Digital Fashion Metamorphosis: Fold and Unfold

by Neo Nuo Chen

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Abstract

The constraints of the current COVID-19 pandemic stimulate the urge for fashion brands and designers to explore 3D technology and utilizing digital space for fashion creation. Being a fashion designer, this urge inspires me to situate my thesis project at the intersection of fashion and technology. I use research-creation as a research approach to engage differently with digital fashion design creation. During my research, I stumbled upon the ancient technique of origami and was drawn to the intricate technique it holds. I also see the possibility embedded in further manipulating the form of origami in digital space through image-based 3D reconstruction photogrammetry technique and 3D software. This thesis project aims to explore how digital body and digitized origami can be combined as an innovative method to influence and create digital fashion design. The creative outcome, *Neo-Metamorphosis* is a video formatted origami-inspired futuristic fashion runway show. Overall, my thesis project aims to explore new perspectives of digital fashion and stimulate artistic inspiration.

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To my cat Haru who's been spending most of the time with me, keeping me accompanied and bearing with my keyboard noises.

To my parents for their constant care and love.

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“I am going to take you on journeys you’ve never dreamed were possible.”

Alexander McQueen, 2010.

1.0 Introduction

Fashion design is well known for being a hands-on discipline, and its craftsmanship survives thousands of years globally (Breward, 1998). Ever since human beings started to gain the awareness of wearing clothes (the scholars believed it was initially for keeping the body warm during cold weathers), the sense of fashion-making has been slowly generated. Throughout fashion history, fashion is often seen as profitable commodities, there is one thing in fashion design that was overlooked, and that is *"the aesthetic"* of fashion design (Kim, 1998). Clothing was originally considered practical items, but when people started to admire the aesthetic of clothing gradually, the admiration stimulated the desire for creating patterns and designs, which became the concept of fashion. It is the aesthetic that brings fashion to more than just products, more than just design, but also an art form that continues to evolve alongside the development of technology, like other art forms, such as paintings and sculptures that are continually seen as representations of their era. Scholars assess fashion documentation, trace it back to the designs and the materials used to analyze their social, psychological, and economic condition.

In the current COVID-19 pandemic, the traditional ways of fashion-making and exhibiting fashion are facing challenges (Grechko, 2020). The impact on the fashion industry is crucial, and most brands and designers are eager to discover a new platform to introduce their creations without the need for physical contact. At the same time, this situation is triggering the invention and conversation around digital materials and digital bodies in the virtual space. The start of mass use of 3D technology[1] in recent years is reflecting on an ongoing collaboration between fashion and technology. The influence that the current pandemic brings stimulates my need for innovative ways to practice fashion design. Being a fashion designer, I am intrigued by these innovative directions and excited about what is happening and what will take place in the future

[1] Introduced in the contextual review chapter

fashion industry. This thesis project is my attempt to explore the creative potential within physical and digital materiality as well as the digital body at the intersection of fashion and technology.

During the initial research and planning stage, I realized that having trouble accessing resources such as fabrics in the pandemic situation was a massive challenge for fashion designers. That was when my focus turned to digital approaches such as 3D scanning and 3D software to look for inspiration and alternative materials. The challenge of this research is to transform unconventional physical objects into digital garments. To test the research methods, I started with experimenting photogrammetry on a pile of shower curtains and applied that to a digital body to serve as a wearable garment. The successful digitizing process outcome encouraged me to dig deeper into the potential of digitized material and prompted my search for other objects accessible at home for the final project. While gathering ideas and thoughts, I stumbled upon the ancient *technique of origami*, brought back some childhood memories, and recalled some of my previous practice experiences in fashion design. I see the connection in both origami-making and fashion-making are representing a series of metamorphoses. I was drawn to origami for not just the intricate technique it holds, but also the possibility embedded in further manipulating the form of origami in digital space. I proceeded to use this scanning strategy to digitize origami as a means of digital materiality to examine how it can be applied to create new forms in digital space.

The thesis project aims to explore how the photogrammetry process of digitized origami can be combined with the digital body as an innovative method to inspire and create fashion design and

fashion-making, as well as the possibilities of developing new concepts for digital fashion design. The digital body is considered the mannequin that supports the digitized origami as well as the carrier of the movement. The combination of the knowledge of traditional fashion design with 3D scanning and modeling technology is utilized to seek the interconnection between the two as the primary research process. The learning and prototyping process of photogrammetry technique and 3D software tools and functions such as "automatic weight" helped me build a strong foundation for the creative goal of this thesis project. In addition, my previous practice in fashion design provides guidelines for positioning the photogrammetric origami with the digital body and the aesthetic in creating the digital runway show.

The creative outcome *Neo-Metamorphosis* is a video formatted, origami-inspired futuristic fashion runway show. This research outcome proposes digital approaches in fashion design aiming at inspiring emerging fashion designers to explore material to immaterial or physical to digital creative perspectives. *Neo-Metamorphosis* emphasizes the transformation between physical and digital materiality through the use of image-based 3D reconstruction technique for photogrammetry and 3D software tools and functions. As for young fashion designers and other audiences, my research aims at triggering the curiosity and interest for exploring digital spatial environments. In addition, my research intends to open the discussion among fashion designers and fashion researchers around the potential of digital fashion, more specifically the idea of transformative materiality and the use of digital platforms to act as innovative approaches for creating and displaying fashion creations.

Throughout this thesis project, the following research questions will be addressed:

- How do photogrammetry technique and 3D software influence the fashion designer's creative process and digital fashion design outcome?

- How does digital space change the way fashion design is experienced, and what does it bring to the audience?

- What is the correlation between the digital body and digitized origami in digital space?

This thesis paper is divided into seven chapters, with the first chapter being the introduction chapter, presenting an overview of the research-creation process. In Chapter 2.0, the Literature Review first addresses how traditional fashion is on the path to digital fashion, reflecting with digital monism and the development of technology. The second section talks about the connection between fashion-making and origami-making through the concept of "fold and unfold." The third section introduces the 3D reconstruction technique - photogrammetry and 3D software - Blender. The third section addresses the connection between digital bodies and digitized origami. The following two sections respectively present the wabi-sabi and "creative chaos" concepts. Related works are introduced in Chapter 3.0, and Chapter 4.0 provides an overview of the methodologies and methods used in this thesis project. Chapter 5.0 demonstrates the experiments and prototypes made for testing the research method - image-based 3D reconstruction photogrammetry technique and 3D software Blender. The outcome of this thesis project, *Neo-Metamorphosis,* is presented in the format of a video introduced in Chapter 6.0 with graphics and description as guidelines. Chapter 7.0 concludes this thesis research project and

reflects on the process and the result, the scope and limitation, as well as the potential future works.

2.0 Literature Review

This chapter consists of five sections, the first section introduces the tendency of traditional fashion transitioning to digital fashion in the context of digital monism, including the influence coming from the development of 3D technology and digital space. The second section discusses

the connection between origami-making and fashion-making through the shared *"fold and unfold"* concept. In section three, the technical methods of photogrammetry technique and 3D software are introduced. The discussion on the digital body and how digitized origami is being reconfigured in the digital space happens in section four. The fifth section presents the Japanese concept - *Wabi-sabi*, that is, the beauty of imperfection. The concept of *"creative chaos"* that could always be found in the artistic and creative process is introduced in section six. Section seven provides a reflection on the literature review chapter.

2.1 From Traditional Fashion to Digital Fashion

The traditional way of fashion design and fashion-making involves a series of processes, including researching, sketching, draping, patternmaking, and sewing. It all starts with a piece of flat fabric, with manipulations like folding, pleating that forms various shapes; these shapes help construct the garment's silhouette and bring the aesthetic of fashion design to life.

While the most common wearable clothing falls under the category of ready-to-wear[2], there is also haute couture. Haute couture is described as a technique that is a high-end form of fashion constructed by hand from start to end, and it usually contains expensive fabrics and unusual materials (Bala, 2019). There is no doubt that haute couture has a fascinating tradition of centuries of craftsmanship. The development of haute couture alongside the application of technology is also apparent throughout the recent decades. Dutch designer and artist Iris van Herpen, who specializes in modern technological Haute Couture, which means in her works, many advanced technologies and materials, such as 3D printing and laser cutting, as well as

[2]Ready-to-wear is the term for ready-made garments, sold in finished condition in standardized sizes.

handworks such as embroidering and textile development are used. She also works with several collaborators to come up with new creations. She studied ballet when she was younger, so she sees movement as a metamorphic force that combines with pioneering techniques and materials to extend the human body's forms and sculpt elegant silhouettes. It is the motivation of challenging and innovating that drives her to explore and experiment in each collection. In her design, there is a transformative power embedded within the structures and the materials and are always showing a type of optical illusion. She wants to have moments of dancing with fabrics. They are a mixture of fashion and technology, and she is utilizing fashion and body as a canvas to sculpt her art and ideas.

According to fashion writer and design expert Bradley Quinn (2013), "As fashion and technology come together now more dramatically than ever before, they reveal their capacity to transform the human experience more than technology alone ever could." Fashion has been actively cooperating with technology, as mentioned in the previous paragraph, Iris van Herpen utilizes 3D printing technology majorly in her design creations. Traditionally, the fashion design process happens within the physical space from the beginning to the end. However, for fashion designers, not having access to materials and other resources has been struggling under the global pandemic situation, it is forcing them to switch their creative approaches. To investigate how to engage creatively with 3D technology and digital space may influence the design and making process. The digital space allows the users to change into outfits that are digitally made, even to put on things that are not physically possible such as a piece of furniture, a vase, or even a shower curtain.

With the growing reliance of the younger generation on social media platforms such as Instagram and Twitter, their online presence is a massive part of their social life. Professor Jules Dagonet, the head of school for fashion at the university for the Creative Arts in Farnham, stated that “Digital fashion is disrupting the industry, and it was not an option to wait. We really see digital fashion as the future of fashion,” when introducing the first digital fashion master’s program in the UK (Marriott, 2021).

2.1.1 Digital Dualism and Digital Monism

The term digital dualism was first introduced by Nathan Jurgenson, founder of the Cyborgology blog, in 2011 (Suler, 2016). Digital dualism is the belief that online and offline are primarily separate and distinct realities. Digital dualists consider digital content as part of a virtual world which separates from the physical reality world.

However, with the increasing use of modern technology and online interactive-based platforms such as Instagram and Twitter, people are actually able to connect with each other even more efficiently, especially in a global pandemic situation. This opportunity offers millions of people to meet virtually, to bring the world closer, and relationships and friendships are built on it. The existence of the digital world has an impact on human interaction, giving more possibilities for molding a tight-bond world. Digital dualism no longer stands tall in this fast-growing digital world. Instead, the developing trend is showing a totally opposite phenomenon from what dualism holds. When introducing the concept of the word “digital” and how it has modified our way of interaction in his editorial for the *Espace* magazine, André-Louis Paré (2017) stated, “The digital is more than a mere collection of tools. It is a new way of seeing, experiencing, and understanding the world. It has led us into a new era, one that Stéphane Vial would label as

'digital ontophany[3]'". We are, in fact, heading towards a direction of digital monism[4], and this means we will most likely be relying more on digital technology as our perceptions continue to extend and embrace the "digital ontophany." The line between virtual and physical is gradually getting thinner and thinner when we realize that we live in a digital-centered world, mixed with both online and offline. And the global pandemic is encouraging people to look at the virtual world as it would possibly become one of the most prominent environments in our lives. It is accelerating the awareness of the need for digital technology development to go beyond the human physical limitation and challenge what a digital world could present us.

2.1.2 The Inevitable Change in Fashion Industry

The word 'rhizome' was used by Deleuze and Guattari as a metaphor to describe the connection between all matters. "In botany, a rhizome is not just a root, but a mass of underground plant stems that could shoot off roots in new directions." (Then & Now, 2018). Everything in the world is rhizomatic, so are fashion and technology, especially when we are approaching digital monism. The development of digital monism is parallel and interlocked to the development of fashion; with technology bringing physical and digital closer, traditional fashion is also approaching the direction of changing and gradually approaching the path to digital fashion. The event of the global pandemic is accelerating the physical and virtual to merge, bringing technology and the Internet more accessible to us than ever before.

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[3] Ontophany: "The process through which the being (ontos) appears (phaino) to us, in the sense that it involves a particular quality of 'being in the world' (Heidegger) or, I would say 'feeling in the world'." (Vial, 2013)

[4] Digital Monism: Digital Monism is the opposite of Digital Dualism. It was introduced by Stephane Vial, as he describes, "We now live in a hybrid environment made of intertwined systems, constantly interlinked, both digital and non-digital, online and offline. We now live in the 'digital ontophany' as a digital-centered unique environment providing new kinds of perception."

Fashion writer Jessica Davis (2020) at Harper's Bazaar UK, wrote an article discussing how the pandemic impacted the fashion industry shared her foresight on what digital technology would affect the future of fashion. She pointed out that "Fashion was already on the brink of monumental change, with pandemic restrictions simply escalating the inevitable, and forcing the industry to rethink old ways." The evolution of fashion has come to an era where there is a need for change. The pandemic is not why the fashion industry is starting to approach digital monism to gain new inspiration and ways of representation. It has already begun long before, but big brands primarily focus on traditional ways of presentation because they have always been the dominant of the fashion industry. Therefore, the global crisis actually pushes the industry to look into some alternative ways to switch their strategies to regain audiences and customers. The big brands are also continuously searching for new blood to attract the younger generation, so using digital platforms to advertise them is undoubtedly intelligent. As for smaller brands, having virtual/digital shows would help reduce the pressure of the funding and resources put into a physical show. It also provides a higher chance to attract more audiences due to the accessibility and inclusiveness that technology and the Internet could offer.

