which was constructed to honor C. Trebonius Proculus Mettius, the governor of Pamphylia-Lycia, it was likely important to visitors entering the city from land. Modestus Gate was designed as a part of the aqueduct carrying water to the city from İslamlar Village. The aqueduct and nearby water reservoirs are evidence that water was carried to Hurmalik Bath through Modestus Gate (Akerdem, 1992; Patara, 1991; Işik, 2000). The bath is also near a sulphurous water spring, which raises the possibility that Hurmalik Bath may have been used as a thermal bath for healing purposes. From the bath's proximity to the harbor, Modestus Gate, and the water spring, one can conclude that it was located in an important spot in the city.

Hurmalik Bath lies in the east–west position and is made up of three juxtaposed rectangles. On the east edge is the frigidarium, in the middle is the tepidarium, and on the west edge is the caldarium. The bath, with its provincial characteristics, can be classified as a small empire bath, especially in light of the palaestra to the north of the bath, which is supposed to have been added to the complex subsequent to its original construction.

The first archaeological excavations of the bath started in 1989 and continued between 1991 and 1997 (Işik, 1990, 1991; Bulba-Kizgut, 1993; Çevik, 1992; Çevik and Kizgut, 1994; Kizgut, 1999; Kizgut and Özhanli, 1996; Kizgut et al., 1997). These excavations focused on the fronts of the west and south frontages and inside the caldarium.

Excavations in 2005 and 2006 supported with Scientific Research Project Funds of the Anadolu University Rectorate focused on the frigidarium, tepidarium, and the front of the north frontage and were primarily aimed at cleaning and arrangement works in and around the bath. One of the main purposes of the 2005 – 2006 excavations was to extract the plan of and document the building. The north frontage, in particular the part from the tepidarium to the east, was the least well known section of the bath. Hence, the excavations were conducted mostly in the north-east, as it would have been impossible to obtain an accurate plan otherwise (Farrington made important contributions to plan developments of Lycian bath architecture. However, the Hurmalik Bath plan lacks some important information. According to the plan, the northeast side of the bath does not exist at all. Hence, a study to locate the missing parts was started in 2006, as it is impossible to truly study the bath from the plan (Farrington, 1995)).

## Advanced technologies for architectural documentation

There is a substantial amount of research on photogrammetry, laser scanning, remote sensing, geographical information system (GIS), digital documentation, and 3D modeling. Phogrammetry is the science and a special method for producing high precision maps and plans. Measurements can be made in two or more photographic images taken from different positions to determine the three-dimensional coordinates of points on an object. Terrestrial photogrammetry methods help to obtain precise measurements easily. Moreover, it is usually the unique solution to obtain reliable measurements of inaccessible physical details on buildings. Depending on the recent technological improvements in terrestrial photogrammetry, new fields of applications have emerged. For terrestrial photogrammetry, expert personnel support is highly necessary. Photogrammetry and laser scanning, a key method used in architectural documentation in archaeological sites, has also been used effectively for different disciplines. In a similar vein, researchers have evaluated and analyzed new documentation technologies for architectural and archaeological applications. According to Warden and Woodcock (2005), documentation of existing environmental elements has been one of the biggest contributors to architecture education through the ages. These authors explained the use and advantages of digital photogrammetry in the documentation of historical environments. Arias et al. (2005), analyzed methods of digital documentation used for the protection of monuments and discussed computer-aided techniques as well as digital photogrammetry. Kucukkaya (2003), explained the applicability of photogrammetry and remote sensing to archaeological work, highlighting the importance of these technologies for the protection of historical areas. Alves and Bartolo (2006), discussed developments in the restoration of historical buildings, a new industry that contributes to cities both spiritually and materially. Alves and Bartolo (2006), discussed the necessity of laser scanning, photogrammetry, and computer visualization for restoration work and detailed a hybrid 3D modeling system.

Song and Wang (2006), stressed the importance of automatic 3D surface reconstruction research in digital photogrammetry and presented a 3D photo-realistic modeling system. Baltsavias (1999), described the basic differences between passive optical sensors and airborne laser scanning for data capturing and processing. Brenner (2005), also focused on laser scanning and images, which have been applied for object extraction for years, and debated automatic and semiautomatic reconstruction methods in detail. Whereas Song and Wang (2006), discussed techniques to be used for 3D automatic surface reconstruction, Olague and Mohr (2001), highlighted the importance of camera location in obtaining the most accurate 3D measurements. Some researchers give detailed information about the applicability of advanced technologies, weights their advantages and disadvantages, compares them with traditional methods and provides examples of the methods in use (Amt, 2000; Böhler, 2000; Bruschke, 2000; Hansen, 2000; Hell, 2000; Hemmleb et al., 2000; Mader, 2000; Schulz, 2000; Stephani, 2000; Steilein, 2000; Weferling, 2000; Wehr, 2000). In sum, an abundance of these researches have focused on the use of advanced technologies in architectural and archaeological work.

In Patara excavation, photogrammetry and laser scanning techniques explained in the aforementioned articles have been applied in various documentation projects. The following sections give more details about these projects.

