Fall 8-2014

Technology in the Fashion Industry: Designing with Digital Media

Adima Cope

TECHNOLOGY IN THE FASHION INDUSTRY: DESIGNING WITH DIGITAL MEDIA

by

Adima Cope

Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Fine Arts in Fashion Design
at
Lindenwood University

Signature: _____ Date: 8/27/14
Adima Cope
Author

Signature: _____ Date: 8/27/14
Chajuana V. Trawick, Ph.D.
Committee Chair

Signature: _____ Date: 8/27/2014
John Troy
Committee

Signature: _____ Date: 8/27/2014
Nasheli J. Ortiz
Committee

Signature: _____ Date: 8-27-2014
Darren Collier
Committee

TECHNOLOGY IN THE FASHION INDUSTRY: DESIGNING WITH DIGITAL MEDIA

A Thesis Submitted to the Faculty of the Art and Design Department
in Partial Fulfillment of the Requirements for the
Degree of Master of Fine Arts
at
Lindenwood University

By

Adima Cope

Saint Charles, Missouri

August 2014

Abstract

Title of Thesis: Technology in the Fashion Industry: Designing with Digital Media

Adima Cope, Master of Fine Art, 2014

Thesis Directed by: Chajuana V. Trawick, Ph.D., Assistant Professor of Art and Design, Fashion Program Manager

The fashion industry has advanced new technologies in the twenty-first century that has made producing apparel more cost effective with faster time-to-market capabilities and greatly reduced steps in the manufacturing process. The reasons for these improvements can be linked to new apparel computer-aided-design (CAD) technologies that have come about in the market as computers have advanced and grown in processing power and reduction in size since the 1980s. Computers are revolutionizing many industries and the way business is conducted in today's modern workplace. The fashion industry has yet to convert all processes to digital means but advancements have been growing in popularity over the years and are certain to increase as the technologies available become better and more reliable. This raises the need for research to take place to survey the market and determine what types of software are available and the capabilities of the technologies.

Essentially, this thesis project consists of first starting with the requirement of using computer-aided patternmaking to design and create a collection of six complete outfits; secondly, to use and incorporate as much digital media or technological effects as possible into those outfits; and finally, 3D draping/modeling will be used to assess fit quality of the six outfits and determine if new 3D technology from Optitex can accurately remove the step of creating real-fabric muslins or test samples as a requirement prior to manufacturing. This is significant because traditionally, the prototyping/sample creation step in the fashion industry manufacturing process takes anywhere from "8 weeks to 18 months."[1]

[1] Apparel Design Partners, "Prototyping," http://www.appareldesignpartners.com/?page_id=105, (Accessed April 1, 2014).

Dedication

This thesis is dedicated to my creator, God; my savior, Jesus; my lover and wife, Roshini, and my beloved and son, Zion.

No one wants to live without love; no one wants to die for love.

- Adima Cope

Acknowledgements

Coming from a technical background, I would like to acknowledge all my professors throughout the course of my studies for instructing me in the discipline of art and the creative process.

Table of Contents

Abstract 2
Dedication 3
Acknowledgements 4
List of Tables 6
List of Figures 7
Introduction 8
Literature Review 9
Methodology 15
Production & Analysis 17
Conclusion 24
Appendices 28
Bibliography 46

List of Tables

Table 1 – CAD Software Company Comparison Matrix 28
Table 2 – Optitex Fashion Technology Company SWOT Analysis 30
Table 3 – Gerber Fashion Technology Company SWOT Analysis 31
Table 4 – Lectra Fashion Technology Company SWOT Analysis 32
Table 5 – Tukatech Fashion Technology Company SWOT Analysis 33

List of Figures

Figure 1 – Open-Knit Digital Clothing Printer Machine 34
Figure 2 – Dita von Teese 3D Printed Gown 35
Figure 3 – La Nuit Garment Digital Pattern Example 36
Figure 4 – La Nuit 3D Modeling Fit Analysis Example 37
Figure 5 – La Nuit Mood Board 38
Figure 6 – La Nuit 3D Prototype & Real Fabric - Garment 1 39
Figure 7 – La Nuit 3D Prototype & Real Fabric - Garment 2 40
Figure 8 – La Nuit 3D Prototype & Real Fabric - Garment 3 41
Figure 9 – La Nuit 3D Prototype & Real Fabric - Garment 4 42
Figure 10 – La Nuit 3D Prototype & Real Fabric - Garment 5 43
Figure 11 – La Nuit 3D Prototype & Real Fabric - Garment 6 44
Figure 12 – La Nuit Accessory 1 45

Introduction

My fashion design thesis project combines technology and business with fabric; worlds that typically do not exist in harmony. I am inspired to create fashion using any and all components of technology available and in doing so my creations tend to have sculptural and architectural elements as a result. I come from a technical and business background, so bringing that thought process to fashion design allows me to think unconventionally during the design process. Depending on the design, I may ask 'how' first, before What or Why. For example, if I want to incorporate lights into clothing, I would have to first ask how I would accomplish the task. This is necessary in order to define a set of requirements and then the entire creative process would be subject to those set of requirements, beginning with the end in mind.

On the other hand, a purely creative process does not answer how first. Instead, inspiration and from that comes design and a set of requirements ultimately translated into fabric or clothing. Both avenues of design exist where frequently inspiration as the source for design in the fashion industry and broader art community is more accepted. As Petty relates, "In the field of the creative arts the inspiration phase is often associated with a search for an individual voice, and with an attempt to conjure up deep feelings of empathy, spirituality, or an intense identification with the subject matter."[2] As a graduate student I had the opportunity to take part in both methods of design; one where I designed purely from inspiration including objects, animals, images and another starting with a requirement that had to be defined first before the inspiration was garnered.

Not only did I take time to understand the reason for designing from both avenues, but I also took the time to understand the steps in the design process from an industry perspective.

---

[2] Geoff Petty, "How to be Better at Creativity," http://www.greenfields.u-net.com/docs/inspiration.html, (Accessed February 2, 2014).

Given my background, I was able to ask pertinent questions to understand why one step would be completed first versus another. This was important to me, for as aforementioned there are obvious differences in approaching design from a technical perspective to a design perspective. In a technical world, requirements (or How) always comes first, while in a creative world, design (or Why) comes first, generally speaking. Indeed, during the inspiration phase, Petty continues, "It is very common...to try to use inappropriate logical thinking."[3] Blending the two worlds in order to obtain the best possible outcome can be challenging but was my main reason for embarking upon this course of study.

As a technology and business professional, my purpose for completing a Master of Fine Arts in Fashion Design versus a Master of Business Administration was to understand the creative process, the requirements/steps and the reasons for those steps in the process. Combining that knowledge with my previous knowledge would make me competent in not only the existing Business and Technology world, but also the creative world for a holistic set of requirements across three different disciplines. It is for this reason that my ultimate objective was to determine what current business processes and technologies are used and what is the next evolution of those mechanisms within the fashion industry to position myself at the forefront of the those changes within the twenty-first century.

Literature Review

As time passes, we as human beings evolve; we migrate and live in different places, socialize with different people, eat different foods, improve the way we create things, increase our standard of living, accelerate our methods of transportation, reduce barriers to communication, embrace change, and much more. As a subset of human existence, the same is

[3] Ibid.

true in the apparel production process; we have always had a need for clothing and the process by which it is created has evolved since man first walked the Earth. Even the *Bible* states that God fashioned clothing from skins for Adam and Eve to wear, so historically speaking, if one believes in God, the first garments ever worn were created by God (Genesis 3:21).

