

HUMAN-COMPUTER INTERACTIONS TO REMATERIALISE FASHION HERITAGE ARTEFACTS

A COLLABORATIVE PROJECT BETWEEN THE GIANFRANCO
FERRÉ RESEARCH CENTER AT POLITECNICO DI MILANO AND
THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

ANGELICA VANDI

Politecnico di Milano
angelica.vandi@polimi.it
Orcid 0000-0002-3627-0059

PAOLA BERTOLA

Politecnico di Milano
paola.bertola@polimi.it
Orcid 0000-0003-1522-4077

EMMA SUH

Massachusetts Institute of Technology
emmasuh@mit.edu
Orcid 0009-0003-2643-3111

Abstract

In fashion, the concept of 'materiality' is evolving under the influence of Industry 4.0 technologies, gaining significant academic interest in Human-Computer Interaction (HCI) fields. Understanding how to deal with materiality in light of digital technology impacts facilitates the revitalisation of culture-intensive artefacts by unravelling knowledge about their manufacturing processes, thus moving towards the design of sustainable production and consumption paths aimed at re-materialising the artefact in innovative ways consistent with their heritage. The article presents the results of a partnership project between the Gianfranco Ferré Research Center (GFRC) at Politecnico di Milano and the Mechanical Engineering Department at the Massachusetts Institute of Technology (MIT). Through a Reverse Engineering approach, the goal was to study and deconstruct an archival garment from the Gianfranco Ferré archive to rematerialise it and to converge HCI principles into educational applications in cultural and design-oriented fields.

Keywords: *Materiality; Fashion Heritage; Additive Technologies; Reverse Engineering Human-Computer Interaction*

FROM REPRESENTATION TO REMATERIALISATION: ADDITIVE TECHNOLOGIES TO REACTIVATE CULTURE-INTENSIVE ARTEFACTS

Within fashion, the tactile experience linked to the materiality of a garment or an accessory plays a pivotal role in truly understanding and communicating artefacts. Materiality has always been part of a research process aimed at materialising the intangible meanings that connect the garment with specific socio-cultural characteristics. Indeed, the tangible aspects of a fashion artefact are mainly the result of material and manufacturing processes that express the identity-building elements of a given territory or traditions (Maddaluno, 2018). These characteristics reflect the material experimentation

that characterises the fashion development process, and have always been applied in seasonal fashion collections as witnesses of the encounter between a constant spirit of innovation in design, and a creative and curious exploration which characterises the essence of fashion.

Materiality thus yields the formation of brands' heritage through recognisable product characteristics that form a cultural milieu and an innovation ecosystem where design acts as a sense-making process (Bertola et al., 2018). These design-driven processes have not only contributed to the global recognition of local landscapes as fertile lands for specific craftsmanship, but they also exemplify the fusion of regional traditions and innovation in contemporary manufacturing practices. Indeed,

looking at the Italian context over the years, material innovation has always been favoured by the close relationships between fashion houses and small and medium-sized companies responsible for manufacturing ready-to-wear collections. These textile/accessories manufacturers have consistently supported and elevated designers' demands by introducing intricate processing techniques and crafting meticulous, even seemingly 'impossible' fabrics. Their expertise has been deeply rooted in the local landscape, a heritage that has made 'Made in Italy' renowned worldwide (Maddaluno, 2018, p. 102) and that has nurtured Intangible Cultural Heritage (ICH), a knowledge carrier in terms of technical know-how and tacit practices (UNESCO, 2003) that resulted in the design of fashion culture-intensive artefacts.