## APPLICATIONS OF ADVANCED TECHNOLOGIES FOR CULTURAL DOCUMENTATION: HURMALIK BATH CASE

Here, we give brief information about field and office technology applications. The material and methods of geodesic research, photogrammetric surveys, remote sensing and laser scanning, and GIS), and visualization performed during the architectural documentation of Hurmalik Bath are explained in turn.

### Geodesic research

The first step in the study was to obtain the site plan. The aerial photographs and the vectoral data provided by Turkish General Commander of Mapping (HGK National Mapping Agency of Turkey) (Figure 2) were used as basis to generate the site plan. The missing areas in the aerial photograph of the site plan were manually measured using a hand-held GPS (Trimble GeoExplorer XH) and the results were added to the site plan.

In order to maintain the integrity and to enable future expansions, the site plan was converted into GIS media using ArcGIS 9.0 (Figure 3). The measured coordinates were then integrated into the national coordinate system using GIS programs. (The coordinates were integrated using WGS-84 datum and according to 35th zone).

With the help of the aforementioned techniques, city plan of the antique city was created at 1/1000 scale. Furthermore a 1/50 scale building plan was also created to carry out structural investigations of the Hurmalik Bath. The building plan is generated using total station (Trimble Dr +200).

To depict the position of Hurmalik Bath and its road connections with its surroundings site plan was generated using balloon photogrammetry (Figure 4)[2]. Control points were placed at 5-m intervals around the building and vicinity. The control points were surveyed with the total station.

Furthermore, all walls and construction contours were also surveyed with the total station. This process was quite difficult and time consuming because it required surveying a large number of control points. Nevertheless, it was absolutely necessary in order to attain the high precision required to match and surpass the results traditionally obtained by detailed hand drawing.

Total station and other similar devices require establishing polygons with known coordinates unless four known polygons already exist in the survey area. Total station was used to set up the polygons. Even though real-time kinematic GPS measurements were not performed in this study, we recommend their use for other surveys. Real-time kinematic GPS provides rapid, efficient and accurate (within centimeter) results. Moreover, compared to total station, real-time kinematic GPS does not require polygon transmission or other similar processes. Thus, it is considerably easier to use.

The use of total station or real-time kinematic GPS measurements are required to produce the photo images of building facades. For this purpose, one must capture the photogrammetric images of the façade and then scale them to their original sizes (rectification) and eliminate perspective and objective distortions using the surveyed control points. This process requires the accurate coordinate information of the control points. Total station was more appropriate to survey the facades' control points as using GPS was almost impossible due to inaccessibility. In fact, in most similar documentation instances using a total station is inevitable. However when one weighs the costs and benefits, photogrammetric surveys carried out with a real-time kinematic GPS-supported total station result in very rapid and highly accurate results.

### Photogrammetric surveys

Altan et al., (2004), analyzed the difficulties encountered and results obtained when balloon photogrammetry is used in surveys. They used a remote-controlled camera installed on a balloon and took pictures in clear weather. They provided Patara Theatre's 1/100 scale stone plan and 1/50 scale plan using balloon photogrammetry.

Two main photogrammetric techniques were used in Patara surveys:

1. Balloon photogrammetry.
2. Terrestrial photogrammetry.

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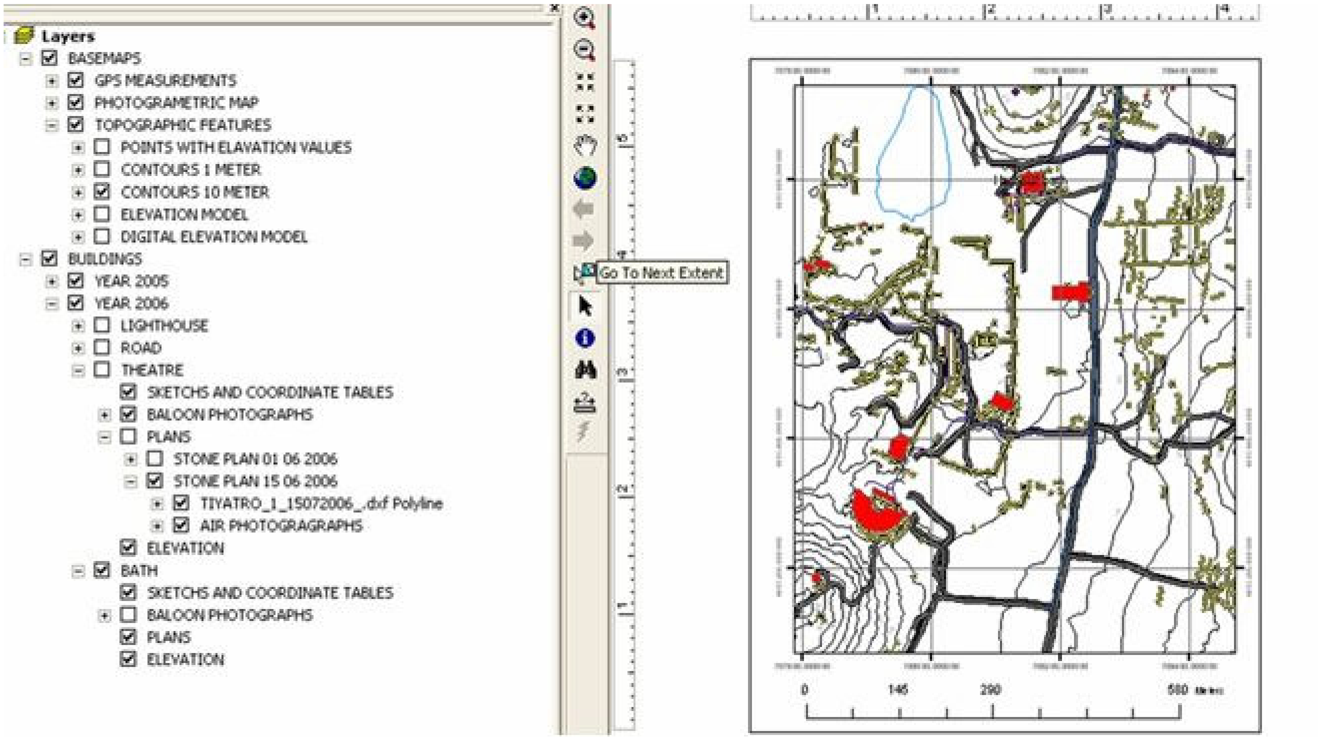
[2] The plan of the building prepared by Abdullah Deveci, Feray Ergincan and Uğur Avdan in 2006, using Total Station measurements was integrated with the plan of the surroundings prepared by using balloon photogrammetry.

