Journal of Digital Media & Interaction
ISSN 2184-3120
Vol. 8, No. 18, (2025), pp. 9-29
DOI: 10.34624/jdmi.v8i18.39453

Virtual Dress, Real Responsibilities: Considerations of 3D CAD Patternmaking to Develop Substitute Garments for Historic Dress Research and Display

Brittany Glassey
MA Bunka Gakuen University, Japan
fashionlacrum@gmail.com
0009-0004-4963-3703

Received: March 23, 2025
Accepted: May 17, 2025

Abstract
This paper explores how 3D virtual reconstructions of historic dress can aid in the development of real substitute garments and serve as a digital visualization tool for display. While virtual reconstruction is presently implemented in other museology fields, the flexible nature of dress suggests a need for an alternative approach, in addition to ethical considerations from the practitioner's involvement. This is demonstrated through the development of a substitute skirt for a circa 1887-1890 Japanese Western-style ceremonial court dress (taireifuku), originally made for and worn by the Meiji Empress. The skirt of the original ensemble is missing and its appearance remains unknown, requiring a substitute skirt to support the original garments when mounted. Following an object-based research approach and advice from specialists in dress history and conservation, the author conceptualized a substitute skirt with the assistance of 3D CAD patternmaking software. The result served as a visual and pattern aid to develop a real substitute skirt that was used with the real taireifuku for two public displays. Further utilization of the virtual reconstruction was demonstrated through the author's development of additional skirt concepts, adapting them for a digital display which was exhibited with the real taireifuku.

Keywords *Historic dress; 3D reconstruction; Digital displays; Virtual heritage; Ethics*

1. Introduction

Costume and fashion design practices strongly link to the understanding of manipulating dimensionality of the body and material. The three-dimensional human form influences how designers transform a commonly two-dimensional material. This relationship defines how designers translate their creative vision from concept to reality, along with how we interact with dress, as wearers and observers. The challenge of using present computer technologies to view real objects stems from our reliance on using static two-dimensional images or restricted video angles on a screen. This digital transition loses the subject's dimensionality, which supported in communicating its original intentions.

Historic dress that originated in a pre-digital world and was intended to be viewed in-situ, naturally struggles to position itself in the digital space while maintaining its sense of dimensionality. When displaying real dress for exhibition, mounting garments on a humanoid form is highly valued for the insight it provides for structure and silhouette (DePauw, 2017). However, observers best understand such benefits in physical exhibitions, where the form can be viewed from multiple angles, providing scale and self-guided learning. When the same form is photographed, only a single viewpoint is captured, limiting this sense of presence and freedom of observation.

An alternative approach to dimension-focused dress display are replicas. Physical reproductions of dress have existed in museums for some time, serving as substitutes while the original remains in storage. Reproductions also have tactile qualities that cannot be replicated virtually, along with providing deeper insight into how the original may have been worn, as it may no longer be in a state of completion or be stable enough for display (Morena, 2013). Garments can also be substituted with extant dress, aiding to complete the image or support the original garments when displayed. However, depending on the subject, creating such reproductions can be difficult or impossible due to the cost of materials, labor and skill required for specialized crafts.

Although three-dimensional (3D) virtual reconstructions of dress lack the tactile qualities of real reproductions, they allow viewers to examine the garment from multiple angles while the real artifact may be unable to view in person (McNulty, 2019). The virtual dress is also native to the digital space, expanding its potential for implementation for other digital mediums and display types. Additionally, there are recognized benefits for non-intrusive research when using representations of real artifacts (Münster et al., 2019), with this offering potential for dress research.

This paper focuses on utilizing virtual reconstructions of historic dress to aid in the development of real substitute garments and as a digital visualization tool. This is demonstrated through the development of a real substitute skirt and virtual conceptual skirts for a Japanese Western-style ceremonial court dress (*manteau de cour*), hereafter referred to as *taireifuku* (大礼服), dated between 1887 to 1890 at the latest. This taireifuku originally belonged to the Meiji Empress, Shōken-kōtaigo (昭憲皇太后) (1849-1914). The real taireifuku was displayed at two public exhibitions; Daishōji Temple (February 2023) and the Meiji Jingu Museum (April 2024). For both displays, the taireifuku was planned to be mounted to resemble a worn garment, but was missing the original skirt, vital for providing visual and structural support. There are no known records of the skirt and how it appeared, meaning the substitute skirt and virtual skirts had to be implemented in a manner that complemented the original taireifuku without creating the assumption that it matched the original.

By referencing existing object-based research frameworks used in dress research, this paper also explores the ethical considerations and risks relating to virtual dress reconstruction from the position of the practitioner. While this developing field of 3D virtual reconstructions already have recognized practical outcomes, it is seldom discussed as to the ethical considerations for the purpose of dress conservation and display. Throughout the project, much discussion was had as to the ethics of digitizing extant culturally significant garments, developing substitute garments with little source material, along with how the original wearer (the Empress) was to be represented by association. Considering such concepts may provide a means to better discern opportunities for including 3D dress reconstructions in material culture research, creating new links and research opportunities between the real and virtual representations.

2. The research gap in virtual heritage and virtual dress reconstruction

Virtual heritage can be described as an experiential medium, combining virtual technologies with cultural heritage, including the reconstruction of data, measurements and observations from reality and the digital space (Champion, 2021b). As virtual heritage is a developing field, intertwined with the rapid development of computer technologies, a recognized concern is a need for regulation. Champion (2021a) notes that virtual heritage faces fulfillment challenges due to the lack of universal standards and no clear agreements on protocols, standards or parameters.

At present, there is no single approach to virtually reconstructing garments that captures all aspects of dress, including flexibility, layering, complex detail, reflection of light, and cost efficiency. Even if this were possible, practitioners cannot conduct the digitization of extant artifacts with the expectation that it is identical to the original. Rather, it is a representation created through mixed interpretations by their own hand and the technology used to digitize it. This is discussed by Champion (2021a) regarding the concept of authenticity in virtual heritage:

> *"Despite improvements in the features, capacity, reliability and precision of 3D formats, there is another, deeper underlying issue: what are these models preserving and what are they communicating to their audience? The question of authenticity is not merely a question regarding the model, but also a question on the intentions of the modelmaker."*

While we cannot control variables specific to the rapid evolution of technology, we cannot disregard our human (practitioner) involvement in transitioning the artifact from reality to virtual, and how we interpret the artifact in this process. By focusing on the practitioner, it may be possible to propose a baseline research approach to guide the development of virtual dress reconstructions in a manner that is adaptable, beneficial, and cost-considerate.

