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GLOBAL FASHION CONFERENCE

Practicing the Work of a Sustainable Digital Fashion Designer/Maker 4.0: Design of an Organic and Modular Clothing System Based on the Industry 4.0 Approach

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Abstract

Industry 4.0 in the Fashion Industries is having its momentum through the application of digital fabrication technologies encompassing 3D modeling or computing-aided design (CAD), additive manufacturing (i.e. 3D printing), and subtractive manufacturing (i.e. laser cutting, cutting through plotter, and CNC machining) technologies in changing the fashion system in all aspects, from the business models to the creative fashion designer professional skills and activities. In the wave of Industry 4.0 (I4.0), a new design paradigm has been emerging based on the cooperation between digital production and manual expertise: new digital artisans/ fashion designers 4.0 emerged as being able to work on scouting old crafting techniques and updating them through the use of digital fabrication technologies to boost their creative abilities, explore aesthetical possibilities, and start-up new economical businesses. This paper aims to present the status of the art of the digital fashion designer/artisans practices through a preliminary literature review as a baseline to present a case study of hybrid digital fashion craftsmanship focusing on the design and implementation of an organic modular garment system based on the I4.0 approach. The case study will serve to describe the impacts, opportunities, and limitations that digitalization and additive manufacturing techniques could have on fashion design in terms of creativity, design and manufacturing processes, new skills and practices, and sustainability.

Keywords: Fashion 4.0, 3D printing technology, fashion design, modular design, cultural sustainability, environmental sustainability.

DOI: 10.57649/GFC.978-989-54263

ISBN: 978-989-54263-3-1

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1. Introduction

Industry 4.0 (I4.0) in the Fashion Industries is having its momentum through the application of digital fabrication technologies DFT encompassing 3D modeling or computing-aided design (CAD), additive manufacturing (i.e. 3D printing), and subtractive manufacturing (i.e. laser cutting, cutting through plotter, and CNC machining) technologies in changing the fashion system in all aspects, from the business models to the creative fashion designer professional skills and activities (Bertola and Teunissen, 2018; Teunissen and Danjoux, 2021). However, it seems that the uptake of these technologies is slow and encounters several barriers that are not only economical but also cultural, rooted in a very traditional sector, that of the Fashion and apparel industries (Digital Manufacturing Lab, 2018; Mosca and La Rosa, 2019). Conversely, the opportunities of Fashion 4.0 for fashion SMEs relying on dedicated and specialized artisanal work are already evidently defined in the literature (Denaro, 2020; Denaro and Petrecca, 2020). The implementation of I4.0 in the Fashion sector has proven to deeply impact the redefinition of design, manufacturing, and consumption logic toward more sustainable practices (Ford and Despeisse, 2015). DFT allows new design strategies to happen in terms of new processes definition, new equipment, and tools for design and prototyping toward positive values in terms of environmental economic, cultural, and social sustainability. DFT could be impacting the environmental sustainability such as improving processes to lower waste, pollution, material consumption, and energy use. In addition to this, given the impact fashion has on culture, education, and societal development (Noris et al, 2021), they could also impact more sustainable business models, awareness of sustainable consumption (Collins, 2019), ethical behaviours (Creangă, 2019) and sustainable design and manufacturing processes.

This holistic view of sustainability reflects more the complexity of current society. The figure of a new eco-digital augmented fashion designer and artisan of goods and relationships is emerging as positively reshaping both design and manufacturing processes through the adoption of pre-production visualization tools (e.g. 3D modeling and CAD-CAM prototyping tools) that allow analysis, defect relief, digital fabrication optimization to minimize production timing, waste of materials, and imperfections (Vallett et al.2017). In this paper, we would like to first reflect on the impact of DFT on sustainability in a systemic and integrated way in the fashion sector, through an integrated and design-driven approach for product, system, and process innovation. In this paradigmatic shift, fashion designers/makers could be conceived as mediators of technological integration and implementation through design-driven decision-making approaches via meaningful creative processes. By challenging current fashion systems and optimizing their processes and practices, new types of thinking can be opened up, toward a more positive sustainable transition in the fashion sector, from a product-level innovation to more complex levels of systemic innovation. This paper takes the design of an organic and modular clothing system based on the Industry 4.0 approach project as a practical means to explore the concept of hybrid digital fashion craftsmanship 4.0. A final reflection on the change in fashion designer / maker practices along with the sustainable impact of the project is provided with further possible implementations.

