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The Process of Creating Accurate Reproductions of Fragile Objects: Fabricating 3D Facsimiles with Limited Resources

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Abstract

Museums and other cultural institutions must consider how to best preserve their collections for an exponentially digital world. Our digital age is providing new avenues for preservation, accessibility, viewing, and interaction. This thesis assesses the feasibility of utilizing and creating accessible and readable 3D digital surrogates and prints. To consider and adapt current best practices "what are the implications of creating accurate reproductions for the research environment as well as for online and in person use"? This thesis presents themes that relate to the broader fields of digitization, reproduction, and fabrication in museums and cultural institutions, presents findings in the form of a literature review, and accounts for my own experimentation with the resources to which I have access at Rochester Institute of Technology (RIT).

This thesis engages collaboration with two key partners: RIT's all-access makerspace, The Construct, and the Melbert B. Cary Graphic Arts Collection. Under the advisement of Mike Buffalin and Dr. Steven Galbraith, I scanned a papier-mâché bound book in 3D to create a digital surrogate which has two purposes: a digital rendering to be made available online and a material output when the file was printed in three dimensions using polylactic acid (PLA) low-cost filament.

The viability of this project is defined by the accuracy of the reproductions, the resources necessary, and the time commitment required for this project to be adapted by small institutions. This project is an inexpensive and proactive alternative to seeking conservation treatment and will further enable non-local audiences to interact with distant materials. Ultimately, the project supplies small institutions with less expensive options to digitize and create surrogates of their collections, offer a model procedure for the fabrication of online and physical facsimiles, and provide a list of digitization connections within the RIT community.

Introduction

Museums are public forums that hold their community's trust by preserving accessible knowledge. However, it is not always feasible to have all their information accessible at one time. Museums, archives, and libraries all have storage rooms full of fragile collections and full shelves. These collections are able to circulate to the public eye irregularly through the means of exhibitions or requests from researchers. What some do not know is the extent to which vast quantities of paintings, rare books, and natural history collections never see the light of day. Small insects are too miniscule to be exhibited in a normal fashion while a newspaper's pages might become too brittle making it difficult to open and read. What museums and other cultural institutions must think about is how to preserve their collections for an exponentially digital world. What they can utilize is digitalization and 3D scanning to produce reproductions for online and in person use. Digitalization is one area of museum and archival practice that is proving pivotal in supporting the longevity of objects.

Museums and archives must think about how their objects are used and what is desired from their visitors and researchers. In today's world, Google is able to supply us answers to the multitude of questions we form every day. However, when an archival object is needed to answer a question, information available is determined by what is made accessible through in-person visits. However, when a researcher is unable to visit, digital avenues must be put in place. In other words, to find a specific painting online a researcher or even the casual enthusiast must rely upon the museum who possesses it to have the item photographed, digitized, and uploaded to their website and allow it to be searchable through popular search engines. The methodology of digitalization includes choosing the piece or collection you wish to digitize, then selecting the necessary technology and equipment, and lastly creating a straightforward technique for

displaying this information online. However, most institutions are on a fixed budget that may not account for such enhancements and have a strict schedule which entails not retracing their steps once a collection is finally catalogued. When new objects are donated or purchased as part of the daily life on a collecting institution, it becomes difficult to concentrate on adding to the cataloguing record by digitizing older, finished collections while new collections and needs are stacking up.

Museums are not blind to the effect technology has had on their constituents. Museums want to be looked at as contemporary locations for additional education and entertainment even though their galleries may act as time capsules. Currently, museums are experimenting with different forms of interaction and accessibility conceived through new technological advances such as the tablet or laser radar scanners. Two areas museums are investigating are the implications of online accessibility and the feasibility of physical object reproduction. In terms of digitization, institutions may desire the ability to proliferate their objects online as well as share them physically through reproductions. What I investigate in this thesis are the best practices behind creating accurate reproductions of objects in the educational environment and online.

Currently, flat images are photographed, sculptures are scanned in three dimensions and 3D printers are used within the exhibition space. However, in this paper, the process of using 3D scanning and printing will be documented throughout the creation of an accessible digital surrogate and an accurate physical copy. This process can be used to rest the original fragile volume. What will be accomplished during the course of this thesis is the determination of best digitization practices and providing small museums and archives with avenues to cheaper and easier options to digitize their collections. For this project, research was done at the Melbert B. Cary Graphic Arts Collection under the advice and guidance of the staff The Construct center. I

will digitize a book that belongs to a collection of tomes located in the Cary Collection - in The Bernard C. Middleton Collection of Books on the History and Practice of Bookbinding. This collection of books has matching intricate, black papier-mâché covers in a wrought iron like designs and delicate leather bindings. Papier-mâché is defined as a plaster like substance that can be made out of paper pulp, rag paper, glue, flour, organic matter, resin, and/or paper sheets.[1] After the plaster and paper is combined with the glue flour it can be applied to molds to form decorations for picture frames, furniture, ceilings, and in this case book bindings.[2] The combination of paper and glue does not produce a strong sub-straight which can lead to damage or missing pieces.[3] The fragile nature of this collection of books due to the weight of the papier-mâché and the delicate leather bindings present challenges and opportunities for this digitization project. After choosing the book, equipment and expertise will be gained from The Construct. The scanners will use a laser array to scan the cover of the book in parts and print it in black filament to match the book's original color. Different iterations will be created to find the best procedure for this process. Ultimately, if a digital surrogate is uploaded to the Cary Collection's website and a physical reproduction is created accurately enough, I will label these procedures and practice a success.

This thesis will start with a literature review that will describe the research presented in this paper, next the procedure will give museum professionals a step-by-step set of best practices and end with a conclusion and an appendix.

[1] Dianne van der Reyden and Don Williams. "The History, Technology, and Care of Papier-Mache: Case Study of the Conservation Treatment of a Victorian "Japan Ware" Chair." Smithsonian Center for Materials Research and Education (2001): 1-16.
[2] Ibid, 4.
[3] Ibid, 5.

Literature Review

Museum professionals have a responsibility to investigate how they can utilize new technology in an innovative way to protect objects from wear, make collections more accessible and preserve collections in ways that overcome obsolescence. "Within prescribed law and best-practice standards, archivists may determine that the original documents themselves must be preserved, while at other times copying the information they contain to alternate media may be sufficient."[4] Digitalization is a current sphere of museum practice and theory that converts the physical to digital alternative media in order to create a back-up copy. Digitalization is defined as a preservation process involving digital conversion while digitization is the mechanical processes of converting analog material to digital. Multiple of my own questions surrounding digitization include: What types of collections should be digitized or replicated? Is it necessary to scan and print the full volume or are parts of the whole acceptable in terms of accessibility? What is the preeminent methodology to scan an object for online and physical use when it is so fragile? Is there a universal record of best practices or procedures when it comes to digitizing and printing in 3D in a small institution? The answers to these questions will guide this thesis and will further assist me in accomplishing two tasks: to digitize a fragile book and to create a reproduction for online and in-person use.

For the purposes of this thesis, I will digitize one papier-mâché bound book from The Bernard C. Middleton Collection of Books on the History and Practice of Bookbinding to display on the website of the Melbert B. Cary Graphic Art Collection and print a surrogate to increase

[4] "SAA Core Values Statement and Code of Ethics," SAA Core Values Statement and Code of Ethics | Society of American Archivists, accessed April 06, 2017.

the book's accessibility and extend its usefulness.[5] Creating a reproduction for educational purposes is necessary because the binding is so fragile it should not be opened or held. The Cary also boasts one of the largest collections of papier-mâché bound books without any damage to their covers. [6]

To assess the digitalization climate in today's museums, research will be organized in to three categories: Technology and Procedure Digitization; Procedure and Online Feasibility; and Technology and Procedure - 3D Printing. Information about why museums digitize, what they digitize, and the technology and equipment they use to digitize is outlined in the section Technology and Procedure - Digitization. In the Procedure and Online Feasibility section, the purpose of digital surrogates will be analyzed, structure of online information will be examined. In the last section, Technology and Procedure - 3D Printing, the interaction between museums and printing will be studied in terms of the use of 3D printing for exhibition purposes, restoration of objects, and the creation of gift shop items for that can generate income for an institution.

Assessing the Digital, Part 1: Technology and Procedure: Digitization

To begin the digitizing process, an institution must take an honest look at its budget, resources, barriers, and goals. In a 2004 survey, the Institute of Museum and Library Services (IMLS) found that museums, public libraries, academic libraries, state library administrative agencies, and archives had aims in the field of digitization.[7] However, as outlined in the article

[5] Papier-mâché is made from paper products – either pulp, strips, sheets or panels – and glue to create decorative pieces to objects. Dianne van der Reyden and Don Williams. "The History, Technology, and Care of Papier-Mache: Case Study of the Conservation Treatment of a Victorian "Japan Ware" Chair." Smithsonian Center for Materials Research and Education (2001): 1-16

[6] The pages of this book will not be digitized due to the fact that the binding can only be carefully opened to be read but scanning would cause much more stress.

[7] Institute of Museum and Library Services. "Status of Technology and Digitization in the Nation's Museums and Libraries." Initiative Publications, (January 2006)

"Status of Technology and Digitization in the Nation's Museums and Libraries," different levels of "adoption, maintenance, funding of, and staffing for technology and digitization activities" for each institution type yielded a variety of individual processes.[8] It was found, with small archives such as the Cary Collection and associated digitization activities, that in comparison to other institutions, half of archives have had the funding for digitizing in 2004.[9] This is true; however, more than 75% of archives do not have a standardized procedure for such activities.[10] But due to the more than 25,000 remaining objects a typical archive has to digitize, the lack of funding and an educated staff as well as the buildup of priorities might hinder the level of success for digitization projects.[11] Even with the presence of a budget, a lack of procedure and the quantity of specialized work can disrupt progress. This thesis aims to remedy such constraints by creating a feasible procedure for a small institution. This paper ends with a survey for archives that will be utilized to evaluate the feasibility of long term digitization projects for the Cary Collection (see Table 3). The survey findings are recorded in the Methodology under the Archival Statement.

In the article "Digitizing Pacific Cultural Collections: The Australian Experience," the authors, Supriya Singh, Meredith Blake, and Jonathan O'Donnell, outline the funding requirements necessary to complete a project similar to that of my thesis. The most constructive information provided within this article is the budget outline for a fully staffed digitization program. When analyzing the viability of having a digitization and 3D printing operation in the Cary collection, budget is the biggest obstacle. The aforementioned article outlines a project that

[8] Ibid, 1.
[9] Ibid, 6.
[10] Ibid, 7.
[11] Ibid, 7.

digitizes 50 objects a day can be accomplished by two digitizers and one researcher.[12] The Cary Collection holds over 45,000 volumes not including photographs, papers and font type in its archives while the Australian Museum holds approximately 60,000 objects. Given these data, the Australian Museum will need one million dollars to accomplish this project in 5 years.[13] The Melbert B. Cary Collection could accomplish this task for less by concentrating on fragile or popular collections over a longer time span. While helpful for the calculation for time and funds, this article was not as descriptive in terms of process as it did not address how the digitization is done.

Comparatively, another essential area of focus is the handling of the objects to avoid damage during the scanning process. This is because no matter how detailed or accurate the digital and physical facsimiles, there is no replacing the original object. The authors, Alexandra Büttner and Michael Kautz, analyzed ways of precautious handling and avoiding harm to their original objects in the article "From a Dispersed Medieval Collection to One International Library: The Virtual Reconstruction of the Monastic Library of Lorsch."[14] To bring together their disseminated collection of manuscripts, digitization enabled the recreation of the original library online. To ensure no harm came to the manuscripts, a Graz cradle was utilized to guarantee the stabilization of the book via a small bar as well as light suction.[15] Flexible camera angles and a laser beam were used to scan the books to minimize the movement of the object.[16]

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[12] Singh, Supriya, Meredith Blake, and Jonathan O'Donnell, "Digitizing Pacific Cultural Collections: The Australian Experience," *International Journal of Cultural Property* 20, no. 1 (02, 2013): 94.
[13] Ibid.
[14] Alexandra, Büttner and Michael Kautz, "From a Dispersed Medieval Collection to One International Library: The Virtual Reconstruction of the Monastic Library of Lorsch," *Art Libraries Journal* 40, no. 3 (2015): 16.
[15] Ibid.
[16] Ibid.

Cradling the book properly is only one way to safeguard the fragility of the digitized object. After cradled properly, the manuscripts' binding, spine, top edge, tail edge, fore edge, front and back pastedowns, recto and verso pages, and color chart was scanned.[17] Another scanner used in this project was the Traveller portable book scanner.[18] This type of scanner could be implemented in a small archive like the Cary's because the objects do not have to leave the safety of the archive to be scanned. Using cradles and portable scanners qualify as best practices because they are needed to ensure the safety of the object during the digitization processes. However, knowing the anatomy of the book is an essential best practice because this information is needed to completely scan the object to ensure authenticity of the information presented online and safely. The authors supply detailed analysis of what materials are needed for digitization; however, the sections on recombining a dispersed library is not necessary information for this project. More research is necessary to determine how to digitize each page and how to cradle the book to minimize damage in the time frame and budget of the Cary.

The Consortium of Academic and Research Libraries in Illinois (CARLI) similarly set up "Guidelines for the Creation of Digital Collections: Digitization Best Practices for Three-Dimensional Objects."[19] This paper focuses on converting 3D objects – an object "that can be measured in terms of height, width and depth" – in to digital data through 2D images.[20] If an institution finds itself without connections in the digitization field a digital SLR camera with a 50 mm lens, tripod, neutral background, cradles and Photoshop can do the job.[21] However, CARLI

[17] Ibid., 17
[18] Ibid., 16
[19] "Guidelines for The Creation of Digital Collections: Digitization Best Practices for Three-Dimensional Objects." Consortium of Academic and research Libraries in Illinois: 1-13.
[20] "Guidelines for The Creation of Digital Collections: Digitization Best Practices for Three-Dimensional Objects." Consortium of Academic and research Libraries in Illinois: 1.
[21] "Guidelines for The Creation of Digital Collections: Digitization Best Practices for Three-Dimensional

recognizes that this form of digitizing "essentially 'flattens' three-dimensional physical objects into two-dimensional digital representations."[22] What this current thesis project can do is solve this issue with the use of three-dimensional scanning. However, some similarities still apply between their 2D images and my 3D scans. These similarities include basic techniques while photographing/scanning such as avoiding shadows, using a neutral background and capturing multiple angles. The only other difference is that 2D images are collected as compound images to imitate its original 3D likeness while 3D scans can be viewed in any angle just like the asthenic object.[23]

The Consortium of Academic and Research Libraries in Illinois have set up a good foundation for small institutions looking to start digitization projects. This paper also outlines the equipment needed, the management of digital images, and the articulation of metadata.[24] But when an authentic representation of an object is sought, only 3D models can provide the identical feel and same look as the original. Photographs take the three-dimensional and flattens them into two-dimensional entities: eliminating some visual information. When a 3D model is created, the original's likeness can be used to replicate a physical interaction when only the digital is available.

