Advances in Virtual Heritage: conditions and caveats

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***Abstract*—Virtual heritage provides researchers with opportunities to ask new questions, gain insight into the past, and disseminate their work to an ever-increasingly digital data-hungry world. The range of VH options has dramatically expanded to include game engines, drones, intelligent agents, multifaceted smartphone apps, and all-digital handheld-device-driven documentation packages. This paper explores the pros and cons of each for real-world projects.**

***Index Terms*—virtual heritage, digital archaeology, photomodeling, drones, intelligent agents.**

I. Introduction

The discipline of virtual heritage (VH) evolved 20 years ago with distinct technological breakthroughs focused on bettering our understanding of the past through the use of interactive 3D computer graphics --a game-changing approach to studying and teaching history [1,2]. The approaches of VH (and its subset, digital archaeology) allow researchers to ask new types of questions, gain new insight, and disseminate their work to an ever-increasingly digital data-hungry world. The pace of change in the tools now available to digital heritage practitioners has quickened and the choices now include game engines, remotely piloted aerial vehicles, multifaceted smartphone apps, all-digital hand-held-device-driven documentation and recording packages, and intelligent agents.

II. The impact of Virtual Heritage

Examining some current tools, in light of three advantages of using VH approaches to studying the past, provides critical apparatus for choosing when to use these new tools.

A. Asking new questions

Archaeological fieldwork and research tend to favor time-honored methods of data collection and analysis. Archaeology is tedious, demanding exactitude, copious documentation, rigorous analy- ses, and prompt dissemination to peers. Fieldwork has its own challenges, such as trying to accurately locate features and artifacts in 3D space. Traditional methods, describing finds, taking measurements manually, doing some drawings, and taking a couple of photographs of contexts and details, suffered from inaccuracies, transcription errors, and taking too long. Some things or view- points were not recorded at all, because their significance was not recognized until it was too late. Standard approaches do not allow hypothesis testing across all the data in real time, nor allow for adjusting field strategies while working. It takes years before all the evidence has been amassed and synthesized, which is unfair. VH offers the discipline new ways to collect, record, and visualize data, creating opportunities to ask new questions.

The ability to ask new questions would come easier if cultural heritage had one software package that kept things digital from data acquisition to publication, integrated all datatypes together, could be used at different types of sites, and put inter- active 3D contexts at the heart of the operation. The goal would be to ease recording and recall for researchers of all backgrounds for all types of field conditions. REVEAL (fig. 1; Reconstruction and Exploratory Visualization: Engineering meets ArchaeoLogy the product of a US National Science Foundation Grant #0808718 "III-CXT-Core Computer Vision Research: Promoting Paradigm Shifts in Archaeology" [3]) was created to do that. REVEAL is a single piece of free and open-source software that coordinates photos, drawings, 3D models, and tabular information with semi-automated tools for documenting sites, trenches and objects, recording excavation and site-evaluation progress, researching and analyzing the collected evidence, and automatically creating virtual worlds.

Imagine an excavation team using only a few hand- held devices. As the dig proceeds, progress photo- graphs are taken, showing all changes in depth, all soil changes, and all finds.

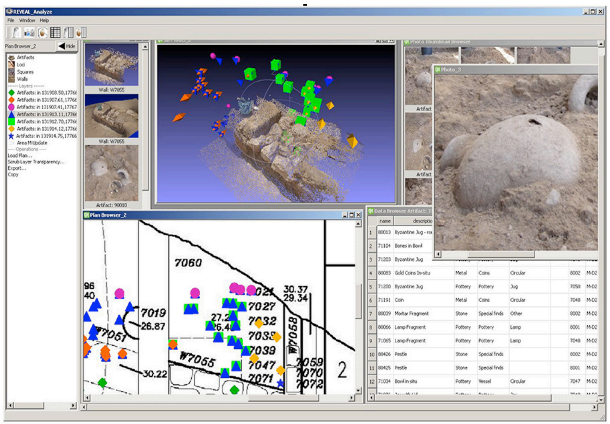

Fig. 1. Screen grab from REVEAL showing the different interactive browser windows (© 2014 Institute for the Visualization of History, Inc.)

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The field team enters observations and object descriptions onto Web forms via their devices and all photos are automatically linked to finds and geo- referenced from trench to trench.

Simultaneously, data extracted from the images are automatically converted into fully textured, dimensionable, virtual reality models, and linked to database notes and daily finds. Every artifact, too, is photographed during excavation and after removal and cleaning. These images also are used to automatically create and geo-reference virtual reality object models. This process continues as the season unfolds. No laser scanners, no survey equipment, no architects, no waiting until the end of the season for results.

