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Research Article

Interactive Digital Twins: Creative Tools for Scientific Study of and Viewer Engagement with Historic Textiles

Professor Kathi Martin[1]* and Professor Emil Polyak[2]

[1]*Department of Design, Drexel University, USA*

[2]*Department of Digital Media, Drexel University, USA*

***Corresponding author:** Professor Kathi Martin, Drexel University, Westphal College of Media Arts & Design URBN Center, 3501 Market Street, Philadelphia, PA 19104, USA.

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Abstract

This paper discusses research using Reflectance Transformation Imaging (RTI) and 3D scanning to create high fidelity, 3D interactives of historic textiles for study by students, scholars and lovers of textiles. The content test bed is the personal collection of iconic American textile designer Jack Lenor Larsen who collected craft and art around the world and assembled the Collection of the LongHouse Reserve in Easthampton, NY. Examples of noninvasive RTI imaging of art textiles from the Collection by Sheila Hicks and Helena Hernmarck illustrate how this tool can be used to heighten the pleasure of the experience of the object through a close and self-guided study of its digital twin; and how the technology can collect and record data for conservation, identification, material properties analysis and reconstruction of the textile. This investigation is part of the research of the Drexel Digital Museum Project, an international group of university and museum professionals focused on new tools for documenting, conserving, exhibiting, accessing and enjoying the world's rich cultural heritage (https://digimuse.westphal.drexel.edu).

Keywords: Reflectance transformation imaging; Digital twins; Hicks; Hernmarck; Textile conservation

Abbreviations: RTI: Reflectance Transformation Imaging; LHR: LongHouse Reserve; CHI: Cultural Heritage Imaging

Introduction

Most museums and collections now embrace some aspect of technology in their responsibility to create an organized archive of the objects and ephemera in their holdings. Many enhance exhibitions with digital displays and disseminate through the world wide web. New technology is creating new challenges and new projects involving different participants in the study of historic textiles. This project is being researched by collaborators from the Fashion and Digital Media programs in the Westphal College of Media, Arts & Design, Drexel University and museum professionals at the Longhouse Reserve in an interdisciplinary union of design, education, and technology to demonstrate best practices for textile research, preservation, exhibition, and dissemination, with an overall goal of making these cultural heritage artifacts more widely accessible for diverse modes of perception, and interpretation.

Founder of the LongHouse Reserve, Jack Lenor Larsen's designs are included in major museum collections around the world, including the Louvre, Paris, and the Metropolitan Museum, New York. He worked in thirty-one countries in the seventy-five-year span of his career and voraciously collected art and craft from each; and promoted and collected the work of emerging artists and crafts people from all categories of media [1]. The Collection resides at the LongHouse Reserve (LHR), Larsen's home and museum (https://longhouse.org). It represents a broad range of styles and forms, reflecting the various threads of artistic and cultural influence that have contributed to the development of contemporary craft and design. LHR has long been a hub for rising and established designers and artists to exchange ideas about craft, culture, and identity. In 2020, faculty from the Westphal College of Media Arts & Design, Drexel University, were invited to apply their research into new technology for imaging and displaying textiles to selections in the Collection, known as the Collection of the Longhouse Reserve since Larsen's passing in 2020, through a series of residencies at LHR. Our project aims to continue the LHR narrative by creating digital twins of selections from the Collection, for interactive, hybrid exhibition and analysis in multiple locations in presence and online.

Materials and Methods

Since its invention in 2001, RTI has been used in situ in archeological excavations and by museums to enhance surface details of artefacts. The Smithsonian Institute uses contact free, non-destructive RTI to research and image a variety of "sensitive and fragile collection objects" such as their Paper Squeeze Project [2]. The fragile, finite "squeezes" are paper molds made from impressions of the surfaces of ancient archeological sights, now extinct. An RTI image conserves both the paper mold and the record of the ancient surface at a particular moment in time. Through the information contained in the RTI image accessibility to the physical object is created. RTI does not, however, produce 3D metric data. Researchers at Historic England recommend laser scanning or photogrammetric survey for 3D metrically accurate measurements [3]. Peter Fornaro, scientific photographer and Professor at the University of Basel, calls his research into 3D representation of complex surfaces Digital Materiality. We were first introduced to RTI via Dr. Fornaro's presentation, Standardized Reflection Transformation Imaging (RTI) for Documentation and Research, at Archiving 2019 [4].