**Figure 2.** Aerial photo [courtesy of HGK).

Our photogrammetric surveys came from three sources:

1. Balloon photogrammetry.
2. Terrestrial image capturing.
3. Aerial photographs provided by the General Commander of Mapping (HGK).

Photogrammetric balloon photographs were taken with a



- Layers
  - ☑ BASEMAPS
    - ☑ GPS MEASUREMENTS
    - ☑ PHOTOGRAMETRIC MAP
    - ☑ TOPOGRAPHIC FEATURES
      - ☐ POINTS WITH ELAVATION VALUES
      - ☐ CONTOURS 1 METER
      - ☑ CONTOURS 10 METER
      - ☐ ELEVATION MODEL
      - ☐ DIGITAL ELEVATION MODEL
  - ☑ BUILDINGS
    - ☑ YEAR 2005
    - ☑ YEAR 2006
      - ☐ LIGHTHOUSE
      - ☐ ROAD
      - ☐ THEATRE
        - ☑ SKETCHS AND COORDINATE TABLES
        - ☑ BALOON PHOTOGRAPHS
        - ☐ PLANS
          - ☐ STONE PLAN 01 06 2006
          - ☑ STONE PLAN 15 06 2006
            - ☑ TIYATRO_1_15072006_.dxf Polyline
            - ☑ AIR PHOTOGRAGRAPHS
        - ☑ ELEVATION
      - ☑ BATH
        - ☑ SKETCHS AND COORDINATE TABLES
        - ☐ BALOON PHOTOGRAPHS
        - ☑ PLANS
        - ☑ ELEVATION