Professor Jeffery Bardzell et al. (2010) proposed that research in fashion design using virtual platforms is significant and essential to the evolution of design concepts. Moreover, they stated, "Fashion has now entered virtual worlds, and virtual fashion has not received the attention it probably deserves as a hot-spot for identity, amateur multimedia, and the social construction of cultural values in virtual worlds. Consequently, a better understanding of virtual fashion has implications both for the design of virtual worlds and also for businesses seeking to operate in

virtual worlds." The efficiency that technology brings to the digital fashion design workflow is one of the unignorable aspects. It reduces waste in traditional fashion-making and allows fashion designers to experiment with draping and pattern making without spending too much time and labor. 3D software can help fashion designers visualize the garments throughout the making process, which boosts working efficiency compared to the traditional fashion design process. However, transitioning to digital space for fashion creation requires technical skill sets and comes with the cost of digital resources. The need for specialized technical skillsets also attracts people from other fields, and this need will boost more collaborations to happen in the future.

When addressing the future of fashion design during the International Conference on Computer and Technologies, professor Detelin Luchev et al. (2013) presented their views on the impact of technology on fashion design and stated: "Its virtual presentation has to be executed through the best tools and techniques in order to continue to write traces in the history of the world arts." and "...but the digital world gives a new vision on fashion creation and performing." Virtual representation and 3D technology are getting more and more utilized in the fashion industry, because they provide such strong potential for creating new means of designing and displaying. They have also prompted a significant shift in the way in which we work, communicate, and develop new relationships with audiences. Technology is a tool, and it becomes powerful when there are innovative ideas and concepts. Simultaneously, digital space grants more tolerance of errors, which means for designers/artists, there is much more freedom to create, try, fail, and eventually succeed.

The head of London's Fashion Innovation Agency, Matthew Drinkwater, stated in his recent interview with *Vogue Business*: "So many of the experiences at digital fashion weeks have felt very flat, both in the content itself and the way in which it was viewed. Creating in virtual reality allowed us to pull the audience through the screen, into an entirely new era of experience and utterly dispel the myth that digital shows can never match the excitement and emotion of a physical one." (Mcdowell, 2020). The use of digital platforms should aim for a brand new experience rather than merely using the internet as a streaming platform, which is what a large number of fashion brands are currently doing. It is true that running a fashion show by simply playing a recorded runway show online, which is open to the public, could be considered a form of digital fashion. However, there lies much more potential in the usage of digital technology for the fashion industry; it would be a shame to hold back and avoid changes as technology is evolving at a fast pace. The digital fashion era is still at its early stage and eager for development. Although digital fashion is not entirely a new attempt, it has become a much-needed way to showcase fashion concepts. This acceleration is not necessarily a bad thing in developing a new type of knowledge and helps shoot the roots of fashion design/studies in new directions like the rhizome.

2.1.3 Digital Space as Extension for Traditional Technique

We are in an exciting time for proposing and investigating digital perspectives in fashion design. Marshall McLuhan (1964) writes in *Understanding Media*, "Any invention or technology is an extension or self-amputation of our physical bodies, and such extension also demands new ratios or new equilibriums among the other organs and extensions of the body." Working with 3D technology is expanding our perception of how objects can be viewed and manipulated, as an

extension that helps us to achieve goals and ideas that can not be simply done in the physical world. Fashion clothing is no longer required to be tangible but can exist as an intangible representation that serves the digital body. But “extended reality fashion experiences don’t replace the ancestral craft,” said fashion designer Damara Inglês (2020), who created her digital garment using an HTC Vive Cosmos VR headset and a Google TiltBrush. “Instead, it opens a whole new dimension of fashion possibilities and future dreaming, allowing us to expand the wearable vocabulary in ways that become inclusive of our digital identities.” Fashion designer and curator Jonathan Anderson also shared his view in an interview, “Craft is innovation. Weaving is probably one of the oldest techniques, and it’s still going on today. I don’t think I own it, and I’m just painting it in a different way.” (Yotka, 2020). This thesis research project is situated at the intersection of fashion and technology. This project aims to develop a new approach based on traditional fashion design, to open up a new scope of engaging with fashion thinking through 3D technology. Harris (2015) quoted an industrial design graduate Guy Dyas in his interview with Myerson, he said, “using a computer is not a craft in itself, it is a utilization of a tool, no matter how creative the outcome; the real skill in utilizing that tool is derived from traditional design knowledge.” This statement supports the idea of technology being a ‘creative extension’ to broaden the existing craftsmanship/technique approaches, which is the purpose and direction of this thesis project. As proposed by Seely (2012), “becoming is never imitating.” In this thesis project, I use the photogrammetry technique and 3D software as an extension to explore the digital approach for fashion design. Traditional fashion becomes digital fashion, and the physical origami becomes digitized origami; they are still the same technique but with a new approach.

Anderson also said: “It has to be a dialogue. The entire history of art is a dialogue with the past, trying to re-establish codes for the future.” (Yotka, 2020). For this thesis project, the engagement between fashion and technology is to have that dialogue, exploring how to transform traditional fashion into a new form of presence, becoming digital fashion. Fashion is movable, and it is something that is transforming right in front of our eye. Ultimately, technology could help shape the future of fashion design and mark a milestone in fashion history. This thesis project sits at the blooming of digital fashion under the pandemic situation, looking at utilizing digital replicas of physical origami and digital body to create original fashion collections.

2.2 Connecting Fashion-making and Origami-making

It is important to establish the connection between the fashion-making technique and the origami-making technique. This section starts with positioning fashion as an art form, then introducing the shared concept of “fold and unfold” between fashion-making and origami-making. Moreover, how fashion-making and origami-making is

2.2.1 Situating Fashion as an Art Form

Fashion is usually considered a commercial product that serves as merely a daily essential object, but it is more than that. The debate of whether fashion belongs to the art category has been going on for ages, and it wasn’t until recent years that several major fashion exhibitions were being held in museums and galleries. (Kim, 1998). These exhibitions started to help people to position and view fashion based on their aesthetic and cultural background. Fashion designer Jonathan Anderson, now the creative director of two major fashion brands, who didn’t see fashion as an

art form at the beginning of his career, later shared his opinion during his interview with *Vogue*. He said, “I went through a phase where I didn’t believe that fashion was art, but I do believe that it is a reflection of society, so, therefore it is an art form. It is an interpretation, and it is fine to reinvent.” (Yotka, 2020). Fashion is inseparable as part of the historical documentation; it is naturally flowing in the stream of history and can be found in painting, literature, and many other art forms. This is evidence to prove that fashion reflects society and its socio-cultural conditions, plus its creative element and the expression of aesthetic puts it in the art category. Art critic Michael Boodro (1990) admits that “the inspiration and motivations of both artists and clothing designers can be strikingly similar” in his article about art and fashion.

The process of fashion-making itself should be considered similar to other art-making methods because they share the same steps where the researching and the making, even the results could be a mixture of tangible and intangible. The exact starting point could lead to different results with different mediums, but they are all considered artistic creations. The relationship between fashion and art should be mutually inspirational and supportive. Fashion is the most appropriate form for “art and issues of body and gender,” said Richard Martin. (Turner, 1996). Fashion could be seen as a medium to express the designer’s self-reflection towards social/political/philosophical issues. The garments are speaking for the designers, the same as the artworks are speaking for the artists.

Also, today’s fashion criteria are based on visual art concepts, the making and evaluating of fashion are thus similar to artistic processes (Martin, 1987). Artists and designers are actively collaborating and drawing inspiration from each other. The visual elements of fashion are critical

and a priority in fashion design. Hence, the showcasing of the creative design is essential and attracts people to purchase because fashion clothing enriches their bodies and becomes a way of expressing their aesthetics. With modern technology growing, fashion designers have more access to the digital space and could utilize it as a new means of creative output. Therefore, fashion as an art form is a versatile socio-cultural and aesthetic phenomenon and a perfect intersection of design and art. With more exchange in ideas between artists and designers, the acknowledgment of fashion as an art form became a more common agreement.

2.2.1 Fold and Unfold

Originally, the Japanese term origami (折り紙) has been primarily associated with the art of paper folding. The word origami comes from the Japanese roots Oru meaning “folding,” and Kami meaning “paper” (Hernandez et al., 2018, pp. 1). Paper was invented in China around 105 AD, and folded paper—or Zhezhi (摺紙)—most likely emerged shortly after. Most modern Chinese paper-folding exhibits an interest in representing inanimate objects, like boats and boxes, or the shape of Yuanbao, an ancient currency. People who had just lost their family member(s) would burn these paper arts to send them to their deceased family members. Paper was then introduced to Japan by the monks in the 6th century. During this time, the practice of paper-folding emerged as a ceremonial Shinto ritual. It was not until Japan's Edo Period (1603 – 1868) that origami came to be viewed as a leisurely activity and art form.

Nowadays, origami would be mostly considered as folding a single sheet of square paper (often with a colored side) into a sculpture without cutting, gluing, taping, or even marking it. (Richman-Abdou, 2017). Origami expresses creativity through the process of folding and

unfolding, and it is an art of exploring forms and transforming forms. Origami could also be seen as a source of inspiration for designing configurable structures and providing a generative design and art inspiration technique. Pioneers in computational origami such as Koryo Miura, Robert Lang, Erik Demaine, and Tomohiro Tachi clarify that the concept of folding two-dimensional sheets into three-dimensional forms can result in both art and practical engineering (Hernandez et al., 2019).

To make an origami involves a lot of folds and unfolds, the creases that were made on the paper mark the trace of the process, the unfolding makes the work go and reveals a number of possibilities. When unfolding, it gives the creator more time to think, to digest, to create. Then we move on to the folding again, the folding is based on the unfolding, which interlock with each other throughout the whole journey of the making. And this folding technique of origami-making echoes with the folding technique of fashion-making.

In fashion-making, the exploration of draping itself is the process of "fold and unfold." It is generating and stimulating ideas. And the process of draping is filled with unexpected encounters of changes; the fold could form new shapes, and unfolding could lead to further experiments with the fabric. Once the draping is done, we need to mark the folding and unfold the material, which brings it back to its original flat form, like the paper used in origami.

Most of the origami aims to create a three-dimensional form that corresponds to an existing creature or object. Meanwhile, the result of fashion design could also be seen as "an artistic expression and achieve sculptural forms" (Bowles, 2017). Both origami and fashion are highly inspired and influenced by the beauty that lies within the natural organic shapes and artificial

geometric shapes. The results of fashion-making and origami-making are always representing some sculptural forms that can be constructed with soft materials and solid materials, such as different types of fabrics and paper. By sharing similar making processes and outcomes, these two art forms form a connection through the fold and unfold.

2.3 Photogrammetry and 3D Software

Throughout my creative exploration, to achieve the goal of exploring photogrammetric objects and their digital representation and how it is going to create new form and inspiration in fashion, the image-based 3D reconstruction technique - photogrammetry - is being majorly used. The photogrammetric process opens up the exploration of physical and digital materiality, and the results lead to a strong foundation of digital assets for this thesis project.

The American Society for Photogrammetry and Remote Sensing (ASPRS) defines photogrammetry as "the art, science, and technology of obtaining reliable information about physical objects and the environment through the processes of recording, measuring and interpreting photographic images and patterns of electromagnetic radiant energy and other phenomena." (Michael, 2014)

In his article discussing the application of photogrammetry in preserving and documenting heritage and landscape, Fabio Remondino (2011) describes photogrammetry as one of the most accessible techniques for processing image data, because of its capacity to deliver at any scale of objects with detailed 3D information based on the measured image correspondences (tie points).

As a beginner-friendly technology, photogrammetry is made for users who desire to reconstruct a scene or an object in digital format. It is not limited to only high-end cameras, and plenty of smartphone applications can run the process. Especially with the emergence of the LiDAR[5] technique, a digital device that carries a LiDAR sensor would provide even faster-processing speed and more detailed results. The photogrammetry technique has also been utilized for digitizing historical sites as part of the documentation for conservation and patrimony purposes. Photogrammetry is also used for film/TV production and game development because it is capable of capturing real-world material; this can help create a virtual environment and bring physical objects into the digital world.

The process of photogrammetry can be broken down into four stages within the software Metashape, and they are: align photos, build the dense cloud, build the mesh, and create texture. The critical stage is the first one, and aligning images requires enough amount of photos (with overlapping angles and correct lighting sources) to be taken and imported into the software. This step allows the program to generate a point cloud, which is the image tie points. After the tie points are calculated in Metashape, they become the dense cloud, which can then be proceeded to construct the mesh and apply the texture paint.

To bring photogrammetric origami into digital space and apply them onto a digital body for creating the runway show animation. The 3D software Blender[6] is being used throughout this thesis project. In the making of the creative outcome, *Neo-Metamorphosis*, the photogrammetric origami are draped onto the digital body by using the "automatic weight" function in Blender.

[5] LiDAR: Which stands for *Light Detection and Ranging,* is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth.
[6] Blender: An open-source 3D software used for creating animated films, visual effects, 3D models, etc.

The “automatic weight” function also allows the photogrammetric origami to inherit the movement that is embedded with the digital body, resulting in the visual effect of the digital body walking down the *catwalk*[7] wearing the photogrammetric origami.

2.4 Digital Body and Digitized Origami

There has always been discussion on the body of fashion models, and the traditional standard for fashion models should not be the only standard in the current society. There are multiple outdated ideological concepts of what standard beauty should be, and there is no universal standard for that. All body types should be treated equally without discrimination. And when it comes to digital fashion, it reveals the question of the appearance or the necessity of the existence of the digital body. Even though in the virtual world, or more specifically, in the gaming world, it offers the users the ability to manipulate their digital presence to their desired body, and the use of digital bodies could be problematic sometimes. However, in this thesis project, and the focus is not on the digital body and it serves merely as the mannequin that carries the movement and provides a clearer view of the origami garments.