To enable imaging across a diverse range of textiles, we constructed a modular, portable structure to house the imaging and visualization components. The framework incorporates an integrated vibration isolation system to eliminate environmental vibrations that could disrupt delicate imaging procedures. The customized illumination components allow directional lighting to be adjusted across multiple axes without introducing stray light or excessive brightness that could damage light-sensitive textiles. This tailored system can be rapidly configured within constrained spaces like our subterranean, windowless imaging lab adjacent to the textile archives at LHR. Effective isolation and adjustable low-impact lighting enable high-fidelity, reproducible digital capture across artifacts of varying fragility and color/pattern complexity (Figure 1).

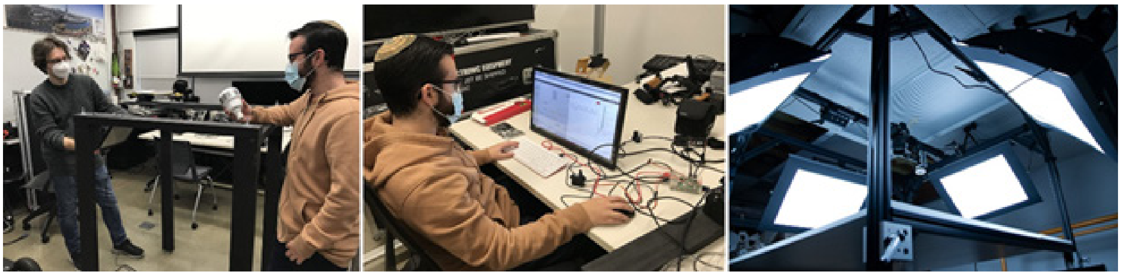

Figure 1: Prototyping the RTI rig. . L-R, Emil Polyak, Professor, Drexel University, Project Co-Director. Elliot Dickman, MS candidate, RA. Designing the interface. Lighting the bed.

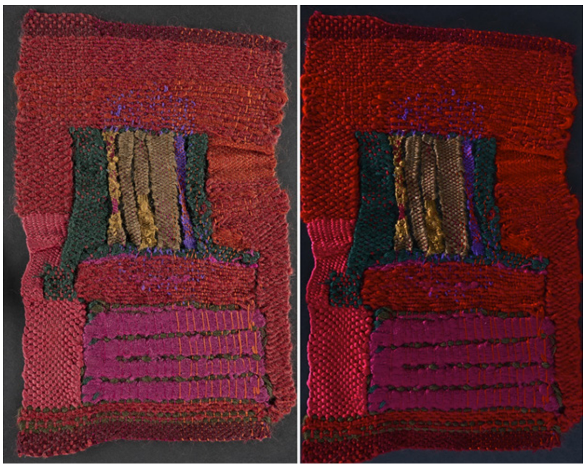

Figure 2: Left, high resolution image. Sheila Hicks . Untitled Minime. Tapestry. Wool and linen. C 1960. 8.5x4.25". From the Collection of The LongHouse Reserve. Gift of Marielle Bancou Segal. Right, Sheila Hicks Mineme, with glare removed through polarizing filters.

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To enable integrated analysis across modalities we extract the surface texture, true color and reflection characteristics of the textile based on open web standards. Our image acquisition method utilizes a capturing sequence comprised of primary, secondary, and tertiary data collection. The primary data enables spatial reconstruction with geometrical elevation of the form. The resulting tessellation reflects core variations and landmarks specific to each artifact. The secondary data is processed to obtain accurate color information of fiber and materials used in the artifact, including the relative perception of translucency. The tertiary data contains high resolution multi-view reflectance models effectively separating diffuse and specular reflection. After processing the tertiary data, a mathematical model is generated to render high frequency detail adding an authentic illusion of realistic incident and reflected light on the digitally reproduced artifact (Figure 2).

The final RTI image looks like a photograph but is, in fact, the documentation of the subject's surface interaction with the light positions at the individual pixel level [VVV20]. To date, we have used RTI for 40+ textiles in Larsen's collection; and scanning technology and photogrammetry to create 20+ 3D interactive twins for ceramics and sculpture. Using industry standard color management and calibration methods, the data is collected at highest accuracy, aiming to meet the requirements of preservation quality formulated by the Federal Agency Digitization Guidelines Initiative [5]. We plan to train students on the open-source tools developed by the Cultural Heritage Imaging [6] organization for processing and web publication of cultural artifacts. These tools will be applied in an ongoing digital twin project with graduate students at the Academy of Natural Sciences, Drexel University, Philadelphia (Figures 3&4).