While these artefacts are usually preserved in corporate and museums' archives as tangible witnesses of ICH, their knowledge related to materiality is difficult to acquire on the one hand because of lacks in process documentation attached to the garment, and, on the other end, because it is challenging to extract this heritage from the individuals who possess the know-how translated into materiality (Cameron & Kenderdine, 2007). "ICH craft-related practices and creative acts are embodied knowledge often handed down through personal exchanges and oral mentoring between craftspeople and apprentices through a process of human knowledge transmission" (Casciani & Vandi, 2022, p. 239) with the consequent high risk of disappearance because of the small number of remaining experts passing on their knowledge mainly in the familiar entourage or within brands walls and the limited number of educated young professionals interested in artisanal jobs. Mass production and outsourcing are other factors contributing to the risk of loss of cultural transmission of ICH in the craftsmanship sectors. In this context, technologies have affected know-how preservation and transformation in fashion. In the transition from reality to virtuality, we are witnessing a loss of materiality in objects (Franceschini, 2019), prioritising the informational aspect of data over the sensory experience. Several scholars (Drucker, 2014; Hayles, 2004; Manoff, 2006) have explored the materiality of electronic objects in various contexts. Building on the idea that information and materiality are separate entities, it is evident that in the digital realm, materiality often takes a back seat to informational function. This is primarily due to the dominance

of vision-based interfaces in digital interactions, perpetuating the notion that the body's materiality is subordinate to its logical or semiotic structures. In light of this, the distinction between tangible and virtual versions underscores the need to reconsider the concept of materiality in the virtual domain (Healy, 2013). Extended Reality (XR) is trying to blend the emancipatory possibilities of the virtual with the sensual involvement of the physical, by researching haptic technologies and related applications (Silvestri, 2020). However, so far these technologies still fail to replicate the complicated tactile qualities that define our interaction with fashion artefacts (Ornati, 2019). However, it has been demonstrated that additive manufacturing technologies can be applied to reintegrate materiality and other non-visual senses into cultural experiences. "Cultural heritage researchers have worked with virtual models and augmented reality for many years. To print out the results to understand them better is the next logical step because multisensory experiences lead to a better comprehension of the object" (Neumüller et al., 2014, p. 121). Although most 3D printers are still limited in material variety and colour palette, rapid prototyping offers a better 3D model experience. Future innovation frontiers in additive manufacturing need to be focused on rematerialising physical attributes like weight, texture, as well as mechanical features, which would allow for a more comprehensive appreciation of the objects produced (Neumüller et al., 2014). Considering the scaling applicability opportunities in fashion, the interest in multi-sensory experiences coincides with the promise of additive manufacturing and advanced robotic systems to revolutionise how research and the industry approach manufacturing processes and techniques. This because recent innovations could also play an essential role in extracting and codifying knowledge from small-scale craft manufacturing processes yet progressing towards cultural sustainability and ICH preservation and valorisation (Casciani & Vandi, 2022, p. 254). In light of this scenario, the project described in this paper highlights how additive manufacturing technologies are not merely utilised to replicate the original artefact as it was but rather to reassess the craftsmanship inherent in these fashion objects. This involves updating the process based on a new form of craftsmanship, namely Craftsmanship 4.0 or Design 4.0 (Bortolotti, 2023), which consists of studying, dematerialising, and rematerialising

the process that imbues these artefacts with high cultural significance. Consequently, a fresh audience will gain insight into the manufacturing process as it was initially conceived while gaining access to new technologies to modernise and revitalise it.

In this context, the archive becomes a living platform to practically experiment with integrating ICH knowledge within contemporary design languages towards manufacturing process innovation.