When a piece of garment is being worn, it activates the kinetic relationship between fabric and body. As Jane Harris (2006) describes when explaining the connection between fabric and body, “Wearable pieces explored further the kinetic form of cloth and the spaces in between, working with the body as the core. Textiles are potentially such a fluid medium, and the author's objective was to explore this through the construction and presentation process. This established the relationship of textile and movement.” The exact relationship could be found between the

[7] Catwalk: Catwalk is the platform along which models walk in a fashion show.

photogrammetric origami and the digital body when they are bonded. The digital body is serving as a support for the photogrammetric origami because the actual carrier of the movement is the rigged skeleton that is covered by the digital skin; the photogrammetric origami is attached to the skeleton instead of the digital skin. This results in the collision of the photogrammetric origami and the digital body; they are no longer separate individuals but bonded entities that both attach to the skeleton, forming a new type of relationship when the data collapse within each other, so the "bodies are thus never completely made, remaining always in the making." (Parr 2011, 26). The digital body is not the same, and it is constantly evolving and changing while moving. In this thesis project, the digital body and digitized origami, along with the movement, opens up the new scope of metamorphosis, emphasizing the role of technology as transformational media in creating distinctive fashion design. Both the digital body and the photogrammetric origami are being liberated inside the digital space. It can be seen as an experiment of testing the limit of digital bodies and digitized materials.

Furthermore, the digital body can also be seen as an extension of the physical body. In this thesis project, through digitizing the physical origami, and the digital body could also be seen as a representation of the human body. The digitized origami was given new characteristics, which creates an illusion to the human eyes, transforming something paper-stiff into fabric-soft. And the fully manipulatable digital origami could alter its shape or scale in the digital space, changing the normal perception of what physical origami would be like.

2.5 Wabi-sabi: The Imperfection and The Flaws

During the process of this thesis project, especially creating digitized origami replicas using photogrammetry technique, there are always unexpected flaws that emerge from the missing data. To embrace that imperfection and consider it a part of the creative process, brings in the Japanese concept called Wabi-sabi. Wabi-sabi is an aesthetic ideal and philosophy that originated from Japanese traditional art practices, such as tea ceremonies and ikebana[8]. The core concept of wabi-sabi, as the American artist and aesthetic expert Leonard Koren describes:

> "Wabi-sabi is a beauty of things imperfect, impermanent, and incomplete.
>
> It is a beauty of things modest and, humble.
>
> It is a beauty of things unconventional." (Koren, 2008, p. 7)

Wabi-sabi challenges the social standard of beauty, which is usually symmetrical and perfect (Svendsen, 2006, p. 89). It expresses the admiration and acceptance of any imperfection that occurred throughout the making of art, and it opens up a range of creative possibilities.

[8] Ikebana (生け花) is the Japanese art of flower arrangement. It is also known as Kadō.

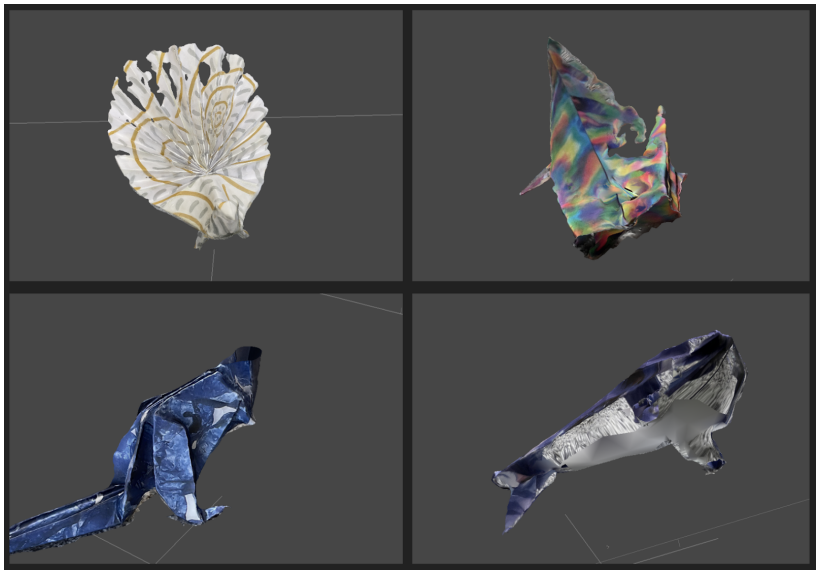


Figure 1: The missing data found on photogrammetric origami[9]

When the computer programs are usually aimed for precision, there still lies imperfection sometimes shown in the form of glitches or bugs. Because the computer executes what it is programmed to, the occasionally generated flaws seem so precious and valuable because it then creates a contrast to what it was supposed to be, which could also be considered an element of surprise. And to accept that flaw and imperfection is to embrace the concept of wabi-sabi. Feeding photos to computer software completes the process and outcome of photogrammetry, but the reconstruction of the captured data is not always smooth. Hence there are always likely missing parts or surfaces that are not reflecting their physical presentation (Figure 1). These outcomes are coherent to the concept of wabi-sabi; the unintentional flaws create new shapes in the digital space that show the process of metamorphosis.

[9] Fig. 1: These are the screenshots during the making of the final project, *Neo-Metamorphosis*.

2.6 Creative Chaos

When addressing the topic of the dynamic process of collaborative design and development for the ETC[10] website and their lecture, Drew Davidson et al. introduced the term - Creative chaos in their book, *Creative Chaos: Learning Lessons on Inclusion & Innovation | Making the Magic.*

> "It is a term we use to try and encapsulate the creative production process... in order to create something innovative a team has to take the risk of exploring new ideas and doing things that they haven't done before... the results are invariably uncertain as a team can't know in advance that their ideas will actually meet the goals. This type of prototyping is an inherently flexible process in which a successful team needs to be comfortable taking risks and dealing with various unknowns... The creative process is intrinsically chaotic: hence, creative chaos."

Davidson talked about "creative chaos" from the perspective of working as a design group, but I also see "creative chaos" in the individual design process. Because for designers and artists, we encounter the struggle of "trying," and although there is usually a clear vision on how we think the outcome should be, the process of making would reveal issues and challenges. That is the risk we need to take, which is also a vital part of learning and correcting for a better result. In fashion design, we see sketches as the base of the collection, which always end up with altered outcome, because during the process of selecting material and draping, hides unexpected elements such as the characteristic of the fabric, or maybe the wanted shape is not practical or even not possible to be constructed ideally, and this is "creative chaos." It helps us locate the problems and polish the design, leading us to the creative outcome.

[10] ETC: The Entertainment Technology Center is a department at Carnegie Mellon University in Pittsburgh, Pennsylvania, United States.

Van Herpen also said that the fashion-making process is chaotic, which is where unexpected things come out (Vogue Greece, 2019). She enjoys this kind of chaos because chaos brings out interesting results. The concept of “the unexpected” and “change” lies in the designer and artist’s creative process when engaging with artistic projects, projects grow as the journey goes. There should always be space left for unforeseen ideas coming up along the way. Van Herpen said, “When I started my design, I didn't want to know where it’s going to end up. It’s like looking for questions that we couldn't answer, I don't want everything to come from logic. That is too predictable to me.” (Vogue Greece, 2019). That is the representation of creative chaos in artistic creation. By putting yourself in an uncomfortable zone and exploring and iterating, you get a fascinating process. Creative chaos reflects the uncertainty of the making process of art and design, and any research-creation is facing the possibility of discovering new pathways during the process. Both fashion-making and origami-making require iteration and exploration. "Creative chaos" is shown in taking the risk in the process of folding and unfolding. With the uncertainty and unexpected variation, the chaos would further inspire a designer/artist’s creative making.

2.7 Reflection

Fashion itself has much potential when it comes to creative expression in support of displays such as showrooms and runway shows. I see fashion as an ongoing evolution that is gradually leaning into the digital space to reflect on digital monism. This tendency relies on the interconnection between fashion and technology, and “the future of fashion is a symbiosis

between biological bodies and virtual environments." (Inglês, 2020). Technology provides motivation for creative techniques, and the emergence of digital materials is a driving force for a new fashion design approach. Combining fashion and technology expands the boundary of traditional fashion design and its digital representation. It brings the fashion experience to another level by constructing abstract forms and building virtual environments.

By examining the potential of the interaction of photogrammetric origami and digital bodies, motivates me to explore the possibilities that lie in the future of fashion. According to Gilles Deleuze, "becoming" indicates that the world is always moving (Braidotti 2002, 43). And the "becoming" in this thesis project is the metamorphosis of physical material to digitized material (origami) and how traditional fashion is becoming digital fashion through a creative chaos process. In the digital realm, the photogrammetric origami is the digital representation of its physical form that resembles its shape and texture. And it becomes a new approach to generate new forms of fashion garments that are being worn by the digital body in the digital space.

In her book *Alexander McQueen*, fashion curator Claire Wilcox wrote, "and it is always about pushing to the extreme, the human body, human nature. As a designer, you're always working with cutting up the body to different proportions, different shapes. This is what a designer's job is, to transcend what fashion is and what it could be." (2015, p. 33). To further expand art and design through new technology sometimes rely on innovating, and the development of technology provides a pathway to go beyond the traditional mediums to try to push to the extreme. And to transform physical origami to their digital representation, and turning the 3D models into digital wearable art pieces, is to fulfill the "designer's job," as Wilcox (2015) said. It

tests the potential in fashion and technology. Both fashion-making and origami-making can be seen as a metamorphosis of 2D material transforming to 3D shapes through the concept of “fold and unfold.” This is the connection between the two techniques, and the merge of these two would generate different forms and push the limit to the extreme, to open up a new scope of fashion design metamorphosis.

3.0 Contextual Review

This chapter presents artworks and designs that focus on fashion and technology in the field of fashion. Throughout the last two decades, fashion designers, scholars, and brands are gradually experimenting with technology, especially the relationship between physical and virtual, and how digital technology such as 3D animation and 3D modeling could be utilized for creating new content. Fashion house Prada collaborated with visual artists to express the aesthetic for their 2008 fashion collection through visual storytelling with 3D animation technique. Fashion researcher Jane Harris experimenting with 3D technology to create digital replicas of physical clothing from the 18th century. The folding and unfolding technique of origami-making was applied to Issey Miyake's 2011 fashion collection. Nowadays, due to the current global pandemic, several fashion brands have initiated their fashion shows in the format of 3D animation with computational texture and clothing. I draw inspiration from these works, and the analysis enriches my knowledge. While photogrammetry is generally used for body scanning in the context of fashion, I situate my thesis project as a distinctive approach where I take on the photogrammetric origami and turn them into digital garments.

3.1 Prada

In 2008, Italian luxury fashion house Prada presented two animated short films for their Spring/Summer and Autumn/Winter Women's wear collection (Clarke and Harris, 2012). Both of the films were made by computer programs and fully animated as a means of storytelling. It was considered an experiment of fashion and technology and an extension in visual art.

Trembled Blossoms

For Prada's Spring/Summer 2008 Women's wear collection, Sight Effect created the animated short film *Trembled Blossoms* based on the concept illustration by James Jane[11]. In this short film, a digital female body was born from a droplet falling off a flower bud; two beetle-like insects approached her and turned into high heels. She then proceeded to walk in them while holding an apple in the woods, where a replica of herself came from behind and put her in a red-checked dress from the Prada woman Spring/Summer 2008 fashion collection. Heading deeper in the woods, a pond awaited, and she fed the apple seed to the fish, who then transformed into a handbag. She grabbed the handbag and started to express her happiness through twirling and dancing (Figure 2).

Figure 2: Screenshots of *Trembled Blossoms*

http://www.jamesjean.com/prada3/2014/12/18/prada-trembled-blossoms-1

[11] James Jean: Taiwanese-American visual artist who works primarily in painting and drawing.

Fallen Shadow

Later in the same year, on September 8th, 2008, at the Prada Broadway Epicenter in New York City, another animated short film, *Fallen Shadow,* was first shown to the public as part of the Autumn/Winter 2008 fashion collection (Clarke and Harris, 2012). Unlike the previous work *Trembled Blossoms,* this animation piece incorporated computer motion capture and cyber-scanning[12] technology in its making. This short film expresses surrealism and futurism through cinematic representation. The film tells a story of a woman and her shadow. "The Shadow is more alive and expressive than the woman," said the director of the film, James Lima, it is a journey of self-exploration within the city scenes. (Figure 3)

Figure 3: Screenshots from *Fallen Shadows*

https://www.prada.com/ca/en/pradasphere/films/2008/fallen-shadows.html#component_text_modul

[12] Cyber-Scanning: Cyber-Scanning is the use of photogrammetry to build a 3D textured model from a non-static object.

As discussed in the literature review chapter, technology such as 3D modeling/printing technology and electronic wearable approaches is not new to the fashion industry. It has always been treated as an inspirational approach to creating something different, to attract the attention of customers. Both of the short films presented by Prada came out the same year and that year only, it shows how eager the fashion industry wants to change but was also struggling with full transportation to digital creation while utilizing digital technology such as 3D scanning and 3D animation. What I have learned from these two films is how 3D animation and its visual power could act as a medium to tell a story without explanation. And combining with the use of cyber-scanning (photogrammetry) brings the physical into digital, creating an environment that expands the boundary between what is real and what is not.

3.2 Jane Harris

The Director of Research and Innovation (Stratford), Jane Harris, has devoted her time to research innovative technology in fashion, such as computer-graphic animation and 3D CG modeling and body scanning, etc. Coming from a textile background, she started experimenting with computer-aided technology in the 1990s, with very limited resources and access to tools, Harris managed to develop her ideas of achieving fashion concepts through digital technologies.

