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A Proposed Low-cost System for 3D Archaeological Documentation

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Abstract

To meet the requirements for rapid, accurate and effective recording and documentation of archaeological excavation sites a prototype system is under development. This paper presents the first results from an easy-to-use system that utilizes photogrammetric and computer science methods, as well as tools for on-site recording, modeling and visualization of an archaeological excavation. The software-component is the main focus of our research. Its aim is multifold, such as to provide a three-dimensional reconstruction of the excavation site in a very accurate way, rapid and almost real-time recording and documentation, multiple outputs for various uses and finally to achieve all these tasks requiring minimal knowledge of Digital Photogrammetry and CAD systems, through a sophisticated and user-friendly interface, easy to be used by people, such as archaeologists that are not experts in Photogrammetry or in Information Science. Finally, in the near future it is planned to evaluate and demonstrate under real circumstances the functionality and the effectiveness of the system, so as to be performed the necessary improvements.

1. Introduction

The nature of an archaeological excavation is destructive and therefore recording is a procedure that must be performed at every stage. Not only the different layers of stratigraphy but also all the containing features, such as walls, post-holes, graves, pits, ditches, must be carefully recorded, in terms of size, depth, shape etc. and photographed. Additionally, at various phases an accurate excavation plan must be created, in order to show the location of features and contexts, as well as the spatial interrelation (topology) of the findings for the subsequent archaeological study. All these records will form "the basis of which all interpretations of the site will be made" [RB91]. The aforementioned procedures are not only time-consuming dramatically postpone the excavation time, but also costly, because of the large amount of data to be recorded. Furthermore, they do not provide the level of absolute accuracy that the archaeologists need for their future research.

In the last years, digital photogrammetry became a major tool in archaeology. Specialists in this area recognize the advantage of fast and accurate mapping, Moreover they use photogrammetric techniques in order to record and document the findings of an excavation [GP96]. Digital photogrammetry offers to archaeologists all the powerful tools for fast and accurate recording and mapping of the archaeological sites [HE97]. The new low-cost digital cameras, providing high-resolution images, in combination with the portable Digital Photogrammetric Stations (DPS), constitute powerful tools for the whole mapping process in the period of one day [BLR97], [Miy96]. This is very important since the archaeological image interpretation is performed in the same day.

Unfortunately, DPS are high-end hardware & software devices, mostly in use for aerial Photogrammetry and normally do not tackle correctly the problems of close-range imaging. Additionally they refer to specialized personnel and characterized by high hardware and software cost. In contrast, in a lot of cases, the needs of architects and archaeologists are much more primary and simpler than these of a cartographer [GP02], [PK95]. However they can always take advantage of some of the value added modules of a Digital Photogrammetric Station such as the 3D viewing and measuring subsystems.

To meet the requirements for rapid, accurate and effective recording and documentation of archaeological excavation sites a prototype system (which is already under development) is proposed.

The software-component of such system is the main focus of this research. Its aim is multifold, such as to provide a three-dimensional reconstruction of the excavation site in a very accurate way, rapid and almost real-time recording and documentation, multiple outputs for various uses and finally to achieve all these tasks requiring minimal

knowledge of Digital Photogrammetry and CAD systems, through a sophisticated and user-friendly interface, easy to be used by people, such as archaeologists that are not experts in Photogrammetry or in Information Science. Finally, in the near future it is planned to evaluate and demonstrate under real circumstances the functionality and the effectiveness of the system, in order to perform the necessary improvements.

This paper presents the specifications and the requirements of the proposed system that utilizes photogrammetric and computer science methods, as well as tools for on-site recording, modeling and visualization of an archaeological excavation. Both research groups will join forces and former experiences presented in [DG00], [MGT*04], [PST98], [PST*99] to propose low-cost solutions to improve current methods, tools and techniques.

2. General principles of system design

The proposed prototype system will allow the rapid and accurate recording and documentation of archaeological excavations. As it is already mentioned, it's aim is to provide mapping and documentation of the site, using overlapping digital images free of distortions and a user-friendly 3D viewer, providing a realistic view of the archaeological findings, with accurate measuring capabilities, and allowing a simple and interactive access to the recorded data. Moreover, it will provide *in-situ* pre-processing of the data and distribution of the processing tasks to remote users.

The aims of the system are:

- To provide a three-dimensional reconstruction of the excavation site in a very accurate (1-2 cm) way.
- To provide a rapid and almost real-time recording and documentation.
- To provide multiple output for various uses. Such outcomes can be 3D vector graphics, Orthophoto mosaics, 3D digital surface models, real-image rendered 3D objects, visualization of 3D objects, interactive 3D models linked with documentation databases and Geographic Information System input, etc.
- To achieve all these tasks requiring minimal knowledge of Digital Photogrammetry and CAD systems, through a sophisticated and user-friendly interface.