1.1 Hybrid digital fashion craftsmanship 4.0 toward sustainability

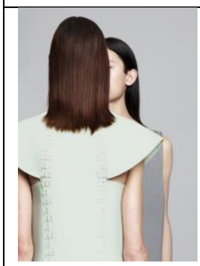
Craftmanship creative acts are based on practiced skills aimed at achieving consistent, exceptional outcomes that focus on the practical embedding of aesthetics and art into the experience of making. The resulting craft objects represent the material culture, ideas shaped through tangible artefacts, witnessing the "intimate connection between hand and head" (Sennet, 2008). Craftspeople are also custodians of Intangible Cultural Heritage (ICH), conceived as practices, representations, living expressions, knowledge, and skills inherited from the past and belonging to specific, situated territories and communities.

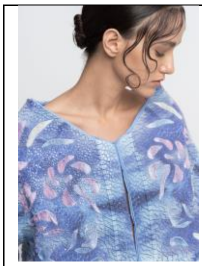
The innovation potential of I4.0 could be a trigger for a radical rethinking of fashion craftsmanship as for new business models, but also igniting creative acts within cutting-edge craft production and new consumption processes. New competitive, cyber-physical scenarios within high-end fashion digital craftsmanship could set up the conditions to seize a human-centered, sustainable, and more prosperous digital future by increasing the digitalization of manufacturing processes and supply chains. However, the process of digital transition and adoption by fashion SMEs is still limited. In the Second Report Industry 4.0 in Italian SMEs (2018), the digital transition of the sectors of Eyewear (9.5%), Jewellery (5.8%), Apparel (14.2%), Textile (8.4%), and footwear (1.6%) encompass a limited adoption of DFT. The main advantages are efficiency, increase in productivity, being able to real-time connect factories and retail channels to allow automatization from design to manufacturing to traceability/control of product; increased value related to the product in terms of customization through co-design activities to answer customers' search for authenticity and uniqueness; increase in quality of products by fastening low complexity and time-consuming manufacturing activities while allowing product variety; maintaining manufacturing in Italy and reshoring locally, thus supporting international competitiveness and new market opportunities. On contrary, barriers to the uptake of DFT and I4.0 in fashion craftsmanship sectors regard the higher costs of implementation of technologies and limited financial resources inside fashion companies, poor knowledge of the I4.0 possibilities, fear of artisanship expertise loss, and the misaligned cultural values and business strategies of the fashion SMEs. In addition, barriers regard also digital literacy due to a lack of internal/external competences, inadequate internal information systems, and difficulty in identifying the right partner/supplier.

Despite this, there are already interesting fashion designers and start-ups (Table 1) that show new hybrid digital artisanship processes and workflows focusing on products and process innovation that can contribute to a paradigmatic shift of the fashion system toward sustainability. Performative Robotic Microfactories (2020) focus on an integrated and systemic design approach via additive manufacturing aided by robotic arms to print the seams, decoration, and structural parts of garments along with repairing the garment on a planar surface. The system is enacted at an urban local size, customizing the garment production to reduce outsourcing of garment and accessory assembly, encouraging urban regeneration, and decreasing transportation costs and the carbon footprint associated with shipping.

Don’t Run Beta (2014), The Post Couture Collective (2014), and Weareable (2020) focus on users’ collaboration and participation in garment making and customizing (at a certain level of variation), thus creating an experience around the purchase of the product. Modular customized design allows for on-demand production, enabling disassembling and repairing activities throughout the product lifecycle. Body scanning technologies and a digital workflow increase the efficiency of single customized garments, reducing waste materials. New materials are also explored, combining technological opportunities with new aesthetics and sustainability challenges. All the examples strive to work on small-scale productions in near-reshored local digital micro-factories through the implementation of new business models and value chains based on collaboration (Behr, 2018).

Table 1. *Fashion Artisan 4.0 case studies*

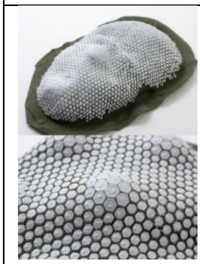
Image	Project name	Year	Author（s）	Technologies used
	Performative Robotic Microfactories	2020	Yokai Studios	3DP CR Software programming
	Don't Run - Beta	2014	Eugenia Morpurgo and Juan Montero	Lasercutting 3DP
	The Post-Couture Collective	2015	Martijn van Strien	Lasercutting

