ABSTRACT

WEIQI, ZHANG. An Exploratory Study of the Application of Laser Technology to Dress Design. (Under the direction of Dr. Traci A. M. Lamar).

The purpose of this research was to explore and classify dress designs created using laser technology. The research methods used in this project included review and analysis through literature review, content analysis of visual artifacts, analysis of survey responses, and subjective evaluation. Literature was reviewed to assess the state of the art and to gain expertise on defining categories for dresses made using laser technology. An image database that consisted of 403 pictures of fabrics and garments involving use of laser technology was established. Initial research steps were undertaken to develop a reliable system of classification and observation for dresses created using laser technology. Later steps in this research were targeted at verifying and refining the categorization system through collecting survey responses and analysis of the survey data. Results demonstrated effectiveness in general in classifying laser treated dresses and also served to further refine the defining characteristics for each category. The final classification system includes three broad categories: Dress Silhouettes, Surface Pattern Effects, and Primary Final Applications, and a number classifications within each category. Within the category of Dress Silhouettes, the classifications established were Trapezium, Calabash and H-Shape Silhouette; within the category of Laser Surface Pattern Effect, the classifications established were Lace and Hollow-out, Laser Engraving, Cutting and Recombining, and Combination of Hollow-out and Engraving; within the category of Primary Final Application, the classifications established were Primarily Decorative and Primarily Functional.

This research provided an improved understanding of the application of laser technology to dress design. Results can applied to guide the use of fabric laser technology for
dress design as well as other textile and fashion applications, delineate the impact that laser application has had on fabrics and textiles, and as a framework for further study of laser application to fashion products. Also, the system of classification developed in this work can be used as a tool for analyzing dresses designed using laser technology. Fashion design beginners and professionals may use it as a reference to analyze or design a dress using laser technology. The categories also provide a foundation for further research.
An Exploratory Study of the Application of Laser Technology to Dress Design

by
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DEDICATION

Dedicated To

My Parents

Wenyuan Zhang & Xiaohong Zhang

For always supporting and encouraging me to do my best
BIOGRAPHY

Weiqi Zhang was born on May 25, 1992, in Inner Mongolia province, People’s Republic of China. In 2011, he became an undergraduate student in Donghua University in Shanghai, China. In his senior year of college, he had a chance to participate the 3+X program that is cooperatively offered by Donghua University and North Carolina State University. Following completion of an undergraduate degree in textile engineering from Donghua University, Weiqi was admitted to the Textile and Technology Management program at NCSU. In the master program, Weiqi worked as a teacher assistant in laser cutting lab. His current interests include surface pattern design, textile design and fashion product development.
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CHAPTER 1 INTRODUCTION

Fabric laser cutting is an important technology to the future of fashion and textile design (Bogue, 2015; Gao et al., 2006). Since it has been used in fashion and textile companies, the pace of its development has become faster and faster (Bogue, 2015; Gao et al., 2006). Laser application to textile materials creates new opportunities like laser cutting, laser marking, and laser engraving for fashion and textile design (Hengyin, 2007; Yuan et al., 2012). In fashion and textile design areas, fabric laser cutting and laser engraving are gradually being adopted by fashion and textile designers (Hengyin, 2007; Yuan et al., 2012). Though the potential of laser application in textile and fashion design is significant, it hasn’t been fully exploited by fashion and textile designers because of existing problems like the unguaranteed and uncontrolled durability of some fabrics, optimization of carving parameters, and limited knowledge about the design process and the application of the laser cutting technology (Hengyin, 2007; Yuan et al., 2012). Therefore, the full potential of laser cutting technology in fashion and textile design fields has yet to be explored.

Women’s dresses comprise a large part of clothing market (Sarkar, 2010). Even though the rate of new dress designs is climbing higher and higher, designers never stop exploring and developing new ideas (Sarkar, 2010). As a new technology, laser cutting can facilitate introduction of novel textile and fashion designs. A framework for understanding
the impact of laser application to textile and fashion products could inform the work of artists and designers, academicians and practitioners alike.

1.1 Purpose of Study

The use of laser technology can expand the possibilities available to designers, meaning that fashion design may possibly become more innovative and flexible (Hengyin, 2007; Yuan et al., 2012).

Laser technology is and has been appearing in haute couture and high-end fashion (Hengyin, 2007; Yuan et al., 2012). However, the rest of clothing market has yet to broadly adopt this new technology when creating new designs (Jie & Ripeng, 2015). This could be in part because there are few references or guides about how to effectively make use of laser technology for fashion design (Jie & Ripeng, 2015). For example, how to create and position the surface pattern so that it can meet the requirements of this technology, and what designers should pay attention to when they make a new design using laser technology.

This research is focused on exploring and classifying dress designs made using CO2 laser technology, which is a laser based on the carbon dioxide gas mixture (Yanabu, et al., 1989; Patel, 1964). First, an image database that includes hundreds of pictures of garments made using laser techniques was established. Next, through visual analysis of the image database, categories were defined. According to the results, a series of fashion designs were
made and some existing images were selected from the image database. Then a survey will be used to verify or redefine categories. Categories were defined by dress silhouettes, surface effects with the surface patterns, and primary final applications. Finally, the research will generate and summarize a completed procedure which can show the whole process of designing a dress using laser technology.

The results aim to guide the use of laser technology for textile and fashion. Results also begin to delineate the impact that laser application has had on fabrics and textiles in the field. The value of defined classification system can be used in the future as a system for content analysis to study changes over time, works of a particular designer, true innovations that happen that result in designs that no longer fit in the system, and the method developed can be applied to developing systems for observing and classifying laser application to different end products.

1.2 Rationale

With the speed of developing science, more and more small-scale laser cutting machines are available for personal use (Hengyin, 2007; Yuan et al., 2012). Moreover, the software that drives laser machines is also becoming easier to use (Hengyin, 2007; Yuan et al., 2012). Therefore, laser cutting is poised to play an increasingly important role for fashion and textile designers. As a central part of fashion, the design of dresses needs to be more
innovative (Sarkar, 2010). Unique styles, fabrics, interesting surface patterns, and colors, etc, are all important factors that can make a dress different (Sarkar, 2010). Laser technology can enable surface patterns with great details, and fabric with unique texture (Hengyin, 2007; Yuan et al., 2012). Furthermore, most fabrics can be treated with this technology, which is good because designers can customize most existing materials to achieve unique artistic effects (Hengyin, 2007; Yuan et al., 2012).
CHAPTER 2 LITERATURE REVIEW

2.1 Introduction of Three Laser Technologies

The year 2015 is called “International Year of Light and Light-based Technologies”, which proposes to commemorate the significant achievements of light science and its enormous contributions to industrial production sector (Bogue, 2015; Gao et al., 2006). Laser technology, as one of the most important light-based technologies, has rapidly developed an efficient and advanced method of manufacture in different industries (Bogue, 2015; Yuan et al., 2012).

The application of lasers in the industrial processing of materials is becoming more and more significant and widespread (Bogue, 2015; Yuan et al., 2012). Different laser sources determine the type of laser machines that best suit particular industries (Bogue, 2015). There are three laser technologies among the many lasers produced now, which are the CO2 gas laser, fiber laser, and ND: YAG laser (neodymium-doped yttrium aluminum garnet) (Hecht, 1986).

2.1.1 CO2 Gas Laser

The carbon dioxide laser (CO2 laser) is a laser based on a carbon dioxide gas mixture which is stimulated electrically (Yanabu, et al., 1989; Patel, 1964). It was invented by Kumar Patel of Bell Labs in 1964, and it had been developed rapidly at that time (Patel, 1964). CO2
lasers have a relatively high efficiency and feature an exquisite beam quality (Yuan et al., 2012). Centering on a wavelength of 10.6 micrometers to 9.4 micrometers, a beam of infrared light can be produced by a CO2 laser, making CO2 lasers mainly suited for working on non-metallic materials and most plastics (Bogue, 2015). Specifically, the CO2 laser is suited for the following materials: wood, acrylic, glass, paper, textiles, plastics, films, leather, stone, etc. (Yuan et al., 2012; Bogue, 2015). Therefore, carbon dioxide lasers are widely used laser types (Yuan et al., 2012). The CO2 laser has become very advanced and it remains one of useful lasers because of the highest-power continuous wavelength (Patel, 1964; Bogue, 2015).