Moving forward in time, clothing production from Ancient Egypt to the Roman Empire (circa 5000 BCE – 476 CE) consisted of reaping plants and extracting fibers which could then be spun into thread for sewing and weaving using horizontal and vertical looms.[4] The final clothing had very little sewing, varied very little from basic construction steps and had simple cuts of fabric wrapped around the body and held in place by a belt.[5] Compared to earlier civilizations, medieval era (circa 500 CE – 1400 CE) clothing was more intricate and had more complex patterns and sewing details as better tools and a wider selection of fabrics were available. From the American Colonial time period, where clothing was produced in New York for slaves working on Southern plantations, the production of ready-made clothing reached industrialization in the 1850's when the first sewing machine was commercially available.[6] "Elias Howe patented the first sewing machine in 1844 although Isaac Merritt Singer, whose name is synonymous with the machine, added modifications and marketed the sewing machine for the first time to the mass public in the early 1850s."[7] By the end of the 1860s, Americans bought most of their clothing rather than making it themselves.[8]

In the modern day computer and information technology age (1950 CE – Modern Day), the invention of the computer chip in 1958, the personal computer in 1974 and the internet in

---

[4] André Dollinger, "Ancient Egyptian Clothing," http://www.reshafim.org.il/ad/egypt/timelines/topics/clothing.htm, (Accessed March 22, 2014).
[5] Ibid.
[6] Susan Rhoades Neel, *Garment History* (Utah State University - HIST 1700, 2013), http://www.srnteach.us/HIST1700/html/projects/unit3/popups/readings/garment.html, (Accessed March 23, 2014).
[7] Ibid.
[8] Ibid.

1989, revolutionized all industries with the advent of new digital processes replacing manual analog processes.[9]

> Since the 1990s apparel manufacturers and retailers have been making strides in furthering the use of computer technologies in clothing production processes "employing the kinds of computer-aided design and computer-aided manufacturing, or CAD/CAM, software previously reserved for architects, designers, and engineers…While pin-bearing seamstresses and mannequins are still used for couture, the maker of clothing bought off the rack is more likely a piece of software."[10]

The fashion industry has not been entirely converted to digital processes over analog/manual tasks. It is only within the last decade or so that digital advancements have grown in capability, availability, popularity and usage. "Because CAD significantly streamlines the design process, it opens the doors for independent designers who may have fewer employees and therefore can't waste time and resources doing sketch after sketch."[11] Additional benefits include "Designs can be saved as templates or the basis for clothing models from which future designs can be made, especially if it is for a specific line, which is how many fashion designers release their clothes."[12]

There have not been many research studies on fashion CAD software available in the marketplace as a result of the newness and changing capabilities of the technology. One study carried out by Casima talks about how consumers preferred the virtual avatars/3D models from Optitex to that of Gerber's V-Stitcher 3D modeling program.[13] Additionally, the study concluded that it is possible to create very specific and detailed grading rules for patterns in a

---

[9] History.com Staff, "Invention of the PC," http://www.history.com/topics/inventions/invention-of-the-pc, (Accessed March 23, 2014).
[10] Candace Lombardi, "CAD Software is the New Black," http://news.cnet.com/CAD-software-is-the-new-black/2100-1012_3-6221810.html, (December 7, 2014).
[11] Giselle Diamond, "Importance of CAD in Fashion Designing," http://www.ehow.com/about_5344814_importance-cad-fashion-designing.html, (January 1, 2012).
[12] Ryan Casima, "The Use of CAD in Fashion Designing," http://www.ehow.com/way_5752123_use-cad-fashion-designing.html, (January 1, 2009).
[13] Ho Sun Lim, "Three Dimensional Virtual Try-on Technologies in the Achievement and Testing of Fit for Mass Customization," (Raleigh, North Carolina: North Carolina State University, 2009).

made-to-measure pattern design system to achieve fit for a number of individuals based on different measurements for the same garment once setup properly the first time.[14] As a result of limited research on software and companies offering these technologies, I performed a research study as listed in Tables 1 - 5, to understand, assess and compare current company offerings in the marketplace for fashion CAD software. The results of the study concluded that Optitex was the industry leader in terms of leading the market with new software tools and capabilities and may be suitable for small to large businesses or individuals for general or niche operations and expertise whereas Gerber may be the preferred option for larger companies and institutions considering size and breadth of offering.

As Roach & Eicher note, truly, throughout history and time we can see "The form of a society's language of personal adornment depend[ed] on environmental resources, technical development and cultural standards for judging what is fine and beautiful."[15] From the first garments to modern society, the process of creating clothing has truly evolved from using animal skins as the fabric to spinning and weaving with looms, skilled artisan workers sewing with makeshift needles in homes to factories, machines, computer-aided design and mass-producing clothing.

Beyond the modern day information age and current fashion manufacturing methods, a new age of garment design and creation is in its infancy. Sher points out one emerging technology, depicted in figure 1, includes digital knitting where a computer "use[s] a digitally controlled knitting machine to tailor-make sweaters according to exact measurements from each

[14] Ibid.
[15] Mary Ellen Roach and Joanne Bubolz Eicher, *The Language of Personal Adornment*, (The Fabrics of Culture: The Anthropology of Clothing and Adornment,1979), 7-21.

single individual."[16] This new technology can be described as seamless garment manufacturing and is one reason why current manufacturing methods may one day become obsolete.

> Seamless garment manufacturing technology works so beautifully that it does away with the tedious and error prone processes of fabric-laying, cutting, sewing and finishing. State of the art circular knitting machines can be programmed to finish whole garments with different stitching patterns.[17]

Measurements can now be captured digitally, automatically, accurately and quickly with the advent of 3D body scanners which recently emerged on the market in 1992.[18] Another new technology involving fabric that will change the way clothing is designed includes "a digitally fabricated conductive cotton T-shirt coloured using OLED paints and thus able to portray a digital moving image, in real time, right on your belly. Ashayer-Soltani confirmed that it could be achieved by combining these technologies."[19] The way current clothing is produced and consumed will eventually change as Sher purports that mainstream consumers "[will be able to] make something yourself and it can look just as good as industrial made items…Brands are not necessary, especially if you consider that most mass produced clothing, both high and low cost, is made in Asia."[20]

Other technologies such as 3D printing have recently been introduced on the mainstream market for other industries that will ultimately have an impact within the fashion industry. As we can see in figure 2, 3D printers have already been used to create a "fully wearable and

---

[16] Davide Sher, "Is Digital Knitting a form of 3D Printing?," http://3dprintingindustry.com/2014/02/24/digital-knitting-form-3d-printing-whether-yes-great-potential/, (Accessed February 25, 2014).
[17] Suntex Industry Group, "How Seamless Garment Manufacturing Technology can be used in Garment Manufacturing," http://www.thesourcingplace.com/seamless-garment-manufacturing-technology/, (September 19, 2013).
[18] Erica Swallow, "The Science Behind Airport Body Scanners," http://mashable.com/2011/11/17/tsa-body-scanner/, (November 17, 2011).
[19] Davide Sher, "Is Digital Knitting a form of 3D Printing?," 2014.
[20] Ibid.

commercially available dress."[21] An inspiration to me, Francis Bitoni, is one designer who has taken the lead in this new digital age and has created a collection "…of [hackable, shareable, and downloadable] products that can be printed through the distributed 3D printer network of 3D Hubs and securely shared with secure file sharing service Secure 3D."[22] This is one example of using new technologies and mediums that could one day change the way clothing is produced; making fashion selectable and available with the push of a button.

