DIGITAL DOCUMENTATION FOR HISTORIC RESOURCES

by

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Under the Direction of Mark Reinberger

ABSTRACT

This paper briefly analyzes the current documentation standards for Federal programs and creates an argument for the use of digital technologies in historic documentation. The technologies of photogrammetry, and laser scanning are addressed as methods for three dimensional modeling and compared to the current standard. Additionally, the issues posed by archiving on digital media are presented and courses of action suggested. Finally, the feasibility of a universal file format for archival purposes is addressed, and current progression toward this goal discussed.

INDEX WORDS: Historic resource documentation, Photogrammetry, Laser scanning, Digital photography, HABS documentation guidelines, Digital storage media, Universal file format

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B.S., State University of New York at New Paltz, 2005

A Thesis Submitted to the Graduate Faculty of The University of Georgia

in Partial Fulfillment of the Requirements for the Degree

MASTER OF HISTORIC PRESERVATION

ATHENS, GEORGIA

2011

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ACKNOWLEDGEMENTS

I would like to acknowledge my major professor, Mark Reinberger, for agreeing to take on this unique topic with me, as well as the other members of my committee for their feedback and suggestions. I would also like to thank my family and friends for their encouragement and support:

Mom, Dad, Stacie, Aunt Beth, Aunt Lynne, Uncle Reid, Grandma, Grandpa, Deb, Betsy, Anne, Nicole, and the Zitomer Family for being my personal cheerleading squad throughout my time in the Master of Historic Preservation program; the Swing Kids, for keeping me smiling over the course of the past year; and my SIG friends, for instilling me with confidence and teaching me that being a geek is awesome. I am lucky to have so many wonderful people in my life.

TABLE OF CONTENTS

LIST OF FIGURES

Page

CHAPTER 1

INTRODUCTION

Graphic documentation in the field of historic preservation is essential to the profession and an invaluable resource to our culture, yet one that has changed little over the course of its life. Documentation keeps record of the past and current conditions of resources in a level of detail for a variety of uses. Based upon these records resources may be reconstructed, restored, and studied by professionals and academics. In contrast, computer technology is an area that has rapidly expanded and changed over the course of the past fifty years. As a result, historic documentation techniques need to be updated to meet with the demands and expectations of a technology-driven twenty-first century. Tasks that in the past would have been done via a manual process are being digitized, both to increase accuracy and speed workflow.

The usage of three-dimensional software in a variety of fields has skyrocketed in recent years as imaging technology has improved. Programs such as Autodesk's AutoCAD, Microsoft Photosynth, and Google's Sketch-Up and Panorama Flythrough have brought the possibility of creating panoramic views and basic three-dimensional imaging to the public. For example, products of Google's Panorama Flythrough may be found online in the detailed panoramic views of famous landmarks, such as the Roman Forum. The product consists of thousands of photos of a particular area, taken by average people and pieced together to created the full scene. The resolution quality allows the user to zoom in as far as an individual's face.

As another example, an even more sophisticated program, PhotoModeler™, created by Eos Systems, Inc., is image-based modeling software based on the science of photogrammetry–taking accurate measurements from a series of two-dimensional photographs and constructing a three-dimensional model from input data. The newest version (6.3), released in 2009, is said to allow the user to capture and measure a wider variety of scenes and objects in addition to improved speed and a lower cost of operation.

This paper proposes that three-dimensional imaging technology be utilized for a multitude of preservation applications, but most effectively in the area of documentation. In measuring structures, generating photo-textured three-dimensional models for realistic "walk-bys," elevation drawings, and rectified photographs, creates a comprehensive system of archival and resource management sources. This technology also has the potential to model structural conditions and allow for recreation in the event of a natural disaster or other unforeseen destroyers. The Historic American Building Survey (HABS) and its sister programs, the Historic American Engineering Record (HAER) and Historic American Landscape Survey (HALS), Federal documentation programs that are among the most heavily used resources in the Prints and Photographs Division of the Library of Congress, could greatly benefit by the use of imaging technology and digital storage methods. They would greatly reduce the amount of time currently spent on hand drawing, precision measurement, and film development, as well as reducing human resources needed for each project, thereby allowing more historic sites to be documented in the same amount of time. Additionally, the storage of digital media versus traditional, would remedy the physical space problem that the Library of Congress is running into. Digital media will also more readily allow for the creation and maintenance of a digital database that may be available for public consumption.

The problems posed by the use of digital technology and storage techniques are numerous but not impossible to overcome. One such problem is making different computer programs compatible so that a variety of users can read the resulting files. After all, an old-fashioned drawing can be read by anyone, at any time now or into the future and computer technology needs to meet this standard. An “intelligent file format” has been proposed which will allow all computer users to access and read a file regardless of the originating program. The World Wide Web Consortium (W3C) currently regulates page programming and file formats circulated on the web, having a standardized set of formats for various purposes that are used internationally. It is possible, and likely, with more information being created and stored only in a digital format, that a standard for non-web based files will soon exist. The beginnings of this can be seen in the practicality and popularity of the current PDF format that can be accessed with the freeware, Adobe Reader. The largest challenge that will need to be overcome to ensure the success of an “intelligent file format” is for software companies, such as Microsoft and Adobe, to all agree to allow export of this file type from within their software.

Another problem with the digital information is the question of longevity. The United States government has created an initiative led by the Library of Congress (which may be viewed at www.digitalpreservation.gov) called the National Digital Information Infrastructure and Preservation Program (NDIIPP). Its mission is to develop a national strategy to “collect, archive, and preserve the burgeoning amounts of digital content, especially materials that are only created in digital formats, for current and future generations." Many are not yet convinced of the longevity of digital media–will they corrupt, rendering the data useless as countless amounts of microfilm has begun to disintegrate? The current preservation standard as outlined by NDIIPP is to archive information on a silver or gold archival CD or DVD, discs literally made of silver, on which data is anticipated to still be readable for up to two hundred years. The information should also be stored on an external hard drive with a universal port, such as USB or Firewire, for more immediate usage. With the rate of technological advancement increasing year by year, it is likely that an even more permanent method than the current standard will be developed before the end of its anticipated lifetime.

The overall goal of this thesis is to show that digital technology has reached a level of quality and reliability so as to compete with traditional documentation methods. Chapter 2 will discuss current documentation standards, Chapter 3 will demonstrate the importance of digital heritage, and Chapter 4 will discuss the technologies that make digital documentation possible. Finally, Chapter 5 will document the problems posed by digital documentation and present possible solutions. The conclusion of this paper, in Chapter 6 will suggest how to begin using digital technology more effectively for historic site documentation, and future points of research.

CHAPTER 2

CURRENT FEDERAL DOCUMENTATION STANDARDS

This chapter examines the current documentation processes practiced by Federal programs, the most important examples of graphic documentation in American preservation. In all cases, the documentation methods need to be updated to accommodate twenty-first century technology. Most information is now available to the public via website databases, but all of the materials originated in a physical form and had to be scanned into a digital format.

Historic American Buildings Survey

The Historic American Buildings Survey (HABS) was established as a Public Works Administration (PWA) program in 1933. Sister programs the Historic American Engineering Record (HAER) and Historic American Landscapes Survey (HALS) were begun in 1969 and 2000, respectively. All are programs administered by the National Park Service (NPS) with the purpose of documenting historic resources. Records generally consist of measured drawings, archival photographs, and written reports. Currently, surveys housed in the Library of Congress are comprised of more than 556,900 measured drawings, large-format photographs, and written histories for over 38,600 historic sites.[1] A separate set of guidelines exists for each of the three main components of a survey, plus one illustrating how the entire package of information should be submitted.

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[1] The Library of Congress, Historic American Buildings Survey. memory.loc.gov/ammem/collections/habs_haer

The most recent edition of *Recording Historic Structures and Sites with HABS Measured Drawings*, published in 2008 by the National Park Service, is available online. The document briefly mentions digital data including photographs and photogrammetric data. All of this information, however, must be provided in print form in addition to being present on a CD-ROM. While computer-Aided Drafting (CAD) is acceptable for basic footprints and outlines, surface patterns must be hand rendered.[2] Further, any digital data recorded is only viable as referential field records and is not considered official documentation. Therefore, a digital scan model may exist but would only serve as a reference for hand drawings to be rendered, rather than as the record itself.

The current standards for photographic submissions are discussed in *HABS/HAER Photographs: Specifications and Guidelines* (2001). According to this document, black and white, large format sheet film between four by five and eight by ten inches is required.[3] Large format photography is necessary because small and medium film formats do not have a sufficient resolution for researchers to examine small areas of the image. Film must be black and white rather than color because black and white negatives and prints have a longer lifespan than their color counterparts, and further guidelines are given for lenses, filters, the paper on which the photograph is printed (fiber versus resin coated), and development technique. A final publication, *Preparing HABS/HAER/HALS Documentation*, outlines archival guidelines and formats for submittal to the Library of Congress. Both of the above documents are also available online through the National Park Service.

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[2] Historic American Buildings Survey. *Recording Historic Structures and Sites with HABS Measured Drawings.* December 2008. www.nps.gov/history/hdp/standards

[3] Historic American Buildings Survey. *HABS/HAER Photographs: Specifications and Guidelines.* June 2001. www.nps.gov/history/hdp/standards

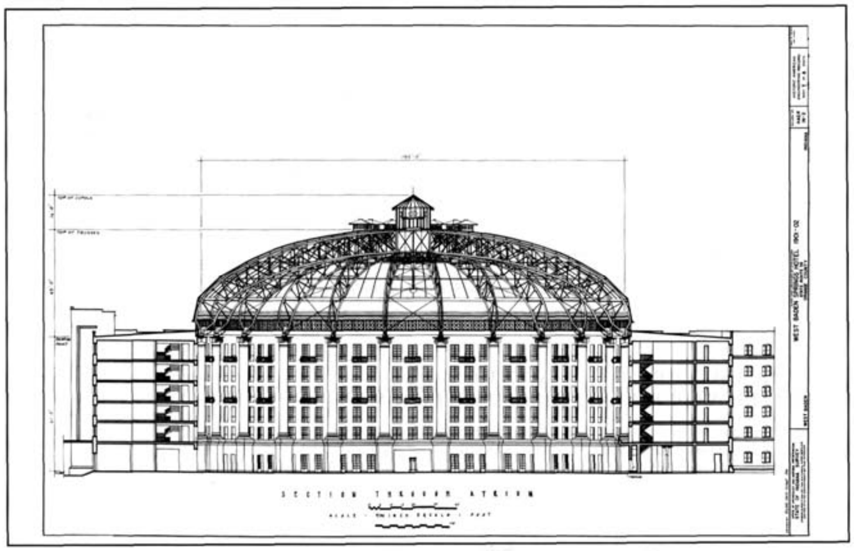

Figure 2.1. Sample Historic American Buildings Survey line drawing. West Baden Springs Hotel, West Baden Springs, Indiana.

Figure 2.2. Labeled negative and archival sleeve from HABS/HAER/HAL submittal guidelines.

Figure 2.3. Sample photo mount card from HABS/HAER/HAL submittal guidelines.

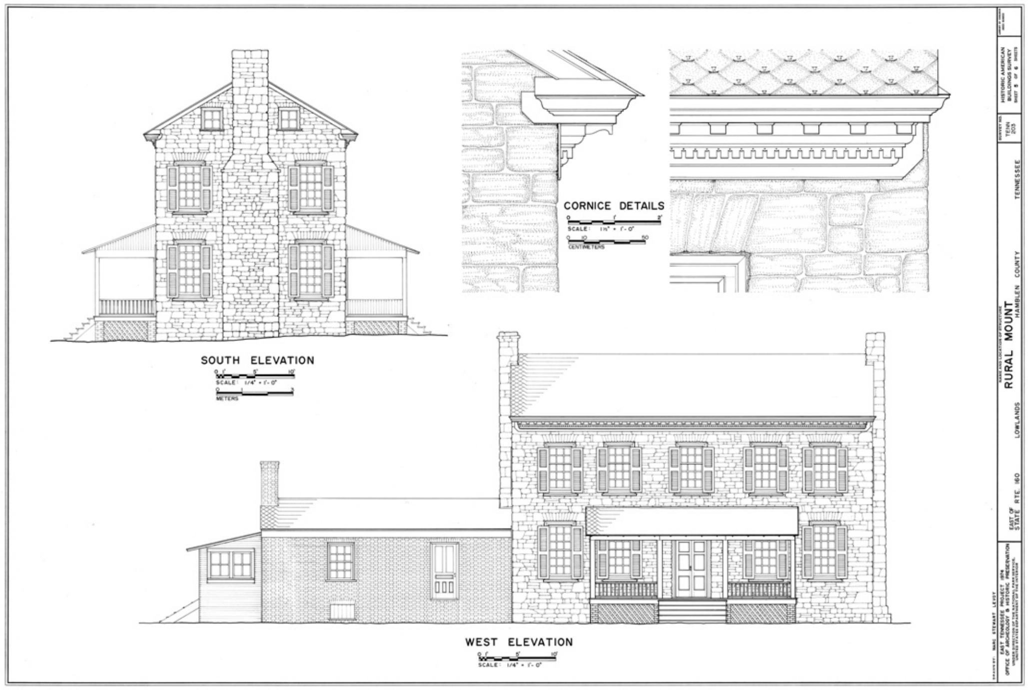

Figure 2.4. Sample HABS line drawing. Rural Mount, Hamblen County, Tennessee.

Figure 2.5. Sample HABS photograph. First Bank of the United States, Philadelphia.

National Historic Landmarks Program

The National Historic Landmarks Program (NHL) documents nationally significant historic places as designated by the Secretary of the Interior. Significance is determined by the exceptional value or quality they possess in illustrating or interpreting the heritage of our country. Fewer than 2,500 historic places currently qualify as NHLs.[4] Slightly differing from HABS, in this case photographs, slides, and a written report are the required components.[5] However, all of these elements are required in a print format.