Figure 4: *Empress's New Clothes* (2004) by Jane Harris

https://ualresearchonline.arts.ac.uk/id/eprint/1318/

Empress's New Clothes (2004) is a 40-second animation recreating an 18th-century silk dress digitally based on the actual garment in the Museum of London (Figure 4). The 3D form was devised, and dancer Ruth Gibson performed a series of choreographic motion that was captured and used for the garment's movement. The purpose of this animation is to boost the use of technology on preserving fragile items and act as an educational way with dynamic visual support. Harris managed to generate "believable" CG textile with 2D/3D texture mapping procedures and motion capture linked to the digital garment. She hoped by utilizing technology would attract younger audiences and form a more robust engagement.

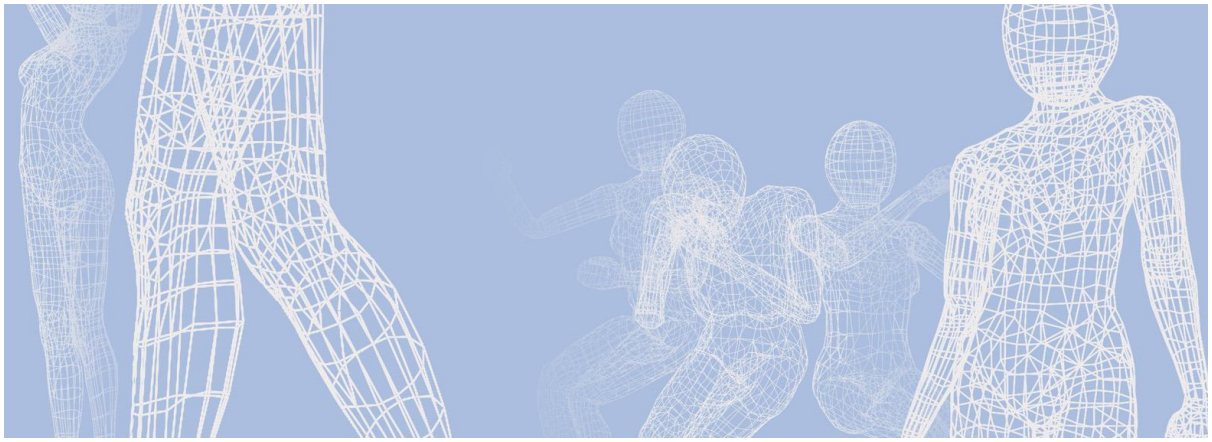


Figure 5: Digital wire-frame 3D form (2006) by Jane Harris

https://ualresearchonline.arts.ac.uk/id/eprint/889/

In 2006, Harris used motion-capture technology to capture a person who was wearing an all-black bodysuit with reflective markers, which allowed the camera to detect and be processed by the computer software to convert into an animated human form. The wire-frame represents the data being captured and indicates the shape of a body, and the body would then be used for the base to hold onto computer-generated virtual garments. (Figure 5)

In her paper on "crafting computer graphics," Harris noted that the digital platforms would become the medium that more and more artists and designers utilize, and the limitation of physical material could be further expanded.

> As a concept, "cyberspace" most engenders the possibility to construct things with digital media that would not ordinarily exist, proposing a form of origination that is of most intrigue to the author as an artist, designer, maker...the term "textile" may be pushed to the broadest limits of abstraction, immateriality, and origination that 3D CG will allow." (Harris, 2005)

The “cyberspace,” as Harris describes, or the 3D technology being used in this thesis project, enables the path of creating new forms out of photogrammetric origami, which expanded its materiality digitally. The “textile” or the characteristic of the origami has changed in the digital platform, and its paper texture no longer exists when draped on a digital body, it changed to fabric-like texture, this also created an illusion to the audience which made them believe that the softness and lightness is actually the natural characteristic of digitized origami.

3.3 Dai Fujiwara for Issey Miyake

Figure 6: The transformation from paper to origami, to their representation in fabric

https://www.vogue.com/fashion-shows/fall-2011-ready-to-wear/issey-miyake

Japanese designer Dai Fujiwara utilized the origami technique in his last collection as the creative director at Issey Miyake[13] in 2011. The show started with several crafty artists folding paper into origami shapes on the stage, once the model arrived, they were put into the paper

[13] Issey Miyake: Japanese fashion brand launched in 1970 by designer Issey Miyake.

origami as a garment piece. Then the resulting paper origami shapes were translated into the 3D digital printed fabric for creating wearable designs. (Figure 6) This process reveals not only the making of fashion and origami, bringing the connection between the two techniques, but also expresses Issey Miyake's original concept of A-POC[14]. And the concept of A-POC echoes with the concept of origami, they both share the same creed of creating three-dimensional pieces from a single piece of flat fabric/paper. I see my interpretation of digital origami fashion as further development of Fujiwara's experiment, and to take on a new approach with photogrammetric origami is to expand the potential in both origami and fashion design.

3.4 Digital Fashion Nowadays

Digital Runway Shows

In the past, several fashion brands have used online platforms such as YouTube or Instagram to live stream their fashion runway shows. But the pandemic limits the chances of in-person interaction, with this situation, fashion runway shows incorporating digital space and 3D animation are emerging as there is the need for showcasing. These digital runway shows draw attention from the younger generation and provide new approaches for the future fashion industry. They also provide various ways of presenting digital fashion, some of them are using digital bodies that look like cartoon characters. And some of them are even not using any digital bodies for their digital runway show, like fashion brand *Hanifa* (Brown, 2020), this is perhaps an approach that only the digital space can easily handle.

[14] A-POC: Short for "A Piece of Cloth," dated back to the 1970s, when Miyake began to experiment with clothing made from single lengths of fabric. Aiming at reducing waste and increasing interactivity.

Fashion house Balenciaga released their Autumn/Winter 2021 fashion collection in the form of a virtual reality runway show through a video game, *Afterworld: The Age of Tomorrow,* using Oculus headsets. In this video game, the viewers experience a futuristic virtual space, where the fashion collection is being showcased. The creative director of *Balenciaga*, Demna Gvasalia, said, "The fashion industry will have to face this inevitable new chapter and come up with its own solutions in everything from how it deals with creativity and innovation to how it makes and communicates product." (Madsen, 2020). Gvasalia is exploring digital fashion to express his vision of the inevitable changes in the fashion industry. He is taking a step into digital materiality to create garments and accessories and apply them onto digital bodies as part of a new experience for viewers and customers. My thesis project is attempting to step into the realm of digital fashion, as well as exploring the transformative materiality and its kinetic relationship with the digital body.

The Fabricant

The Fabricant is a digital fashion house that only designs clothing in the digital space, and they aim to create a new narrative to reduce the waste in fashion. Their creation exists in digital platforms such as Instagram and Facebook, and their clients would wear their designs on these platforms to showcase the aesthetic of the digital garments. The founder of The Fabricant, Kerry Murphy, also sees the young generation as more accepting of the approach because they are more comfortable with digital content (Product Innovation, 2019). For the younger generations, a combined physical and digital perspective is more and more embedded in their daily lives. As presented in the literature review chapter, an approach to digital monism reflects that the fashion industry is heading towards a hybrid stage of physical and digital fashion. The co-founder of The

Fabricant, Amber Jae Slooten, expressed her insight into how she sees that digital fashion allows people to live their fantasies online and avoid the waste and pollution related to traditional fashion (Fairs, 2020). Moreover, waste and pollution in the fashion industry have always been an ongoing issue that requires solutions. This approach to digital fashion could be one of the answers to help reduce waste in the mass production of fast fashion.

The way The Fabricant portrait their creation is considered one of the inspirations of the creative outcome, *Neo-Metamorphosis*, which is to have a similar kind of dynamic digital fashion experience by showcasing a digital fashion collection in the digital space.

4.0 Methodology and Method

In this chapter, the methodology and methods that are being used throughout the thesis project will be discussed. I am using research-creation as my design approach as well as "creative chaos" through the 3D technology methods inspired by the origami concept of the "fold and unfold." The methods and methodologies are driven by a creative research approach.

For fashion students, research projects are usually inspirational-based rather than problem-oriented. Ræbild stated that it is usually hard to define a specific methodology for fashion research and studies because they are reflecting one's interpretation throughout the process. Fashion design in the academic perspective comes in a very different way than other art or design majors. Traditionally, fashion mentors' guidance would become the student's methodology that could be unique to their specific design and research approach. The personal concept and design development process are essential for the designer, hence the pieces become the representation of one's self-interpretation, and each layer of fabrics has specific meanings (Ræbild, 2012).

However, Professors Owen Chapman and Kim Sawchuk from Concordia University talked about research-creation and how it led to a creative research approach. They stated,

> "'Research-creation' is an emergent category within the social sciences and humanities that speaks to contemporary media experiences and modes of knowing. Research creation "theses" or projects typically integrate a creative process, experimental aesthetic component, or an artistic work as an integral part of a study. Topics are selected and investigated that could not be addressed without engaging in some form of creative

practice, such as the production of a video, performance, film, sound work, blog, or multimedia text." (2012)

I see fashion and origami as complimentary art forms that both involve processes and iterations that aim at developing artistic propositions. For this thesis project, I am combining fashion and origami, using the 3D photogrammetry technique and 3D software. Through prototyping and experiment, I construct a creative fashion collection engaging with artistic exploration.

According to Ahmed et al. (2020), there are four main steps when creating new designs approaches inspired by origami:

1. Reviewing the previous designs inspired by origami in different fields of application.
2. Start playing with paper with keeping in mind the bases of paper folding.
3. Modeling your design on the most suitable software and testing its performance.
4. Reaching the final accurate design, then start choosing the suitable fabrication method making models and prototypes.

I use these steps as a guideline for constructing this thesis project. I started off by researching previous fashion projects that were related to origami and the utilization of 3D technology, such as 3D scanning and animating. Once the use of photogrammetry to reconstruct origami digitally has been decided, the making of physical origami started with patterned paper. The next step is to locate the choice of using an image-based 3D reconstruction technique - photogrammetry in Metashape to capture origami's shape and texture. As well as 3D animation/modeling software - Blender to apply the photogrammetric origami onto the digital body for prototyping. Lastly, once the prototypes provide the desired outcome, I can move on to the making of the final project.

The “fold and unfold” initially happens in making the physical origami. The second stage of “fold and unfold” by draping the origami onto the digital body to achieve a wearable art piece that is both a digital sculpture and a digital fashion garment. And the movement that the digital body offers is stimulating the origami piece’s movement, becoming new forms of shapes and structures; this is considered a third stage of folding and unfolding, hence the digital fashion metamorphosis completes.

The “creative chaos” can be seen related to the concept of wabi-sabi introduced in the literature review chapter. It is exactly the chaos that is generated during the process, stimulating new ideas to emerge. In my thesis project, “creative chaos” can be found throughout the process of prototyping and making. One example would be the unexpected results caused by the missing data on the digitized origami when capturing data during the scanning of the physical origami. And also, while draping photogrammetric origami onto the digital body, new shapes occurred, which can also be seen as part of the “creative chaos.” The “creative chaos” concept does not only help to improve and correct but also provides inspiration and reflection, eventually reaching a stage where we learn from the iterative process and embrace the imperfect and unexpected outcome.

5.0 Experiment and Prototype

Throughout this thesis project, to achieve the goal of transitioning physical origami to digitized origami, the photogrammetry technique is used. 3D software Blender is used for applying the photogrammetric origami onto digital bodies to create a digital fashion runway show. Both the photogrammetry technique and 3D software are the key methods to obtain the assets and help generate the final project. This chapter introduces the process of the initial experiments and prototypes that were made to examine the research methods.

5.1 Experiment 1: Capturing The Shower Curtain

Experiment 1 aims at experimenting with the photogrammetry technique. Metashape is the software for reconstructing photogrammetry 3D models. When the imported photos are overlapping with surrounding angles and good lighting sources, it will generate clean outcomes with sharp detail and texture. It usually requires certain amounts of photos imported for better capturing the data. In this thesis project, all photogrammetric origami was using the number of photos from the range of 65-90. Even though the more pictures imported would usually result in more data capture, since origami are relatively small objects instead of an open environment, the numbers of photos under 100 suffice the need.

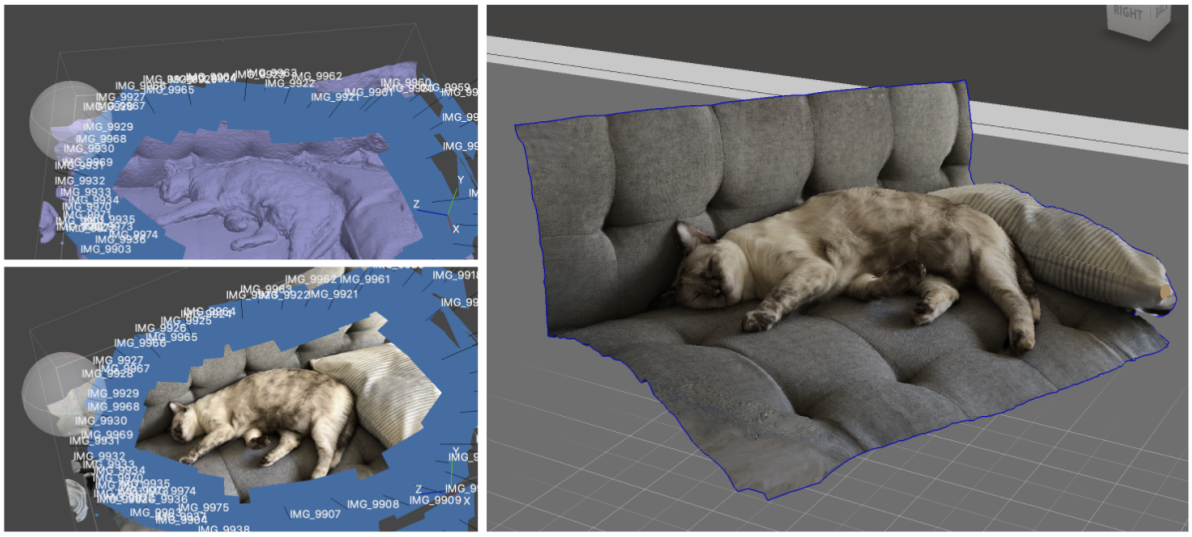


Figure 7: Experiment with 3D reconstruction process and editing the exported file

To test out and also practice using Metashape, I took photos of my cat on the couch and followed the instruction to reconstruct the photogrammetric scene. After the reconstruction is done in Metashape, it can be exported as editable 3D models such as an Fbx file or Obj file as shown in Figure 7.