2.1.2 Fiber Laser and Nd: YAG Laser

Fiber lasers and Nd: YAG laser (crystal laser) both belong to the solid state laser group (Wandera, 2006). Metals, coated metals, and plastics are the main materials that can be used with these two light-based technologies (Wandera, 2006). Fiber lasers can output 1.064 micrometers wavelength and ND: YAG lasers have the same wavelength as fiber lasers (Wandera, 2006). Because of this, they can both produce a minuscule focal diameter (Wandera, 2006). However, it is impossible for CO2 lasers to a similar job with a 10.6 or 9.4 micrometers wavelength (Wandera, 2006). In other words, with the same average power, the intensity of fiber lasers and crystal laser is much higher than that of CO2 lasers (Wandera, 2006; Abela et al., 1982; White et al. 1998). But CO2 lasers are capable of higher continuous
output power than ND: YAG. Also, the cost per watt of CO2 output is about 50 percent that of ND: YAG output (Wandera, 2006; Abela et al., 1982; White et al. 1998).

Fiber lasers can be used without maintenance at least 25,000 laser hours (Wandera, 2006). Unlike fiber lasers, crystal laser needs relatively expensive pump diodes (Wandera, 2006). They must be replaced after 8,000 to the 15,000 laser hours (Wandera, 2006). The crystal itself also has a shorter service life than a fiber laser (Wandera, 2006).

2.2 CO2 Laser Cutting Machine

Typically, the CO2 laser cutting machine consists of four essential parts: central control computer, carving control software (CAD/CAM software), electric control cabinet and the electric machine (Jie & Ripeng, 2015). The carving control software is divided into cutting control software and computer aided design software such as CorelDraw, Adobe Illustrator, etc., which are mainly used in pattern design (Yuan et al., 2012; Zhou et al., 2009; Jie & Ripeng, 2015). Vector patterns can be recognized and printed into cutting control software to be further edited. After making sure the file is correct with cutting control software, the machine is able to start the programmed operation (Yuan et al., 2012; Zhou et al., 2009; Jie & Ripeng, 2015). In the cutting control software, cutting or engraving parameters including cutting PPI (PPI means pixels per inch, which is a measure of the sharpness), cutting quality grade, cutting power and cutting speed can be set and adjusted.
according to the database or results of testing samples (Yuan et al., 2012; Jie & Ripeng, 2015). The next few paragraphs provide an example of one particular laser system.

Figure 2.1 (a), (b), and (3) are three layouts of the Universal Laser System control panel. Designers can control each parameter by using the Defaults in the Materials Database Function or adjusting according to the effect they need using Manual Control (“Universal Laser Systems User Guide”, 2008). In Materials Database, the designer can find the material to be used according to the category (“Universal Laser Systems User Guide”, 2008). In figure 2.1 (a), if the material is natural cotton fabric, the designer can directly choose Cotton in the Fabric & Leather category, and the only thing to do is to measure the thickness of the material, and control the intensity adjustment according to the final effect needs (“Universal Laser Systems User Guide”, 2008). Figure 2.1 (b) is the defaults for cotton fabric in Materials. If the defaults can’t meet the design requirements, Manual Control System is an excellent choice. The designer can test samples by adjusting the Power, Speed, PPI and Z-Axis to get the ideal setting (“Universal Laser Systems User Guide”, 2008). Also, the designer can assign designs to different colors which mean different preset settings (“Universal Laser Systems User Guide”, 2008). In this way, the operator can set unique carving parameters in different parts of one pattern so that it is possible to achieve various effects in one design (“Universal Laser Systems User Guide”, 2008).
Figure 2.1 Three layouts of Universal Laser System control panel

(a) Material Database in the Universal Laser System control panel

(b) Defaults for cotton fabric in the Universal Laser System control panel

(c) Manual Control in the Universal Laser System control panel
The Universal Laser System is used as an example of CO2 laser cutting. With this system, the processes of laser etching are as follows. First, the designer creates a design for laser etching and then converts the color mode of the design to greyscale using Adobe Photoshop or Adobe Illustrator software (“Universal Laser Systems User Guide”, 2008). The designer can adjust the contrast and levels to make the pattern clearer (“Universal Laser Systems User Guide”, 2008). Third, the designer needs to input the design files into the Universal laser system control panel (“Universal Laser Systems User Guide”, 2008). Next, the designer needs to make sure the etching speed in the manual control option is optimized because the fastest speed and specific PPI can guarantee the efficiency of processing (“Universal Laser Systems User Guide”, 2008). After setting the correct power data, the designer places the fabric on a honeycomb cutting table in a cabinet (“Universal Laser Systems User Guide”, 2008). The designer needs to adjust the position of the pattern so that the pattern can be etched in the correct place on the fabric (“Universal Laser Systems User Guide”, 2008). The laser Focus View function can help when designer is trying to find the location of the laser etching area (“Universal Laser Systems User Guide”, 2008). Last, the designer initiates laser etching of the surface pattern onto the fabrics. Figure 2.2 shows an example of the fabrics obtained with laser etching.
Continuing the example, the processes of laser engraving are similar to laser etching. First, the designer creates a pattern design for laser engraving (“Universal Laser Systems User Guide”, 2008). The pattern should consist of a single line so that the laser lens can recognize and trace the line to engrave the pattern on the fabric (“Universal Laser Systems User Guide”, 2008). Then the designer sets the color of each line to RGB blue using Adobe Illustrator software in RGB color mode (see Figure 2.3) (“Universal Laser Systems User Guide”, 2008). The designer next inputs the design files into the Universal laser system.

Figure 2.3 File settings for laser engraving (RGB Blue, 0.001 pt. stroke)
The processes of laser cutting and laser engraving are similar. The designer needs to create a pattern that consists of a single line so that the laser lens can recognize and trace the line to engrave the pattern on the fabric (“Universal Laser Systems User Guide”, 2008). The difference in cutting and engraving is that the designer sets the color of each line to RGB red using Adobe Illustrator software instead of RGB blue (see Figure 2.5) (“Universal Laser Systems User Guide”, 2008). The remaining processes are the same. Here is an additional example of laser cutting on denim fabric (see Figure 2.6):
Figure 2.5 File settings for laser cutting (RGB Red, 0.001 pt. stroke)

Figure 2.6 Sample of laser cutting on denim fabric (Designed by Weiqi)
2.3 The State of Laser Technology in Fashion and Textile Design

“Techno-Fashion” is a familiar word in the 21st century (Hengyin, 2007; Yuan et al., 2012). The combination of fashion and technology has become a hot topic in the contemporary fashion industry (Hengyin, 2007; Yuan et al., 2012). Laser technology has many advantages and has been applied widely in today’s textile manufacturing industry widely (Yuan, Jiang, Newton, & Au, 2013). This is not only because it has high efficiency and operability, but also because it has an endless potential for sustainability (Jie & Ripeng, 2015; Yuan, Jiang, Newton, & Au, 2013). Many different kinds of lasers can be applied to the textile manufacturing industry and CO2 lasers are very common among all the laser technologies with its various values (Jie & Ripeng, 2015; Yuan, Jiang, Newton, & Au, 2013). As a dry and clean technology, the CO2 laser is a very efficient and suitable laser for textile materials, which do not conduct heat and electricity, because they can absorb the wavelengths of the CO2 laser efficiently (Jie & Ripeng, 2015; Yuan, Jiang, Newton, & Au, 2013; Zhou et al., 2009).

At the same time, the application of science and technology is running through fashion designing, fashion production, marketing, etc. (Hengyin, 2007; Yuan et al., 2012). As a high-tech means of processing, laser cutting is rapidly integrating into clothing and textile processing. In fashion design, successful use of laser technology can expand design
possibilities which means that fashion design can be more multitudinous and changing (Hengyin, 2007; Yuan et al., 2012). At present, laser technology applications are frequently appearing in more and more haute couture and high-end fashion (Hengyin, 2007; Yuan et al., 2012).

2.3.1 Applications of Laser Technology in Fashion Design

Laser technology can create a variety of artistic effects when it is applied to the secondary processing of fashion fabrics (Hengyin, 2007; Yuan et al., 2012). With the rapid improvement of laser technology, it has been widely used in the field of fashion design (Hengyin, 2007; Yuan et al., 2012). The two primary applications of laser technology are laser engraving and laser cutting (Hengyin, 2007; Yuan et al., 2012).

