

# Photogrammetry and GIS Integration for Archaeological Documentation of Ahl-Alkahf, Jordan

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**Abstract**—Protection and proper management of archaeological heritage are an essential process of studying and interpreting the generations present and future. Protecting the archaeological heritage is based upon multidiscipline professional collaboration. This study aims to gather data by different sources (Photogrammetry and Geographic Information System (GIS)) integrated for the purpose of documenting one of the significant archeological sites (Ahl-Alkahf, Jordan).

3D modeling deals with the actual image of the features, shapes and texture to represent reality as realistically as possible by using texture. The 3D coordinates that result of the photogrammetric adjustment procedures are used to create 3D-models of the study area. Adding Textures to the 3D-models surfaces gives a 'real world' appearance to the displayed models. GIS system combined all data, including boundary maps, indicating the location of archeological sites, transportation layer, digital elevation model and orthoimages. For realistic representation of the study area, 3D - GIS model prepared, where efficient generation, management and visualization of such special data can be achieved.

**Keywords**—Archaeology, Close range Photogrammetry, Ortho-Photo, 3D-GIS

## I. INTRODUCTION

THE archaeological heritage constitutes the basic record of past human activities. Its protection and proper management is therefore essential to enable archaeologists and other scholars to study and interpret it for the benefit of present and future generations. The protection of archaeological heritage must be based upon effective collaboration between professionals from many disciplines. In this research, knowledge from different sources and research areas should be integrated to establish the geographic documentations of the historical and archeological area (Ahl-Alkahf, Jordan, Fig. 1). Fig.1 shows, the Aerial image with 1m resolution taken at 2000m altitude, where the location of Ahl-Alkahf area with respect to other major cities in Jordan are illustrated.

Photogrammetry has been applied to the planning, recording, reconstructing, and revitalizing of the world heritage sites. Archaeology and preserving the cultural heritage are among

the emerging application areas for the three dimensional Geographic Information (3D GIS). In this study, 3D GIS has been prepared for further efficient generation, management and visualization of the large 3D landscape, maps, monuments, digital elevation models, Orthophoto, satellite images and the various models developed by the Photogrammetry for the major archeological discovery of the recent time (Ahl-Alkahf, cave in Jordan). Section II will briefly describe a historical background of the Ahl-Alkahf; Section II will also focus on the architecture of the structure. The photogrammetric processing including generating digital elevation model, Orthophoto and three dimensional textured model of the study will be discussed and presented in Section III. Section IV will deal with preparing geographic layers and three dimensional GIS. Finally, a conclusion and future work will be presented in Section V.

## II. REVIEW OF THE STUDY AREA

### A. Historical and Religious Importance of the Study Area

Chapter 9 of the Holy Qur'an, Suratul Al Khaf describes the history of Ahl-Alkahf that happened cross the Byzantine era almost during the years 408 -450 AC; being governed by the imperial Theodosius. Recitation an odd number of person's who went to the cave running away from their folk and persecution governor to pray and worship God, and then God kept them asleep for at least 309 years.

Ahl-Alkahf cave is located at the south-east of Amman City in Al-Rajeeb village about (4) kilometers from the Jordan Television Broadcasting Station and about (1.5) kilometer from Abu-Alanda. The height is about (750) meters from the mean sea level.

### B. Site Structures and Description of the Study Area

The sketch which indicates the layout of the study area is shown in Fig 2.

The main entrance of cave the historical place of Alkahf and a full image of the site after being remodeled appear in Fig 3. Fig. 4 shows Al-Kahaf as the main feature under consideration.

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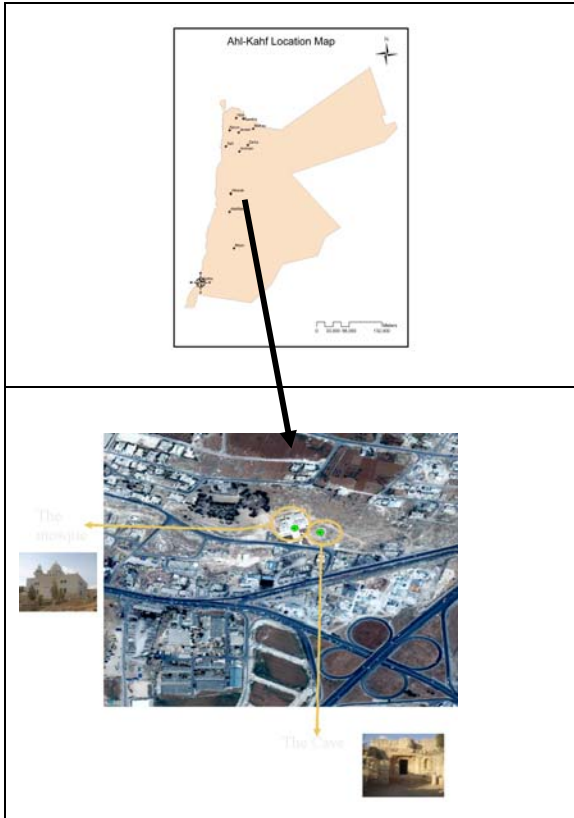