Photographic prints must be black and white, unmounted, ideally at the size of eight by ten inches, and made on appropriate archival (fiber) paper. Six to twelve color slides must also accompany NHL nominations. In the case of the NHL Program, it seems that the collected data is used largely to assess and review the site for designation. While the information is then public record, the photographs and slides become a resource for publications, publicity, the web, and other promotional materials, rather than as an official resource for researchers. For more information regarding NHL nomination requirements, see the National Register Bulletin, *How to Prepare National Historic Landmark Nominations*, available on the National Park Service website.

National Register of Historic Places

Authorized by the National Historic Preservation Act of 1966, the National Register of Historic Places (NRHP) is the official list of the United States' historic sites worthy of preservation. The Register only requires a written nomination report and photographs that must be black and white, printed on fiber paper (preferably eight by ten

[4] National Park Service. National Historic Landmark Program. www.nps.gov/history/nhl
[5] "How to Prepare National Historic Landmark Nominations." *National Register Bulletin.* U.S. Department of the Interior, National Park Service. 1999.

in size) and be unmounted.[6] More information may be found on the National Park Service's website in a National Register Bulletin titled, *How to Complete the National Register Registration Form*.

In all of the above cases, a digital format both for initial production and archiving is not favored. While these programs allow submission of digital materials, they will not fulfill any of the official documentation criteria. Black and white film is required in all systems because color film degrades more quickly. The NRHP prefers eight by ten or larger photographic prints so details are more evident, but the minimum print size is three-and-a-half by five inches. The HABS and NHL programs require large format photography, which allows for even more detail to be clearly seen than small or medium formats. Large format cameras also have the ability to use adjustments, such as swings and tilts, necessary for perspective correction and having all areas of the image in sharp focus, making them preferred for official documentation.

Creating drawings and reports only as digital data is not recommended. Without the guarantee of long-lasting media and universal file formats that will allow them to be readable in the future, archivists are not likely to accept digital media as a primary resource anytime in the near future.

<u>National Digital Information Infrastructure and Preservation Program</u>

Legislation in December 2000 called for the Library of Congress to work with other federal agencies as well as a variety of stakeholders to develop a national approach to digital preservation. One hundred million dollars was appropriated by Congress for the creation of the National Digital Information Infrastructure and Preservation Program

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[6] "How to Complete the National Register Registration Form." *National Register Bulletin.* U.S. Department of the Interior, National Park Service. 1997.

(NDIIPP).[7] The initial work of this group focused on gathering and connecting with stakeholders from around the country to develop a plan for the program. The report, *Preserving Our Digital Heritage: Plan for the National Digital Information Infrastructure and Preservation Program* was approved by Congress in 2003.[8]

In 2004, the Library of Congress funded proposals for establishing a network of preservation partners, and NDIIPP entered into a partnership with the National Science Foundation in 2005 to undertake a pioneering program to support advanced research into the long-term management of digital information.[9] In following years, the program has entered into collaboration with a number of professional organizations, research laboratories and academic partners, each addressing specific areas of interest.

The Library of Congress funded the Preserving Creative America initiative to target preservation issues across a broad range of creative works, including digital photographs, cartoons, motion pictures, sound recordings, and even video games, in 2007.[10] The work is conducted by a combination of industry trade associations, private sector companies and nonprofits, as well as cultural heritage institutions. Several of the projects involve developing standardized approaches to content formats and metadata (the information that makes electronic content discoverable by search engines, such as Google), which are expected to enhance the plausibility that the digital content of today will survive to become America's cultural legacy.[11] Although many creative content

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[7] Library of Congress. National Digital Information Infrastructure and Preservation Program. http://www.digitalpreservation.gov/library/program_back.html

[8] Library of Congress. National Digital Information Infrastructure and Preservation Program. http://www.digitalpreservation.gov/library/program_back.html

[9] Library of Congress. National Digital Information Infrastructure and Preservation Program. http://www.digitalpreservation.gov/library/program_back.html

[10] Lamolinara, Guy. "Digital Preservation Program Makes Awards to Preserve American Creative Works." News Releases: Library of Congress. August 3, 2007. http://www.loc.gov/today/pr/2007/07-156.html

[11] Lamolinara, Guy. "Digital Preservation Program Makes Awards to Preserve American Creative Works."

industries have begun the process of examining what will be needed to sustain digital content over time, the monies awarded to the Preserving Creative America projects will provide added motivation for collaborations within and across media, as well as with libraries and archives.

The following year, the Preserving State Government Information Initiative began with the support of four projects involving twenty-three states.[12] States face formidable challenges in caring for digital records with long-term legal and historical value.[13] A series of Library-sponsored workshops held in 2005 revealed that the large majority of states lack the resources to guarantee that information produced in digital form only, such as legislative records, court case files and executive agency records, are preserved for long-term access.[14] The Initiative will collect several significant categories of digital information, including geospatial data, legislative records, court case files, Web-based publications and executive agency records. Each project within the Initiative will also work to share tools, services and best practices in order to help every state make progress in managing its digital heritage.

While the programs under the NDIIPP are relatively new, the United States government's efforts are a large indicator toward the trend of digital information serving as a primary resource. In order to guarantee accessible data and a continued legacy of

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News Releases: Library of Congress. August 3, 2007. http://www.loc.gov/today/pr/2007/07-156.html

[12] Library of Congress. National Digital Information Infrastructure and Preservation Program. http://www.digitalpreservation.gov/library/program_back.html

[13] Lamolinara, Guy. "Digital Preservation Program Adds New Partners to Preserve State Government Digital Information. News Releases: Library of Congress. January 7, 2008. http://www.loc.gov/today/pr/2008/08-004.html

[14] Lamolinara, Guy. "Digital Preservation Program Adds New Partners to Preserve State Government Digital Information. News Releases: Library of Congress. January 7, 2008. http://www.loc.gov/today/pr/2008/08-004.html

both creative and governmental information, methods of digital preservation must be refined and standardized.

CHAPTER 3

THE IMPORTANCE OF DIGITAL HERITAGE

Background

The role of three-dimensional (3D) computer graphics in studying and preserving historic sites has grown significantly since the 1990s, but is still under-utilized. Advances in scanning techniques, virtual reality, computing power, 3D modeling tools, and related technologies have made it possible to accurately recreate buildings and other resources for use by future generations. These endeavors are collectively referred to as "virtual cultural heritage," and they make it possible to conserve and interpret a historic resource in ways that were previously inconceivable through photographs and other available techniques.[15]

Virtual heritage is the use of electronic media to recreate or interpret culture and cultural artifacts as they are today or as they might have been in the past.[16] Most applications of this technology to date have been architectural reconstructions centered on a building or monument.[17] The larger goal of virtual heritage is to recreate cultures, not just objects, as living museums where users can gain an understanding of a culture that is different from their own. For example, high-quality 3D renderings of existing artifacts can make them accessible to a wider audience while preserving the often fragile originals.

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[15] Moltenbrey, K. "Preserving the Past." *Computer Graphics World*. September 2001. pp. 24-30.
[16] Jacobsen, Jeffrey and Holden, Lynn. "Virtual Heritage: Living in the Past." *Techne: Research in Philosophy and Technology*, Vol. 10, No. 3, spring 2007, pp. 55-61.
[17] Jacobsen, Jeffrey and Holden, Lynn. "Virtual Heritage: Living in the Past." *Techne: Research in Philosophy and Technology*, Vol. 10, No. 3, spring 2007, pp. 55-61.

In the 1990s, issues of graphic quality and speed dogged virtual world heritage developers, forcing simplistic representations that triggered criticism from the heritage community.[18] The first use of a virtual tour was a 3D reconstruction of Dudley Castle in England. Queen Elizabeth II became one of the first users of a virtual tour when she opened the castle's visitor center in June 1994. The system consisted of a computer-controlled laserdisc designed by British engineer, Colin Johnson, and provided a "walk-through" of the Castle as it would have been in 1550.[19]

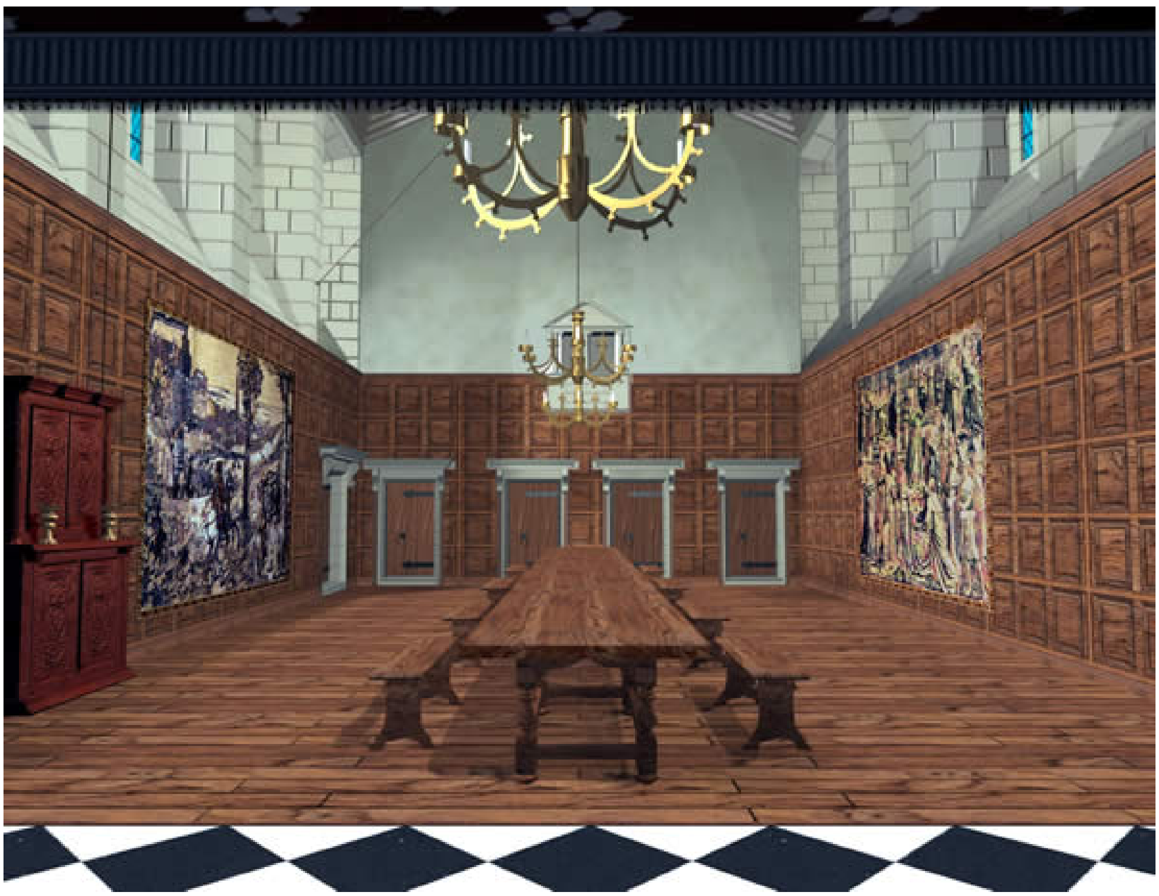

Figure 3.1. Reconstructed virtual image of Dudley Castle 's Great Hall, 1994.[19]

[18] Addison, Alonzo C. "Virtualized Architectural Heritage: New Tools and Techniques." *IEEE Multimedia*, November/December 2003, pp. 32-41.
[19] Johnson, Colin. "Computer Visualization of Dudley Castle c1550." Exrenda. 1994. http://www.exrenda.net/dudley/dudley.htm

While this was a well-done project that garnered public engagement at the time, it is clear from the graphic quality that it would never be able to be used for academic research or preservation initiatives. Additionally, the hardware required to run such a tour was not something readily available to the public. Significant technological advances have been made since the mid-1990s, but accurate virtual representation of historic and cultural landmarks has been limited by a lack of tools to quickly, inexpensively, and accurately model reality in an interactive environment that follows a data standard. [20]

Figure 3.2. Current condition of the Great Hall of Dudley Castle.[19]

Karen Moltenbrey, chief editor of *Computer Graphics World*, has vast experience writing and editing feature articles pertaining to the area of graphic technology. In September 2001, she explored the use of digital technology to preserve the past by interviewing a number of experts. These experts included Alonzo Addison, director of the Center for Design Visualization at the University of California, Berkeley, and cofounder of the Virtual Heritage Network, and Donald Sanders, the president of Learning Sites, Inc. and The Institute for the Visualization of History, Inc.

"Early data-intensive virtual heritage projects, generally created by universities or commissioned by large companies, were performed on costly supercomputers or produced as pre-rendered animations on video."[21] Still, accuracy was limited by the hardware and software that were available at the time. Few of these early ventures

[20] Addison, Alonzo C. "Virtualized Architectural Heritage: New Tools and Techniques." *IEEE Multimedia*, November/December 2003, pp. 32-41.

[21] Moltenbrey, K. "Preserving the Past." *Computer Graphics World*. September 2001. pp. 24-30.

satisfied all parties: the preservationist's need for documentation, the historian's need for interpretation, and the public's need for visual realism.[22] Additionally, most early projects were intended to serve as studies of sites that no longer existed, rather than as proactive tools to document the current conditions and monitor them for future conservation or preservation.