2.3.1.1 Laser Engraving and Sustainable Design

As Figure 2.7 shows, “laser engraving is the removal of material from the top surface down to a specified depth (“Laser Engraving”, 2016).” The maximum etching depth and speed of etching can be determined by the type of material and different levels of laser power (“Laser Engraving”, 2016). Typically, shallow engraving is a faster process than deep engraving (“Laser Engraving”, 2016). Furthermore, lower density materials have a more rapid engraving speed than that of higher density materials, and increasing the laser power improves the speed of laser engraving (“Laser Engraving”, 2016).
CO2 lasers of 10.6-micron wavelength are mainly used for engraving non-metal materials (“Laser Engraving”, 2016). Most of the CO2 laser energy can be reflected, so CO2 lasers are not typically used for metal engraving (“Laser Engraving”, 2016). “However, fiber lasers with 1.06-micron wavelength can be used for shallow engraving into metal (“Laser Engraving”, 2016”).

Laser engraving is used as one main application of laser technology in fashion and textile areas (Yuan et al., 2012; Zhou et al., 2009; Jie & Ripeng, 2015). Through the laser burning process, the texture surface color can be removed by laser engraving, and multi-level color effects can be generated on the fabric surface (Ondogan et al., 2000).

Laser engraving is environmentally friendly, so it is useful for sustainable design (Yuan et al., 2012; Zhou et al., 2009; Jie & Ripeng, 2015). In modern textile and fashion industries, sustainable design is well known in business and enterprises, but the level of
practice of sustainable design for most companies is still at an early stage (Yuan et al., 2013; Xinjie, 2014). At the same time, enterprises and investors usually focus on the amount of money that a company makes or how many honors one enterprise can earn (Herva et al., 2014). The textile and fashion industries have a strong relationship with economic development (Herva et al., 2014). But an enormous cost, including the high consumption of resources, energy and heavy damage to the environment is behind the achievement of the fashion industries (Herva et al., 2014). So sustainability has become more and more significant for the apparel production industries (Herva, et al., 2014). Use of green energy resources and adopt of manufacturing techniques as well as facilities with low waste and high recycle rates would lessen the environmental and resource impact of the industries (Herva, et al., 2014, Xinjie, 2014).

Denim is a popular fabric in today’s textile and apparel product market because of its distinctive surface characteristic and structure, yet it has a negative environmental and ethical impact (Yuan et al., 2012; Zhou et al., 2009; Jie & Ripeng, 2015). Reducing water consumption in denim processing is important (Trotman, 2015). Guangdong, which is called The Base of the Jeans Industry in China, has thousands of jeans companies (Pendle, 2015). However, because many manufacturers lack enough advanced science, technology, equipment and management skill, they are not doing well in protecting the environment (Pendle, 2015). As reported, rivers and other waterways near these factories are heavily
polluted with chemicals used for dyeing, printing, bleaching and washing, even heavy metals can be found (Pendle, 2015). Some estimates suggest that producing one pair of jeans requires more than 2,500 gallons of water, nearly a pound of chemicals and vast amounts of energy (Pendle, 2015).

In 1999, sustainable denim design and eco-jeans design were predicted to be the new jeans revolution (Berkhout & Smith, 1999). Designers have a deep love for utilizing each characteristic of denim to explore and discover the unexpected (Dascalu, et al., 2000). Consumers are seeking a more personalized lifestyle, encouraging designers to create unique designs which can meet these needs (Dascalu, et al., 2000). Laser engraving offers new possibilities for making production more straightforward and efficient with the minimal use of water, bleach and chemicals (Dascalu, et al., 2000). Compared to the traditional printing and dyeing methods, and washing processes, laser engraving treatment has the advantage of energy saving and environmental protection (Dascalu, et al., 2000; Pendle, 2015). Figure 2.8 (a) and (b) show the laser etched denim jacket designed by Siena Baldi.

Laser technology also offers great versatility in customizing designs (Yuan et al., 2012; Zhou et al., 2009; Jie & Ripeng, 2015; Xinjie, 2014). In addition to the denim fabric, leather, polyurethane and other textile materials such as cotton, silk, polyester, etc. can also be treated to achieve similar effects (Hengyin, 2007; Yuan et al., 2012). The process is fast,
clean and flexible with no use of water, and no effluent requiring disposal (Hengyin, 2007; Yuan et al., 2012; Xinjie, 2014).

(a) Denim jacket for etching  (b) Final product

Figure 2.8 Denim jacket by Siena Baldi (“Laser Etched Denim Jacket”, n.d.)
2.3.1.2 Laser Cutting

As Figure 2.9 shows, “laser cutting is the complete removal and separation of material from the top surface to the bottom surface along a designated path (“Laser Cutting”, 2016).” Laser cutting can be performed on a single layer material or multi-layer material (“Laser Cutting”, 2016). When cutting multi-layer material, the laser beam can be precisely controlled to cut through the top layer without cutting through the other layers of the material, if desired (“Laser Cutting”, 2016).

![Figure 2.9 Laser cutting diagram](image)

Laser cutting can be used in selected sections of a garment to create some diverse artistic effects such as an occasional broken appearance, tassels, etc. (Yuan et al., 2012; Zhou et al., 2009; Jie & Ripeng, 2015). One major merit of laser cutting is that the cut edge is
smooth, which cannot be achieved by the traditional methods like tearing (Yuan et al., 2012). The next sections illustrate applications of laser technology in fashion.

The first set of images (see Figure 2.10) show designs accomplished with slashing techniques. Figure 2.10 (a) is a dress designed by Jolka Wiens. Jolka utilized laser cutting to cut hundreds of strips on the neoprene fabric (“A Passion for Lasers”, 2015). Every strip is cut finely and tidily. Figure 2.10 (b) is also a cool dress designed by Visbo De Arce, with an elegant cut design on the back section (“Laser Cut Dress with Sculptural Rib Cage Details by Visbo De Arce”, 2013). Visbo De Arce used laser cutting to cut two rows of strips. The symmetrical strips on both sides resemble a sculptured rib cage (“Laser Cut Dress with Sculptural Rib Cage Details by Visbo De Arce”, 2013). Figure 2.10 (c) is another dress designed by Iris van Herpen. She utilized laser cutting to cut the fabric and create structural and dimensional effects (“Laser Cut Dress with Graphic Surface Patterns”, 2015). Figure 2.10 (d) is a fabric texture design by Dion Lee. He cut the fabric and manipulated it to a structural and dimensional design by twisting the stripes (“Neoprene Top with Cut & Twist Spine Detail”, 2013).
(a) Graduate dress designed by Jolka Wiens (“A Passion for Lasers”, 2015)

(b) Laser cut dress designed by Visbo De Arce (“Dress with Sculptural Rib Cage Details”, 2013)

(c) Laser cut dress by Iris van Herpen (“Laser Cut Dress with Graphic Surface Patterns”, 2015)

(d) Fabric manipulation by Dion Lee (“Neoprene Top with Cut & Twist Spine Detail”, 2013)

Figure 2.10 Images showing designs accomplished with slashing techniques
Because of the high accuracy and small cutting aperture of laser cutting, it can also be used to carve delicate and intricate patterns, which show a hollowed-out appearance (Yuan et al., 2012; Zhou et al., 2009; Jie & Ripeng, 2015). The speed of laser cutting is also far faster than the rate of traditional cutting methods (Zhou et al., 2009).