THE PROJECT “REMATERIALIZING FASHION CULTURAL CAPITAL THROUGH ADDITIVE MANUFACTURING TECHNIQUES”

The following paragraphs regard the first in a series of summer school projects organised by the Gianfranco Ferré Research Center (GFRC) at Politecnico di Milano (POLIMI) and the MIT-Italy Programme, involving selected students from the Mechanical Engineering Department of Massachusetts Institute of Technology (MIT). The project phases were executed within the framework of the “Rematerializing Fashion Cultural Capital Through Additive Manufacturing Techniques” programme, which is part of a GFRC research initiative focused on disseminating technical and scientific knowledge from the Gianfranco Ferré archive, donated by the Ferré family in 2021 to POLIMI. Under the guidance of two POLIMI PhD students, one specialising in Fashion Design and the other in Mechanical Engineering, visiting MIT students studied and attempted to recreate an archival artefact, exploring the potential of innovative manufacturing processes, reflecting Gianfranco Ferré’s pioneering approach to materials and answering the question: How can culture-intensive garments become catalysts for innovation in HCI fields regarding manufacturing processes through technological hybridisation? This aim converges into one of the objectives of the GFRC: as part of POLIMI, the GFRC is rooted in a design-driven, research-oriented nature, aiming to bring together the technical-scientific know-how and design culture with the tangible and intangible heritage related to the history, culture and techniques of fashion preserved and valorised in the Gianfranco Ferré archive.

In this configuration, researchers faced the task of preserving the inherent heritage values associated with a selected historical fashion artefact (Calanca,

2020; Pistilli, 2018) while using the same values as foundational principles for codifying an augmented process aimed at rematerialising and recontextualising the artefact.

ARCHIVAL LITERACY

Gianfranco Ferré is considered one of the major fashion designers contributing to make Italian fashion and the ‘Made in Italy’ concept renowned worldwide. According to him, reflecting on *the matter* means setting the ground to explore “expressive horizons balanced between innovation and experience, technology, and craftsmanship” (Airaghi et al., 2023, p. 21), meeting a desire for innovation and technological experimentation with fabrics, textiles, and other materials that extended beyond traditional fashion. In his lesson *Designing the Material* held at Central Saint Martin in 1998, Ferré systematised his approaches to the matter, describing how and why an essential part of his creative process was always characterised by “*an innovative and curious approach to material*” (Frisa, 2009, p. 88), a successful blend of reason and emotion that always had characterised his approach towards the tangible existence of fashion –the material– where fashion gets its foundation from. Indeed, over the years, Ferré has always employed cutting-edge processes, increasingly sophisticated treatments, and technological experimentation to create unprecedented possibilities for using materials in his collections.

This aspect brought him to codify three different approaches:

- The pure material, where precious fabrics are selected without altering their noble characteristics but rather emphasising their value and high quality through his designs and style.
- The reinterpreted material regards the “proper and improper uses of materials” (Frisa, 2009, p.90) that are part of the clothing tradition, challenging established norms such as breaking down or redefining the distinctions between menswear and womenswear, day and nightwear, and formal and informal clothing.
- The invented material –the most cutting-edge– born from the desire to gain a deeper understanding of the characteristics and manufacturing methods of what already exists. It emerges from a learning-by-doing approach and the continuous efforts

invested season after season. Rather than causing disruptions, it represents a constant desire for evolution. For instance, it involves strengthening the most precious natural fibres through technological enhancements, applying high-definition industrial treatments to traditional materials, and skillfully combining different materials to harness their respective qualities.

In light of this introduction, the selected garment for the project experimentation was The Golden Jacket, belonging to the Ready-To-Wear (RTW) Fall-Winter 1993 collection, a signature jacket witnessing the experimental approach Ferré wanted to keep towards reinterpreting pure materials offered by nature. Indeed, the jacket is made with a cotton cord, only reworked and elaborated by hand to meet his idea about RTW, closer to Haute Couture values rather than the ideas of reproducibility and universality carried on by the nature of RTW. Indeed, one of Ferré's firmest beliefs was in the perseverance of luxury as a never ending pursuit of quality, uniqueness, and originality beyond fashions and seasons (Frisa, 2009). It is therefore not surprising that the central aesthetic appeal of the jacket is the royalty derived from the historical concept of the gilded "mittel Europe" of the 19th century. (fig. 01)

Given this scenario, accessing the related ephemeral documents was essential to acquire a holistic overview of how the artefact was initially designed, produced and communicated. This allowed reflections on (i) the eventual gap and shortcomings in the documentation at an archival level and (ii) the opportunities to expand and update the archived knowledge in light of the technological tools available nowadays.