In the study of real dress, there is no singular framework that offers a clean and systematic research approach. Existing approaches have been largely passed down through experience from curator to assistant, having origins in anthropology and art history research (Mida et al., 2015). Recognizing this gap, modern resources have been published that discuss broader object-based research approaches for observing and interpreting dress for display. Mida and Kim's *The Dress Detective* (2015) presents an object-based research framework, structured plainly to help researchers identify and reflect on evidence contained in forms of dress. Additionally, DePauw's *The Care and Display of Historic Clothing* (2017) works to address the practical aspects of managing a costume collection along with theoretical, historical, and display considerations. Both resources reference wider approaches to object-based research, but present their own adaptations to better address specific considerations of dress research.

Although the aforementioned resources are linked to the tangible limitations of real dress, such approaches could be referenced in establishing a baseline research framework for how real dress could be observed and interpreted for digitization and display. While software literacy is needed to develop virtual dress, implementing such skills should also be directed by prior understanding of how real garments look and are made, thus ensuring their virtual interpretation faithfully represents the original (Kuzmichev et al., 2018).

2.1. Virtual reconstruction approaches in consideration to extant historic dress

While dress is a physical artifact, it continuously changes by design, posing challenges for how one should digitize it. Being made to reflect the flexibility of the human form, the way a garment is worn, lit and displayed can alter how it is perceived (Morena, 2013). While dress in museum collections will never be worn again in the interests of their preservation (Liu et al., 2022), recognizing their materiality and purpose to be worn could be a valuable link for how it is represented digitally.

The tools available to develop 3D virtual reconstructions of dress have expanded in the last decade (Liu et al., 2022). One approach utilizes software primarily made for developing 3D models in the gaming and animation industry. While useful, many of these programs are not developed exclusively for making dress and require wider expertise. Another approach involves capturing the real object through photogrammetry, 3D scanning or similar methods, where data is processed through a proprietary 'black-box' technology, generating a three-dimensional model. These technologies have present applications in other museology fields, with ongoing ethical discussions as to the challenges of not being able to examine or verify the processes used to create the 3D result (Dennis, 2021). However, it should be noted that virtual reconstructions excel in fields that rely on the artifact being static in form, enabling the virtual representation to remain as a solid unanimated 3D model. Simulating the active flexibility of real textiles in their virtual representation is more difficult by comparison (Liu et al., 2022).

2D CAD (computer-aided design) software has existed for the apparel industry since the 1970s (Sayed, 2014), its next evolution being 3D. The shift to 3D CAD enables new tools for simulating textiles and garment construction in a virtual environment, primarily intended for product visualization and pattern development in the apparel industry (Choi, 2022). An important shift with 3D CAD patternmaking compared to other 3D tools is that it is intentionally developed for students, designers, and specialists from fashion and garment-related backgrounds. When designers use 3D CAD pattern software to make virtual garments, knowledge of how real garments are constructed and perform is closely referenced, along with software literacy. However, commercial use and education in 3D CAD prioritize implementation for product development or realizing an imagined concept, rather than digitizing an extant garment with a complex history.

While it is valuable to showcase the technical methods and feats computer technologies provide to digitize historic dress, current research in this developing field appear to focus less on the ethical, cultural, and social considerations of these efforts, despite being such vital focuses in the wider fields of museology, conservation, and dress display. While the approaches and considerations to preserve and display real dress are directly linked to it being the original artifact and not a representation, replicas of dress still carry connotations of the original. Morena (2013) highlights that replicas of dress can alter the viewer's perceptions if they are noticeably different and used in frequency, in some cases being seen by as synonymous with the original. Additionally, for cases where the physical original garment is unobtainable or no longer exists, viewers may perceive the image (representation) becoming the original. Therefore, if we are to

justify such technologies in dress research, we should recognize the practitioner's involvement in conjunction with technical literacy. Recognizing this gap is crucial as there is a degree of responsibility involved when representing cultural heritage virtually, as influences from the practitioner's approaches and unconscious biases can further impact how audiences engage with it (Carter, 2021).

2.2. Understanding taireifuku

A notable distinction between regular dress and dress in museum collections is the context for why the latter is considered valuable for preservation. As exploring wider contextual information provides a greater understanding of the artifact in question (Mida et al., 2015), it supports the development of virtual reconstructions, especially one with such a layered history as taireifuku.

Taireifuku originated in the Meiji period (1868-1912), a time of rapid development and modernization in Japan across many fields, including the westernization of formal dress (Nakamura et al., 2012). After being isolated for almost three centuries, Japan opened to the world in 1854. Under the Meiji Government (1868-1912), men in the Japanese court began wearing Western-style taireifuku earlier than women. In 1886, the Meiji Empress was encouraged to start wearing Western clothing for public appearances in preparation for the promulgation of the new constitution on February 11, 1889. This decision reflected her position, and the country she represented to the rest of the world as an equal power. This was expressed in a series of photographs of the Empress taken in June 1889 (figure 1). The Western-style taireifuku in the photo is thought to be the first that was made for the Empress (Bethe, 2020).

Figure 1. Portrait of Empress Shōken. Suzuki Shin'ichi I / National Museum of Asian Art Archives, Smithsonian Institution, The Alice Roosevelt Longworth Collection of Photographs from the 1905 Taft Mission to Asia, FSA_A2009.02_05b (Detail).

Taireifuku was the most formal of court attire, worn for significant events and public appearances. From the 1887 New Years celebration onwards, taireifuku exclusively became the official dress to wear to such events (The Imperial Household Agency, 2014). Today, only three Western-style taireifuku that originally belonged to the Empress are known to still exist (Yoshihara, 2022).

Even though regulations existed for women's Western court dress, they were not stipulated by law (Bunka Gakuen Costume Museum, 2013). The Empress's taireifuku depict an amalgamation of Western trends, along with Japanese aesthetics and skill during this transitionary period (Bunka Gakuen Costume Museum, 1991). They express how the Empress was able to adapt to Western influences while maintaining strong support for local industry and Japanese craftsmanship (Bethe, 2023).