Figure 2.11 (a) shows elegant details of the cutting pattern for Vera Wang's bridal dress. This pattern is very intricate with lots of curves (“A Close-Up Image of Silk”, 2011). However, it can be easily and accurately cut by laser in a relatively short time (“A Close-Up Image of Silk”, 2011). Figure 2.11 (b) is low rise legging by Blue Life Fit featuring laser cut side panels and a neutral lining (“Blue Life Fit Laser-Cut Legging”, 2015). The pattern is very delicate, creating a strong visual effect. Figure 2.11 (c) is a jacket designed by John Richmond. The pattern on the jacket is all cut by laser cutting (“Truly Stunning Laser-Cut Leather”, 2014). Each motif of the pattern for this jacket is tiny and fine so it is hard to use traditional cutting method to get the same effect (“Truly Stunning Laser-Cut Leather”, 2014). Figure 2.11 (d) is a coat designed by Tamas Walter. The pattern also consists of tiny motifs. Besides using laser cutting to cut the pattern on the leather fabric, the designer also utilized laser engraving to add some decorative lines (“AW13 Laser Cut Pattern by Tamas Walter”, 2013). Besides, the designer utilized laser engraving to remove some dark brown color (“AW13 Laser Cut Pattern by Tamas Walter”, 2013). Through etching on the leather fabric, the color of some parts becomes brassy yellow changing the visual impact and effect.
(“AW13 Laser Cut Pattern by Tamas Walter”, 2013). As can be seen, laser cutting and laser engraving can be combined as needed.

(a) Laser cut floral pattern for Vera Wang's bridal dress (“A Close-Up Image of Silk”, 2011)

(b) Urban Outfitters designed by Blue Life (“Blue Life Fit Laser-Cut Legging”, 2015)

(c) Laser-cut jacket at John Richmond’s SS 2014 Show in Milan (“Truly Stunning Laser-Cut Leather”, 2014)

(d) Laser cut fashion by Tamas Walter (“AW13 Laser Cut Pattern by Tamas Walter”, 2013)

Figure 2.11 Images showing designs accomplished with hollowed-out techniques
2.3.2 Challenges of Laser Technology Applications in Fashion Design

While the development of laser cutting and laser engraving have excellent prospects, there are still some technical problems in some processes which have limited full integration of lasers into fashion and textile companies (Jie & Ripeng, 2015).

2.3.2.1 Fabric Decoherence Problem

Laser cutting utilizes laser beams with high temperature that rapidly heat the surface of the material to the evaporation temperature (Yanabu, et al., 1989; Jie & Ripeng, 2015). The evaporation temperature causes a hole in the fabric, and each hole is connected in a line which achieves cutting the fabric (Jie & Ripeng, 2015). While laser cutting features high accuracy and efficiency, the position of yarns will move if the carved fabric has been used for a long time. This will bring about threads slipping out from the fabric, called fabric decoherence (Jie & Ripeng, 2015; Hengyin, 2007). Figure 2.12 (a) and (b) shows two pieces of denim fabrics. Figure 2.12 (a) is the original piece. After being touched and rub several times, (a) became (b), which illustrates the decoherence.

Fabric decoherence adversely affects people’s feeling of dressing as well as the appearance of the garment (Jie & Ripeng, 2015). This situation happens often, especially for woven and knitted fabrics, which require stable structures to keep good quality (Jie & Ripeng,
2015; Hengyin, 2007). So, durability is one major factor that restricts the widespread use of laser technology in the textile and fashion industry (Jie & Ripeng, 2015; Hengyin, 2007).

![Denim fabric decoherence](image)

**Figure 2.12** Denim fabric decoherence (designed by Weiqi)

2.3.2.2 The Optimization of Cutting Parameters

In the process of laser cutting, with increasing complexity of the design, carving defects happen more frequently (Jie & Ripeng, 2015). For example, if some lines in a pattern have a large degree of angle change, it is easy to cause unequal levels of discoloration on the material surface (Jie & Ripeng, 2015). This is because the laser beam will stay for a longer time in the turning point, thus the defect is easy to generate (Jie & Ripeng, 2015). This defect impact the quality as well as the appearance of fabrics (Jie & Ripeng, 2015). To reduce this phenomenon, the technical designer needs to optimize the scanning line, adjust controls to
reduce the speed variation and power variation (Jie & Ripeng, 2015). Figure 2.13 is a comparison of two nonwoven cotton fabrics which were cut at the same power but different speed setting. By comparing with the sections in red and green circle of (a) to the sections in red and green circle of (b), it can be clearly seen that (a) has less discoloration, because the laser lens stayed longer in the turning point of the pattern.

![Comparison of two nonwoven cotton fabrics](image)

(a) Cut using: Power: 25%, Speed: 100%    (b) Cut using: Power: 25%, Speed: 50%

Figure 2.13 Comparison of two nonwoven cotton fabrics (designed by Weiqi)

To achieve the best effect for laser cutting or laser engraving, the designer needs to test settings which have varying levels of intensities on the fabric (Jie & Ripeng, 2015; Hengyin, 2007). After treating samples, the designer need to compare among the samples so
that the best samples can be selected and the best laser setting data can be identified and recorded for further reference (Jie & Ripeng, 2015; Hengyin, 2007).

For laser engraving, the power is also very critical (Hengyin, 2007). Table 2.1 shows a collection of denim samples created through laser engraving. Laser engraving can give denim fabric unique color removal effects (Jie & Ripeng, 2015). However, too much power will cause excess laser energy to the denim fabric surface so that the fabric is damaged as in Table 2.1 (f). At the same time, too little power will not allow the effect to be shown clearly after washing as in Table 2.1 (a). Only accurate power can give the denim fabric best effect like sample in Table 2.1 (c).
<table>
<thead>
<tr>
<th>No.</th>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>15%</td>
<td>20%</td>
<td>25%</td>
</tr>
<tr>
<td>Result</td>
<td><img src="image-a.png" alt="Image" /></td>
<td><img src="image-b.png" alt="Image" /></td>
<td><img src="image-c.png" alt="Image" /></td>
</tr>
</tbody>
</table>

(Speed: 100%; PPI: 500; Z-Axis: off)

<table>
<thead>
<tr>
<th>No.</th>
<th>(d)</th>
<th>(e)</th>
<th>(f)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>30%</td>
<td>40%</td>
<td>50%</td>
</tr>
<tr>
<td>Result</td>
<td><img src="image-d.png" alt="Image" /></td>
<td><img src="image-e.png" alt="Image" /></td>
<td><img src="image-f.png" alt="Image" /></td>
</tr>
</tbody>
</table>

(Speed: 100%; PPI: 500; Z-Axis: off)

Laser cutting also needs the correct power setting to cut the fabric totally (Jie & Ripeng, 2015). It is necessary to get well-cut pieces so the edge can be neat and clear without fuzzy threads (Jie & Ripeng, 2015). Too much power will cause excess laser energy to the
fabric surface so that the fabric can easily get burned (Jie & Ripeng, 2015). Too less little power will not cut totally through the fabric (Jie & Ripeng, 2015).

2.4 Motif Sources in Laser Cut Surface Patterns

In the process of fashion design, surface pattern is often a critical in laser cut or etched designs (Xinjie, 2014). Designers need to integrate the pattern type with the correct laser method to be used (Xinjie, 2014). Selecting the appropriate approaches and parameters according to the design of the surface patterns can help designers easily recreate the fabrics that have novel aesthetics (Xinjie, 2014).

2.4.1 Patterns of Bionic Elements

Bionic elements are from nature (Xinjie, 2014). Nature gives us endless inspiration, which mainly has three aspects (Xinjie, 2014). The first one is the shape or structural elements of creatures, for example, the cascade structure and unique shapes of the wings of insects (Xinjie, 2014; Lesley, 2002; Steed & Stevenson, 2012). In this case, designers can carve out the structural elements, floral or animal shaped patterns, or relevant details on fabrics (Xinjie, 2014; Lesley, 2002; Steed & Stevenson, 2012). The second aspect is the pattern and gradient elements of creatures (Xinjie, 2014; Lesley, 2002; Steed & Stevenson, 2012), for example, some patterns on the wings of the butterflies display natural transition effects of light and shade (Lesley, 2002). This kind of pattern can be used to create a graphic
design to be cut or engraved on the fabric, which can then show the similar effect as the wings of the butterfly (Xinjie, 2014). The third aspect is surface texture elements (Xinjie, 2014; Lesley, 2002). The natural world is full of beautiful skin textures on animals, and flora (Lesley, 2002). For example, designers can use various lines to show the texture of petals (Xinjie, 2014). By cutting or engraving, the natural texture can be displayed directly on the fabric (Xinjie, 2014). Figure 2.14 shows some photography works showing bionic elements of nature. Figure 2.15 shows some laser cutting patterns reflecting bionic elements applied to fashion and accessory design. Figure 2.16 shows three original pattern designs based on bionic elements, which are cut in nonwoven cotton fabric by laser cutting.