Considering this experiment happened when we were in lockdown due to the global pandemic, I was limited with the resources and was expected to stay at home. That was when I came up with the idea of doing photogrammetry using my bathroom shower curtain. Although the plastic texture on the shower curtain can be found in various fashion collections, it was the way that the shower curtain piled up on the floor and the shape made with unintentional folds that really caught my eyes.

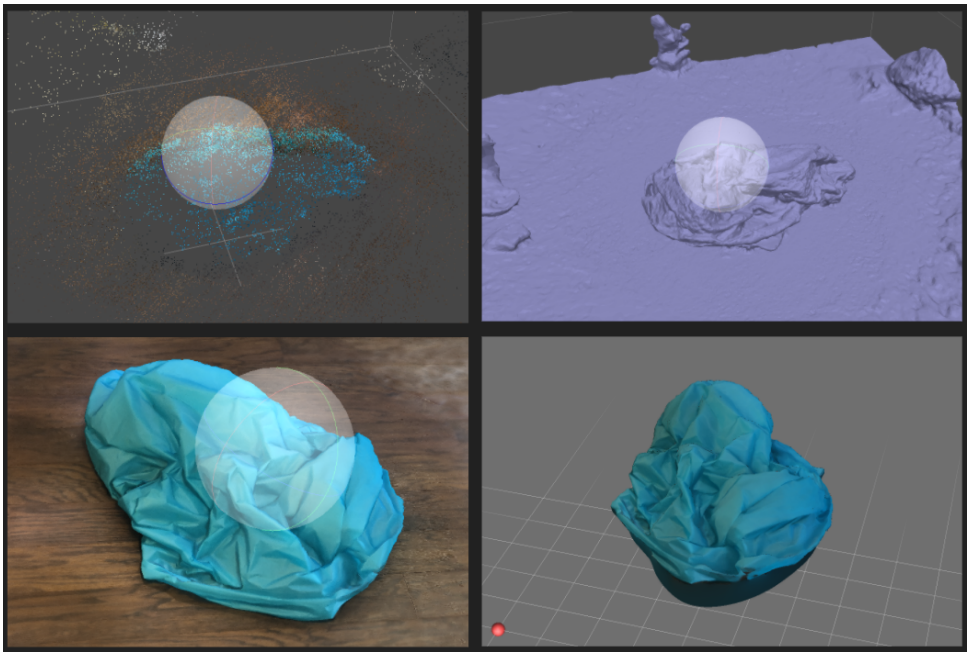


Figure 8: Process screenshots of the development of photogrammetric shower curtain

A point cloud is a set of data points in space. If there is missing data, the scan might not be fully completed. As shown on the top left in Figure 8, it seems like there are missing data due to the shadows created by the foldings and the slightly reflective texture of the shower curtain. However, on the top right of Figure 8, the reconstruction of the mesh came out surprisingly clean and full of details, and this led to a very clean and detailed texture rebuild. Hence the result can be exported as an Obj file and be modified in 3D modeling software Meshmixer.

5.1.1 Reflection on Experiment 1

The making process of *Experiment 1* is a great example of "creative chaos," as it leads to an unexpected outcome in terms of the form and the texture. The photogrammetric shower curtain provides a strong foundation and grants confidence in the making of the prototypes. The process

of *Experiment 1* also highlights that with photogrammetry, the initial point cloud does not necessarily indicate the final result but could be taken into consideration.

5.2 Experiment 2: Capturing The Physical Body

In *Experiment 2*, the goal is to create a functional digital body, which was originally planned to be applied with the digitized shower curtain from *Experiment 1*. I used both the smartphone application Display.land[15] and computer software Metashape to attempt to reconstruct a digital replica of myself. Display.land could generate a result in a relatively short amount of time, including the environment the body was in (Figure 9).

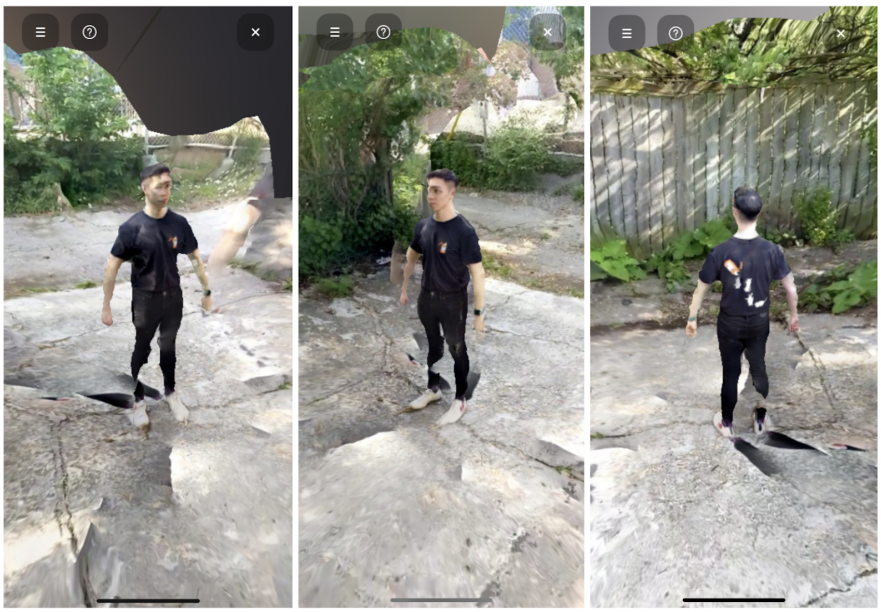


Figure 9: Body and environment scan by smartphone application Display.land

[15] Display.land was a free Cloud 3D model scanner and AR (augmented reality) tool. Their service stopped on August 11, 2020.

To better compare the two photogrammetric approaches, I also had a bunch of photos taken of myself for reconstruction in Metashpe. Based on the point cloud in Figure 10 indicates that the result of this reconstruction may not be successful. Still, considering that the shower curtain's point cloud also had missed some data but had good results afterward, I decided to proceed and keep the experiment going. Unfortunately, the result was not as good as the result of *Experiment 1*, and the head part would be challenging to reconstruct without the proper texture map (Figure 11).

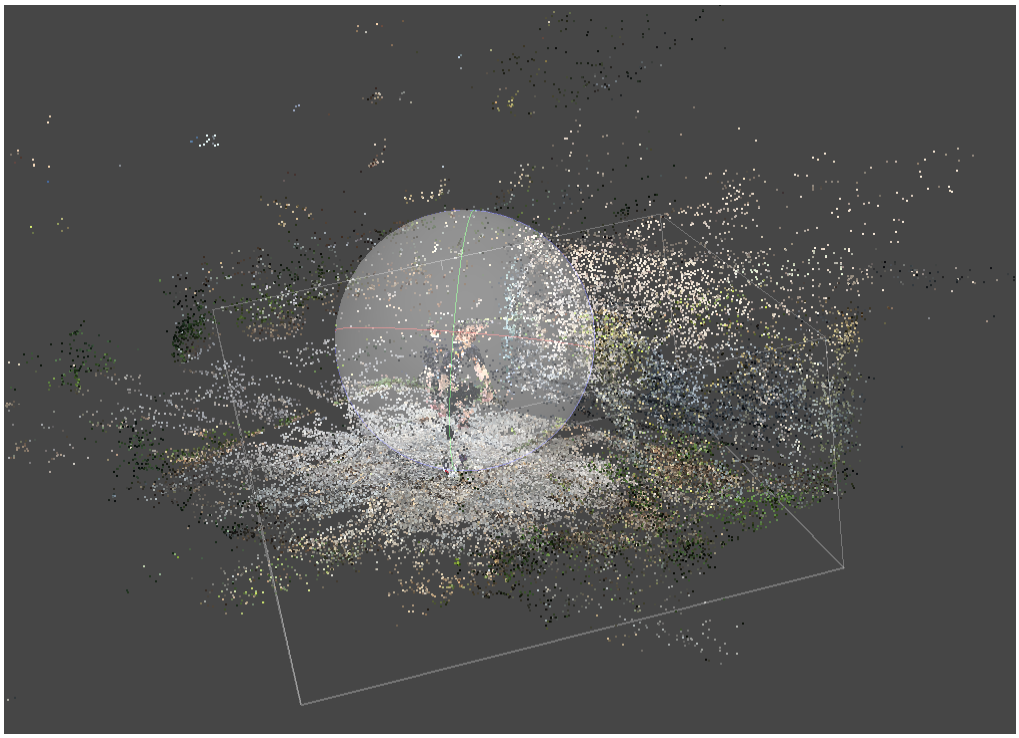
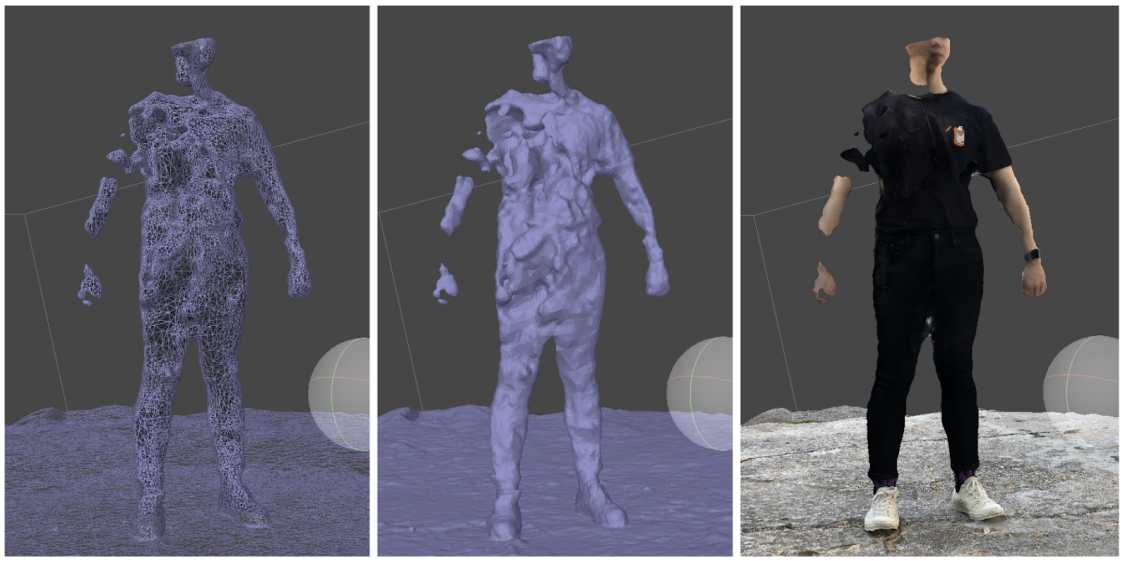


Figure 10: The point cloud of body capturing



Wireframe View Solid View Texture View

Figure 11: Three views on the reconstructed digital body

5.2.1 Reflection on Experiment 2

The results of the two digital body reconstructions from both Display.land and Metashape showed that capturing a detailed human body with photogrammetry technique requires a more intricate process for better capturing the body data. *Experiment 2* eliminated my original plan of using my own body for the prototyping stage and the final project. However, it would be an interesting approach in future works.

5.3 Prototype 1: Walking in The Shower Curtain

The goal of *Prototype 1* is to successfully drape the digital shower curtain onto the digital body for movement. Based on the unsatisfied results from *Experiment 2*, an existing digital body was

downloaded from Adobe Mixamo[16] for the process of *Prototype 2*. As Figure 12 shows, the photogrammetric shower curtain can be draped on the digital body with the "automatic weight" function in Blender. And Fig.13 indicates that the photogrammetric shower curtain is actually relying on the skeleton covered by the digital skin. Once the play button is hit, the animation that was embedded in the digital body would be activated, and the photogrammetric shower curtain would also move along with it, creating a result that looks like the digital body is wearing the photogrammetric shower curtain.

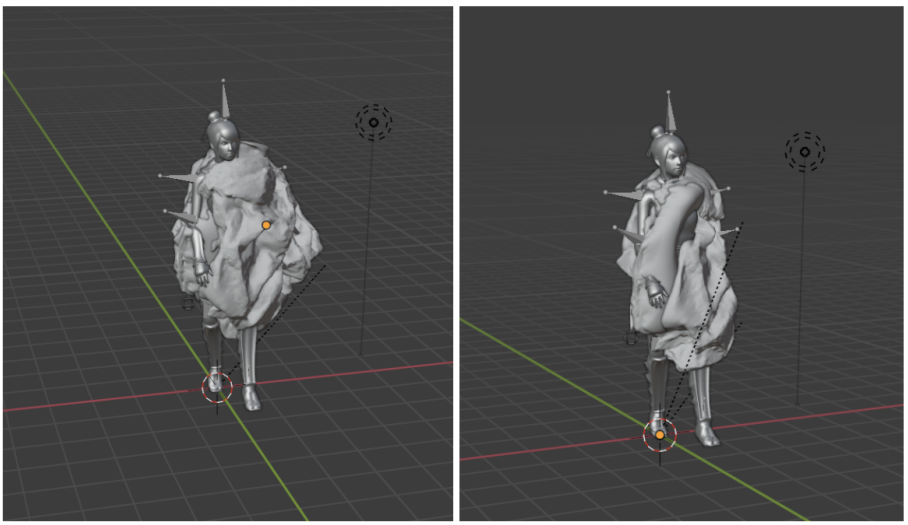


Figure 12: The before and after the automatic weight function applied on the shower curtain and the digital body

[16] Adobe Mixamo is an online platform that provides ready-to-use characters, automatic character rigging function and pre-made animations.