**Figure 3.** Plan generated in ArcGIS environment.

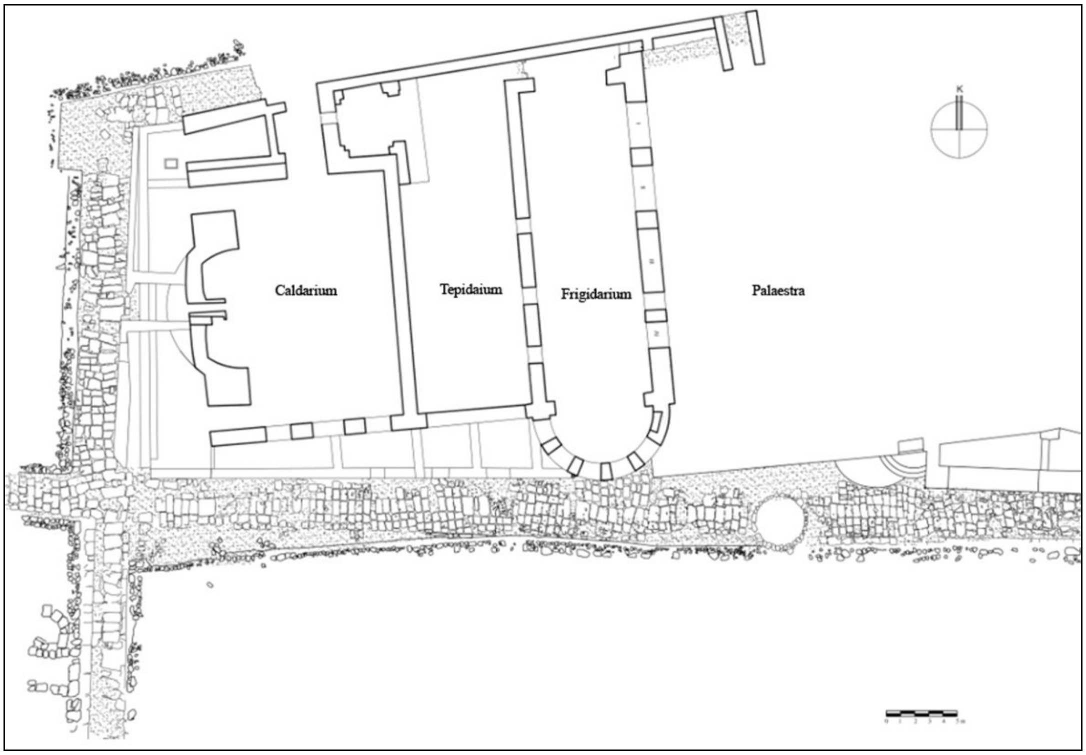


**Figure 4.** Structural plan and furnishing plan obtained from balloon photogrammmetry.

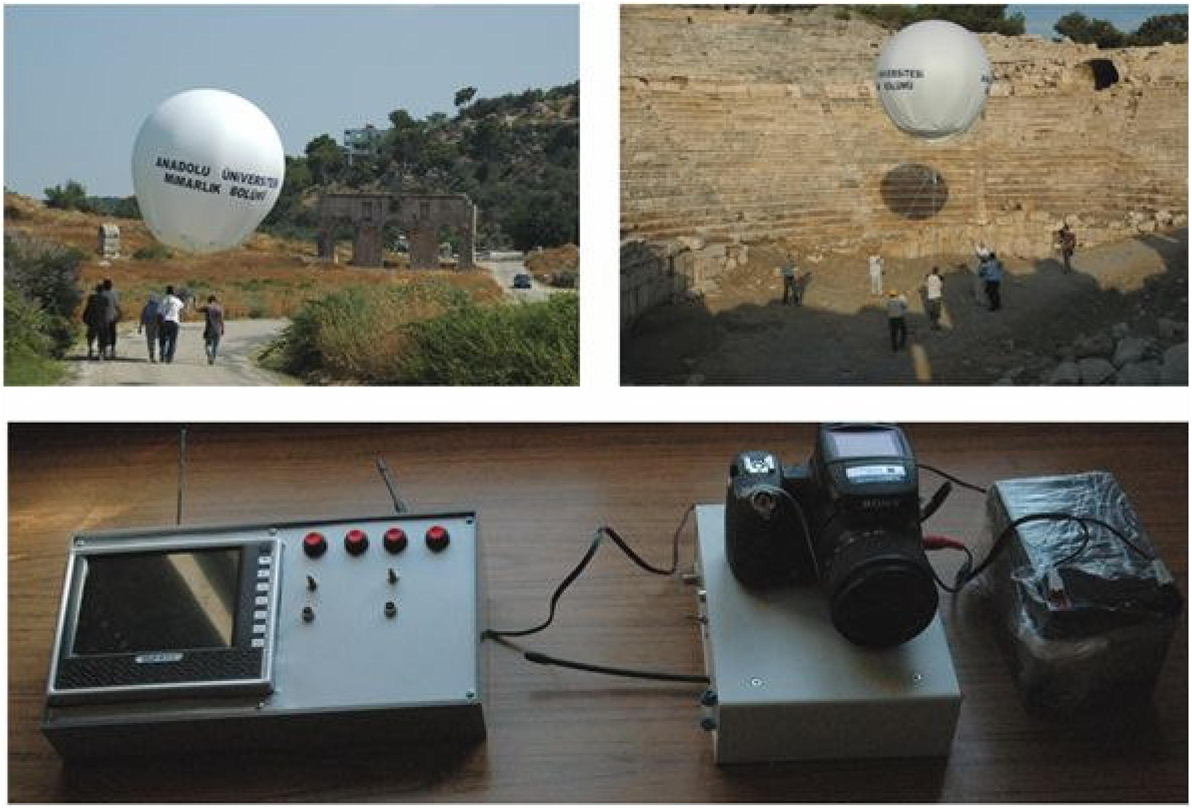


**Figure 5.** Structural equipment on the air vehicle and ground control unit.

**Figure 6.** Aerial images and control points captured by the balloon.

7-mm lens (Sony DSC-V3; Tokyo, Japan), and were processed with Pictran Software. An air vehicle (balloon) specifically designed for photogrammetric image capturing was used to extract the site plan. The vehicle consisted of two parts: A ground control unit and an integrated camera (Figure 5). Figure 6 shows an example of some balloon images and control points on land. This method also employed for extracting the stone plans during each stage of the project. Thus, highly accurate stone plans were prepared very quickly.