More recent projects are living up to the promise of early hopes for the medium and enable accurate data collection, representation, and distribution. "A major breakthrough has been the introduction of 3D digitizing systems such as laser scanners, [improved] photogrammetry, and image-based modeling software, which have made it possible to rapidly gather extensive and highly accurate data sets for virtual reconstruction."[23] Virtual heritage can be an invaluable tool, but if not applied wisely it has the potential to do as much harm as good. For example, dozens of virtual Pompeiis exist, yet few are historically accurate enough to be useful and, worse, some are misleading. Alonzo Addison, co-founder of the Virtual Heritage Network (VHN) believes that, "historical accuracy will become more important than ever in a digital landscape."[24]

By 2005, there were virtual Pompeii projects at Amherst College, the University of California at Los Angeles, the University of Virginia, and more, in addition to Italian travel sites and amateur photographers creating their own "tours" of the ancient city. Today, even Google Street View offers a walk through the thoroughfares of Pompeii! The most recent virtual Pompeii is being created at the University of Arkansas through a

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[22] Moltenbrey, K. "Preserving the Past." *Computer Graphics World*. September 2001. pp. 24-30.
[23] Moltenbrey, K. "Preserving the Past." *Computer Graphics World*. September 2001. pp. 24-30.
[24] Addison, Alonzo C. "Virtualized Architectural Heritage: New Tools and Techniques." *IEEE Multimedia*, November/December 2003, pp. 32-41.

joint venture of the Classical Studies and Humanities program in collaboration with the Center for Advanced Spatial Technology.[25] The goal of the project is to create a comprehensive database for visual art and material culture at Pompeii. The database will be linked with 3D models that can be explored in real time, in a walk-through like mode. In addition to using a combination of methods including CAD drawings and laser scanning, a video game engine, Unity (a free cross-platform player), is also used to allow for the online-hosted walkthrough to be manipulated by individual users.

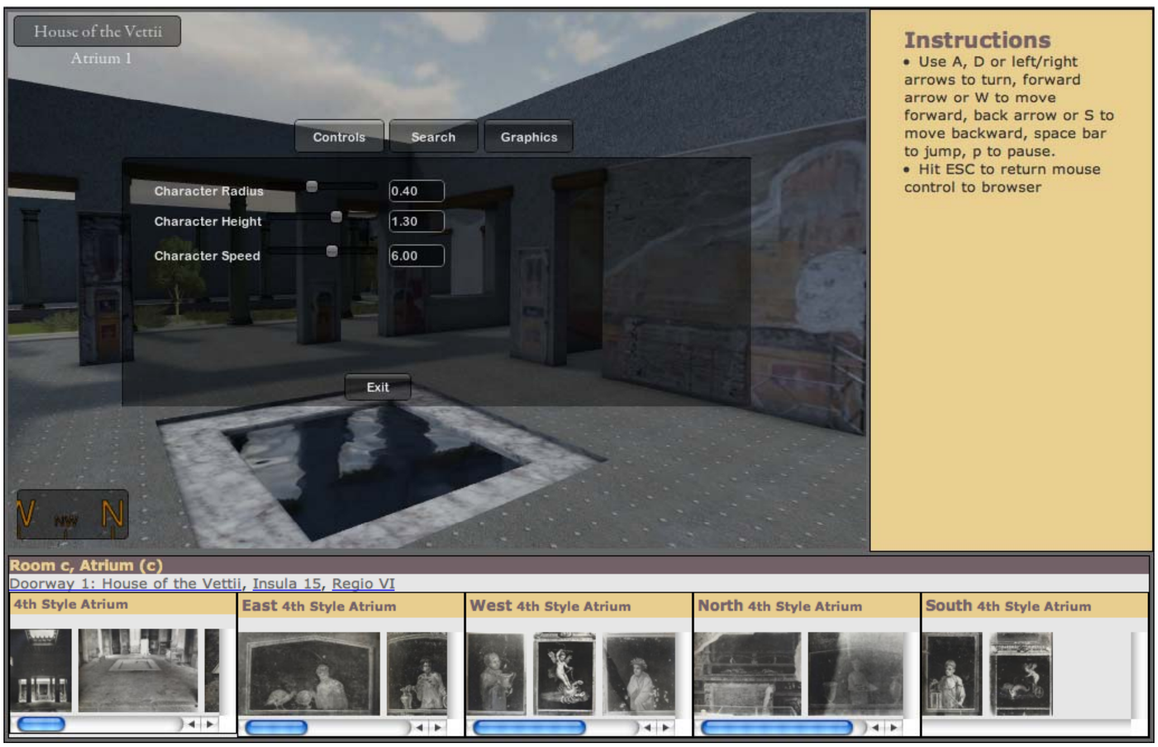


Figure 3.3. A screenshot of the University of Arkansas' virtual Pompeii. The virtual world may be explored in the same manner as a video game.[25]

Fewer than one dozen of the nearly 700 designated UNESCO World Heritage Sites have been virtually reconstructed as authentic re-creations.[26] CyArk is a non-profit organization with the mission of digitally preserving cultural heritage sites through

[25] "Digital Pompeii." J. William Fullbright College of Arts & Sciences: Humanities. University of Arkansas. http://pompeii.uark.edu/index.html
[26] Moltenbrey, K. "Preserving the Past." *Computer Graphics World*. September 2001. pp. 24-30.

collecting, archiving, and providing open access to data created by state-of-the-art technologies.[27] CyArk in its current incarnation was formed in 2008 with a pilot project that resulted in the digital preservation of seventeen heritage sites around the world including Ancient Thebes, Angkor Wat, Pompeii, and Mesa Verde. The project also initiated relationships with over sixty heritage organizations and service providers across the globe.

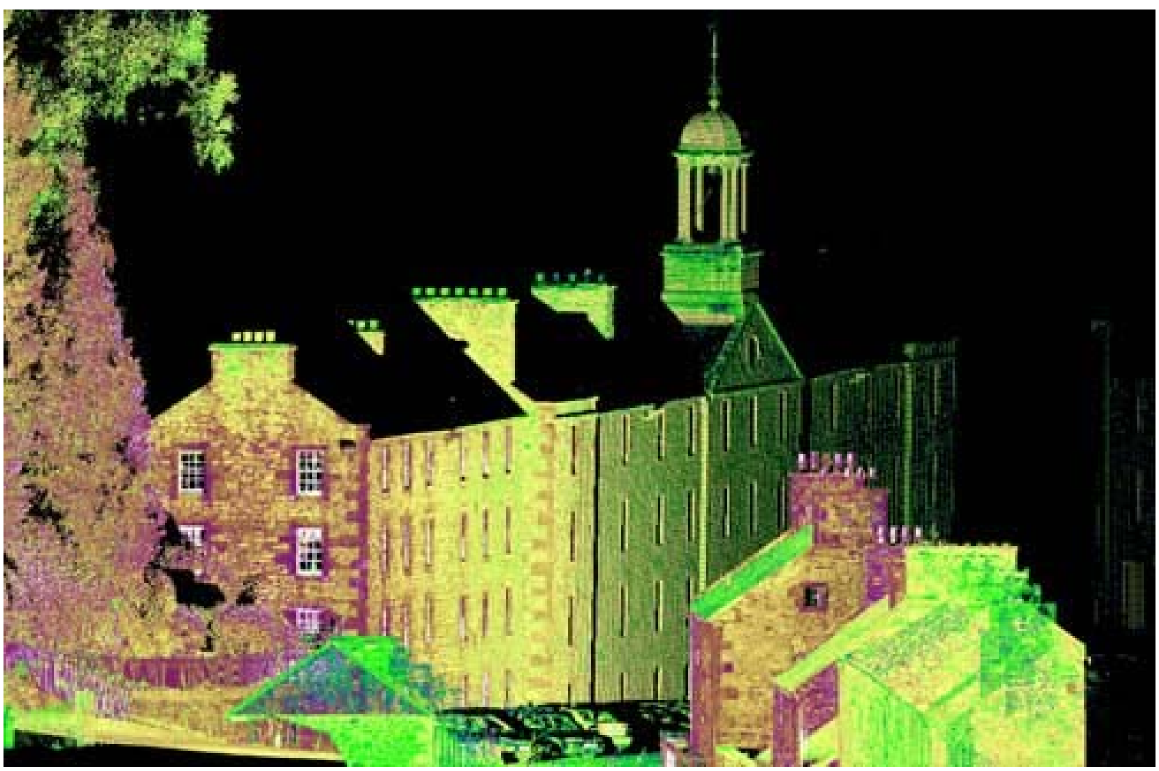
One of the organizations working in conjunction with CyArk is The Scottish Ten. The goal of this organization is to use cutting edge technology to create digital models of Scotland's five UNESCO designated World Heritage Sites and five international sites, including Mount Rushmore (see figure 3.6 below) within five years.[28] The Scottish Ten is a collaborative between Historic Scotland – the national heritage agency – and the Glasgow School of Art. The group uses high-speed terrestrial laser scanning systems and aerial optical remote sensing technology. The combination of these methods measures billions of survey points for an unprecedented accuracy in the resulting models.

Time can be a historic site's worst enemy with data being destroyed by both natural degradation and experimental human intervention. Aside from time, other limiting factors to digital heritage are money and available information. Most previous projects have been funded with government grants or through academia, rather than being funded and run by the non-profit groups that manage the sites.[29] Site access, especially in countries experiencing political unrest, is also a huge stumbling block. The same may be said of antiquities in museums or cultural centers which tend to be unwilling to loan their treasures for fear of losing appeal to visitors. With the obliteration of many landmarks

[27] About CyArk. archive.cyark.org/about
[28] "About the Scottish Ten." The Scottish Ten. www.scottishten.org
[29] Moltenbrey, K. "Preserving the Past." *Computer Graphics World*. September 2001. pp. 24-30.

Figure 3.4. An aerial view of the cotton manufacturing settlement, New Lanark.[28]

Figure 3.5 A 3D scan of a building in New Lanark, Scotland, 2009. [28]



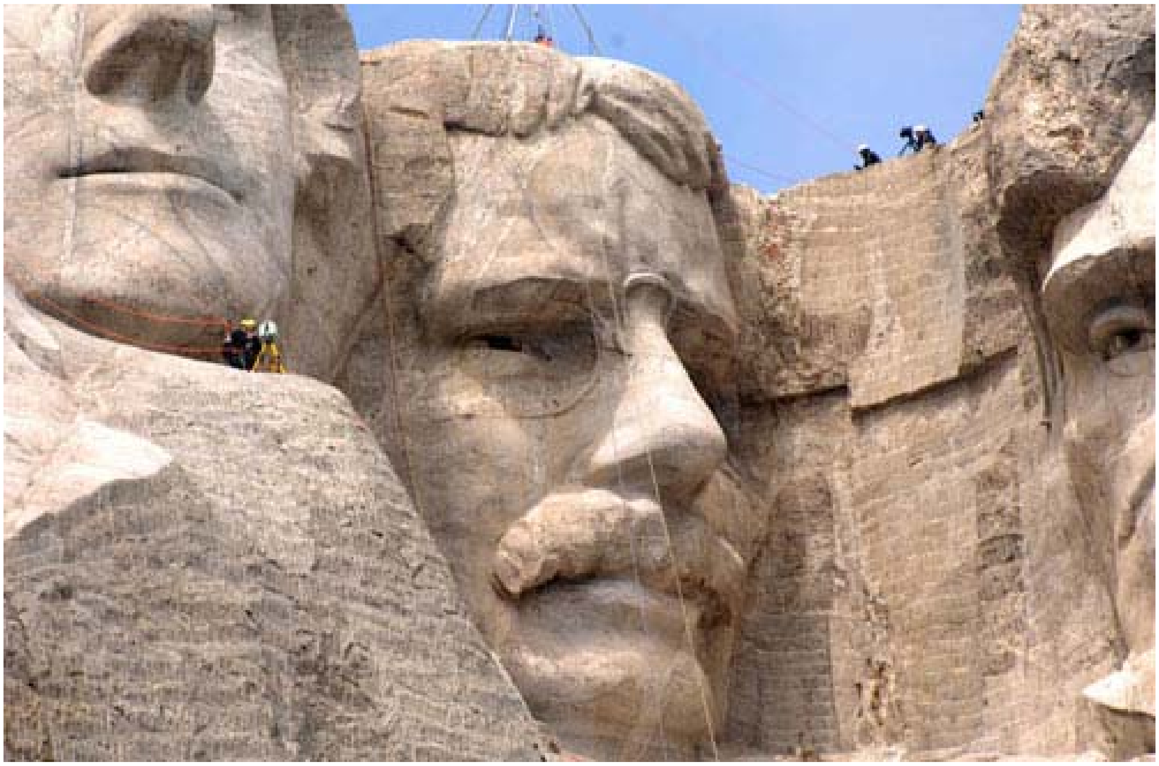
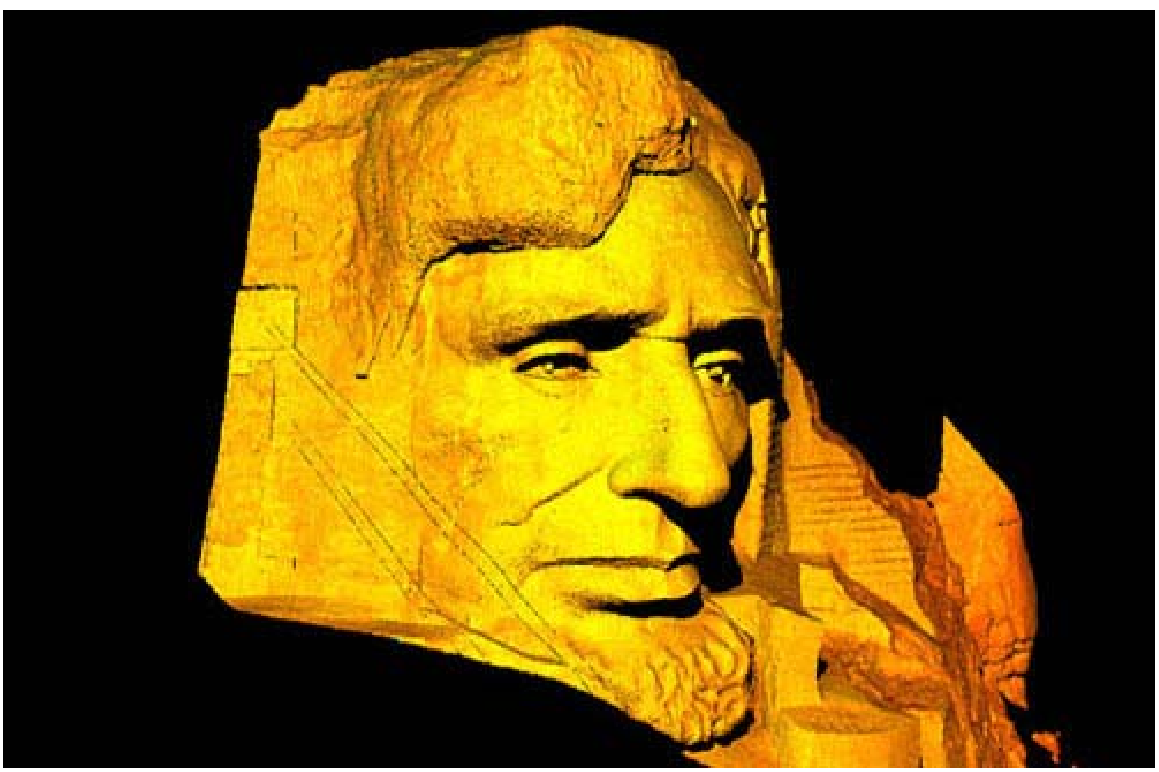


Figure 3.6. Scanning preparations at Mount Rushmore in Keystone, SD, 2009.[28]

Figure 3.7. A 3D scan of Lincoln's face on Mount Rushmore, 2009. [28]



becoming inevitable, re-creating historic sites using virtual technology may be just the savior that needed in order to have the benefits of the historic data available to future generations. We must be careful that the availability of such technology, however, does not make society complacent about the destruction of the original resource.