	WeAreAble	2020	Ganit Goldstein and Stratasys	3D scanning 3DP

1.2 3DP and lasercutting of modular elements impacting fashion sustainability

DFT provides a real advantage in terms of efficiency, and increase in productivity, being real-time connected with factories and retail channels, products, and final customers to test results during the design and manufacturing process and to allow automatization from design to manufacturing to traceability/control on product; increased value related to the product in terms of customization through co-design activities involving also the customers and flexibility of the supply chain, increased quality of products by fastening low complexity and time-consuming manufacturing activities while allowing product variety and creativity; customer service enhancement through products differentiating to answer customers' search for authenticity and uniqueness; more competitive, faster, and versatile production, impacting on Business management innovation. In particular, 3DP is posing a number of advantages compared to traditional manufacturing processes, including an accelerated design process, less production time, and lower costs related to inventory, warehousing, packaging, and transportation (Vanderploeg et al., 2016). In Fashion, 3DP opens new possibilities in aesthetic and functional performance (Sheikh et al., 2020), particularly when combining 3DP on textiles that allows the creation of rigid, sculptural shapes with embedded flexibility as well as soft materials imbued with additional functionality (Rivera et al., 2017). Examples of experimental research through design have focused on creating 3D printed functional joints, snaps based on polymer–textile deposition that will contribute to new applications and functional products such as orthopedic braces for medical use or for decorative features such as buttons and trimmings for garments (Pei et al., 2015). More advanced is Fabriclick, an exploration about interweaving mechanical pushbuttons into Fabrics Using 3D Printing and Digital Embroidery (Goudswaard, 2020). Many experiments rely on the 3D printing over stretchable textile allowingo functional and aesthetical selective tension of the material that could be shaped without chemical and additional tools. In this regards, 3D printing technology of materials with different layer thicknesses on stretched textiles in fashion allows the creation of fascinating composite materials (Self-shaped textiles, 2019), footwear (Active shoes, 2013), or architectural elements (Programmed Deformation V2.0, 2020) with enhanced smooth aesthetic appearance and pre-programmed behaviours such as living and tension-active structures, thus allowing inherent material efficiency, and efficient manufacturing processes that reduce time, work and materials. In addition, the possibilities of programming, simulating, and testing in virtual platforms the dynamic behaviours and the structural stability of these composite materials (Nervous system, 2018) allow the preview of both the self-structuring properties and the aesthetical output and also eventually to adapt and customize this structures to any body shape (Table 2).

Table 2. *3D printing on fabric case studies*

Image	Project name	Year	Author（s）	Technologies used
	Active Shoes	2013	Studio Guberan	3DP
	Self-forming structures by 3d-printing on pre-stretched fabric	2018	Nervous System	3DP，Boundary-First Flattening algorithm
	Programmed Deformation V2.0	2020	Madalin Gheorghe & Mateusz Zwierzycki Design Morphine	Parametric design, 3DP
	Self-shaping textiles	2019	Agata Kycia	3DP

Modularity, in the context of design, refers to the degree to which a product's components may be reconfigured, removed and/or added and the rules that enable or prohibit this (Mansour, 2017). Modular design enables the creation of products with a second life thanks to the reconfigurability of the product through adaptable and removable sections, which allow growth and change over time (Hur and Thomas, 2011). Modular design offers the advantages of ease of assembly/disassembly, customization and cost-effectiveness, providing flexibility due to the wide variety of novel and versatile design outcomes. Many designers employing the principles of modularity focus on eco-efficiency in production and embodied emphatic experience in product consumption (Mansour, 2017). Thus, modularity allows personalization to meet the needs of the user, so to be considered an inclusive design technique (Ying and Meng-Mi, 2018). Based on the modularity approach, the MINTA project (2021) combines the logic of sustainable materials (textiles, cherry, and walnut wood), lasercutting technologies, and handcraft assembly without limitation in terms of shape, size, and patterns. More technologically advances, aided by Artificial Intelligence and Augmented Reality, the Modular Augmented Capsule project (2020) creates modular garment designs starting from discarded fabric that is digitally processed through pixelation, 3D scanning, and generation of design patterns of clothing (Table 3).

Table 3. *Lasercutting for modularity case studies*

Image	*Project name*	*Year*	*Author（s）*	*Technologies used*
	MINTA	2021	Orsi Orban	Lasercutting, 3D modeling
	Modular Augmented Capsule	2020	Mathilde Rougier	Augmented Reality Artificial Intelligence 3D scanning Lasercutting