The equipments used in balloon photogrammetry are difficult to control and operate in windy and hot locations such as Patara. We recommend the use of remote controlled (unmanned) air vehicle, or helicopter-mounted light detection and ranging (LIDAR) instead of balloon photogrammetry. Airplane-mounted LIDAR would not be

**Table 1.** Calibration values for Canon EOS-1D Mark II 35-mm camera.

| | |
|---|---|
| Focal length | 28.6948560 |
| Principal point [x] | 0.1566250 |
| Principal point [y] | -0.1356200 |
| R0 | 0 |
| A1 | -0.000110832 |
| A2 | 1.83278e-07 |
| A3 | 0.000809979 |
| A4 | -1.29025e-05 |
| A5 | 2.09742e-05 |
| A6 | 9.86347e-06 |
| Sensor size [width] | 28.70000000 |
| Sensor size [height] | 19.10000000 |

satisfactory because of the airplane's speed and altitude the number of control points to be collected would be insufficient to attain the high level of accuracy required by the detailed plans of architectural conservation.

The positions of land control points used in the coordinatization of the balloon photogrammetry images have to be measured with high precision. Large size control points are mounted on the ground to increase their visibility in the aerial images (Figure 6). The most difficult aspect of balloon photogrammetry was taking a large number of images vertically and at as low altitude as possible to capture the details of the buildings hidden by the high facades that in fact should be visible on the plan.

As a second method, we used terrestrial photogrammetry to survey the building facades. The only difference between this technique and balloon photogrammetry was the position of the camera, which was vertical to ground level; thus captured images were parallel to the vertical plane (x-z or y-z). Unfortunately, our Nikon D70 6MP SLR (single-lens reflex) camera could not capture images with the desired resolution, and the control points on the facades were not clearly detectable. Consequently, some of the rectified photogrammetric images resulted in errors of up to 4 or 5 cm. However, our Canon EOS 16MP metric SLR camera captured clear, high-resolutions images of the facade details and easily detected the control points. Table 1 shows the calibration values for Canon EOS-1D Mark II 35 mm camera. The errors in the rectified images were no more than 1 to 2 cm.

The ortho-photos obtained from both balloon, and terrestrial photogrammetries constitute a plane. The drawings are made on the plane. Therefore, the images of the work site should be as vertical as possible, without a difference in depth. In archeological sites high degree of surface deformation is observed. In such sites, the use of close-range photos and balloon photogrammetry may cause inaccuracies in drawings. This drawback is overcome by layering several planes, and producing ortho-photos of each layer separately. Another consideration is to ensure that the images do not deviate from the vertical line because minor slants may cause deformation in ortho-photos. The problem is remedied by taking multiple images and eliminating the ones with improper light and verticality. Those images with proper light and angle are then used to produce and valuate the ortho-photos.

Control points are positioned such that they coincide with the corners of the photographic images. Under normal circumstances 3 control points would be sufficient to produce an ortho-photo; however error calculation is not possible with only 3 control points. Therefore, in our study, we ensured that there are at least 4 control points in every image. All control points are measured with total station. In the final ortho-photo images, we achieved millimeter-level precision using Pictran software (Figure 7). Note that Pictran does not provide vectorization capability, and it stores the generated ortho-photo images in Geotiff format. Unfortunately many CAD (computer aided design) packages cannot open Geotiff files with coordinate information. For vectorization, we used AutoCAD Map 3D 2005 which supports Geotiff format.

In the work site, several facades were too large to fit into a single photographic frame. These facades had to be photographed by taking multiple frames and producing multiple ortho-photos. Once produced, it was quite straightforward to accurately juxtapose the ortho-photos with the help of CAD software, thanks to the coordinate information contained in the ortho-photos (Figure 8).