Benefits

The representation of built heritage requires two distinct forms of 3D data – current, real-world conditions and virtual or theorized historical interpretations. For example, researchers can now use a virtual replica of a monument to illustrate the future destructive effects of pollution over a given period of time, or can digitally restore a damaged building to its original state. [30] This will be explored with an example in the next chapter. More importantly, they can project both forward and backward without altering or affecting the original specimen.

The Virtual Heritage Network (VHN) is an international organization promoting the use of technology in preserving cultural heritage. "The most immediate benefit of creating a virtual version of an historic site is that it establishes a 'living' record of a site that no longer exists."[31] Technology may also solve one of the largest problems concerning cultural heritage – destruction by public usage. Allowing the public to tour virtual copies of a site, and thus limiting the site's exposure to human contact, can save valuable resources in preserving the site and preventing damage caused by something as simple as the natural oils on individuals' hands.[32] While this would not totally replace the real experience, the visualization would be detailed enough to "walk" through the site and

[30] Moltenbrey, K. "Preserving the Past." *Computer Graphics World*. September 2001. pp. 24-30.
[31] Addison, Alonzo C. "Virtualized Architectural Heritage: New Tools and Techniques." *IEEE Multimedia*, November/December 2003, pp. 32-41.
[32] Moltenbrey, K. "Preserving the Past." *Computer Graphics World*. September 2001. pp. 24-30.

inspect it in 3D. Even small surface features such as cracks and fungi could be present in these recreations.

If the preservation and archaeology communities expect others to get excited about ancient cultures or historic resources, a more interactive approach is needed. The past did not occur two-dimensionally (2D), nor does the present, and it can be more effectively studied in an interactive environment than as a series of static images.[33] In a day when "personal digital video and music players, GPS-enabled camera cell phones, wireless high-speed home networks, and laptops for schoolchildren are commonplace, why is it so difficult to convince scholars that interactive 3D environments are instructive and not simply eye-catching novelties?"[34]

Interactive 3D computer graphic formats offer the opportunity to reproduce historic built environments as precise replicas, yet most scholars continue to illustrate their publications, teaching materials, and research with the same 2D plans, sections, and elevations that have depicted architecture for centuries. As with the early use of photographs, when computer graphics are included, they are often merely illustrative asides. For reasons similar to those that slowed the acceptance of photography, interactive 3D graphics have been slow to become widely adopted: equipment is awkward and expensive and breaks down frequently; the perceptions that results cannot be trusted (the belief about computer graphics that the images can be too easily

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[33] Sanders, Donald H. "Why do Virtual Heritage?" *Archaeology*. Online features, March 13, 2008. www.archaeology.org/online/features/virtualheritage

[34] Sanders, Donald H. "Why do Virtual Heritage?" *Archaeology*. Online features, March 13, 2008. www.archaeology.org/online/features/virtualheritage

manipulated; the same was said of early photographs); and too few people know how to competently utilize the technique.[35]

While twenty or even just ten, years ago, many of these trepidations would have been valid, the technological advances seen with imaging equipment within this time frame have overcome these issues. Equipment is now more reasonably sized to allow for ease of transportation, and the pieces themselves have become sounder as initial flaws have been addressed by later generations of the technology. True, 3D imaging equipment remains expensive in comparison to drawing supplies but the value will balance out by allowing for a more efficient team that can accomplish the documentation of more sites in the same amount of time. In terms of digital images being falsely altered, that is a risk that will continue so those who need such resources for academic work must be sure they are acquiring their data from a reputable source.

Historian David Staley, executive director of the American Association for History and Computing, wrote:

> Computer visualization can do what prose cannot capture. The real impact of the computer has been as a graphics tool more than as a processor of words. Thus computer graphics can present a deeper and more richly rewarding history by giving a 3D solidity to past places and events, and at the same time act as a repository for the images, words, and objects that together define who we are and how we got here.[36]

Sanders believes that by not utilizing 3D modeling for research, teaching, and publications, academics will be depriving both the profession and the general public of vital information necessary to understanding the past.

[35] Sanders, Donald H. "Why do Virtual Heritage?" *Archaeology*. Online features, March 13, 2008. www.archaeology.org/online/features/virtualheritage

[36] Sanders, Donald H. "Why do Virtual Heritage?" *Archaeology*. Online features, March 13, 2008. www.archaeology.org/online/features/virtualheritage

Engaging the Public

Three dimensional (3D) renderings are an efficient tool for collaborative work, allowing professionals to access and share data easily world-wide. A good model can serve as a basis for scholarly discussion, as well as imparting a sense of place to students and others who view it.[37] Some historic resources must be unfolded, and the key is in the way the object or space presents itself to the observer. For example, an Egyptian Temple has hieroglyphics and other visual cues that are tightly integrated with the physical space itself. Virtual Heritage may be used by on-site archaeologists to convey mental images from the existing fragments, thus becoming a bridge between experts and novices – professionals to laypeople.

The use of virtual models to educate the public about both the history of a site and how to respect the existing facilities should be a top priority of cultural preservation.[38] Until the last decade, models were not easily accessible to the public because personal technology was not at a high enough standard. Currently, powerful multimedia computers with graphics cards are relatively low-cost, and increased Internet bandwidth allows for short download and stream times. While the level of detail that may be shared with the general public is not the quality required by researchers, a lower-resolution model may be supplemented with links to other forms of media including video files.

In 1993, Virtual Stonehenge was the first virtual heritage project to break the supercomputing boundary by running on the common Pentium Pro platform.[39] The Virtual Stonehenge project was created using site data collected by English Heritage, an

[37] Jacobsen, Jeffrey and Holden, Lynn. "Virtual Heritage: Living in the Past" *Techne: Research in Philosophy and Technology*, Vol. 10, No. 3, spring 2007, pp. 55-61
[38] Moltenbrey, K. "Preserving the Past." *Computer Graphics World*. September 2001. pp. 24-30.
[39] Moltenbrey, K. "Preserving the Past." *Computer Graphics World*. September 2001. pp. 24-30.

organization formed by England's 1983 National Heritage Act. While at a resolution of two centimeters it did not allow for the inspection of minute details in the stones, it offered the educational capability to view the site at various stages through time.

Currently, English Heritage is using a combination of 3D laser scanning and digital imaging technology to survey "every inch of every stone that makes up Stonehenge to produce the most accurate digital model ever for the world famous prehistoric monument."[40] Despite the large number of archaeological and academic studies on the site, relatively little is known about the surfaces of the stones themselves. The availability of high-resolution laser scanners means that details and irregularities on the stones surfaces may be recorded as a resolution of 0.5 millimeters. It is hoped that "historic graffiti" hidden under lichen may be revealed upon analysis.

Projected completion of the current Stonehenge study is April 2011 and will serve a number of purposes.[41] The data will serve as a base-line to monitor the physical condition of the monument as it is subjected to daily weathering and will be a valuable resources to those producing the next digital models for public understanding. As the data is processed between April and June 2011, the English Heritage interpretation team will be working on such displays for a proposed visitor center near the site.

The trend of public availability is still in place today with the complex worlds of online games, such as Second Life, running on contemporary off-the-shelf Pentium processors and accelerated graphics cards. Computer-based video game companies have been the key in advancing desktop applications, spending time and money to develop real-time 3D engines that specifically deal with presenting textured and shaded worlds on

[40] English Heritage. "Stonehenge in High Definition." www.english-heritage.org.uk
[41] English Heritage. "Stonehenge in High Definition." www.english-heritage.org.uk

the standard computer. "Access to virtual heritage on the desktop is slowly moving in the right direction, but there are still many technological obstacles, such as…the bandwidth in most locations [needed] for downloading web-based applications."[42] Despite distribution challenges, however, current standards do allow for the building of virtual models of adequate quality for the benefit of the general public.

[42] Moltenbrey, K. "Preserving the Past." *Computer Graphics World*. September 2001. pp. 24-30.

CHAPTER 4

DIGITAL DOCUMENTATION TECHNOLOGIES

As technology plays an increasingly larger role in daily life, documentation is no exception to its influence. Graphic documentation methods are slowly beginning to play primary roles in the preservation of cultural heritage. The demand for 3D models of historic sites is increasing steadily in the architectural and archaeology fields. The motivations vary from documentation in case of loss or damage to tourism and education.[43]

Technology Advances in 3D Modeling

Data collection tools can be grouped into two primary categories: contact or touch and noncontact or camera. Touch systems range from the steel or fiberglass surveyor's tape (and the measuring string of ancient builders) to the optical theodolite or "total station" as today's highly integrated, computer-linked instruments are known.[44] More recently, user-friendly GPS receivers and terrestrial photogrammetry systems are increasingly being supplemented. All touch systems are speed constrained, which affords high accuracy but is by nature slower and more time consuming when used with large architectural-scale objects.

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[43] Remondino, F., El-Hakim, Sabry. "Image-Based 3D Modeling: A Review." *The Photogrammetric Record*, Vol. 21, No. 115, 2006, pp. 269-291.

[44] Addison, Alonzo C. "Virtualized Architectural Heritage: New Tools and Techniques." *IEEE Multimedia*, November/December 2003, pp. 32-41.

Noncontact or camera tools include projected light stripe digitizers, prototype automated stereo video photogrammetry systems, and an array of laser-based scanners.[45] These tools are generally much faster than the contact systems, yet the majority of architectural heritage measurement work today is still performed with relatively limited technology from this area. Noncontact digitizers are beginning to see some use, though limited range hinders usage for landscapes or full sites.

An opportunity exists for these two classes of reality capture technology to come together to offer an integrated suite of tools to the world heritage community. The primary technological hurdles of quality and speed have been overcome, and it now remains to figure out how to perpetuate these technologies and their products into the future. The generation of a 3D model is achieved using non-contact systems based on light waves interacting with sensors.[46]

The two main non-contact technologies that can provide detailed and reliable 3D surface models are photogrammetry through image-based modeling and terrestrial laser scanning (TLS) through range-based modeling.[47] Requirements for the successful application of these technologies in the documentation of cultural resources include: “high geometric accuracy, photo-realism…automation, low cost, portability and flexibility of the modeling technique.”[48]

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[45] Addison, Alonzo C. “Virtualized Architectural Heritage: New Tools and Techniques.” *IEEE Multimedia*, November/December 2003, pp. 32-41.
[46] Remondino, F., El-Hakim, Sabry. “Image-Based 3D Modeling: A Review.” *The Photogrammetric Record*, Vol. 21, No. 115, 2006, pp. 269-291.
[47] Salonia, Paolo, et. al. “Multi-scale cultural heritage survey: Quick digital photogrammetric systems.” *Journal of Cultural Heritage*, Vol. 10, 2009, pp. 59-64.
[48] Remondino, F., El-Hakim, Sabry. “Image-Based 3D Modeling: A Review.” *The Photogrammetric Record*, Vol. 21, No. 115, 2006, pp. 269-291.

Image-Based Modeling and Photogrammetry

Imaged-based modeling (IBM) is a widely used method for geometric surfaces of architectural objects that uses 2D image measurements to recover 3D object information through a mathematical model.[49] IBM may also obtain 3D data using methods such as the determination of shape from shading, texture, or contour. The most accurate measurements are acquired from information gathered from multiple 2D views of the subject (more views equals more accuracy), though a less accurate method does allow for the acquisition of 3D information from a single image. IBM systems are generally very portable, with relatively low-cost software, with financial positives allowing for more widespread use in addition to the possibility of recovering 3D information regardless of the size of the resource. The most well known form of image-based modeling is photogrammetry.

Photogrammetry is defined as: "the art, science, and technology of obtaining reliable information from noncontact imaging and other sensor systems about the Earth and its environment, and other physical objects and processes through recording, measuring, analyzing and representation."[50] It offers an ideal way of capturing, analyzing, measuring and plotting data from images.[51] In the past, photogrammetry was limited in its usage for large buildings and monuments due to its complexity and the need for the use of sophisticated and costly instruments, which in turn limited the number of individuals who could properly learn the technique and employ it accurately.

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[49] Remondino, F., El-Hakim, Sabry. "Image-Based 3D Modeling: A Review." *The Photogrammetric Record*, Vol. 21, No. 115, 2006, pp. 269-291.
[50] International Society for Photogrammetry and Remote Sensing (ISPRS). www.isprs.org
[51] Lerma, Jose L. "Automatic Plotting of Architectural Facades with Multispectral Images." *Journal of Surveying Engineering*, Vol. 131, No. 3, August 2005, pp. 73-77.

The most widespread usage of photogrammetry has been for the representation of the facades/elevations of historic buildings and structures. With consistently improving techniques, digital close-range photogrammetry has become a more efficient and more economic method. One of the most important advantages of using this technology is in measuring dangerous or inaccessible areas.