Documenting every aspect of a cultural heritage project, uploading data, taking notes, testing hypotheses, looking at the evidence in new ways, preparing interactive 3D models, querying the results so that project strategies can be readily adjusted, and preparing publishable output all happen in real time, as the work unfolds. This is the more efficient (and paradigm-shifting) world that innovations like REVEAL promise. However, such all-inclusive cultural heritage software are often not comprehensive. REVEAL, for example, lacks GIS layering support and its photomodeling processes can be slow and cumbersome compared to com- mercial alternatives. There can be a serious learning curve to these packages and some customization is needed for specific sites and their data structures.

The citadel mound at Nimrud (ancient Assyria, present-day Iraq) has been excavated for nearly two centuries. Traditional field notes, photographs, and sets of often conflicting or incomplete plans give Assyriologists only general information about the function, design, and whereabouts of buildings. VH methods allowed researchers to test new hypotheses and visualize the results in ways that led to more definitive and insightful results.

The data formats and visualizations of VH are all the more critical and valuable when sites become the focus of wanton destruction. Digital surrogates remain the only ways of studying such cultural significant sites as Nimrud. Further, tracing the buying, selling, and looting of Assyrian sculpture is a daunting task for those looking to understand sites in their entirety. Over 320 bas-reliefs in over 70 museums and private collections across the world are known from just the Northwest Palace at Nimrud alone. Due to the global distribution, neither scholars nor the general public can fully comprehend the site. Interactive 3D computer models are important, since they allow us to reassemble all the reliefs (and bits of architecture) back into simulations of their original contexts and study them from the point of view of the original inhabitants. When sites are targeted during wartime, 3D computer models provide more permanent digital records to educate future generations.

Asking new questions leads to new discoveries. Despite 60 years and dozens of publications and scholarly analysis, none of the drawings of the central area at Nimrud provided more than guesses about the missing palace of Tiglathpileser III. 2D data could not provide enough information about what is a 3D data problem--where exactly was the palace, what was its specific spatial layout, and how did its location affect the circulation across the citadel? After 3D modeling, scholars could "visit and see" the site from the ancient Assyrians point of view and intuit the location of the missing palace, gain new insight about the pathways up from the lower town to and across the citadel, and create for the first time a viable reconstruction of the site during the 8th c. BCE (fig. 2; [4,5]).

VH visualizations must have a solid scholarly base, be transparent in their adherence to the evidence, and not appear to be a video game background. Adequate modeling takes training and attention to detail. These are not so much disadvantages, as they are caveats to the use of what has become affordable and easily learned software [6].

B. Gaining new insight

Digital data recording and documentation packages and innovations in 3D modeling provide the means for producing new insight. But what about very large sites, sites with complex topography, or lots of large standing structures or sculpture? Remotely piloted, unmanned, aerial vehicles (drones) can easily photograph these features, augment fieldwork, and feed into photomodeling software. The enormous religious center of Jebel Barkal, Sudan, is first mentioned around 1500 BCE [7]. Since then, over two dozen temples, palaces, ceremonial kiosks, and pyramids were built as the site became the center of kingship and coronation ritual through the 4th c. CE. Barkal has been excavated since the early 20th c. and work still uncovers new buildings. The size of the site, the number of structures and standing sculpture, and the nuances of the mesa dominating the site make traditional mapping expensive and time-consuming. With many excavation areas, blowing sand, and a limited time left to dig, the fieldteam sought new ways to capture data quickly, create 3D models to test hypotheses, and guide fieldwork priorities.

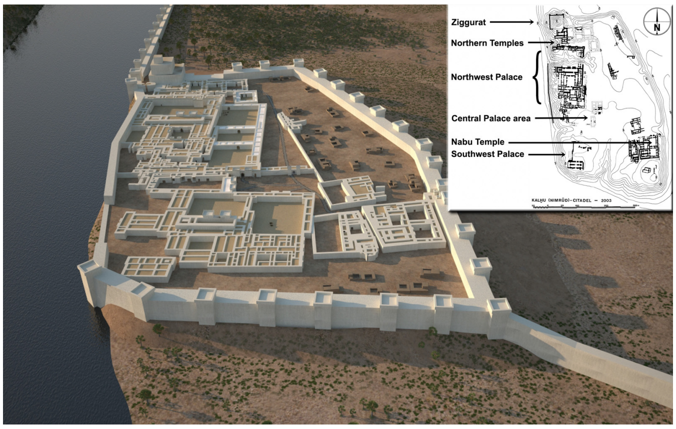

Fig. 2. Rendering of the citadel at Nimrud, extracted from the virtual world of the citadel created by Learning Sites; inset is a traditional plan of the same site, showing how much is lacking based on 2D information alone; © 2015 Learning Sites, Inc.

Last year, we flew a commercial quadcopter over the site to photograph the terrain, buildings, and sculptures. The drone can stay aloft for about 20 minutes, travel quite a distance from the home control unit, and capture high-resolution still images or HD video. Photomodeling software generated detailed, high-resolution 3D models (fig. 3) for studying architectural remains, building reconstructions, and rapidly and efficiently visualizing the entire site garnering new insight into the organization, circulation, and function of buildings and site features that could not happen with reliance on traditional 2D static imagery alone.