> Defining the visual and formal language of our generation, Francis Bitonti Studio will be releasing their first ever collection of luxury goods Fall 2014. With a strong focus on 3D printed fine jewelry and multi-material accessories, continuing into ready-to-wear in 2015, Francis Bitonti's first collection, driven by computational design techniques and emerging manufacturing technologies, will be available exclusively in limited edition, with each piece made to order and serialized. The collection will be available internationally with pre-orders beginning early Fall 2014.[23]

In another arena of fashion, historically, technology has not advanced far enough to make fabric and technology seamless but with future advancements in nanotechnology, thinner and smaller computer chips and OLED thin screen capabilities, we will start to see a new age of fashion where technology is seamlessly integrated into clothing. Kowitt supports that leading companies in the fashion industry such as Burberry are now attempting to push the integration of fashion and technology with its "digital approach to everything" in an attempt to embrace younger consumers who "[live and] shop in the digital world."[24] Fast forward to October 2013, Maney states that Apple hired the same CEO from Burberry in a hope that "…a marriage of fashion and technology will finally produce something really good."[25]

---

[21] Michael Molitch-Hou, "3D-Printed Dress Designer Goes Cloud Commercial," http://3dprintingindustry.com/2014/02/13/3d-printed-dress-designer-goes-cloud-commercial/, (Accessed February 25, 2014).
[22] Ibid.
[23] Francis Bitonti Studio Inc.,"Francis Bitoni Studio," http://www.francisbitonti.com/, (Accessed February 25, 2014).
[24] Beth Kowitt, "High Tech's Fashion Model," *Fortune*, June 11, 2012, 67-70.
[25] Kevin Maney, "What Would Steve Jobs Wear?," *Newsweek*, October 25, 2013, 1-4.

We can see the digital landscape changing the way fashion is created right before our eyes with the institution of these new manufacturing processes and advancements in new technologies. We are witnessing a transformation in the fashion and clothing manufacturing process with the advent of new CAD software that translates these digital instructions into automated steps performed by machines previously performed manually by hand. I am truly inspired and motivated by these new designers, companies and inventors of the new machines aforementioned that will once again change the way clothing is created and produced much like how Elias Howe and Isaac Singer did with the invention of the first sewing machine. It is for this reason I was similarly inspired to use and incorporate as much technology as possible into this thesis project and collection.

Methodology

As previously mentioned, the nature of this thesis project is to use software from the company Optitex to create clothing patterns digitally in the CAD software and then use 3D modeling to fit test the patterns against a 3D representation of a dress form. This is innovative because the CAD software and 3D modeling capabilities are relatively new to the fashion industry. Digital patternmaking has been available longer, but only recently has 3D modeling been available. As the industry leader in 3D capabilities, Optitex has only been in business since 1988; 3D modeling was available well after and has only recently become popular in the twenty-first century as faster processors and graphic video cards have made this more technologically feasible.[26]

[26] Optitex Ltd, "Optitex Design Your Future," http://www.optitex.com/, (Accessed, March 1, 2014).

The 3D model measurements were modeled after a size 8 PGM dress form.[27] It should be noted that the 3D model measurements do vary somewhat from the actual measurements of the dress form since the dress form is a rigid shape, whereas the software attempts to be intelligent and interpret the measurements input as they would exist in true human form. For example, one measurement for the waist and another for the hips will be constrained to a certain degree which would be reflective of a plausible human body; the software will not allow you to create a waist measurement proportionally smaller than that of the hip measurement. This may be an area of future research if indeed the clothing does have an issue with fit on the dress form as opposed to an actual model; a future test would use measurements from a fit model instead of a dress form.

Next steps included creating the digital patterns from the sketches and illustrations researched during the investigation phase of the project. Figure 3 displays an actual digital pattern created in the Optitex software and used in the creation of a garment for this project. Each pattern was created with acute attention to detail and revised multiple times in order to ensure correct seam allowance was given, pattern measurements matched opposite pieces and generally fit industry standard and accepted practices for sewing construction. Without ensuring and understanding these basic principles, the clothes could not be constructed properly in real fabric, much less modeled on a three dimensional model. Once the patterns were created sufficiently, digital sewing instructions were given in the program and the clothing was draped on the 3D model in the virtual environment. Figure 4 depicts the 3D modeling program and the fit analysis that can take place using the Optitex software as compared to the traditional muslin or real fabric prototype. One can see actual measurements of the 3D model compared to the

[27] PGM-Pro, Inc., "Ladies Full Body Form," http://www.pgmdressform.com/dress-form-ladies-full-body-forms-c1_32/ladies-full-body-form-industry-pro-605a-p400.html, (Accessed April 1, 2014).

measurement of the fabric draped around the body, and in addition, the software can also determine the percentage of stretch in the material. Also, it is possible to display a tension map to determine where the fitted areas are on the model determined in gram force centimeter which is a unit of surface tension.[28] Last, but not least, it is possible to draw lines and obtain measurements right on the 3D model to check an abstract measurement just as one would use a tape measure on a live model or on a real dress form.

My work is ultimately attempting to communicate that fashion design can be converted into digital instructions that virtually translate to real world clothing. Moreover, the principles are the same when constructing a garment in real fabric compared to a digital three dimensional plane so the process is the same but translated in a new medium essentially. The clothing produced as a result of this project is proof that those digital instructions can be understood and translated from a virtual environment to the real world environment.

Production & Analysis

My inspiration for the 'La Nuit' collection is derived from a previous mini collection. As seen in figure 5, the collection is intended to provide the viewer with a sense of dark sophistication, hard metallic objects, sharp lines, netted darkness, and glimmers of light with subtle, yet distinct curves. This imagery is intended to invoke feelings of darkness and weight as if the viewer was transported one hundred years into the future where robots are part of daily life and digital billboards are seen everywhere. The intended use for the garments are some purely art to wear on the runway or in a gallery, whereas others are ready-to-wear and could be seen in a nightclub, a night out on the town, an elegant sophisticated dinner and more.

[28] ANVICA Software Development, "Gram-Force/Centimeter," http://www.translatorscafe.com/cafe/EN/units-converter/surface-tension/3-1/gram-force%2Fcentimeter-newton%2Fmeter/, (Accessed April 30, 2014).

The first garment depicted in figure 6 is a wide-leg pant accompanied with a bustier or corset top. The wide leg pant is made with a black viscose knit fabric for a very smooth, soft feel and drape which contrasts with the hard, rigid shape and material used in the top. The bustier is constructed with a medium weight black stretch denim piped with pleather and embellished with fiber-optic fabric lit with a white LED light and powered by CR2032 batteries. Fiber-optic fabric is a fabric that "literally lights up…[and] is made from ultra-thin optical fibers, directly woven with synthetic fibers."[29] Both garments are fully-lined using a black posh polyester lining fabric for a clean finish from the interior of the garment. The pant includes a black invisible zipper and the top includes a #5 class silver aluminum bottom separating zipper for closure. The hem of the pant was sewn using a blind hem stitch and black polyester thread. The garment achieves the initial inspiration for the collection because the soft drape and movement of the fabric in the wide leg pant provides the dark sophistication contrasted with hard and sharp lines in the bustier top along with glimmers of light in the fiber-optic panel. One challenge in the construction of the garment was selecting the correct stabilizer or interfacing for the pants due to the soft drape of the fabric; some structure was required to hold up the waist of the pant properly so the under-stitch of the lining would fall properly behind the real fabric.

In figure 7, a hooded dress is depicted and was constructed mainly using a black stretch denim with black pet screen mesh see-through paneling in the arms along with pleather piping detail for edge finishing. The entire hood and dress is fully lined for a clean finish and comfortable wear. A front 27 inch #5 class double-separating zipper is the only glimmer of light

[29] LumiGram, "Luminous Fiber Optic Fabric," http://www.lumigram.com/catalog/P8_LUMINOUS_FABRIC.php?osCsid=jcqp4145pvfsbsrord8un13786, (Accessed April 26, 2014).

in this piece as it provides a metallic silver finishing effect.[30] Out of the collection, this is one of two garments that does not have any direct lighting effects. The garment does fit the inspiration of the collection because the mesh paneling achieves a netted darkness effect along with the hood of the dress providing the weight and darkness feelings. One thing I would change in this look is to increase the size of the hood. Draping the hood purely in digital form and on the 3D model did not give me a full sense of the volume the hood would carry so this is simply something to keep in mind when designing with digital media and that is to consider volume and take more time during the fit analysis step to ensure proper sizing.