(a) Plant (“Plant photograph by Karl Blossfeldt”, 2013)
(b) Leaf vein (“Green Nature Texture”, n.d.)
(c) Dragonfly’s wing (“Fragile Beauty”, 2014)
(d) Sea plants (“Okinawa Nature Photography”, 2011)
(e) Butterfly’s wing (“Photography by tokyo-bleep”, 2015)
(f) Bird wings (“Monochrome Feather Textures”, n.d.)

Figure 2.14 Photography works showing bionic elements of nature
(a) Laser cut top by Roger Rich (“FHM Collections Germany”, 2009)
(b) Laser cut earrings by Jessica Coleman (“Wooden Dragonfly Wing”, n.d.)
(c) Art fashion designed by Caterina Ciuffoletti (“Get out of Your Skin”, 2014)

Figure 2.15 Laser cut fashion and accessory design showing bionic elements of nature

Figure 2.16 Nonwoven cotton fabrics showing bionic elements of nature (designed by Weiqi)
2.4.2 Patterns of Traditional Elements

Traditional pattern plays a significant role in textile and fashion design (Xinjie, 2014; Lesley, 2002; Steed & Stevenson, 2012). Different countries and areas have their traditional patterns with different features (Lesley, 2002), as illustrated in the following examples. Some traditional patterns of Chinese minorities usually feature solid color (Xinjie, 2014; Lesley, 2002). Blue, red, black and white are primary colors used (Xinjie, 2014; Lesley, 2002). Figure 2.17 shows three dresses using traditional Chinese pattern and Figure 2.18 shows three typical Chinese graphic patterns. Typically, Chinese patterns convey special meanings (Xinjie, 2014). For example, birds and flowers mean prosperity and happiness, and fish mean affluence (Xinjie, 2014). Figure 2.19 shows textiles of Japanese patterns and graphic Japanese pattern designs. Figure 2.20 shows examples of Russian pattern designs.

There are also three main applications of using laser cutting and engraving in traditional pattern design (Xinjie, 2014). The first way is to cut the traditional surface pattern on the fabric quickly and accurately using laser cutting (Xinjie, 2014). The effect is very similar to traditional Chinese paper cut, but laser cutting saves energy and time (Xinjie, 2014). Designers can cut each pattern on several fabrics in different colors or single color so that they can get several pieces (Xinjie, 2014). Then designers can stitch or bond these pieces on the garment to give it richer details and textures (Xinjie, 2014). The second application is engraving the traditional patterns on a fabric (Xinjie, 2014). Some traditional designs with
solid color can be easily and quickly applied to the fabric by laser engraving (Xinjie, 2014). For some traditional patterns with multiple colors, the designer can enhance the color contrast by adjusting the laser parameters like power and speed (Xinjie, 2014). The third application is using laser technology to create accessories which can match the design of fashion (Xinjie, 2014). To achieve the best effect in fashion look, designers often use accessories (Xinjie, 2014). Designers can use laser cutting or laser engraving to create accessories quickly and conveniently (Xinjie, 2014). Usually, wood, plastic, and some metal materials are excellent for making accessories by laser cutting and engraving. Laser application can achieve a highly ornamental effect (Xinjie, 2014). Figure 2.21 shows some laser cut and laser engraved patterns about traditional elements, which are applied to accessory designs.
(a) Chinese paper cut dress top (‘‘Chinese Paper Cut Dress Top’’, 2009)
(b) Chinese traditional dress by Yumei Tao (‘‘Chinese Traditional Dress’’, n.d.)
(c) Art dress designed by Guo Pei (‘‘Miss Universe China’’, 2012)

Figure 2.17 Samples of dresses based on Chinese traditional patterns

(a) Chinese traditional fish pattern (‘‘Chinese Papercut Golden Fish’’, 2009)
(b) Chinese traditional animal pattern by Jiacai Yin (‘‘Chinese Papercut Owl’’, 2000)
(c) Chinese traditional floral pattern (‘‘Blue and White Porcelain’’, 2014)

Figure 2.18 Samples of Chinese traditional patterns
(a) Fabrics with traditional Japanese print (“Fabrics with traditional Japanese print”, 2011)

(b) Traditional Japanese patterns (“traditional Japanese patterns”, n.d.)

(c) Colorful traditional Japanese patterns (“Colorful traditional Japanese patterns”, n.d.)

Figure 2.19 Samples of Japanese traditional patterns
(a) Traditional Russian decorative pattern (“Traditional Russian decorative pattern”, n.d.)

(b) Traditional Russian pattern (“Traditional Russian pattern”, n.d.)

(c) Linen table cloth and towels with traditional Russian print (“traditional Russian print”, 2003)

Figure 2.20 Samples of Russian traditional patterns

(a) Mandala leather cuff by RockBody (“Mandala Leather Cuff”, 2015)
(b) Laser cut leather cuff bracelets by RockBody (“Laser Cut Leather Cuff Bracelets”, 2015)
(c) Laser cut leather bracelet by RockBody (“Butterfly Laser Cut Leather Bracelet”, 2015)

Figure 2.21 Laser cut and engraved accessory designs based on traditional patterns
2.4.3 Patterns of European elements

European style pattern usually features intricate curves and details (Xinjie, 2014; Meller et al., 1991; Lesley, 2002). As a decorative pattern with delicate details, there are three laser methods that can be used for textile and fashion products (Xinjie, 2014). Cutting the whole European-style pattern on the fabric is the first method (Xinjie, 2014). Through carving out the complicated and delicate pattern, the fabric of solid color can show intricate surface texture (Xinjie, 2014). Second, designers can engrave the whole pattern directly on the fabric (Xinjie, 2014). Because a tonal change of yellow can emerge on the fabric surface after laser engraving, it is very suitable for the fabric with the European style pattern to give an aged look to the style (Xinjie, 2014). The last method is the combination of these two approaches (Xinjie, 2014). Sometimes, designers can carve out part of the Europe-style pattern and engrave the rest of the design so that they can achieve a good visual balance (Xinjie, 2014). Figure 2.22 shows several types of Europe-style graphic patterns. Figure 2.23 shows an original pattern design based on European style pattern, which is engraved on polyester fabric.
(a) Vintage gold European style pattern (“Vintage Gold Floral Pattern”, 2014)
(b) Paisley European style pattern (“Paisley European Style Pattern”, 2014)
(c) European style pattern (“European Style Pattern”, 2011)
(c) Black and white paisley pattern (“Black And White Paisley”, n.d.)

Figure 2.22 Samples of European style pattern

Figure 2.23 Laser etched European style pattern on polyester fabric
2.5.4 Patterns of Punk Elements

Fashion design with the punk style pattern is usually targeted to young people, and shows more individuality, exaggeration, modernization, and innovation (Xinjie, 2014; Steed & Stevenson, 2012). For punk style pattern, laser technology is widely applied in denim and leather fabric. Figure 2.24 images (a), (b), and (c) show three fashion products using punk-style patterns. Figure 2.24 images (d)-(g) show denim clothes using punk style patterns.
(a) Women punk style T-shirt (“Skull Skeleton Punk Style Back”, 2012)
(b) Punk style shirt (“Black And White Punk Style Shirt”, 2015)
(c) Punk style knitwear (“Punk style fashion”, 2014)

(d) Punk style jeans with holes (“Skull Embroidery Men’s Jeans”, 2015)
(e) Japan punk street style jeans (“Japan Punk street style jeans”, 2015)
(f) Punk style denim jacket (“Punk style denim jacket”, 2014)
(g) Crust punk style denim jacket (“Crust Punk Studded Denim Jacket”, 2010)

Figure 2.24 Punk style fashion
2.5 Classifications of Dresses

2.5.1 The Type of Dresses According To the Dress Length

According to the dress length, dresses can be classified into several types: Micro Mini Dress, Mini (Mid-thigh) Dress, Above the Knee Dress, Knee Length Dress, Cocktail Length Dress, Midi Dress, Long Dress, Maxi Dress, Evening Length Dress, and Floor Length Dress (Qishu, 2012; Sarkar, 2010). The Figure 2.25 and Table 2.3 that follow provide details on this classification.