2.2.1. The Daishōji taireifuku

The subject of this research project, referred to as the *Daishōji taireifuku* (figure 2), came into the possession of Daishōji Imperial Convent in Kyoto when it was donated by the Empress in 1909 (Bethe, 2020). It is believed to be one of the earliest Western-style taireifuku to have been made for the Empress, and the earliest known to still exist (Bethe, 2024). After this taireifuku was received by Daishōji, the train was dismantled and cut into two, repurposed as altar cloths (*uchishiki*, 打敷) and later temporarily sewn back together for display purposes.

Figure 2. Bodice and Train of the Daishōji Taireifuku.
Copyright 2014 by Daishōji Imperial Convent. Reprinted with permission.

The whereabouts of the Daishōji taireifuku skirt and its appearance is unknown; only the bodice and train remain of the ensemble (Bethe, 2020). In 2018, The Project for Research, Conservation and Preservation of the Empress Shōken's Taireifuku was launched from a partnership with the Medieval Japanese Studies Institute and Meiji Jingū (Bethe, 2024). Spanning six years, the project's efforts unearthed discoveries pertaining to the construction and history of the taireifuku. While practitioners

from the project were not directly involved with the virtual reconstruction of the Daishōji taireifuku in this paper, their discoveries, thoughts and feedback were invaluable for the research that was conducted and its outcome.

The Daishōji taireifuku possesses conflicting traits compared to other court dress at the time. The fabric reflects a European Neo-Rococo design with a rose motif that is not original to the taireifuku, with the origin of this specific textile being presently unknown (Bethe, 2024). The use of the fabric is uncommon for court dress from this period, with gold work embroidery added across the bodice and edge of the train, over the woven patterning (Bethe, 2023) (figure 3). This gold work technique closely replicates techniques used on men's court dress (Bethe, 2024). While the embroidery appears Western in style, evidence points to it having been made in Japan (Bethe, 2020).

Figure 3. Gold work embroidery on a section of the Daishōji taireifuku train. Captured at Sengiren Studio for the Conservation of Cultural Properties. October 2022.

With the only unaltered part of the taireifuku remaining being the bodice, the information it provides is crucial. The taireifuku bodice features truncated sleeves, reminiscent of the taireifuku in the 1889 portrait. The shaping of the back indicates a bustle, which further aids to inform the approximate date of the taireifuku (Bethe, 2024).

3. Developing a digitization approach based on real costume mounting practices

Prior to developing the substitute skirt, more understanding was needed for how the virtual taireifuku was to be realized. This was gained by the researchers, including the author, exploring how the real taireifuku was to be displayed to the public and how vital it was to be mounted as a dimensional form. While the train pieces were temporarily sewn together for these displays, they were to be separated again afterwards when entering storage, recognizing their evolution into altar cloths as part of the artifact's history (Marschner et al., 2024). Due to the additional work and manipulation of the textile for

this process, this may be one of the last times that the Daishōji train is displayed to resemble a worn garment.

When deciding which type of mount is used to support the garment and provide context (such as silhouette), considerations involve how much of an influence the mount itself should have on the real garment. In a dress mount, the degree of human representation (or the absence of) alters how the garment is perceived (Brooks, 2017), along with how it conveys a sense of the original wearer (Gresswell et al., 2017). In preparation for exhibiting the Daishōji taireifuku, a major consideration involved how the Empress was to be represented in association with the taireifuku. This included the historic context surrounding taireifuku and also how viewers would perceive the Empress as physically wearing the garment.

While contemplating a digitization approach for the taireifuku, a common observation was the possibility of displaying the internal layers and structure of the taireifuku in virtual 3D. This offered a means to showcase details of the garment, which would be impossible with real mounting techniques. While achievable, doing so needed to align with the requirements of the project, along with how it was to be displayed in respect to the Empress. Dress, more so than other artifacts, have a strong association to the individual who wore it, as described by Brooks (2017):

> *"Garments that protected, shaped and presented the body in life can become surrogate bodies in the museum, evoking and memorializing the absent wearer. (…) Wrinkles recall movement; stressed areas suggest the bending of a body that strained – or even burst through – fabric and seams."*

The direct association with the body beneath the dress was a particular concern for this project. Prior to the Meiji era, Emperors and Empresses rarely made public appearances (Yoshihara, 2022). Despite their increased public presence, the Meiji Emperor and Empress remained protected and revered figures. High-ranking ladies-in-waiting would serve as substitutes for garment fittings that were intended for the Empress (Yamakawa, 2016, in Yoshimura, 2023). The House of Worth, who made court dress for a range of international clientele, noted that the Meiji Empress was their most difficult client to dress, due to extreme restrictions regarding how much of the body and décolletage could be exposed (Trubert-Tollu et al., 2017). The historic representation of the Meiji Emperor and Empress carries influence today, especially when expressing the physical presence of such esteemed figures. This posed a particular challenge for the taireifuku bodice, being closely shaped to the human form by design. In consideration of this context, the research team decided to develop an archival 'floating mount' for the bodice. Using a flexible yet sturdy felt to create a historically accurate silhouette (Esguerra, 2024), it would provide stability and minimize handling for future displays. This archival mount now rests inside the bodice, concealing and protecting the internal construction of the garment. The mount also ensures that viewers today only observe what was intended to be seen by the public when the Empress originally wore the taireifuku. The bodice being form-fitted benefitted this approach, as the mount reflects how the garment naturally wants to rest. The mount was constructed from direct measurements of the bodice (Esguerra, 2024), rather than the body beneath, meaning it references how it may have rested, but does not over-insinuate the human form itself.

Additionally, a removable detailing was included to resemble a diaphanous blouse worn under the bodice, as seen in the 1889 portrait of the Empress. Often these were worn with taireifuku, aiding to conceal the exposed chest and arm openings (Bethe, 2024).