Assessing the Digital, Part 2: Procedure and Online Feasibility

After digitization is completed, uploading digital images online is the next step to ensure

Objects." Consortium of Academic and research Libraries in Illinois: 2.

[22] "Guidelines for The Creation of Digital Collections: Digitization Best Practices for Three-Dimensional Objects." Consortium of Academic and research Libraries in Illinois: 1.

[23] Compound images are a collection of images that are ordered from front to back, left to right to show every angle of the original object. "Guidelines for The Creation of Digital Collections: Digitization Best Practices for Three-Dimensional Objects." Consortium of Academic and research Libraries in Illinois: 7.

[24] "Guidelines for The Creation of Digital Collections: Digitization Best Practices for Three-Dimensional Objects." Consortium of Academic and research Libraries in Illinois: 1-13.

access and interaction. Most articles in the area of digitalization and online accessibility state that a level of access must be determined, collaboration amongst different countries should not be hindered and information should be ordered in a way that makes sense to the researcher. In all, the ultimate goal of digitization is to make a copy to ensure preservation through the creation of surrogates. In the article, "Preservation in the Age of Google: Digitization, Digital Preservation, and Dilemmas," the author Paul Conway believes that "material culture artifacts will serve as the ultimate backup for their digital surrogates."[25] The most common theme in this field of research is that the physical relies on the digital to be preserved but the digital still needs the physical to ensure authenticity. After overcoming the various digitization dilemmas outlined in this article, recommendations are outlined in the last few pages. Best practices include ensuring a sustainable archive environment for longtime preservation, finding ways to digitize audio-visual materials which they state as the most challenging material due to neglect, collaborating between cultural heritage communities, digital conversion factories – digitization labs - and lastly finding was to evolve from experimental digitization to creating procedures for large scale preservation.[26] The pivotal idea that this article represents is that Google can help us transform artifacts and extend "their useful life."[27] A useful life can be thought as the time frame between when an object is brand new and when it finally falls apart due to over use and deterioration.

The purpose of creating best practices and a detailed procedure is to facilitate the continuation of this thesis project, first by on digitizing the rest of the papier-mâché collection and then to other fragile materials in the Cary Collection. One thing to overcome is how to give a

[25] Paul Conway, "Preservation in the Age of Google: Digitization, Digital Preservation, and Dilemmas," *The Library Quarterly: Information, Community, Policy* 80, no. 1 (2010): 75.
[26] Digital conversion factories are an epithet attached to spaces that are dedicated to the act of digitizing. These include an archive's or museum's workrooms were equipment and space are provided Ibid., 75
[27] Ibid., 76.

digitized collection a feeling of unity while items are uploaded one at a time or separately. Once digital surrogates are created, the structure of the online interface must be evaluated to ensure the context of the original texts are not disturbed or confused. One aim in the article "Annotated Facsimile Editions: Defining Macro-Level Structure for Image-Based Electronic Editions," was "to display either the original structure of the book or the page from the main text alongside the corresponding page or pages from the commentary."[28] In other words, if a page in a book corresponds with another in the same series or collection those pages can be displayed together and make connections the reader may not have thought of. This format may respond well to the chosen papier-mâché volume because this process would be interesting to look at in the future if the entire bound papier-mâché collection is digitized.

After figuring out how to display the digitized object online, the website's accessibility must be evaluated. This may even be done during the creation of the website or before the project is even on its way. The authors of the article "Museum Web Accessibility: A Pilot Assessment of Mid-Atlantic Museums" wanted to stress the importance of Section 508 from the Rehabilitation Act and its positive effects on the disabled community. Some characteristics an accessible website should have under Section 508 are limited flicker frequency to not harm those prone to seizures, the ability to skip repeated navigation tools at the top of the webpage for those with vision impairment who need their webpages read to them, and alerts for time responses if a user needs more time to fill out surveys then is provided.[29] These maybe known as common courtesies; however, large museums such as the Museum of Modern Art in New York City are

[28]Neal Audenaert, and Richard Furuta, "Annotated Facsimile Editions: Defining Macro-Level Structure for Image-Based Electronic Editions," *Literary and Linguistic Computing* 24, no. 2 (June 1, 2009): 147.
[29] Lesley Langa, Jonathan Lazar, Taiwo Adesina, David Michael Baumgart, Vladimir Brockmeyer, Hollis Leroy Bush III, Edwin Corpuz, et al. *"Museum Web Accessibility: A Pilot Assessment of Mid-Atlantic Museums." International Journal of the Inclusive Museum* 4, no. 1 (January 2012): 20.

surprisingly one of the top violators, as of 2012.[30] Ensuring a website is accessible guarantees that the hard work that you are doing to digitize collections are able to be appreciated as well as utilized.

Assessing the Digital, Part 3: Technology and Procedure: 3D Printing

In addition to digitization, 3D printing is another way to increase the accessibility of fragile objects. Museums are utilizing 3D printing and additive manufacturing to inform the public in different ways. In the article, "Use of 3D Printing by Museums: Educational Exhibits, Artifact Education, and Artifact Restoration," Daniel Short discusses that museums are using "3D printers and 3D sculpture inside exhibition spaces to show how this technology can be used in industry, medicine, and individual innovation" in the future.[31] Museums are also using 3D scanners and printers to replicate artifacts for revenue and for the restoration of damaged objects.[32] Replicas are even replacing objects on display that are too fragile such as handmade crepe paper and wax leaves from the 1940s at the Peabody Museum, the natural history collection, at Yale University.[33] The awe and novelty of 3D printing will fade but preserving an object by creating a 3D printed facsimile will ensure the life span of information and culture. However, having 3D printing visible within the museum space can increase interest through interaction and therefore increase funding.

On the forefront of 3D scanning technology is the use of a Frequency-Modulated Laser Radar system to capture data that could be missed when using typical scanning techniques.

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[30] Ibid., 22.
[31] Daniel B. Short, *"Use of 3D Printing by Museums: Educational Exhibits, Artifact Education, and Artifact Restoration." 3D Printing and Additive Manufacturing* Volume 2, (Number 4, 2015): 210.
[32] Ibid., 213.
[33] Ibid., 214.

Compared to the optical laser array scanner available to the Cary Collection and I through the Rochester Institute of Technology's The Construct, the Frequency-Modulated Laser Radar system is able to overcome the shine, dark color and shadows created from the form of a three-dimensional object that could lead to missing data.[34] Just as this thesis considers the dark black and burnished sheen of the papier-mâché book covers, the article "Digital Three-Dimensional Modelling of Donatello's David by Frequency-Modulated Laser Radar" focused on the dark bronze sculpture of Donatello's *David* that posed similar frustrations to digitizers.[35] Donatello's dark bronze form created shadows and produced a reflective surface that was hard to scan.[36] The solution includes the triangulation of scans to achieve a more complete image.[37] The most beneficial information in this article includes the measurement of hours dedicated to complete this project. Because this project was disrupted by one month and some data had to be re-gathered, it took around 400 hours.[38] I do foresee the papier-mâché book as having this issue because of its dark, and has a glossy finish. The best practice outlined in this article is to use the Frequency-Modulated laser radar, however, The Construct's 3D scanner is optical. Looking into how to utilize the best practices outlined in the article, "Digital Three-Dimensional Modelling of Donatello's David by Frequency-Modulated Laser Radar," with the resources available at RIT is the biggest obstacle of this thesis.

One of the most useful articles for this project is "3D Scanning and Replication for Museum And Cultural Heritage Applications" because of its clarity of process. The article walks

[34] Gabriele Guidi, Alessandro Spinetti, Luca Carosso, and Carlo Atzeni, "Digital Three-Dimensional Modelling of Donatello's David by Frequency-Modulated Laser Radar," *Studies in Conservation* 54, no. 1 (2009): 3.
[35] Ibid.
[36] Ibid.
[37] Ibid., 9.
[38] Ibid., 8.

the reader through the current state of 3D scanning and, its practicality, describes the SLA – Stereolithographic – printer which may be used to create a final reproduction of the papier-mâché binding; discusses, the stability of the materials, and 3D scanner functions as well as, accuracy, speed and processes of the scan and print.[39] This article is a strong foundation for this thesis because it can be relied upon for defining the tough definitions that are required of this project as well as provide suggestions for preferred technology and procedure in this field. Similarly, the diagrams and images used within this article unearth the inner working of a scanner and show examples of the end product, the digital surrogate. My work can take its cues from this article in terms of the success of the print as well as the extent of clarity of the text. Some recommendations delineated in this article comprise the application of less durable 3D materials as models and digital surrogates used as archival resources.[40] Other considerations relevant for this thesis include the possible off-gassing of the PLA filament and reaction with other materials within the archive. Other best practices include recommended equipment such as the Breuckmann triTOS-HE structured light scanner and tripod.[41] Tripods can be used to replace the need for cradles because they can be positioned in any direction to view to object. This was the same suggestion made by Mike Buffalin of The Construct.

Conclusion

The research gathered above served primarily as a foundation for my experimentation in The Construct and the Melbert B. Cary Graphic Arts Collection. Information about scanning

[39] Melvin J. Wachowiak and Basiliki Vicky Karas, "3D Scanning And Replication For Museum And Cultural Heritage Applications," *Journal of the American Institute for Conservation* 48, no. 2 (2009): 141-58.
[40] Ibid., 147
[41] Ibid., 148

difficult materials and how to present digitized images online are valuable concepts that can be used to begin formulating best practices through this thesis. The feasibility of scanning and printing difficult materials was outlined in the "Technology and Procedure - 3D Printing" section and this information will be evaluated in terms of a small archive space. Similarly, the section "Technology and Procedure – Digitization," outlined the digitization of sensitive and remote materials which will help when considering digitizing fragile materials. After this initial research was completed, I undertook some 3D scanning in the Construct. Throughout the research process, questions that I had about digitizing three-dimensional objects were answered by The Construct's director, Mike Buffalin. Dr. Steven Galbraith, Curator of the Cary Collection, also helped me to select the papier-mâché bound book from The Bernard C. Middleton Collection, which served as my primary test subject. For the project, I scanned the papier-mâché cover of the book and printed it in portions to ensure quality. In consultation with my thesis advisors and Buffalin, and building upon the information from my literature review, I decided not to digitize pages from the book due to the fragility of the book's binding. Thus, the content of this literature review has shown that it is possible to use 3D scanning and printing within a museum environment as well as exhibiting a need for these preservation techniques in the museum field. A blend of theory and praxis is the basis of this thesis: I have created a pragmatic procedure based on these case studies tailored to the Cary Collection and the papier-mâché specimen.

Methodology

Archival statement

This thesis makes specific use of the collections housed at the Cary Collection, specifically a papier-mâché volume. Before investigating the process behind digitization, an explanation of the book's composition and context is necessary. After the specimen is chosen

and thoroughly researched the two institutions utilized, the Cary Collection and The Construct, are described to give the readers a clearer perception of RIT's digital forward and friendly community.

Papier-mâché is defined as the architectural and decorative medium that includes paper in its core.[42] The three varieties of papier-mâché include using paper pulp that is casted or extruded into a mold, paper strips that are laid and adhered together over a form and paper sheets that are bonded and pressed between a mold to form light weight shapes.[43] Depending on the time period in which the papier-mâché object was created it would have been produced in one of these three ways.

The particular book that will act as the specimen for this project is William Shakespeare's *Sentiments and Similes* bound by Henry Noel Humphreys (see Figure 1).[44] This book is a collection of similes and passages of plays and poems by Shakespeare that was bound around 1863.[45] *Sentiments and Similes* was "printed letter-press by Vizetelly Brothers … [the] …binding designed by H.N. Humphreys" and the Chromolithograph plate [on the first page was] printed in Paris by Engelmann & Graf.[46] Born 1810 and deceased 1879, Henry Noel Humphreys was an accomplished author of entomological and archeological research, a historian of printing and writing history and a book binder.[47] He bound this book in a "black ornate frame … set in a

[42] Dianne van der Reyden and Don Williams, "The History, Technology, and Care of Papier-Mache: Case Study of the Conservation Treatment of a Victorian 'Japan Ware' Chair," Smithsonian Center for Materials Research and Education (2001): 1-16.
[43] Ibid., 2.
[44] William Shakespeare, "Sentiments and Similes of W. Shakespeare," Rochester Institute Of Tech. - Wallace Mem. Library /Full Catalog. Albert.rit.edu. N.p., 2017. Web. March 7, 2017. http://albert.rit.edu/record=b1839070~S3 .
[45] Ibid.
[46] This information was obtained from the catalogue record for the item in the Rochester Institute of Technology's web catalogue. See William Shakespeare, "Sentiments and Similes of W. Shakespeare," Rochester Institute Of Tech. - Wallace Mem. Library /Full Catalog. Albert.rit.edu. N.p., 2017. Web. March 7, 2017.
[47] "Henry Noel Humphreys," Wikipedia, accessed March 23, 2016,

border with a red [silk] background showing through the strap-work. A terracotta oval medallion relief of Shakespeare's head is inserted in the center of the upper board … [and] a similar relief of his initials in terracotta is inserted on the back (see Figure 1)."[48] Additionally, all edges are gilt, the spine and hinges are leather and is one of the nine papier-mâché specimens in the Bernard C. Middleton Collection of Books on the History and Practice of Bookbinding.[49] Because it was bound in 1863, the binding process consisted of using a panel or blank of papier-mâché rather than individual sheets or pulp.[50] This new alternative process shifted away from the time consuming process of applying layer after layer of papier-mâché strips in to a mold and instead used pre-made and softened panels to manipulated into decorations.[51] It is because of this papier-mâché medium that this book is considered fragile.

