

A DIGITAL FUTURE FOR CULTURAL HERITAGE

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ABSTRACT:

The tools and standards of best practice adopted by cultural heritage (CH) professionals will determine the digital future of CH work. This paper explores issues influencing adoption decisions and discusses emerging digital technologies encouraging widespread adoption of digital practices. The paper explores a digital future for cultural heritage through key principles: adoption of digital surrogates, empirical provenance, perpetual digital conservation, and the democratization of technology. The paper elucidates digital surrogates as trusted representations of “real world” content in digital form. The paper also explains how empirical provenance can contribute to the authenticity and reliability of digital surrogates, while perpetual digital conservation can ensure that digital surrogates will be archived and available for future generations. The paper also investigates the emerging technologies’ potential to democratize digital technology making digital workflows easy to use for CH professionals and CH materials widely available to diverse audiences. The paper concludes with a discussion of the implications of these fundamental principles and the emerging technologies for the cultural heritage field.

1. INTRODUCTION

An essential element of the world's transformation through time is surprise. The one thing the past clearly tells us about the future is that it will contain the unexpected. The following pages will not speculate about the future, they are limited to what the world has taught us, particularly in the recent past, and an assessment of where we stand today.

The tools and standards of best practice adopted by cultural heritage (CH) professionals will determine the digital future of cultural heritage work. We will explore issues that influence these adoption decisions and showcase examples of emerging digital technologies designed to remove the existing obstacles to widespread adoption of digital practices.

Humanity's legacy can be unlocked and shared between people through digital representations. Digital representations can communicate elements of our CH in a variety of ways. For clarity, we can define three types that distinguish different uses for these representations; art and entertainment, visualization, and digital surrogates of the world we experience.

Digital content can be fine art in its own right. It can also entertain. This content can also be used to visualize concepts, and illustrate hypotheses. For example, a computer animation of a large asteroid impacting the Yucatan Peninsula 65 million years ago is helpful to visualize the cause for worldwide dinosaur extinction. These images are useful not because they faithfully show the shape and color of the actual asteroid moments before impact but because they effectively communicate an idea. Visualizations are speculative in nature to varying degrees. Current research is exploring ways to explicitly describe the extent of this speculation. (Hermon, S., et al, 2006)

Digital surrogates serve a different purpose. Their goal is reliably represent ‘real world’ content in a digital form. Their purpose is to enable scientific study and personal enjoyment without the need for direct physical experience of the object or place. Their essential scientific nature distinguishes them from

speculative digital representations. Digital surrogates are the focus of this paper.

Digital surrogates of our ‘real world’ cultural heritage can robustly communicate the empirical features of CH materials. When digital surrogates are built transparently, according to established scientific principles, authentic, reliable scientific representations can result. These representations allow repurposing of previously collected information and enable collaborative distributed scholarship. Digital surrogate archives remove physical barriers to scholarly and public access and foster widespread knowledge and enjoyment of our ancestors’ achievements.

2. PRINCIPLES FOR WIDESPREAD ADOPTION OF DIGITAL SURROGATES

Analysis of current impediments to and potential incentives for digital surrogate adoption in CH reveals three core principles:

Empirical Provenance: For digital surrogates to find widespread use in science and CH scholarship, easy to use, transparent qualitative evaluation of their authenticity and reliability by others is essential.

Perpetual Digital Conservation: The people who potentially could use digital surrogates and acquire the empirical data used to build them need archival conservation methods that will guarantee their work’s availability for future generations. The conservation plan must include capacity for contribution and stewardship from individuals, organizations and institutions worldwide.

Democratization of Technology: For those who study and care for our past to do their work digitally, the means by which robust digital information is captured and synthesized into digital surrogates requires great simplification, cost reduction, increased ease of use, and improved compatibility with existing working cultures.

For the first time, recent research breakthroughs in computer graphics, robotics, and machine vision have converged to make a new generation of robust digital tools for construction of

digital surrogates possible. Adaptation of these breakthroughs to the requirements of the CH community is underway. This work is explored in Section 5.

For widespread cultural heritage adoption of digital surrogates to occur, the CH workers who build and use digital surrogates must be able to employ these new tools themselves. The existing digital technology model where a separate class of technology savvy digital documentation ‘providers’ service the documentary needs of professional CH ‘consumers’ has proven expensive, cumbersome, unproductive and unpopular. In the following pages, we will examine how new approaches can simplify digital surrogate workflows and promote their adoption.

