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Claudio Gambardella *Editor*

For Nature/With Nature: New Sustainable Design Scenarios

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Claudio Gambardella
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For Nature/With Nature: New Sustainable Design Scenarios

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Series Editor's Foreword

Springer Series in Design and Innovation (SSDI) explores all aspects of design that provide innovative innovation-oriented approaches in the different fields of application and design development, with a particular focus also on cross-cutting approaches and emerging research areas that can represent essential opportunities for economic and social development.

The design culture is committed to addressing the growing environmental concerns carefully considered by the 193 UN member countries that signed the 2030 Agenda for Sustainable Development in 2015. And in order to give adequate answers, I believe that we must look at a broad horizon that includes a technical/humanistic approach.

It is in this frame of reference that the series welcomes the volume *For Nature/With Nature: New Sustainable Design Scenarios* on the crucial theme of Nature, which results from the homonymous call launched in November 2022 by the Department of Architecture and Industry of the University of Campania "Luigi Vanvitelli".

"What does 'Nature' mean nowadays? What effort is required of us to reposition ourselves with respect to it? How can we reconsider our history, our being in the world and the future with respect to a new idea of Nature? Finally, what is our correct position to establish the most effective actions in order to improve the living conditions of men on Earth?" These are the enlightening questions that have been posed to the scientific community by the Publisher of the call and of the book, Prof. Claudio Gambardella.

In our opinion, these ideas are useful for interweaving new visions of nature with new lines of design research.

The book, divided into three parts, Nature and artifacts, Nature and digital technologies, Nature and "fourth environment", deals with the theme of the relationship with nature from multiple points of view. Starting from the relationship between human and nature, the essays collected in the book investigate the main sectors of intervention of design. From product design to design for living environments, to fashion design, through studies on innovative materials and sustainable industrial production processes, up to the relationship between design, craftsmanship, and innovation.

Particular attention is paid to the theme of technological innovation dealt with in the second part of the book, from the opportunities of digital innovation to artificial intelligence's ethics, from design for robotics to biomedical design, up to sustainable innovation for the "fourth environment" dealt with in the third part.

In conclusion, the book presents a very interesting reflection on a particularly topical theme, offering a broad and articulated reading that opens up new terrains of comparison and debate for design.

Francesca Tosi

Foreword

For Nature/With Nature. A New Awareness

Today the lifestyle. A sustainable global issues of ecology and consumerism impose a call to the consciousness of design to assume its responsibility with respect to the environmental sustainability of a contemporary process that must use natural resources at a rate so that they can be regenerated naturally. Today, humanity is living in an unsustainable manner, consuming the limited natural resources of the Earth faster than it can regenerate them. The collective social effort to adapt the human consumption of these resources within a level of sustainable development is a matter of paramount importance for both the present and future of mankind.

Since the 1980s, the term "sustainability" has been used in the sense of human sustainability on planet Earth and this has resulted in the definition of sustainable development as a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. While raising the living standards of the developing world, the challenge for sustainability is to limit Western consumption without increasing the use of the resources as well as the environmental impact. This must be done by using strategies and technology that break the bond between economic growth and environmental damage.

In the context of development economics, the concept of economic sustainability is at the core of the considerations. In this perspective, consumers are using their purchasing power for 'ethical consumerism' practiced through either "positive buying" (the ethical products are favored) or "moral boycott". A major hurdle to achieving sustainability is the alleviation of poverty, one of the main sources of environmental degradation. It is therefore futile to attempt to deal with environmental problems without a broader perspective that encompasses the factors underlying world poverty and international inequality. In this sense, the environmentally conscious design is the philosophy of designing physical objects, built environment, and services to comply with the principles of social, economic, and ecological sustainability. The intention of sustainable design is to eliminate negative environmental impact completely through skillful, sensitive design, that requires renewable resources, minimizing the environmental impact, and relating people with the natural

environment. Beyond the elimination of negative environmental impact, sustainable design must create innovative projects capable of shifting behavior, generating the respect of both the environmental and social differences.

In a memorial service held in Tucson (Arizona, 2011-01-12), President Barack Obama called on the Americans to sharpen the instinct for empathy to become a more civil people. In the opinion of Jeremy Rifkin (The Empathic Civilization: The Race to Global Consciousness in a World in Crisis), being empathic means being open to the plight of others. For Rifkin, empathy is the emotional and cognitive means by which we express intimacy and sociability. To empathize is to experience another's condition as if it were our own. It is to recognize their vulnerabilities and struggle to flourish and be. Empathy is the real "invisible hand" of history. Today, empathy includes the whole of humanity. We are coming to see the biosphere as our indivisible community, and our fellow human beings and creatures as our extended evolutionary family. In this sense, empathic design is a user-centered design approach that pays attention to the feelings toward a product.

