EUROGRAPHICS Workshop on Graphics and Cultural Heritage (2016)
C. E. Catalano and L. De Luca (Editors)

On-site AR Interface based on Web-based 3D Database for Cultural Heritage in Egypt

Y. Yasumuro[1,3], R. Matsushita[1], T. Higo[2,3] and H. Suita[2,3]

[1]Dept. of Environmental and Urban Engineering, [2]Dept. of Letters,
[3]Center for the Global Study of Cultural Heritage and Culture,
Kansai University, Japan

Abstract

We have been developing a web-based 3D archiving system for supporting the diverse specialties and nationalities needed for carrying out the survey and restoration work of the archaeological project at the Mastaba of Idout in Saqqara, Egypt. Our 3D archiving system is designed for the spontaneous updating, accumulating, and sharing of information on findings in order to better enable frequent discussions, through a 3D virtual copy of the field site that a user can visit, explore, and embed information into, over the Internet. This paper proposes an AR (augmented reality) interface for on-site use to enhance access from mobile devices at the actual site to the archiving system. We utilize SFM (structure from motion) to organize the photos and their shooting viewpoints in 3D space. Then solving the Perspective-n-Point (PnP) problem, a photo taken at the site can be stably matched to the pre-registered photo sets in the archiving system and the archived information is automatically overlaid on the photo with precise perspective, just in the same manner as exploring the virtual version of the site on desktop PCs. This paper shows effective AR representation performance with millimeters precisions of the AR representation at the on-going project site, as well as the implementation details.

Categories and Subject Descriptors (according to ACM CCS): DATABASE MANAGEMENT [H.2.4]: Systems—Object-oriented databases; INFORMATION STORAGE AND RETRIEVAL [H.3.5]: Online Information Services —Web-based services; COMPUTER GRAPHICS [I.3.7]: Three-Dimensional Graphics and Realism—Virtual reality

1. Introduction: Project Overview

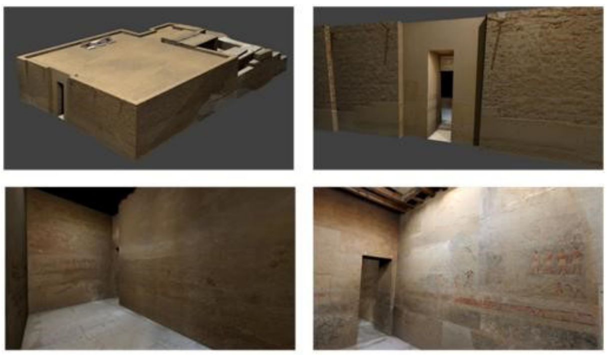

Figure 1: *3D view of the aboveground structure of the mastaba, which the user can explore on a web browser*

The mural paintings in the burial chamber at Idout in Saqqara, Egypt, are very beautiful, as well as being valuable historically. Kansai University have been conducting Egyptian-Japanese Mission for the Mastaba Idout in 2003 to survey the site [SAN*04]. The aim of this mission is to preserve the murals in the underground burial chamber as well as the whole structure of the mastaba (tomb) of Princess Idout, which dates from around 2360 BC. The mission promotes research that transcends the boundaries of nations and academic disciplines. The people working in these groups are experts in humanities fields such as Egyptology, in the restoration of cultural heritage, cross-cultural studies, and in the science and engineering fields, including geotechnical and structural engineering, analytical chemistry, microbiology, high polymer chemistry, and information engineering. These researchers, from Japan, Egypt, and Poland, jointly work to achieve the mission to preserve and utilize our cultural heritage worldwide.

Although the multinational and multidisciplinary team is carefully organized, it is still difficult to promote a heuristic manner of study and to explore synergies between the different academic fields and cultures. Especially under the recent severe circumstances of political uncertainty and terrorism threat, continuous communication is difficult to maintain, joint surveys and meetings cannot be held so often, and the sites and relics are being exposed to the risk of vandalism or theft.