Because of the weight and fragility of papier-mâché bound books, researchers wondered how they could have functioned as books. What was revealed in the painting *The Awakening Conscience,* by the artist William Holman Hunt painted in oil, was that books bound in papier-mâché were symbols of status and therefore treated as display objects rather that simple machines (see Figure 2).[52] To the right of the gentleman and his presumed companion, there is a papier-mâché bound book on the table in an apartment he kept for her.[53] It was determined that this apartment was recently decorated and therefore the décor and objects present are avant-garde

https://en.wikipedia.org/wiki/Henry_Noel_Humphreys.
[48] Ibid
[49] William Shakespeare, "Sentiments and similes of W. Shakespeare," Rochester Institute Of Tech. - Wallace Mem. Library /Full Catalog. Albert.rit.edu. N.p., 2017. Web. March 7, 2017.
[50] Dianne van der Reyden and Don Williams, "The History, Technology, and Care of Papier-Mache: Case Study of the Conservation Treatment of a Victorian 'Japan Ware' Chair," Smithsonian Center for Materials Research and Education (2001): 4.
[51] Ibid., 4.
[52] "The Awakening Conscience," Wikipedia, accessed April 04, 2017,
[53] Ibid.

on the verge of "'nouveau-riche' vulgarity."[54] Because members of society of the gentleman's class were trying to display their wealth, a displayed papier-mâché bound book is appropriately depicted. Objects of this sort, which functioned more as aesthetic than functional artifacts, were intended to be viewed, perhaps moreso than to be read.

Such a context seems a fitting parallel to the digitized cover that has been the focus of this thesis project where the front cover of an ornate volume was digitized to create a 3D digital surrogate and physical print. The pages of this book were not digitized due to the delicate leather spine. If every page was held open for a substantial amount of time, the same amount of time it would take to digitize each page, the weight of the binding could tear the leather spine and the covers would fall off. To ensure safety only the exterior was digitized keeping to this binding's tradition. Once the digital model is created and the physical copy printed it acts like the original visual object.

The Melbert B. Cary Graphic Arts Collection houses nine papier-mâché books in the Bernard C. Middleton Collection of Books on the History and Practice of Bookbinding (see Figure 4). Four out of the nine are bound by Henry Noel Humphreys.[55] The Bernard C. Middleton Collection numbers approximately 2,000 books with in the Melbert B. Cary Graphic Arts Collection.[56] These books range from books about bookbinding and those that are binding specimens. Steven Galbraith, Ph.D., is the curator of the Cary Collection at The Wallace Center at Rochester Institute of Technology.[57] Before this current position, Galbraith held the Andrew W. Mellon Curator of Books position at the Folger Shakespeare Library in Washington, D.C.,

[54] Ibid.
[55] William Shakespeare, "Sentiments and Similes of W. Shakespeare," Rochester Institute Of Tech. - Wallace Mem. Library /Full Catalog. Albert.rit.edu. N.p., 2017. Web. March 7, 2017.
[56] "Cary Graphic Arts Collection," Cary Graphic Arts Collection, accessed March 24, 2017, http://library.rit.edu/cary/.
[57] Ibid.

was a "visiting professor and curator of Early Modern Books and Manuscripts at Ohio State University and reference librarian at the University of Maine."[58] The Cary Collection is a research archive filled with graphic communication history from cuneiform tablets to the iPad. Stores of metal font type, printing presses, graphic arts collections, and artists' books make the Cary a rich research environment for RIT students, staff and international researchers. The collection houses approximately 45,000 volumes on top of hundreds of archival resources on typography, collections of graphic designers, posters, and printing history.[59] The Cary Collection became the home for this experiment because of its variety of collections, its connection to a tech forward campus and its role in the printing community. Already active in other digitizing pursuits such as scanning, a good next step is to 3D scan their three-dimensional artifacts. This is because a 2D photograph does not retain the essence of a 3D object and traditional 2D scanning methods are not equipped to handle anything other than flat sheets. There were many three-dimensional specimens to choose from, from wood font type or cuneiform tablets. We chose the papier-mâché bound book *Sentiments and Similes* by William Shakespeare described above. At the close of this project, the Cary Collection receives a digitally-rendered surrogate which acts as a physical educational object and an access copy for use during tours. The Cary also receives the digital scans of the book cover for education and access use online which may, in turn, incite interest in the Cary, its collection, and this particular book in the collection.

To determine whether this project is feasible for a small institution, like the Cary Collection, a survey like the Institute of Museum and Library Services Technology and

[58] Marcia Morphy, "Steven Galbraith Named Curator of RIT's Cary Graphic Arts Collection: The Collection is a Renowned Resource for Printing and Graphic Communication History," *[RIT] University News*, October 25, 2011, accessed February 23, 2017,
[59] "Cary Graphic Arts Collection," Cary Graphic Arts Collection, accessed March 24, 2017, http://library.rit.edu/cary/.

Digitization Survey can be helpful to evaluate budget, scope and future goals.[60] The "Background on Archives" section defines the budget. Galbraith defines the Cary Archive as affiliated with a university, with an annual budget of approximately $200,000, and 3.5 full- time employees.[61] Galbraith reported that, in last 12 months, the Cary has received funding for technology from their internal budget and that, in the next 12 months, the Cary will have the budget for technology from gifts from donors and state funds.[62] Even though they have this sustainable funding they define themselves as short of meeting their mission due to a limited technology capacity. Their mission's goals include making "programs and exhibits more interactive…[providing]… a richer educational experience…[increasing] … the number of people who participate in programs… [and increasing]… access to institutional resources and series."[63] These goals would prove to fruition with the help of digitization programs; however, the Cary Collection's technology hindrances include lack of funds, lack of necessary equipment, software and/or networking and lack of staff time.[64] The parameters identified above, as reported by Galbraith, may be defined as "limited resources"—the type of institution that is the focus of this study.

Under the Digitization section, the Cary defines themselves as not having the funding for digitization activities in the last 12 months.[65] However, the do plan on allocating some of the budget to these endeavors in the next 12 months.[66] Their primary goals include "preserving materials of importance or value, increase access to collections/materials/files [and] minimize

[60] Institute of Museum and Library Services, "Status of Technology and Digitization in the Nation's Museums and Libraries," *Initiative Publications* (January 2006).
[61] Ibid, 134.
[62] Ibid., 135.
[63] Ibid., 138.
[64] Ibid.
[65] Ibid., 142.
[66] Ibid.

damage to [the] original materials."[67] These three goals perfectly reflect the reasoning behind this thesis. The roughly 501 to 5,000 objects they have already digitized, the Cary has objects that include films, videotapes, art work, artifacts, manuscripts, interviews, photographs, rare books, and special exhibits.[68] However, when they do digitize, they do not focus on whole collections. The Cary Collection focuses on rarity, fragility, and use/demand in that order. The Cary Collection's Digitization hindrances include: "lack of staff time, lack of funds, lack of necessary equipment and/or software, other projects that have higher priorities [and concerns] about costs of preservation and management."[69] Later in this thesis, it is demonstrated that most of these hindrances have solutions.

After this survey was completed by Galbraith it was easier to evaluate whether this project could be turned in to a feasible, long term program at the Cary Collection. I assess that a program based around 3D digitization, digital model creation and physical facsimile fabrication is possible because they budget, interest and need is there. All that is needed now is one employee to become 3D fluent. And, at RIT, this solution is nearby.

The Construct is a maker space for all Rochester Institute of Technology's students (see Figure 3); although all members of the RIT community are welcome to use its resources. Here, students are allowed to use the space and equipment to laser cut or engrave wood, build robotic models and print 3D parts (see Figure 3). Open during the day, students come to work on projects for school or for pleasure for free. When looking into the use of their 3D printers, the medium, PLA, is free to print with up to 50 grams. Passed that PLA costs 5₡ per gram. Similarly, the software and hardware needed for this project was also borrowed from the

[67] Ibid., 147.
[68] Ibid., 143-144.
[69] Ibid., 150.

Construct. The program ScanStudio and the Next Engine scanner were both needed to scan *Sentiments and Similes* in three dimensions for online and improved physical access. This was all possible with the help of Mike Buffalin, the Lab Director.[70] It only took a few sessions at the Construct to learn how to use the equipment and software necessary for this project with his help and was a helpful partner during the official scanning process. Proximity and collaboration with institutions that have equipment and expertise is key for making digitization projects feasible for archives or museums with a constrained budget and large collections.

Test and Procedure: 3D Digitization (see Table 1)

Digitization will encompass the technology that is available on RIT's campus. The feasibility of using 3D processes for a small institution depends on the connections and availability of technology in the surrounding community. Thankfully, The Construct offered two scanners to choose from and the ability to download the required software. This section will cover the selection of equipment, digitization procedure and the evaluation of the finished model.

To begin digitization, the necessary equipment must be obtained. Secondly, the equipment needed to be approved by Curator Galbraith to ensure the safety of the object. To confirm safety, two scanners – The Fuel 3D and the Next Engine 3D scanners - were compared and the winner was then approved for use. Both scanners are available through The Construct from Mike Buffalin, the Lab Director, for the digitization of three-dimensional objects; however, due to the scanner's price and size, small institutions should be able to obtain these devices easily. The Fuel 3D scanner comes equipped with a DSLR styled flash to gather color data, auto stitch software to stitch six images together for the digitizer and is handheld to allow the object to be scanned by a multitude of angles. The most appealing feature is this ability to freely move

[70] The Construct, "RIT's All-Access Makerspace," The Construct @ RIT, accessed March 24, 2017, http://hack.rit.edu/.

and handle the scanner. The Fuel 3D object has two handles and light weight to allow the digitizer to freely gain access to any angle of the object. Another positive characteristic is the auto-stitching feature because it saves so much time. These features give the Fuel 3D scanner a leg up on its competitor; however, the scans read shadows as raised areas in the scan so this machine was not chosen for this experiment. The Next Engine 3D scanner is a stationary scanner that has a group optical lasers that scan on a horizontal plane. This means that the book must be propped up to face the lasers to achieve a clean scan. However, this was not an issue because the Cary Collection has several mounts and cradles. The Next Engine was used to scan the book's cover twice: once from the front and once on an angle. These two scans were manually stitched together to prove that this machine was a perfect fit for this project and therefore was chosen. Luckily, this machine is easy to use, unfortunately, scanning one piece can take three or more minutes. Similarly, the Next Engine 3D scanner is less expensive than its competitor at $2,800 while the Fuel 3D is $3,000 plus the cost of its software. The Fuel 3D scanner also is plagued by malfunctions that need attention which could increase the price throughout its useful life. Utilizing The Construct as a partner will save time and cost while providing expertise. Finding an ally in the digitalization field will be the most invaluable asset for a small institution on a budget. The cost is an important factor when choosing equipment and determining if this process is viable for your institution.

The Next Engine 3D scanner is portable, easy to use and cheaper than the other option. Portability is a desirable characteristic for the Cary Collection because the object will not need to leave the safety of the climate controlled reading room to be scanned or risk damage or theft. This is especially true because the book is fragile and rare. Similarly, stitching scans together in the archive space is observed to be easier when the object is in front of you even though the

scanning software makes stitching possible anywhere. Research states that most digitization projects require two to three digitizers and hundreds of hours.[71] However, this project consists of one digitizer along with the assistance of Galbraith from the Cary Collection and Mike Buffalin from The Construct. The procedure begins with downloading the Next Engine software on to the digitizer's computer (see Table 1). After transporting the equipment over from The Construct, the Next Engine system was simple to set up. The body of the scanner needs to be plugged into a power source as well as a computer. To scan open ScanStudio, click the scan icon and highlight the section of the object you wish to scan in the window (see Figure 6). Start with a neutral, single scan to test the object's surface. When scanning the object, the surface must be 6 inches away from the lasers which is accomplished by selecting a stand for the papier-mâché book (see Figure 5). When the laser is only 6 inches away it is hard for the optical lasers to view the object in its entirety. To achieve a complete scan of the book on the stand was moved from left to right and raised upwards to scan the entirely of the book in pieces. The top half of the book was scanned in five pieces and each scan can take up to 3 minutes. The profile of William Shakespeare in the medallion was scanned separately to ensure clarity. The bottom half of the book was then scanned, after it was raised, in five more sections. Any information that was missing was gained through additional scans.

When the scans are finished, they can be combined, cleaned, and polished (see Figure 6). When the scan exhibits extraneous data from neighborly objects such as the stand or cradle on which the object rests, the digitizer can use the trim button to clean up the scan to remove the unwanted parts. The extraneous data can be simply highlighted, in red, and deleted using the trim brush tool. After the individual scans are cleaned, the scans can then be combined with the help

[71] Supriya Singh, Meredith Blake, and Jonathan O'Donnell, "Digitizing Pacific Cultural Collections: The Australian Experience," *International Journal of Cultural Property* 20, no. 1 (02, 2013): 77-107.

of the align button to complete the model. While fusing, the screen will only show two scans at a time and three primary colored pins. To fuse, the scans must be neighborly pieces and have some common features. These shared features are then emphasized with the pins which the software will use to fuse these areas together. After this process, it can be observed that more scans might be necessary in order to fill in any missing data. However, through these processes, there will still be holes in the scan. To ensure a complete scan, the next step is to fill the finished model, with the fill tool, to smooth out the rest of the missing data.

This procedure was then used to complete the model by scanning the spine, fore edge, top edge, text block, and back cover in the same fashion. To ensure that the model will be a three-dimensional object the spine and fore edge are necessary pieces. It was observed that when the back cover scans were adhered to the front cover they would combine on a two-dimensional plane instead of leaving a space where the pages would go on the three-dimensional plane on the ScanStudio software. By combining the fore edge and spine first to the back cover the back cover would not directly adhere to the front cover and visually allow space between the covers as if there were pages in-between them. However, because of the difficulty of this process it was decided to concentrate on the front cover. This also saved time while finalizing the model and money when we printed. A next step in the future could be picking up where I left off and adhere the spine, back cover and fore edge to the front cover. This will allow for a complete experience online and a complete model for any Augmented Reality projects that the Cary Collection might want to pursue. This process took three sessions at the Cary Collection, and one at The Construct for a total of six hours.

It was observed that the finished model allowed for a much closer examination of the books details (see Figure 7). The software allowed the user to spin and magnify model's surface

to get a better view. This was because the scanner was able to collect more than the human eye could ever observe just like how the human eye was assisted in seeing the moon by the telescope. The model allowed a closeness to the object that the original could never offer in its authentic fragile form. Digitization fosters access and knowledge that might not be available in the physical world. With this in mind, the next step was to clean up the entire scan and print a preliminary model at The Construct. A physical and digital copy can give the interested viewer the capacity to hold and view the object in more ways than the authentic one could ever.