Fig. 1- General overview of Ahl-Alkahf location in Jordan

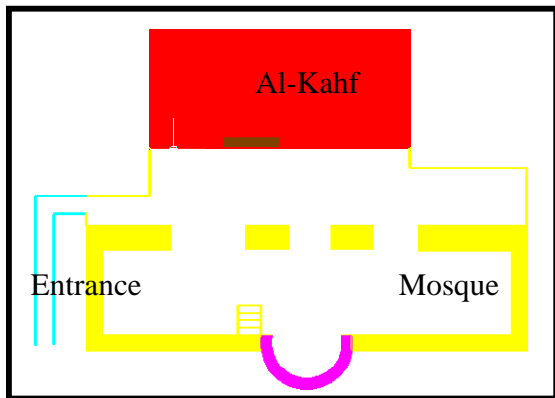


Fig. 2- Description of the Study Area

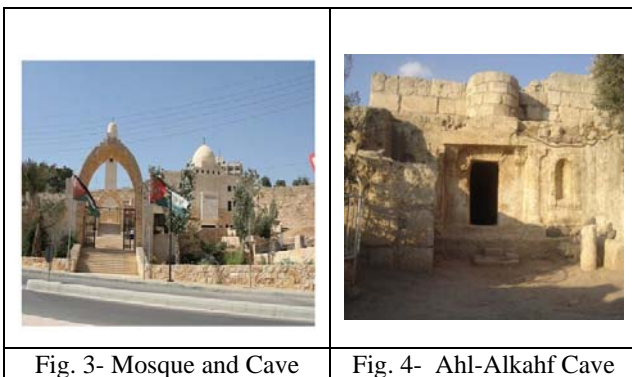


Fig. 3- Mosque and Cave

Fig. 4- Ahl-Alkahf Cave

Fig. 5 portrays the Left and Right sides of the Parry Room, and the entrance part of the cave.

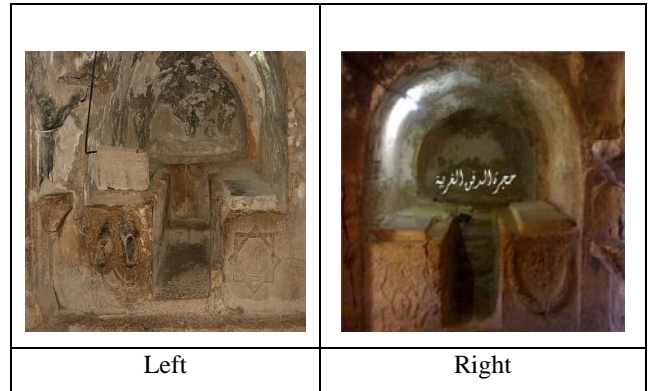


Fig. 5- Left and Right of the Parry Room

Finally, observe the (alkowah) in Fig. 6



Fig. 6- Alkowah

### III. PHOTOGRAMMETRIC PROCESSING

Photogrammetry is concerned with deriving measurements of the size, shape and position of the objects from the measurements made to photographs. Photogrammetry has been applied to the planning, recording, reconstructing, and revitalizing the world heritage sites. With the advent of digital Photogrammetry and image processing technology the photogrammetric recording process of the heritage sites has rapidly increased. Working in a digital environment allows flexibility choice of computer hardware and software and enables non-photogrammetrist to produce an accurate data for the recording purposes. Digital object enhancement and 3D-modelling techniques are also possible and usually give clear presentation of heritage sites. Considerably enhancing the recognition of the construction material, shape and area, as well as their spatial distribution, which is considered to be one of the most difficult and time-consuming tasks for architects [5]. In brief, Photogrammetry offers a rapid and an accurate method of acquiring three-dimensional information regarding cultural monuments. Combining the measurements obtained from the photogrammetric record and 3D CAD models will provide means to recreate historic environments.

Consequently it is facilitating the generation of an accurate digital records for the historical and archaeological objects, while reducing the overall costs. In this paper photogrammetric processing is used for three main productions; digital terrain Model (DTM), Orthophoto and 3D modeling for the existing archeological structure.