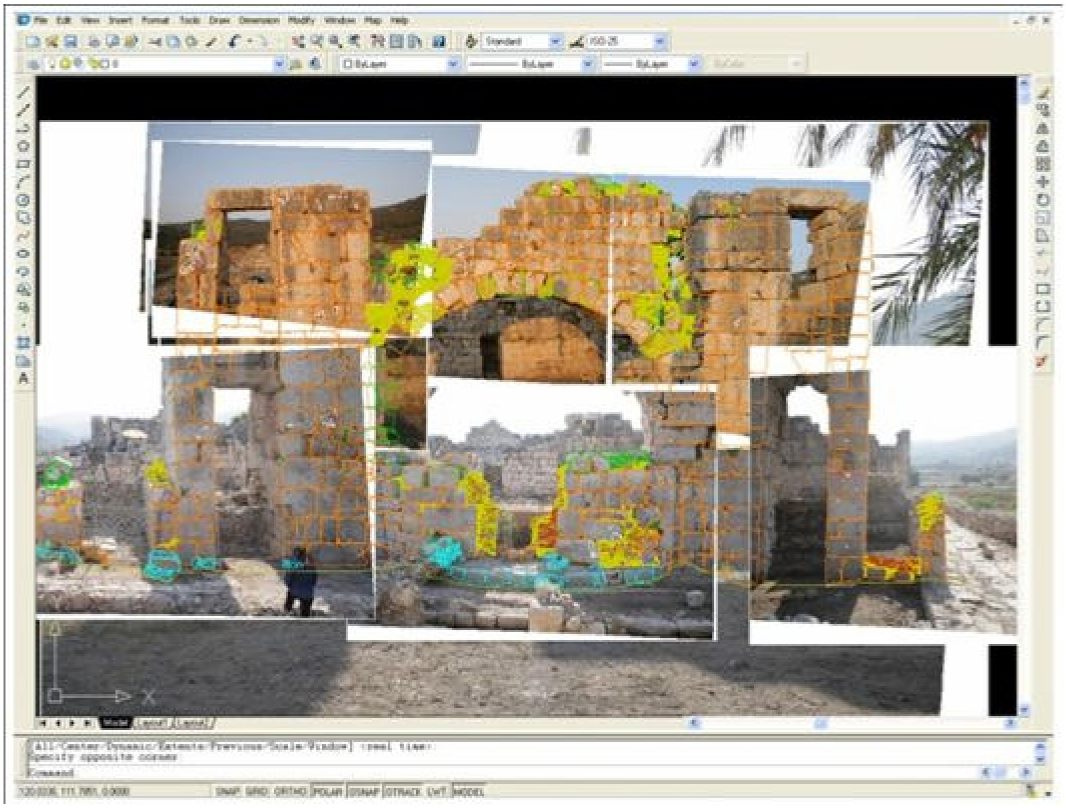
When the depth difference is negligible, photogrammetry method proved to be appropriate in archeological sites that are hard to access or difficult to work in. When the depth difference increases, the decision on whether or not to prefer photogrammetry depends on the scale to be used. Photogrammetry is still plausible, if the error resulting from the depth difference can be eliminated with the scale factor. Otherwise we recommend either stereo photogrammetry or laser scanning.

## Laser scanning

Our work area consists of different geometric surfaces. As a result, it became necessary to use 3-D evaluation method with the laser scanner. Laser scanning is carried out in two main stages: scanning at work site, and post-processing in the office.

There are a number of commercially available laser scanners. Our experience showed that it is important to choose a scanner that is compatible with the conditions of the work site and type. We had to use two different

**Figure 7.** (a) Raw images from Patara Hurmalik Bath, control points on the buildings and rectified image. [b) Images obtained by laser scanning.



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[All/Center/Dynamic/Extents/Previous/Scale/Window] <real time>:
Specify opposite corner:
Command:
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**Figure 8.** Hurmalik Bath western facade hand-drawings overlaid orthophotos.

scanners as the results obtained with one of them did not meet the high-fidelity requirements of archeological documentation. We will briefly compare the capabilities and the results of the two scanners we used. To maintain anonymity, we will refer to the scanners as Scanner A and Scanner B. We preferred Scanner A to extract cross-sections and plans, and to create 3-D models and up-to-date animation of Hurmalik Bath.

Scanner B collects spatial coordinates (x, y, z), color information (r, g, b) and density information. Scanner A

**Figure 9.** 3D model generated using scanner B.

**Figure 10.** 3D model generated using scanner A.

also collects spatial coordinates, and density information, but color information is collected with an add-on photographic camera mountable on the scanner. Therefore, Scanner A feeds data faster than Scanner B.

Scanner A can incline 0 to 45 degrees on the vertical axis, a feature that we found very convenient particularly in the archaeological sites. This feature lacks in Scanner B. Another disadvantage of Scanner B was the performance issues caused by the heat. In hot climates such as Patara, Scanner B was inefficient as it heated up very quickly and frequently malfunctioned.

Another difference between the two scanners was the software packages on these devices. Scanner B comes with two separate software packages, one to collect data from site, and the other for post-processing the collected data. Scanner A comes with one package that both collects and then processes data.

Initially, we only had access to Scanner B. We used 150 observation points to produce the 3-D model which took approximately 10 days to complete. Unfortunately, the ortho-photos obtained from the 3-D model were not suitable to generate the drawings (Figure 9). Because Scanner B collects color information together with spatial and density information, color distortion due to sunlight is observed. Therefore we did some investigation to find a more suitable scanner and chose Scanner A. We had to repeat the scanning work with Scanner A which took approximately same amount of time. The 3-D models of Hurmalik Bath produced by Scanner A and Scanner B are shown in Figures 9 and 10, respectively.