2. Research aim

I4.0 changes the production and manufacturing processes from a centralized to a decentralized control, with the aim of establishing highly flexible personalized and digital production systems, and advanced aesthetics of products and services through enhanced creative methods. However, the uptake of DFT is at the very early stages and new possible expressive languages along with new consumption behaviours and design techniques could be investigated to have better products. Small and medium enterprises (SMEs) in the fashion sector are focused on highly skilled craftspeople whose expertise and know-how could be enhanced through the use of digital technologies that could both drive new creative processes toward more customized products and more sustainable production systems. In the wave of I4.0, a new design paradigm has been emerging based on the cooperation between digital production and manual expertise: new digital artisans / designers emerged as being able to work on scouting old crafting techniques and updating them through the use of digital fabrication technologies to boost their creative abilities, explore aesthetical possibilities, and start-up new economical businesses (Rautray and Eisenbart, 2021). Accordingly, new fashion digital designers/makers are exploring the expressive possibilities of digital technologies that enable not only new products and services' imaginaries and expressivity but also the activation of new design processes, thus requiring new skills and competencies.

The main research questions are: which kind of new forms of cooperation among stakeholders in the fashion supply and value chain could be created? How old crafting techniques could be updated and revived using DFT? How digital technologies could enhance the creativity of fashion designers and makers, generating more complex and precise products exalting precision and uniqueness along with fastening repetitive cyclical activities?

3. Research methodology

This paper aims to present the status of the art of the digital fashion designer/artisans' practices through a preliminary presentation of best practices that serve as a baseline to describe the experimental case study of digital fashion craftmanship. The project of an organic modular garment system based on the I4.0 approach is presented and will serve as an example to describe the impacts, opportunities and limitation that digitalization and additive manufacturing techniques could have on the fashion digital designers / makers. The development of the project follows a research through design methodological approach (stappers, 2006) where the designer reflects during and after the design phases on design processes, activities, methods, techniques, tools and design results, and products, providing critical insights in terms of creativity, design and manufacturing processes, new required skills and developed hybridized fashion craft practices, and sustainability impacts. Therefore, results and conclusions focus on materializing knowledge and insights based on the developed hands-on design work.

4 Design of an organic and modular clothing system based on the I4.0 approach

This section presents the features of an organic and modular garment design implemented using 3D printing technology on fabric and creating different modules, connected similarly to the building block principle, that implements the Fashion 4.0 parameters as follows: (i) organic shapes enhancing aesthetical expressivity; (ii) modularity allowing adaptable multiple configurations; (iii) customization through co-design configurator of the modular shapes in relation to specific body features; (iv) 3DP digital pattern to shape and connect the modular parts; (v) on-demand and networked production allowing re-shoring the manufacturing processes where the product should be delivered.

4.1 The inspiration for the concept of the organic and modular clothing system

The concept of organic form refers to bio-morphic shapes inspired by nature, breaking the regularity of geometric shapes with natural features, especially curvilinear aesthetics and biological forms. The system is inspired by the structure of cells in nature as complex and delicate various structural components that cooperate to self-regulate within a continuously changing environment. Similarly, the clothing system is based on a collection of modular garments built on organic-shaped modules that work together to create an organic system for the wearer. By converting two-dimensional flat patterns into tridimensional unit structures through a 3DP printed method, sculptural modular allows the creation and transformation of a variety of garments (Figure 1).