In approaching this issue, the authors have been developing an archiving system that uses a web-based application to realize a "physical" object-oriented database for updating and sharing project information. Based on the precise dimensions of the target site, the on-site situation is reconstructed as a 3D model on a web browser, which enables users to access the findings and supporting data of the project for both accumulating and browsing them anytime from anywhere (Figure 1). This system provides the utility of a database using a 3D virtual site as a portal. The present study aims to enhance the portability of the web-based archiving system to convey its utility to the site by providing an easy-to-use AR user interface.

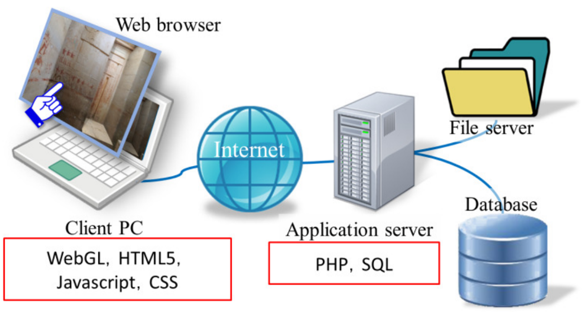

Figure 2: *System configuration; rich Internet application framework based on HTML5 standard*

2. System design

2.1. Digital Archiving with 3D Portal

3D measurement and modeling techniques are being used more and more in academic fields dealing with the preservation, reconstruction, documentation, research and promotion of our cultural heritage [Bru12]. Visualization systems are more oriented to interactive and experience-based systems using virtual reality (VR) environments based on actual 3D measurements [NN12, RGL*12]. In such systems, to help the user explore the virtual site, navigation functionality with guidance on the cultural property is provided. As for the data-updating utility, Okamoto proposed a semiautomatic algorithm to detect specific regions that have characteristics of interests in archeology on the surface of 3D models based on a scanned point cloud. A user may specify the regions on the surface of the 3D model, so that the region is associated with additional information that can be used as annotations addressed to visitors of the system [Oka10].

As with many VR-based cultural heritage applications, our archiving system employs visualization from the first-person perspective to allow a visiting user to explore the 3D space of the site. Many specific parts and areas (regions of interest, ROI) in the 3D model are associated with additional information that pops up as the user notices and selects them (Figure 2). We use the HTML5 standard for compatible implementation of both the graphical view capability, such as using WebGL on the client side and a standard messaging interface for interactive communication [MYS14]. Many document, image, and video formats can be handled by HTML5, and thus just a browser alone is sufficient to display all of these media files, versus having to install multiple individual native software applications. On the server side, the core functionality for manipulating the database is realized by using PHP in conjunction with JavaScript to access a file server. From a web browser on a PC, server access can be easily established by specifying the IP address, the port, and the HTML location by asynchronous communication. User types are assumed to be general end-users, academic users, and project members. In this way, project members can spontaneously accumulate fresh information, from which items of news are released to the public without excessively burdening project members. As shown in Figure 3, a virtual 3D space of the Mastaba of Idout is provided on the Internet; the user can visit this space and explore it intuitively. Once the user selects an ROI in the space, the client sends an associated request of action to the database of the server side. The server generates structured query language (SQL) statements based on the requests, searches and/or updates the database, and then sends back the results to the client for display on the browser.

2.2. AR Interface for 3D Portal of the Archive

Since the archiving system is implemented as a web-application, networked mobile devices can be used to access it in the same manner as desk-top PCs. Considering the on-site use, however, overlaying the archived information directly onto what the user is actually looking at is a more natural style for accessing the database, rather than making a virtual tour when the user already has access to the real thing. Since the sites are the insides of stone structures or underground chambers, image-based localization is suitable for implementing AR. Taking the most advantage of the existing 3D archiving system, we came up with the idea shown in Figure 4, in which we only focus on how to initiate the access to the archiving system using images of physical scenery from the user's viewpoint.