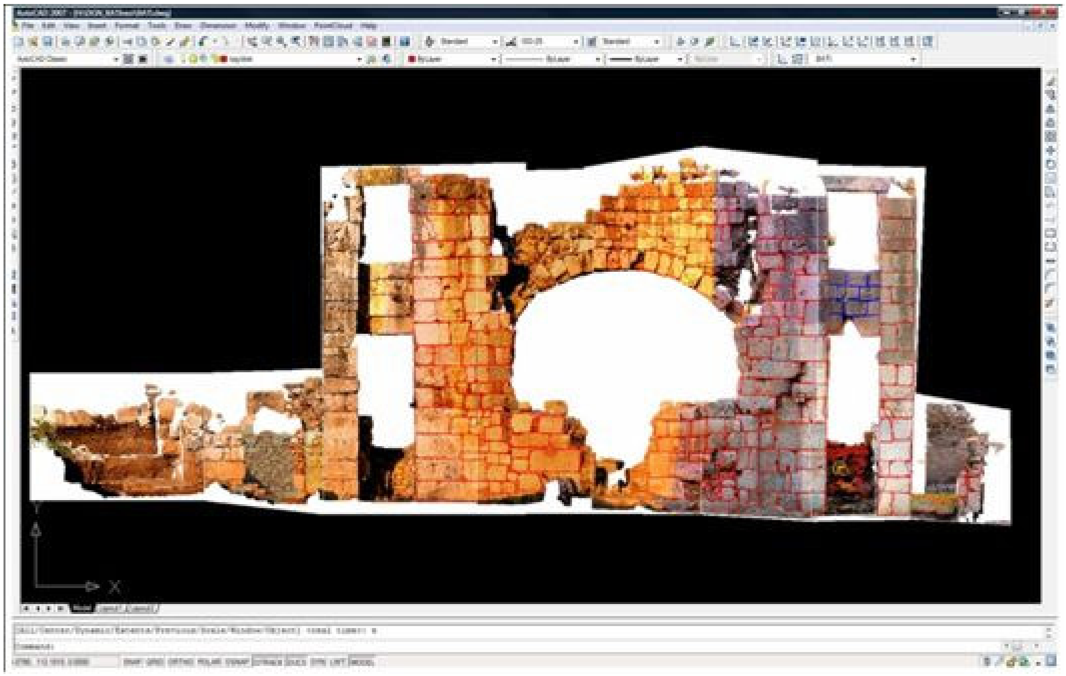

**Figure 11.** Ortho-photo of Hurmalik Bath Western Façade [seen in AutoCAD) obtained by using laser scanning.

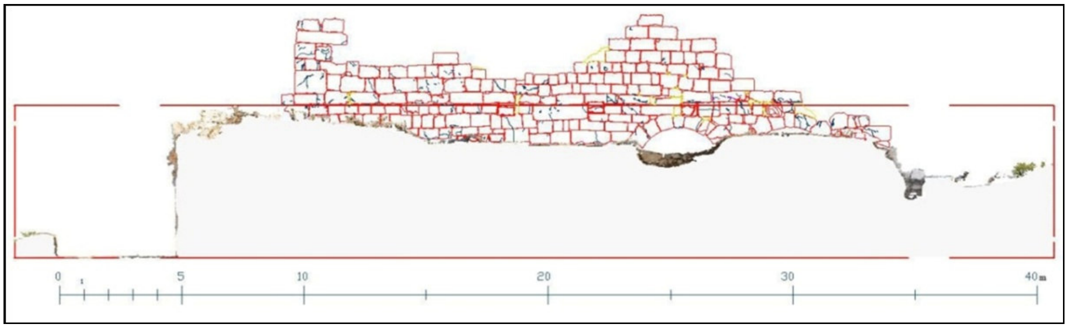

**Figure 12.** Hand-drawing of Hurmalik Bath Western Façade and elevation based on the orthophoto and 3D model.

Having completed the scanning stage at the work site, we started the post-processing stage in the office which includes vectorization and generating plans for elevation and view. Note that, using the 3-D model, one can produce plans from different levels or produce elevations from any location.

With the 3-D model obtained with Scanner A, it was possible to produce ortho-photos (Figure 11). These photos were then scaled to the original sizes (rectification), perspective was eliminated and objective distortions were corrected. With this technique, we successfully produced ortho-photos for all facades and interior walls of Hurmalik Bath. These photos depict the original structure accurately with a negligible error as small as 2 to 8 mm.

Finally the detailed hand-drawings were made using the information from ortho-photos (Figure 12). Overall time spent in the office for post-processing was approximately 6 to 8 months.

We produced the ortho-photos such that they can be used together with 3-D points clouds. If needed, the ortho-photos and 3-D point clouds can be overlaid on each other for better results. Using this technique, it is also possible to generate the 3-D animations of the work

**Table 2.** Method stages and accuracy.

| Technology | Hardware/software | Process | Accuracy |
|---|---|---|---|
| Terrestrial photogrammetry | Pictran software | Rectification of the image<br>Transformation of the rectified image into geotiff format | ± 2 mm - 3 cm |
| | AutoCAD Map 3D | Transfer of the photogrammetric image in geotiff format to AutoCAD | |
| | AutoCAD | Vectorization | ± 2 - 10 cm depending on the precision of the image and the digitizing operator |
| Balloon photogrammetry | 7-mm Sony-camera-integrated balloon | Documentation | |
| | Photogrammetric air vehicle equipped with 10 MP single-lens reflex [SLR) metric camera, image links, remote control | Extraction of building plan | ± 3 cm |
| | | Extraction of stone plans | ± 5 cm |
| Geographical information system | ArcGIS 9.0 | Applications within the bath | |
| | | Documentation | ± 10 cm |
| | | Excavation management | |
| | | Archival | |
| | | Creation of data image bank | |
| | | Analysis and examination | |
| | | Integration of all spatial data | ± 10 cm |
| | | Applications in the whole city | |
| | | Visualization | |
| Global positioning system [GPS) | Trimble geoexplorer [personal digital assistant + GPS) | Extraction of city plan and marking of findings on it | ± 2 m |
| | Trimble real-time GPS | Surveying of control points on plan plane for photogrammetry | ± 2 mm |
| | | Carrying of polygons connected to the main polygon net | ± 2 mm |
| Total station survey | | Surveying of control points on plan plane for photogrammetry | |
| | | Surveying of control points on facade plane for photogrammetry | |