Widespread endorsement of the principles of empirical provenance, perpetual digital conservation, and democratization of technology can guide decisions regarding which tools and methods are adopted. Implementation of new working practices based on these principles can provide the necessary pre-conditions to realize a fourth principle with far-reaching advantages:

Tolerance of diversity – So long as the principles of empirical provenance, perpetual digital conservation, and democratization of Technology are followed, particular information acquisition and management practice variations due to local conditions or the nature of the examined field can be tolerated.

Considered along with the powerful dynamic of change attached to all things digital and the history of human nature’s resistance to conformity, adoption of digital surrogate-based workflows will be encouraged by permitting decentralized optimization of digital information architectures. The scholarly, discipline-based, evolving standards of best practice will continue to guide local practice as it always has. Worldwide access to, evaluation, and oversight of these practices, aided by semantic query enabled access to empirical provenance and by use of perpetual digital conservation practices for digital surrogates along with their source data, can allow the proven, self-corrective mechanisms of the scientific method to do their work.

The advantages presented by adoption of digital surrogates are great, but can only be attained if well recognized obstacles are overcome and the related incentives realized. As discussed below, the fundamental means to enable adoption of digital surrogates are understood and the necessity to produce them is now driving the ongoing development of new tools, methods, and standards. The following three sections examine these principles to aid digital surrogate adoption and offer a roadmap for hope.

3. EMPIRICAL PROVENANCE

A fundamental problem of the digital age is the qualitative assessment of digital surrogate reliability during scientific inquiry. A solution to this problem is necessary for there to be a digital future for cultural heritage.

Widespread adoption of digital surrogates by science in all fields, including the multi-disciplinary study of our cultural heritage, requires confidence that the data they represent is reliable. For a scholar to use a digital surrogate, built by someone else, in their own work, they need to know that what’s represented in the digital surrogate is what’s on the physical original. If archaeologists are relying on virtual 3D models to

study Paleolithic stone tools, they must be able to judge the likelihood that a feature on the model will also be on the original and vice versa. If they can’t trust that it’s an authentic representation, they won’t use the digital surrogate in their work.

We suggest that the concept of ‘empirical provenance’ offers to advance our understanding of the role of digital surrogates in scientific inquiry, enhance the development of techniques to digitally represent our world, and increase the adoption of digital surrogates as source material both for scientific research in general and the study of our collective cultural heritage in particular.

An essential element of traditional scientific inquiry is the systematic gathering of observations about the world through the senses. In the very, very old and still vigorously pursued epistemological discussion about the nature of human knowledge, the observations of the senses are labeled ‘empirical’

Within scientific discourse the methodology employed in the process of generating scientific information has been traditionally called the inquiry’s ‘provenance’. This provenance is carefully recorded in lab notebooks or similar records during the inquiry and then becomes an integral element of the published results. This provenance explains where the information came from and permits replication experiments, central to scientific practice, to confirm the information’s quality. Such provenance may include descriptions of equipment employed, mathematical and logical operations applied, controls, oversight operations, and any other process elements necessary to make both the inquiry and its results clear and transparent to scientific colleagues and the interested public.

Widespread adoption of digital surrogates requires that they be able to pass this traditional lab notebook test. Empirical provenance is for digital surrogates the equivalent of what a lab notebook is for non-digital representations. Empirical provenance is the extension of classic scientific method into digital documentary practices used to build digital surrogates.

Empirical provenance records the journey of original, unaltered empirical evidence from its initial data capture all the way through the image generation process pipeline to its final form as a digital surrogate. Just as “real-world” cultural material requires a provenance identifying what it is, establishing its ownership history, and proving its authenticity, digital surrogates require an empirical provenance, to document the imaging practices employed to create them. Empirical provenance ensures access to both original empirical data, original photographs for example, and the complete process history enabling the user to generate a confirmatory representation to evaluate the quality and authenticity of the data. That way, the user can decide for themselves whether to rely on the digital surrogate, or not. Empirical provenance permits the assessment of digital surrogate accuracy. The experience of those engaged in distributed, Internet-based scientific inquiry confirms the necessity of documenting how digitally represented information is generated. These collaborations, frequently found in the biological sciences, rely heavily on process accounts of digital data creation to assess the quality of information contributed by the cooperating partners and make their own work valuable to others.