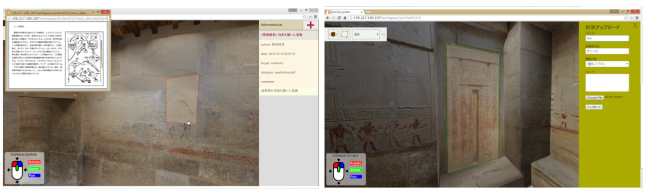

Figure 3: *Data viewing (left) and data registration (right)*

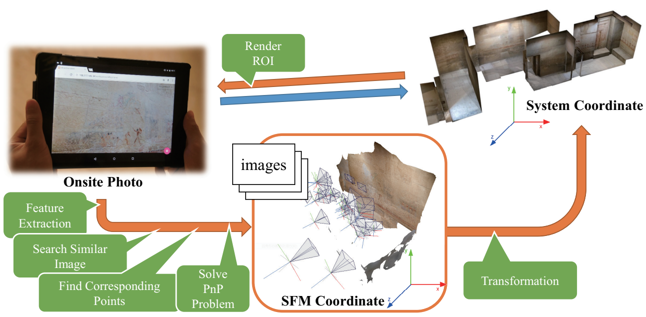

Figure 4: *Vision-based method for positioning user's viewpoint*

We prepare a large photo collection of the site and organize it within an identical 3D space. Using the structure from motion (SFM) technique, extracted feature points on the images can be matched to each other and their 3D coordinates can be estimated. We also calculate the transformation matrix between the space of SFM output and the 3D space in the archiving system. When a new photo comes in from the mobile user, its feature points are extracted and immediately used for searching for the most similar image in the pre-registered image set. The Perspective-n-Point (PnP) problem is solved, that is, 2D feature points on the input photo are associated with the corresponding 3D coordinates in the SFM space, and finally an extrinsic camera parameter of the mobile device can be estimated in the archiving system coordinates. Thus the object in the newly taken photo and the ROI in the 3D space of the archiving system are associated and the corresponding information can be rendered on the user's photo.

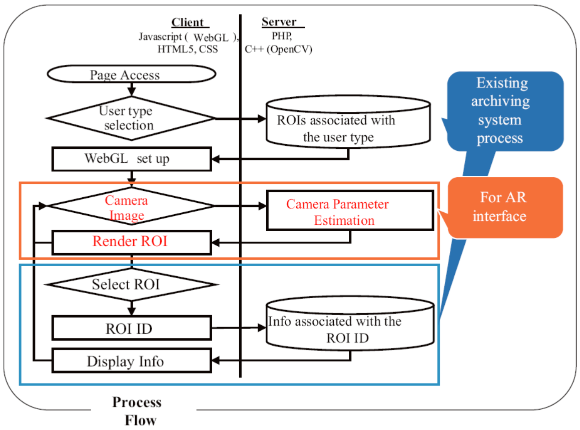

Figure 5: *Process chain of the proposed system*

2.3. Implementation

After receiving a photo image from the mobile client-side, red-highlighted part in Figure 5 is newly implemented to realize AR function on the server machine to estimate extrinsic parameters of the mobile device camera, while the other blue parts are already running on the archiving system. We use SURF (Speeded up robust features) [BTG06] as the keypoint for feature extraction, considering the robustness and computational costs. Since the same feature points should be extracted from the input photo newly taken by the on-site user, we use the same keypoint extraction implementation for on-site process as well. To retrieve the most similar image quickly out of the photos used for SFM process, we employ kd-Tree structure to accumulate the photos. All these processes are coded with C++ using OpenCV libraries. The server program composed with PHP runs these native programs by exec() function, so as to flexibly integrated them into the web application framework. As for the client-side, the mobile device receives the camera parameters calculated and sent from the server-side and uses them to render the ROIs overlayed on the photo. Through this display, the user can access to the database of the archiving system exactly same as the PC version's functionalities. We implemented the AR functionality using 28 actual photos of the 3rd chamber and 22 photos of the 9th chamber in the aboveground structure of the Mastaba of Idout. SFM is performed by using Visual SFM [Wu13]. The photo images were taken by two different types of cameras; Nikon CoolPixL280 and GoPro Hero4. The examples of the photos are shown in the Figure 6 (top). The bottom part of Figure 6 shows the reconstructed point cloud (3D coordinates of the feature points) and estimated positions and the orientations of the cameras. The point cloud is colored by original photo information. The green truncated pyramids depict the camera positions and the orientations. Then those 3D-reconstructed feature points have both 2D coordinates on the photo(s) and 3D coordinates which are spontaneously defined by SFM process. We calculate a transformation matrix to register the SFM 3D coordinate of each chamber into archival system coordinate by finding corresponding points between them, using a point cloud editing software, CloudCompare.