**Table 2.** Contd.

| | | | |
|---|---|---|---|
| | | Extraction of building plan with traditional methods | |
| | | Locating and surveying of control points to extract stone plans | |
| | | Establishment of main polygon points | ± 2 mm -± 10 mm |
| Laser scanning | Riegl 390I/RiScan Pro<br>Trimble GX200/Pointscape<br>Trimble GX200/Realworks Survey [ver: 6.0) | Unification of data collected from various locations [Registration)<br>Elevation and plan creation<br>Ortho-photo production | 2 - 8 mm |
| | | Unification of data collected from various locations [Registration) | 2 - 8 mm |
| | | Elevation and plan creation<br>Ortho-photo production | 2 - 8 mm |
| Remote sensing and digital image capturing | Sony 10 MP high-resolution metric camera | Drawing of building plans with photogrammetry | 3 - 50 cm, depending on altitude |

site. However, two disadvantages restrict the widespread use of this technique for archaeological documentation. First is the huge size of the high point density. Even computers configured for high capacity data processing may fail to view or process the laser-scanning data. Second is the cost, overall cost of the systems is at least 200000 - 300000 USD. Table 2 shows the information and accuracies corresponding the different methods used in this study.

## Conclusion

With regard to archaeological applications in Turkey, it would not be inaccurate to say that there are still problems with interdisciplinary communication and collaboration. The methods for undertaking most of the significant work of archaeological excavation (e.g., documenting buildings with drawings, plans, cross-sections, and views; creating probable reconstruction drawings for findings; examining ancient buildings) are incomplete and deficient. Strong interdisciplinary relations, as well as eagerness and determination to use advanced technologies for rapid and accurate results, are needed to remedy this.

Terrestrial photogrammetry and real-time kinematic GPS are the preferred technologies in disciplines such as geodesy, geography, and geology. These technologies are of great importance for collecting, archiving, and modeling data for archaeological and architectural reconstruction. Although Turkey has a unique archaeological heritage, it also has insufficient equipment and inexperienced technical personnel. In many cases, Turkish experts rely on the support of foreign teams. Deficiencies in archaeological documentation threaten the survival of Turkey's cultural heritage, and inaccurate or incomplete building surveys, restoration, documentation, and reconstruction pose their own risks to this heritage. The use of advanced technologies represents a significant solution to this problem. The development of methods for documenting and monitoring cultural heritage would be very helpful for architectural protection as well as research in archaeology, architecture, art history, and the history of architecture. Photogrammetry rapidly extracts precise and accurate architectural drawings and is applicable to analytical ocumentation. Developments in computer technologies, increasingly high-resolution images, better data collection capacity, and considerably lower software prices combine to enable more frequent application of digital photogrammetry in architectural surveys.

In sum, compared with traditional methods, the advantages of advanced documentation technologies are as follows:

1. Cost: The number of personnel required to use these methods is minimal, and so is the cost. Collecting data through images or fieldwork decreases time spent revisiting the site and making CAD drawings.
2. Convenience: As soon as fieldwork is complete, the building is documented. The remaining work is easily done in the office regardless of weather conditions.
3. Accuracy: The accuracy of the drawings depends on the scale and can be adjusted. Results are very accurate.
4. Selectivity: Certain items can be selected from the images. For example, surface texture details may be ignored to create a general silhouette.
5. Accessibility: Documentation can be made from distant locations. This is ideal for inaccessible facades, high towers, archaeological sites, and dangerous industrial areas. Weather conditions are only slightly limiting.
6. Homogeneity: Every point, element, and detail is surveyed and drawn with the same accuracy regardless of changes in route, team, or weather conditions.
7. Flexibility: Advanced technology surveys can be done in two steps. In the first step, images are captured and surveys are done. In the second step, the images and the survey results are examined and drawings are extracted. The second step can either be performed immediately or be postponed. In fact, if the first step is properly performed and the data are saved well, the second step can be started years later.

The technologies require costly hardware and software and experienced and trained personnel to handle the equipment and manage the project rapidly, accurately, and precisely. Despite their obvious advantages, the advanced technologies are not the only solution in several areas. Other traditional techniques may be more appropriate in particular cases. Depending on the case at hand, a combination of both advanced and traditional techniques can be also considered. Regardless of the technique used, to maintain the integrity of the work it is crucial to use the same coordinate system throughout the survey.

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