Figure 8 displays a fiber-optic lighted sheath dress. The dress is constructed of black stretch denim, black pet screen mesh paneling, pleather finishing and a large fiber-optic panel lit by two white LED lights and powered by two AAA batteries. Additionally, the garment is fully-lined for a clean finish using black posh polyester lining fabric that is also necessary to disguise the large fiber-optic panel from the wearer and a smooth finish against the body. For closure, a 36 inch #5 class two-way silver aluminum zipper is inserted in the back of the dress.[31] In order to fit the inspiration of the collection, the dress provides see-through in the mesh paneling, darkness in the fabric color choice, weight in the stiffness of the black stretch denim and sophistication and glimmers of light in the large lighted panel in the front. This particular garment does have some fit issues that are primarily the result of incorporating such a large fiber-optic panel that did not allow for proper darts or princess style lines to be sewn in to fit the garment better to the dress form. If I had to do this garment over, I would construct the pattern in a simple bodice top with no attempt to conform to the curvature of the dress form or body

[30] ZipperShipper.com, "Two-Way (Double or Dual) Zippers," http://www.zippershipper.com/two-way-double-or-dual-zippers, (Accessed April 24, 2014).
[31] Ibid.

because the initial requirement of incorporating the lights forces the pattern creation in a different direction than purely accurate fit.

In figure 9, one can see a fitted stretch pant along with a fiber-optic lighted bodice top. The pants are constructed of a moleskin rough fabric which is primarily a nylon fabric that provides a lot of stretch in the material. The pant also incorporates stretch pleather in two large panels in the front for contrast along with two #5 class 5 inch long aluminum zippers at the ankle for additional visual interest. The bodice top is constructed mainly with a medium weight black stretch denim, stretch pleather for edge finishing and a long, slim fiber-optic panel lit by a white LED light and powered by two CR2032 batteries. For closure the bodice top includes a #5 class heavy jacket separating zipper and the pant includes a #5 class 6 inch long closed bottom aluminum zipper at the center back. The bodice top is fully lined with a black posh polyester lining fabric for a clean finish and it also hides the fiber-optic lighted panel from the wearer for a smooth feel against the body. There is a slight curve in the design of the stretch pleather when stretched around the front leg to provide a subtle and yet distinct curve as the inspiration suggests. Additionally, the garment achieves the collection inspiration by bringing in the glimmers of light in the fiber-optic lighted panel in the bodice top and the weight of darkness with the color choice and variation in the pieces along with a little sophistication in the overall look and different textures contained in the garment.

There was one challenge with the fit of the stretch pant in this garment because it was the first garment taken from the three dimensional program and constructed in real fabric and while the program drapes the fabric onto the form flatly it does not account for a real human being having to pull the stretch pant up over the body. It is up to the designer to take this information into account so given this as my first test in using the software, I would need to include

additional ease in the stretch material to allow proper fitting of the stretch material without having to insert a zipper in the center back. Additionally, the stretch pleather did not stretch as much as anticipated, so that further complicated the stretch pant design whereas an entire pant made of the moleskin rough fabric would have fit perfectly fine without requiring zipper placement.

The signature piece of the collection is depicted in Figure 10 of the appendix which displays a LED lighted bustier dress. This dress is constructed of black stretch denim and black stretch pleather hem finishing along with a 36 inch long by 3 inches wide LED light series and powered by 8 AA batteries. The interior of the garment is lined with a black posh polyester fabric for a clean finish, smooth feel against the body and to mask the light strip and construction details. In the front, the LED light strip is covered with 8 gauge vinyl to provide a protective layer against the technology but can be seen perfectly through the clear material. LED strip lights are a relatively new technology and are sold on the internet by many companies.[32] While the technology is readily available and can be purchased easily on the internet, incorporating such technology into clothing requires a great deal of skill and understanding by the designer, not to mention technical troubleshooting of wiring, circuits and bonding the lights to the fabric in some fashion.

This signature piece aligns to the inspiration of the collection primarily because of the glimmers of light and it provides the viewer with an idea of people walking around with digital effects in their clothing as commonplace in the future. This is the one garment that could be seen in a stage production show or a concert because of the illuminated nature of the garment and the effect it provides the viewer. The controller for the lights can even run different patterns and

[32] HitLights, "HitLights; Sustainable, Affordable LED Lighting," http://www.hitlights.com/, (Accessed April 26, 2014).

colors of light depending on wearer preference and even change according to the input of sound or music. Similar garments have been featured in recent times by Hollywood stars in award shows and on the red carpet. One example is Carrie Underwood at the 2013 Grammy award show where she wore a dress that had a visual video effect projected onto the garment as Carrie specifically stated she wanted "…to be artful and dramatic…[and provide] something visually attention-capturing."[33] Another example is Kanye West performing at the Grammys in 2008 with a LED lighted jacket.[34]

In order to construct the garment I used the standard process of an outer layer for the finished fabric, an inner layer for the understructure and a lining layer all stitched together at the top and under-stitched in the lining layer to pull the lining down from being visible from the front of the garment. In the understructure of the garment I had to interface the fabric heavily to support the LED light panel, controls and battery pack. I did not want the shape to have a box form so I used medium weight interfacing to still provide the contour and fit in the bustier top in the understructure and where the LED lights sit, I used a pet screen polyester mesh fabric to act as a stabilizer (i.e. the fabric was rigid and would not move). I used 3M double-sided tape to stick the lights onto the pet screen fabric and in hindsight I would have even used a strong glue to provide extra strength to hold the lights in place although gluing the lights down does truly mean the garment can never be washed which would force the piece to be a gallery-only display piece. The current setup does allow for the lights to be removed but not easily. One challenge was the weight of the battery pack so as soon as it is inserted into the hidden pocket on the inside understructure of the garment it starts to pull the fabric everywhere so the hem can look

[33] Melody Chiu, "Carrie Underwood's Glowing Grammys Dress: All the Scoop," http://stylenews.peoplestylewatch.com/2013/02/11/carrie-underwood-grammy-dress-theia/, (February 11, 2013).
[34] Julia Unknown, "Kanye West features LED jacket during Grammy Award," http://www.talk2myshirt.com/blog/archives/416, (February 12, 2008).

distorted. The battery power of the lights would need to be smaller or weigh less to achieve better drape of the hem or the entire hem of the garment would need to be interfaced and stiff to provide the control necessary for an even hem drape. Another challenge was dealing with short circuiting of the series of LED lights; some of the connections were not working as expected and further troubleshooting and purchasing of more light strips would have helped this issue in a real production scenario.

A circle skirt paired with a rope necklace top is depicted in figure 11. The skirt is constructed of black georgette as the top layer of fabric and lined with a black/silver metallic rayon/lurex blend, which is visible through the georgette. The two different textures provide a shiny silvery black sheen and the movement of one layer over the other provides subtle glimmers of light consistent with the initial inspiration. An invisible zipper is used for closure and one half an inch of mesh pet screen fabric was woven into the seam joining the top layer of fabric to the lining as a stabilizer around the waist. Additionally, an under-stitch helps the lining fabric fall underneath the top layer of fabric so it is not readily visible to the viewer. Both hems are finished with a rolled hem considering the lightweight semi-transparent material. The rope necklace top is made out of 5/8" thick black polypropylene rope, 7/8" wide nickel plated washers, 5/8" wide zinc plated steel spacers, .032 mm thick aluminum sheet metal, aluminum clasp closures, 1/4" wide black and silver link chain and industrial grade adhesive all purchased from the hardware store.[35] Again, the mood of this look fits the initial inspiration because there are glimmers of light in the metallic silver fabric that is visible through the black georgette and in the metal the rope necklace is constructed with. Also, the drape of the combination of fabrics in the circle skirt provide the viewer with a sense of the darkness in the color of the fabrics and

[35] Lowes, "Blue Hawk 5/8-in Braided Polypropylene Rope (By-the-Foot)," http://www.lowes.com/pd_349188-258-BKSBP582BK_0__?productId=3613924, (Accessed April 26, 2014).

sophistication in the movement. Additional sophistication is extracted from the notion that the wearer has no other visible top other than a rope necklace which is sure to grab attention. Lastly, the rope necklace has a subtle and yet distinct curve that fits neatly around the chest of the body.