Figure 3: Detail Hicks' Minime. Comparison, high resolution imaging, reflectance removed, right.

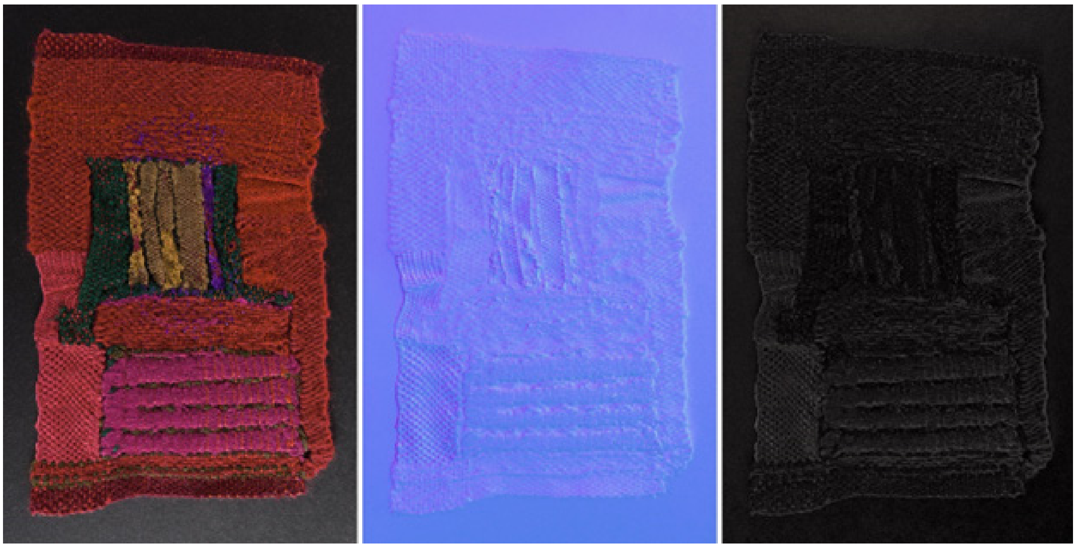

Figure 4: Data maps for imaging Hicks' Minime. Left to right: Albedo map of accurate color information. Normal map of elevations across the surface of the textile. Reflectance model effectively separating diffuse and specular reflection.

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By separating out specular reflections into an additional layer in our image processing pipeline, we can reveal subtle surface shapes and textures in the textile unseen in conventional imaging. This specular reflection layer is weighted by normal map data that stores measurements of light incidence angles on the textile surface. The selective integration of controlled specular reflections, precise normal map modeling, and color-accurate base textures is guided by the diverse expertise of our transdisciplinary research team spanning art, science, and digital media domains. This unified approach allows the complex interactions of light, color, and intricate textile geometry to be effectively reproduced for in-depth analysis or display while avoiding distortions from widely varying specular dynamics across the textile surface.

Results and Discussion

An RTI enabled interface allows the audience to control the light direction, zoom in, and rotate the object in full panorama. The user can rake the light across the surface to reveal discrete details of the topology of the textile and the surface of the fibers spun into the yarns, like a digital super-loupe, to determine the textile's construction and, along with the luster revealed by the raking light, fiber content (Figure 5).