DTM generation required an image correlation strategy to be used for an automatic extraction of the conjugate points. Moreover, an adaptive method should be used to generate a DTM with grid format, where the nature terrain (hilly, flat) is considered; first, a DTM file that was created with a 20m post spacing to provide the whole project area within an initial elevations of the terrain model where each post was edited to ground and saved. Then another DTM was built with 5m post spacing, where an improved representation of the real terrain for 1:10000 photo-scales could be obtained. Finally, the consistency test between the generated DTM and collected GPS check points was carried out to insure the quality of the produced DTM. Fig. 7 shows the DTM generated along for the study area where height ranges from 737 to 823 meter above mean sea level.

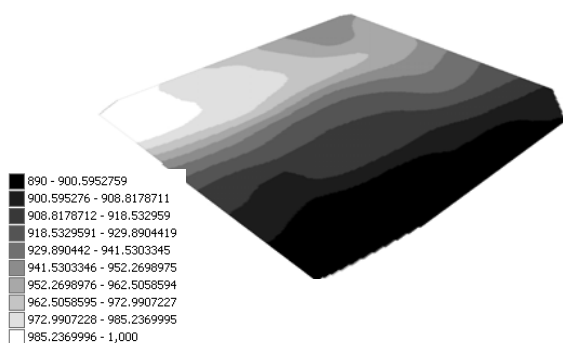


Fig. 7 Digital Elevation Model for the Study Area

Next stage in processing is to generate an *Ortho-photo* as in Fig.6. Basically the Ortho-photo is a photograph transformed from perspective to orthogonal projection, or otherwise said, corrected for tilts and relief displacements. The produced DTM is to be used for Orthophoto generation. Regions that are not edited correctly in the DTM file appear on the Orthophoto as breaks and cuts in the region. These errors were removed by manual editing of the DTM based on visual inspections. Fig.8 shows the generated Orthophoto.

The last part in photogrammetric processing is the 3D modeling that deal with real representation of the features, shapes, and texture based on *Close Range Photogrammetry*. The principle of the 3D modeling is to give the features the same dimension and texture as reality. As mentioned before, Photogrammetry offers a rapid and an accurate method for acquiring three-dimensional information regarding cultural monuments. Combining the measurements obtained from the photogrammetric record and the 3D CAD models will provide the means to recreate historic environments. Hence this will

facilitate the process of generating accurate digital records for the historical and archaeological objects, while reducing the overall costs.



Fig. 8 Generated Orthophoto for the Study Area

When using the photogrammetric techniques for recording and documenting the cultural heritage, the factors with impact on recording accuracy and archiving efficiency must be considered: namely, metric characteristics of camera, imaging resolution and requirements of the bundle adjustment procedure. The mathematical model that incorporates self-calibration and bundle adjustment procedure for accurate estimation of the interior and exterior orientation parameters has been adopted. This is a necessary prerequisite for accurate and reliable 3D-reconstruction.

After estimating the interior orientation parameters of the camera, experiments are conducted based on real data to build a three dimensional model. For this purpose, the calibrated SONY DSC-F707 digital camera is used to capture convergent images at three different locations with 90° rotation around the Z-axis at each exposure station. An arbitrary datum is chosen as reference for the object space, where conjugate points are selected. These measurements are introduced into the bundle adjustment in order to estimate their grounds synchronize. Selection of the points was performed while considering the following issues:

- 1) Distribution of points. The measured points must be well distributed and must cover the whole objects under study.
- 2) Visibility of each point in two or more images. If the same points appear in larger number of images, the geometrical strength as well as the accuracy of three-dimensional coordinates will be improved.
- 3) Adequacy of selected points for the reconstruction of different shapes from an architectural point of view. For example, to draw a circle, at least three points on the circumference must be located.

As shown in Fig. 9, the three dimensional coordinates resulting from adjusting procedure are used to reconstruct 3D model for Alkahf that mentioned in Fig.4.

Surface rendering, which involves the generation of a 3D

model with a real world surface texture, is constructed, Fig.9. That means, the surface textures are added to the 3D model surfaces to give a real world appearance to the displayed model. The 3D surface rendering is very important for the presentation of a ruined heritage sites where architects and renovation experts must have a realist view of the ruin for further inspiration. Moreover, the 3D model can be digitally rotated to give a whole range of perspective views.