In 1967, the first long play by the Italian singer-songwriter Francesco Guccini, Folk Beat No. 1, contained a song, Noi non ci saremo (We won't be there) that told of the rebirth of life after an atomic war, a threat considered at the time as very likely. The lyrics, poetic like all of Guccini's songs, drew an apocalyptic vision of a planet that, destroyed by a fiery event "greater than the sun", like a phoenix "after a thousand centuries at least" was able to rise from its ashes, bringing once again the waves of the sea to resound on the beaches, snow and fir forests to cover the mountains, rainbows to shine high in the sky. One bleak truth accompanied the rebirth: the "new world" witnessed the self-destruction of the human species and the crumbling of houses, buildings, and cities. The refrain that accompanied each verse, Ma noi non ci saremo/Noi non ci saremo (but we won't be there/We won't be there), thundered like an epitaph and drew the bitter vision of a definitive disappearance, whose conscious and historical reference to the dramatic events of Nagasaki and Hiroshima attributed the cause to the human hand.

The recent events between Russia and Ukraine have reawakened the fear of nuclear war throughout the world. But there is now an equally powerful, possible, and imminent risk: the disappearance of the human species from planet Earth due to harmful climate and environmental change. This risk makes it necessary to speak out on urgent issues such as building a healthy continent, combating climate change, and environmental challenges, and an economy at the service of people: an awareness of a countdown that, if not reversed, cannot avoid asking in the near future: but won't we be there?

Aversa, Italy Ornella Zerlenga

Preface

July 16th, 1945—the date of Trinity Test in Alamogordo, New Mexico, just three weeks before the launch of "Little Boy" on Hiroshima City—is considered the symbolic date of the end of Holocene and the beginning of Anthropocene, the name created in 2000 by Paul Crutzen in order to indicate the present glacial era. The latter has this name because to condition the terrestrial environment is the «telluric force» of man—as Stefano Mancuso defines it—so much so that in 2020 "[...] the weight of materials produced by man—cement and plastic—has exceeded the weight of life on the planet" (Tonfoni 2021). However, it is relevant to declare that the increasing of CO2 and CH4 concentrations in the atmosphere is the most significant signal that human actions negatively influence life conditions on the planet; that means they cause desertification, pluvial wood destructions, increasing of ground karst phenomena, loss of usable surface for agricultural crops due to erosion or overfertilization, ozone hole, and climate alterations. In order to oppose such events, the 193 UNO member countries signed the 2030 Agenda for Sustainable Development in 2015 (Nazioni Unite n.d.). The 2030 Agenda indicates 17 Sustainable Development Goals and 5 key concepts such as to grant prosperous and full lives in harmony with nature; to protect the natural sources and climate of the planet for the future generations. On the basis of its 2050 long-term strategy (Unione Europea n.d.), the EU has the ambitious objective to reduce net emissions by 55% by 2030 in respect of 1990 levels and to become the first climate-neutral continent by 2050. It needs to consider how much the recent energy crisis due to the Ukraine war will slacken decarbonization plans and the process of abandoning fossil fuels by modifying the European Green Deal program and its timescale.

Nevertheless, "[…] to say that the nature is in a dangerous situation is senseless", Salvatore Natoli says in his lectio magistralis in 2011: (Festival*Filosofia* dedicated to the Nature theme). "Man hasn't the […] force to destroy something more powerful than him and in which he was generated […] eventually man by abusing of nature or not using it in the right way destroys the conditions of his life and so puts himself in danger […]" (Natoli 2019). This behavior is due to the consideration that man doesn't feel, as in the ancient world, "[…] a being created in the φύσις […] its own product", but he is separated from it (Natoli 2019). Science has increased the sense of alienation

toward nature lived in tragic way by our present society by arriving at paradox "[science] identifies itself with nature in order to allow men to detach from it as possible [becoming the manipulative dimension], in these two centuries in particular; this means science has become our natural way to live […]" (Natoli 2019) through the use of "[...] technique which has become the essence of science" (Galimberti 2019). "This industrial society had upset the relationship between man and nature by subjecting the nature to man so the technological society that was born through the quantitative increase of industrial society produces qualitative transformation which is the subordination of nature and man to technology" (Galimberti 2016, p. 356). "The unfolding of the Baconian formula [scientia est potentia] has changed the scenario: no longer the power of man over nature, but the power of technology over man and nature. In this type of condition, the anthropocentric horizon is already dissolved because the power belongs to technique now and no longer to man. The technique imposes to the supposed holder of power (man) its correct use, so man becomes a passive executor of the technical possibilities that are exercised over nature, which suffers them passively" (Galimberti 2016, p. 524). The self-governing of technique which "moves over the human-nature relationship" (p. 524) emphasizes the skill to diagnose—one by one—in a "technical" way the pathologies affecting the planet and to answer with right "technique" remedies to the same pathologies. Plants are considered machines—that set humidity, produce oxygen, absorb CO2 and microparticles—in green architecture and urban furniture in order to give the present towns a way to live better.