The challenge in this research is to develop automatic or semi-automatic photogrammetric techniques, which could provide the required accuracy with the minimum intervention from the part of the user, compensating thus to the degree of the required knowledge, as well as safeguarding for mistakes. Besides automation and robustness issues, the proposed software will be equipped by user-friendly interface, in order to be easy for the user to navigate through the different tasks and perform them with a low degree of experience.

Additionally, the proposed system must be able to run on desktop and laptop computers. Therefore, it must not use high resources from the hosted computer.

3. System Design

The proposed system will be developed up to a pre-industrial level and will consist of a low-end hardware component, a developed software component and a user-manual. The system consists of the following components.

3.1. Hardware Component

The hardware-component will be low-end and off-the-shelf aiming at minimizing the start-up cost of the whole system. It is planned that the minimum required hardware will consist of a Personal Computer (or a Notebook) with Ethernet and Internet capabilities, enhanced by special 3D-graphics card with (if possible) active polarization or interlaced capabilities. Networking and Internet connections will enable the user to distribute the recording and documentation tasks to remote group-members while active polarization ability will enable the user to see and measure in three dimensions using polarization glasses. Alternative, if the graphics card cannot provide stereoscopic abilities, a stereoscopic view with Blue/Red glasses will be used.

For the recording phase, additional hardware will consist of a (low-end) digital CCD camera. Current technology provides for such a low-cost hardware, which although is very reasonable in price, suffers by often severe distortions either due to electronics or due to the lenses.

3.2. Software Component

The software-component will include all the procedures that are needed in order to achieve the aim of the project, in modules, under a common interface. One of the main targets of the project is to keep the included basic photogrammetric tools as much "hidden" from the user as possible (using automatic or semi-automatic procedures). (Figure 1)

The modules are:
i. Calibration and interior orientation of the camera. Standard calibration techniques for the compensation of the distortions induced by the low-cost digital cameras will be included.

ii. External orientation. This is one of the procedures that usually cannot be fully automated and the help of the final user will be needed. The user must indicate the control points to the system in order to solve the external orientation of the images. This module has already been developed. Further implementation will include the fully

automatization of the procedure with the use of pre-defined control points.

iii. Triangulation. Excavation sites usually give very high textured images. This means that triangulation, which will produce a very dense (every 5-10 cm) network of points of the excavation surface, is a procedure that can be easily automated. A new and effective algorithm (low CPU cost) will be embedded in the system for the search of conjugate points on the epipolar images. The new technique differs from the typical approach in a way that can lead fast and easy to the correct x-parallax value of the epipolar images for the desirable ground point. Moreover, manual addition of points will be possible by the user in case of poor textured images. This module has also been developed and is now under accuracy testing.

iv. DTM/Grid creation. The above network of points will be used in order to produce a grid of points for the excavation surface by creating a TIN based on Delaunay Triangulation. This module is not implemented yet.

v. Orthophoto/mosaic generation. The system will give the ability to produce an image or a mosaic of images (Orthophoto) of the excavation site free of rotation and anaglyph errors. With the creation of orthophotos, archaeologists have an accurate (as a map) and complete (as a photograph) background without the need to do any surveying of the sites, other than taking overlapping digital photographs. This background will be used for making the archaeological interpretation in vector format as a layer on top of the Orthophoto. This interpretation will be inserted in CAD programs as a vector file. The sub-component of the Orthophoto generation is already developed.

vi. Basic measurement functions. User will be able to see a pair of images in stereo (using polarization or blue/red glasses) and measure some basic attributes of objects like distance and area. This module will be developed in the final stage of the project, when the final GUI of the software will be known. The major sub-components of the module (e.g. Stereo viewing, 3D measurement functions, etc) are already developed.

vii. Mono-plotting ability. In addition to basic measurement functions, the system will also include a mono-plotting module. That is with the orthophoto as a background, the archaeologist will be able to extract 3D metric information (distances, angles, areas and volumes) as well as 3D vector mappings of the sites, without using stereoscopy. In fact, the planimetric coordinates (x, y) will be picked from the cursor movement, whereas the altimetry (z) will be on-the-fly interpolated by the "underneath" DSM. For drawing purposes, the user will have the ability to measure and draw 3D objects of the excavation site in a CAD environment. For the moment, the implementation of this module is being developed for the Autodesk AutoCAD environment. Further implementation will include other CAD environments (like Bentley Microstation).