Recognizing my position as the practitioner, there was a degree of responsibility needed for the virtual taireifuku to align with the historic context of the taireifuku, in a manner that was informative to the project's needs, yet considerate to the original wearer. In reflection of the actions made by the research team, I opted for using an invisible mannequin, with the dimensional form of the bodice mirroring how the real garment appears on the felt mount. As this would expose the internals of the virtual taireifuku when viewed from various angles, I simplified or omitted such details from the final 3D renders, removing the attention from these areas when displayed. This prevented viewers from seeing the internal structure, thus protecting the privacy of the real garment that it is a representation of. A diaphanous blouse was also virtually constructed to serve the same purpose as with the real taireifuku, but was treated as a separate element and used exclusively for display purposes.

3.1. Constructing the Daishōji bodice and train

I used CLO, a 3D CAD patternmaking software, to virtually reconstruct the Daishōji taireifuku. It was selected based on the practical needs of the project, specifically flexibility, as the substitute skirt would likely alter the shape and position of the extant garments. Additionally, freedom of exploration was needed to determine how to pleat the waist of the train, as this was impossible to observe with the real taireifuku until the exhibitions commenced. At the time, the virtual taireifuku served as closest visual reference for how the taireifuku was to appear when exhibited, providing an opportunity to explore multiple avenues before committing to the final display.

I referenced precise measurements of the bodice and train, provided by the research team, drafted these into CLO as a 2D pattern and then draped them in 3D. I used high-resolution photographs to document each section of the bodice and train, which I adapted to create textures for each panel. From these photographs, each layer of the fabric and embroidery were digitally separated and given individual properties to simulate the fabric and the gold work embroidery (figure 4). This method supported replicating the luster of the silk fabric more precisely, which the research team and myself deemed to be crucial as it is a key visual characteristic of the taireifuku.

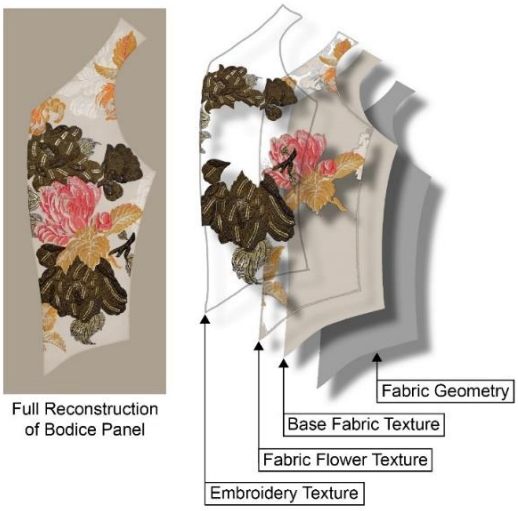

Figure 4. Diagram showing the layers of a panel from the digitized Daishōji bodice.

To support experimentation for pleating the taireifuku train at the waist, I added a temporary translucent skirt (figure 5). While knowledge is lost for the original construction and pleating of the Daishōji taireifuku, remaining clues indicate it may have been lined and padded in a similar means to a circa 1900 taireifuku also worn by the Empress, now in the collection of the Bunka Gakuen Costume Museum (Bethe, 2020). Because the other train tapers to the waist, adaptations were made to the pleating for the virtual taireifuku, as the Daishōji train is rectangular in shape with no taper.

Figure 5. Bodice and train of the Daishōji taireifuku virtual reconstruction, with a temporary skirt.

During development, not all information I needed from the real garment was clearly legible through measurements and photography alone. This was especially the case for the detailed construction of the bodice. When observing real garments in object-based research, making drawings provides a deeper record of details that can be interpreted more clearly by the researcher (Mida et al., 2015). While virtual garments are not constructed in the same manner as real garments, these details need to be digitally represented in a way that is believable to the real garment. While the internals of the taireifuku were omitted in the final renders, I still utilized them in development to support the accuracy of the external appearance. By making technical

drawings of the taireifuku inside and out (figure 6), this minimized the risk of overlooking them later in development, especially when the detailed fabric and embroidery made the virtual garment more visually complex. Furthermore, this deeper understanding of the bodice construction supported how the substitute skirt was to be positioned with the existing garments, especially regarding the angle of the boning, which was essential for creating the bustle shape.

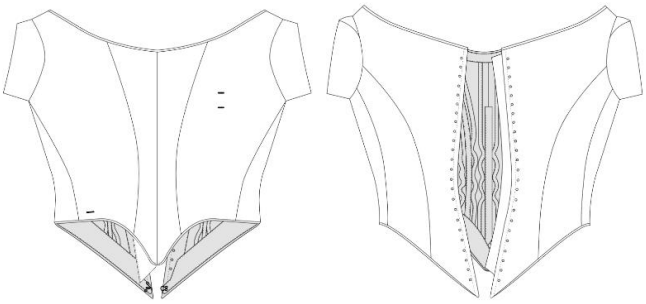

Figure 6. Technical drawings of the Daishōji taireifuku bodice.
Left: Front view.
Right: Back view.

4. Developing the substitute skirt for the real Daishōji taireifuku

This project revolved around the undeniability that we do not know what the real skirt looked like and depending on how the substitute skirt is used, it may alter how the taireifuku is interpreted. To address this, I focused on gathering extensive contextual research, collaborating with experts and scrutinizing how the substitute skirt was to be positioned alongside the Daishōji taireifuku.

The remaining two extant taireifuku offer tangible information for the skirt; however, these date later, circa 1900 (Yoshimura, 2023) and 1912 (Kawai, 2020) respectively. The circa 1900 taireifuku does provide a reference for the length of the skirt, but stylistically differs from what would have been worn in the late 1880s. A more period-accurate reference for the skirt's possible visual appearance is the skirt worn in the Empress's 1889 portrait, but this is difficult to observe as it no longer exists.

In February 2023, the 8.1 Transboundary Fashion Seminar was held at Bunka Gakuen University in Tokyo, to explore the wider history of the Empress and court dress, including discussing the preservation and display of the Daishōji taireifuku (Takagi, 2023). Attendees from Japan and abroad participated, having involvement with The Project for Research, Conservation and Preservation of the Empress Shōken's Taireifuku. These included from Bunka Gakuen University, the Kyoto Costume Institute, Historic Royal Palaces (United Kingdom) and the Los Angeles County Museum of Art (United States of America). Multiple discussions led up to the final session involving a collaborative workshop, where I developed the substitute skirt in CLO, based on real-time feedback from the participants.