Figure 12 depicts one accessory for the collection that was created to be worn around the neck in either the bustier top and wide leg pant or the bustier light dress for additional visual interest in the neckline. The accessory is made out of the same materials as the rope necklace shown in figure 11 and described above. This piece was created above and beyond the original collection of 6 garments and as a display of mastery in related fashion topics and different materials than just fabric and lighting. The piece also helps to build the viewer's mood towards the initial inspiration of dark sophistication, glimmers of light and subtle, yet distinct curves. This is accomplished by the definitive silver metallic lighting elements coming from the hardware store along with the darkness portrayed in the black braided rope that was further braided itself three times to give curvature for an eye-pleasing silhouette around the neck.

Conclusion

The objective of this thesis project, designing with digital media and attempting to replace the muslin/prototype step, was ultimately successful. I was able to create six garments digitally in the Optitex software program, model/drape those garments in 3D, fit test each of the garments in 3D and replicate the same digital sewing instructions in real fabric with each garment fitting the dress form. The caveats and difficulties of the thesis project are two-fold. First, incorporating digital media in the form of LED and fiber-optic light panels proved to distort the pattern creation for garments away from truly conforming to the curves of the body. Until technology exists that can be seamlessly woven into the fibers of fabric, only basic shapes and patterns can be used to incorporate these types of lighting without fitting the curves of the

body. Secondly, the three-dimensional draping process does not appear to support Avant-Garde designs with a lot of fabric manipulation and abstract pattern creation without extensive time-consuming trial-and-error troubleshooting in the software that could otherwise be performed draping manually by hand more efficiently. For couture applications and designs, it is probably best to continue draping those higher-end garments by hand for a better custom and one-of-a-kind fit and feel. Additionally, the software is not capable of draping hard accessory objects such as those depicted in figures 11 and 12. Keep in mind that the aforementioned observations are purely my opinion at this point in time having used the software for around seven months by self-training and with limited help from expert professionals using the same or similar software.

My thesis project contributes to the fashion design discipline because it is a representation of the previously discussed combination of technology and fabric which is an emerging concept in the industry. I accomplished this combination in two different and distinct ways. In one way, I combined the old or current method of manufacturing clothes from patterns made using real cloth with a new concept where the patterns were created digitally first and modeled in 3D for fit testing instead of manually draping by hand. Secondly, I created a new fabric, one where LED lights were used to replace where fabric traditionally would have been placed in garments. In essence, I am combining traditional methods of garment creation with new methods of manufacturing and new technologies now available on the market. All industries go through cycles of growth and change; I am simply exploring, testing and validating these new methods and technologies that may ultimately take the place of the traditional/old methods used today.

The strengths of the project include the methods in which the collection was produced by starting with new three-dimensional modeling technologies and digital patterns to create the

garments. An additional strength in the project is the incorporation of recently available LED lighting technology and fiber-optic fabric as lighting and technological effects into the created garments. Resources such as a 3D body scanner, plotter, digital cutter and software training were a limitation of the research.

The new knowledge of this thesis project does relate to existing research, in that, it is possible to create digital patterns, model them on three-dimensional avatars and customize measurements according to different body types on those three-dimensional avatars.[36] The patterns used in other research studies were of simple form including a basic jacket pattern; clothing items that people are typically accustomed to wearing. There is no research to support any Avant-Garde pattern designs modeled in industry CAD modeling programs that works effectively so this is an area yet to be tested. Company statements in the field do state that rigid objects in other industries such as car seats, handbags, purses and more can be designed and modeled in 3D but I have not found specific research proving this other than company testimonials of the product.[37]

After the completion of this degree, my plan is to start an online fashion company. It will take a few years to put all the pieces together but my future area of research will be directed specifically to putting those components together for a successful business venture. Other future areas of research include working with three-dimensional printers as a substitute for garments created from fabric, using digital pattern creation to electronically cut out fabric and using machines to stitch garments together; all future advancements in technology soon to come to the fashion industry at large. Additionally, I plan to spend time removing the initial requirement of

[36] Ho Sun Lim, "Three Dimensional Virtual Try-on Technologies in the Achievement and Testing of Fit for Mass Customization," 2009.
[37] Optitex Ltd, "Optitex Design Your Future," http://www.optitex.com/, (Accessed, March 1, 2014).

designing garments with embedded technological lighting effects and focus on using three-dimensional modeling software and body scanning to achieve accurate fit compared to draping manually using muslin as the primary focus of the research.

In sum, the thesis project is an overwhelming success considering the challenges and circumstances as a whole. More time spent refining the knowledge and pushing the software to its true limit will expound on the new information and technology. Throughout history and time, clothing was made and manipulated with the tools and the technologies available at the time and as those same tools and technologies improved and became more powerful, the clothing improved; it fit better, more complex patterns were possible, new fabrics were created, different fabric manipulations were possible and more. The first sewing machine was invented in 1844 and revolutionized the way clothing was made and produced; since then the industry has moved towards industrialization and mass production.[38] Generally speaking and in my opinion, the subject of fashion in the last century and a half has been about one fabric choice versus another, one style-line versus another, one stitch versus another with cycles of clothing repeating and only slight changes here and there all encompassed in the capabilities of one small technology; the sewing machine. I believe the industry has not seen revolutionary new technology like the sewing machine in over one-hundred fifty years and only now are we seeing new technologies on the horizon that could do what the sewing machine did to clothing production in the nineteenth century, now in the twenty-first century. Given my previous technological expertise along with my newfound education in the discipline of fashion, it is these new tools and technologies I hope to explore and master to help usher in a new age of fashion in the twenty-first century.

[38] Susan Rhoades Neel, *Garment History*, 2014.

Appendices

Table 1 – CAD Software Company Comparison Matrix

Industry Fashion CAD Software Comparison Matrix										
			Company							
#	Item Description	Weight	Optitex	Weighted	Gerber	Weighted	Lectra	Weighted	Tukatech	Weighted
1	Company is currently in business and offers fashion CAD software products to the public	3	3	9	3	9	3	9	3	9
2	Timeliness in response to customer inquiries	2	3	6	1	2	2	4	0	0
3	CAD Pattern Design software available	3	3	9	3	9	3	9	3	9
4	CAD Grading software available	3	3	9	3	9	3	9	3	9
5	CAD Made to Measure Rule Based Pattern Design Software available	2	3	6	3	6	2	4	3	6
6	CAD Marker Making capabilities	3	3	9	3	9	3	9	3	9
7	CAD Smart Marker Making based on pattern repeat capability	2	3	6	3	6	3	6	3	6
8	Ability to scan a paper pattern into digital form	3	3	9	3	9	0	0	0	0
9	Ability to use a picture to digitize a paper pattern	1	0	0	3	3	0	0	0	0
10	Ability to create patterns in 3D	1	3	3	3	3	1	1	3	3
11	Ability to take 3D patterns and convert into 2D	1	3	3	3	3	1	1	3	3
12	Ability to convert 2D patterns on a 3D body form	2	3	6	3	6	3	6	3	6
13	Ability to assimilate 3D body scan data into a digital avatar	2	3	6	2	4	2	4	2	4
14	Ability to create own mannequin based on user data input for use in 3D scenarios	3	3	9	2	6	2	6	2	6
15	Ability to simulate 3D fabric drape	1	3	3	2	2	2	2	2	2
16	Student software rental program	1	2	2	0	0	0	0	3	3
17	Company sells plotters or has plotting service	1	0	0	3	3	3	3	3	3
18	Company sells fabric spreaders or has fabric spreading service	1	0	0	3	3	3	3	0	0
19	Company sells fabric cutting machines or has cutting services	1	0	0	3	3	3	3	0	0
20	Company offers Computer Cafes with equipment and software available to end-users	1	0	0	0	0	0	0	3	3
21	Company sells 3D body scanner	1	0	0	0	0	0	0	2	2
22	Company offers product lifecycle management software	2	0	0	3	6	3	6	2	4
23	Company offers Color Recution, Knit/Weave creation, and Repeat design software	2	0	0	3	6	3	6	2	4
24	Number of users of the software across the globe	3	3	9	3	9	3	9	2	6
25	Software allows export of files to multiple other systems for use in downstream systems	2	3	6	3	6	3	6	3	6
26	Software Windows 7 & 8 compatible	3	3	9	3	9	3	9	3	9
27	Software Ease of Use	2	3	6	3	6	3	6	3	6
28	Company Website	3	3	9	3	9	2	6	2	6
29	Company help website/training material/YouTube Channel	2	3	6	2	4	2	4	2	4
30	Company sponsored webinars	2	3	6	2	4	1	2	2	4
31	Software Cost	3	2	6	1	3	1	3	3	9
32	Software Lease to Own Option or Rental Option	1	3	3	0	0	0	0	2	2
33	Software Training Cost	3	3	9	1	3	1	3	3	9
34	Software Support Fees	3	2	6	2	6	2	6	2	6
	Total:	69	75	170	78	166	66	145	75	158