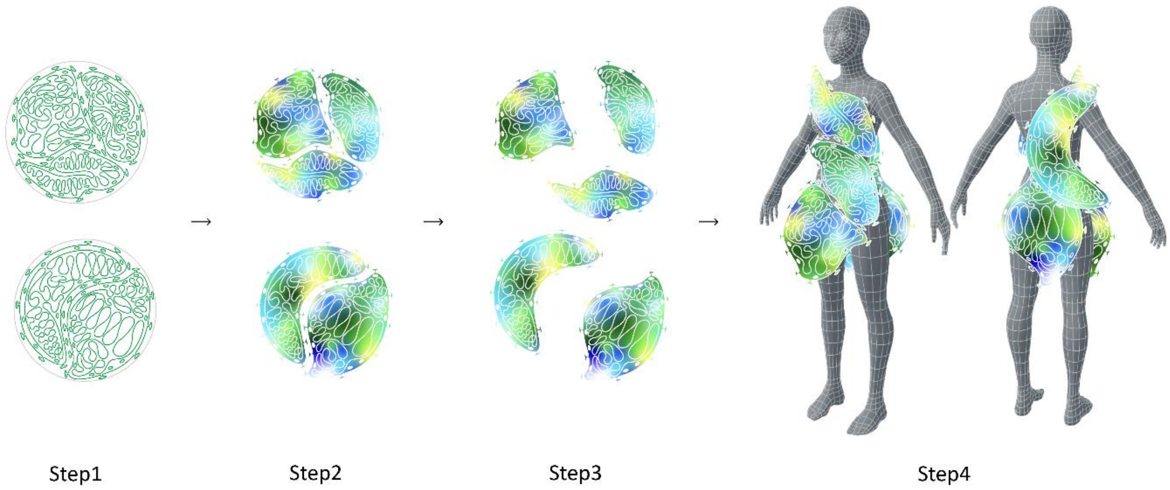


Figure 1. Organic Fission project sketch

4.2 Reflecting on creativity, design practice, and manufacturing processes

The design process focuses on highly digital activities early in the process enhancing creativity and is followed by hybrid activities of hands-making and 3D printing during manufacturing processes, and ends with a simplified handcrafting process of the garment through the user collaboration in the assembly and configuration phases. The clothing design and manufacturing processes encompass four steps (Figure 2).

Step 1 – Pattern design

The design of the curves of the modules is done through a digital software (e.g. Adobe Illustrator) allowing vectorial definition of the structural lines and edge line. The structure line determines the 3D structure of the module after 3D printing, and the edge line provides the combination functions between the modules. Two-dimensional drawings were converted into 3D files with a CAD software, then sliced with CURA software to generate the code for 3D printing.

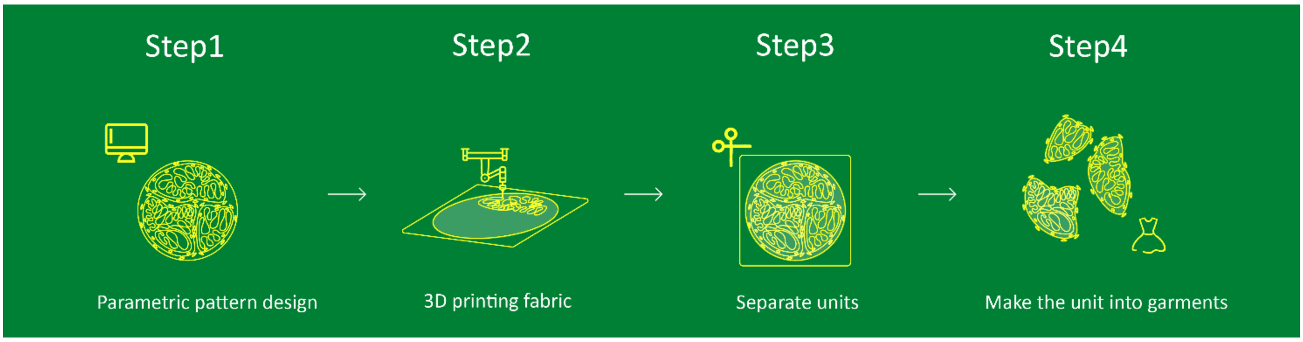


Figure 2. Organic Fission project design system

The maximum area of the cell has been set accordingly to the maximum printing area of the 3D printer used in the prototyping stage which is 100cm in diameter. Each cell contains one or more modules, which are of different shapes and sizes. Therefore, the final design of the project is eight cells, which contain 19 modules, which can be combined with each other so that many combinations can evolve (Figure 3). At the same time, the design of the pattern of the fabric has been digitalized for double-sided digital printing processes (Figure 4).