The attributes of empirical provenance information for a given digital surrogate are dependent on the tools and methods employed to build it. For a digital photograph, the empirical provenance information would include XMP data such as: the camera make and model, firmware version, shutter speed, and aperture; parameters used to convert the raw sensor data into an image like color temperature; and all editing operations performed in tools like Photoshop such as cropping, re-sizing, distortion correction, sharpening, etc. These editing operations can have a profound impact on image reliability and are examined in greater detail below. For a 3D geometric model displaying photo-realistic surface texture and reflective material properties, the empirical provenance is complex. For these digital surrogates, complete process history accounts are required for the alignment of shape data acquired from different viewpoints, the registration of textural image data to geometry, the correction of geometric acquisition errors such as voids, smoothing in low signal to noise ratio situations, the effects of compressive data reduction, and other issues raised by the selected imaging method. In each case, whether digital photo or 3D model, the attributes including quantity of records, and ease, difficulty, or even possibility of empirical provenance collection result from the practices used to build the digital surrogate.

Only practices able to provide a complete empirical provenance can be used to construct reliable digital surrogates. Practices unable to produce a complete empirical provenance cannot be used to create reliable digital surrogates since their digital artifacts cannot be subjected to rigorous qualitative evaluation.

The requirement for empirical provenance information informs digital technology development and adoption. Tools and methods used to build digital surrogates that feature simplification and automation of empirical data post processing, including empirical provenance generation, present significant benefits over those that call for significant amounts of subjective judgments by a skilled operator, since every operator action that transforms empirical content must be documented in a digital log for future scientific evaluation.

The importance of automation in the construction of reliable digital surrogates is highlighted by a recent major study (Berns, R.S., et al, 2005). This study examined the digital imaging practices in leading US museums and libraries. The study states,

“Most museums included some visual editing and other forms of image processing in their workflows...When investigated closely, it was found that visual editing decreased color accuracy in all cases... In addition to visual editing, many images also incurred retouching and sharpening steps. The fact that many of the participants sharpened the images either at capture or before the digital master was saved raised the question of whether the implications of the choices made were well understood. Most of the image processing carried out was not automated; automation represents a possibility for improvement in setting up consistent, reproducible workflows.”

While an artist's touch can increase the sales of a print in a museum gift shop or create a stunning cinematic effect, it has little direct role in the scientific construction of digital surrogates. The development of many of today's digital imaging tools was driven by the entertainment industry's desire to create special effects for movies and television, computer animations, video games, and multimedia products. Unlike the entertainment business where a good-looking image is the goal,

scientific documentation requires that the material be represented reliably. If the empirical provenance, enabling assessment of reliability, is lacking, the digital representation may be enjoyed for visualization or entertainment purposes but not used as a digital surrogate.

As well as reliability, the synergistic combination of empirical provenance and automated digital processing offer advantages for the organization, communication and preservation of digital knowledge. Once the process used to construct a digital surrogate is automated, an empirical provenance log describing the process can be automatically produced. In turn, the types of process history actions entered into this log, can be mapped by a trained specialist to semantically robust information architectures. Once this mapping process has been completed, digital processing can automatically record empirical provenance information into these selected information management architectures as the digital surrogates are 'born'.

An example of a robust semantic common language is offered by the International Council of Museums. A working group of ICOM's Committee on Documentation (CIDOC) is now in the process of mapping Empirical Provenance structures into their Conceptual Reference Model (CRM), ISO standard 21127.

4. PERPETUAL DIGITAL CONSERVATION

We advocate for both individual professional responsibility and multi-institutional, multi-disciplinary curatorial management of digital heritage content for the foreseeable future. Unlike the physical archives of the Library of Alexandria, lost forever to humanity, digital heritage can be in more than one place at a time and in more than one form, potentially assuring its longevity despite the ephemeral nature of the media. This multiplicity of location and form is both the promise and the peril of digital heritage.

With increasingly diverse data formats, larger file sizes, changing media types, distributed databases, networked information and transitive metadata standards, how are today's heritage specialists to plan for such an uncertain virtual future? It is increasingly difficult for individual scholars and researchers to do the right thing when it comes to digital heritage conservation. The accountability for the conservation of digital heritage falls to all in the CH field, but what is a reasonable course of action in the face of such adversity.