In most instances, photogrammetry is the process by which two or more two dimensional (2D) images are translated into three dimensional measurements or models of topography, buildings, or objects. Photographs are taken from different angles offering multiple fields of view. A field of view refers to how much visual information a camera can perceive – meaning what may be seen through the lens. A field of view may get larger or smaller depending upon the camera's focal length and its distance from the subject. These fields of view are overlapped and points of commonality are ascertained in order to calculate measurements. Reference points are mapped and then triangulated in relation to one another. As a general rule, the more points that are mapped, the greater allowance for detailed, accurate measurement.

The practice of photogrammetry itself is over one hundred years old, but its digital form is comparatively young. Almagro states that the goal of the International Committee of Architectural Photogrammetry (CIPA) should be to streamline photogrammetry and related techniques into a universal system to allow more widespread use.[52] Most importantly, this should occur with digital photogrammetry and the possibility of using increasingly inexpensive, well circulated computer technology. More common knowledge of computers and sophisticated computer-aided drafting (CAD)

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[52] Almagro, Antonio. *Photogrammetry for Everybody.* 27th CIPA International Symposium on Architectural Photogrammetry, Recife, Brazil, October 1999.

software, as well as the lowering costs of computer hardware are beginning to make this a technique no longer exclusively for specialized technicians. The only slight hindrance is that individuals must be trained in this method of documentation at least in technique and the program basics, but Almagro maintains that this should not be difficult, as most CAD programs are more complex than photogrammetric software.[53]

Studies connected with digital close-range photogrammetry have enhanced its reputation and expanded its use in architectural fields. The most widespread usage of photogrammetric technology is for the representation of facades or elevations of historic structures.[54] In situations where 2D drawings may be inadequate to understand the building and its surroundings, 3D models created through digital photogrammetry and CAD programs allow for a more explanatory illustration of the site. One of the greatest advantages of the technique is the significantly shorter time required to measure the resource.[55] A further advantage is that this method does not require physical contact with the object, thereby avoiding possible damage and allowing for the documentation of areas that are inaccessible to individuals.[56] Quick, high quality data paired with millimetric accuracy for 3D reconstruction and inspection pulls photogrammetry to the forefront of documentation processes.[57]

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[53] Almagro, Antonio. *Photogrammetry for Everybody.* 27th CIPA International Symposium on Architectural Photogrammetry, Recife, Brazil, October 1999.

[54] Yilmaz, H.M. et. al. “Importance of digital close-range photogrammetry in documentation of cultural heritage.” *Journal of Cultural Heritage*, Vol. 8, 2007, pp. 428-433.

[55] Arias, P. et.al. “Methods for documenting historical agro-industrial buildings: a comparative study and a simple photogrammetric method.” *Journal of Cultural Heritage*, Vol. 7, 2006, pp. 250-254.

[56] Arias, P. et.al. “Methods for documenting historical agro-industrial buildings: a comparative study and a simple photogrammetric method.” *Journal of Cultural Heritage*, Vol. 7, 2006, pp. 250-254.

[57] Salonia, Paolo, et. al. “Multi-scale cultural heritage survey: Quick digital photogrammetric systems.” *Journal of Cultural Heritage*, Vol. 10, 2009, pp. 59-64.

Close-range photogrammetric techniques have proved to be useful tools for conservation and restoration projects. The information provided by this method can be used to project work when a reconstruction process is in progress, avoiding alterations to the physical resource.[58] Software such as PhotoModeler™, by Eos Systems, Inc., utilize multi-image photogrammetry and represent a new generation of photogrammetric technology in which photo-realistic textures are now possible in addition to the classic wire-frame model.[59] This development could allow for future use in interactive virtual realities.

Figure 4.1. Original (pre-fire) condition of the subject building in Konya.[61]

Photogrammetry should be promoted and taught to professionals in areas of cultural heritage such as architects, archaeologists, art historians, curators, and preservationists. It is fast becoming a methodology that can be accessible to all and is not more costly than any other common computer software. Almagro states, "photogrammetry should be not only be a synonym for precision, but also one for speed and efficiency as regards to documentation, and an ideal system for producing 3D images…"[60]

[58] Arias, P. et. al. "Control of structural problems in cultural heritage monuments using close-range photogrammetry and computer methods." *Computers and Structures*, Vol. 83, 2005, pp. 1754-1766.
[59] Arias, P. et. al. "Control of structural problems in cultural heritage monuments using close-range photogrammetry and computer methods." *Computers and Structures*, Vol. 83, 2005, pp. 1754-1766.
[60] Almagro, Antonio. *Photogrammetry for Everybody.* 27th CIPA International Symposium on

Example: Konya, Turkey.[61] A historic, run-down eighteenth century, two-story building in Konya, Turkey was destroyed by two fires within a short time span. The Conservation Office of Turkey wanted to reconstruct the historic building, but no official drawings, measurements, or other documentation existed with which to start the project. Coincidentally, about a year prior to the fire, engineering students had used the building in a study to evaluate photogrammetric procedures. The photographs taken by the students were uploaded to the software Photomodeler™, along with pictures of the current remains of the structure. Control points were established and a subsequent line drawing, followed by a 3D skeletal model was created by mapping the established points. Finally, a reconstruction project was drawn by expert architects with full 3D rendering including color and texture. Today, on the site of a destroyed historic building, which had no official documentation, is a nearly exact replica serving as an office building.

Figure 4.2. Post-fire conditions after fire one (left) and fire two (right).[61]

Architectural Photogrammetry, Recife, Brazil, October 1999.

[61] Yilmaz, H.M. et. al. "Importance of digital close-range photogrammetry in documentation of cultural heritage." *Journal of Cultural Heritage,* Vol. 8, 2007, pp. 428-433.

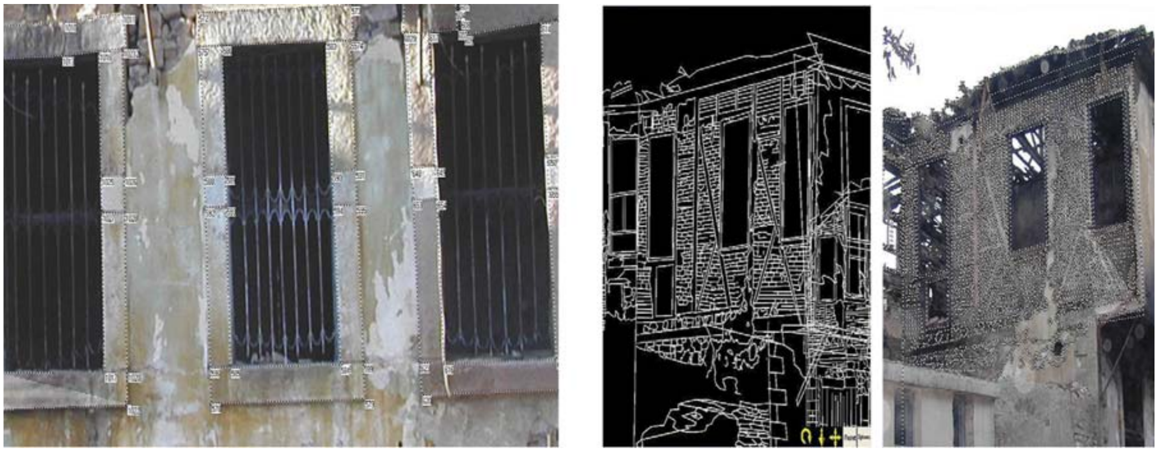

Figure 4.3. The photogrammetric process: identifying points (left), creating a line drawing (middle), and overlaying the photographic image (right).[61]

Figure 4.4. The fully rendered (including color and texture) model of the building in Konya, Turkey.[61]

Figure 4.5. The current state of the reconstructed historic building in Konya, Turkey.[61]

Range-Based Modeling and Terrestrial Laser Scanning

Range-based modeling (RBM) directly captures 3D geometric information, but is based on costly sensors that rely on artificial lights or pattern projection.[62] The past thirty years has seen the development of many active 3D sensors, and advances have been in the field of solid-state electronics. Commercial solutions are becoming widely available, not just to the scientific community, but to non-expert users, including the heritage community.

The sensors involved with RBM are designed for specific ranges or applications and are affected by the reflective characteristics of the subject's surface.[63] These methods demand some expertise based on knowledge of the capability of each type of RBM technology at the desired range, and how the resulting data must be filtered and edited to reflect accurate results. Most of these systems focus only on the acquisition of 3D geometry and provide a monochrome intensity value instead of accurate coloration and texture. There are options that record color information for each pixel, while others have a camera attached to the instrument so texture and color is always registered with the geometry. The method of having a camera attached directly to the scanning equipment however, often does not provide the best results since ideal conditions for scanning and photographing are not the same.[64]

Due to the difficulty of obtaining accurate color and texture information from scans, 3D models are often enhanced by textures recorded by separate high-resolution,

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[62] Remondino, F., El-Hakim, Sabry. "Image-Based 3D Modeling: A Review." *The Photogrammetric Record*, Vol. 21, No. 115, 2006, pp. 269-291.
[63] Remondino, F., El-Hakim, Sabry. "Image-Based 3D Modeling: A Review." *The Photogrammetric Record*, Vol. 21, No. 115, 2006, pp. 269-291.
[64] Remondino, F., El-Hakim, Sabry. "Image-Based 3D Modeling: A Review." *The Photogrammetric Record*, Vol. 21, No. 115, 2006, pp. 269-291.

color digital cameras. The benefit is a highly detailed and accurate representation of most shapes that does not need further manipulation to produce a 3D resource. If long-range sensors are involved, however, there is often a smoothing or blurring effect along the edges of the captured image, which itself will only encompass a portion of the resource if it is a building or site.[65] To account for this fault, overlapping scans must be taken and melded together in a separate process.

Terrestrial laser scanning, a form of range-based modeling, has emerged with the potential to be of major value to architectural documentation over the course of the past decade.[66] Range scanning has a wide variety of applications, though it has traditionally been used in manufacturing inspection to detect defects and in computer-aided design to reverse engineer old mechanical parts.[67] Architectural documentation is among the method's newer uses along with crime investigation and film special effects. It makes a scan or sweep of the environment to map the positions of surfaces within the scanner's line-of-sight.[68]

3D scanning is a surface-based measurement technique that has become more popular with the commercial availability of laser scanners, which automatically and rapidly measure the angles and distances from point to point.[69] As its use in cultural heritage recording has increased, many began to wonder if it could replace close-range

[65] Remondino, F., El-Hakim, Sabry. "Image-Based 3D Modeling: A Review." *The Photogrammetric Record*, Vol. 21, No. 115, 2006, pp. 269-291.
[66] Barber, D., J. Mills and P. Bryan. *Laser Scanning and Photogrammetry: 21st Century Metrology*. Proceedings of the Surveying and Documentation of Historic Buildings - Monuments - Sites Traditional and Modern Methods, *CIPA 2001 International Symposium*, Potsdam, 2001.
[67] Low, Kok-Lim. "Making Digital History." *Innovation*, Vol. 8, Issue 3, page 42–43, 2008.
[68] Low, Kok-Lim. "Making Digital History." *Innovation*, Vol. 8, Issue 3, page 42–43, 2008.
[69] Boehler, W. and Marbs, A., 2004. *3D scanning and photogrammetry for heritage recording: a comparison*. Proceedings of the 12th International Conference on Geoinformatics, Gavle, Sweden, 7th to 9th June 2004.

photogrammetry.[70] With the accuracy of the technology widely ranging between five millimeters and five meters (dependent upon the equipment available for the job), in comparison to photogrammetry's one millimeter to five centimeters, scanning becoming the sole form of documentation is not likely in the near future. The other main disadvantage of this technology is the high cost of the scanning equipment itself in addition to the proper software kit that is necessary to process the raw point data to achieve satisfactory results.[71]

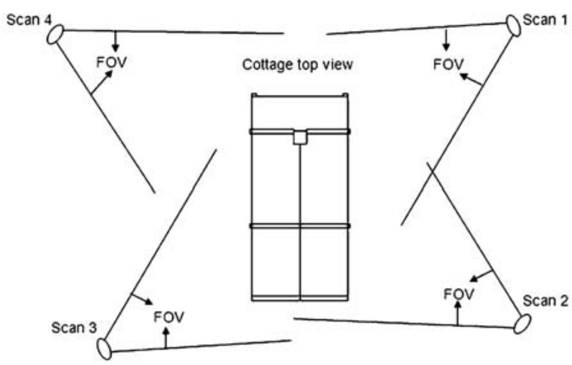

Figure 4.6. Plan view of Cook's Cottage in Melbourne illustrating the positions of the laser scanning stations.[72]

Example: Cook's Cottage, Melbourne, Australia.[72] Cook's Cottage is a heritage site and popular tourist attraction in Melbourne on which a TLS survey was conducted with a Riegl/Nikon D100 combination. Four scanning stations were utilized to gather two million data points and four digital images. Stations were selected to ensure sufficient overlap between images and support subsequent adjustment. In the initial orientation phase, the image coordinate system at one of the camera stations was adopted as the reference system. Subsequent adjustment of the other three stations was performed with

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[70] Boehler, W. and Marbs, A., 2004. *3D scanning and photogrammetry for heritage recording: a comparison*. Proceedings of the 12th International Conference on Geoinformatics, Gavle, Sweden, 7th to 9th June 2004.

[71] Arias. "Methods for documenting historical agro-industrial buildings: a comparative study and a simple photogrammetric method."

[72] Al-Manasir, Khalil, and Clive S. Fraser. "Registration of Terrestrial Laser Scanner Data Using Imagery." *The Photogrammetric Record*, Vol. 21, No. 115, 2006, pp. 255-268.

the same coordinate datum. Identification of common and conjugate points allowed for adjustment of all data sets on the same scale. Alignment of the four laser scans was carried out via equation, resulting in a 3D point cloud.