Test and Procedure: 3D Printing (see Table 2)

Before the printer can be warmed up and the PLA threaded, the scan must go through another round of edits. This time the edits will consist of including a bottom to support the scan's surface. This aim was remedied with the software Meshmixer. The 64-bit Meshmixer for Windows is free to download and edits 3D models that imported by users. This software is a little cumbersome and slow; however, a simplified procedure is as follows: first once the 3D model is imported the digitizer must correct the angle of the scan. When I imported my scan of the papier-mâché binding it was at a severe angle when compared to the printing bed. I suggest using the Transform tool under the edit icon to correct the angle of the scan in both the x, y and z axes. Once corrected, use the select lasso tool to highlight, in orange, any irregular edges that should be discarded. Then highlight one section of the scan and select the modify tab to "select all" to highlight the entire surface of the model (see Figure 8). This is to prep the surface to attach a bottom to the scan. This is necessary because after using ScanStudio the width of the scan was about 1 mm. This is too thin to print. After the entire surface is selected, an additional Edit window will pop up. Select Edit and Extrude. The Extrusion tool will stretch one part of the scan to add more mass. In the Extrude tool, select the y-axis and offset in the drop-down menus

(see Figure 8). Then use the Offset slider bar in the positive direction to stretch the width of the scan's surface to form a base (see Figure 8). When the digitizer is happy with the outcome of the model's base it is time to hit print on the Meshmixer software.

Some challenges I observed that a digitizer might run into include the Extrusion tool not responding, Meshmixer not responding, or there are too many holes present. At first, making sure the model is level is difficult because you cannot zero out the axes to form 90 degree angles. In other words, you must "eyeball" it. When creating a base the Extrude tool can crash the system. Once the Extrude tool is working the Offset is the only slider bar the digitizer needs to use: the Harden or Density bars will blur or fill-in the surface of the scan. This would end up losing some or all of the visual data gained through ScanStudio and the Next Engine scanner. If the scan is not level the Extrude tool will only add mass in the y-direction at 0 degrees. If the model is at an angel mass will be added above and below 0 degrees. The most detrimental challenge to the time frame are the small holes created from the scanning process. The small holes in the surface of the scan start to act like tunnels through the whole model (see Figure 9). These holes crash computers, software and 3D printers alike. To fix this just fill and smooth each hole individually using Autodesk ReMake. ReMake allows you to select each whole and choose to smooth or flatten the missing area. Too many triangles, the medium that makes up the scan, can make the files too large and similarly crash the software (see Figure 9). When ReMake was utilized the extraneous pillars was removed by eliminated all the holes. Closing these holes made the model water tight. A new base was extruded and the amount of triangles were decreased from around 1,600,000 to around 400,000. Decreasing the number of triangles made the model simple enough to print. The last thing to ensure a successful print is to make sure the model was leveled off and made flush with the printing bed. If any issues do arise, You Tube has a good

cache of expertise and information about the software products used. Because of these challenges, preparing the model for print has taken five days more than expected. Make sure to allow time for tinkering when printing reproductions for archival use.

Up until this point of this project, the budget for this project has not been touched due to the collaboration and borrowing of equipment from The Construct. The next step is the printing process that typically is free for the first 50 grams of PLA used at The Construct. After that the typical going rate is $0.025 per gram. However, because this project falls under the area of research, RIT paid about $700 for the PRUSA 3D printer and 25,995 for the printer and $71.20 for the cartridge for the Versauv printer that will be used later in this project.[73] Before this final print could be created the first print must be created as a trial run. The printing procedure starts by making the model smaller to reduce the print time and increase the level of detail. After we agreed that slicing the layers of PLA to .15mm by narrowing the extruder would be best for the detail so the layers would not be visible, in theory. This was done through the software Repetier (see Figure 10). This final file was saved in gcode on a flash drive and converted over to a SD card so it could be plugged in to the 3D printer. The first print was created on the original PRUSA 3D printer that is capable of high resolution detail (see Figure 10). The Repetier predicted that the print would take 8 hours and 30 minutes, but the 3D printer took 9 hours and 13 minutes. The print was then pulled off the printing bed and the excess, spider web like, PLA was wiped off. The last step is to paint portion of matte gray to heighten the detail but this is optional. This print is almost identical to the original unlike the first print that is smaller and has a layered look (see Figure 11). With the help of RIT, the next step is to print the final print with the PRUSA 3D printer in the model's authentic size. This followed the same procedure as the

[73] "Original Prusa i3 MK2 3D Printer kit with LCD." Prusa Research. Accessed May 03, 2017. & "VersaUV LEF-200 Flatbed Printer | Roland DGA." Roland Website. Accessed May 03, 2017.

first; however, it took about 20 hours instead of 9. After printing it was observed that the facsimile moved during the printing process that created a staggered look. This did not harm the accuracy of the print. Next epoxy was painted over top of the print to smooth the extruded layers (see Figure 14). This was mostly successful because the only layers left visible were on Shakespeare's face and hair. To prepare this facsimile for the 3D color printer, the model was then spray painted white to create a light base for the ink (see Figure 14). Then the print was moved onto the VersaUV flatbed printer to cure color to its surface (see Figure 15). This printer is able to recognize the y-axis making it perfect to print on three-dimensional objects. The color is sprayed ink that is immediately cured by UV light (see Figure 15). The placement of the object is crucial to apply color in the correct area. When we placed the object it was a bit off; however, this was not the only visible difference when compared to the original. The black ink was not dark enough, the brown for the medallion was too dark and the red for the silk was more of a powdered pink (see Figure 16). To correct this, some hand painting was necessary to touch up the black and fill in the pink areas with a deeper red. The red was not accurate enough because the ink is sprayed on to the surface and particles cannot be precisely controlled. This gave the silk areas a bluish, pink shade. The original, first, and final print are compared below (see Figure 17). To increase accuracy a next step could entail sanding off the thin back of the first print to create holes where the red silk should poke through and a lattice effect where the black papier-mâché should still be. This idea came from the book artist and scholar, Richard Minsky, whom suggested to sand off the back with a belt sander and buy a piece of silk to adhere to it. Then a piece of wood or flat piece of PLA could then provide protection and a structure for the silk to ensure durability while making the facsimile more like the original. In conclusion, after the editing was complete, the printing portion of this project was one of the simplest.

Final Verdict on the Facsimile

In this section I will compare the look of the 3D scan, the first print created from the PRUSA printer, and the second print created from the 3D color printer to the original object (see Figures 12 and 17). This final verdict will determine if creating a 3D model and 3D physical facsimile is a feasible avenue to increase access to a fragile object, increase interest in the object as well as the digitization process and evaluate whether 3D digitization is a feasible procedure for preservation. These three points will depend upon how accurate the scan and prints are compared to the original.

The scan that was made from ScanStudio and The Next Engine 3D scanner of the book *Sentiments and Similes* by William Shakespeare is observed as accurate (see Figure 12). Because the scan was made up of images of the original and pieced together to in the same orientation the scan can be visually and physically measured against the original object. The scan retains the same size and shape of the original as well as its color. The only issue is because it is pieced together the color is not uniform which gives a patchwork look. However, the red of the silk and the brown of the terracotta is applied to the correct places. When compared to each other the original and scan, under the shaded view, look identical.

When comparing the first print to the authentic object they look very similar. The detail is in the right places and is black like the original (see Figure 11). However, the first print had to be smaller than the authentic object because time and detail was a factor (see Figure 13). We made the print about 40% smaller and applied a .15mm slice for the extruder to ensure the detail would not look too layered or limit the amount of extraneous noise.[74] However, the .15mm layers still can be seen and the size is obviously different when compared next to each other (see Figure 13).

[74] Noise is defined as any excess PLA being applied to areas to which it should not be applied.

This could have been fixed with some sand paper but it would risk losing some detail. Similarly, shiny black filament was the chosen material while something a bit more matte would have been more preferred. This can be resolved with a coat of matte gray spray paint. Gray paint would highlight the detail but risk making the 3D facsimile look even more different. However, this was not necessary because the detail captured in the print is satisfactory because it looks like the original. From multiple observations of the print being handled by my peers, faculty, and friends I can say that this facsimile is doing its job. Most ask to hold the print and then gently take it from my grasp. However, the soon learn that they can hold it up, flip it over and touch its surface. I also exhibited this piece in environments that have food: if any got on the print I just wiped it off. This facsimile definitely gives the presentation of this object more flexibility. It can withstand situations the original could not have. In conclusion, the small 3D print passes the observational test because it looks so much like the original that it can be used as an educational reproduction.

The final print created from the VersaUV printer is identical to the original (see Figure 17). The 3D color printer produces smooth, accurate and colorful prints. The only observable difference that can be discerned is that the original object has a glossy lacquer and the print that is produced from this method is matte. The image used by the VersaUV printer to apply color was a TIFF image from the Cary Collection. Other than this difference the 3D color print and the original object look identical. They are the same size, shape, and color. The terracotta medallion is correctly replicated as brown, the silk is red and the black banners exhibit gradients of black (see Figure 16). This is unlike the first 3D print where the PRUSA printer only extrudes the color of PLA that is threaded to the machine. In this case, the PLA used is black and therefore the entirety of the first print is black (see Figure 11). When the whole print is one solid

color some of the original object's visual information is lost. The UV color cure printer used ensures that color is preserved and therefore the original object is preserved through this facsimile. However, it is observable that the facsimile is lighter in color (see Figure 17). The red color painted to replicate the red silk may also still be too pink. The staggered edges also create another difference when compared to the original. Because the authentic object and the final print are almost identical, holding and interacting with this final print should produce a similar experience to holding the original. This is especially true when some fragile or rare original objects have restrictions to physical access so handling it is not an option. Collaboration is crucial in this project because without RIT and The Construct there would be no feasible access to a 3D color printer for small institution because their cost ranges from $12,000 to $150,000.[75] Because this 3D print is accurate and thus successful in reproducing the authentic object it shows that connections are key for a small institution that could implement a similar digitization project.

Online Application of the Model

At this point, the scan is finished and the physical prints have been made. The next step is to gain the attention of the research and education communities. This can be done through the internet to encourage people to come in to interact with the facsimile in ways they could not have before with the primary material. Online, on the Cary's website or Facebook page, researcher, students, and anyone who becomes interested in this object can magnify, tilt and spin the model to see it at any distance or angle they desire. The digital model can educate, entertain, and interest students and practitioners of Graphic Design or, in the case of this book, those

[75] Martin Lansard, "What are the Best Full-Color 3D Printers on the Market?" Aniwaa, November 12, 2016, Accessed April 05, 2017, URL.

individuals with interests in Shakespeare or nineteenth-century bindings. Seeing the surrogate online may intrigue them to see the original. Once at the Cary, they can observe the original and interact with the reproduction: they can hold the model up close to their face to see detail just like the 3D surrogate online but now you can feel the detail too. These are two activities that are not encouraged with the authentic object, thus indicating how providing access to the model via the internet can also increase accessibility. To provide internet access to the digital surrogate the model needs to be saved as an STL file which is the most flexible file type. Then the model can be applied to the website, content can be written. and interest can be kindled.

Later, the scan could also be converted for use in augmented reality and virtual reality. The front cover, and eventually the whole book, could contribute to digital archives and be viewed via mobile devices, computers, or virtual reality headsets. Converting the model in these ways could advance the reach of these models, supply another avenue for education and make learning fun. This is one area tested by Google Arts and Culture for classrooms. Virtual reality can even place you in the correct environment to give the object context: this is currently one goal of the Cary Collection.

Finally, facsimiles have also been observed to outlive the original, either through decay or destruction. Having a digitized facsimile online can also preserve the original through the new medium of the internet. The rule of thumb goes that once something goes online it is hard to erase. Unlike a bad picture from middle school, this fact is constructive because it makes a digital facsimile practically immortal. The positive aspect of digitizing objects in three-dimensions is that the digital can have the same, almost tangible, qualities of the original. Like what was said before the model can be spun and tilted as if the object was in the observer's hands. Because of this simulated physicality, preserving objects online is functional and feasible.

Conclusion

When determining the best practices for an institution there is a choice between the reactive and the proactive. Digitizing objects is a proactive move to preserve objects online progressively as well as indefinitely. Digitization also increases accessibility, interest in objects and can be used to create physical facsimiles. This digitization project's success resides in the answers to the questions and goals as outlined as the project's viability defined by the accuracy of the scan and print, the ease of finding expertise and equipment as well as the feasibility allotting the time and funding necessary. At its essence, the digital scan and 3D print's purpose is to expand upon the accessibility of the authentic object. Because of its innate fragility, due to the composition of papier-mâché, the books by Henry Noel Humphreys have constrained access. These books are placed on foam cradles and are only handled by researchers and experts. The purpose behind archives is to allow access to primary information; however, how can this be when the primary object requires limited access.[76] 3D scans can allow a closer observation of the surface's details by magnifying it, spinning the model or, in other words, digitally "handling" this object. Just like the digital conversion of a paperback novel to an e-book makes text this also makes the object more accessible, flexible, immediate, and possibly more enjoyable. A 3D model of *Sentiments and Similes* can reach a larger audience online, kindle interest and spur a visit.

The digital scan was also used to create a three-dimensional physical reproduction of the book's front cover. The Construct on RIT's campus provided the 3D printers and the expertise because this phase was observed to have the largest challenges. These challenges resulted from

[76] "SAA Core Values Statement and Code of Ethics," SAA Core Values Statement and Code of Ethics | Society of American Archivists, accessed April 06, 2017, http://archivists.org/statements/saa-core-values-statement-and-code-of-ethics.

old software, Meshmixer, and the presence of hole and tunnels through the scan. The "Test and Procedure: 3D Printing" section acted as its own "what not to do" piece. However, this does not mean an automatic failure to anyone who attempts 3D digitization in their archive. Digitizers can use the knowledge gained through my trial and error to leapfrog the challenges to produce their own successful project. This project ended up producing a 3D scan, a preliminary 3D print and a final 3D print in color. In the future, one avenue to expand upon the usefulness of the print is to create a mold to help make new papier-mâché bindings by using the offset of the scan. This can lead to historical projects and educational activities centered around this 3D printed mold and paper pulp: New tools can be used to think about older processes. This is perfect for a working archive such as the Cary Collection.