3. Case Study

We prepared a server at the laboratory in Japan to provide the archival data through the Internet, and accessed from the aboveground structure of the mastaba at Saqqara, Egypt by a mobile tablet. The objective is to evaluate the precision of the AR presentation of ROI overlaid on the actual photos taken on the spot, using the proposed method. A Nexus9 (Google Inc.) machine equipped with a 1280x720 px camera was used as the mobile tablet.

The AR contents and the ROI setups are prepared by the Egyptologist members in the project to mark up the specific hieroglyphs

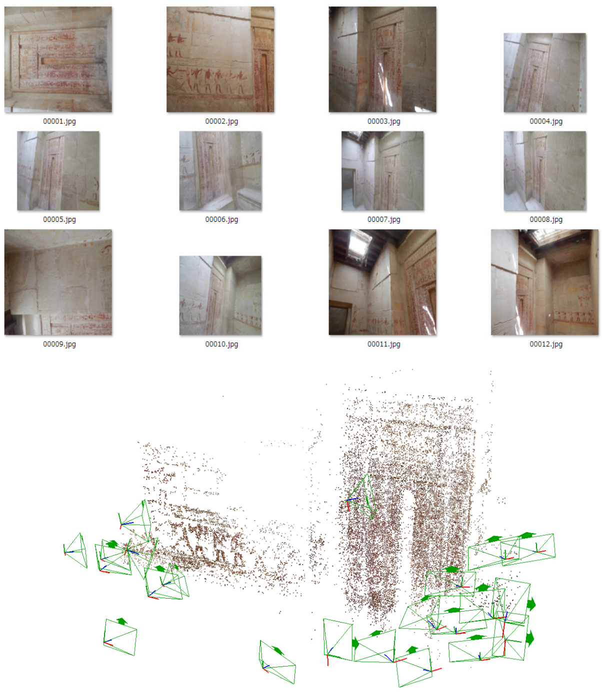

Figure 6: *SFM input photos (top) and the result (bottom)*

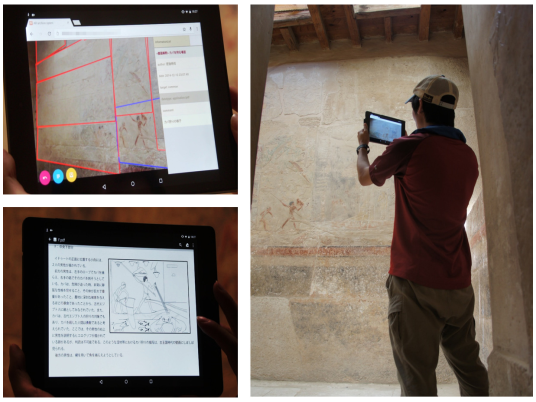

Figure 7: *AR use on a mobile tablet; photo shooting situation (right), AR representation onto a live photo (top left) and retrieved information (bottom left)*