Fashion CAD Companies

Legend
Weight
3 = Very Important
2 = Key
1 = Desirable
Fit
3 = Good Match
2 = Satisfactory
1 = Minimal
0 = No Match

Source: Adima Cope, *Industry Fashion Computer Aided Design Software* (Lindenwood University, June 2013).

Table 2 – Optitex Fashion Technology Company SWOT Analysis

Optitex

Strengths	Weaknesses
• Best CAD Patternmaking Tools on the Market • Best 3D Tools on the Market • Only Company that offers Lease to Own Software • Best company free webinar offering • Only company that offers free open access online help/knowledgebase • Best 3D Draping/Visualization Tools • Can Design/Create Patterns in 3D • Company focus is geared towards CAD research	• Is not a large public company with large pools of resources/funds • Does not have Product Lifecycle Management (PLM) tools • Does not have plotter, fabric cutting or spreading technologies • Only specializes in CAD Patternmaking & 3D software tools in the fashion industry • Has to export to outside formats for production
Opportunities	**Threats**
• Fashion Product Lifecycle Management (PLM) software capabilities • Can provide suggestions for future improvement of tools potentially suited for business/research needs • In-depth research can be performed given the breadth and number of software modules and capabilities offered in the apparel arena	• Equipment companies could decide to change file formats they accept for production tools • Investing large amounts of money in CAD software with a smaller private company could be seen as a risk • Larger companies could close the knowledge gap or software capability gap Optitex currently holds thereby making them obsolete

Source: Adima Cope, *Industry Fashion Computer Aided Design Software* (Lindenwood University, June 2013).

Table 3 – Gerber Fashion Technology Company SWOT Analysis

Gerber	
Strengths	**Weaknesses**
• Oldest and second largest company in the Apparel CAD marketplace • Serves more than 100 Fortune 500 companies • Most comprehensive apparel CAD company; provides professional CAD software and the equipment to print, cut, spread fabric and sells related production technologies • Heavily used in large corporate apparel companies	• Large public company; potential red tape and slow response times • Costly software products at $3 - $10K plus per module per license and no rental or lease-to-own program • Costly and time-intensive training • No self-service training • Information not as readily available/accessible
Opportunities	**Threats**
• Dedicated representatives for faster response times • Relationship product manager where software improvements and ideas can be assimilated quickly from user community • Needs student software rental program • Needs software rental/lease-to-own program	• Large public company red tape does not allow research and design ideas from community to keep pace with other companies • Would not be used by smaller companies with limited budgets

Source: Adima Cope, *Industry Fashion Computer Aided Design Software* (Lindenwood University, June 2013).

Table 4 – Lectra Fashion Technology Company SWOT Analysis

Lectra

Strengths	Weaknesses
• Largest Fashion CAD company in the market • Only apparel CAD company publicly traded on NYSE • Has state-of-the-art cutting rooms and technologies available in partnership with the company	• Expensive software at around $6 - $10K per module per license and no rental or lease-to-own program • Costly training • Relatively new to the 3D design process as of March 2013 • Minimal webinars/tutorials on software use • Website not organized neatly; not easy to find information on products and capabilities
Opportunities	**Threats**
• Needs student software rental program • Needs software rental/lease-to-own program • Needs better help website/documentation • Tools could be updated/brought up-to-date with offerings currently on the market	• Company too large to keep pace with smaller niche companies in apparel CAD software products • Would not be used by smaller companies with limited budgets

Source: Adima Cope, *Industry Fashion Computer Aided Design Software* (Lindenwood University, June 2013).

Table 5 – Tukatech Fashion Technology Company SWOT Analysis

Tukatech

Strengths	Weaknesses
• Smaller and newer company but very specialized in apparel CAD software • Only company to offer a 3D body scanner • Offers 13 Tuka Computer Labs with software, equipment and training available to anyone for apparel production capabilities (2 located in U.S. – LA & NY) • Cheapest apparel CAD software on the market • Cheapest software rental program on the market	• Is not a large public company with large pools of resources/funds • Slow response times for customer inquiries • No pattern digitizing technology found on website
Opportunities	**Threats**
• Pattern digitizing from paper to computer capability is needed • 3D body scanner Styku is integrated into CAD patternmaking product • Lowest cost professional CAD products available could be used by many start-up companies	• Smallest and newest of the four apparel CAD companies; could be overtaken by other niche market leaders or larger companies • Lesser known company in the apparel CAD marketplace

Source: Adima Cope, *Industry Fashion Computer Aided Design Software* (Lindenwood University, June 2013).

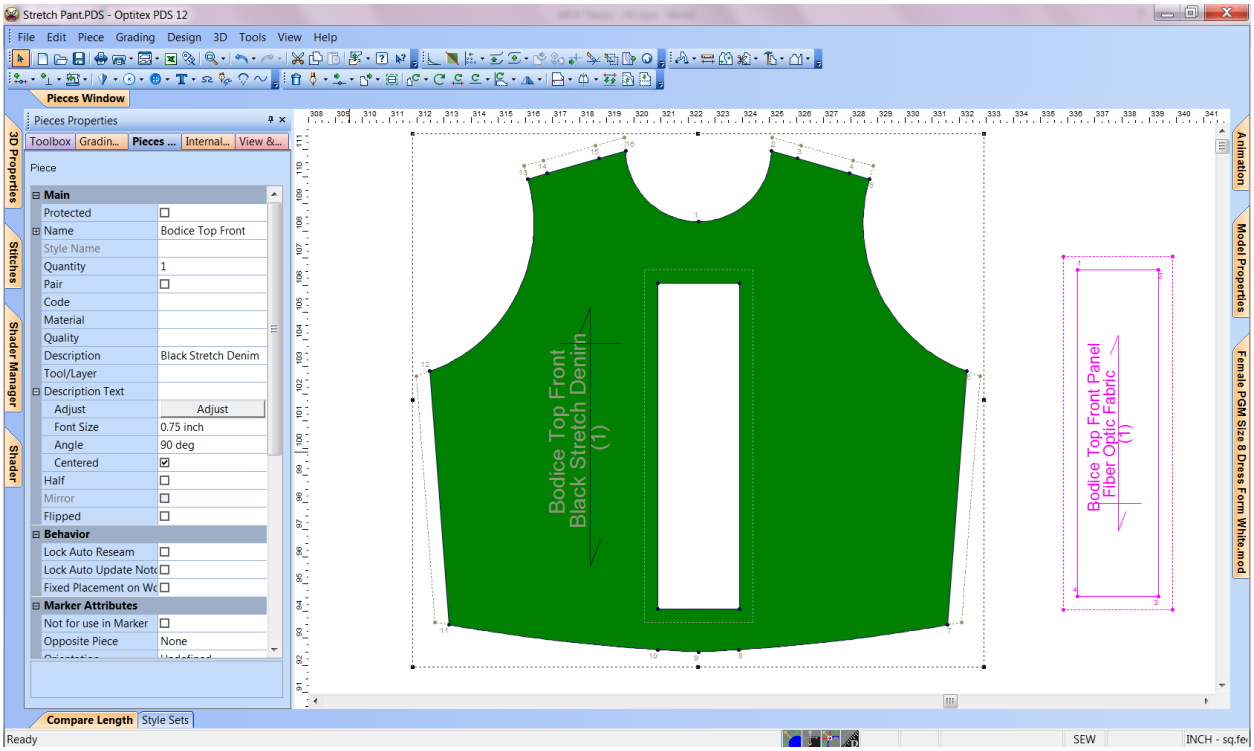
Figure 1 – Open-Knit Digital Clothing Printer Machine

Source: Gerardo Rubio, *Made in The Neighbourhood* (vimeo.com/user769878, 2014).