I find this project successful because it showed that a young museum professional can learn from scratch how to digitize and print in three-dimensions within the period of two semesters. The digitization process took three sessions of about two hours each. Even though the clean-up had its own trials it only took about a week. Because I made connections that lead to an extensive collaboration with The Construct, no equipment, software or materials were bought. Similarly, RIT covered the cost of the final print in the name of research. In conclusion, because the facsimiles are almost identical to the original, the time frame is adequate after the initial learning curve and with the aid of collaboration no funds were spent, I find this experiment to see whether a small institution on a budget could have a 3D digitization program a success.

THE ROCHESTER INSTITUTE OF TECHNOLOGY

COLLEGE OF LIBERAL ARTS

The Process of Creating Accurate Reproductions of Fragile Objects:

Fabricating 3D Facsimiles with Limited Resources

Appendices

A THESIS SUBMITTED
IN PARTIAL FULFILLMENT OF THE
BACHELOR OF SCIENCE DEGREE
IN MUSEUM STUDIES

DEPARTMENTS OF PERFORMING ARTS AND VISUAL CULTURE AND HISTORY

BY

Katherine E. Curran

May 2017

Appendices

I. Pictures of original object

Figure 1. Images of the Papier-mâché Book Specimen, photos by Amelia Hugill-Fontanel, Associate Curator of the .

Left: Front cover of *Sentiments and Similes* by William Shakespeare and bound by Henry Noel Humphreys with profile of Shakespeare – papier-mâché.

Right: Back cover of *Sentiments and Similes* by William Shakespeare and bound by Henry Noel Humphreys with initials – papier-mâché

Figure 2. ***The Awakening Conscience*****, painting by William Holman Hunt (1853),**

This painting depicts a man and presumably his mistress in a room specifically decorated for her.[1] If we look close to the man's elbow on the table we will be able to see a papier-mâché bound book reinforcing that these binding were for display only.[2]

[1] "The Awakening Conscience." Wikipedia. March 24, 2017. Accessed April 04, 2017.
[2] Ibid.

II. Collaborated Institutions

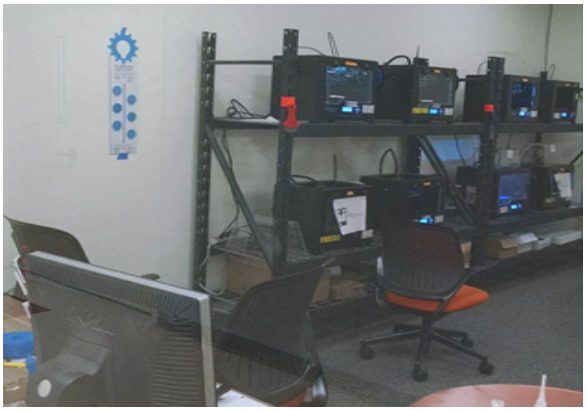


Figure 3: The Construct, photo from The Construct @ RIT Facebook page and their 3D printing room, photo by author

Left: The Construct on the 4th floor of Institute Hall on RIT's campus

Right: New 3D printing room down the hall from The Construct

Figure 4: The Melbert B. Cary Graphic Arts Collection, photo by author

The Cary Collection on the 2nd floor of the Wallace Library on RIT's campus

III. Digitization Procedure

TABLE 1: DIGITIZING PROCEDURE

WITH THE NEXT ENGINE SCANNER

(TABLE CREATED BY AUTHOR)

STEP 1 - DOWNLOAD	Download the Next Engine software called ScanStudio which comes standard[3]
STEP 2 – SEP UP SCANNER	Set up scanner on a sturdy table, near a power source and in a climate controlled environment to ensure object safety. Plug Next engine in to outlet and computer.
STEP 3 – SET UP OBJECT	Place object either on the table, turn table, cradle, stand no more than 6 inches away
STEP 4 – SET UP SCANNER	Open ScanStudio, click scan. On the scan page highlight section of the object you wish to san in the window. Start with a neutral, single scan.
STEP 5 - SCAN	Click scan. May take up to 3 minutes for one scan.
STEP 6 - TRIM	When the scan is finished and there is extra data from other objects captured in the scan, click the trim button. There click the circle icon and highlight, in red, the areas you want to

[3] Webmaster@nextengine.com. "Everything You Need to Scan and Build 3D Models." NextEngine. Accessed March 20, 2017. http://www.nextengine.com/products.

	delete.
STEP 7 - STITCH	When two scans need to be combined, click the align button. The align screen will show the two scans in question and three primary colored pins. Click and drag one pin at a time to sections of each scan they have in common. The computer will then use these shared points to stitch the scans together.
STEP 8 - FILL	If there is still missing data, the fill option can fill in the gaps manually or automatically depending on the circumstance.
STEP 9 - SAVE	When the model is saved, you can save it on to a flash drive to be used later during the 3D printing process or export.

IV. Images of photography station and cradle for digitization process

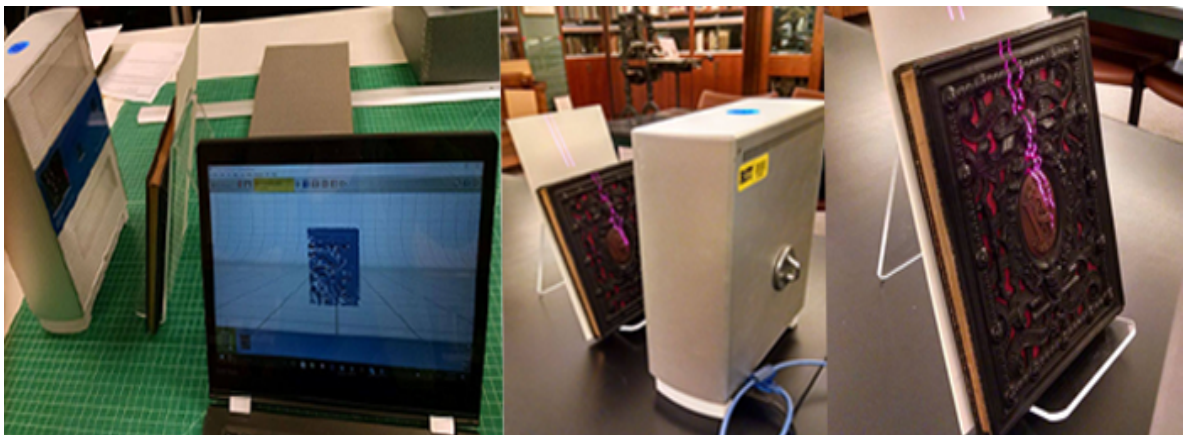


Figure 5. Digitization Set Up, photos by author.

Left: Typical set up of the laptop computer connected to the Next Engine Scanner and book on its stand

Middle: The Next Engine scanner is set up close to the book (six-inches to be exact) to ensure the lasers can read the object

Right: Image of book on stand with a white piece of poster board to limit the viewing distance of the laser. The red laser can be seen to be tracing the surface of the object.

V. Scans from 3D scanner

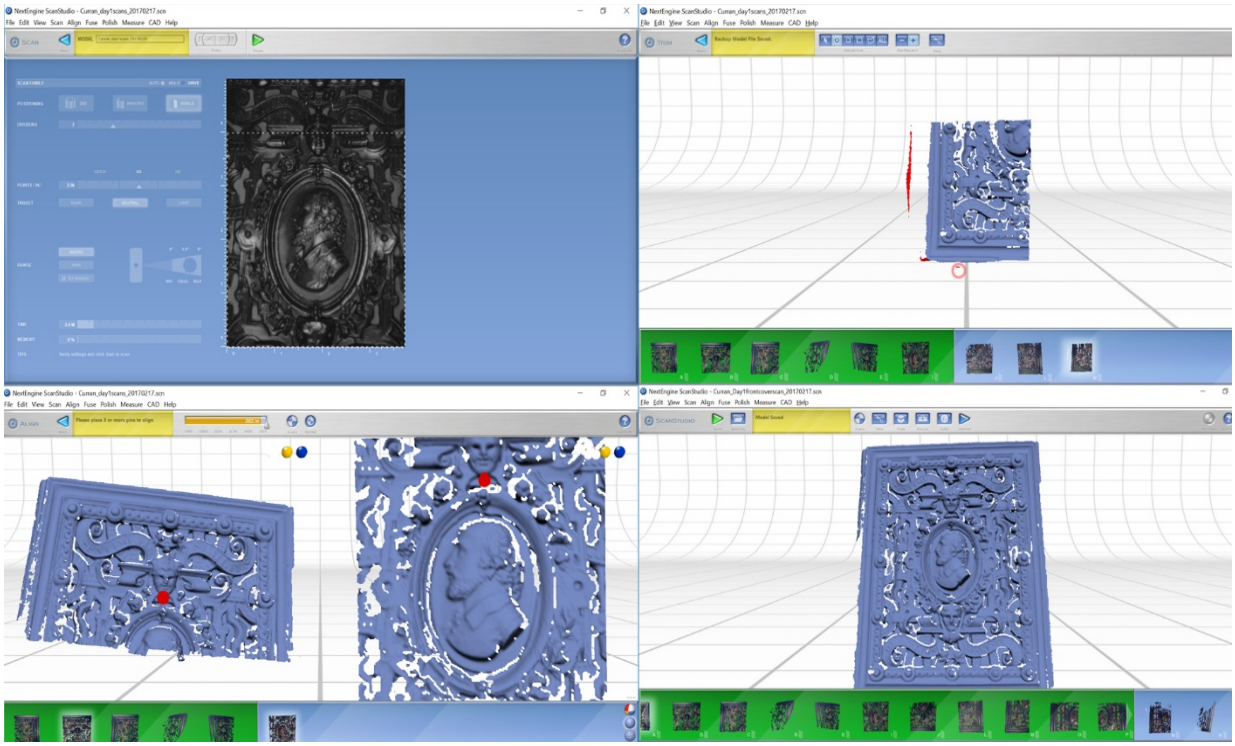


Figure 6. ScanStudio Screenshots, photo by author.

Upper Left: The scanning screen on the ScanStudio software supplies options including the number of scans per sessions, the contrast of the object being scanned, the range and time frame of the scan. What the scanner is viewing is presented in the middle of the page and the digitizer can drag and click the section the digitizer wants the scanner to focus on.

Upper Right: After a piece of the object is scanned, the digitizer can use the trim tool to delete sections of the scan that are extraneous or unneeded.

Lower Left: After, at least, two pieces of the object are scanned and trimmed, the digitizer can align them together. Three pins are necessary to combine the images. As seen in the image above the red pin is placed in the same place - underneath the chin of the face – in both scans.

Lower Right: After all the pieces are stitched together the digitized object will look whole

but include some missing data from shadows or the dark coloring.

Figure 7. 3D model in ScanStudio, photo by author.

Left: During the scanning process, The Next Engine scanner collects color data. After the scan is filled to reduce the amount of missing data the look to the scan is almost identical to the original object while in Color View.

Right: This image is the same as its sibling but under the Shaded View where only the form can be seen. This image is also after the model is made whole after using the fill tool.

VI. Printing Procedure

TABLE 2: PRINTING PROCEDURE AT THE CONSTRUCT (TABLE CREATED BY AUTHOR)

STEP 1 - SAVE	Save file as a STL file. Save on to flash drive to start final cleaning
STEP 2 – PREP WITH MESHMIXER	Download the free software, Meshmixer, to add a base to your 3D scan to add support. Transform to angle the scan parallel to the bed. Then highlight the whole scan, click edit

	and Extrude. Extrude on the y-axis and use the flat function to create the new bottom in the positive direction. Do not use the tool harden under the Extrude tool.[4]
STEP 3 – FILL HOLES	Use Autodesk ReMake to fill holes in the original scan. The holes can be filled all at once and then use Extrude again to replace the foundation.
STEP 4 – SAVE PRINT	Save the print as a gcode.
STEP 5 - SLICE	Determine whether accuracy or speed is your aim: this decision will determine the size of the slice. The default size is .2mm. The size of the slice used in this project is .15mm.
STEP 6 - PRINT	We used the PRUSA 3D printer because it can print in High Definition. Plug the SD card into the printer
STEP 7 – CLEAN UP	After the print is finished there might be excess PLA around, underneath or on top of the print. Either pull off, sand off or brush off the excess. If necessary sand the surface. To finish, the digitizer can paint the print in a matte color like gray to highlight detail.

[4] If any issues do arise, You Tube has a good cache of expertise and information about this software

VII. Screenshots and Images from 3D print tests

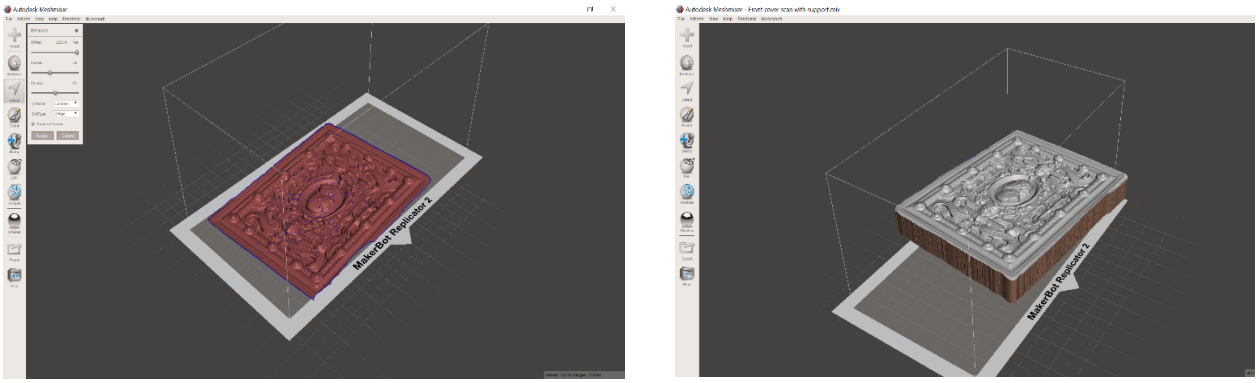


Figure 8: 3D model editing in Meshmixer, photo by author.

Left: The thin, almost two dimensional, 3D scan is highlighted after made parallel to the printing bed. This image shows the Extrusion tool before it is implemented.

Right: This image depicts the look of the model after the Extrusion tool is used in Meshmixer. A base is stretched width wise using from underside of the scan. The base is slightly exaggerated in this image to clearly exhibit it; however, when printed, the base is about ½ inch wide.