In tandem, to continue unfolding the knowledge preserved inside this unique piece, the team interviewed a collaborator of Gianfranco Ferré, who witnessed the jacket fabrication in 1993, thus representing an unparalleled resource of historical oral knowledge. Besides prompting further design steps, this phase also provided the opportunity to document and represent this knowledge, enriching the archive with textual and audio recordings, and understanding how to start conversations with other testimonies from a manufacturing point of view.

Concerning the jacket, the team rearranged interview results focused on the manufacturing process and reported them below in steps.

1. The jacket resulted from a fruitful



Fig.01

collaboration Ferré relied on with the embroidery factory Ricami Laura in Reggio Emilia, where he could carry out the most daring and original experiments regarding embroideries applied to materials in this place.

2. The manufacturing process started with a naturally coloured cotton cord laid out on an adhesive sheet so that the patterns could be constructed in a manner that would be maintained. This was the step in which the jacket cut-out patterns were created manually. The intended design was traced out on the sheet beforehand, and the cord was placed to fulfil this design with slight improvisations. From analysing the jacket, it was assumed that this was done for two layers.
3. The motifs of each cut-out piece of the jacket were then hand-sewn to preserve the shapes created in the first step.
4. After stabilising the design, each cut-out piece was plated with a golden foil by an artisan specialising in creating antique book covers. The same approach was afterwards applied with a silver foil on the outer surface of the layers.
5. After the painting steps were completed, the pieces were heat-treated to maintain the metallic material.
6. Following the final heat treatment, the Mattioli factory assembled the cut-out pieces to make the jacket look like a continuous

cord.

REVERSE ENGINEERING

Reverse Engineering (RE) has been appropriated by fashion in the context of fashion cultural heritage as a new approach to unfolding and disseminating archival knowledge (Vacca & Vandi, 2023). Through *acquisition, simulation, and restitution phases*, it aims to codify the in-depth study of archival artefacts through educational, research-driven activities. In the project's context, learning how the jacket was historically crafted allowed a deep understanding of materials, crafts techniques and technologies employed originally. Hence, RE was then employed to activate these archival discoveries and to produce new knowledge to share with different actors.

After evaluating the options at hand to reverse engineer the jacket, researchers started by outlining two main paths for acquiring the jacket digitally:

- 3D scanning
- Manual digital design

The first attempt at scanning was achieved by employing the photogrammetry RealityScan APP (<https://www.capturingreality.com/realitycapture>). With only pictures shot on an iPhone, it was possible to convert 200 photos of the jacket on a black mannequin into a coloured mesh. The process took less than an hour, and it seemed the perfect solution for acquiring a copy of the digital jacket. However, although the mesh was visually precise, the geometry of it was very rough and inaccurate; thus, the model could not be prepared to be printed. (fig. 02)

The second scanning attempt involved two rounds, the first with the AI-driven Artec Leo 3D scanner (<https://www.artec3d.com/portable-3d-scanners/artec-leo>) and the second with the EvixScan 3D Quadro+ (<https://evixscan3d.com/3d-scanners/quadro/>). Although these scanners are among the most advanced and are used in the automotive industry and for mixed-reality applications, the experiment with the jacket did not yield positive results. Nonetheless, this did provide some insights into the underlying issue. Despite the high pattern intricacy, the main problem was related to the golden effect of the jacket, which bounced the laser beams. The only potential solution would have been to change the jacket's surface to a matte finish, but this presented a dilemma as it would jeopardise the integrity of an archival garment. Despite contradicting the objective of formalising