![Diagram of dress lengths](image)

Figure 2.25 Types of dresses according to the dress length (Qishu, 2012)
## Table 2.2 Types of dresses according to the dress length

<table>
<thead>
<tr>
<th>Dress Type</th>
<th>Skirt Length</th>
<th>Representative Image</th>
<th>Others</th>
</tr>
</thead>
</table>
| Micro Dress | Skirt length is extremely short, typically finishes at less than 15 inches (about 40 cm) and can be as short as 8 inches (about 20 cm) (Qishu, 2012; Sarkar, 2010). | ![Representative Image](image) | **Alternative terms:** Belt Skirt (Sarkar, 2010)  
**Introduction:** 1960s (Davis, 1980)  
Micro dress may expose the underwear or buttocks of wearers (Qishu, 2012; Sarkar, 2010). |
| Mini Dress  | Skirt length is very short, typically finishes at mid-thigh, approximately 15 inches (about 40 cm) (Qishu, 2012; Sarkar, 2010). | ![Representative Image](image) | **Introduction:** 5th century before the common era (Davis, 1980)  
**Popular:** 1960s (Davis, 1980)  
Mini Dress can make the legs appear longer in proportion to the body (Qishu, 2012; Sarkar, 2010). |
Table 2.2 Continued

<table>
<thead>
<tr>
<th>Above-the-Knee Length Dress</th>
<th>Skirt length finishes at 1 to 2 inches (about 2.5-5cm) above the mid-knee (Qishu, 2012; Sarkar, 2010).</th>
<th>Popular: 1920s (Davis, 1980)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Knee Length Dress</td>
<td>Skirt length finishes at the middle of the wearer’s knee cap (Qishu, 2012; Sarkar, 2010).</td>
<td>Popular: 1920s, 1950s (Davis, 1980)</td>
</tr>
<tr>
<td>Cocktail Length Dress</td>
<td>Skirt length finishes at 1 – 3 inches (2.5-7.5cm) below the knee (Qishu, 2012; Sarkar, 2010).</td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
</tbody>
</table>

**Alternative terms:** Below the Knee Length, Street Length (Davis, 1980; Sarkar, 2010)

**Popular:** mid 1910s (Davis, 1980)

Cocktail Length Dress is often considered a very flattering length as it sits at the slimmest part of the leg (Davis, 1980; Sarkar, 2010)

<table>
<thead>
<tr>
<th>Midi</th>
<th>Skirt length finishes at midway between the knee and the ankle (Qishu, 2012; Sarkar, 2010).</th>
</tr>
</thead>
</table>

**Alternative terms:** Mid-calf length, ballerina length, intermission length, tea length (Davis, 1980; Sarkar, 2010)

**Introduction:** 1920s (Davis, 1980)

**Popular:** 1920s-1950s (Davis, 1980)
Table 2.2 Continued

| Dress       | Skirt length sits a couple of inches below the middle of the calf, approximately 10 inches (25cm) from the floor (Qishu, 2012; Sarkar, 2010). | Alternative terms: Below Mid-Calf (Davis, 1980; Sarkar, 2010)  
**Popular:** 1920s (Davis, 1980) |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Long Dress</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Maxi        | Skirt length traditionally finishes at approximately 8 inches (20cm) above the floor), but can be long enough to touch the floor (Qishu, 2012; Sarkar, 2010).                                                                                                                    | Alternative terms: Lower calf length (Davis, 1980; Sarkar, 2010)  
**Introduction:** at least the 16th century (Davis, 1980)  
**Popular:** 1970s, 2000s (Davis, 1980; Sarkar, 2010) |
|             |                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                  |
Table 2.2 Continued

<table>
<thead>
<tr>
<th>Evening Length Dress</th>
<th>Skirt length typically finishes at approximately 1 inch (2.5cm) from the floor (Qishu, 2012; Sarkar, 2010).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor Length Dress</td>
<td>The floor length dress touches the floor (Qishu, 2012; Sarkar, 2010).</td>
</tr>
</tbody>
</table>

*Alternative terms:* Formal length, Full length (Sarkar, 2010; Davis, 1980)

*Introduction:* at least 16th century (Davis, 1980)
2.5.2 The Type of Dresses According To the Dress Overall Look

According to the dress overall look, dresses can be classified into three main types: Barrel Overall Look, Fit and Flare Dress, Tiered Dress (Qishu, 2012; Sarkar, 2010; Davis, 1980; Hillhouse & Mansfield, 1948). Table 2.3 that follow provides details on this classification.

Table 2.3 Types of dresses according to the dress overall look

<table>
<thead>
<tr>
<th>Skirt Overall Look</th>
<th>Description</th>
<th>Representative Image</th>
<th>Representative Dress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barrel Overall Look</td>
<td>A straight dress in its simplest form is a rectangle of fabric, either long or short, with an elastic waistband project (Qishu, 2012; Sarkar, 2010). This is the easiest type of skirt to sew and it makes an ideal beginner's sewing project (Qishu, 2012).</td>
<td><img src="image" alt="Barrel Dress" /></td>
<td>Barrel Dress / Tube Dress / Straight Dress / Pencil Dress / Column Dress (Qishu, 2012; Sarkar, 2010; Davis, 1980; Hillhouse &amp; Mansfield, 1948)</td>
</tr>
<tr>
<td>Fit and Flare Overall Look</td>
<td>Fit and flare overall look means a dress that fitly hugs the body through the bodice and right past the hip, where the skirt then flares away from the body project (Qishu, 2012; Sarkar, 2010). The Fit-and-flare overall look can also accentuate a woman’s small natural waist or even create the appearance of a tiny waist for women with less definition project (Qishu, 2012; Sarkar, 2010).</td>
<td><img src="image" alt="Fit and Flare Dress" /></td>
<td>Fit and Flare Dress / A-Line Dress / Trumpet Dress / Mermaid Dress (Qishu, 2012; Sarkar, 2010; Davis, 1980; Hillhouse &amp; Mansfield, 1948)</td>
</tr>
</tbody>
</table>
2.5.3 The Type of Dresses According To the Skirt Size

According to the skirt size, dresses can be classified to several types: Tight Skirt, Straight Skirt, Semi-tight skirt / semi-fitting Skirt, Flare Skirt, Half-circle Skirt / Semicircular Skirt / Circular Skirt (Qishu, 2012; Sarkar, 2010). The Figure 2.26 and Table 2.4 that follow provide details on this classification.

| Tiered Overall Look | A tiered dress is a type of skirt in which the fabric is layered all the way down the skirt, making it appear as if it is made up of different tiers project (Qishu, 2012; Sarkar, 2010). It often gives the skirt a layered, ruffled appearance that can look very feminine and dressy project (Qishu, 2012; Sarkar, 2010). | Tiered Dress (Qishu, 2012; Sarkar, 2010) |
Figure 2.26 Types of dresses according to the skirt size (Qishu, 2012)

Table 2.4 Types of women’s dresses according to the skirt size

<table>
<thead>
<tr>
<th>Skirt Type</th>
<th>Description</th>
<th>Representative Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tight Skirt</td>
<td>Hip ease is approximately 4 cm. The skirt part closely hugs the hip. Skirt hem is short (Qishu, 2012; Sarkar, 2010).</td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Straight Skirt</td>
<td>The overall look of straight skirt is similar with tight skirt. Hip ease is also approximately 4 cm (Qishu, 2012; Sarkar, 2010). The different part is the skirt bottom part that shows straight (Qishu, 2012; Sarkar, 2010).</td>
<td></td>
</tr>
<tr>
<td>Semi-tight skirt / semi-fitting Skirt</td>
<td>Hip ease is approximately 4 - 6 cm (Qishu, 2012; Sarkar, 2010). The skirt hem is a little bit wide and the structure of the skirt is simple, which is easy to walk (Qishu, 2012; Sarkar, 2010).</td>
<td></td>
</tr>
<tr>
<td>Flare Skirt</td>
<td>Hip ease is more than 6 cm. The skirt hem is wider, which resembles a trumpet (Qishu, 2012; Sarkar, 2010). The structure is also relatively simple but shows more dynamic (Qishu, 2012; Sarkar, 2010).</td>
<td></td>
</tr>
</tbody>
</table>
Table 2.4 Continued

<table>
<thead>
<tr>
<th>Shape Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half-circle Skirt / Semicircular Skirt / Circular Skirt</td>
<td>The skirt hem is larger, which shows more activeness and enthusiastic feeling (Qishu, 2012; Sarkar, 2010).</td>
</tr>
</tbody>
</table>

2.5.4 The Type of Dresses According To the Skirt Silhouette

According to the skirt silhouette, skirts can be classified to several types: X-Shape, H-Shape, A-Shape, T-Shape, and O-Shape (Qishu, 2012; Sarkar, 2010; Davis, 1980; Hillhouse & Mansfield, 1948). Table 2.5 that follow provides details on this classification.