The importance of developing sensible plans to preserve our digital heritage cannot be minimized. Responsible preservation of our most valued digital data requires answers to key questions: Which data should we keep and how should we keep it? By digital heritage conservation, we mean the decision-making criteria to discern what *must* be saved from what *can* be lost. Everything can't be saved nor is it desirable to do so. How is this data to be saved to ensure access in five years, 100 years or 1,000 years? In the next 100 years, we will go through dozens of generations of computers and storage media, and our digital data will need to be transferred from one generation to the next, by someone we trust to do it. Finally, who will pay for all this?

We can think of digital heritage in terms of what the value is of what is being saved, its viability, how available it is to stakeholders, and how long it will last. In other words, an ideal digital heritage repository would conserve archival quality

digital surrogate files in an openly accessible way, forever. This is the simplest definition of a trusted repository.

The Library of Congress devised a set of sustainability factors for digital content that are as pragmatic as they are difficult to maintain over time. The core principles we advocate in this paper strongly adhere to these sustainability factors. (LC., 2004)

Adoption: Wide adoption of a given digital format makes it less likely to become obsolete while reducing investment by archival institutions for its migration or emulation.

Transparency: Open to direct analysis without interpretation, transparency is characterized by self-evidence and substantive metadata. Those who use digital surrogates benefit from complete and accessible empirical provenance.

Self-documentation: XMP (Extended Metadata Platform) and other key forms of self-evidence, such as automatically generated empirical provenance data, dramatically increase the chances for a digital object to be sustainable over time.

External dependencies: The less a media form is dependent on proprietary software/hardware, the better. If two documentation methodologies can yield similar results in terms of accuracy and productivity, the more open / less externally dependent method is recommended.

Impact of patents and copyrights: Intellectual property limitations bound to content can inhibit its archival capabilities in profound ways. Whenever possible, unambiguous, open licensing for content is recommended.

Technical protection mechanisms: “No digital format that is inextricably bound to a particular physical carrier is suitable as a format for long-term preservation; nor is an implementation of a digital format that constrains use to a particular device or prevents the establishment of backup procedures and disaster recovery operations expected of a trusted repository.” Additionally, limitations imposed by digital rights management (DRM) or archaic security protocols severely limit the long-term viability of digital content.

Furthermore, the Archaeology Data Service (ADS) in the UK defines the most critical factor for digital heritage sustainability is to “plan for its re-use.” (ADS web 2007). Indeed, the design of decision making principles for digital heritage conservation should above all aim to the perpetual use and re-use of this content by striving to assure its reliability, authenticity and usability throughout the archival lifecycle.

Digital technology and the creation of ‘born digital’ content are indispensable aspects of cultural heritage management today. From low-tech documentation like Microsoft Office, html websites, PDF, and photography, to more complex technologies such as panoramas, object movies, laser/lidar scanning, scanning electron microscopy (SEM), x-ray fluorescence (XRF), Global Positioning System (GPS), 3D modelling, and distributed databases, to cutting edge techniques including Web 2.0, reflection transformation imaging (RTI), algorithmic generation of drawings from surface normals, and the family of photogrammetry influenced texture and 3D geometry acquisition tools, these new media types form a spectrum of opportunities and challenges to the preservation field that did not exist even 30 years ago.

We are at a unique point in history, where cultural heritage professionals must work to care for the physical past while assuring that there will be a digital record for the future. Peter Brantley, Executive Director of the Digital Library Foundation, thinks, “The problem of digital preservation is not one for

future librarians, but for future archaeologists.” If one imagines that the well-intentioned efforts of researchers and scholars in the modern era could be unreadable only fifty years from now, there is tremendous responsibility on individual CH professionals to insure a future for their digital work.

As explored in Section 2, in the mid 1990’s, a critical gap between those who provide information for conservation (providers) through construction of digital heritage documentation and those who use it (consumers) was identified by the International Council of Monuments and Sites (ICOMOS), the Getty Conservation Institute (GCI) and the International Committee for Architectural Photogrammetry (CIPA), who together formed RecorDIM (for Heritage Recording, Documentation and Information Management) Initiative Partnership (Getty Trust 2005).

A 2006, GCI-led literature review demonstrates that most of the key needs identified in RecorDIM are evidently still with us. After reviewing the last 20 years of cultural heritage documentation, the authors concluded, “only 1/6th of the reviewed literature is strongly relevant to conservation.” (Eppich,R., Chabbi, A., 2006) Their suggested remedy is to correlate the needs of conservation with the potential documentation technologies by involving more diverse audiences and by creating active partnerships between heritage conservationists, heritage users, and documentation specialists.