What does "Nature" mean nowadays? What effort of repositioning is required of us with respect to it? How can we reconsider our history, our being in the world also future with respect to a new idea of Nature? Finally, what is our correct position to establish the most effective actions in order to improve the living conditions of man on the Earth? These "human" questions are necessary to find our nature vision, to found it again and put it into new topics of research in disciplines which seem so far from philosophy.

First of all, the culture of the project such as scientific research and training is involved in the necessary change of course to establish a new balance between man and nature because "Many problematic situations of our world are the result of planning decisions" (Thackara 2005, p. 1). They are often wrong decisions not due to mistakes of calculi but to the approach they are derived from. Nature is considered as consumer goods in exhaustion because of a pervasive and reductive economic vision of the world. Therefore, we prefer simpler names instead of Nature to avoid philosophical or religious problems and to keep it under the easy control of a fragmenting thought, so we use words as "planet", "earth", "biosphere", etc.

The German philosopher Gernot Böhme (2012), overcoming the representation of a world shaped by circulating conceptions of Nature and the Man-Nature relationship, shows new scenarios in which "[...] nature presents itself today [...] as a task that is in front of us" (p. 5). Therefore, we are invited to "[...] recognize as our great collective task not the defense, but the construction of nature as a foundation for human life, and to work in a serious way in respect of it" (p. 24). Böhme's suggestion (2012)

can wisely be taken up by the person who works within the project culture in order to feel fully involved in this "task".

Scholars have been invited to contribute to the construction of a multi-voice mosaic on the theme of nature and the relationship between Man (understood as designer) and Nature through the call *For Nature/With Nature: New Sustainable Design Scenarios*, which was issued in the autumn of 2022 by the Architecture and Industrial Design Department of Vanvitelli University. To be more precise, innovative, and sustainable proposals from the field of design were requested, in its many facets and interdisciplinary contributions. Although it is indisputable the creative and economic effort that designers, institutions, and companies carry out for years to improve human living conditions, in this volume preference has been given to scientific contributions (unpublished or not yet fully known case studies, projects of strategies, products, systems and services, theoretical contributions, communication) that are the expression of a new approach to Nature, seen as our ally and subject of an Ethic of Care.

The focus was the design both in its role as innovation driver and interpreter of social evolution that must be considered within the human-nature relationship.

The following topics identify some of the most relevant fields of development in which "Design Driven Innovation" can be developed in the respect of perspective of a new relationship with nature.

A. Nature and artifacts

- biomimicry and biocompatible materials in industrial, fashion, and textile design;
- project, production, design management for sustainability (packaging, communication, etc.);
- memory and innovation of processes and products in handmade design.

B. Nature and digital technologies

- toward sustainable, humancentric, and resilient industry 5.0;
- smart mobility and green vehicles;
- pervasiveness and sustainability of apps.

C. Nature and "fourth environment"

- Orbiting stations: design for living;
- dress design and new materials for space tourism;
- the design of new low orbit habitats.

Many scholars responded to the call and among the numerous papers received, after a first screening of the abstracts, sixty-one were selected through a process of double-blind peer review. The result is reasonably satisfying, especially given the brief time spent promoting the call. Certain authors have focused only on some of the subtopics

indicated in the call, while others have preferred to compete on a mainly theoretical treatment and, for this reason, they have been placed at the beginning of the first part. Moreover, it was not always easy to find the exact location of a paper within the first and second parts of the book relating to the first two topics. While it was obvious the placement of papers in the part related to the fourth topic, definitely specialized and, therefore, treated only by some scholars. The succession of papers within each part was made starting from broader arguments, proceeding successively along the lines of subtopics and, therefore, for increasingly specialized themes. For these reasons, each part is named with the topic only, without specifying subtopics.

Aversa, Italy Claudio Gambardella

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Re-think. Re-design. Re-start: New Tools for a More Sustainable Fashion Design Process

Maria Antonia Salomè

Abstract The object of study in this research is the possibility of integrating new tools into the Fashion design process in order to implement the sustainability and productivity of the process. By new tools, we mean (a) digital prototyping with three-dimensional models as an additional tool to physical prototyping and (b) the introduction and application of zero waste methodology in pattern design. The study analyze the application of these tools in existing design processes and research testifying to the state of the art. The Covid-19 pandemic facilitated and, in some cases, intensified the use of new technologies in design processes and the development of new technologies to implement design phase transformation. At the same time, the pandemic period has encouraged and stimulated reflection on the issue of sustainability within the fashion supply chain, bringing to light the various possibilities offered by the design of a zero-waste mode. The increasing introduction of technology into production processes has accelerated and implemented the design possibilities of designers and style offices, improving the interaction between the creative and production sectors. Despite the adoption of various solutions, only a few companies have fully integrated 3D prototyping into their production workflows. Fashion schools and training programs have begun offering courses and modules to prepare future digital designers, but skepticism persists in the industry that hinders technological evolution.