During the seminar, the need for a late 1880s bustle for the skirt continued to be emphasized. Additionally, the skirt needed to be elongated at the back with its own train, as this would support the positioning of the taireifuku train over the bustle to the floor. Available pattern resources for Western-

style 1880s skirts were difficult to reference without requiring adaptations as they were not for court dress, instead being for day or evening dress.

From discussions during the seminar, the participants selected two skirt patterns as primary references. Both patterns were from Janet Arnold's Patterns of Fashion series, with adjustments needed to reflect the needs of the taireifuku train. These patterns were an 1882-83 dinner dress to reference the skirt shape, along with the apron pattern from an 1887-89 dinner dress (Arnold, 2022). The apron served as a reference to the 1889 portrait skirt as it appears to have a draped panel over the front underskirt, along with being stylistically accurate to the period.

The participants also discussed whether the original skirt would have been patterned and if the substitute should reflect this. A known practice of European court dress of that era involved balancing a complex or patterned bodice and train with a more simplistic skirt – and vice-versa, a patterned skirt with an un-patterned remaining ensemble (Marschner, 2023). Due to the unique context of taireifuku possessing both European and Japanese aesthetics, it is difficult to determine if the Daishōji taireifuku followed the same considerations so precisely. However, this was reflected in the Empress's 1889 portrait, where the skirt is patterned, but the bodice and train are not, with the exception of sectioned embroideries on the bodice.

An additional reason for the substitute skirt to not use patterned fabric was to prevent the skirt from becoming a distraction when viewing the real bodice and train of the taireifuku, increasing ethical concerns for misinterpretation by the hand of the practitioner. Substitute garments are intended to complement, not dominate, enhancing the viewer's understanding of the garment as a period piece and how it may be interpreted (DePauw, 2017). To best complement the taireifuku in this respect, the textile of the skirt was made of silk with a slight luster and was dyed to match the off-white base of the taireifuku.

During the final session of the Transboundary Fashion Seminar, the participants made collaborative drawings on a whiteboard (figure 7). These drawings, in addition to Janet Arnold's patterns informed my development of the substitute skirt, while everyone observed and provided feedback in real time (figure 8). The workshop concluded with a plan towards constructing the real skirt in the following week, using the virtual taireifuku and skirt as a visual guide for its expected appearance when mounted with the real bodice and train. The virtual skirt also provided a base for developing a sewing pattern to make the real skirt.

Figure 7. Drawings made during the collaborative workshop, by Joanna Marschner. Captured at Transboundary Fashion Seminar 8.1: Manteaux de Cour of the Meiji Empress: Conservation, Preservation, and Display. Bunka Gakuen University. February 4, 2023.

Figure 8. Live feed of the Daishōji taireifuku substitute skirt being developed, using CLO. Captured at Transboundary Fashion Seminar 8.1: Manteaux de Cour of the Meiji Empress: Conservation, Preservation, and Display. Bunka Gakuen University. February 4, 2023. https://transboundaryfashion.wordpress.com/2024/04/02/seminar-8-1-manteaux-de-cour-of-the-meiji-empress-conservation-preservation-and-display/

In the week following the seminar, I continued to make adjustments to the virtual taireifuku and skirt in Tokyo, then sent visuals and pattern data to the team in Kyoto, who were creating the real substitute skirt. Primary revisions focused on the apron, which required several refinements (figure 9), as Arnold's reference pattern draped too low on the skirt. It appeared unbalanced considering the Empress's stature, who was believed to be no taller than 150 centimeters (Yoshimura, 2023). Additionally, the bustle needed greater prominence. The final skirt featured an adapted apron pattern to accommodate these considerations (figures 10, 11).

Figure 9. Various apron explorations during development, outlined in red.
Left: Arnold's original apron pattern, deemed too long.
Centre: Adapted apron based on feedback, deemed too short.
Right: Final adapted apron design.

Figure 10. The final virtual substitute skirt, with the virtual taireifuku bodice and train.

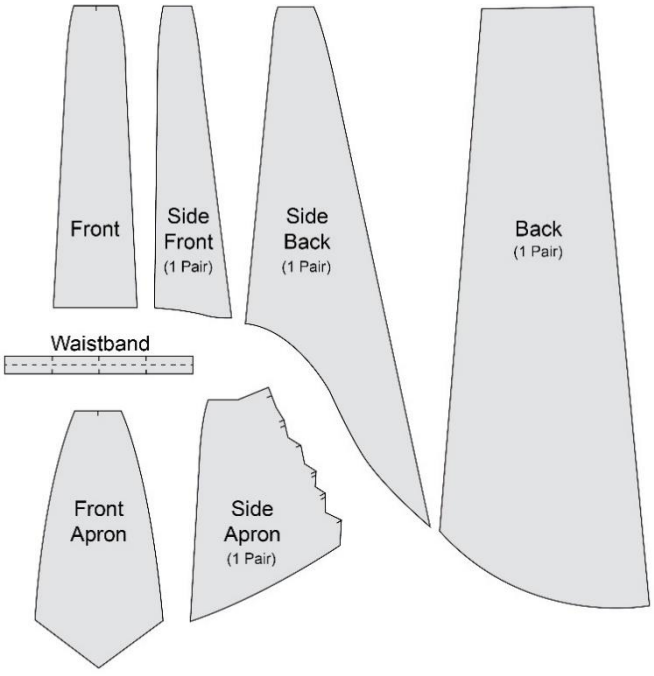

Figure 11. Flat pattern of the final substitute skirt.

The dimensional mount of the Daishōji taireifuku with the substitute skirt was implemented for both the exhibition at Daishōji and at the Meiji Jingū Museum (figure 12). A special hip mount was also constructed for the taireifuku, which supported in making the period-accurate bustle appearance of the late 1880s (Esguerra, 2024).

Figure 12. The Daishōji taireifuku, with the substitute skirt on display. Captured at the Meiji Jingū Museum. April 4, 2024.

5. Developing virtual concept skirts for exhibition

An opportunity that emerged during the project was the possibility to explore additional skirt concepts without the end-goal to have a real-life replica be made. The real substitute skirt addressed structural and silhouette concerns for mounting the taireifuku, but providing only one skirt concept to the viewer may suggest it represents the most likely appearance of the original, despite that not being the case.