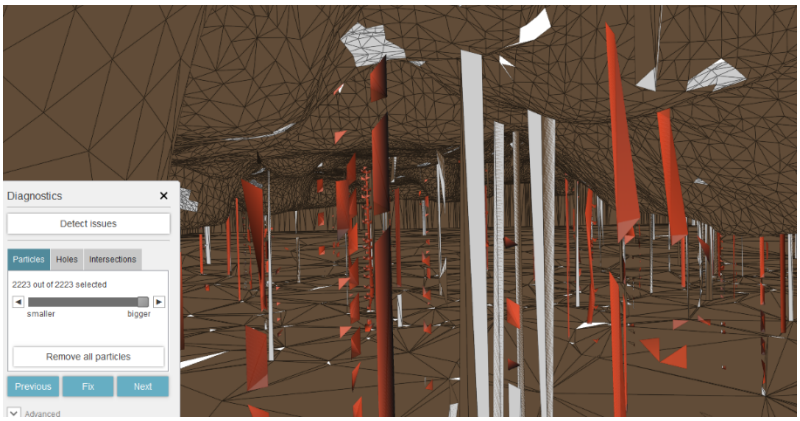


Figure 9: Autodesk ReMake screenshot, image provided by Mike Buffalin

Screenshot of the space between the front cover and the model's base. This error results in too many triangles that causes failure in 3D printing software hindering the printing process.

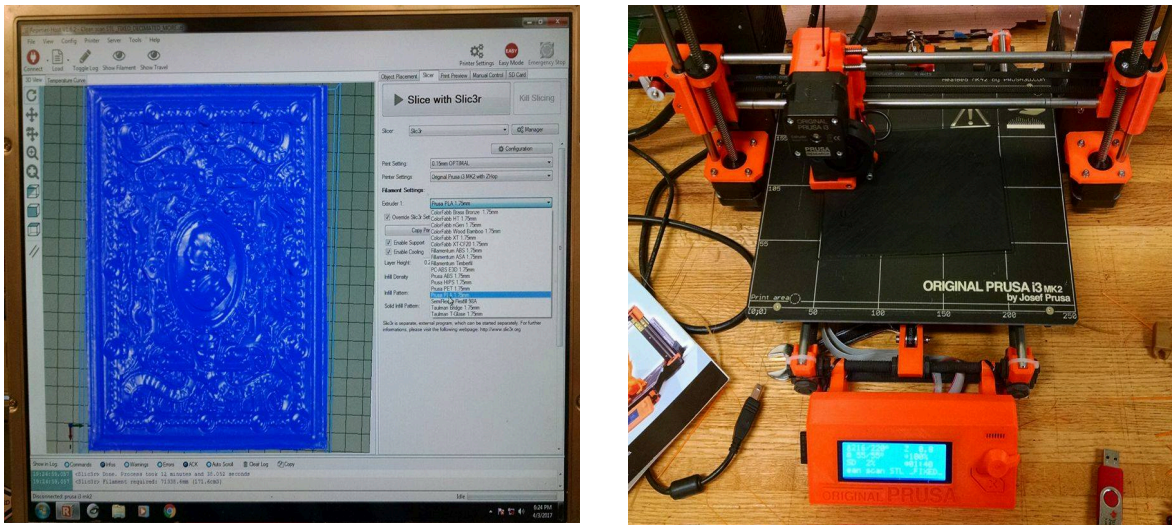


Figure 10: Printing Process, photos by author

Left: An image of the Repetier software used to program the size of each slice of the print

Right: PRUSA 3D printer used in this project. This printer is made from 3D printers.

Figure 11: The 3D Print, photo by author

This image is of the 3D print using the 3D scanned model of the book *Sentiments and Similes*

by William Shakespeare that took four scan days, five edit days and 9 hours and 13 minutes to create. Major detail is still there, it looks like the original and can be easily passed around as an educational tool. Aside from its size and layered look, I qualify this print an acceptable educational model of the original.

VIII. Authentic Vs. Print, photos by author

Figure 12: Comparing The authentic front Cover, photo by Amelia Hugill-Fontanel, to the Reproduction Scan and Print, photos by author

Left: Front cover of *Sentiments and Similes* by William Shakespeare and bound by Henry Noel Humphreys with profile of Shakespeare – papier-mâché.

Middle: During the scanning process, The Next Engine scanner collects color data. After the scan is filled to reduce the amount of missing data the look to the scan is almost identical to the original object while in Color View.

Right: 3D print of the *Sentiments and Similes* Front Cover using the PRUSA 3D printer using PLA. Aside from its decreased size and layered look from the printer, I say that this is an adequate facsimile.

Figure 13. First 3D print and original object respectively, photo by author

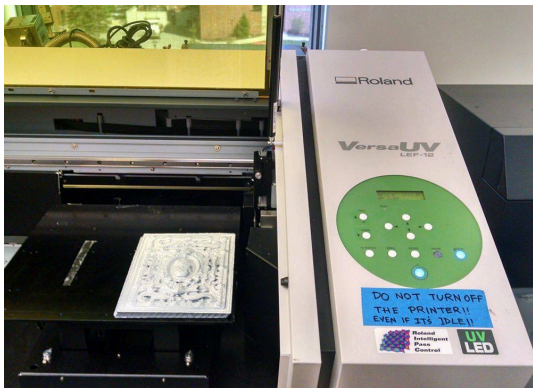
The 3D print is shown next to the original to show size and resolution of the extruded detail.

Figure 14. Second and final print was also created from the PRUSA PLA printer, photos by author.

Left: This version was printed in its accurate size ; however, the layers were still visible. One layer of epoxy was painted over the entire form to smooth out the surface and reveal detail.

Middle: View of print after expoxy coat.

Right: To prepapre the print for a color layer, the fascimile was spray painted white.



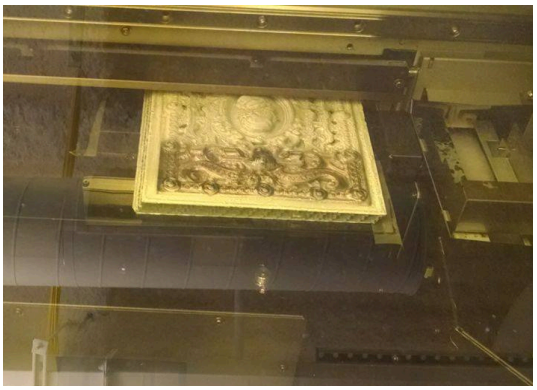


Figure 15: Printing on the VersaUV ink cured printer, photos by author.

Left: View of print on printing bed before starting the printer. The printer acted just like a normal color printer except it recognizes the y-axis making it perfect for 3D objects.

Right: View of facsimile half way into color application during the first layer. Two layers were cured on top of the print totaling a ten minute procedure (five minutes a piece).

Figure 16. Finished color 3D Print, photo by author.

Created from both the PRUSA printer and VersaUV color cure printer. It is accurate size but the red representing the silk was too light and blue to be considered accurate. The red was then printed in by hand to darken up the color. The shade of red is close enough to the original shade.

Figure 17. Comparison of the two physical prints to the original, photo by author. On the left is the first smaller print without color, in the center is the original object created by Henry Noel Humphreys and on the right is the last print printed from the same PRUSA printer with two layers of cured ink from the Versa UV printer. The last print is almost the same size as the original so it is classified as accurate, the difference is the result of the scanning process. The color of the second was soon corrected after this photo to match the authentic object.

IX: Technology and Digitization Survey

TABLE 3. Status of Technology and Digitization in the Nation's Museums and Libraries Survey by The Institute of Museum and Library Services

BACKGROUND ON ARCHIVES

A. Your archive is which type of archival institution? (Select the one best option.)

- ❍ Federal government archive
- ❍ State government archive
- ❍ Local government archive (e.g., county, municipal)
- ❍ Affiliated with a college or university
- ❍ Affiliated with a museum
- ❍ Affiliated with a historical society
- ❍ Separate/independent archive

B. What is the size of your archive's annual budget? (Select the one best option.)

- ❍ Less than $250,000
- ❍ $250,001 - $500,000
- ❍ $500,001 - $750,000
- ❍ $750,001 - $1,000,000
- ❍ $1,000,001 - $5,000,000

❍ $5,000,001 - $10,000,000

❍ $10,000,001 - $25,000,000

❍ More than $25,000,000

C. What is the current size of your archive's paid, full time equivalent (FTE) staff? (Select the one best option.)

❍ Less than 5

❍ 6 – 10

❍ 11 – 25

❍ 26 – 75

❍ 76 – 150

❍ 151 – 250

❍ 251 – 500

❍ 501 – 1,000

❍ 1,001 – 1,500

❍ More than 1,500

TECHNOLOGY

In this survey **technology** refers to using and managing information in digital formats through use of computers (hardware and software), automated systems to support services, Internet and other network connections, Web sites and Web-based services, office productivity applications like word processing and e-mail, staff to support these activities, and the range of technologies that help staff and users search, access, and experience collections on-site and virtually.

1. In the past 12 months, did your institution have funding for technology? (Select the one best option.)
   - ❍ No
   - ❍ Don't know/Not applicable
   - ❍ Yes (If yes, select all that apply below.)

If yes, you obtain your funds from: (Select all below that apply.)

- ☐ Endowment funds
- ☐ Foundation grants, including Gates Library Initiative
- ☐ Gifts from donors
- ☐ IMLS Museum National Leadership Grants
- ☐ IMLS LSTA State Program and Library National Leadership Grants
- ☐ Grants from other Federal agencies (e.g., Dept. of Ed., NEH)
- ☐ Institutional operating funds
- ☐ State funds
- ☐ City, county or other local government funds
- ☐ Corporate sponsors
- ☐ Other (Please list): _____

2. In the next 12 months, do you plan to obtain funding for your technology? (Select the one best option.)
   - ❍ No
   - ❍ Don't know/Not applicable
   - ❍ Yes (If yes, select all that apply below.)

If yes, you plan to obtain funds from: (Select all below that apply.)

- ☐ Endowment funds
- ☐ Foundation grants, including Gates Library Initiative
- ☐ Gifts from donors
- ☐ IMLS Museum National Leadership Grants
- ☐ IMLS LSTA State Program and Library National Leadership Grants
- ☐ Grants from other Federal agencies (e.g., Dept. of Ed., NEH)
- ☐ Institutional operating funds
- ☐ State funds
- ☐ City, county or other local government funds
- ☐ Corporate sponsors
- ☐ Other (Please list): _____

3. What percent of your institution's technology needs are met by current funding? (Select the one best option.)

- ❍ 0%
- ❍ 1%-25%
- ❍ 26%-50%
- ❍ 51%-75%
- ❍ 76%-99%

4. Indicate the degree to which you agree with the following statements. (Select one in each row.) My institution is able to:

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Not Applicable
a. Maintain its current level of technology	❍	❍	❍	❍	❍	❍
b. Add new uses of technology to meet evolving needs	❍	❍	❍	❍	❍	❍

5. To what extent does your institution have the technology capacity (e.g., equipment, software, connectivity, skills and expertise, staffing) necessary to meet its mission? (Select the one best option.) Our technology capacity:
   - ❍ Currently meets our mission
   - ❍ Almost meets our mission
   - ❍ Is short of meeting our mission
   - ❍ Does not meet our mission
   - ❍ Don't know/Not applicable

6. What technologies has your institution used in its day-to-day operations within the past 12 months, or plan to acquire or implement in the future? (Select one in each row.)

	Used in past 12 months	Plan to acquire or implement in next 12 months	Plan to acquire or implement more than 12 months from now	Do not plan to acquire or implement/ Don't know
a. Accounting/payroll software/HR	❍	❍	❍	❍
b. Broadband Internet connection	❍	❍	❍	❍
c. Computerized catalog of library or other collections	❍	❍	❍	❍
d. Computerized collections management system	❍	❍	❍	❍
e. Database software or system for membership development	❍	❍	❍	❍
f. Desktop computers	❍	❍	❍	❍
g. E-mail	❍	❍	❍	❍
h. GIS (geographic information systems) applications	❍	❍	❍	❍
i. Integrated library system (ILS)	❍	❍	❍	❍
j. Intranet	❍	❍	❍	❍

k. LAN (local area network)	❍	❍	❍	❍
l. Marketing and promotion software and systems	❍	❍	❍	❍
m. Meta- or federated searching in online collections and catalogs	❍	❍	❍	❍
n. Modem (dial access) Internet connection	❍	❍	❍	❍
o. Multimedia services or collections	❍	❍	❍	❍
p. Notebook or tablet computers	❍	❍	❍	❍

	Used in past 12 months	Plan to acquire or implement in next 12 months	Plan to acquire or implement more than 12 months from now	Do not plan to acquire or implement/ Don't know
q. Office productivity software, including word processing, desktop publishing and spreadsheets	❍	❍	❍	❍
r. PDA (personal digital assistant handheld devices, e.g. Palm)	❍	❍	❍	❍
s. Personal information management (PIM) software	❍	❍	❍	❍
t. Point-of-sale software and systems	❍	❍	❍	❍
u. RFID (radio frequency identification) in services or collections	❍	❍	❍	❍
v. Software to manage public access computers and printing	❍	❍	❍	❍
w. Video tours	❍	❍	❍	❍
x. Virtual reality tours	❍	❍	❍	❍
y. Web portal or gateway for services or collections	❍	❍	❍	❍
z. Web site for your institution	❍	❍	❍	❍
aa. Wireless network, including WiFi	❍	❍	❍	❍
bb. Other (Please list): _____	❍	❍	❍	❍

7. For which of the following purposes has your institution used technology to serve your community (i.e., users and visitors that your institution serves, supports, and engages) in the past 12 months, and for which purposes does your institution plan to start using technology to serve this community in the next 12 months? (Select one in each row.)

	Used in past 12 months	Plan to start using in next 12 months	Plan to start using more than 12 months from now	Do not plan to use for this purpose
a) To disseminate research findings and publications by our institution's staff	❍	❍	❍	❍
b) To orient and instruct users about available services	❍	❍	❍	❍
c) To present educational programs	❍	❍	❍	❍
d) To provide access to computers	❍	❍	❍	❍
e) To provide access to the Internet	❍	❍	❍	❍
f) To provide educational programs offered by our institution	❍	❍	❍	❍
g)To provide information literacy instruction	❍	❍	❍	❍
h) To provide orientation, introduction and educational information on exhibits	❍	❍	❍	❍

	Used in past 12 months	Plan to start using in next 12 months	Plan to start using more than 12 months from now	Do not plan to use for this purpose
i) To provide user services (e.g., provision of career, health, government information)	❍	❍	❍	❍
j) Other (Please list): _____	❍	❍	❍	❍

8. Indicate the degree to which you agree with the following statements. (Select one in each row.) Technology has been useful in your institution because it:

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Not Applicable
a. Makes programs and exhibits more interactive	❍	❍	❍	❍	❍	❍
b. Provides a richer educational experience	❍	❍	❍	❍	❍	❍
c. Increases the number of people who participate in programs	❍	❍	❍	❍	❍	❍
d. Increases access to institutional resources and services	❍	❍	❍	❍	❍	❍
e. Other (Please list): _____	❍	❍	❍	❍	❍	❍

9. What are the primary hindrances to your institution's use of technology? (Select your **top three (3)** hindrances from the list below.)