Keywords Zero-waste pattern design · 3D fashion prototyping · 3D model · Fashion design · Design process

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1 Fashion, Digital and Pandemic

1.1 The Topic of the Research

The work presented here is an opportunity to reflect on the possibilities offered by the use of 3D modeling software in the field of fashion design. As a tool for the investigation and prototyping of paper patterns, it represents the application of a practice that, in the writer's opinion, may prove capable of transforming design processes in the fashion supply chain.

The research activity, which began individually and independently on the basis of the author's training and professional experience within small and medium-sized clothing companies, is now taking place within a doctoral program with the intention of investigating how digital technologies are reconfiguring current fashion practices in its creative, production, communication and distribution processes. Digital design, augmented and virtual reality are tools that are already widespread in a number of industries and creative sectors, and are becoming increasingly central to this field as well. These innovations enable Fashion brands and companies to design, produce and market their collections more sustainably, reducing costs and impacts, and expanding their market to a wider range of communities, physical and digital.

The paper topic, drawing from the digital transformations initiated by the pandemic, wants to put a focus on the digitization of the fashion design process through 3D software. The purpose of this research aims to be a reflection on these new tools since, according to the author, they represent the possibility of implementing sustainability in the production chain by combining digital prototypes and a zero-waste approach to the paper pattern design.

1.2 The Digital Pandemic in the Fashion Industry

The COVID-19 pandemic left a landmark marking in contemporary human history. The many restrictions imposed by governments in every state have forced millions of people at different times to live segregated at home, to converse virtually and to understand the potential of digital tools. From education to remote work, we have learned that distance is not a limitation but can become an unexpected opportunity to increase knowledge and experience, that we can renew and innovate the way things work, and that we can improve processes to achieve more sustainable production.

The COVID-19 outbreak took place at the end of 2019 in Wuhan city in China, and since then, it has spread across the world. The virus has not only affected the health of millions of citizens, as, in such a globalized and interconnected system, it has also affected the lives and daily activities of human beings. In this context, the fluctuating global economy has led many companies to modify and reframe their strategies, and the fashion industry has not been excluded from these changes aimed at

further engaging customers and encouraging sales on e-commerce platforms (Noris and Cantoni 2021).

The subsequent crisis has led the fashion system to reflect on the future of fashion and its configuration, and many have wondered how and how significant the changes in the fashion industry have been (Roberts-Islam 2020). The conditions imposed by the pandemic prompted brands to undertake various experiments with new technologies to preserve their survival in the market and in users' memories. However, this push also proved to be a way to analyze and re-evaluate the business model to try to build a more sustainable business future in line with new global needs.

By preventing and limiting physical contact, the pandemic crisis forced change and pushed the fashion industry to adopt the digital dimension (Roberts-Islam 2020). In addition to redefining the business model, the crisis has inspired new models related to the digital dimension. These include numerous collaborations between old brands and digital startups, such as The Fabricant, a virtual fashion incubator built on blockchain (Campaci 2022) that has found particular success through collaborations with famous brands such as Napapijri.

In particular, it contributed to the creation of digital samples to replace physical ones, supporting brands and the production chain, becoming an example of how it is possible to eliminate textile waste from the supply chain and, at the same time, generate fascinating images that can communicate the creative process in the digital dimension (Roberts-Islam 2020). As a result of this collective epiphany, a new production dynamic has taken off based on the use of digital tools for sharing documents and materials, even in those contexts where until 2020 it was difficult to rely completely on work done digitally. The difficulties, on the other hand, were really reduced for all those companies and schools that had already chosen to incorporate 3D design into their workflow, finding themselves facing the transition with ease (Campaci 2022).

1.3 Digital and Sustainable Fashion

In the fashion world, many designers have experimented with the possibilities offered by new technologies and virtual reality, altering the perception of fashion and transforming the fashion show, thanks to technology, into a new expressive platform (Hang Ta 2011). The experience of creating, producing, using and sharing the product of fashion and luxury has changed profoundly with the spread of digital technologies, offering numerous new possibilities for experiencing the creation of the fashion garment entirely in three-dimensional virtual environments and providing additional opportunities for value creation (Ornati 2011).