Figure 4.7. The 3D point cloud resulting from the combination of the data sets from the four scans.[72]

Modeling Combination – The Best Practice

The questions of which technique is better than the other cannot be answered, because, as of yet, there is no one method that satisfies all of the requirements of effective 3D modeling. The technologies discussed above can supplement one another in creating high-quality 3D models. Range sensors are more suited to creating high-resolution geometric models – models that show the overall shape and form of an object. In comparison, digital photogrammetry is the more accurate method for creating models that include color, texture, and pattern.[73]

Photogrammetry and laser scanning have therefore been combined in many instances, particularly for complex or large architectural objects or sites, where no one technique alone could efficiently and quickly provide a complete and detailed model.[74]

[73] Guarnieri A., Remondino F., Vettore A., 2006. *Digital photogrammetry and TLS data fusion applied to Cultural Heritage 3D modeling*. In Proc. of ISPRS Comm. V Symposium "Image Engineering and Vision Metrology", Dresden, Germany.
[74] Remondino, F., El-Hakim, Sabry. "Image-Based 3D Modeling: A Review." *The Photogrammetric Record*, Vol. 21, No. 115, 2006, pp. 269-291.

Having both photo-realism and smooth navigation through a 3D model is not usually feasible without simplification or creative rendering techniques.[75] Computer hardware is always improving, but as it does so the standard for realism increases as well in a perpetual cycle.

Figure 4.8. A photograph of the south façade of Villa Giovanelli.[76]

Example: Villa Giovanelli, Brenta Riviera, Italy.[76] Villa Giovanelli represents one of the most important buildings among the Venetian villas along the Brenta Riviera. Built in 1670 in the Palladian style and enlarged in 1738, by adding the great staircase on the main façade, the villa is located close to the city of Padua. The Villa represented a

[75] Remondino, F., El-Hakim, Sabry. "Image-Based 3D Modeling: A Review." *The Photogrammetric Record*, Vol. 21, No. 115, 2006, pp. 269-291.

[76] Guarnieri A., Remondino F., Vettore A., 2006. *Digital photogrammetry and TLS data fusion applied to Cultural Heritage 3D modeling*. In Proc. of ISPRS Comm. V Symposium "Image Engineering and Vision Metrology", Dresden, Germany.

challenging task for 3D modeling, given its complexity – in addition to the regular geometry of the body of the building other architectural details such as columns, turrets, statues, and stairs. In order to create a unique 3D model of the entire exterior of the Villa with enough quality of both geometric and detail information such as color and texture, a hybrid method of independent surveying techniques was adopted.

A survey of the exterior of Villa Giovanelli was performed with a high precision Terrestrial Laser Scanner (TLS), in this case the Leica HDS 3000.[77] This system allows for a larger field of view as well as the ability to acquire minimal color data at different user selected pixel resolutions, through a built-in camera. Point clouds were acquired with a spatial resolution of one centimeter. This value was chosen as an acceptable compromise between level of detail in the final model and the time and computing resources needed. Fifty scans were performed over the course of multiple days, resulting in a dataset of thirty million points.

A photographic survey was also performed, composed of high-resolution digital images captured with a Casio Exlim 750 camera.[78] About three hundred images were acquired in one day, keeping the camera at the minimum focal length with the highest resolution in order to accurately document textures. Image overlap was at least fifty percent, and the distance of the camera from the structure was between five and forty meters. The data from both survey methods were first processed independently creating two different 3D models.

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[77] Guarnieri A., Remondino F., Vettore A., 2006. *Digital photogrammetry and TLS data fusion applied to Cultural Heritage 3D modeling*. In Proc. of ISPRS Comm. V Symposium “Image Engineering and Vision Metrology”, Dresden, Germany.

[78] Guarnieri A., Remondino F., Vettore A., 2006. *Digital photogrammetry and TLS data fusion applied to Cultural Heritage 3D modeling*. In Proc. of ISPRS Comm. V Symposium “Image Engineering and Vision Metrology”, Dresden, Germany.

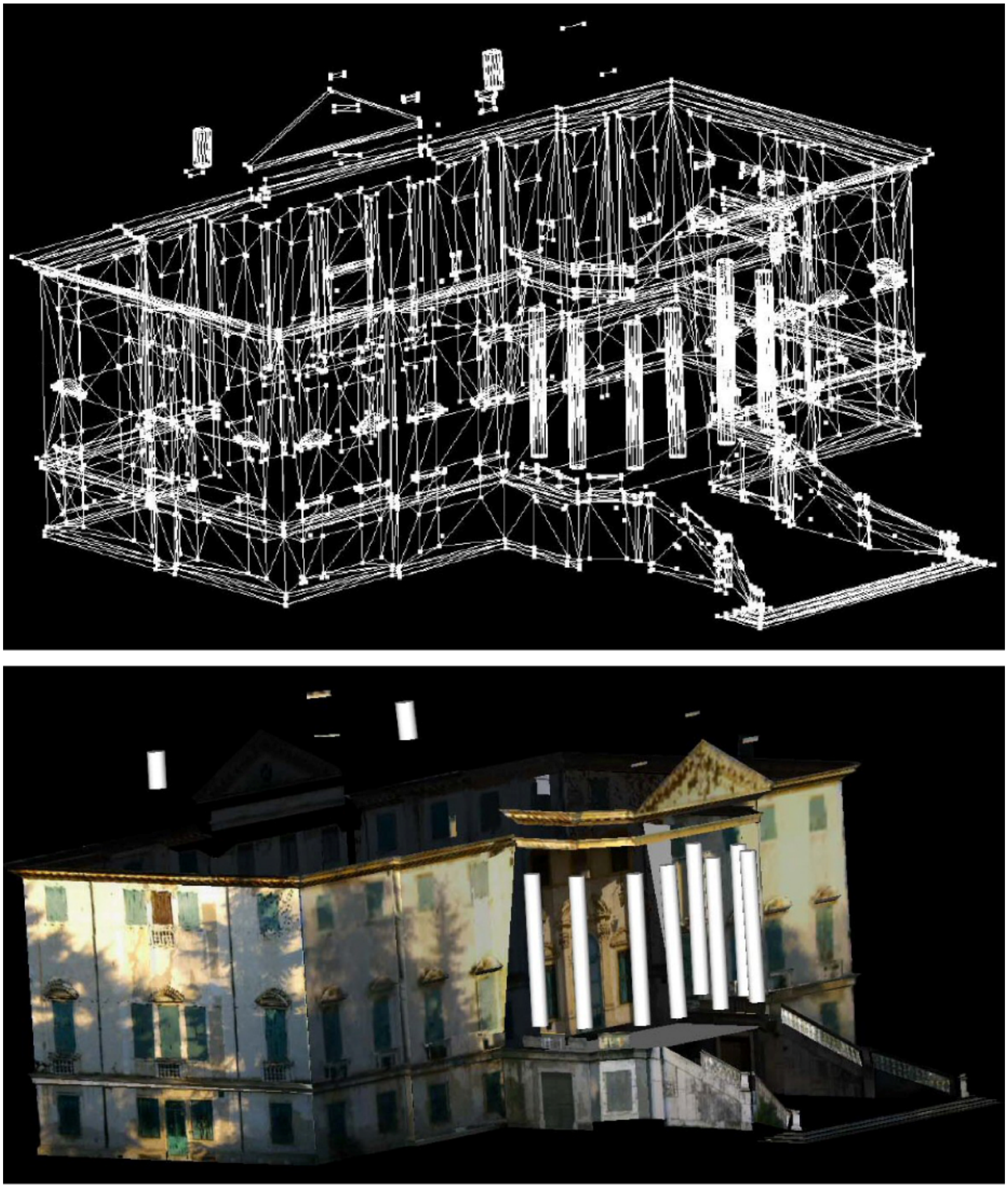

Figure 4.9. Photomodeler™ results from the photogrammetric data in wireframe mode (left) and after image texturing.[79]

About ninety of the three hundred digital images were uploaded into Photomodeler™ software to create a 3D model.[79] The data was divided into four project sets of information by façade. For each project a first set of matching points was manually selected among adjacent images and the corresponding orientation computed. Further geometric details such as cylinders were added to improve the detail of each project model. Then all four project models were merged together by selecting commonly distributed points from within the partial models. The successive generation of the geometric model is one enhanced by the application of textures onto the generated surfaces. It should be noted that shadows and vegetation may prevent the generation of a proper photo-realistic model. Obstructions are obviously undesirable and should be removed as much as possible in a pre-processing step.

To align and merge the data from the scans and produce a model, Polyworks™ software was used. At the end of the process, a residual error of nine millimeters is obtained.[80] Once 3D registration is completed, data reduction is applied in order to obtain a simplified model that can be easily edited, triangulated, and combined with the photogrammetric model. Redundant data is generally in the overlapping areas of the scans, and the best set of non-overlapping data points are identified. This will reduce the memory usage and speed up the process of meshing the 3D models. After data reduction, the point cloud contains approximately three million points. A triangulated surface model

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[79] Guarnieri A., Remondino F., Vettore A., 2006. *Digital photogrammetry and TLS data fusion applied to Cultural Heritage 3D modeling*. In Proc. of ISPRS Comm. V Symposium "Image Engineering and Vision Metrology", Dresden, Germany.

[80] Guarnieri A., Remondino F., Vettore A., 2006. *Digital photogrammetry and TLS data fusion applied to Cultural Heritage 3D modeling*. In Proc. of ISPRS Comm. V Symposium "Image Engineering and Vision Metrology", Dresden, Germany.

is generated and modeling efforts are made with those elements that represented a hard task for the photogrammetric process – in this case the turrets, staircase, and statues.

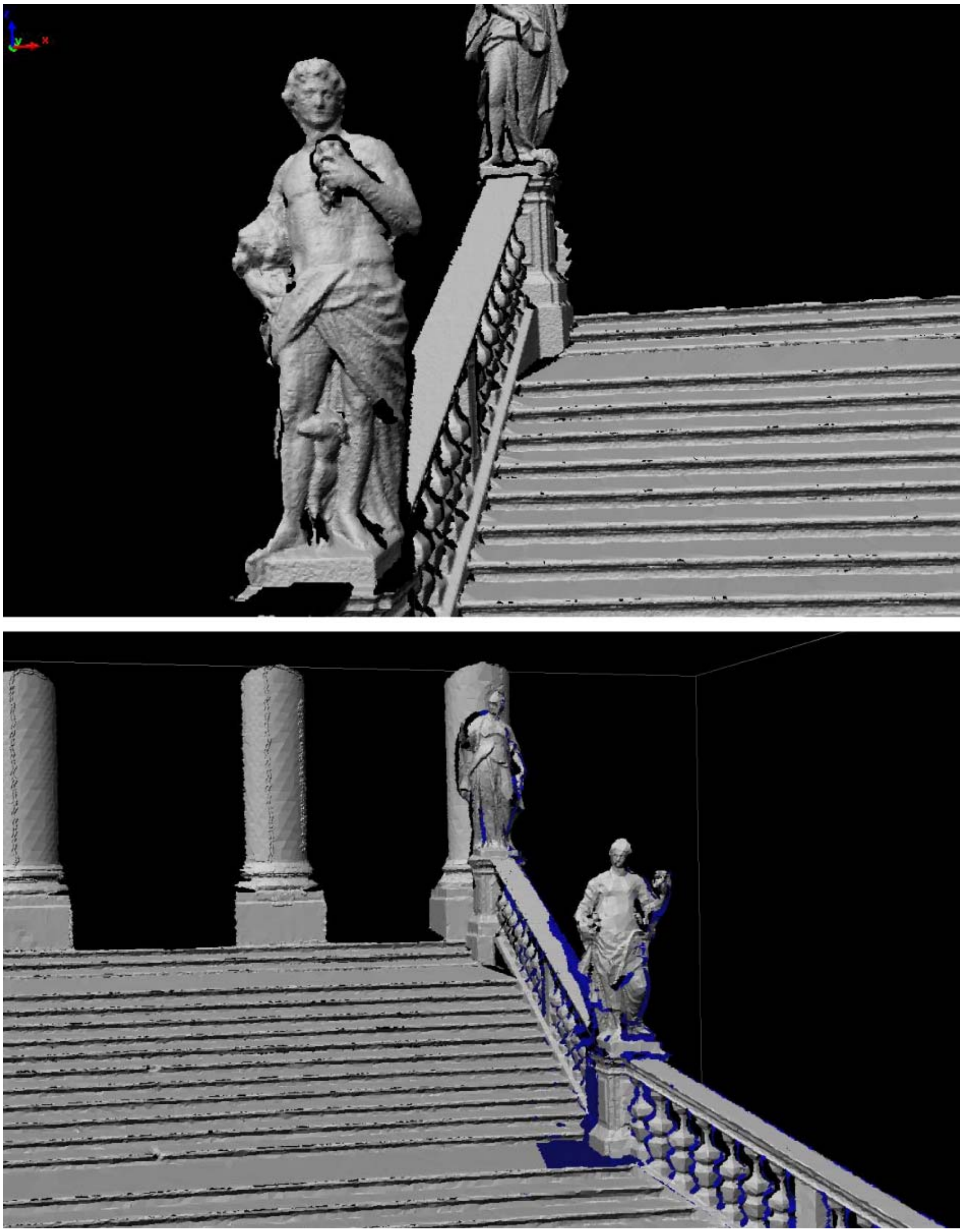

Figure 4.10. Results of the laser scan data combined in Polyworks™.[80]

This project aimed to create a unique 3D virtual representation where photogrammetric and laser scanning data are merged together so that the final product can be seamlessly explored.[81] In order to be properly combined, the two datasets must first be related in a common reference system, which in this case was defined by the total station survey. Both 3D models are imported into Rhino™ software to achieve the final representation of the Villa. The unified model is edited in order to create or reconstruct those parts of the building which could not be properly imaged or scanned given their geometry and position with respect to data capture stations. The main points of editing were the roof, the turrets, and other minor elements such as two chimneys.