Q Lack of staff time

Q Lack of staff skills and expertise

Q Lack of funds

Q Lack of necessary equipment, software and/or networking

Q Concerns about intellectual property issues

Q Security concerns

Q Technology is not appropriate for our collection and services or the pubic we serve

Q Technology is not supported by management and/or the Board

Q Other (Please list): _____

10. To what extent do you have sufficient, skilled staff to accomplish your technology activities? (Select the one best option.)

❍ We do not have enough skilled staff to accomplish our technology activities

- ❍ We have the right amount of skilled staff to accomplish our technology activities
- ❍ We have more than enough skilled staff to accomplish our technology activities
- ❍ Other (Please list): _____
- ❍ Don't know/Not applicable

11. Where in your institution's organizational structure are the staff with technology responsibilities (e.g., procurement, installation, resource allocation, operations and maintenance) placed? (Select all that apply.)

Q Management

Q Separate Information Systems/Technology Department

Q Integrated within operational departments

Q Other (Please list): _____

Q Don't know/Not applicable

12. Do you conduct needs assessments of user or visitor needs for technology supported services or experiences at your institution? (Select the one best option.)

❍ No (**Please skip to question 14**.)

❍ Don't know/Not applicable

❍ Yes

13. Are you taking action based on the results of your assessments? (Select the one best option.)

❍ Yes

❍ Don't know/Not applicable

❍ No (If no, select all that apply below.)

If no, because of: (Select all below that apply.)

Q Lack of staff time

Q Lack of staff skills and expertise

Q Lack of funds

Q Lack of appropriate equipment, software and networking

Q Not appropriate for our mission/goals

Q Other (Please list): _____

14. Which of the following statements best describes the attitudes of **your institution's Directors or Trustees** towards technology acquisition and technology use by your institution? (Select the one best option.)

❍ The Directors / Trustees of my institution generally promote expansion of my institution's technology capabilities and they provide specific guidance of these efforts

❍ The Directors / Trustees of my institution generally promote expansion of my institution's technology capabilities, but they provide little specific guidance of these efforts

❍ The Directors / Trustees of my institution are generally neutral on the subject of expanding my institution's technology capabilities

❍ The Directors / Trustees of my institution generally oppose the expansion of my institution's technology capabilities

❍ Don't know/Not applicable

15. Which of the following statements best describes the attitudes of **the population served by your institution** towards technology acquisition and technology use by your institution? (Select the one best option.)

❍ The population served by my institution generally promotes expansion of my institution's technology capabilities and offers suggestions for these efforts

❍ The population served by my institution generally promotes expansion of my institution's technology capabilities, but provides few suggestions for these efforts

❍ The population served by my institution is generally neutral on the subject of expanding my institution's technology capabilities

❍ The population served by my institution generally opposes the expansion of my institution's technology capabilities

❍ Don't know/Not applicable

DIGITIZATION

Digitization is the process of converting, creating, and maintaining books, art works, historical documents, photos, journals, etc. in electronic representations so they can be viewed via computer and other devices.

16. What digitization policies does your institution currently have in place or in development? (Select one in each row.)

Policies in place		Policies in development	No policies in place or in development/ Don't know
a. Access	❍	❍	❍
b. Best practices	❍	❍	❍
c. Conversion of digital files to next generation formats	❍	❍	❍
d. Digital format (e.g., TIFF, GIF, PAL)	❍	❍	❍
e. Evaluation	❍	❍	❍
f. Institutional repository	❍	❍	❍
g. Intellectual property issues	❍	❍	❍
h. Materials to be digitized	❍	❍	❍
i. Priorities for digitization	❍	❍	❍
j. Preservation	❍	❍	❍
k. Quality control	❍	❍	❍
l. Standards	❍	❍	❍
m. Metadata	❍	❍	❍
n. Security	❍	❍	❍
o. Other (Please list): _____	❍	❍	❍

17. Do you provide direct funding or services to other institutions for their digitization activities? (Select the one best option.)
    - ❍ No
    - ❍ Don't know/Not applicable
    - ❍ Yes (If yes, select all that apply below.)

If yes, the following activities are funded by your institution: (Select all that apply.)

Q Digitizing library collections

Q Digitizing special collections (like rare books or historical documents)

Q Supporting cooperative digitizing projects or partnerships

Q Accessing digital products (e.g., historical collections on-line)

Q Supporting **statewide** digitizing projects, such as developing strategic plans, surveying collections and implementing digitizing facilities

Q Supporting **inter-state** digitizing efforts, such as developing strategic plans, surveying collections and implementing digitizing facilities

Q Other (Please list): _____

18. In the past 12 months, did your institution have funding to support your digitization activities? (Select the one best option.)

- ❍ No
- ❍ Don't know/Not applicable
- ❍ Yes (If yes, select all that apply below.)

If yes, you obtained your funds from: (Select all below that apply.)

- ❍ Endowment funds
- Q Foundation grants
- Gifts from donors
- Q Grants from other Federal agencies (e.g., Dept of Ed, NEH)
- ❍ IMLS LSTA State Program and Library National Leadership Grants
- ❍ IMLS Museum National Leadership Grants
- Q Institutional operating funds
- Q Q State funds
- City, County or other local government funds
- ❍ Corporate sponsors
- ❍ Other (Please list): _____

19. In the next 12 months, do you plan to obtain funding to support your digitizing activities? (Select the one best option.)

- ❍ No
- ❍ Don't know/Not applicable
- ❍ Yes (If yes, select all that apply below.)

If yes, you plan to obtain funds from: (Select all below that apply.)

- ❍ Endowment funds
- Q Foundation grants
- Gifts from donors
- Q Grants from other Federal agencies (e.g., Dept of Ed, NEH)
- ❍ IMLS LSTA State Program and Library National Leadership Grants
- ❍ IMLS Museum National Leadership Grants
- Q Institutional operating funds
- Q Q State funds
- City, County or other local government funds
- ❍ Corporate sponsors
- ❍ Other (Please list): _____

20. What materials has your institution digitized or imaged, and what additional materials is your institution planning to digitize or image? (Select one in each row.)

	Began digitizing more than 12 months ago	Began digitizing in last 12 months or currently	Plan to begin digitizing in next 12 months	Plan to begin digitizing more than 12 months	Do not plan to digitize/ Don't know
a. Correspondence, diaries and other personal records	**digitizing**		**from now**		
b. Course material	❍	❍	❍	❍	❍
c. Education and training material about the collections	❍	❍	❍	❍	❍
d. Films, videotapes	❍	❍	❍	❍	❍
e. Government publications	❍	❍	❍	❍	❍
f. Historical documents/archives	❍	❍	❍	❍	❍
g. Items in the collections (e.g., art work, artifacts, furniture, plants, animals)	❍	❍	❍	❍	❍
h. Information on the institution	❍	❍	❍	❍	❍
i. Journals and other serials	❍	❍	❍	❍	❍
j. Manuscripts	❍	❍	❍	❍	❍
k. Maps	❍	❍	❍	❍	❍
l. Music and other recorded sound	❍	❍	❍	❍	❍
m. Newspapers	❍	❍	❍	❍	❍
n. Photographs	❍	❍	❍	❍	❍
o. Rare books	❍	❍	❍	❍	❍
p. Records about the collection	❍	❍	❍	❍	❍
q. Sheet music	❍	❍	❍	❍	❍
r. Special exhibits	❍	❍	❍	❍	❍
s. Theses and dissertations	❍	❍	❍	❍	❍
t. Other (Please list):	❍	❍	❍	❍	❍
_____	❍	❍	❍	❍	❍

21. **If you had the resources**, which of the following kinds of materials would you digitize or image? (Select your **top three (3)** from the list below.)

- ❍ Correspondence, diaries and other personal records
- ❍ Course material
- ❍ Education and training material about the collections
- Q Films, videotapes
- ❍ Government publications
- ❍ Historical documents/archives
- ❍ Items in the collections (e.g., art work, artifacts, furniture, plants, animals)
- ❍ Information on the institution
- ❍ Journals and other serials
- Q Manuscripts
- ❍ Maps
- ❍ Music and other recorded sound
- ❍ Newspapers
- ❍ Photographs
- Q Q Rare books
  Records about the collection
- ❍ Sheet music
- ❍ Special exhibits
- ❍ Theses and dissertations
- ❍ Other (Please list):

_____

22. What are your institution's primary digitization priorities? (Select your **top three (3)** priorities from the list below.)

- ☐ Correspondence, diaries and other personal records
- ☐ Course material
- ☐ Education and training material about the collections
- ☑ Films, videotapes
- ☐ Government publications
- ☐ Historical documents/archives
- ☐ Items in the collections (e.g., art work, artifacts, furniture, plants, animals)
- ☐ Information on the institution
- ☑ Journals and other serials
- ☑ Manuscripts
- ☐ Maps
- ☐ Music and other recorded sound
- ☐ Newspapers
- ☐ Photographs
- ☑ Rare books
- ☑ Records about the collection
- ☐ Sheet music
- ☐ Special exhibits
- ☐ Theses and dissertations
- ☐ Other (Please list): _____
- ☑ Don't know/Not applicable

23. In the past 12 months, how many digital materials or images has your institution created? (Select the one best option.)

- ❍ 0
- ❍ 1-500
- ❍ 501-1,000
- ❍ 1,001-5,000
- ❍ 5,001-10,000
- ❍ 10,001-25,000
- ❍ More than 25,000

24. How many more digital materials or images does your institution have to digitize or image? (Select the one best option.)

- ❍ 0
- ❍ 1-500
- ❍ 501-1,000
- ❍ 1,001-5,000
- ❍ 5,001-10,000
- ❍ 10,001-25,000
- ❍ More than 25,000

25. What is your institution's obligation to make digitized materials or images available, to sustain the digital materials or images, and to sustain user access to them? (Select all that apply, and at least one in each row.)

❍ We have no obligation to maintain digital materials or images or access to them. (**Please skip to question 26**.)

	Make digitized materials available	**Sustain digitized materials**	**Sustain user access to digitized materials**	**Not Applicable**
a. It is mandated by regulatory or legislative authority	Q	Q	Q	Q
b. It is mandated by organizational directives or by-laws	Q	Q	Q	Q
c. It is compelled by licensing agreements	Q	Q	Q	Q
d. It is compelled by membership participation	Q	Q	Q	Q
e. It is compelled by public expectation	Q	Q	Q	Q
f. It is compelled by consortia commitment	Q	Q	Q	Q
g. Other (Please list): _____	Q	Q	Q	Q

26. How does your institution undertake its digitization activities? (Select all that apply.)

Q Contractual staff were hired to perform these activities in-house

Q New institutional staff were hired to perform these activities

Q Current staff were trained to perform these activities

Q Current staff were reassigned to perform these activities

Q Volunteers perform these activities

Q These activities are performed by commercial vendors off-site

Q Materials are digitized off-site at another institution's digitization center

Q Other (Please list): _____

Q Don't know/Not applicable

27. Do you make some or all of your digital image collections available to the public? (Select the one best option.)

❍ Yes, some of our digital image collections are available to the public

❍ Yes, all of our digital image collections are available to the public

❍ No, our digital image collections are not available to the public (**Please skip to question 29**.)

❍ Don't know/Not applicable

28. How are your digital image collections made available? (Select all that apply.)

Q On the premises on our computer network (LAN)

Q On the Web

Q Through a third party

Q Don't know/Not applicable

29. Who can access some or all of your institution's digital image collections, and is there a charge for service? (Select one in each row.)

Pays for access	Does not pay for access	Does not have access	Don't know/Not applicable
a. General public who have Internet access	❍	❍	❍	❍
b. Anyone who subscribes to a commercial agent that provides access (e.g., AMICO)	❍	❍	❍	❍
c. Onsite visitors at your institution	❍	❍	❍	❍
d. Members (e.g., library card holders, museum members)	❍	❍	❍	❍
e. Your staff	❍	❍	❍	❍
f. Consortia/partners	❍	❍	❍	❍
g. Researchers/scholars at your institution	❍	❍	❍	❍
h. Faculty at your institution	❍	❍	❍	❍
i. Educators not part of your institution	❍	❍	❍	❍
j. Students at your institution	❍	❍	❍	❍
k. Students at affiliated institutions	❍	❍	❍	❍
l. Alumni	❍	❍	❍	❍
m. Outside researchers and scholars	❍	❍	❍	❍
n. Other (Please list): _____	❍	❍	❍	❍

30. Are your digital materials or images listed in a digital registry (e.g., Association for Research Libraries' Digital Initiatives Database, UIUC OAI Metadata Harvesting Project)? (Select the one best option.)

- ❍ No
- ❍ Don't know/Not applicable
- ❍ Yes (Please list): _____

31. What are the primary goals for your institution's digitizing activities? (Select your **top three (3)** goals from the list below.)

Q Preserve materials of importance or value Q

Increase access to collections/materials/files Q

Minimize damage to original materials

Q Provide access to material via the Web

Q Increase interest in the institution

Q Save space in the institution

Q Present more of the collection than is on display at any one time

Q Save cost by eliminating duplication of materials

Q Provide access to materials for specific audiences (e.g., reserve room materials for students)

Q Encourage cooperation among institutions to increase the number and variety of materials available

Q For distance or other e-learning programs

Q Provide greater information about the institution's collections to artists, scholars, students, teachers, and the public

Q Increase access to state services

Q For our institution's internal records

Q Support educational programs

Q Other (Please list): _____

Q Don't know/Not applicable

32. If you had no constraints, why would you digitize your materials? (Select your **top three (3)** from the list below.)