The 3D modeling tool for fashion, integrated with pattern-conscious design and, in particular, zero-waste pattern design, can offer new possibilities for optimizing the supply chain by rethinking the design process and reorganizing the design steps leading to apparel production. Most of the attempts in the industry to reduce waste occur in the creation phase of the placement and not in the design phase, where most of

the waste is determined (McQuillan 2020). In fact, when we talk about sustainability and circularity, we always take into consideration the terminal phase of the textile supply chain. This is the phase where the fabric and resources are worked with, where prototypes and garments are made, and, in particular, we continue to take into consideration the production phase, which, in reality, is the final phase of a much more complex and articulated supply chain.

The introduction of digital reality into the design process, through the study of modeling software, facilitates an understanding of the potential of these tools. In addition, developing in the 3d environment the model provides an overview of the results that can be aspired to in order to improve business sustainability and productivity through new workflows and the consequent opportunities that the use of 3D software enables in the design process (McQuillan 2020). At the same time, it provides an understanding of the possible limitations of this application so that companies can be oriented toward solutions that are compatible with their business model.

A greater understanding of the needs, requirements and difficulties that companies face will make it possible to adopt digital prototyping in the fashion/clothing industry. It will be easier to understand what avenues to take to improve: (a) the training of designers; (b) the collaboration between different parts of the supply chain and, in particular, the relationship between the design/style department and the product development/prototyping department; and (c) developing technological and logistical solutions to implement the manufacturing sector's technological transition to Industry 4.0.

2 The Digital Fashion Dichotomy

2.1 The Rise of Three-Dimensional Fashion

The dichotomy between man and machine (Campbell 2016) has always played a key role in the creative process of fashion. The advent of the sewing machine, along with the creation of standard-size patterns, enabled couturier Charles Frederick Worth to transform tailoring production into a primordial industrial chain capable of reducing garment processing and delivery times (Bolton 2016). More than a century later, new technologies opened a debate on new production possibilities through the development of fashion-specific 3D modeling software.

From the late 1980s, the introduction of computers and early graphic software encouraged experimentation and allowed the integration of tools as diverse as analog drawing, digital drawing, and photography. The computer added to the other tools made available to the fashion designer with the advantage of abruptly reducing working time, since changes and errors are completely reversible (Ciammaichella 2011).

However, technological innovation and the effect of the application of information technology, with the development of specific software for production and design,

has been for a long time only partial (ibid.). In fact, with rare exceptions, high-end apparel companies have been slow to adopt three-dimensional (3D) modeling technologies, favoring the traditional approach, which relies on tactile methods of product development (fabric cutting, sketching, modeling, prototyping, and testing on standard models) that are still widely used. In the broader apparel industry, on the other hand, there have been many developments in Computer Aided Design and 3D virtual modeling software, with innovations focused on mass production and reducing collection development time (Hang Ta 2011).

In the years prior to the pandemic, the various CAD software capable of representing the garment in three-dimensional form were predominantly solution-oriented, unintuitive, and unsuited to the needs of the fashion system because they offered different and distinct approaches to design. On the one hand, software for reconstructing the three-dimensional model directly on the avatar, without the possibility of obtaining a paper pattern outline related to the drawn model; on the other hand, software for developing and generating paper patterns to be used for cutting the garment without a three-dimensional section and without a design part (Bolton 2016).

This awareness of the virtual environment has led to the development of software and the implementation of existing ones in accordance with "new" work needs: testing and verifying the validity of samples and collections by giving up physical prototypes, shipping with the concrete possibility of significantly reducing the time frame. In addition to fascinating the manufacturing world, the newly discovered digital world has paved the way for a debate on new technologies, their use in production (McQuillan 2020), and the conflicting or non-conflicting relationship with artisanship, extending the issue to sustainability policies.

2.2 Digital Prototyping in Fashion

When talking about digital fashion, it is difficult to understand what the real dimension in which we are moving is. The topic has spread in the fashion industry through different forms and with a variety of media covering the area of design, prototyping to communication and display/presentation of the final product in e-commerce. The type of digital media evokes great fascination; however, digital fashion is mostly used as an external part of the production chain as it is mainly intended for product communication and advertising (McQuillan 2020).

Drawing with a computer represents a personal and artistic act in which, unlike manual technique, we are offered the opportunity to go through the entire process of a project, starting from sketching to prototype making (Gaiani 2004).

The software used in the different stages of collection development can be usually distinguished into Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM). The most widely used software in the design phase are vector-based programs (such as Adobe Illustrator and Corel Draw) that allow the initial sketch to be translated into an input needed for the later development of the paper model used

in the prototyping and production phase of the garment. The integration of CAD and CAM technologies offers designers and manufacturers the opportunity to automate and optimize creative and production processes with the creation of prototypes and real samples (Hang Ta 2011).