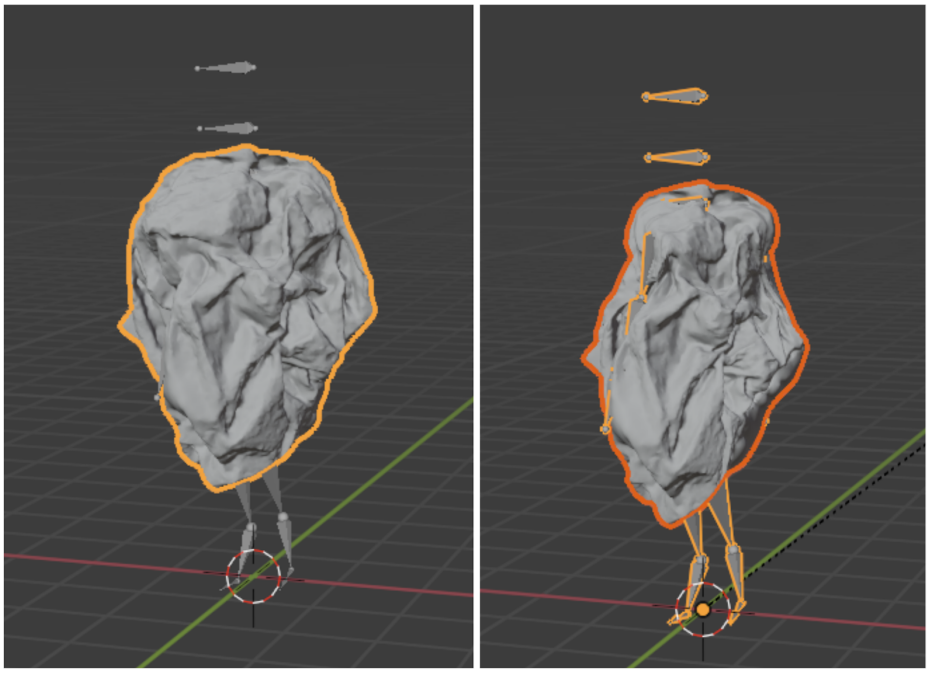


Figure 13: The relationship of the photogrammetric shower curtain and the digital body (the skeleton)

Before rendering the video, the digital body needed to be scaled to desired proportion with the photogrammetric scene[17], as well as placing the correct light source and camera setting (Figure 14). The final step is to import the video into A-Frame[18] and set up a 360 environment for a more immersive experience (Figure 15).

[17] The photogrammetric scene was one of the experiments done prior to the prototype stage.
[18] A-Frame is an open-source web framework for building virtual reality experiences.

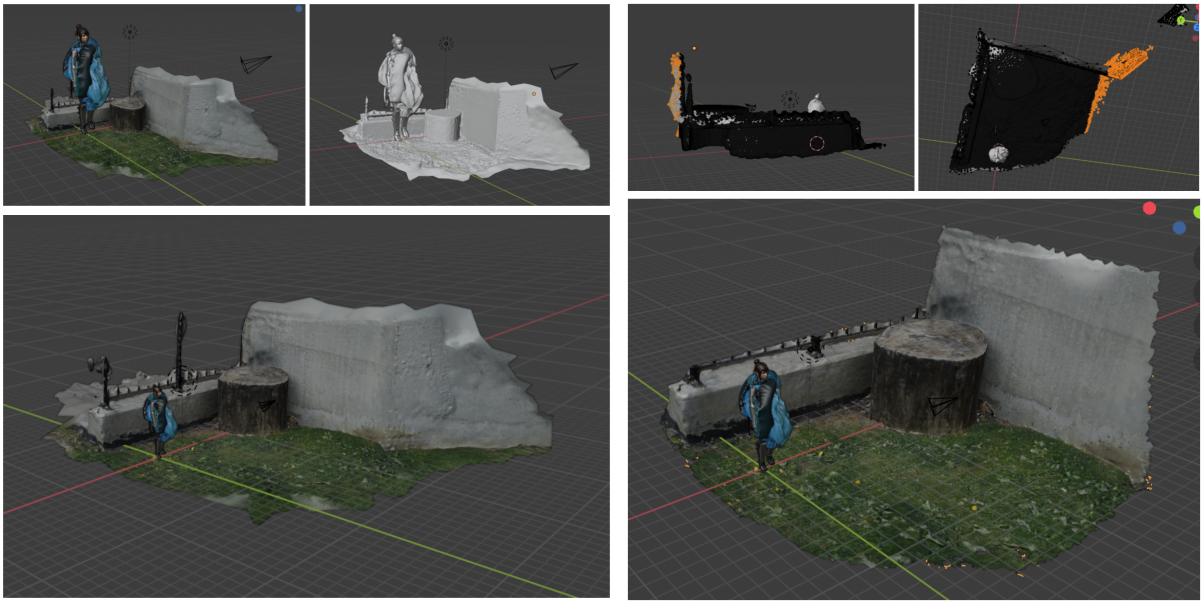


Figure 14: Scaling the digital body and modifying the digital environment

Figure 15: Video Playing on A-Frame, video link: https://youtu.be/9JMGnNTh3Wg

5.4 Reflection on Prototype 1

When I was working from the traditional fashion hand-made approach, I was facing the challenge of being short on resources due to the lockdown in the global pandemic. *Prototype 1* that I did grant me the motivation to attempt combining photogrammetry technique with fashion digitally. It was the photogrammetry technique that opened up a new path to fashion-making and thinking through transforming physical objects into digital material. The capacity of digital space increases the number of unexpected elements that would sparkle inspiration for artists and designers.

5.5 Prototype 2: First Origami Look

When thinking about transforming daily objects into their digital replicas with photogrammetry technique, the ancient art form origami came to my mind. Origami paper cranes are considered the most iconic and well-known shape within origami history because cranes usually have a meaningful representation and a relatively simple one to make for children. Origami cranes are also a personal reflection of my childhood memories because whenever I have a piece of square paper, I would always turn it into an origami crane unconsciously. Later on, when I started studying fashion design, I encountered a roll of fabric with origami cranes printed all over it, which inspired me to make origami cranes out of the fabric. The concept of "fold and unfold" from origami also became one of my main design inspirations when creating fashion creation (Figure 16). It is not just because of the historical connection we share. Still, I envision the great potential in origami and how it could be utilized to create an artistic digital fashion collection.

Figure 16: Origami-inspired shirt and dress, made by me in 2015

Based on the previous prototype I made with the shower curtain, I then proceeded to create the second prototype with origami as a preparation for the final project. Firstly, I managed to create an origami crane from a piece of paper with random lines drawn on it (adding texture helps the data be captured in the photogrammetry process). A towel was placed underneath to prevent the table from reflecting the light, also providing a big contrast with the origami, which will be easier to be edited out later. Unlike my earlier experiment, I stopped using Meshmixer for mesh editing and stayed in Metashape to generate and modify the 3D model (Figure 17).

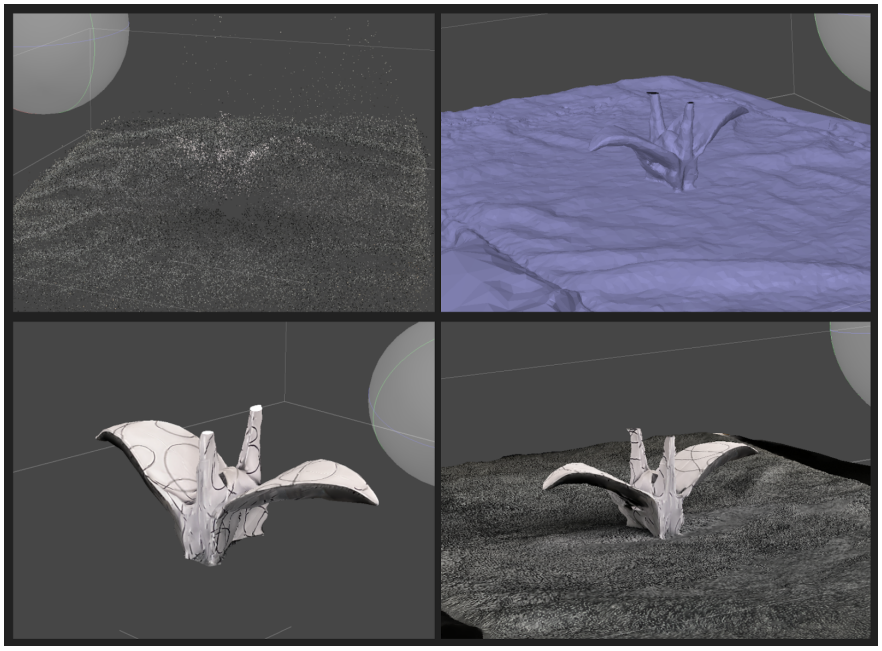


Figure 17: Photogrammetric origami crane process

The next step is to create the digital body. I discovered a software named MakeHuman, which allows the user to create and adjust a digital body as wished, from the body shape to even the fingers' length. To better situate the role of the digital body in this thesis project, which is to emphasize the origami garments and provide the movement as a mannequin. I have created a neutral[19] digital body without any specification. Then the digital body could be uploaded to Adobe Mixamo for character rigging[20] and embed movements (Figure 18).

[19] The making of a digital body is based on the creator, there is no standard for what a neutral digital body should look like, it is solely my decision.
[20] Rigging means applying a set of digital skeletons inside of the digital character, which could enable the movement for animation.

Figure 18: Creating a digital body in MakeHuman and rigging the digital body in Adobe Mixamo

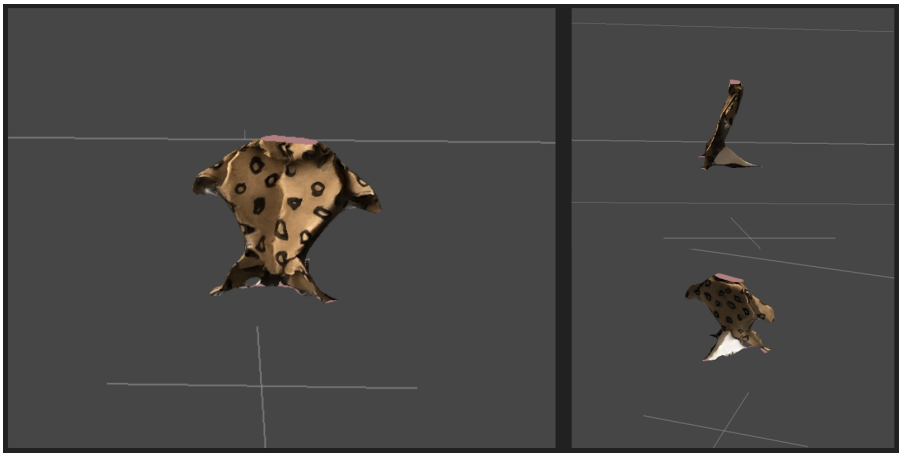


Figure 19: Photogrammetric origami turtle process

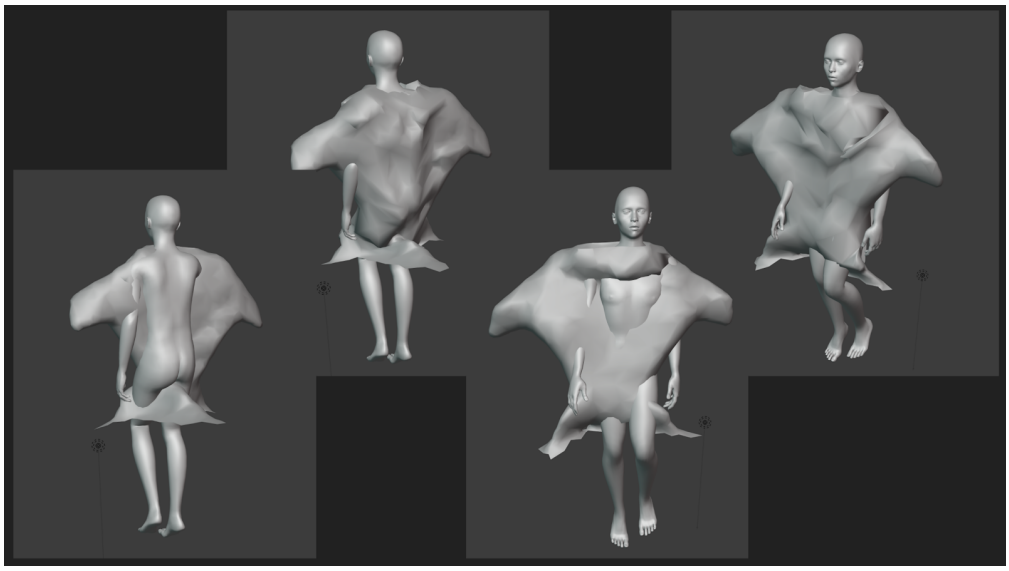


Figure 20: Fixing origami turtle with sculpting tools on the digital body

To construct prototype 2, I used the photogrammetric origami crane and the photogrammetric turtle. While reconstructing the photogrammetric turtle, part of its head was missing, as shown in Figure 19, but it can now be seen as an opening for the collar or the waist, which inadvertently turning it more garment-like. This unexpected result is echoing the concept of wabi-sabi. Meanwhile, the photogrammetric turtle is a bit flat and could not cover much of the digital body, so I used the sculpting tool in Blender to give it more volume (Figure 20). By doing this also aims for a better result when applying the automatic weight function, there will be a more defined silhouette of origami garment.