Drones take practice to control, fly adequately for field photography, and pilot at great distances in windy conditions. They have a limited range, short battery life, and poor warning systems of imminent danger. Parts tend to break or stop working; on-board cameras with extreme wide-angle lens are not ideal for archaeological photomodeling; and most commercial drones cannot carry more complex, and heavier, DSLR cameras with special custom-built-attachments without becoming very expensive.

Now, suppose a student enters a museum and sees an object with many triangular-shaped surface incisions. Curious, the student aims a smartphone camera at the object and clicks. The images are uploaded into an app that generates an interactive 3D model of the object and an English translation of the inscription (fig. 4). The student may become the first person to have read that text! CUNAT, the CUNeiform Automated Translator (from our NSF SBIR Phase II grant #IIP-1330139 “Extracting Valuable Information Automatically from Objects with Surface Impressions via Photographs and Interactive Digital Surrogates”) offers this research power and excitement of discovery to anyone, any-where, anytime, because neither special equipment nor complex calibration or lighting are necessary to produce results with unprecedented efficiency and accuracy. CUNAT’s innovations address critical needs because hundreds of thousands of cuneiform-inscribed objects languish untranslated simply for a paucity of experts. The app’s functionalities will expand to solve problems in numismatics and the new digital art history, ands enable schools to 3D print replicas for hands-on learning.

Like any processor-intensive app, CUNAT can be slow to provide adequate visualizations, and it will take some time for the handheld devices to handle real-time 3D viewing. CUNAT is now limited in the number of ancient languages it can translate; but will change as new scripts and new surface segmentation routines are added.

C. Disseminating to a digitally aware audience

New data collection and visualization methods provide the opportunity to ask new questions leading to new insight into the past, which, in turn, should be disseminated with interactive visual- izations and evidence transparency intact. Game engines and intelligent agents can accomplish those goals. Game engines (e.g., Unity3D and Unreal) offer inexpensive, cross-platform, interactive, scal- able programming environments for fully textured, lush, and lit 3D models. They also allow links from features in the worlds to the photographs, drawings, and descriptive text that demonstrate why the world has been reconstructed as it has and provide teaching hooks. Automated translators, all-digital excavation recording and documentation packages, and drone-based photomodeling create impressive new complex virtual environments. Within such large and detailed worlds, how will users find their way, comprehend the scale of unknown spaces, and learn the new history that immersive worlds offer?

Intelligent agents or remotely controlled avatars could provide intermediary support. Our Nimrud virtual world includes a virtual tour guide (fig. 5- bottom) answering: where are the obelisks; can you show me the throne room; what was the function of this building? Once the guide knows what the user wants, he will lead the user to the appropriate location or feature in the world.

The Vari 3D model reconstructs an ancient Hellen- istic Greek farmhouse excavated 50 years ago. Implemented in Unity3D, the virtual world features a digital puppet (fig. 5-top; farming family who lives there. We project the Vari world onto a large screen, so that the house and puppet are life-sized to enhance audience engagement. Under the control of a live remote puppeteer (who sees the audience through a Webcam), the avatar communicates directly to the audience through voice and gesture, moving freely through the virtual space.

Fig. 3. Jebel Barkal, Sudan; upper left--samples of the photomodels created with images captured by our drone; lower right--the Phantom drone in flight; main image--the Great Temple of Amun 3D model overlain on the photomodel of the excavated terrain (© 2015 Learning Sites, Inc.)

He can discuss the house itself, daily life, or respond to questions from on- lookers. For depth of conversation, a human puppeteer is superior to artificial intelligence to help visitors navigate a complex site. Intelligent agents can provide guidance, information sharing, global collaboration, and remote puppeteer-controlled mixed-reality education. Integrating intelligence into virtual worlds is not a trivial programming task. Characters are not yet widely accepted as a trusted means of imparting vital in-world information, and simplistic decision trees or cartoony figures are turn-offs before the advantages are explored by users.

III. Conclusion

While not an exhaustive overview of either the new technologies available for recording and studying the past, nor a thorough discussion of the examples cited, the discussion illustrates the critical impact that VH has had on archaeological fieldwork, data analysis, and public outreach. Despite the advances and impressive array of digital tools, there are still cultural heritage professionals and general public onlookers who think interactive 3D visualizations are just pretty picture, products of video games, and eye candy, rather than serious research, analysis, educational, and publication essentials. With such diverse engaging, enlightening, and educational tools, it should not be difficult to re- emphasize that since the past happened in 3D, in color, and as a sequence of real-time events, that is the way it should be studied, taught, and published.

Fig. 4. The CUNAT app; © 2015 Learning Sites, Inc.

Fig. 5. Top--Vari House virtual world and avatar talking to a teacher; bottom--the Central Palace virtual world with the tour guide and his guidebook; © 2014-2015 Learning Sites, Inc.

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