Working with 3D modeling software involves developing the design in detail, this involves constant confrontation with the complexity of paths that require constant modifications, creative solutions, and expedients to overcome the limits imposed by the medium: digital making can thus have the same dignity as manual making (Ferrarini 2022). The object modeled as an image of reality becomes a simulation of the design concept and at the same time represents the form of the project, a digital twin (Crista 2022) to be confronted with, the preview of a reality with which to "see in advance" (Gaiani 2004).

The 3D fashion model serves as an intermediate step between design and prototyping and offers many opportunities for designers and pattern makers to compare notes (Cardinali 2019a). Through digital prototyping, it is possible to verify the design with a model that corresponds to the "digital twin" of the actual physical model, without having to make the garment. Much of the research and studies on the digital world of fashion focus on the aesthetic aspects, the function that these images play within the digitized world. This research, on the other hand, wants to shine a spotlight on the design aspect, on the concrete possibility of rethinking the design process and the prototyping phase through new 3D software. These software it could be a tool for investigating and prototyping patterns, which can transform design practices (McQuillan 2020) and improve the sustainability of the supply chain at the beginning of the process.

As with the procedure outlined by Gaiani (2004) regarding 3D modeling for architectural design, the process of generating digital models for fashion has two stages:

- modeling, i.e., the creation of a realistic geometric image representing the calico, i.e., the fabric maquette made as a study model of the garment to be worked on. The creation of this maquette involves, in turn, the design and realization of the geometry, which, in fashion, corresponds to the paper pattern, which is followed by the cutting of the fabric and the assembly of the parts of the garment through the sewing operation;
- rendering, which is the creation of a realistic image in which material properties and physical and reflectivity characteristics are indicated. In fashion, this stage, at present, can be carried out after digitizing the maquette, with the help of dedicated 3D software.

Digital model simulations offer greater control and the opportunity to modify the design, with the ability to visualize, interact and prototype. Through this process, immediate feedback (ibid.) of the design idea can be provided, with a significant impact on reducing design and pre-prototyping time and costs. In the pre-prototyping phase, digital models provide a valuable model for testing and identifying problems

that may arise during the various stages of design development, offering several possibilities for answering the question "what if…?" and for analyzing the performance of various parts and materials in relation to the proposal to be validated (ibid.).

By following this procedure, and with the help of the 3-D model, one overcomes the design process that is the basis of every fashion designer's training (still taught in schools), in which the design phase is divided by the creation of the paper pattern (modeling) and the verification and realization of the garment.

2.3 Software for Digital Prototyping

Unlike many other 3D design industries where the use of 3D software has transformed both workflows and outcomes, the fashion industry has been relatively slow to implement the use of 3D software in the design process (McQuillan 2020). 3D design opens up many possibilities, from the design process to production cycles, from communication with external suppliers to meetings between different internal departments. It represents an opportunity to reduce textile resources and waste. Working in a 3D environment, the designer can create shapes in real time by simultaneously developing 2D patterns and digital stitching in digital space. The fit, silhouette and materials can be verified through simulation on an avatar. By incorporating this design method, companies will be able to save a lot of time when it comes to making decisions and creating prototypes, as well as save resources such as meters of fabric used to make samples. The adoption of 3D virtual design is a very effective, powerful and sustainable way of working for the future of the fashion and product design industry (Williams 2021).

The digital tools in the Fashion industry. The digital design tool provides a new design approach to direct practices toward possible waste reduction. The fashion industry has slowly implemented the use of 3D software in the supply chain. Mainly because of the poor quality of the images produced and then because of the difficulty of integrating the 2D part with the 3D phase by obtaining realistic rendering of materials (Ciammaichella 2011). 3D fashion software must be accurate and functional to be included in the prototype development process. Currently, 3D software allows 3D visualization and export of the paper pattern for use in prototype creation and subsequent production. Digital prototyping allows design development by reducing waste production and potentially using the rendering for sale.

These applications represent the alternatives that have also experienced the greatest increase due to the pandemic crisis. Also through a strong competition that pushes developer companies constantly implement software functions, it is possible to find different solutions that allow digitizing all that part of the supply chain that develops from design to the first stage of sampling. The following is a list of software used for 3D modeling in fashion design with a description of the main features. The research work aims to deepen the knowledge of each software in order to understand its functionality and potential to be applied to the design process, check its limitations, and understand possible applications in subsequent stages of the research.

VStitcher from Brozwear's 3D apparel design solution. The aim of the company is "drives digital transformation in the apparel industry through the power of true-to-life 3D prototypes". They offer a combination of software for Fashion design, development, marketing, and collaboration with a comprehensive suite of easy-to-use solutions to get the market faster. The VStitcher software can create drawings, edit patterns, grading, create technical packages and it is a 3D fashion design software for garment design and development.