Figure 2 – Dita von Teese 3D Printed Gown

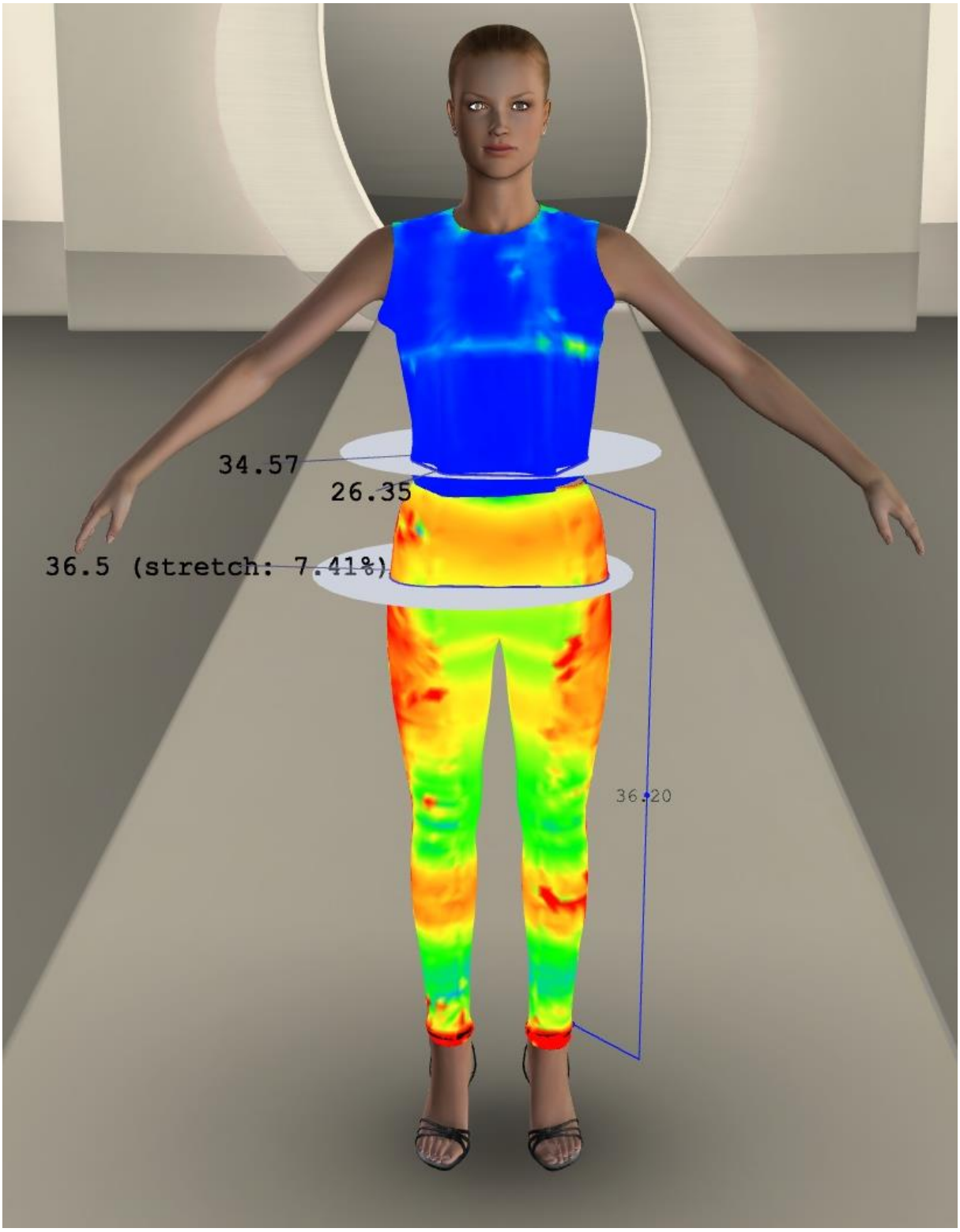
Source: Francis Bitoni, *Dita von Teese 3D Printed Gown* (francisbitoni.com, 2013).

Figure 3 – La Nuit Garment Digital Pattern Example



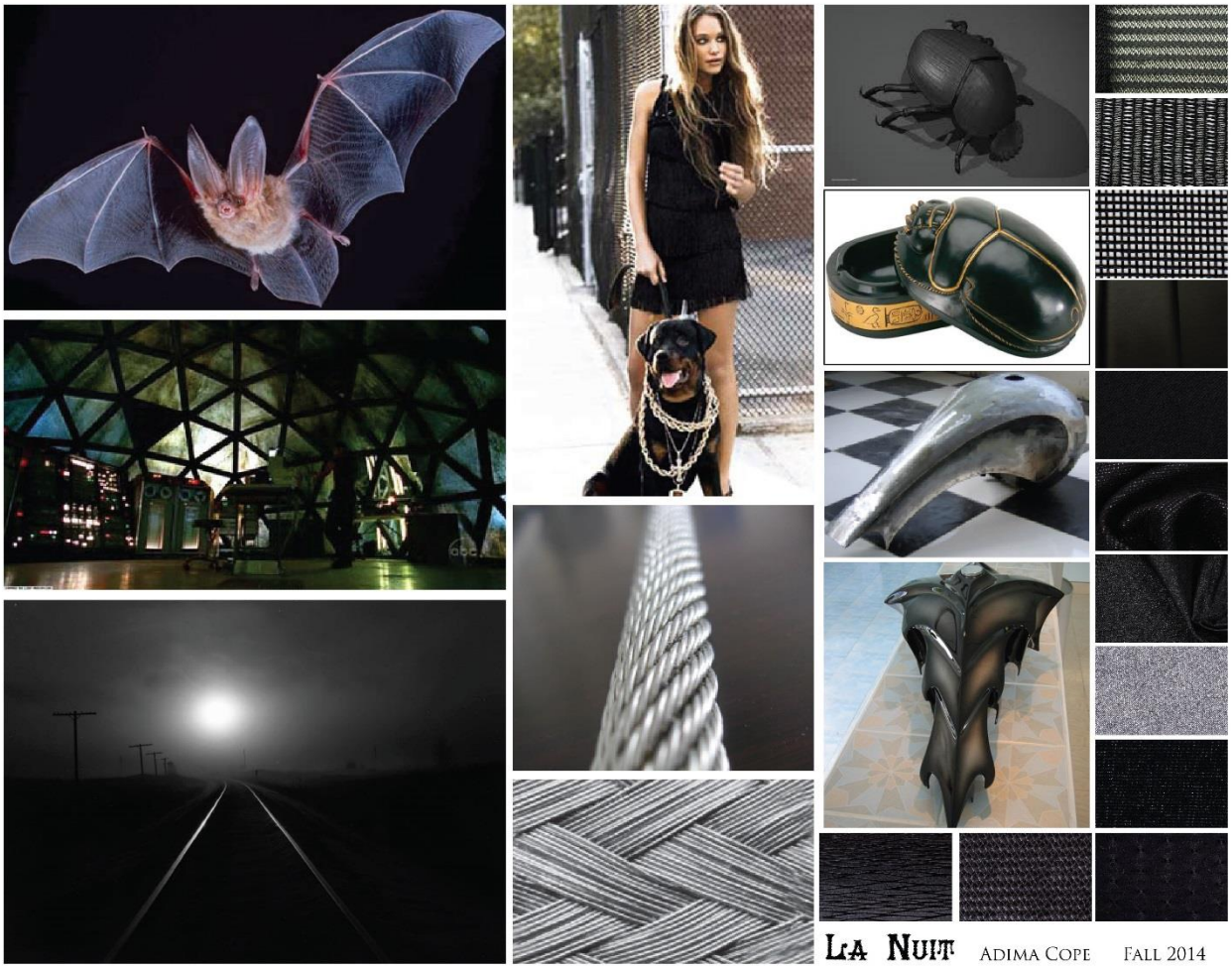
Source: Adima Cope, *La Nuit Collection* (Lindenwood University, Spring 2014).