We are focusing on another gap, between cultural heritage and digital heritage, that has been created as we have shifted away from paper in favor of pixels throughout all of our communication and analytic processes globally. In 2000, the Library of Congress recognized that “never has access to information that is authentic, reliable and complete been more important, and never has the capacity of libraries and other heritage institutions to guarantee that access been in greater jeopardy.” (LC, 2002)

We see the crisis not between producers and consumers of digital data, but in the capacities of cultural heritage specialists to produce the content for themselves in ways that can adhere to the principles defined by the LOC and other key international standards bodies. There is a desperate need for methodologies for digital heritage conservation that are manageable and reasonable, and most importantly, can be enacted by cultural heritage professionals as essential elements of their daily work. The collaboration between cultural heritage professionals and digital specialists should lead to the democratization of technology through its widespread adoption, not the continued mystification of technology that is still being defined by the persistence of a producer/consumer model (Tringham/Ashley).

5. DEMOCRATIZATION OF TECHNOLOGY

The evaluation of emerging technologies presented here is completely pragmatic. We will describe some of the many tools that can remove the impediments to and promote adoption of digital surrogates in CH work.

Recent work has shown that computational extraction of information from digital photographs can create digital surrogates that reliably describe the 2D and 3D shape, location, material, and reflection properties of our world. Among these new technologies are single and multi-view reflection transformation imaging, the algorithmic extraction of surface feature drawings from reflection information, as well as

photogrammetric breakthroughs that permit automatically calibrated and post-processed textured 3D geometric digital surrogates of objects and sites. We will explore these developments in detail later in this section.

The emergence of the new family of robust digital documentary tools offering automatic post-acquisition processing overcomes an important barrier to the adoption of digital workflows. As was discussed in Section 3, automation offers enhanced reliability and greatly reduces the computer technology expertise necessary to manage a digital workflow. These methods leverage new knowledge to enable CH professionals to build digital surrogates with a minimum of additional training. In turn, this automation frees CH workers to concentrate on the CH tasks before them.

Digital photography skills are already widespread and disseminating rapidly. Employing digital photography to provide the empirical data for digital surrogates also lowers financial barriers to digital adoption. As will be seen below, rich 2D and 3D information can be captured with the equipment found in a modern wedding photographer's kit

Reflection Transformation Imaging (RTI), invented by Tom Malzbender of Hewlett-Packard Laboratories (HP Labs), is an example of computational extraction of 3D information from a sequence of digital photographs. RTI data acquisition analyzes reflections from a subject's surface. When a surface is photographed from a fixed position and illuminated from different known locations, the surface's properties of shape and many material attributes, including color, can be computationally revealed. Reflections disclose shape by capturing the directional vector, mathematically named a 'normal' that is perpendicular to the surface at the photographically sampled location. Knowledge of surface normals permits construction of the surface's 3D geometry as in the process of photometric stereo or codification of the normal information on a per-pixel-basis in a 2D image as in polynomial texture mapping (PTM) (Malzbender, T., et al, 2001).

3D lighting models use this normal information to permit relighting of the subject from any direction and with any illumination source in interactive viewing software. The normal information can also be mathematically enhanced to disclose surface features that are difficult or impossible to see, even under direct physical examination (Mudge, M., et al, 2005). RTI has been widely used in law enforcement, natural science, and cultural heritage

Automatic acquisition and post-processing using photometric stereo in combination with RTI has been demonstrated to effectively document cuneiform inscriptions from the collection of the Katholieke Universiteit Leuven (KUL) (Willems, G., et al, 2005)

Two projects—one involving teams from the University of Southern California (USC) and the University of Illinois, Urbana-Champaign, and the other a partnership between USC and the Oriental Institute of the University of Chicago—are extensively using RTI in combination with PTMs to document dozens of cylinder seals and thousands of cuneiform tablets from ancient Mesopotamia and Persia. These projects use fixed light position dome capture apparatus modelled after similar equipment designed by HP Labs and Cultural Heritage Imaging (CHI) (Mudge, M., et al, 2006) (Malzbender, T., et al, 2001) and automatic scripts developed by CHI to generate the finished

RTIs. The scripts create a log file of all operations performed. Combined with information stored in Adobe software .XMP files generated during conversion of the original RAW digital images, all empirical provenance for the RTIs is recorded. The Institute for Information Science and Technology (ISTI) of the Italian National Research Council has used RTI to document bas-relief sculpture and architectural details. This technique employs site-specific, algorithmically generated templates to determine illumination locations. Their work has also demonstrated the effects of light position sample quantities and spatial distribution upon the accuracy of captured normal information (Dellepiane, M., et al, 2006).