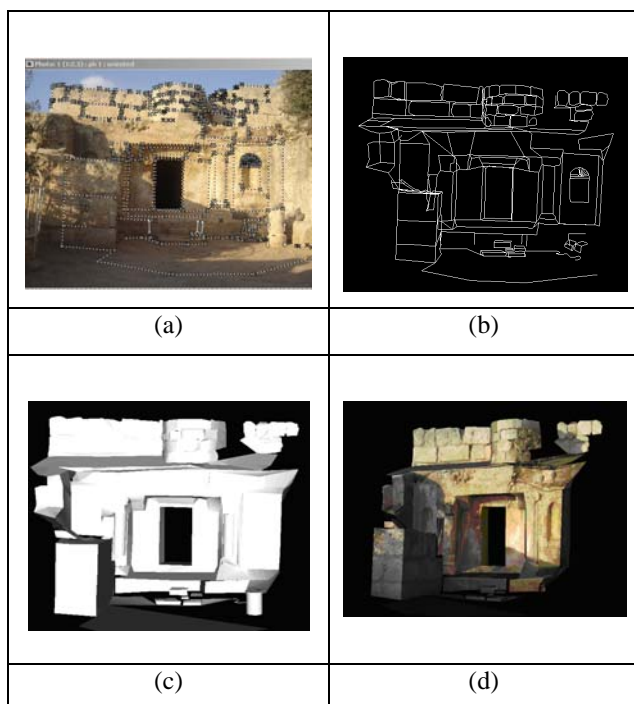


Fig. 9 Three Dimensional Model of the Cave with surface rendering:  
 a) Original Cave, b) Wire Frame Model  
 c) Render Model and d) Textured Model

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#### IV. THE ROLE OF GIS IN ARCHEOLOGICAL DOCUMENTATION

A Geographic Information System is a collection of information technology, data, and procedures for collecting, storing, manipulating, analyzing, and presenting maps and descriptive information about features to be represented on the maps [6].

Cultural heritage objects often have a very irregular complex geometry. Thus, a good digital reconstruction requires a very detailed 3D model with a lot of geometry elements. So there are two main requirements for the 3D GIS.

The first is a support for the acquisition and handling of large amounts of complex and non-planar 3D geometry. The second is the visualization of these objects which consists of a lot of geometry elements [7].

This study highlights the representation and integration of photogrammetric products, which illustrated in Section 4. In geo-referenced maps and images, the huge database can be manipulated, managed, and visualized. The obvious and accurate geometric overlaying of these different data will be helpful and great support for interpretation and analysis of the results.

It should to be mentioned that diversity of superimpose data that can be represented in the GIS system will include (Boundary Maps, Point Location of Archeological Sites, Transportation Layer, Hydrological Maps, Digital Elevation Model, Aerial Images (Ortho-rectified), Satellite Images, Land Classification Image, Aquifer Profiles and Geology of the Area). All these layers are associated with database and descriptive attributes. The system should to be designed in away that allow an easy and flexible updating of the new coming database. Fig.10 shows digitized features (Building, Streets, Parcels...) in GIS dropped over the digital elevation model.



Fig. 10 Digitized GIS features

Fig. 11 shows the terrain in three dimensional representations with GIS features with extruded height to enhance the viewing of the archeological site.



Fig. 11 Three Dimensional Model for Archeology Site

#### V. FINAL REMARKS AND FUTURE WORK

The final products of this work cover the following task:

### Photogrammetry

- 1) Analysis the satellite and aerial imagery to generate a land use and geology maps for Ahl AlKahf area.
- 2) Identification of archeological sites in the study area to be presented in a map for tourism purposes or to provide an educational resource for the students and researchers about the latest achievements in relevancy.
- 3) Processing aerial photographs (stereo pair) in the study area to produce:
  - a. High resolution Orthophoto image (Image with same characteristics of maps, where it is distortion free image, has constant scale and can be used for actual measurement in GIS systems)
  - b. High resolution Digital Elevation Model.
- 4) 3D models of historical archeological structures in Ahl-Alkahf area (Cave). During the generation of these models, requirements such as high geometric accuracy, availability of all details, and efficiency in the model size and photo realism must be met by the different approaches used for data collection [EL-Hakim et al 2002].

### Geographic Information System (GIS)

- 1) Developing 3D GIS Model or Ahl-Alkahf area including: the Boundary Maps, Point Location of Archeological Sites, Transportation Layer, Hydrological Maps, Digital Elevation Model, Aerial Images (Ortho-rectified), Satellite Images, Land Classification Image, Aquifer Profiles and Geology of the Area).
- 2) Using 3D models to renovate or to reconstruct such cultural heritage objects. The provided 3D models will be basis for preservations or interactive presentations of the historic site.
- 3) In archaeological and cultural heritage projects object semantics are typically just as important as the actual geometry. Thus, it is a key requisite to assign thematic information to the entire also to make it possible to select, analyze or edit the geometry and the appearance of objects based on semantic criteria.

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