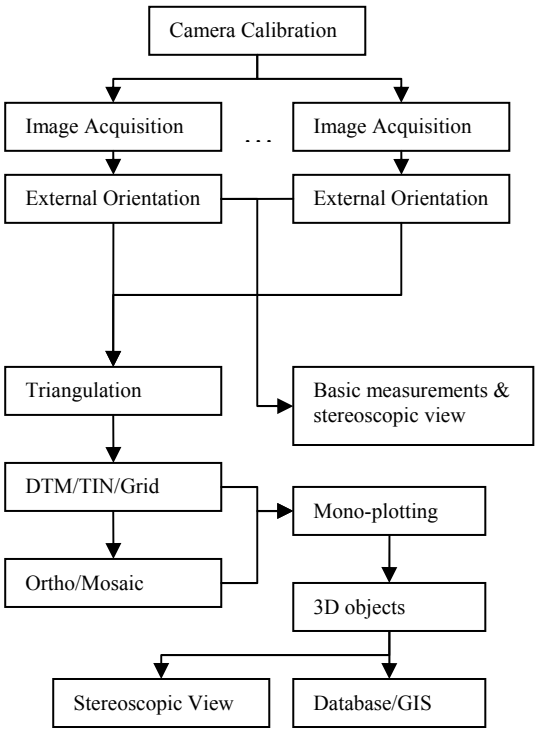

Figure 1: *Basic flow chart of recording procedure*

4. Data handling

Parallel to above procedures and modules, the system will include a complete part for the management and the exploitation of the data accumulated during documentation work on the field. These data can have very different nature (textual, graphical, photographical…). For the storage of the knowledge, databases will be created, with which it will be possible to interact thanks to the creation of an Information System (IS).

We purpose our IS in the form of interactive 3D models (resulting from the three dimensional reconstructions of the excavation site achieved before), which elements will be linked with the records of the databases. Likewise, interactive 2D plans could be generated (in SVG for instance) from maps and drawings done by the archaeologists on the field. These interactive plans could also be an access interface to the information of the database.

This will allow a best spreading and communication of the information about the archaeological site [KS99], as well as a beneficial valorization. This would also be a help for the analysis and the understanding of the site (in permitting quickly to synthesize and to confront very different types of documents) [MGP05].

The system we propose will not be a pure Geographical Information System (GIS), since we will integrate very diverse types of data, but the information search will

be done in a localized way via the 3D models and the 2D plans of the site. The 3D and 2D representations serve as access interfaces to the data. For the archaeologists working on the site, they will also serve as interfaces for the modification and the updating of the recorded information [MGP06].

Moreover, we propose to develop a system that will work over the Internet (so that we will be independent of any commercial software), in a simple and clear way, both for the consultation and for the modification of information.
The technical computer platform will be based on free software. Clients will use traditional browsers like Internet Explorer, Mozilla Firefox or Netscape. The main interface will be accessible through a PHP web server like EasyPHP. Web pages of the site could be coded in PHP and JavaScript, with the use of CSS style sheets. Connection to the database could be done thanks to a PHP script language. Queries on the database will be written in SQL language. The database system could be MySQL.

Textual data will be described in XML and automatically recorded in the MySQL database. 3D models will be described in VRML or X3D, widespread languages currently for the visualization of 3D scenes on the Web. And 2D plans will be created in SVG, so that we will work in coherent and standardized formats.

The following schema (Figure 2) illustrates the computer behavior of the platform that will be developed.

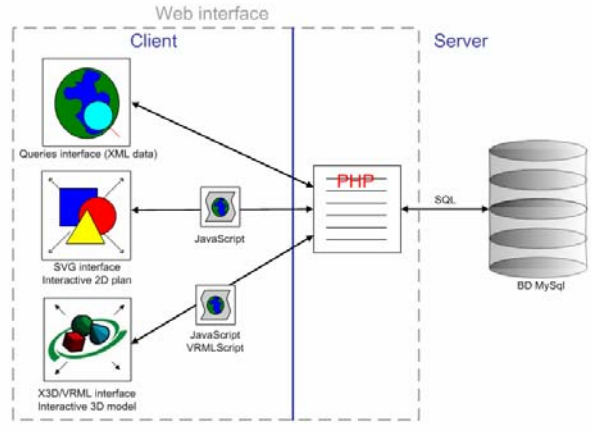

Figure 2: *Schema of the computer behavior of the coming web Information System*

5. Evaluation phase

The major phases are of the proposed research are given in Table 1. The whole system is going to be evaluated and tested under real circumstances to perform the necessary improvements. The testing material will also provide the data for how-to-do-it user manual, which will be developed at the last phase.

Phase	Time Table (months)				Project Work
	06	12	18	24	
1					Acquisition of the necessary hardware Development of the necessary interfaces Development of low level software for major hardware functionalities Testing of hardware component
2					Development of major software components
3					Testing of the software components under simulated and real situation
4					Development of user interface
5					Evaluation and improvement of the system
6					Development of user manual

Table 1: *Major phases are of the proposed research*

6. Conclusions

The proposed research concerns the development of a prototype system for the rapid and accurate recording to improve archaeological excavation and documentation by merging experiences from both research groups.
The hardware component will use digital images free of distortions and a user friendly 3D navigator.
The software component will include automatic or semi-automatic procedures of photogrammetric tools and rethink a prototype system to make it available for non specialists.
For the data handling, we project to use interactive 3D models linked with the records of the databases in an Information System. 3D and 2D representations will serve as access interface to the data and the system will be available to users via browsers.

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