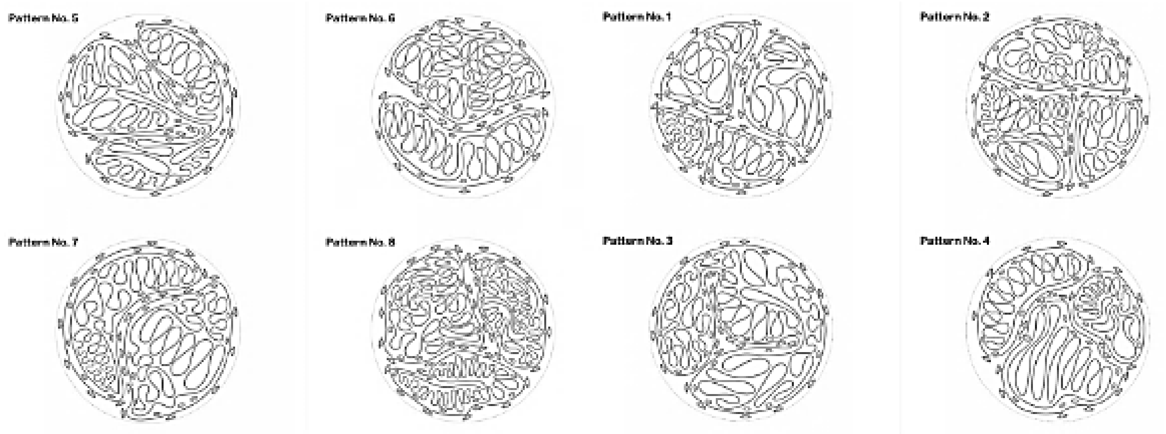


Figure 3. Organic Fission project- pattern and model

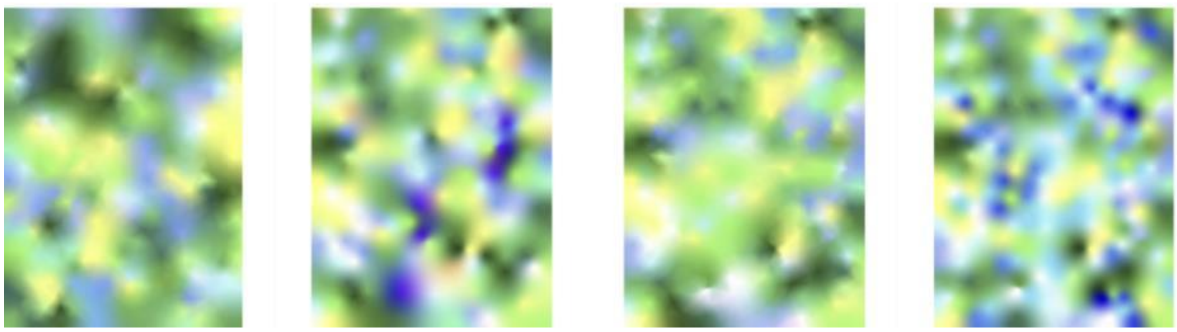


Figure 4. Organic Fission project- pattern design for digital printing

Step 2 - 3D printing on fabric

The designer works iteratively from digital design imported on the 3D printer to adjustment of the machine parameters to manually fix and stretch the textile on the 3D printer bed and check the printing layers to ensure the best features in terms of material flexibility, elasticity, and 3D bending of the final shape, to achieve both aesthetic and structural characteristics. For the prototyping activities, the Delta WASP 3MT has been used with White CoexFlex™ 60A TPU 3D printed on silk fabric (97% polyester 3% spandex, fabric weight 225g/m). Iterative testing activities to check the behaviours of the material between the elasticity of fabrics and the rigidity of printed plastics have been implemented toward the creation of a permanent 3D structure with aesthetic and structural features to directly become a part of garments (Figure 3-4).

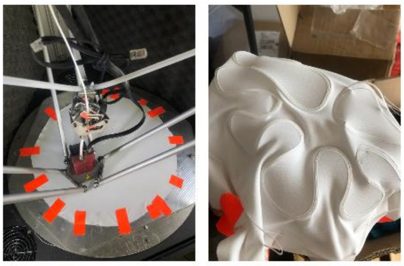
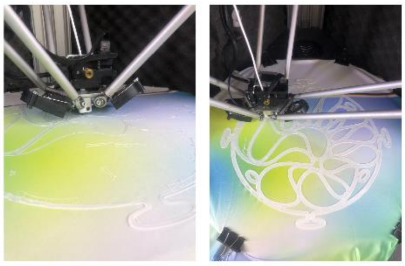
TEST SAMPLE 01		TEST SAMPLE 02	
Materials:	PLA and polyester	Materials:	TPU and polyester
Test process picture:		Test process picture:	
Advantages:	The PLA material used in the 3D printer has high hardness, which can make the fabric show a more three-dimensional structure after 3D printing.	Advantages:	TPU material and polyester fabric have a high degree of adhesion, and they are very firm.
Disadvantages:	The low adhesion between PLA and polyester fabric makes it easy for PLA to peel off from the fabric.	Disadvantages:	The line thickness of the pattern is too wide, resulting in weak three-dimensional effect of the overall fabric after 3D printing.
Firmness and Comfort level:	Firmness: 30% Comfort: 50%	Firmness and Comfort level:	Firmness: 90% Comfort: 30%