Figure 8: *Outstanding difference in AR presentation view on a smart phone*

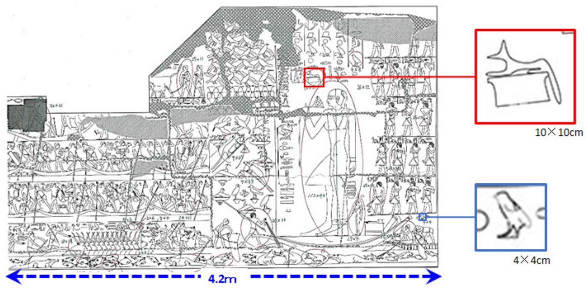

Figure 9: *Examples of hieroglyphs on the relief of the site*

and relief patterns. Also their interpretations and related informations are associated with each ROI on the walls in the 3rd and the 9th chamber. The largest displacement was observed in the case that the farthest part of the wall in the field of view is at a distance of 5.5m as shown in Figure 8. The left-hand side in Figure 8 is AR representation and the right-hand side is the CG representation of the archival system. Both of the ROIs are rendered from the same (estimated) viewpoint. The circled regions are magnified to show the differences between them at the corner positions of the ROIs. The maximum displacement, which is the worst case, is about 14 pixels on the display which is equivalent to 8.4 cm in the physical dimension. This is larger than the size of some hieroglyphs on this wall as shown in Figure 9. However, when the user comes closer to the wall within 1m distance to take a look at the details, for example, every displacement is supposed to become within 1cm size on the wall surface. Consequently, AR representation for adding and browsing annotations even on a single hieroglyph is possible in terms of the AR representation accuracy.

4. Conclusions

This paper described an AR interface for an archiving system whose portal is associated with a graphical 3D copy of a physical object. Especially, our method does not require any additional facilities or systems to install sensors and equipment on the site. Further more, wireless network communication is available in many historical sites in Egypt. The implemented system so far uses only single photo images as input, since the through put of the local network for data communication on the cell phone is not so high enough for realtime transmission of image data. Our next step is to introduce this AR system to more variety aspects of the works and services in the project to evaluate the total system performance based on the on-site operation at Saqqara.

Acknowledgements

This work was partially supported by the Center for the Global Study of Cultural Heritage and Culture (CHC) at Kansai University, Grant-in-Aid for Scientific Research (15H02983, 15H02983) by JSPS and Supreme Council of Antiquities and Saqqara Inspectorate.

References

[Bru12] BRUTTO L.: Computer vision tools for 3d modeling in archaeology. *International Journal of Heritage in the Digital Era 1* (2012), 1–6. 2

[BTG06] BAY H., TUYTELAARS T., GOOL L. V.: Surf: Speeded up robust features. In *In ECCV* (2006), pp. 404–417. 3

[MYS14] MATSUSHITA R., YASUMURO Y., SUITA H.: Digital archive system with 3d web portal interface, digital heritage. In *Progress in Cultural Heritage: Documentation, Preservation, and Protection* (2014), vol. 8740, pp. 564–571. 2

[NN12] NETO J. N., NETO M. J.: Immersive cultural experience through innovative multimedia applications. *International Journal of Heritage in the Digital Era 1* (2012), 101–106. 2

[Oka10] OKAMOTO Y.: *Interactive Information Sharing System Using Large 3D Geometric Models*. PhD thesis, The Graduate School of Information Science and Technology, The University of Tokyo, 2010. 2

[RGL*12] RUGGIERO C., GALLO A., LIO A., ZAPPANI A., FOURNATO G., MUZZUPAPPA M.: An integrated meth-odology for digitization, survey and visualiza-tion of santa maria patirion's church. *International Journal of Heritage in the Digital Era 1* (2012), 21–26. 2

[SAN*04] SUITA H., AKARIS A., NISHIURA T., SHOUAIV A., YONEDA F.: The restoration project of the burial chamber of the mastaba of idout in saqqara. In *Proc. 9th International Congress of Egyptologists* (2004), vol. 3, pp. 1741–1749. 1

[Wu13] WU C.: Towards linear-time incremental structure from motion. In *Proceedings of the 2013 International Conference on 3D Vision* (2013), vol. 8740, pp. 127–134. 3