Historically and still today, museums focus on the materiality of artifacts and the physicality of observing history from within the museum space (Ciolfi, 2021). Recently there has been a noticeable shift towards prioritizing visitor experiences over object-centeredness (Wu et al., 2022). This shift can benefit virtual heritage, as the intention is similar in terms of providing informative and more personal experiences for visitors observing such objects (Ciolfi, 2021). However, when only part of the real artifact remains, it creates a grey area regarding how technology could or should be used to express what is missing and how it may have appeared originally.

The research team decided that three virtual skirt concepts would be made and included in a four-minute video, used for the exhibition at the Meiji Jingū Museum (Glassey, 2024). The video also showcased other features of the Daishōji taireifuku that were missing or difficult to notice. The adaptability of the virtual taireifuku was invaluable in providing this insight, especially since it was unreasonable to manipulate the real garment due to its delicate nature and incomplete state. Utilizing digital tools alongside the real artifacts in display can provide a more mindful experience of ‘augmenting’ the tangibility of an object, rather than substituting it, finding this balance can be what provides a deeper experience for visitors (Ciolfi, 2021).

The three virtual skirts were based on different historic sources, one having more significant focus, being inspired by the skirt in the Empress's 1889 portrait. The two remaining skirts were more distant interpretations of other garments. The first being a skirt from a circa 1886 chureifuku, another form of court dress worn for evening parties and banquets (Bunka Gakuen Costume Museum, 2013). This chureifuku was originally worn by Princess Kitashirakawa (1862-1936). Made by Max Engel, it was to be displayed as part of the same exhibition (Kasumi Kaikan, 2024). The other skirt would draw inspiration from a court dress worn by Margherita, Queen of Italy (1851-1926), in a portrait painted by Pasquale Di Criscito in 1878. I adapted these skirts to reflect the frame of the Empress, while simplifying the styling. The three different skirts were selected due to their variance in design, supporting the notion that we cannot be sure of the true appearance, but through this knowledge gap we can explore a range of potentials linked to historical sources.

Discussions arose regarding earlier ethical considerations relating to whether the virtual skirts could be patterned or remain simplistic, like the real substitute skirt. The dominant consensus among the research team favored that more complex skirt concepts could be explored virtually only. Observers may better differentiate them as concepts as the video was to be exhibited with the real taireifuku, itself having a larger presence as the focus of the exhibition and serving as the primary reference. This decision was considered as a specific exception regarding the context of the exhibition and may have been treated differently if the real taireifuku was not in the presence of observers.

During the completion of this project, I raised concerns regarding how a practitioner would approach adapting these existing skirt designs in a manner that was considerate to the project's intentions, without introducing personal factors, such as bias. While the substitute skirts were based on historical sources, a degree of creative involvement was necessary to make changes so they could 'suit' the Daishōji taireifuku. There are existing ethical discussions in the field of archaeology as to the amount of interpretation that is required by the practitioner when developing 3D reconstructions, as the result can be unclear to observers as to where the line is between the original data and the practitioner's creative involvement to create a more complete, yet uncertain image (Barratt, 2021). While these considerations are difficult to measure and evaluate, the research team discussed this extensively. In dress research, depending on the researcher's background, different skillsets and preferences arise, whether it be related to the aesthetic, function, or other aspects of dress (Mida et al., 2015). As the research team involved with the Daishōji taireifuku was international, with varying expertise and backgrounds, this range of perspective was a unique and valuable asset for this project. The skirts were developed by creating and sharing dozens of skirt concepts over several months with the research team, with my goal to work towards an agreeable conclusion from the feedback that was received and discussed. The final three outcomes from this process were used for the exhibition video (figures 13, 14, 15). When presented to the public, the virtual skirts were accompanied by images of the original reference garments, along with statements noting these depictions were intended to express how the skirts and other attributes of the taireifuku may have been used, but did not claim to be true to reality.

Figure 13. The virtual Daishōji taireifuku, with a concept skirt inspired by the Meiji Empress's 1889 portrait.

Figure 14. The virtual Daishōji taireifuku, with a concept skirt inspired by Pasquale Di Criscito's 1878 painting of Margherita, Queen of Italy.

Figure 15. The virtual Daishōji taireifuku, with a concept skirt inspired by the circa 1886 chureifuku worn by Princess Kitashirakawa.

6. Conclusion

Highlighting the importance of this project, built on the aim to present the Daishōji taireifuku as a three-dimensional form, Joanna Marschner shared her reaction after observing the Daishōji bodice for the first time (Marschner et al., 2024):

> *"Having just spent a week looking at wonderful – but mainly flat – textiles, the great moment was when out of the little storage room (…) came a beautifully paper-wrapped parcel. It was undone, very carefully and with a good deal of ceremony – out of it came the little boned bodice. (…) For me this evoked the person, in its three-dimensionality. As a monarchical historian, straight away I was back in the middle of the nineteenth century, already beginning to think about an Empress who in other circumstances could have met Queen Victoria, a figure from history with whom I was so familiar."*

The Daishōji taireifuku is an intricate and greatly treasured artifact, evident in its construction and history, with its mysteries making it an enigma to study. The Project for Research, Conservation and Preservation of the Empress Shōken's Taireifuku exemplified what an international team of practitioners can accomplish, contributing a range of specializations and skills. Developing the substitute skirts represented only part of the wider picture, greatly benefitting from research and advice provided by others.

The rich historic context of the Daishōji taireifuku provided a unique perspective into the ethical and cultural considerations necessary for this project. While it benefited from an international team of specialists, this also revealed how stylistic preferences and approaches differed between individuals. This cultivated a highly collaborative environment to discuss what was most suitable for the context of the exhibition and connection to the Meiji Empress. Understanding these needs and concerns aided in informing a digitization approach for the Daishōji taireifuku and subsequent skirt concepts, along with how they were displayed to the public.

Even with the extensive research available for this project, it could not replace verifiable evidence of how the skirt would have originally appeared, which was impossible to determine. We had embraced that this was something that we could not replace or claim that it would have appeared a certain way. This posed a particular challenge, as the dimensionality of the Daishōji taireifuku was a priority for its display, requiring a skirt for support. The specific needs of this project guided a unique approach to reconstructing the taireifuku and developing substitute skirts, presented in this paper to generate thought for how a practitioner may need to adapt to the unique needs of other forms of dress that have their own complex stories.