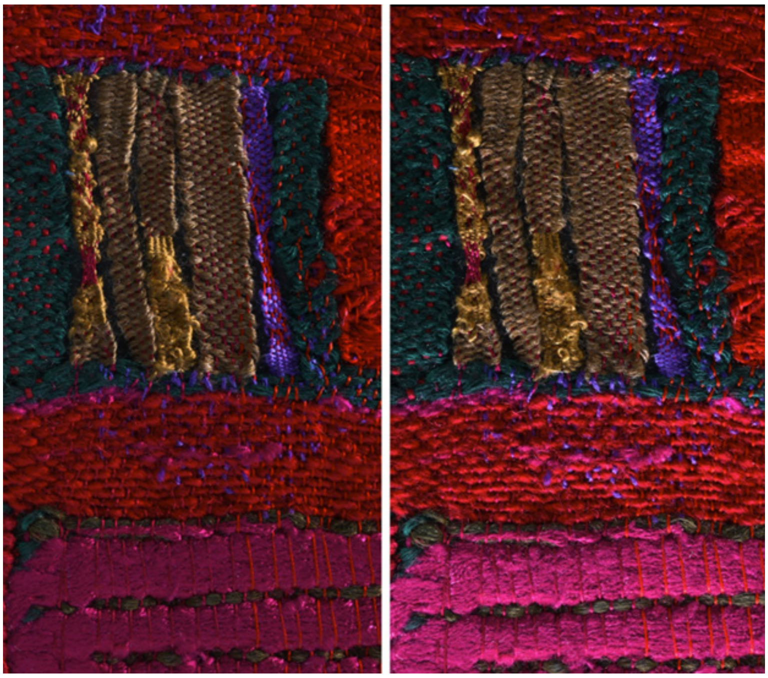

Figure 5: Detail Hicks' Mineme. Raking light source across image.

We are augmenting the interface with a built-in measuring tool with which the user can establish dimensions from point to point. A normal map provides a visual representation of height and depth of surface. A color picker displays the Hex, RGB, HSB and HSL values for any area of the surface of the textile and allows the user to derive a color library. The user will be able to access the full archival record for the textile, and notes and ephemera connected to the textile.

Irina Cina Ansi Sanu, Conservation Scientist for the PERCEIVE project at the Munch Museum in Oslo, identifies five types of cultural heritage objects where the type of data we are collecting can be used to estimate changes in color due to fading: polychromatic classic sculpture, paintings and graphic prints, historic photographs, born digital art and textiles [7]. This information can aid in decisions for conservation of the object, determining storage and exhibition requirements. For creative practices, color changes linked to particular materials, such as pigment and dyestuff, could help determine what materials to avoid or to use in future production. Sanu envisions "how we can predict not only the future but also look at the past" using scientific data and scientific interpretation to create a user experience of these material color changes and using algorithms to simulate them digitally [8]. The data collected in the image could be used to reconstruct damaged areas or to match fragments of an historic textile. It also could help detect the authenticity of related works by the designer.

Our second example is a maquette for one of Helena Hernmarck's wall size, sometime 10 x 20 feet, tapestries (Figure 6). Hernmarck was a longtime friend of Jack Lenor Larsen with whom she shared roots and inspirations from the Pacific Northwest. The Collection of the LongHouse Reserve includes several of her artworks, purchased by and given as gifts to Larsen. RTI heightens the spectacular color illusions of her work. Our imaging allows us to see how adept she is at mixing color and sheen both within the yarns and in the progression of the stitches. The raking light enabled by RTI illuminates her play between the shine of the lustrous rya wools from multiple angles of light (Figure 7).

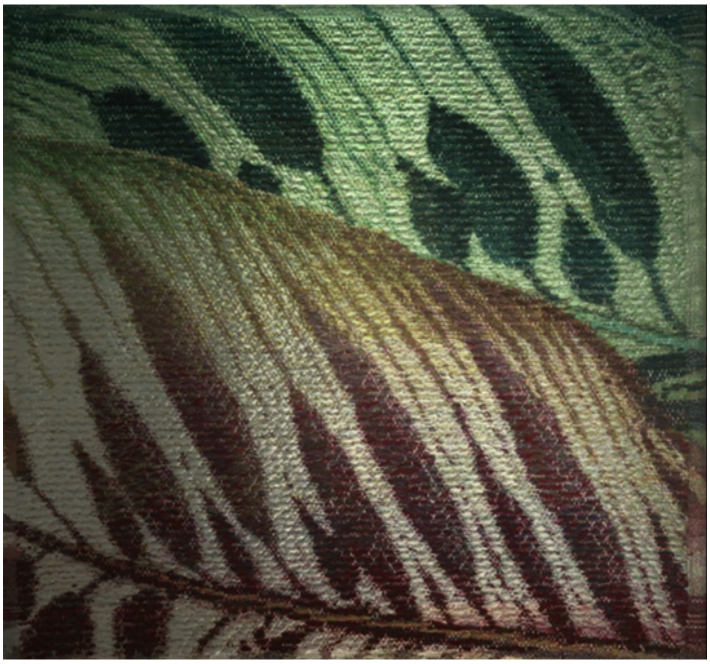

Figure 6: High resolution image. Croton Leaves. Helena Hernmarck. Tapestry. Wool and linen. 1997. Detail 7 x 6.5 inches. From the Collection of The LongHouse Reserve. Image Collection: Drexel Digital Museum T001_2022.