- ○ Preserve materials of importance or value
- ○ Increase access to collections/materials/files
- ○ Minimize damage to original materials
- ○ Provide access to material via the Web
- ○ Increase interest in the institution
- ○ Save space in the institution
- ○ Present more of the collection than is on display at any one time
- ○ Save cost by eliminating duplication of materials
- ○ Provide access to materials for specific audiences (e.g., reserve room materials for students)
- ○ Encourage cooperation among institutions to increase the number and variety of materials available
- ○ Provide greater information about the institution's collections to artists, scholars, students, teachers, and the public
- ○ Increase access to state services
- ○ For our institution's internal records
- ○ Support educational programs
- ○ Other (Please list): _____
- ○ Don't know/Not applicable

33. Who do you consider your primary target audiences for your institution's digital materials? (Select your **top three (3)** target audiences from the list below.)

Q General public who have Internet access

Q Onsite visitors at the institution

Q Members (e.g., library card holders, museum members)

Q Your staff

Q Consortia/partners

Q Researchers/scholars at your institution

Q Faculty at your institution

Q Educators not part of your institution

Q Students at your institution

Q Students at affiliated institutions

Q Alumni

Q Outside researchers and scholars

Q Other (Please list): _____

Q Don't know/Not applicable

34. **If you had no constraints**, for what audiences would you target your digitized materials? (Select your **top three (3)** target audiences from the list below.)

Q General public who have Internet access

Q Onsite visitors at the institution

Q Members (e.g., library card holders, museum members)

Q Your staff

Q Consortia/partners

Q Researchers/scholars at your institution

Q Faculty at your institution

Q Educators not part of your institution

Q Students at your institution

Q Students at affiliated institutions

Q Alumni

Q Outside researchers and scholars

Q Other (Please list): _____

Q Don't know/Not applicable

35. Do you conduct needs assessments of user or visitor needs for digitized materials and images in your institution? (Select the one best option.)

❍ No (**Please skip to question 37**.)

❍ Don't know/Not applicable

❍ Yes

36. Are you taking action to meet the needs of users based on the results of your assessments? (Select the one best option.)

❍ Yes

❍ Don't know/Not applicable

❍ No (If no, please select all that apply below.)

If no, because of: (Select all below that apply.)

Q Lack of staff time

Q Lack of staff skills and expertise

Q Lack of funds

Q Not appropriate for our mission/goals

Q Other (Please list): _____

37. Does your institution actively collaborate (through specific partnering agreements) with other institutions and organizations to digitize materials? (Select the one best option.)

❍ No (**Please skip to question 39**.)

❍ Don't know/Not applicable

❍ Yes (If yes, please select all that apply below.)

If yes, we collaborate with: (Select all below that apply.)

Q State library agencies

Q Academic libraries

Q Individual public libraries

Q County, municipal or other local government agencies or archives

Q Universities and colleges

- ☐ Private libraries
- ☐ Museums
- ☐ Consortia
- ☐ State archives
- ☐ Special libraries
- ☐ Historical societies
- ☐ Federal government agencies or archives
- ☐ Other state government agencies
- ☐ Community organizations
- ☐ Private companies
- ☐ Foundations
- ☐ State library associations
- ☐ State museum associations
- ☐ Other professional associations
- ☐ Other (Please list):

_____

38. In what ways does your institution collaborate with other libraries, museums, archives, and other institutions in digitization activities? (Select all that apply.)

- ❍ By coordinating state-wide, regional or consortial digitization activities
- Q By identifying the materials or collections to be digitized
- Q By providing financial support
- By providing staff, equipment or technical expertise for digitization projects
- ❍ By undertaking demonstration projects on digitizing
- Q By providing a digitization center to which institutions send their materials for imaging
- ❍ By setting policies or standards on digitizing, selecting materials and collections for digitizing
- Q By providing Best Practices and Guidelines
- Q By providing consultation to local libraries or museums on digitizing, management of digital collections
- ❍ By encouraging cooperative digitizing projects
- Q Q By issuing sub-grants for digitization
- Other (Please list): _____
- Q Don't know/Not applicable

39. Rate on a scale from 1 to 5, with 1 being "Deficient" and 5 being "Fully Capable," how capable your institution is in the following areas for initiating, accomplishing and sustaining digitization activities.

	Deficient 1	2	3	4	Fully Capable 5	Not Applicable
a. Staff skills and expertise	❍	❍	❍	❍	❍	❍
b. Equipment and software	❍	❍	❍	❍	❍	❍
c. Funding	❍	❍	❍	❍	❍	❍
d. Established digitization plan	❍	❍	❍	❍	❍	❍
e. Established digitization policies	❍	❍	❍	❍	❍	❍
f. Established quality standards	❍	❍	❍	❍	❍	❍
g. Established procedures for preparation for creating digital images	❍	❍	❍	❍	❍	❍
h. Established procedures for the management of images and files	❍	❍	❍	❍	❍	❍
i. Other (Please list):	❍	❍	❍	❍	❍	❍

_____

40. Indicate the degree to which you agree with the following statements. (Select one in each row.) Digitization activities in your institution are hindered by:

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Not Applicable
a. Lack of staff time	❍	❍	❍	❍	❍	❍
b. Lack of staff skills and expertise	❍	❍	❍	❍	❍	❍
c. Lack of funds	❍	❍	❍	❍	❍	❍
d. Lack of necessary equipment and/or software	❍	❍	❍	❍	❍	❍
e. Lack of an established digitization plan	❍	❍	❍	❍	❍	❍
f. Lack of established digitization policies	❍	❍	❍	❍	❍	❍
g. Lack of established quality standards	❍	❍	❍	❍	❍	❍
h. Lack of established policies and procedures for preparation of materials for digitizing	❍	❍	❍	❍	❍	❍
i. Lack of established policies and procedures for the management of images and files	❍	❍	❍	❍	❍	❍
j. Other projects that have higher priorities	❍	❍	❍	❍	❍	❍
k. Concern about intellectual property issues	❍	❍	❍	❍	❍	❍
l. Security concerns	❍	❍	❍	❍	❍	❍
m. Not having collections worth digitizing	❍	❍	❍	❍	❍	❍
n. Concern about costs of preservation and management	❍	❍	❍	❍	❍	❍
o. Management is unaware of the benefits of digitization	❍	❍	❍	❍	❍	❍
p. Other (Please list): _____	❍	❍	❍	❍	❍	❍

41. What are the primary hindrances of your institution's digitization activities? (Select your **top three (3)** hindrances from the list below.)

- ○ Lack of staff time
- ○ Lack of staff skills and expertise
- Q Lack of funds
- Lack of necessary equipment and/or software
- Q Lack of an established digitization plan
- Lack of established digitization policies
- ○ Lack of established quality standards
- ○ Lack of established policies and procedures for preparation of materials for digitizing
- ○ Lack of established policies and procedures for the management of images and files
- Q Other projects have higher priorities
- ○ Concern about intellectual property issues
- Q Security concerns
- ○ Do not have collections worth digitizing
- ○ Concern about costs of preservation and management
- Q Other (Please list): _____
- Q Don't know/Not applicable

IMLS ROLE

42. What are the top three (3) ways IMLS should support the implementation of appropriate **technologies** in your institution? (Select your **top three (3)** from the list below.)

- Q Identify the costs and resources required
- Q Identify and provide information about models
- Q Provide funding
- Q Provide information on sources of funding
- Q Identify and promote standards
- Q Identify and promote technology best practices (e.g., cost effective technologies, efficient technology implementation)
- Q Inform us about the advantages and challenges of implementing technology
- Q Report on the current status of technology implementation
- Q Provide referral information on projects, resources, standards, guidelines, etc.
- Q Other (Please list):

_____

- Q IMLS should not have a role in technology implementation
- Q Don't know/Not applicable

43. What are the top three (3) ways IMLS should support **digitization activities** in your institution? (Select your **top three (3)** from the list below.)

- Q Identify the costs and resources required
- Q Identify and provide information about models
- Q Provide funding

Q Provide information on sources of funding

Q Identify and promote standards

Q Identify and promote best practices

Q Inform us about the advantages and challenges of digitization

Q Help with intellectual property issues

Q Support development of a Web portal/Web site to enable users to search digital resources

Q Lead and promote national digitization efforts

Q Provide referral information on projects, resources, standards, guidelines, etc.

Q Other (Please list):

_____

Q IMLS should not have a role in digitization efforts

Q Don't know/Not applicable

Bibliography:

Audenaert, Neal, and Richard Furuta. "Annotated Facsimile Editions: Defining Macro-Level Structure for Image-Based Electronic Editions." *Literary and Linguistic Computing* 24, no. 2 (June 1, 2009): 143–51.

Bao, Zonghao and Kun Xiang. "Digitalization and Global Ethics." *Ethics and Information Technology* 8, no. 1 (03, 2006): 41-47.

Benhamou, Francoise, and Victor Ginsburgh. "Is There a Market for Copies?" *Journal of Arts Management, Law, and Society* 32, no. 1 (Spring 2002): 37–55.

Bertacchini, Enrico, and Federico Morando. "The Future of Museums in the Digital Age: New Models for Access to and Use of Digital Collections." *International Journal of Arts Management* 15, no. 2 (Winter 2013): 60–72.

Brinkman, Herman. "The Hengwrt Chaucer. Digital Facsimile." *Literary and Linguistic Computing* 17, no. 2 (June 1, 2002): 261–63.

Büttner, Alexandra and Michael Kautz. "From a Dispersed Medieval Collection to One International Library: The Virtual Reconstruction of the Monastic Library of Lorsch." *Art Libraries Journal* 40, no. 3 (2015): 11-20.

Conn, Steven. "Do Museums Still Need Objects?" In *Do Museums Still Need Objects?*, 20-57. (Philadelphia: University of Pennsylvania Press, 2010).

Conway, Paul. "Preservation in the Age of Google: Digitization, Digital Preservation, and Dilemmas." *The Library Quarterly: Information, Community, Policy* 80, no. 1 (2010): 61-79.

Federal Agencies Digitization Guidelines Initiative, *"Technical Guidelines for Digitizing Cultural Heritage Materials: Creation of Raster Image Files."* (September 2016).

Graham, Chelsea Alene. "Applications of Digitization to Museum Collections Management, Research, And Accessibility." *Department of Archaeology and Ancient History at Lunds Universit*, (2012): 1-104.

"Guidelines for The Creation of Digital Collections: Digitization Best Practices for Three-Dimensional Objects." Consortium of Academic and research Libraries in Illinois: 1-13.

Guidi, Gabriele, Alessandro Spinetti, Luca Carosso, and Carlo Atzeni. "Digital Three-Dimensional Modelling of Donatello's *David* by Frequency-Modulated Laser Radar." *Studies in Conservation* 54, no. 1 (2009): 3-11.

"Henry Noel Humphreys." Wikipedia. Wikipedia Foundation. 23 March 2016. https://en.wikipedia.org/wiki/Henry_Noel_Humphreys.

Institute of Museum and Library Services. "Status of Technology and Digitization in the Nation's Museums and Libraries." *Initiative Publications*, (January 2006).

Langa, Lesley, Jonathan Lazar, Taiwo Adesina, David Michael Baumgart, Vladimir Brockmeyer, Hollis Leroy Bush III, Edwin Corpuz, et al. “Museum Web Accessibility: A Pilot Assessment of Mid-Atlantic Museums.” *International Journal of the Inclusive Museum* 4, no. 1 (January 2012): 15–28.

Lansard, Martin. "What are the Best Full-Color 3D Printers on the Market?" Aniwaa. November 12, 2016. Accessed April 05, 2017. http://www.aniwaa.com/blog/what-are-the-best-full-color-3d-printers-on-the-market/.

Li, Wen-chang. "Developments in China's Digitalized Museums." *Museum International* 60, no. 1-2 (03, 2008): 59-67.

Morphy, Marcia. “Steven Galbraith Named Curator of RIT’s Cary Graphic Arts Collection: The Collection is a Renowned Resource for Printing and Graphic Communication Jistory.” University News, October 25, 2011. Accessed February 23, 2017. http://www.rit.edu/news/story.php?id=48658.

"Original Prusa i3 MK2 3D Printer kit with LCD." Prusa Research. Accessed May 03, 2017. http://shop.prusa3d.com/en/3d-printers/59-original-prusa-i3-mk2-kit.html.

"SAA Core Values Statement and Code of Ethics." SAA Core Values Statement and Code of Ethics | Society of American Archivists. Accessed April 06, 2017. http://archivists.org/statements/saa-core-values-statement-and-code-of-ethics.

Scharff, Annemette Bruselius. "Use of a Digital Camera for Documentation of Textiles." In *First Aid for the Excavation of Archaeological Textiles*, edited by Gillis Carole and Nosch Marie-Louise B., 31-40. *Oxford: Oxbow Books*, 2007.

Short, Daniel B., “Use of 3D Printing by Museums: Educational Exhibits, Artifact Education, and Artifact Restoration.” *3D Printing And Additive Manufacturing* Volume 2, (Number 4, 2015): 209-215

Singh, Supriya, Meredith Blake, and Jonathan O'Donnell. "Digitizing Pacific Cultural Collections: The Australian Experience." *International Journal of Cultural Property* 20, no. 1 (02, 2013): 77-107.

"Status of Technology and Digitization in the Nation's Museums and Libraries." *Institute of Museum and Library Services*, January 2006, 1-153.

"The Awakening Conscience." Wikipedia. March 24, 2017. Accessed April 04, 2017. https://en.m.wikipedia.org/wiki/The_Awakening_Conscience.

Wachowiak, Melvin J., and Basiliki Vicky Karas. ″3D Scanning And Replication For Museum And Cultural Heritage Applications." *Journal of the American Institute for Conservation* 48, no. 2 (2009): 141-58.

Webmaster@nextengine.com. "Everything You Need to Scan and Build 3D Models." NextEngine. Accessed March 20, 2017. http://www.nextengine.com/products.

William Shakespeare. “Sentiments and Similes of W. Shakespeare" Rochester Institute Of Tech. - Wallace Mem. Library /Full Catalog. Albert.rit.edu. N.p., 2017. Web. 7 Mar. 2017.

van der Reyden, Dianne and Williams, Don. “The History, Technology, and Care of Papier-Mache: Case Study of the Conservation Treatment of a Victorian ‘Japan Ware’ Chair.” *Smithsonian Center for Materials Research and Education* (2001): 1-16.

"VersaUV LEF-200 Flatbed Printer | Roland DGA." Roland Website. Accessed May 03, 2017. https://www.rolanddga.com/products/printers/versauv-lef-200-flatbed-printer.

Yale Center for British Art, Lec Maj. “Sentiments and similes of William Shakespeare”. Accessed March 02, 2017. http://collections.britishart.yale.edu/vufind/Record/2034429.