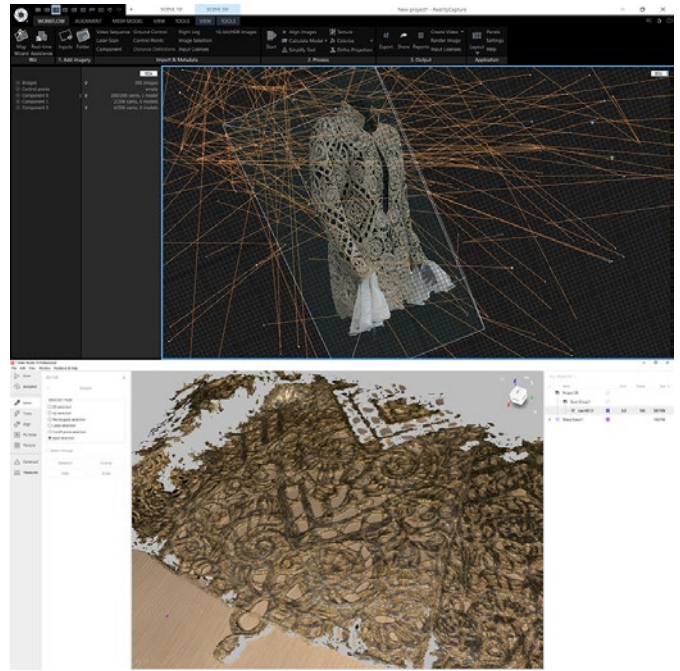


Fig.02

a smooth, technologically-supported RE process, the team started by digitally documenting the jacket's characteristics. This initial step allowed us to acquire and simulate its shape and subsequently translate the original manufacturing process into a technological one.

Given the intricacy of the piece and the complexity of its manufacturing process, the archive lacked the paper pattern. Consequently, the team set out on a meticulous reconstruction phase involving deep observation and precise measurements to lift the pattern digitally, which comprised two pieces in the front, one central piece in the back, two side panels, and the sleeves.

The subsequent step involved establishing a method for capturing the motifs from images, particularly after identifying systematically repeated modules. Initially, the team successfully extracted the pitch and diameter of the intertwined three yarns to form the cord. These specifications were used to model the cords as meshes in Blender, allowing the cords to intersect. Once the cord was created, the images of the jacket pieces were imported into Blender to serve as references, using the 2D pattern as a guide. By aligning the base spline to direct the cord over the image, the team could trace the pattern using a single cord for all the pieces and finally simulate and return the jacket digitally. (fig. 03)

REMATERIALISATION

Additive and subtractive technologies have been considered the new frontiers in product manufac-



Fig. 03

turing due to their ability to offer greater design flexibility, sustainability, and efficiency. Specifically, 3D printing was chosen as the preferred fabrication method since it aligns with Ferré's emphasis on material research and novelty, providing a means to experiment with various materials and gain valuable insights. Additionally, additive manufacturing is at the forefront of fashion innovation as the industry seeks sustainable methods for producing recyclable garments without waste. Moreover, Ferré's jacket exemplifies what he referred to as 'the invented material', as the cotton cord was patterned and coated to mimic a lace-like golden structure. Similarly, the single 3D printing extruder excels in replicating the complex outlined configuration, which is challenging to achieve with other additive or subtractive manufacturing techniques.

A small pattern selection was chosen to start the trials, and its mesh was exported as an STL. To turn the STL into a printable file, Meshmixer allowed the mesh to be easily made solid and removed any open surfaces that would be problematic for the printing software. The STL was then uploaded to Prusa Slicer, and a GCode was extracted for printing. The first trials were done with Sharebot printers, which are ideal for experimenting with polymers, especially PLA (polylactic acid). Approaching TPU seemed logical for the project, being a flexible filament that can add an aspect of adaptability to a potential fabric. This flexible material enables the printing of the piece in an orientation that can later be unfolded, allowing for simultaneous printing of larger sections. Due to the

incompatibility with the ShareBot printers, TPU was printed using the Ultimaker U3 printer, whose results provide flexibility in its bending properties. Moreover, initial experimentations regarded the use of the Desktop Metal printer, which allowed the printing of a small section of the pattern using steel. Although more time-consuming, the outcome yielded an accurate definition of cord details and facilitated additional speculation regarding the reinterpretation and potential reuse of the printed object. (fig. 04)