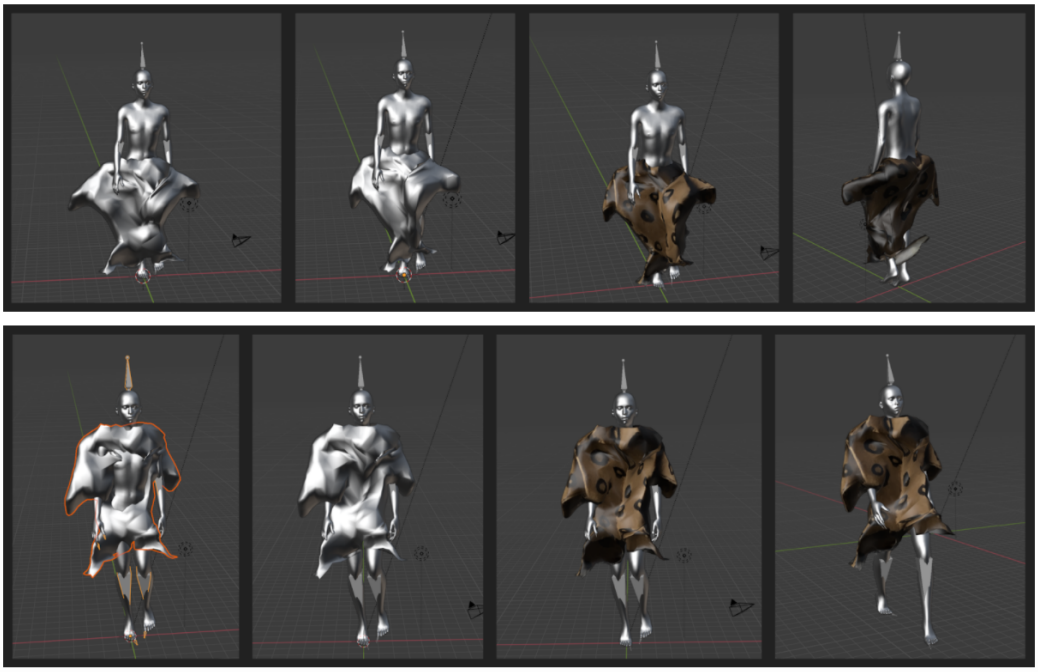


Figure 21: Different placement of the origami turtle on the digital body

Once both the photogrammetric origami and the digital body are imported in Blender, the making of prototype 2 is started. The origami turtle itself on the digital body is already looking like a skirt or an oversized shirt, and the pattern of the paper gives the texture (Figure 21). By

adjusting the placement and the origami's proportion, comes to the result of prototype 2 (Figure 22).

Figure 22: The making of Prototype 2

5.6 Reflection on Prototype 2

After the previous experiments and prototypes, I was astonished by the idea and the result of how transforming daily objects into digital material, and combining that with a digital body could create such dynamic outcomes. The successful result of *Prototype 2* supports my idea that utilizing origami can open up a new path of exploration. What I have learned from making the prototypes is that this "creative chaos" is essential to the design process. It was the unexpected

elements that occurred during the iteration that helped me to improve the work and expanded my understanding of digital perspectives. Therefore, the prototypes built up a strong research approach supported by my research methods and creative exploration, both influencing my creative research outcome, which is an origami-inspired fashion collection within a digital spatial environment.

6.0 Neo-Metamorphosis

6.1 Project overview

This chapter introduces the process and the building of the creative outcome, *Neo-Metamorphosis*. The traditional fashion industry, or as the fashion industry always was conceived, is supposed to be human-centered and aiming to solve the daily "what to wear" question. The clothing is serving as an accessory or an extension, or as Vreeland would describe, "ornamentation for the human body." (Kim, 1998). However, I would argue that fashion is more than just clothing and it serves as an expression of the aesthetic and ongoing art form that continues to evolve with the development of technology. I do support Ingrid Loschek's views when she stipulates that "The social limits of toleration are also being continually renegotiated and are therefore subject to constant change, which is why acceptance of innovative creations and ultimately of new fashions develops at all." (2009). The global pandemic is stimulating the urge for fashion designers to accept and explore innovative approaches to experience and create fashion, which inspires this thesis project to switch the traditional focus of the practicality and wearability of physical fashion, to one that introduces the development of digital fashion and the potential in digitized materials.

Neo-Metamorphosis is a digital fashion runway show that includes 6 looks made with photogrammetric origami. It aims to express a futuristic aesthetic through a visual presentation that was animated and rendered in 3D software Blender. *Neo-Metamorphosis* starts with the introduction of the photogrammetric origami and the digital body, then proceeds to merge and

result in various fashion looks and displays them in the form of a runway show. As fashion guru, Rei Kawakubo once said, “the body becomes dress becomes body” (Svendsen & Iron, 2006). The origami serves as a garment and as an individual entity, combining with the digital body, results in new forms and configuration; this transformation is considered a metamorphosis. It provides a sensational and visual experience, stimulating the viewer’s perception.

The achievable shapes of origami are countless and still being invented by handcraft artists. No matter the inspiration comes from animals or lifeless objects, there is a way to transform that one piece of paper into the desired form. Throughout the whole thesis project, I have made over 14 origami, and 12 of them are animal-shaped, the other two being lotus and rose. I believe that to better express the concept of metamorphosis, and there is nothing better than recreating animals and plants in the form of origami. Not only because of the historical relation to my previous practice and experience but also creating animal forms out of a piece of paper can be seen as the metamorphosis that happens in the transformation from paper to origami. And the second time the metamorphosis happens during the transformation from physical origami to photogrammetric origami. By draping the photogrammetric origami onto the digital body, the third time of metamorphosis happens. And each time, the “fold, unfold and refold” (Conley, 2005) occurs, making the whole process into a cycle of metamorphosis through the process of changing. Animals and plants experience growth and transformation along with their lifespan; the origami is acting as a representation of their metamorphosis, or even a “still image” of their one specific life stage; this offers a metaphoric concept embedded in this project.

6.2 Making The Collection

In the process of making this fashion collection with photogrammetric origami, ten types of origami were used as shown in Figure 23. Flaws are shown in the form of missing parts, and some of the hollows are filled with extra texture on the 3D reconstructed origami. This means in the transition from physical to digital, the physical origami does not just become digital, but also transform their shape due to the missing/adding data. This process of creative chaos has the concept of wabi-sabi embedded in and generates the potential of digitized materials. The process of draping photogrammetric origami is similar to the traditional way of draping fabrics on a mannequin, and there are a number of combinations and ways of positioning the material, except in the digital space, the fast workflow provides a much faster and visual result (Figure 24).

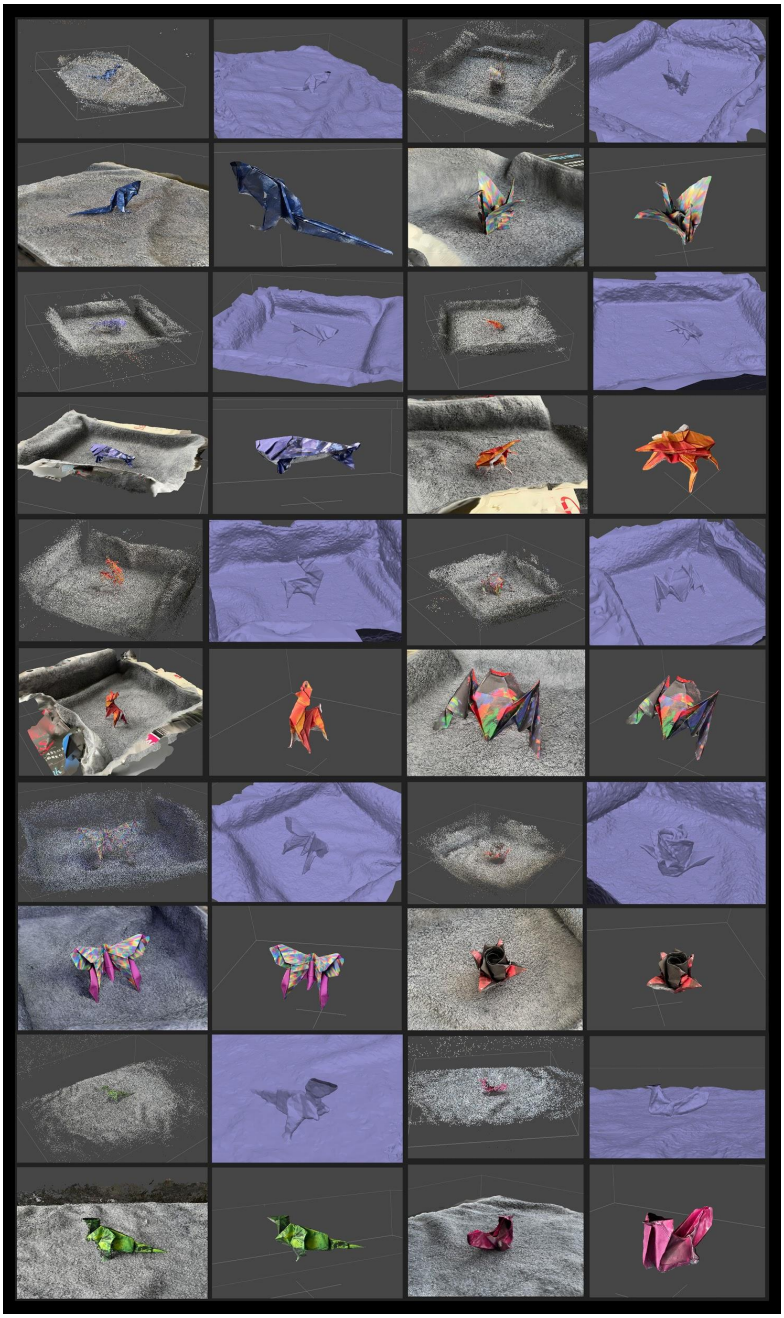


Figure 23: Photogrammetric origami used in the making of the creative outcome

Figure 24: Final collection consists of six looks

6.3 Building The Environment - Galaxy

The idea of constructing a galactic environment was inspired by the look of the point cloud, each point within the point cloud representing a tie point, the captured data flowing in the 3D digital space creating the illusion of a galaxy. And the 3D digital space is also like the actual galaxy, broad and endless, providing possibilities for digital creation and imagination.

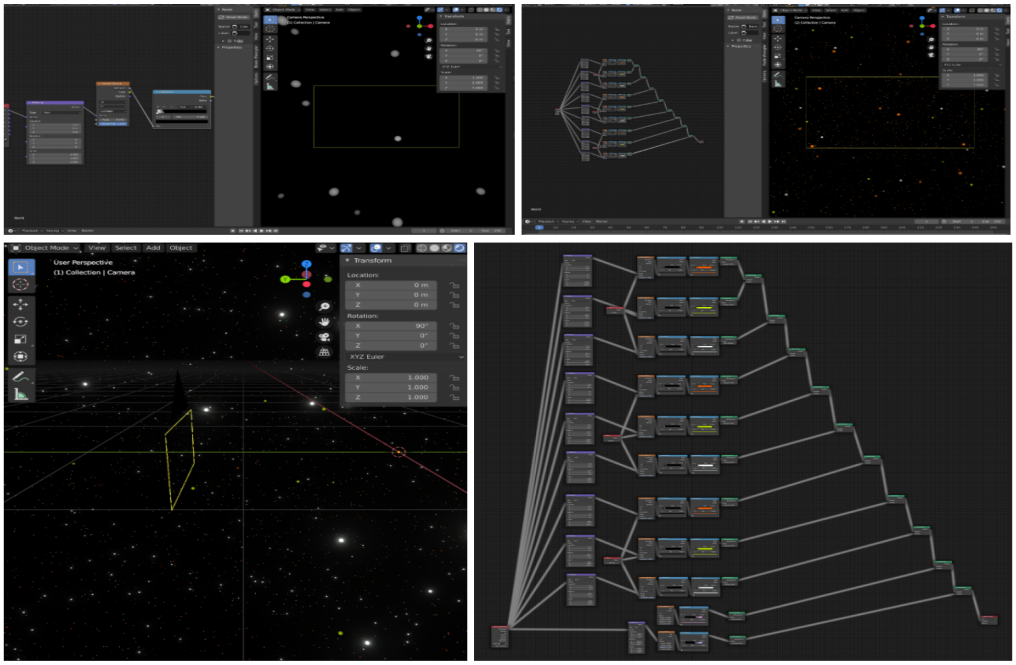


Figure 25: Process of making the environment in Blender

Figure 26: Example of the look in the digital galactic space

6.4 Rendering the Video

In this section, the making of *Neo-Metamorphosis* is introduced in three sub-section: the opening, the show, and the closing.

The Opening

To echo back with the origami paper, I created a square plane consisting of 20000 particles to represent the points in the point cloud, and the particles draw the image of a photo of a piece of origami paper, which once the animation starts, would flow upwards and mimicking the effect of the points being disturbed by turbulence in the air (Figure 27). The opening of *Neo-Metamorphosis* aims to give out a vibrant and intriguing visual impact to the audience, grabbing attention and triggering curiosity (Figure 28).