Style3D from Linctex. Style3D offers a combination of software for Fashion design, development, marketing, and collaboration with easy-to-use solutions to get the market faster. The suite consists of five software offering different tools to model the idea in three-dimensional real time; to create digital fabrics and manage leftovers, to interact with suppliers; and a platform of digital fashion source of 3D models.

Clo3D. The history of this software began in 2009 with the first version of Marvelous Design, software employed by the CG community to create virtual outfits. Finding strong success, in 2010 a software dedicated exclusively to the clothing industry was developed that reflected the initial idea that is cloth simulation technology. The two software programs are still on the market with updated versions, and as of 2018, Clo3D has been joined by the *CLO-SET* cloud platform developed to support the textile supply chain to share tech pack and production information. Clo3D offers the opportunity to simultaneously develop the 3D prototype and paper pattern, develop sizes and placements of graphics, embroidery and prints, and perform renders and videos as well as the ability to set up sets for fashion shows.

Audaces 360. The software system offered by the Audaces 360 suite aims to digitize the design and production process through a series of CADs that take care of scanning and digitizing paper patterns, developing and verifying samples in a 3D environment through an avatar, and applying the digital paper pattern to the next production stage. The Audaces 360 program consists of several modules, oriented to different stages of the fashion production: from PLM management part to the creation of the technical drawing with the visualization of the pre-cost of the garment, to creation of 3D design, digitizing of paper pattern and automatic pattern placing that integrates specific algorithms to optimize and reduce fabric use.

According to Tufarelli (2019), the level of software analyzed is more than mature in terms of performance, M. Tufarelli (2019), at least compared to the software available on the market up to a decade ago, when visual rendering was poor and there were several problems in pattern management (Ciammaichella 2011). Currently, the typology of 3D fashion software caters equally to designers and pattern makers, allowing integration with 2D CAD files already in use in companies. With the exception of CLO3D and Style3D, both of which can be accessed for free for a short period of time, other software can only be requested and used by textile-fashion professionals and companies. In general, the workflow, set on the use of digital tools, offers the possibility to digitize collections by reducing the quantity and shipment of collection samples (Milner 2023). The application of the digital tool to the design workflow changes the system, disrupts the way fashion approaches the system, as we know it and how it has been set up over time (Oliveira 2022).

3 The *Zero-Waste* Approach

3.1 The Function of the Paper Pattern

In fashion design processes, the sketch or an existing garment can be a critical step in the process and result in a loss of control over the design process when cutting the pattern impacts the outcome of the planned aesthetic (McQuillan 2020). As a result, garments before being marketed are cut and made at least three times.

The first time to make the prototype, that is, the first garment developed from the sketch and derived from the bases in the company and for which a new pattern is made. The workmanship is very similar to artisanship, since again it is a single garment subject to several stages of correction and adaptation. A second pattern is then made for samples made in a single size that represents the ideal type with which the company and/or brand is identified. These one-size-fits-all garments go to make up the sample collection, presented at trade shows (or on the runway) and in the company/brand showroom. Medium- to low-cost companies produce the sample book in multiple copies (even more than 10) that are distributed to different representatives.

The type of processing at this point is industrial, both for economic advantages and to check production processes, costs and machinery. In the final stage we move to actual production, in which garments are made in the quantities and assortments of sizes and colors in which they were sold. In cutting prototypes, despite the sartorial training of the supply chain, it is essential to set up the work divided by departments. These departments will be in charge of production and make the sample book taking into account the subsequent industrial processing of the garment. For this purpose, they will have to calculate and report the fabric consumption and the best arrangement of the pattern pieces. This phase of studying the placement of pieces is called placing.

In mass production, the study of placement also becomes essential with the help of the digitized model (with 2D CAD). According to Rissanen (McQuillan 2020), the relationship between the 2D process (the sketch, the idea, the rough draft) and the 3D process (understood as the prototype of the design idea) is characterized by the use of methodologies that develop different challenges (from the design point of view), and because of this it becomes difficult to be able to contain waste. Rissanen says that when a designer develops a proposal very often he or she does not take into account how the parts come together and how to develop the paper model.

In some of the design processes analyzed, he points out a slowdown where the paper model is an important step in the process itself. In fact, if the prototype does not reflect the design idea, or if changes need to be made, the process leading to prototyping must be repeated, as many times as there are changes or improvements to be made, in either construction or style. In Rissanen opinion (ibid.), this is largely due to the lack of knowledge of the paper pattern on the part of designers who, not having sufficient notions, do not understand its construction, let alone the real importance of the paper pattern in the process or do not know how this process

works specifically. In this context, the lack of notions in the training of designers compromises communication between the two departments and generates additional difficulties and slowdowns in prototyping.