Figure 5. Experimental printing tests

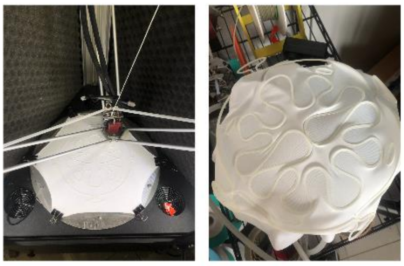
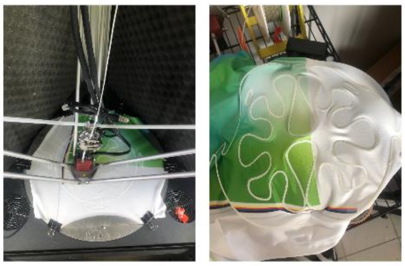
TEST SAMPLE 03		TEST SAMPLE 04	
Materials:	PETG and polyester	Materials:	TPU and polyester
Test process picture:		Test process picture:	
Advantages:	PETG can make polyester fabric show a certain three-dimensional effect after 3D printing.	Advantages:	The adhesion between TPU material and polyester fabric is high. The fabric shows a certain degree of three-dimensional effect after 3D printing, and ensures comfort.
Disadvantages:	The adhesion between PETG material and polyester fabric is not high, and the stereoscopic degree of the fabric after 3D printing is low.	Disadvantages:	After 3D printing, TPU did not make the fabric present a very three-dimensional 3D structure like PLA .
Firmness and Comfort level:	Firmness: 40% Comfort: 60%	Firmness and Comfort level:	Firmness: 90% Comfort: 90%

Figure 6. Experimental printing tests

Step 3- Cell unit separation

The third step is to cut the 3D printed fabrics and remove the redundant parts to get the final independent modules (Figure 7).

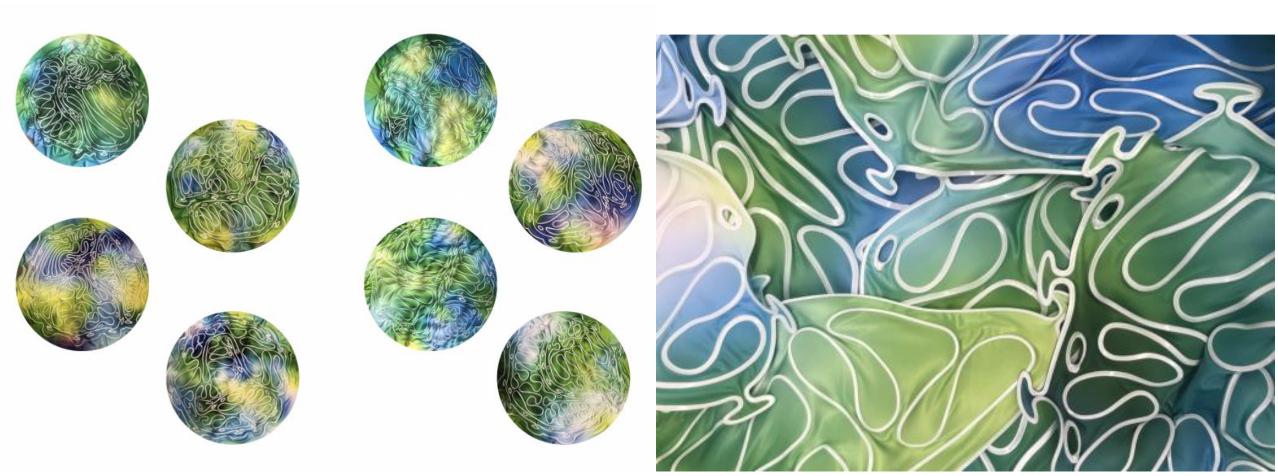


Figure 7. The independent unit and modules obtained after cutting

Step 4- Make the units into garments

Assemble sub-modules freely. The ingenious design of the buckle of the module allows each sub module to be combined, which can combine different clothing silhouettes and styles (Figure 8-9). The modules can be flexibly combined and adjusted according to different body shapes to create clothes that conform to the wearer's body shape. At the same time, the wearer can choose different module combinations to flexibly achieve the goal of wearing more than one garment in terms of garment functions.

Figure 8. Project final shooting

Figure 9. Modular combinations

The effect of various artistic forms and convenient functions on one piece or set of clothes by changing the combination of its modules is called "cross-dressing", which means "changeable clothes". In our daily clothes, a complete coat can be transformed into a chic vest through the disassembly or reorganization of one sleeve, which primarily uses the concept of "cross-dressing" to achieve the goal of "wearing more than one garment"

4.3 Design system for a holistic sustainability perspective

In terms of sustainability, the application of 3DP and the modularity technique for the organic modular garment system enhance the quality, creativity, and productivity, allowing the designer to test more styles through the application of digital vectorial and CAD drawings. The iterative testing from the digital tools to the physical prototyping activities with the 3DP machines allow to achieve interesting results and finished prototypes and products in a shorter timeframe, also ensuring product uniqueness, and exclusivity (cultural sustainability). The modularity system allows applying circular design strategies for product lifetime extension through reconfiguring, upgrading, repairing, remanufacturing, and refurbishing products (environmental sustainability), thus determining waste reduction or reuse, lowering inputs/outputs of material (environmental sustainability). Modularity is also promoting waste minimization through a zero-waste technique, allowing the creation of structural parts by 3D printing directly on the fabric only where it is needed. In addition to this, the polyester fabric and TPU materials used for structural pre-programmed garment shapes are made of recyclable materials that are easily decouplable through thermal heating and can be recycled after the clothing is discarded (environmental sustainability).