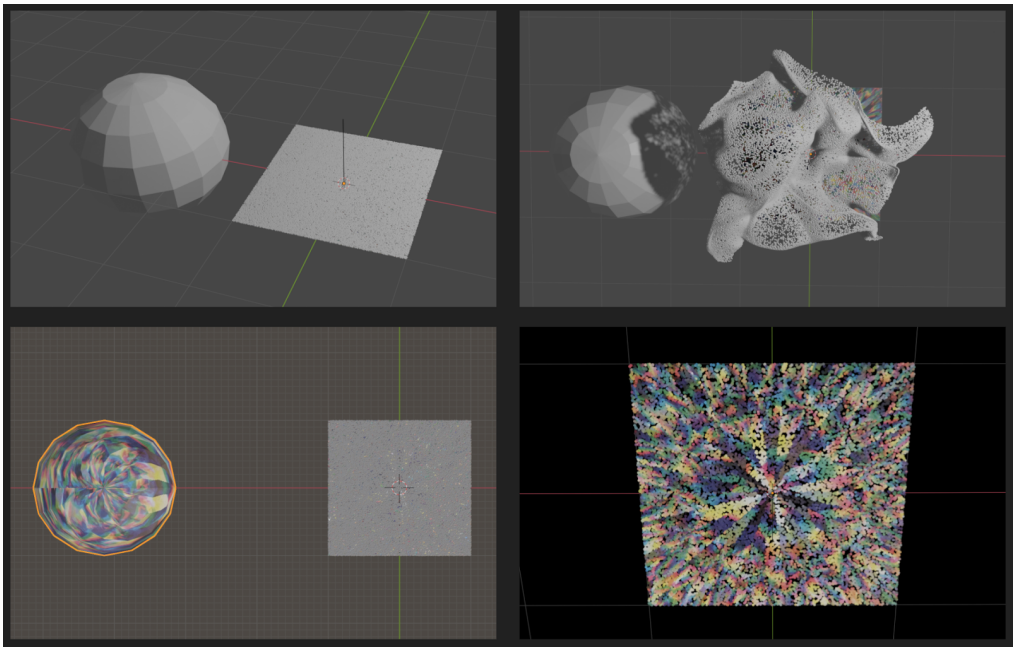


Figure 27: Process of making the opening scene in Blender

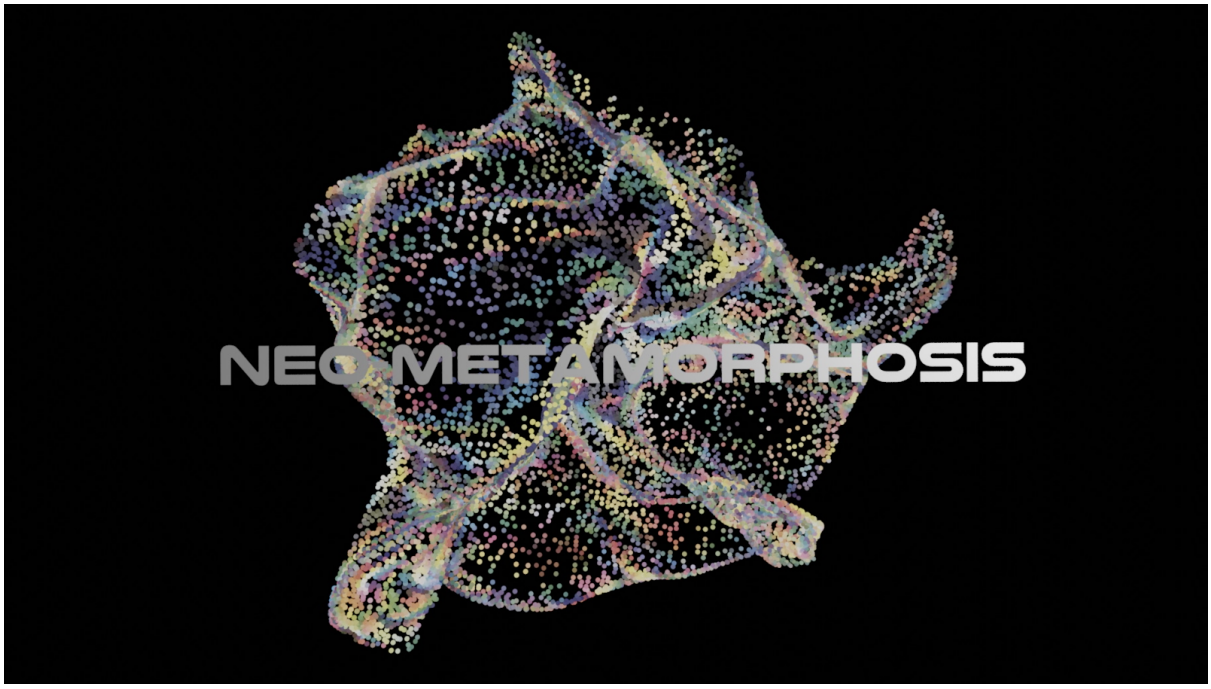


Figure 28: Screenshot from the opening scene

The Show

The runway show is the central part of this project, and it showcases the six looks constructed with photogrammetric origami walking in the digital space, displaying the details of the looks. After introducing the photogrammetric origami, the runway show is edited with different camera angles to better present the dynamic movement (Figure 29).

Figure 29: Screenshot of *Neo-Metamorphosis*, video link: https://youtu.be/FqyupMw8dgc

The Closing

The closing of *Neo-Metamorphosis* is a reverse of the opening, all the floating particles are gathered back to their original shape of a square. This represents the root of this thesis project is from the 2D piece of paper, and in the digital space, the alternation of materiality is easily manipulated. It also forms a loop of transformation, embedded in the idea of connecting physical and digital through the concept of digital monism.

6.5 Reflection

This digital fashion runway show, Neo-Metamorphosis is reflecting the unignorable potential of transformative material through the kinetic relationship of the digital body and the photogrammetric origami. The fashion collection shown in the video consists of six looks in

total, and each look is orchestrated with different positioning and scaling photogrammetric origami. The computer programs provide the possibility of achieving this project at the intersection of fashion and technology.

The creative outcome, *Neo-Metamorphosis* indicates that combining digitized origami and digital body can lead to a unique approach of digital fashion creation that not only reflects on the transformative materiality, but also opens up a gate to future digital fashion exploration for my research and creation. In the process of making *Neo-Metamorphosis*, I have learned that the kinetic relationship between the digital body and the digitized origami can be initiated once the digitized origami is being draped onto the digital body within the 3D software interface. Therefore, the metamorphosis of the digitized origami is triggered and forms new shapes along with the movement of the digital body. This finding builds up a path when thinking about the future development of this thesis project; more digitized material can be brought into the 3D software interface to create this narrative of digital fashion exploration.

Irish poet William Butler Yeats wrote, "The visible world is no longer a reality, and the unseen world is no longer a dream." In this project, the visible world is our physical world, and the unseen world is the digital representation. Human creativity is being expressed through the development of modern technology. With the assistance of digital platforms such as social media and online representations, new paths for creative creation open up. Playing with digitized origami and forming new shapes with digital bodies is bringing the unseen world to our eyes. The physical representation is no longer a necessary way of achieving the creative outcome, and it is the extension of humanity that technology has brought to us that leads to this result.

6.6 Exhibition Format

Figure 30: Exhibition mockup

Due to the current COVID-19 pandemic, a physical exhibition is unlikely to take place. However, the creative outcome *Neo-Metamorphosis* would be ideally shown on a large screen in a gallery, preferably in a dark room where the audience can get a more immersive experience with the dynamic visual and music (Figure 30).

7.0 Conclusion

Neo-Metamorphosis aims at provoking the audience and engaging emotionally with the unconventional forms of the digital body and digital garments, initiating a debate around this innovative method of exploring fashion design digitally. This project presents the process of transformation from physical to digital matter to accentuate the focus on metamorphosis. The photogrammetric origami moves the original tangible origami pattern into an intangible digital replica. A metamorphosis is triggered by a digitizing process transforming the rigid paper into a fabric-like soft, malleable digital garment. This creative process reveals the potential of 3D technology for digital fashion experienced inside a digital spatial context. This creative research approach also raises the question of how 3D reconstructed material could act as wearable pieces through abstract shapes in the digital space. With the possibilities that it offers, the digitized material and the digital body can be folded and unfolded, liberating the fashion designers from physical constraints and stimulating creative freedom in digital space.

"Creative chaos" is embedded in *Neo-Metamorphosis* and brings an answer to how does photogrammetry technique and 3D software influence the fashion designer's creative process and digital fashion design outcome. The flaws shown in the form of missing data on the photogrammetric origami bring up the concept of wabi-sabi. During the process of this thesis project, the flaws are beneficial, inspiring, and creative. They force the research to focus on embracing the unexpected error and offer the potential of new inspiration rising with the flaws. This "creative chaos" could be further developed and utilized in future artistic and design works because letting errors happen, could stimulate new ideas, help polish the work and lead to a better result along the creative journey. And this is what my research outcome is meant to convey

to other designers and artists. My thesis project aims to contribute to the fast and ongoing development in digital fashion, hoping to stimulate exploratory direction in transforming physical to digital materiality.

Traditional fashion design requires the designer to work closely with physical materials such as fabrics and other textiles. The element of wearability lies in the process of fashion design because the physical body is an intrinsic part of the fashion design outcome. However, digital materiality calls for a discussion, and wearability should be viewed differently in the digital space when the digital body and digital materiality can both be easily altered. The correlation between the digital body and digitized origami is influenced by the freedom provided in the digital space, the characteristics of the digital materiality being altered in terms of its form and texture as well as the importance of wearability being reduced.

As a fashion designer, I have learned a lot through the process of researching and making during this thesis project. With the creative goal of achieving digital fashion in the current pandemic situation, I discovered the potential of transformative materiality, that is, digitizing origami to create their digital replicas using the photogrammetry technique. I am exploring digital fashion, and the obsession with making, motivated me to dive into the realm of 3D scanning technology and 3D software tools and functions as creative research methods. Experimenting with photogrammetric origami draped on the digital bodies has extended the possibility of creating digital garments with physical material; this inspired me to dig deeper in this digital fashion direction.

I present my conclusion based on this year-long journey of experimenting, prototyping, and questioning how photogrammetry and 3D software influence the way that fashion designers interpret and interact with materials. These research methods provided a unique approach to transforming tangible objects into intangible data in digital space, expanding the boundary of physical material, and rethinking the possibility of manipulating digital replicas as innovative ways of developing digital fashion outcomes. In the digital space, the digital body and the digitized material, inherit a similar kinetic relationship to that of the fabric and the human body. However, in the physical world, fashion clothing needs to prioritize the human body first. Still, in the digital space, the digital body acts as the supportive mannequin that holds the origami and grants it the movement to make it more fabric-like. This kinetic relationship not only brings origami to life but also stimulates the metamorphosis in the digital space. And this helps me to work creatively with 3D technology and produce the creative outcome *Neo-Metamorphosis*.

Moreover, the digital space offers accessibility to attract more audiences than the traditional way of a fashion runway show. Finally, as we gradually move towards a world of digital monism, digital fashion has a huge potential to help reduce the waste and pollution from the current fast fashion production. In conclusion, this thesis project offers digital perspectives on fashion development in the spirit of contributing to further research in the field and inspiring emerging fashion designers and researchers' future work direction.

7.1 Scope and Limitation

This thesis project focuses on exploring digital fashion with digitized origami by using photogrammetry technique, as well as building the connection between photogrammetric origami and digital body through 3D software Blender. The exploring process challenged my technical skill in terms of the utilization of photogrammetry technique and 3D software, as they were key techniques to this project. As discussed in previous chapters, for fashion designers, to change to a digital workflow could be beneficial to the prototyping process and overall workflow, but it does require a specific skill set and an understanding of the software interface. During the journey of this thesis project, I have developed my technical skillsets for constructing the creative outcome, *Neo-Metamorphosis*, and also expanded my knowledge of the growth and potential in digital fashion. Due to the current COVID-19 pandemic, the original plan of 3D printing the digital garments as a set of physical representation was canceled, this plan has been moved to the future work section as an alternative option.

7.2 Future Works

Neo-Metamorphosis is the creative outcome of my thesis project, also the foundation for me to further explore digital fashion. The transformative quality of digital data could be further developed by testing on other physical objects, this would open up more possibilities in creating digital garments, as well as offering inspiration for more artistic creation. Because fashion design continuously evolves, the future development of this project opens up to a number of possibilities. Through creating digital garments with photogrammetric origami, it became

undoubtedly intriguing to think about what these digital representations would look like when translated back to physical reproductions.

Future works could be an attempt to make the same collection with real fabric, the recreation of digital shapes would then be a real challenge. My future works could also include a set of 3D printed models of the digital garments from *Neo-Metamorphosis*. In addition, to echo the growing needs of digital representation as presented in my literature review chapter, the digital garments from *Neo-Metamorphosis* could also be worn by digital bodies through virtual platforms such as those used in the video game world. These future work possibilities may trigger the conversation around the transition from materiality to immateriality and further dig into the potential of digital fashion.

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Appendices

Appendix A. Unused Designs

Appendix B. Intro Video for *Neo-Metamorphosis*

An intro video made prior to the final project, video link: https://youtu.be/nTq4kS9c3oQ

Appendix C. Neo-Metamorphosis

Neo-Metamorphosis, The creative outcome of this thesis project, March 2021.
[Neo-Metamorphosis - Neo Nuo Chen]
Video link: https://youtu.be/nTq4kS9c3oQ