RTI's can also be acquired using a method developed by a collaboration between CHI and HP Labs called Highlight RTI (HRTI). (Mudge, M., et al, 2006) HRTI includes one or two shiny black spheres in each image of the photographic sequence. The light source location is recorded on the sphere(s) as a highlight, or bright spot, on the sphere's surface. This highlight indicates the directional vector pointing to the illumination location. HRTI permits determination of illumination location after the image acquisition session and offers several additional advantages: it permits a broad subject scale range, from 1-2 cm in diameter to several meters; pragmatic selection of light direction sampling locations, which is helpful in avoiding environmental obstructions, especially during field work; and the use of a simple, low-cost photographic equipment kit. HRTI has been used to document: Magdalenian petroglyphs at the Paleolithic Petroglyphs of the Côa Valley UNESCO site in Portugal by the Côa Valley Archaeological Park, the Centro Nacional de Arte Rupestre, the Universidade do Minho (Minho) and CHI. (Mudge, M., et al, 2006) Software that automatically identifies black ball highlights is being developed by a collaboration between Minho, HP Labs and CHI.

Traditional work practice in many CH disciplines use drawings as a medium for dissemination and interpretive discourse. Non-photo-realistic rendering (NPR) research by Szymon Rusinkiewicz and others is using surface normal information to enable the algorithmic generation of drawings. These drawings use both photographically captured color and 3D surface shape data to enable a broad range of user selected drawing styles to represent desired surface features. These information rich graphic representations integrate the power of digital imaging with proven, widely used, and familiar modes of CH professional activity.

Recent developments in photogrammetric technologies can generate 3D textured geometric digital surrogates of objects and sites from automatically calibrated and post-processed sequences of digital photographs. The European Project for Open Cultural Heritage (EPOCH), a seven year European Union sponsored initiative to develop digital tools for CH, fostered a major advance in photogrammetry-based 3D imaging using uncalibrated digital photos. The EPOCH 3D Webservice, developed by the computer vision group at KUL allows archaeologists and engineers to upload digital images to servers where they perform an automatic 3D reconstruction of the scene and return the textured 3D geometry back to the user (EPOCH web, 2007). The ISTI research group has created a loader for this 3D content into their own EPOCH open source tool MeshLab (MeshLab web, 2007). MeshLab provides a set of tools for editing, cleaning, healing, inspecting, rendering and converting 3D polygonal textured geometry. MeshLab can

create an automatic log of all operations it performs on 3D content, generating an empirical provenance record.

Commercial software, initially developed for the aerial mapping and mining industries by Adamtech, an Australian company, can automatically calibrate digital photo sequences from one or more cameras, automatically generate dense textured 3D polygonal geometry from one or more image pairs, and automatically align this 3D content using photogrammetric bundle adjustment (Adam web). These tools have been used by U.S. Bureau of Land Management researchers Neffra Mathews and Tom Noble to document Native American petroglyphs at Legend Rock Wyoming State Park in collaboration with the Wyoming State Parks, Wyoming State University and CHI. Photogrammetry digital image sequences were captured tandem with CHI's RTI photo sequence. The integrated photo sequences demonstrate the synergies between automated photogrammetric capture of range-based geometry and reflection-based capture of normal data. These synergies, presented at the Computer Applications in Archaeology conference in Berlin, April 2007 include co-registered RTI images free of optical distortions, algorithmically generated NPR drawings, and dense, textured 3D geometry. CHI submitted the same image sequence of a bas-relief sculpted architectural feature to test the 3D geometry produced by Adamtech software against that returned from the EPOCH 3D Webservice. The results showed dense 3D geometrical information of equivalent quality.

6. CONCLUSIONS

The principles of empirical provenance, perpetual digital conservation, democratization of technology, and tolerance of diversity provide a digital future for cultural heritage. Informed by these principles, emerging tools and methods will enable CH professionals to build reliable, reusable, archive friendly, digital surrogates by themselves. Archives of digital surrogates can enable distributed scholarship and public access. The aesthetic quality, usefulness to convey ideas, and completeness of empirical provenance information can guide decisions regarding which digital representations are perpetually conserved.