The effectiveness of the virtual substitute skirt developed from the Transboundary Fashion Seminar was observed through the clear visual similarity between the virtual concept and the real result. While the skirt was conceptualized during the collaborative session, the final virtual and real skirt were constructed by different individuals, over long-distance communication. The real substitute skirt provided structural and silhouette support, improving observers' understanding of this period dress, with the virtual skirt performing as an assistive tool to achieve this result.

A notable observation from this project is the high commitment of time and resources needed to achieve complex virtual reconstructions such as the Daishōji taireifuku. This type of in-depth approach

is unlikely to be feasible on a large scale for digitizing museum collections, but offers potential for use in specialized research projects. This highlights the potential benefit of developing a practitioner-focused, object-based research approach to digitizing dress. This approach could be adapted for other projects, developing our insight as practitioners to realize new opportunities when observing real dress and seeing how digitization may benefit it.

While ethical considerations were explored and referenced in wider discussions throughout the project, a limitation of this research was that it lacked a means to evaluate public perception when the exhibitions commenced. Feedback throughout the project was provided by specialists with their own experience of preserving and displaying dress. This research is presented with the intention to provide an early insight into how object-based research frameworks of real dress could be implemented in virtual dress research, aiding to establish this developing field. Even as the technologies we use inevitably evolve, the benefits of dress and material culture research remain prevalent. By allowing the artifact to guide how its story should be told, we can find means to communicate those stories with the tools we have at present.

Acknowledgements

Some of the research in this paper is based on work conducted for the author's unpublished master's thesis, submitted in January 2024 to the Graduate School of Fashion and Living Environment Studies (Bunka Gakuen University). Adjustments were made after new research emerged from work developed for part one of the exhibition: *Dresses of the Meiji Era: A Treasured Legacy* (受け継がれし明治のドレス) held at the Meiji Jingū Museum from April 6, 2024, until May 6, 2024.

References

Arnold, J. (2022). *Patterns of Fashion 2* (M. Braun, L. Costigliolo, S. Passot, C. Thornton, & J. Tiramani, Eds.; 1st ed.). London: The School of Historical Dress.

Barratt, R. P. (2021). Speculating the Past: 3D Reconstruction in Archaeology. In Erik Malcolm Champion (Ed.), Virtual Heritage: A Guide (pp. 13–23). London: Ubiquity Press. doi: 10.5334/bck.c

Bethe, M. (2020). 織り糸が語る内と外 : 昭憲皇太后大礼服研究修復復元プロジェクトの現状 [Facing Both Ways: Report on the Project for Research and Conservation of the Meiji Empress's Court Gown]. *明治神宮国際神道文化研究所 「神園」[Journal of the Meiji Jingū Intercultural Research Institute (Kamizono)]*, *23*, 19–49.

Bethe, M. (2023). 昭憲皇太后の白い大礼服の伝来について : 昭憲皇太后大礼服研究修復復元プロジェクト 研究ノート [When did the Meiji Empress Wear the Taireifuku now at Daishōji?]. *明治神宮国際神道文化研究所 「神園」[Journal of the Meiji Jingū Intercultural Research Institute (Kamizono)]*, *29*, 181–185.

Bethe, M. (2024). 明治の皇后の宮廷服物語 [The Story of the Meiji Empress's Court Dress]. In 受け継がれし明治のドレス 昭憲皇太后の大礼服 [Dresses of the Meiji Era — A Treasured Legacy — A Ceremonial Court Dress of Empress Shoken] (pp. 5–8). Tokyo: Meiji Jingū.

Brooks, M. M. (2017). Reflecting Absence and Presence: Displaying Dress of Known Individuals. In M. M. Brooks & D. D. Eastop (Eds.), Refashioning and Redress: Conserving and Displaying Dress (1st ed., pp. 19–32). Los Angeles: Getty Conservation Institute.

Bunka Gakuen Costume Museum. (1991). 洋装 [Western Clothing]. In 宮廷の装い [Court Costumes of the Meiji, Taisho and Showa Periods] (p. 3). Tokyo: Bunka Gakuen Costume Museum.

Bunka Gakuen Costume Museum. (2013). 宮廷服の種類 [Types of Court Clothing]. In 明治・大正・昭和戦前期の宮廷服 –洋装と装束– [Imperial Court Costumes of the Meiji, Taisho and Pre-War Showa Era – Western and Traditional Clothing –] (pp. 108–110). Tokyo: Bunka Gakuen Costume Museum.

Carter, W. M. (2021). Animating Past Worlds. In Erik Malcom Champion (Ed.), Virtual Heritage: A Guide (pp. 39–54). London: Ubiquity Press. doi: 10.5334/bck.e

Champion, Erik Malcolm. (2021). Preserving Authenticity in Virtual Heritage. In Erik Malcolm Champion (Ed.), Virtual Heritage: A Guide (pp. 129–137). London: Ubiquity Press. doi: 10.5334/bck.l

Champion, Erik Malcom. (2021). Virtual Heritage: From Archives to Joysticks. In Erik Malcolm Champion (Ed.), Virtual Heritage: A Guide (pp. 5–11). London: Ubiquity Press. doi: 10.5334/bck.b

Choi, K.-H. (2022). 3D dynamic fashion design development using digital technology and its potential in online platforms. *Fashion and Textiles*, *9*(1). doi: 10.1186/s40691-021-00286-1

Ciolfi, L. (2021). Hybrid Interactions in Museums: Why Materiality Still Matters. In Virtual Heritage: A Guide (pp. 67–79). London: Ubiquity Press. doi: 10.5334/bck.g

Dennis, L. M. (2021). Getting It Right and Getting It Wrong in Digital Archaeological Ethics. In Erik Malcom Champion (Ed.), Virtual Heritage: A Guide (pp. 105–113). London: Ubiquity Press. doi: 10.5334/bck.j

DePauw, K. M. (2017). *The Care and Display of Historic Clothing* (1st ed.). Maryland: Rowman & Littlefield Publishers.

Esguerra, C. (2024). ロサンゼルス・カウンティ美術館服飾専門学芸員 クラリッサ・エスグエラ氏 [Clarissa Esguerra, Curator of Costume at the Los Angeles County Museum of Art]. *明治神宮国際神道文化研究所 「神園」[Journal of the Meiji Jingū Intercultural Research Institute (Kamizono)]*, *32*, 29–30.