Figure 4 – La Nuit 3D Modeling Fit Analysis Example



Source: Adima Cope, *La Nuit Collection* (Lindenwood University, Spring 2014).

Figure 5 – La Nuit Mood Board



Source: Adima Cope, *La Nuit Collection* (Lindenwood University, Spring 2014).

Figure 6 – La Nuit 3D Prototype & Real Fabric - Garment 1

Source: Adima Cope, *La Nuit Collection* (Lindenwood University, Spring 2014).

Figure 7 – La Nuit 3D Prototype & Real Fabric - Garment 2

Source: Adima Cope, *La Nuit Collection* (Lindenwood University, Spring 2014).

Figure 8 – La Nuit 3D Prototype & Real Fabric - Garment 3

Source: Adima Cope, *La Nuit Collection* (Lindenwood University, Spring 2014).

Figure 9 – La Nuit 3D Prototype & Real Fabric - Garment 4

Source: Adima Cope, *La Nuit Collection* (Lindenwood University, Spring 2014).

Figure 10 – La Nuit 3D Prototype & Real Fabric - Garment 5

Source: Adima Cope, *La Nuit Collection* (Lindenwood University, Spring 2014).

Figure 11 – La Nuit 3D Prototype & Real Fabric - Garment 6

Source: Adima Cope, *La Nuit Collection* (Lindenwood University, Spring 2014).

Figure 12 – La Nuit Accessory 1

Source: Adima Cope, *La Nuit Collection* (Lindenwood University, Spring 2014).

Bibliography

ANVICA Software Development. January. *Gram-Force/Centimeter.* 1 2014. Accessed April 30, 2014. http://www.translatorscafe.com/cafe/EN/units-converter/surface-tension/3-1/gram-force%2Fcentimeter-newton%2Fmeter/.

Apparel Design Partners. 2014. *Prototyping.* January 1. Accessed April 1, 2014. http://www.appareldesignpartners.com/?page_id=105.

Casima, Ryan. 2009. *The Use of CAD in Fashion Designing.* January 1. http://www.ehow.com/way_5752123_use-cad-fashion-designing.html.

Chiu, Melody. 2013. *Carrie Underwood's Glowing Grammys Dress: All the Scoop.* February 11. Accessed April 26, 2014. http://stylenews.peoplestylewatch.com/2013/02/11/carrie-underwood-grammy-dress-theia/.

Diamond, Giselle. 2012. *Importance of CAD in Fashion Designing.* January 1. Accessed 1 2014, April. http://www.ehow.com/about_5344814_importance-cad-fashion-designing.html.

Dollinger , André. 2012. *Ancient Egyptian Clothing.* August 1. Accessed March 22, 2014. http://www.reshafim.org.il/ad/egypt/timelines/topics/clothing.htm.

Francis Bitonti Studio Inc. 2014. *Francis Bitoni Studio.* January 1. Accessed February 25, 2014. http://www.francisbitonti.com/.

Gerber Scientific, Inc. 2013. *Gerber Technology Fast Facts.* January 1. http://www.gerbertechnology.com/en-us/aboutus/fastfacts.aspx.

History.com Staff. 2011. *Invention of the PC.* January 1. Accessed March 23, 2014. http://www.history.com/topics/inventions/invention-of-the-pc.

HitLights. 2014. *HitLights; Sustainable, Affordable LED Lighting.* January 1. Accessed April 26, 2014. http://www.hitlights.com/.

Kowitt, Beth. 2012. "High Tech's Fashion Model." *Fortune, Vol. 165 Issue 8*, June 11: 67-70.

Lectra. 2013. *About Us.* January 1. http://www.lectra.com/en/about-lectra/business-activity.php.

Lim, Ho Sun. 2009. *Three Dimensional Virtual Try-on Technologies in the Achievement and Testing of Fit for Mass Customization.* Raleigh, North Carolina: North Carolina State University.

Lombardi , Candace. 2007. *CAD Software is the New Black.* December 7. http://news.cnet.com/CAD-software-is-the-new-black/2100-1012_3-6221810.html.

Lowes. 2014. *Blue Hawk 5/8-in Braided Polypropylene Rope (By-the-Foot).* January 1. Accessed April 26, 2014. http://www.lowes.com/pd_349188-258-BKSBP582BK_0__?productId=3613924.

LumiGram. 2014. *Luminous Fiber Optic Fabric.* January 1. Accessed April 26, 2014. http://www.lumigram.com/catalog/P8_LUMINOUS_FABRIC.php?osCsid=jcqp4145pvfsbsrord8un13786.

Maney, Kevin. 2013. "What Would Steve Jobs Wear?" *Newsweek Global, Vol. 161 Issue 38,* October 25: 1-4.

Molitch-Hou, Michael. 2014. *3D-Printed Dress Designer Goes Cloud Commercial.* February 13. Accessed February 25, 2014. http://3dprintingindustry.com/2014/02/13/3d-printed-dress-designer-goes-cloud-commercial/.

Neel, Susan Rhoades. 2013. *Utah State University - HIST1700 - Garment History.* January 1. Accessed March 23, 2014. http://www.srnteach.us/HIST1700/html/projects/unit3/popups/readings/garment.html.

Optitex Ltd. 2013. *Optitex Design Your Future.* January 1. http://www.optitex.com/.

Petty, Geoff. 1997. *How to be Better at Creativity.* January 1. Accessed February 2, 2014. http://www.greenfields.u-net.com/docs/inspiration.html.

PGM-Pro, Inc. 2014. *Ladies Full Body Form.* January 1. Accessed April 1, 2014. http://www.pgmdressform.com/dress-form-ladies-full-body-forms-c1_32/ladies-full-body-form-industry-pro-605a-p400.html.

Roach, Mary Ellen, and Joanne Bubolz Eicher. 1979. "The Language of Personal Adornment." *The Fabrics of Culture: The Anthropology of Clothing and Adornment* 7-21.

Sher, Davide. 2014. *Is Digital Knitting a form of 3D Printing?* February 24. Accessed February 25, 2014. http://3dprintingindustry.com/2014/02/24/digital-knitting-form-3d-printing-whether-yes-great-potential/.

Suntex Industry Group. 2013. *How Seamless Garment Manufacturing Technology can be used in Garment Manufacturing.* September 19. Accessed March 23, 2014. http://www.thesourcingplace.com/seamless-garment-manufacturing-technology/.

Swallow, Erica. 2011. *The Science Behind Airport Body Scanners.* November 17. Accessed April 1, 2014. http://mashable.com/2011/11/17/tsa-body-scanner/.

Tukatech Inc. 2013. *Tukatech.* January 1. http://www.tukatech.com/.

Unknown, Julia. 2008. *Kanye West features LED jacket during Grammy Award.* February 12. Accessed April 26, 2014. http://www.talk2myshirt.com/blog/archives/416.

ZipperShipper.com. 2014. *Two-Way (Double or Dual) Zippers.* January 1. Accessed April 24, 2014. http://www.zippershipper.com/two-way-double-or-dual-zippers.