3.2 The Zero-Waste *Pattern Design*

The study of the paper pattern is of great importance in the production process of the manufacturing supply chain and is one of the fundamental steps that ensures the high quality of the finished product (Beduschi and Italiano 2013). In the study of the paper pattern, each part that makes up the garment plays a fundamental role and is connected to the others in a specific sequence. This sequence, the result of several centuries of study on the proportions of the human body and aimed at ensuring the right fit, results in a set of well-defined rules that outline the positioning and cutting of each piece. Unlike traditional pattern making, in the zero-waste approach the pattern is conceived as a single piece from which individual parts are separated (in the traditional process individual parts are drawn and designed to form the garment). For this reason, when working on a zero-waste pattern, it becomes particularly complex to modify a single part without compromising the overall pattern design (ElShishtawy et al. 2022).

In the zero-waste paper pattern, these rules can be subverted by dividing the surface area (of the fabric) only according to the space to be used and not according to the lines to be followed. In this way, the garment generated with the paper pattern will have a variable fit and volume compared to the same paper pattern constructed with the traditional method. The zero-waste approach to the paper pattern generates an arrangement of individual parts that differs from the traditional technique, and, as a result, placement can be done by optimizing fabric consumption and achieving a 15–20% reduction in waste compared to the traditional technique governed by "straight-thread" cutting, i.e., essentially, by the direction of thread flow.

4 Conclusions

4.1 The Problem of Research in the Design Disciplines

The research presented in this paper represents the initial part of a much larger research that aims to investigate the application of digital tools in the fashion design process. Nowadays, one can try to start a first reflection on what the topic is, and how it is approached and analyzed. Assuming that the topic is in part very recent and related to a historical context that is perhaps too close to be interpreted objectively, the writer believes that there is little attention to the digital transformation of the manufacturing sector in the Italian context with regard to the design phase and everything that may

concern the creative issue. A probable sign of the progressive estrangement between academic research and the world of design practice (Cianfanelli 2019).

In contrast, media attention has been more focused on addressing social and productive current events, focusing on the different ways in which fashion experienced the digital world during the pandemic and how it is still experiencing it today. Numerous magazines and blogs have chronicled the tools and results of digitization from different perspectives, highlighting the production side, the sustainable issue or the entertainment aspect, each time pandering to the needs and interests of readers.

The opinions found are varied. First, the idea of appropriation, according to which fashion has tapped (although a bit too late) into the world of gaming to increase users' entertainment on virtual platforms, and consequently revenues from digital purchases (Bain 2021). Second, the evidence of an 'Italy lagging behind on the digitization of processes that in 2012 was still the last sector in the Bel Paese to work with mainly manual processes (Stil'è 2021).

4.2 Considerations on the Future of Fashion Design

If we look at the digital fashion trend from a business and production perspective, what we see emerging is a demand, on the one hand, for greater digitization of the industry (ibid.) and a focus on training the actors (designers and pattern makers) who are part of it (Cardinali 2019b). Thus, if 3D, understood as digital context and three-dimensional modeling, is the main pillar of Industry 4.0, a persuasive and functional solution will have to be sought to spur the companies in the sector that still show reluctance (Stil'è 2021).

Currently, about 35% of materials used in fashion supply chains end up in waste and 18.5% of garments go unsold (Oliveira 2022). 3D fashion, in combination with the zero-waste approach to pattern design, offers us an opportunity to cut waste and reduce the environmental footprint of the fashion industry, a major carbon emitter and a heavy consumer of resources. A new generation of designers is being formed, learning new digital skills and reinventing the traditional model of fashion design, making it faster, greener, more accurate in defining the design idea, able to provide a new visual imagery, capable of producing real change for the fashion supply chain.

The fashion designer of the future will have to confront high-level hybridizations between the physical and digital worlds, discovering and developing new ways to transform the design process. This ability to see into the future and the possibilities for innovation to create cleaner and more environmentally friendly fashion designs (Aguileta De La Garza, n.d.) will involve figuring out what education to implement in fashion to learn and practice fashion with radical and responsible approaches (Vaccari and Franzo 2022).

In the context of education, it is important to focus on the digital tool as an additional—not a replacement—for those already in use. In fact, to make the best use of this tool, it is important—and perhaps essential—to have "live" experience, to know the materials, to understand them in their physical behavior, in their interaction

with the human body. 3D software can and should be an additional tool that the designer chooses to rely on. The advantage of using 3D software in education lies in its use as a learning tool. In this way, it offers a high margin for error that allows students and emerging designers to learn and experiment with colors, cuts, materials, and textures (Oliveira 2022). Also, offering them the opportunity to create their own brand independently and without having to submit to the antiquated mechanisms of the supply chain (Roberts-Islam 2021).

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