Glassey, B. (2024). バーチャルで見る 昭憲皇太后の大礼服 [The Meiji Empress's Court Dress Virtual Presentation]. In 受け継がれし明治のドレス 昭憲皇太后の大礼服 [Dresses of the Meiji Era — A Treasured Legacy — A Ceremonial Court Dress of Empress Shoken] (p. 50). Tokyo: Meiji Jingū.

Gresswell, C., Hashagen, J., & Wood, J. (2017). Concepts in Practice: Collaborative Approaches in Developing the Bowes Museum's Fashion and Textile Gallery. In M. M. Brooks & D. D. Eastop (Eds.), Refashioning and Redress: Conserving and Displaying Dress (1st ed., pp. 145–158). Los Angeles: Getty Conservation Institute.

Kasumi Kaikan. (2024). ローブ・デコルテ(北白川宮家旧蔵)の修復 [Restoration of robe décotellé, formerly owned by the Kitashirakawa Imperial Family]. In 明治天皇と華族会館 受け継がれし明治のドレス [Dresses of the Meiji Era — A Treasured Legacy — Emperor Meiji and the Kazoku Kaikan (Peers' Club)] (pp. 124–130). Tokyo: Kasumi Kaikan.

Kawai, Y. (2020). 共立女子大学博物館所蔵の近代の皇室に関わる服飾作品 [A piece of clothing related to the modern imperial family owned by the Kyoritsu Women's University Museum : study of the work mainly on Western-style clothing]. *Kyoritsu Women's University Museum Annual Report & Bulletin*, 21–39. Retrieved from https://kyoritsu.repo.nii.ac.jp/records/3422

Kuzmichev, V., Moskvin, A., & Moskvina, M. (2018). Virtual Reconstruction of Historical Men's Suit. *Autex Research Journal*, *18*(3), 281–294. doi: 10.1515/aut-2018-0001

Liu, K., Zhao, J., & Zhu, C. (2022). Research on Digital Restoration of Plain Unlined Silk Gauze Gown of Mawangdui Han Dynasty Tomb Based on AHP and Human–Computer Interaction Technology. *Sustainability*, *14*(14), 8713. doi: 10.3390/su14148713

Marschner, J. (2023, February 4). 19th-Century Court Dress in Perspective: Historical Developments in Styling. *Transboundary Fashion Seminar 8.1 Manteau de Cour of the Meiji Empress: Conservation, Preservation and Display*. Retrieved from https://transboundaryfashion.wordpress.com/2024/04/02/seminar-8-1-manteaux-de-cour-of-the-meiji-empress-conservation-preservation-and-display/

Marschner, J., Takeda, S., Bethe, M., Yoshimura, K., & Katsura, M. (2024). セッション3 パネルトーク昭憲皇太后の思いを継いで [Session 3: The Empress and Her Legacy]. *受け継がれし明治のドレス [A Treasured Legacy: A Ceremonial Court Dress of the Meiji Empress]*, 36–46.

McNulty, R. (2019). Future Applications of Digital Clothing for Historical Costume: The past, present and future of fashion. *Proceedings of EVA London 2019*, 239–242. doi: 10.14236/ewic/EVA2019.45

Mida, I. E., & Kim, A. (2015). *The Dress Detective* (1st ed.). London: Bloomsbury Publishing.

Morena, J. K. (2013). *Costume and "the copy": defining authenticity in the analogue original, the reproduction, and the digital garment within the museum and archive* [The University of Texas at Austin]. Retrieved from https://repositories.lib.utexas.edu/items/9371882f-832d-4329-8b11-fc4c626deab7

Münster, S., Apollonio, F. I., Bell, P., Kuroczynski, P., Di Lenardo, I., Rinaudo, F., & Tamborrino, R. (2019). Digital Cultural Heritage meets Digital Humanities. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLII-2/W15*(2/W15), 813–820. doi: 10.5194/isprs-archives-XLII-2-W15-813-2019

Nakamura, S., Tokuyama, T., Sasazaki, A., Fujita, K., & Morita, T. (2012). *明治維新期におけるフランスからの男子服意匠の導入の歴史 [The Introductory History of Men's Clothes Design from France in the Meiji Restoration]*. Kobe.

Sayed, A. (2014, July 6). *Uses of Computer in Textile and Apparel Industry*. Retrieved from https://textileapex.com/uses-of-computer-in-textile-and-apparel-industry/

Takagi, Y. (2023, February 3). *Seminar 8.1: Manteaux de Cour of the Meiji Empress: Conservation, Preservation, and Display*. Retrieved from https://transboundaryfashion.wordpress.com/2024/04/02/seminar-8-1-manteaux-de-cour-of-the-meiji-empress-conservation-preservation-and-display/

The Imperial Household Agency. (2014). *昭憲皇太后実録 [The Chronicles of Empress Shōken]*. Tokyo: Yoshikawa Kōbunkan.

Trubert-Tollu, C., Ttart-vittu, F., Martin-hattemberg, J., Olivieri, F., & Lacroix, C. (2017). *The House of Worth, 1858-1954: The Birth of Haute Couture*. London: Thames & Hudson.

Wu, Y., Jiang, Q., Liang, H., & Ni, S. (2022). What Drives Users to Adopt a Digital Museum? A Case of Virtual Exhibition Hall of National Costume Museum. *Sage Open*, *12*(1). doi: 10.1177/21582440221082105

Yamakawa, M. (2016). *女官明治宮中出仕の記 [A Record of a Lady-in-Waiting Serving at the Meiji Imperial Court]*. Tokyo: Kōdansha.

Yoshihara, Y. (2022). *歴史を拓いた 明治のドレス [Dress of Meiji That Developed History]* (1st ed.). Tokyo: G.B.

Yoshimura, K. (2023). 昭憲皇太后と女性の洋装 [Shōken Kōtaigō and the Westernization of Women's Dress]. In 日本の洋装化と文化学園のあゆみ [Adoption of Western Clothing in Japan and the History of Bunka Gakuen] (pp. 76–78). Tokyo: Bunka Gakuen Costume Museum.