Table 2.5 Types of dresses according to the skirt silhouette

<table>
<thead>
<tr>
<th>Shape Name</th>
<th>Basic Skirt Shape</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-Shape</td>
<td><img src="image" alt="Image" /></td>
<td>The shape of the skirt part is like an X (Qishu, 2012). This shape is commonly seen in mermaid dresses, which can give strongly elegant and beautiful feeling to people (Qishu, 2012; Sarkar, 2010).</td>
</tr>
<tr>
<td>Shape</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>H-Shape</td>
<td>The H-shape skirt is the core shape for skirts (Qishu, 2012). It has a simple structure with a fit hip part and straight skirt bottom part (Qishu, 2012; Sarkar, 2010). This kind of skirt can give people a grace and modest feeling, so it is very suitable for business wearing (Qishu, 2012; Sarkar, 2010).</td>
<td></td>
</tr>
<tr>
<td>A-Shape</td>
<td>The A-shape skirt has a fairly wider bottom part which can show more lovely and ethereal part of wearers (Qishu, 2012; Sarkar, 2010).</td>
<td></td>
</tr>
<tr>
<td>T-Shape</td>
<td>The T-shape has a relatively tight waist, and it can stand out the beautiful curve of hip part. It can show the good shape of the wearer’s body (Qishu, 2012; Sarkar, 2010).</td>
<td></td>
</tr>
</tbody>
</table>
Table 2.5 Continued

| O-Shape | The O-Shape skirt shows much of relaxation. This type of skirt usually attracts people by its unique and exaggerated features (Qishu, 2012; Sarkar, 2010). |

---

2.6 Summary

The literature review focused on two main parts, the applications of laser technology in textiles and fashion, and classifications of dresses. In the first part, three technologies CO2 gas laser, fiber laser, and Nd: YAG laser, are introduced. These laser sources determine the type of laser machines that best suit industries. Then an example of a CO2 laser cutting machine was introduced by the Universal Laser System laser cutting machine. Next, applications of laser technology in fashion design were introduced doing with two challenges of laser technology applications in textiles: fabric decoherence problem and the optimization of cutting parameters. At last, four types of surface patterns were introduced by illustrating several applications in laser cutting and engraved design. The second part is classifications of
dresses based on the dress length, dress overall look, skirt size, and skirt silhouette were
introduced by giving representative images.

There is little published literature about application of laser technology in dress
design. None was found about classifications of dress made using laser technology, nor the
classifications of surface pattern effects made by the laser technology, or the final functions
of the fashion using the laser technology. This study analyzes applications of laser
technology in textile and fashion by looking at dress design. It seeks to provide a framework
for understanding how laser technology is used in design, which is useful to academics and
beginners.
CHAPTER 3 METHODOLOGY

The purpose of this research was to explore and classify dress designs using CO2 laser technology. The methodology used to address this objective is presented in two sections. The first section describes the progress of visual analysis to summarize the preliminary category and the defined category for dress design using the laser technology. The second section describes the analysis of the survey data for investigating more characteristics for each refined category. The methodology includes development of image database, visual analysis method, development of an evaluation tool, data collection method, and data analysis method.

3.1 Developing an Image Database

Because there is limited literature regarding laser use in fashion, visual research is especially needed. Visual analysis allows researchers to “make quantitative generalizations about visual and other forms of representation, on the basis of reliable classification and observation” (Van & Jewitt, 2004, pp. 10-34). Visual analysis begins with some precise question about well-defined variables (Van & Jewitt, 2004). In this research, the variables include types of dress silhouettes, types of surface pattern effects and primary final applications. Through the literature review, there are three questions: As a new technology, laser cutting and engraving change the fabric surface unlike printing and embroidery and
other traditional techniques. Is it possible that a reliable system of classification for dresses designed using laser technology is different from the classifications of dresses without using this technology. Systems introduced in literature review were developed without a specific focus on laser treated dresses. Second, the literature introduced laser cutting and laser engraving as well as four types of surface patterns in laser cutting design. It is unclear due to the very limited literature if this is an adequate system of classifying laser treated dresses and if it captures the many types of surface pattern effects a designer could apply to dress design. Finally, there is no literature to indicate if the primary intents for dresses created using laser technology is for function or is it primarily used for dresses created for decorative purposes.

Initial research steps were undertaken to develop a reliable system of classification and observation for dresses created using laser technology, while later steps in this research were targeted at verifying and refining categories.

For visual analysis, an image database is critical. By creating an image database, the images to be used for research can be easily found. What’s more, an image database can help the researcher to make the most of the image resources. Building the image database was data collection for developing the system of classification. The images were collected and stored so that they could be revisited and studied conveniently, it wasn’t intended for this study to serve anyone but researcher in doing this work. In the future, it could be further developed as a tool to assist designers or in classes. There are several considerations needed
to make when creating an image database. First, a cloud drive is required because it provides flexible access. Whenever a useful image is found online, it can be uploaded and saved conveniently. In this research, Google Cloud Drive was chosen as the cloud storage tool to house all of the images. Second, each image needs to be renamed. Often, when an image has been downloaded from a web site, it has a generic file name that means nothing. The content of the image, including keywords, the description of design, the information of the designer, date, and other information can guarantee that each image downloaded has a correct citation. It also allows the researcher to search images by description or keyword quickly. Finally, backup copies of the image database are needed in case some images get broken or deleted. In this research, besides Google Cloud Drive, a local folder which was updated with the updating of the Google Cloud Drive was set up in the computer drive. There are two reasons for duplicating. One is because it is faster to move and copy images in the local folder than doing it on the internet. The other is because a copy of an image database can make the resource safer in case one copy is missing or destroyed.

Each image was found and obtained online. Pinterest and Google Images were two main search tools used to find the images. Key words searched include “laser cut fashion”, “laser cut dress”, “laser cut fabric”, “laser cut design”, and “laser engraving design”. When an image was found, the image was selected to view the information about the original source. The information collected about the images includes designer, design purpose, design
date, and description such as the materials used, cut method used, and inspiration source. By looking through the information, there were three situations for determining if an image could be included into the image database. First, images that had a detailed description including use of laser technology could be added into the image database. Second, images that had a brief title or simple information about using laser technology could be added into the image database. Last, if an image had information about using a cut method, but not saying whether the cut part was made by laser cutting or not, more considerations were needed. Because laser cutting is a physical treatment (Xinjie, 2014), if the cut piece in image could also be dealt with laser technology and achieve the same effect, it could be added into the database. If not, or if the material in image the image can’t be treated with laser technology, it was not added into the database. Information for each image that was added into the database including designer, design purpose, design date, and brief description like the materials used, cut method used. Information was recorded. The relevant information was recorded in APA format, which could also be used for citations and reference list. At the same time, rename the image was renamed using the most important information about the image.

In this research, 403 images including clothes, fabrics, accessories, etc. which featured use laser technology were found and compiled into the image database. According to the information recorded, the general time range of the scope of the images was from 2000
to 2016, with most from 2010 to 2016. Not every image had no specific date, so some dates are unknown. In 403 images, 48 dresses have two views: detailed view and entire garment view both showing the same garment. Therefore, 355 unique pieces were represented in the database.