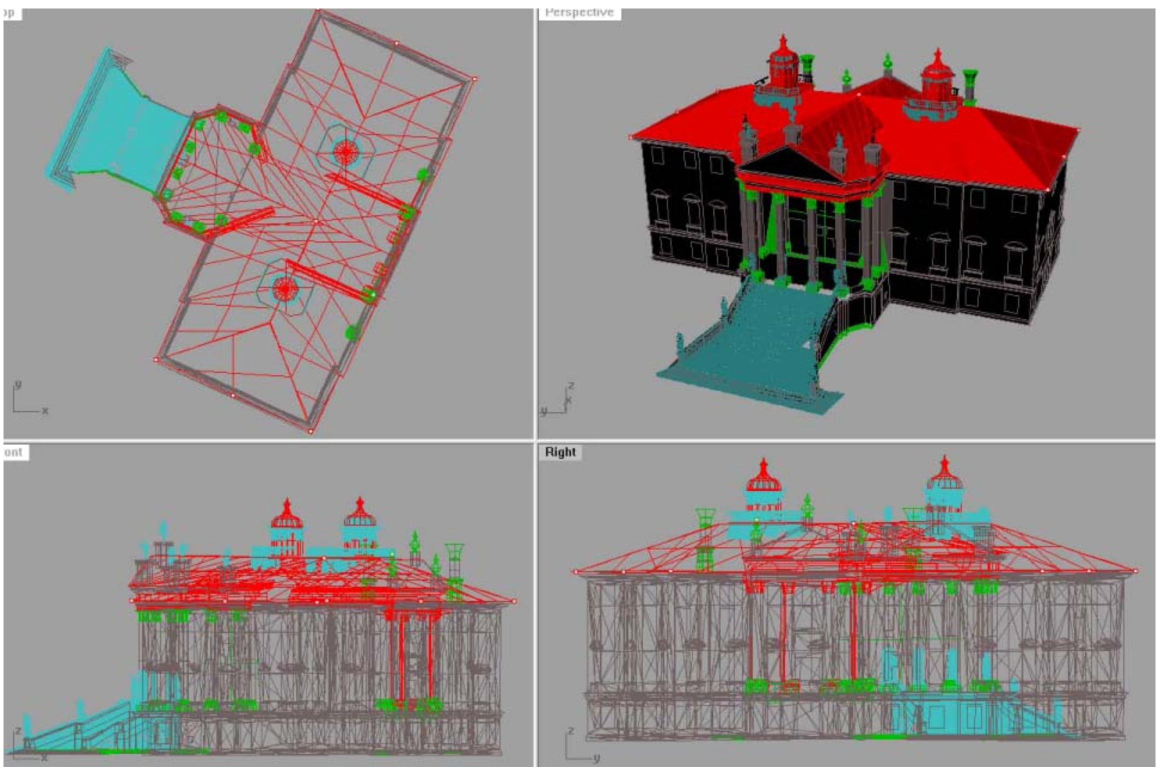

Figure 4.11. Resulting wireframe model when the photogrammetric and laser scanned models are combined.[81]

[81] Guarnieri A., Remondino F., Vettore A., 2006. *Digital photogrammetry and TLS data fusion applied to Cultural Heritage 3D modeling*. In Proc. of ISPRS Comm. V Symposium "Image Engineering and Vision Metrology", Dresden, Germany.

The last step is rendering the 3D model using the textures already existing and associated to the photogrammetric model and creating new ones for the laser scanner data.[82] New elements, such as landscaping are added via a materials library within Rhino™. The different resolutions of the photogrammetric and TLS models did not cause a problem during integration. Improper photo-realistic results were caused by shadows and vegetation – issues which, in the future, should be considered before image acquisition. This hybrid project demonstrates that these technologies, when properly employed, can supplement each other to create high-quality 3D models and presentations.

Figure 4.12. Unified 3D model of the heritage building, fully rendered with color, texture, and landscape elements.[82]

[82] Guarnieri A., Remondino F., Vettore A., 2006. *Digital photogrammetry and TLS data fusion applied to Cultural Heritage 3D modeling*. In Proc. of ISPRS Comm. V Symposium "Image Engineering and Vision Metrology", Dresden, Germany.

CHAPTER 5

PROBLEMS POSED BY DIGITAL DOCUMENTATION

In 1998, at UNESCO's World Panel on Communication and Information, Vasquez de Parga stated that digital preservation is "the greatest challenge facing the archive community throughout the world."[83] Aside from potential language barriers, an ancient scroll document is "accessed" much in the same way as a modern book. We know that photographic negatives, transparencies, and prints last a long time and may still be reprinted 100 years into the future. With digital media however, there is, as yet, no such guarantee. The evolution of both hardware and software at a rapid pace often makes viewing older files a difficult proposal. Many also fear that since the common usage of digital media has been but a short time, a similar fate may befall the information stored in this way as did the microfilm of the 1930s. The longevity problem may be divided into two questions: the lifespan of the physical media upon which the information is stored; and the obsolescence of the file format and hardware.

Physical Media

Digital information must be stored on physical media, and the lifespan of these mediums are limited.[84] CD-Rs and DVD-Rs both use organic dyes that respond to temperature and humidity over time.[85] "Accelerated aging" tests have been conducted by

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[83] Thomaz, Katia P. "Critical Factors for Digital Records Preservation." *Journal of Information, Information Technology, and Organizations*, Volume 1, 2006.

[84] Jackson, Julian. "Digital Longevity: the lifespan of digital files." Digital Preservation Coalition. www.dcponline.org/graphics/events/digitallongevity.html. Accessed July 7, 2009.

[85] Wantanabe, Keith. *Evolution, Availability, Longevity*. Joint Technical Symposium, 2004.

manufacturers, which subjected discs to high temperatures and humidity.[86] A failure point was estimated after analyzing the degradation data. The National Institute of Standards & Technology (NIST) found DVD-R authoring discs to last twenty-five years using a similar testing process.[87] The reflective layer of most CD-Rs and DVD-Rs consists of aluminum, which can be subject to "rot" as the metal oxidizes. A more stable Silver CD, which is estimated to last one- to two- hundred years, is recommended.[88] The physical lifetime of the media is however, no match for its obsolescence.

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According to Rothenberg, on average, a given digital storage medium becomes obsolete within five years.[89] While this was the case with many previous disc forms – multiple sizes of floppy, SuperDisk, Iomega Zip, etcetera – at present, CD-ROMs have been in use for over that length of time. Additionally, with the introduction of external hard drives that are accessed via universal USB and/or Firewire connections, the same mediums will likely be used for many more years with minor improvements, such as the amount of information that may be stored on one device. Archiving on older media types

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[86] Rothenberg, Jeff. "Ensuring the Longevity of Digital Documents." *Council on Library and Information Resources*. February 1999. Accessed June 20, 2009. http://www.clir.org/pubs/archives/ensuring.pdf (expansion of January 1995 article appearing in *Scientific American*, Vol. 272, No. 1, pages 42–27)

[87] Rothenberg, Jeff. "Ensuring the Longevity of Digital Documents." *Council on Library and Information Resources*. February 1999. Accessed June 20, 2009. http://www.clir.org/pubs/archives/ensuring.pdf (expansion of January 1995 article appearing in *Scientific American*, Vol. 272, No. 1, pages 42–27)

[88] Wantanabe, Keith. *Evolution, Availability, Longevity*. Joint Technical Symposium, 2004.

[89] Rothenberg, Jeff. "Ensuring the Longevity of Digital Documents." *Council on Library and Information Resources*. February 1999. Accessed June 20, 2009. http://www.clir.org/pubs/archives/ensuring.pdf (expansion of January 1995 article appearing in *Scientific American*, Vol. 272, No. 1, pages 42–27)

brings in the issue of hardware. Computers with floppy disk drives or zip drives would have to be maintained in order to be able to access the data stored on them.

Format and Hardware

A larger concern than the corruption, degradation, or obsolescence of the storage media is the likelihood of outdated hardware and unavailability of the appropriate software.[90] The rapidity with which technology evolves can become a hindrance as new media or formats supersede the current iteration.

Many file types embed special data that only the software that created them can interpret. For example, word processing programs include information to describe typography, layout, and structure (identification of titles, chapters, headings, etc.).[91] Essentially, document files are miniature programs, consisting of instructions and data that can be properly decoded only by the authoring software. Therefore, without the original program, or compatible equivalent, the document is “held hostage to its own encoding.”[92]

Thus far, the evolution of information technology has continually created new paradigms due to abandoning its predecessors rather than incorporating them.[93] Future software should allow for the import of documents from older comparable programs. For example, Microsoft Office 2007 can open documents created as far back as Word97,

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[90] Rothenberg, Jeff. “Ensuring the Longevity of Digital Documents.” *Council on Library and Information Resources*. February 1999. Accessed June 20, 2009. http://www.clir.org/pubs/archives/ensuring.pdf (expansion of January 1995 article appearing in *Scientific American*, Vol. 272, No. 1, pages 42–27)

[91] Rothenberg, Jeff. “Ensuring the Longevity of Digital Documents.” *Council on Library and Information Resources*. February 1999. Accessed June 20, 2009. http://www.clir.org/pubs/archives/ensuring.pdf (expansion of January 1995 article appearing in *Scientific American*, Vol. 272, No. 1, pages 42–27)

[92] Rothenberg, Jeff. “Ensuring the Longevity of Digital Documents.” *Council on Library and Information Resources*. February 1999. Accessed June 20, 2009. http://www.clir.org/pubs/archives/ensuring.pdf (expansion of January 1995 article appearing in *Scientific American*, Vol. 272, No. 1, pages 42–27)

[93] Rothenberg, Jeff. “Ensuring the Longevity of Digital Documents.” *Council on Library and Information Resources*. February 1999. Accessed June 20, 2009. http://www.clir.org/pubs/archives/ensuring.pdf (expansion of January 1995 article appearing in *Scientific American*, Vol. 272, No. 1, pages 42–27)

creating convenience for the typical user, but those involved with archiving would further benefit if files created in Microsoft Works or Word Perfect were also readable within the current interface. Ideally the future software that replaces Word (or Photoshop, or any other major program) will allow for full backward compatibility along with the necessary technical support. This is feasible with the technology and programming knowledge currently held by software and hardware companies. The main issue will be convincing major companies that additional programming time and money will be profitable.

A digital document depends not just upon the specific software program that created it, but the entire suite of hardware that allowed the program to run, the operating system, processor and more.[94] One way to ensure that digital documents are readable is to include the software and hardware information on the same media, so that it can be recreated if possible.

In many cases the physical presence of the original software and hardware is not necessary. Referring to the appropriate application and system software via compatibility mode on current hardware (for example, PCs running a Windows platform simulate as far back as Windows 95), allows old programs to be mirrored on new operating systems. Additionally, the amount of free (public-domain) software, often referred to as freeware, is multiplying on the Internet. One of the best known, Open Office, is a freeware version of Microsoft Office that includes comparable and exchangeable word processing, database, presentation, and spreadsheet platforms. Ideally copyright and royalty restrictions will expire as programs become obsolete, making them available for future access to historical documents as freeware.

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[94] Rothenberg, Jeff. “Ensuring the Longevity of Digital Documents.” *Council on Library and Information Resources*. February 1999. Accessed June 20, 2009. http://www.clir.org/pubs/archives/ensuring.pdf (expansion of January 1995 article appearing in *Scientific American*, Vol. 272, No. 1, pages 42–27)

<u>Digital Preservation Options</u>

A 1996 report to the United States Commission on Preservation and Access delineated strategic approaches for keeping digital information viable over time.[95] Three options were discussed as possibilities for digital data preservation:

Refreshing. Refreshing involves periodically moving a file or files from one type of physical storage media to another to avoid the physical decay or obsolescence of the medium.[96] For example, information on floppy and zip disks would need to be copied to CD-ROMs and/or external hard drives so the drivers to read the outdated medium would not need to be maintained. While this is a step in the right direction, transferring data files to new media alone is not enough if the appropriate software is not available to read them.

Migration. This process encompasses refreshing, copying the files onto fresh, new media, but in addition includes translating the data file from one encoding format to another that is usable in a current computing environment (for example: from Word95 to Word2007 or Photoshop7 to PhotoshopCS5). [97] "Migration seeks to limit the problem of files encoded in a wide variety of formats that have existed over time by gradually bringing all former formats into a limited number of contemporary ones."[98]

Migration requires consistent effort as future access depends upon an unbroken chain of migrations with a cycle time short enough to prevent both the media and file

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[95] Jackson, Julian. "Digital Longevity: the lifespan of digital files." Digital Preservation Coalition. www.dcponline.org/graphics/events/digitiallongevity.html. Accessed July 7, 2009.
[96] Jackson, Julian. "Digital Longevity: the lifespan of digital files." Digital Preservation Coalition. www.dcponline.org/graphics/events/digitiallongevity.html. Accessed July 7, 2009.
[97] Rothenberg, Jeff. "Ensuring the Longevity of Digital Documents." *Council on Library and Information Resources*. February 1999. Accessed June 20, 2009. http://www.clir.org/pubs/archives/ensuring.pdf (expansion of January 1995 article appearing in *Scientific American*, Vol. 272, No. 1, pages 42–27)
[98] Jackson, Julian. "Digital Longevity: the lifespan of digital files." Digital Preservation Coalition. www.dcponline.org/graphics/events/digitiallongevity.html. Accessed July 7, 2009.

format from becoming physically degraded or entirely obsolete.[99] Given the current technology development rate, migration cycles would need to be as frequent as every three- to- five- years. Migration's translation approach side-steps the ultimate need for a standardized file format, but compounds the problem of losing information, in the way that transcribing ancient writings to modern English would. An alternative to translating a digital document is to view it by using the software that created it. This would require saving the authoring programs and any system software required to run those programs along with the digital document files in one place. Though a daunting task, this is feasible, especially with the capacity currently available on one media device.

The migration process also eliminates the need to preserve storage device readers such as disk drives, but systems and application software are still dependent on hardware, both for viewing and editing.[100] An obvious approach would be to maintain older computers in working condition, but this will quickly become problematic as models are phased out and replacement parts are not available for repairs. Moreover, if records were migrated to newer media, using old computers would require building special-purpose interfaces between each old computer and new generations of storage media.