RESULTS AND DISCUSSION

Considering the rematerialisation affordances to redesign a fashion garment, as discussed throughout the process, several technological limitations still emerge regarding acquiring and printing the actual jacket materiality and shape. Firstly, the most advanced laser scanner could not acquire the jacket because of its complicated pattern and reflectivity, forcing researchers to opt for a manual digitisation process aided by virtual prototyping technologies. Secondly, research on flexible and wearable materials is ongoing and still immature, while printer beds need to be wider to print out garments. To this end, future project developments will involve understanding how to combine the jacket pieces seamlessly. One solution could be integrating the chainmail technique as an excellent method of deriving mobility and adaptability from rigid structural links, even though incorporating it into the design will compromise the original jacket pattern. However, these findings hold significant research value and provide insights about how culture-intensive garments and the related manufacturing processes become catalysts for innovation in HCI fields through technological hybridisation. Indeed, what truly stands out is a new encoding of the process that aims to extract and represent the implicit and tacit knowledge enclosed in artefacts of high cultural value through advanced digital-aided techniques. At a systemic impact level, reflections regard:

- the role of Craftsmanship 4.0 or Design 4.0 that brings about innovation potential to artisanship that is not just a repetitive technique but a creative exploration of a method, "a creative act" that confers real quality and authenticity as values for final consumers (Sennett, 2012, p. 77). Indeed, the capacity to integrate reframed craft