In addition, the modular dressing method ensures the wearer's comfort and gives the space to independently conceive and explore the structural changes of the clothing itself. The wearer will get a certain sense of freedom when combining the different modules, thus stimulating a series of positive experiences in the act of wearing and possibly defining more durable purchase experiences (Maldini et.al, 2017). The modular garment allows consumers to extend the service life of garments, expanding the style by purchasing added modules (economic sustainability).

Digital files made for manufacturing allow a networked modality of production: the garment can be manufactured locally where it should be distributed through digital printing and 3Dprinting on fabric using local fabric supplier. This requires the creation of a sustainable local-based supply chain of materials and a systemic production of modular items that could be assembled by the user thanks to predesigned instructions. Therefore, the project is showing the possibility of eco-efficient localized on-demand small-scale production, by manufacturing in Italy and reshoring locally, supporting international competitiveness and allowing new market opportunities through urban micro-factories that reduce lead time and logistics impacts (cultural and economic sustainability), thus reconfiguring also supply and value chains through on-demand selling approaches, no stock of unsold products, and innovative distribution models.

5. Conclusions and future implementations

As an exploratory study, this paper uses the design of a 3D printed organic modular garments as a prompt to explore the possibilities of paradigmatic changes stemming from I4.0 application through a design-driven approach toward sustainability. The modular organic system is designed and produced according to sustainable design principles with a holistic perspective. The semi-automated production model applied to the project allows to enhance the skills of the designer / artisans in garment modeling and draping for more creative and aesthetically pleasant solutions. The significance of the project is to present a unique clothing design system and provide a new design mindset for the fashion industry. Therefore, the project is used to reflect on the impact of new design and manufacturing processes on the creativity of the designer via the acquisition of new skills and practices aided by technologies, exploring the collaboration with both the engineering side and also the consumers in personalization and assembly of the garment. In addition to this, the project is focusing on new purchase and wearing experiences for the consumer, and therefore also to new business models allowing a positive transition toward holistic sustainability for the fashion system. The system gives the wearer the space to conceive and explore the structural changes of the garment, bringing consumers a unique and personal DIY experience. The future of fashion design requires a rethinking of the way products are designed and produced in a systemic way, which means changing the overall culture from designers, company and consumers' perspectives.

What clearly emerges is that designers play a vital role in the transition to sustainability because their strategic decisions both on consumption models, materials selection, manufacturing processes, and design practices could affect the entire supply and value chain and determine the environmental, cultural, economic, and social impacts of the designed product. However, further implementation can be explored to increase the impact of projects like this toward sustainability:

- *Use of parametric design for enhanced customization and increased creative output through the definition of* starting conditions and parameters (input), generation mechanism (rules, algorithms, etc.), variant generation behavior (output), and the selection of the best variant. Through parametric design, organic patterns can be automatically generated through programming, thus enhancing designers' creativity.
- *Increase the 3d printing area* to better exploit the fabrics' dimensions. This can be done through using 3D printing machines with wider printing areas through FDM processes or incorporating Fused Filament Fabrication (FFF) technologies onto a robotic arm.
- *Incorporating laser cutting technology into the production process* to maximize the automatic production of products with higher precision of smaller details, thus the connectors could become a more subtle mechanism.

- *Materials durability and recycling through experimental activities* for testing the resistance of the structural printed modules via different washing processes. In addition, tests should be conducted to find and an easy process of thermal decoupling of TPU 3Dprinted filament and polyester fabric at the end of the life of garments for materials recycling.
- *User experience tests* to be conducted to understand consumers' interests toward modularity and customization, self-assembly along with feedback on comfort, configurability, adaptability, and durability of organic modular garments systems.

This systemic implementation could inform further research directions for academicians and practitioners to further understand the impact of DFT on the supply chain and value chain transformation toward smarter, faster, and more sustainable products, services, and processes, through research through design methodologies.

ACKNOWLEDGEMENT

The authors would like to express their gratitude to SUPERFORMA for their kind support in 3DP on textiles.

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