7. REFERENCES

- ADAM web. ADAM Technology website. <http://www.adamtech.com.au> (accessed 8 June 2007)
- ADS web Archaeological Data Service Website (accessed June 2007) <http://ads.ahds.ac.uk/project/faq.html>
- Berns, R.S., Frey, F.S., Rosen, M.R., Smoyer, E.P.M., Taplin, L.A. 2005. Direct Digital Capture of Cultural Heritage Benchmarking American Museum Practices and Defining Future Needs - Project Report, *MCSL Technical Report*.
- Dellepiane, M., Corsini, M., Callieri, M., Scopigno, R., 2006 High Quality PTM Acquisition: Reflection Transformation Imaging for Large Objects, *Proceedings of the 7th International Symposium on Virtual Reality, Archaeology and Cultural Heritage (VAST2006)*, Eurographics Association, pg 179-186
- EPOCH web, EPOCH Webservice (accessed April 2007) <http://homes.esat.kuleuven.be/~visi3d/websevice/html/>
- Eppich, R., Chabbi, A., 2006 How Does Hi-tech Touch the Past? Does It Meet Conservation Needs? Results from a Literature Review of Documentation for Cultural Heritage, *The e-volution of Information Communication Technology in Cultural Heritage* Epoch Publication, pg 94-99
- Getty Trust, 2005., About RecordIM, (accessed 4 June, 2007) <http://extranet.getty.edu/gci/recordim/about.html>
- Hermon, S. Nikodem, J., Perlingieri, C., 2006 Deconstructing theVR – Data Transparency, Quantified Uncertainty and Reliability of 3D Models, *Proceedings of the 7th International Symposium on Virtual Reality, Archaeology and Cultural Heritage (VAST2006)*, pg 123-129
- LC, 2002 Preserving Our Digital Heritage: Plan for the National Digital Information Infrastructure and Preservation Program. Council on Library and Information Resources (CLIR) and the Library of Congress, Washington, D.C. LC., 2004., Sustainability of Digital Formats, Washington, D.C., <http://www.digitalpreservation.gov/formats/intro/intro.shtml> (accessed 4 June, 2007)
- LC., 2004, Sustainability of Digital Formats, Washington, D.C., <http://www.digitalpreservation.gov/formats/intro/intro.shtml> (accessed 4 June, 2007)
- Malzbender, T., Gelb, D., and Wolters, H. 2001. Polynomial Texture Maps. *Proceedings of ACM Siggraph 2001*
- MeshLab web, MeshLab website (accessed May 2007), <http://meshlab.sourceforge.net>
- Mudge, M., Voutaz J.P., Schroer C., Lum M., 2005. Reflection Transformation Imaging and Virtual Representations of Coins from the Hospice of the Grand St. Bernard, *Proceedings of 6th International Symposium on Virtual Reality, Archaeology and Cultural Heritage (VAST2005)*, Eurographics Association, pp. 29– 39.
- Mudge, M., Malzbender, T., Schroer, C., Lum, M., 2006 New Reflection Transformation Imaging Methods for Rock Art and Multiple-Viewpoint Display, *Proceedings of the 7th International Symposium on Virtual Reality, Archaeology and Cultural Heritage (VAST2006)*, Eurographics Association, pg 195-200
- Smith, A., 2001. The Evidence in Hand: Report on the Task Force on the Artifact in the Library Collections, Washington, D.C. <http://www.clir.org/pubs/reports/pub103/contents.html> (accessed 4 June, 2007)
- Smith, A., 2006. Academic Amnesia: Who Is Preserving Our Data?, Berkeley, CA. (accessed 4 June, 2007) <http://cshe.berkeley.edu/events/index.php?id=208>
- Tringham, R., Ashley Lopez, M., 2001, The Democratization of Technology, *Virtual Systems and Multimedia Proceedings 7th International Conference on*
- Willems, G., Verbiest, F., Moreau, W. Hameeuw, H., Van Lerberghe, K., Van Gool, L., 2005. Easy and cost-effective cuneiform digitizing. In: *Proceedings of the 6th International Symposium on Virtual Reality, Archaeology, and Intelligent Cultural Heritage*, Pisa, Italy, pg. 73-80.