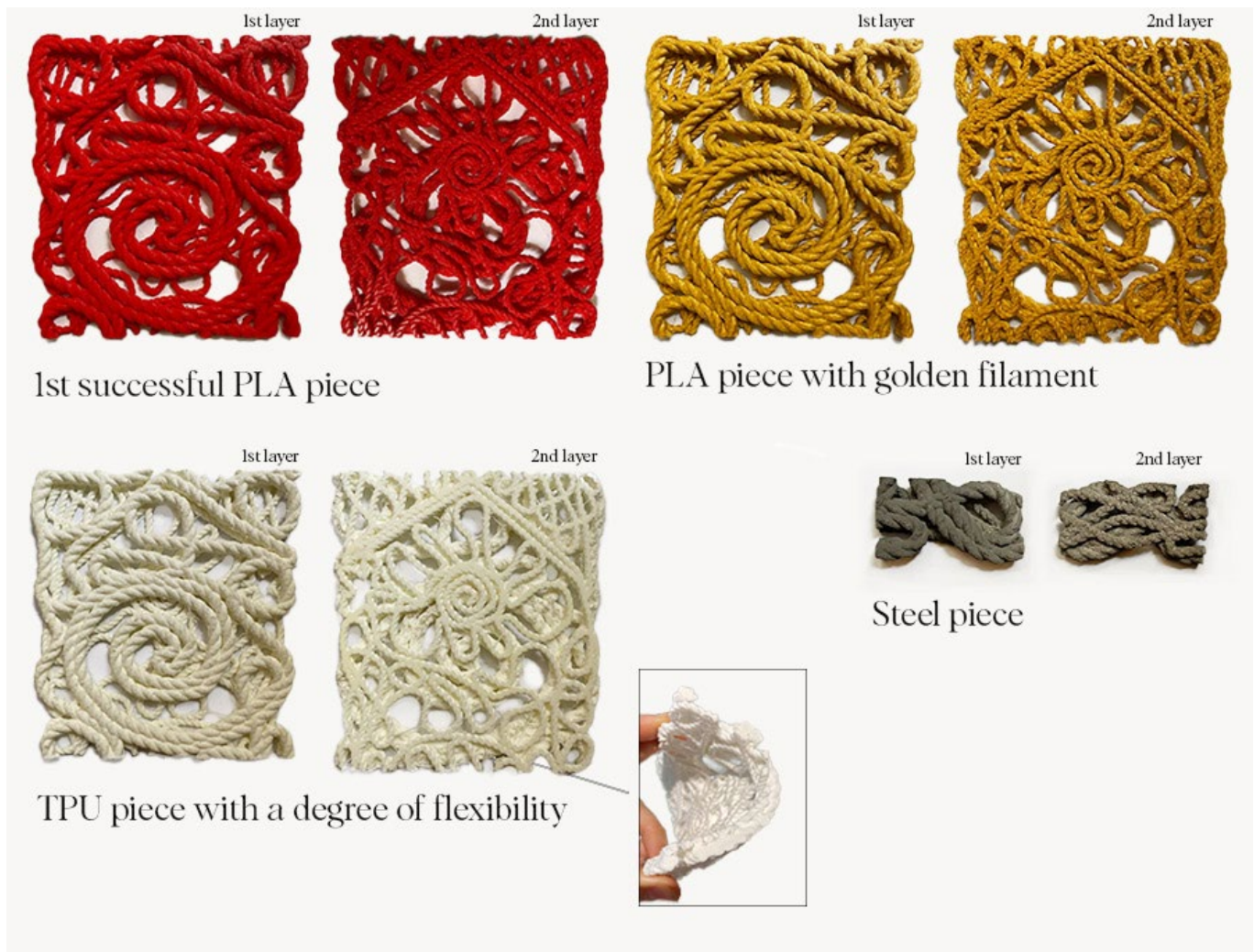


Fig. 04

techniques with advanced manufacturing processes can lead not only to the in-depth study of the materiality of the garment through RE but also to the codification of new, unreplicable business models that resonate with modern consumers' demands for sustainable development.

- interdisciplinarity as an asset when considering technologies as media that allow an in-depth study of the artefact to unlock different production and consumption perspectives that grow from the archive (Schnapp, 2013). Contextually, professionals in Human-Computer Interaction, Engineering, and techno-scientific disciplines, in general, are new stakeholders that enable the application of advanced technical solutions to extract knowledge from artefacts to inform further production and consumption paths, impacting academia, fashion companies and cultural institutions. This context subverts the idea of 'authorized heritage discourse' (Petrelli et

al., 2023), where historians and curators are the only ones to preserve and keep track of archival knowledge to be disseminated to the general public.

- the evolution of the archive into a learning organisation, a social laboratory (Sennett, 2012, p. 77) wherein knowledge no longer adheres to an elitist dimension (Pecorari, 2019) but instead becomes democratised, accessible, and actively disseminated among diverse stakeholders, catalysing collaborative learning and fostering inclusive participation. The culture preserved within becomes the asset for innovation and differentiation, and its narrative content is recognised as a value for final customers. Indeed, it is proven (Bertola et al., 2016) that the use of heritage assets and their potential to embed cultural content into final garments improves strategic marketing purposes and digital narratives (Martin & Vacca, 2018) to attract clients operating in the luxury segment and final customers.

CAPTIONS

[fig. 01] The Gianfranco Ferré Fall Winter 1993 *Golden Jacket* from the runway show. Archival Images. Courtesy of Centro di Ricerca Gianfranco Ferré <https://www.centroricer-cagianfrancoferre.it/home/FGFhome.php?lang=it>

[fig. 02] 3D Scanning acquisitions with the Reality Capture App and the AI-driven Artec Leo 3D Scanner. Source: Authors

[fig. 03] Reconstructed digital pattern on Illustrator and consequent 3D prototyping and renderisation on Blender. Source: Authors

[fig. 04] Final 3D printed pieces. Source: Authors

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