Emulation. This approach focuses on the applications software rather than on the specific files containing information.[101] Emulators are programs that mimic the behavior of obsolete hardware and can be used to take their place within a modern computing

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[99] Rothenberg, Jeff. "Ensuring the Longevity of Digital Documents." *Council on Library and Information Resources*. February 1999. Accessed June 20, 2009. http://www.clir.org/pubs/archives/ensuring.pdf (expansion of January 1995 article appearing in *Scientific American*, Vol. 272, No. 1, pages 42–27)

[100] Rothenberg, Jeff. "Ensuring the Longevity of Digital Documents." *Council on Library and Information Resources*. February 1999. Accessed June 20, 2009. http://www.clir.org/pubs/archives/ensuring.pdf (expansion of January 1995 article appearing in *Scientific American*, Vol. 272, No. 1, pages 42–27)

[101] Jackson, Julian. "Digital Longevity: the lifespan of digital files." Digital Preservation Coalition. www.dcponline.org/graphics/events/digitiallongevity.html. Accessed July 7, 2009.

system.[102] Supporters of emulation want to build software that is capable of mimicking every type of application that has ever been written for every type of file format, and make them run within whatever the current computer environment is, effectively allowing programs such as WordStar to run on a modern computer. Emulation eliminates the need to maintain older model computers and hardware, as well as the need to migrate files to newer formats, though a refreshing process would still be necessary to keep data on compatible media. This has already begun to successfully occur amongst special interest network groups, currently creating and sharing emulators for obsolete video game processors, like the original Nintendo Entertainment System (NES) and early personal computers, such as the Apple II.

File Format Standardization

Today's standards of information circulation – much of it existing exclusively in a digital format – have caused digital document accessibility to become a major concern.[103] In 2008, the National Digital Information Infrastructure and Preservation Program (NDIIPP) convened working groups to draft guidelines for digitization to advance the possibility of standardization.[104] The World Wide Web Consortium (W3C) is a group that develops web standards based on the premise that all individuals, internationally, who have access to the Internet should be able to view all posted information, creating a truly global information system.

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[102] Rothenberg, Jeff. "Ensuring the Longevity of Digital Documents." *Council on Library and Information Resources*. February 1999. Accessed June 20, 2009. http://www.clir.org/pubs/archives/ensuring.pdf (expansion of January 1995 article appearing in *Scientific American*, Vol. 272, No. 1, pages 42–27)

[103] Turro, Maireia Ribera. "Are PDF Documents Accessible?" *Information Technology and Libraries*, Vol. 27, No. 3, pp. 25-43, 2008.

[104] Fleischhauer, Carl. "Digitizing History (and Preserving History in the Making)." Presented at the Government Video Technology Expo, Washington, D.C., December 3, 2008.

Many countries have enacted legislative measures concerning digital accessibility, generally concerning legibility for disabled persons such as those who are blind.[105] For example, HTML documents are considered universally accessible if they comply with the Web Content Accessibility Guidelines, produced by W3C in 1999 and updated in 2006.[106] Their true universality, however, is dependent upon the compatibility of the browser and necessary assistive technologies such as screen magnifiers and screen readers.[107]

It is possible, and likely, with more information being created and stored only in a digital format, that a standard for non-web based files will soon exist. A standard is the best solution to the long-term management and preservation of digital information, as it will avoid the compatibility problems faced by current archivists in future generations. The beginnings of this can be seen in the practicality and popularity of the current PDF format that can be accessed with the freeware, Adobe Reader, giving all personal computer users access to this file type.

Thus far, the PDF remains a "de facto standard," meaning that it is a standard only as long as Adobe chooses not to change it.[108] The PDF is a descendent of Postscript and, in its latest versions, "incorporates functions of digital management of access rights (DRM) and allows information providers to regulate the permission to view, print, extract, and modify the content."[109] It is also possible to have PDF documents of varying quality:

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[105] World Wide Web Consortium. www.w3.org/wai/policy

[106] World Wide Web Consortium. www.w3.org/tr/wacg20

[107] Turro, Maireia Ribera. "Are PDF Documents Accessible?" *Information Technology and Libraries,* Vol. 27, No. 3, pp. 25-43, 2008.

[108] McCargar, Victoria. "Standards Are on the Way, but Will They Help?" *The Seybold Report: Analyzing Publishing Techniques,* February 9, 2005.

[109] Turro, Maireia Ribera. "Are PDF Documents Accessible?" *Information Technology and Libraries,*

PDF image files are scanned or photographed versions of a print document. This will allow an individual to open the file and view the content, but not to alter it. It is also problematic for those with disabilities, as the text will not be encoded for screen readers to read aloud.

PDF text documents are created from scans or photographs, but the text has gone through an optical character recognition (OCR) process and incorporates the words as text rather than image. This does allow for screen readers, as well as the export of the content to a word processing program for editing. The amount of errors found in these documents is dependent upon the quality of the initial scan and of the OCR program used. An additional problem is that nuances such as footnotes and headers may not be translated clearly as such.

PDF documents with ordered text have the correct reading order established, clearly identifying footnotes, sidebars, headers, and other devices. Ordering the text can happen during the initial creation of the PDF document or during an edit at a later stage.

Tagged PDF documents offer the highest level of accessibility, containing ordered text, and structural tags that identify tables, lists, etcetera, in addition to footnotes and headers. Tagging is only achieved through post-processing a PDF document that has already been created.

The PDF is becoming increasingly full-featured and now allows the embedding of audio and video. It is also the main format used for digital publishing, such as the electronic versions of academic journals.[110] The PDF/A, or archival PDF, is a sub-format of the PDF and is the preferred file type for digital preservation in many large libraries,

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Vol. 27, No. 3, pp. 25-43, 2008.

[110] Turro, Maireia Ribera. "Are PDF Documents Accessible?" *Information Technology and Libraries*, Vol. 27, No. 3, pp. 25-43, 2008.

including the Library of Congress.[111] With all of these benefits, however, the vast majority of PDFs are still image files that allow little flexibility.

The largest challenge that will need to be overcome in order to ensure the success of an intelligent or universal file format is for software companies – such as Microsoft and Adobe – to agree to allow export of this file type from within their software. Programmers will be caught between the desire for open standards and the desire of software vendors to be proprietary. The PDF is a proprietary format, but Adobe regularly publishes the specification of format, allowing it to be used by third parties free of charge.[112]

The PDF format still faces three major challenges before it can serve as a true standard: the creation of authoring tools within Acrobat that allow for easy editing; a further opening of the format by Adobe; and a greater wealth of tags and other attributes that allow for full access by disabled users.[113] The latest versions of Adobe PDF have greatly increased possibilities with regard to universal accessibility and are almost comparable with that of HTML on the Web.

Once the ideal of a file standard has been accomplished, it will still remain to develop a system of digitally archiving all such documents. "One area where standardization is undergoing close scrutiny is the development of metadata for preservation."[114] Metadata is information that describes the data within a file – a type of keyword system. With the beginnings of digital archiving there has been a rush to

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[111] Turro, Maireia Ribera. "Are PDF Documents Accessible?" *Information Technology and Libraries*, Vol. 27, No. 3, pp. 25-43, 2008.
[112] Turro, Maireia Ribera. "Are PDF Documents Accessible?" *Information Technology and Libraries*, Vol. 27, No. 3, pp. 25-43, 2008.
[113] Turro, Maireia Ribera. "Are PDF Documents Accessible?" *Information Technology and Libraries*, Vol. 27, No. 3, pp. 25-43, 2008.
[114] McCargar, Victoria. "Standards Are on the Way, but Will They Help?" *The Seybold Report: Analyzing Publishing Techniques*, February 9, 2005.

develop metadata suites designed to enhance search and retrieval, in addition to allowing for long-term access.[115] Known as PREMIS, Preservation Metadata Implementation Strategies is a project working to create a core metadata standard for long-term sustainability. [116]

In another ambitious effort, in 2004 the national archives of the United Kingdom began to develop a registry of file formats and their technical requirements, both current and obsolete.[117] This registry, called PRONOM, includes 600 file formats, 250 software products, and about 100 vendors. Large companies such as Microsoft and Adobe have provided information about their file formats to the registry and encourage participation from others. A major challenge to the project is convincing companies to release enough useful information to support preservation activity of a multitude of file types before a universal standard is accomplished.

While a myriad of issues are still present with regard to universal accessibility to digital data, current technology is beginning to address the issue, and great strides will likely be made within the next decade. Adobe's PDF is clearly the leader in standardized file formats, but whether more advantageous alternatives exist remains to be seen. For the present time, it is important to remember that: "digital resources will not survive or remain accessible by accident: pro-active preservation is needed."[118]

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[115] McCargar, Victoria. "Standards Are on the Way, but Will They Help?" *The Seybold Report: Analyzing Publishing Techniques*, February 9, 2005.
[116] McCargar, Victoria. "Standards Are on the Way, but Will They Help?" *The Seybold Report: Analyzing Publishing Techniques*, February 9, 2005.
[117] McCargar, Victoria. "Standards Are on the Way, but Will They Help?" *The Seybold Report: Analyzing Publishing Techniques*, February 9, 2005.
[118] Jackson, Julian. "Digital Longevity: the lifespan of digital files." Digital Preservation Coalition. www.dcponline.org/graphics/events/digitiallongevity.html. Accessed July 7, 2009.

CHAPTER 6

CONCLUSION

While the topics discussed in this thesis will continue to be developed throughout the course of the next decades, a roadmap toward digital documentation and archiving is clearly set. Increasingly, academic research and documents exist solely in a digital format, and this is bound to increase as time passes. Each successive generation incorporates technology into their lives to a greater degree, so fully digital archival processes are not just a possibility, but an eventuality. Photogrammetry and terrestrial laser scanning are leading the way for digital documentation of historic resources, and the archival PDF is the beginning of a system to ensure that documents will continue to be accessible into the future.

A question that is raised by the information acquired through the course of this research is whether documentation standards should change before the digital preservation issues outlined in the last chapter are solved. While there may be monotonous, time-consuming conversion involved until the availability of truly universal file and media formats, it is entirely feasible to keep files relevant and readable. Whether or not the academic and research community is ready, digital documentation is already prevalent and there is much research that is not published in any other manner.

The examples displayed in the course of this research in addition to the many more that may be accessed by the public via the websites of CyArk, The Scottish Ten, and similar organizations show that current technology has the capability to compete with the quality traditional documentation methods. It is file longevity and compatibility issues that pose problems, but the foundation to overcome these has already been laid. If governments and organizations begin the digitization efforts small, and build upon them in an internally compatible manner, success will follow. The rate at which technology changes, while a flaw when considering file and software compatibility can also be its greatest asset as a comprehensive and straightforward solution should be created in the near future.

While it may be prudent to be cautious about solely digital documentation for the time being, it should also not be discounted as a primary informative source. The current standards of Federal programs allow submission of digital materials, but do not allow it to fulfill any documentation criteria. A small start would be to accept digital photographs rather than large format film. Resolution, file size, and color versus black and white preference may be specified. Additionally, one of the largest arguments against digital photographs – that a 35mm digital camera could not compete with the quality of a large format film camera – has become moot.

Hardware called “digital backs” have been gaining in popularity amongst professional photographers for the last five- to- seven years. These backs are compatible with most medium and large format camera bodies, allowing for the full range of advantages of the format – rise and fall, tilt, shift, swing, etcetera – but the resulting digital product is stored either on the internal memory or a data card within the back. Further the resolution of digital cameras has become such that it can fully compete with film. Leaf, one of the leaders in digital camera backs, released the Leaf Aptus II - 12 in 2010 which creates images with an astonishing resolution of 80 megapixels.

While the hardware to get a digital documentation program started is costly, it will pay for itself in the end as the need for film and printing will be eliminated. Digital image files should be saved in the JPEG (or JPG) format, as this file type is the most likely to be readable with all future technology. JPEG has been the preferred image format since it has been in continuous use for twenty years.

Future research may address an actual plan or programming model for digital compatibility, outlining how long migration cycles should be and how long successive computer models should be up-kept before abandoning them for newer iterations. Taking a cue from the realm of video gaming, emulators should be perfected and expanded, because maintaining updated emulators would eliminate the need to retain outdated hardware and software.

As the practices of photogrammetry and 3D scanning progress, ways to incorporate the data from each into one comprehensive format, and eventually a method that encompasses both technologies in one process would increase the accuracy and efficiency of digital documentation. As with any process, a series of best practices must be outlined and utilized to exploit the advantages of each technology while at least compensating for if not overriding the weaknesses.

A digital future for cultural resources would benefit the academic community and the general public. Scholars from anywhere in the world would have the ability to study resources via highly-detailed models, and everyone from students to history enthusiasts would be able to interact with previous cultures in a virtual world. Further it is almost inevitable that some heritage resources are lost to natural disaster and human intervention. Maintaining a digital record now, especially a three-dimensional one will allow for future generations to see what is no longer present. Perhaps it will encourage them to be better stewards of world heritage than the past and current generations.

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<u>Organizations</u>

American Society for Photogrammetry and Remote Sensing (ASPRS)
www.asprs.org

Association for Preservation Technology International (APTI)
www.apti.org

CyArk.
archive.cyark.org

Digital Preservation Coalition.
www.dpconline.org

Historic American Buildings Survey
www.memory.loc.gov/ammem/collections/habs_haer/
www.nps.gov/history/hdp/habs/index.htm

International Council on Monuments and Sites (ICOMOS)
www.cipa.icomos.org

International Society for Photogrammetry and Remote Sensing (ISPRS)
www.isprs.org

National Center for Preservation Technology and Training (NCPTT)
www.ncptt.nps.gov

National Digital Information Infrastructure and Preservation Program.
www.digitalpreservation.gov

Scottish Ten
http://www.scottishten.org/

World Wide Web Consortium (W3C)
www.w3.org