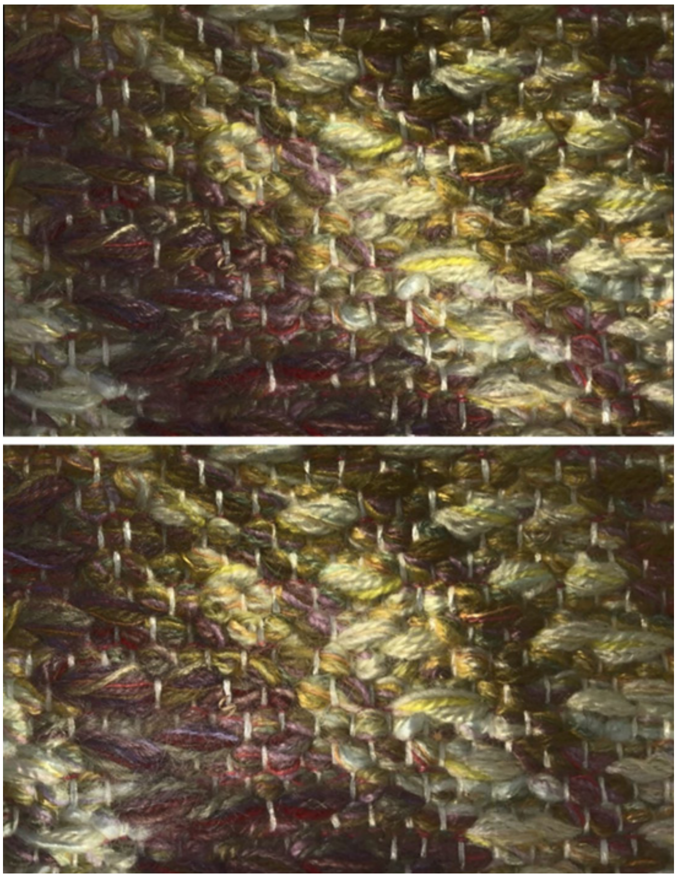

Figure 7: Raking light, detail Croton Leaves.

An early experiment with 3D scanning is the Ceremonial Toradja armor in Figure 8. It was gifted to the Collection by Larsen's good friend American playwriter Edward Albee with whom he shared an appreciation of craft from Southeast Asia (Figures 8&9). You can view the panorama of the armor here. The paillettes shine like gold but are, in fact, made from polished water buffalo horn. Close examination shows them laced together with plant fiber, and to a woven underpinning of split bast fiber. To precisely capture the intricate textures and topographies of the textiles, we have recently started employing a high-resolution structured light scanning system optimized for sub-millimeter (0.04 mm) reproduction of cultural heritage artifacts. This utilizes an advanced digital light projector to display a sequence of coded grid patterns onto the textile surface while simultaneously capturing distortions in these grid patterns caused by the textile's surface geometry. During post-processing we extract a highly accurate 3D surface based on the triangulation of matched points across the pattern sequence.

Figure 8: 3D scan. Toradja (Suwaleesi) Armor. Horn and bast fiber. Early 20th century. 28 x 15 x 5 inches. From the Collection of The LongHouse Reserve. Gift of Edward Albee.

Figure 9: Details, Toradji armor.

The User Experience

Color vision, the perception of differences between light frequencies, varies in humans. Color is used both in nature and culture as a powerful signal, assigning an emotional meaning to particular hues and values. Individuals pair particular colors with experiences, objects and messages, attaching these associations in memory and imbuing color with an emotional context [9]. Hicks produced over 1000 of these Minime, small, all under 13" in height, artworks across a career span of 50 years. The colors Hicks uses in this artwork may have been inspired during her Fulbright sponsored studies of Andean weaving in Chile in 1957 (Figure 2) [10]. Hicks revisits the deeply saturated palette of reds, pinks, purples, blues and golds throughout her career, in Faldo, made in Oaxaca in 1960, in Megador, made in Bangalore in 1966, in Passage de Nuit, made in France in 1989, and in Red Chief, Fifty Years, made in Paris in 2005 [11]. As a viewer, constrained by inaccessibility to the physical textile, zooms in and investigates the 3D Interactive Hicks Minime, the hue, saturation and brilliance of the colors of may evoke the viewer's own memories of a colorful event, object, landscape, adding their own deep level of interpretation and connection to the presence of the textile [12].

A participatory user experience can transform the conventional curator determined exhibition event, unfolding in a linear path, to a non-linear encounter without beginning, middle or end. The RTI enabled interface will be utilized in exhibition for attendees to manipulate the digital twin of and object on display and for distribution on the world wide web, an interactive space where anyone with an internet connection can manipulate and investigate the digital twins, a ubiquitous museum where the viewer is free to engage their personal perspective in interpretation of the textile. Our development team consists of humanities, digital media and informatics specialists. With the transdisciplinary team comes cross fertilization that makes the project of interest across sectors. Novel presentation, aesthetically beautiful images and textiles, an intuitive interface, captivating interaction, and a focused context can bring the viewer closer to the physical textile by creating 'Presence', a state where the viewer connects with the physical textile through the digital twin, accepting the digital twin as the textile [13].

Best Practices

An important element in the digitalization of cultural artifacts is the appropriate preservation of their story and identity. Adam Lowe, founder of Factum Arte, believes that,

"facsimiles, and especially those relying on complex (digital) techniques, are the most fruitful way to explore the original and even to help re-define what originality actually is." And that "the digital is just one instance in the life of the original object" …"works of art respect the complex and dynamic nature of material evidence, and that, in treating the object as an ever-evolving artifact, our view of how the past conditions the present is influenced. " (K & Lowe 2016) [14].

He contends that, in reading a digital facsimile, we are witnessing the many layers of its past, including its conservation history, its present state, and even perhaps anticipating how the object will be interpreted in the future.

Our images meet FADGI standards and our data is compliant to the standards of the Open Archive Initiative Protocol for Metadata Harvesting. We are making our metadata comprehensive through Metadata Object Description Schema (MODS) mapping.. MODS is a robust metadata schema maintained by the Library of Congress which provides a high degree of granularity and extensibility and can be used to describe a wide variety of physical and digital objects. MODS also supports the use of embedded Uniform Resource Identifiers (URIs) for entities such as names and topics, which facilitates exposure of these assets via linked open data. To provide a framework for this, we worked with our university repository to map metadata from the customized fields in our database to MODS, enabling discovery of our research objects across multiple platforms.

Rich descriptive metadata of the objects, combined with the comprehensive technical metadata we are creating, not only contributes to the credibility and veracity of the data but provides a fertile resource for multi-point access to the objects and to our processes via the world wide web, the most democratic means of disseminating cultural heritage and increasing the LHR audience. We plan to continue sharing our images and data with the PA aggregator hub for the Digital Public Library of America (DPLA). Developments in Linked Open Data (LOD) and the Open Provenance Model (OMP) increase the ability for provenance information of both the art object and its digital twin to be exchanged between systems.

Media, such as images, videos, or 3D objects that are accessible through websites, are not only viewed by humans, but by artificial intelligence. Increased access poses a threat from data gobbling AI, particularly as we prepare our data for LOD publishing. With increased use of artificial intelligence, digitized art and craft collections have become subject to data harvesting and machine learning without appropriate identification or digital safeguards to protect them. Datasets with incorrect or missing information are still processed by artificial intelligence applications with little to no possibility for updating. Groups like The Coalition for Content Provenance and Authenticity (C2PA) have been created to accelerate the pursuit of pragmatic, adoptable standards for digital provenance for creative professionals who want attribution for their work. As members of C2PA, we adopt these standards for our work.

Conclusion

Digital twins of historic textiles can help museums and collections expand the ways in which the public can encounter and interact with their holdings. Enabling the viewer to manipulate the image, select areas of interest and attach their memories, adds to the artifact's heritage, albeit not in a directly measurable manner. Digital twins of textiles can be captured at intervals throughout the life of the object to create a record of changes in color and luster and any stress produced by handling. This can provide a predictive tool for designers and manufacturers of and for museum professionals

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charged with the care of the object. Developments in standards increase the ability for provenance information of both the art object and its digital twin to be exchanged between systems. Rich descriptive metadata plus comprehensive technical metadata can provide multi-point access to the digital twin and to the processes used to create them via the world wide web, bringing us closer to our goal of creating accessibility to these beautiful textiles.

Our textile visualization project aligns with the goals of broader digital preservation efforts to make cultural heritage objects accessible while retaining their intrinsic beauty. Training students in specialized techniques like Reflectance Transformation Imaging enriches the next generation of digitization experts who can drive such multidomain initiatives forward. The processing and interactive display methods students learn can be broadly applied across natural science and textile datasets to create engaging exhibits that reveal unseen details.

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Conflict of Interest

Authors declare no conflict of interest.

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