3.2 Preliminary Laser Cut Surface Pattern Effects Classification

Manual organization is a vital step. Initially, all the images in the image database were downloaded and uploaded into the database without classification. Thus each image needed to be classified by characteristic into each group in the further research step by step. Dress silhouette, surface pattern effect and primary final application were chosen as three categories for classifying an image according to the characteristics it shows. There are two reasons dress silhouette was chosen as a categorizing criteria. First, according to the literature review, classifications of dress silhouettes are important in all aspects of dress design (Qishu, 2012). No research was found about the application of lasers to dress design, so it is unknown whether reliable classification of dress designs using laser technology is different than classifications introduced in the literature review. If some differences exist, but the research directly relies on the classifications of dress silhouette introduced in the literature review, the results may be not precise. Therefore, exploration of the silhouettes of dresses made using laser technology is an important step. Second, as a new technology in terms of
application to garment design, laser cutting and engraving can enable fabric surface with
great details and unique texture (Hengyin, 2007; Yuan et al., 2012). Unlike fabrics treated
with printing technology, laser cut and engraving treatment can change the fabric suppleness,
which may cause some challenges to dress design. For example, if a hard fabric is cut with
rich details, it may become soft and can no longer be used for some structural dress designs.
Also there is a need to know which section of dress can support use of these technologies and
which surface pattern effects is work for particular dress silhouettes. Therefore, silhouette of
dress designs using laser technology needs to be explored and classified.

After developing the original image database, all of the images in the database were
divided into two groups. Group 1 included the images that only showed parts of the dresses
or other clothes, fabrics, and accessories. As Figure 3.1 shows, Images (a) (b) (c) and (d) are
representative pictures from Group 1. From image (a), it can only be known that the fabric
has been treated with laser cutting, but whether it is a part of a garment is unknown. From
image (b), it can be known that the laser cutting is on the shoulder, but the rest of the garment
is unknown. From image (c), it can be known that the laser cutting is on a bodice which also
belongs to a garment, but the type of the garment is unknown. Image (d) is a leather cuff that
belongs to accessories.
Dress is the main object of the research, so Group 2 only included the images that showed the entire dress silhouette. As Figure 3.1 shows, Image (e) (f), (g), and (h) are four representative images in Group 2 which show the whole garment as well as details. Also, they represent four situations: runway, product photography, artistic photography, and mannequin. From these four pictures, it can be known each dress’s silhouette, surface features, and final application.
(a) (“Laser Cut Silk”, n.d.)

(b) (Collection “Insomnia” by Kyoung eun Hong”, 2013)

(c) (“Gold laser cut leather dress”, n.d.)

(d) (“Mandala Leather Cuff by RockBody”, 2015)

(e) (“Giles at London Spring 2013”, 2013)

(f) (“Laser Cut Dress by Emilio Pucci”, 2008)

(g) (“Arachne Collection by Malgorzata Dudek (2)”, 2013)

(h) (“Wearable Art details Yiqing Yin”, 2012)

Figure 3.1 Representative images the original image database
All the images in Group 1 can be used by observing and recording characteristics of
the surface pattern effects. All of the images in Group 2 can be used by observing and
recording characteristics of the dress silhouettes, surface design effects, and final application.
Group 1 had 240 images, and Group 2 had 163 images.

In Group 1, each image was tagged through manually renaming the image according
to the major surface design effect shown. For example, image (a) has the tag “Lace or Paper
Cutting Effect”; image (b) has the tag “Cutting and Recombining”; image (c) has the tag
“Combination of Hollow-out and Laser Engraving”; and image (d) has the tag “Laser
Engraving”.

Because the pictures in Group 2 can also show surface features, after tagging Group 1,
each picture in Group 2 was moved according to the major surface pattern effect shown. For
example, image (e) has the tag “Lace or Paper Cutting Effect”; image (f) has the tag
“Hollow-out Effect”; image (g), it has the tag “Lace or Paper Cutting Effect”; image (h) has
the tag “Cutting and Recombining”.

After tagging all of the pictures in Group 1 and Group 2, a new folder called Original
Surface Pattern Effect was created. Next, subfolders were created and given tagged with the
category name. Next, each image in Group 1 and Group 2 was copied and moved to each
subfolder according to the tag. It can be found that six subfolders include all of the 355
images, which means each subfolder represents one surface pattern effect category. The six subfolders’ names are: Lace and Paper Cut Effect, Hollow-out Effect, Cutting and Recombining, Laser Engraving, Hollow-out and Engraving, and Uncertain. The flow process chart is shown as follows:

Figure 3.2 Flow process of classifying the original surface pattern effect of images
The number of images used in this process is 355. The quality and proportion of images in Uncertain Category was 6 and 1.69%. Except for the uncertain category, the result of classifying each image into the original category of surface pattern effect is shown as follows:

Table 3.1 Results of the original category of surface pattern effect

<table>
<thead>
<tr>
<th>Tag Name</th>
<th>Representative Images</th>
<th>Features</th>
<th>Quality / Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lace or Paper-cut Effect</td>
<td><img src="image" alt="Lace or Paper-cut Effect Image" /> (&quot;Crazy for Laser Cut Clothing&quot;, 2014)</td>
<td>The surface pattern features lacy, openwork or papercut design effects. The pattern of Lace Effect can be very delicate and intricate with full of details.</td>
<td>171 / 48.17%</td>
</tr>
<tr>
<td>Hollow-out</td>
<td><img src="image" alt="Hollow-out Image" /> (&quot;Laser cut top by Roger Rich (&quot;FHM Collections Germany&quot;, 2009))</td>
<td>The surface pattern features larger voids and holes in the fabric. Compared to lace effect patterns, the hollow-out pattern can be relatively simple.</td>
<td>41 / 11.55%</td>
</tr>
<tr>
<td>Cutting and Recombining</td>
<td>Cutting and recombining effects may utilize cut parts or garment sections. Recombining cut pieces to create structural and dimensional effects also fits in this category.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(“Nieuwenhuys worked with pieces of plywood”, 2011)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laser Engraving</td>
<td>Laser engraving adds ornamentation by changing the fabric color, texture or both through a burning process that alters the fabric surface. Multitonal effects can be generated on the fabric surface.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(“Laser Engraving Logo”, n.d.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hollow-out and Engraving</td>
<td>Combination hollow-out and laser engraving effects utilize techniques of both categories together in design to create added detail and complexity.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(“AW 2010-11 Dress Design by Haider Ackermann”, 2011)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 114 | 32.11% |
| 7 | 1.97% |
| 16 | 4.51% |
3.3 Preliminary Dress Silhouette and Primary Application Classification

After copying and moving all the images in Group 2, each picture was given two more tags according to the dress silhouette and its primary final application. For example, Image (e) in Figure 3.1, was tagged “H-Shape” and ”primarily functional”; Image (f), was tagged “H-Shape” and ”primarily functional”; Image (g), was tagged “X-Shape” and ”Primarily decorative”; and Image (h), was tagged “H-Shape” and ”Primarily decorative”.

After tagging all of the pictures in Group 2, a new folder called Silhouette was made. Subfolders were created and each subfolder was given a silhouette tag name. Next, each picture in Group 2 was copied and moved to each subfolder according to the silhouette tag name. It can be found that seven subfolders for Dress Silhouette category can include all of the images in Group 2, which means each subfolder represents one Dress Silhouette category. The seven subfolders’ names are: A-Shape, X-Shape, H-Shape, K-Shape, Y-Shape, O-Shape, and Uncertain category. The flow process chart is shown as follows:
Figure 3.3 Flow process of classifying the preliminary Dress Silhouette category and Primary Final Application category of dresses

The number of total images in Group 2 was 163. The quality and proportion of images in Uncertain Category for Dress Silhouette was 26 and 15.96%. The table below provides information for each category shown as follows:
Table 3.2 Results of the preliminary category of Dress Silhouette

<table>
<thead>
<tr>
<th>Tag Name</th>
<th>Representative Images</th>
<th>Features</th>
<th>Quality / Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-Shape</td>
<td>(&quot;Giles at London Spring 2013&quot;, 2013)</td>
<td>The shape of dress resembles the letter H. The silhouette is slender, with a roughly straight-line outline and a straight skirt. The waist is loosely fitted if at all. Above the waist, it can be structured, natural or strapless.</td>
<td>87 / 53.37%</td>
</tr>
<tr>
<td>X-Shape</td>
<td>(&quot;Marchesa Spring 2010 RTW Black and White Laser-Cut Floral Stencil Dress&quot;, 2010)</td>
<td>The shape of dress resembles the letter X. The dress shape is tightly fitted and snug at the waist and flared in the skirt. This silhouette emphasizes the curves of the body. And it has a relatively simple structural design in shoulder part.</td>
<td>28 / 17.18%</td>
</tr>
<tr>
<td>Silhouette</td>
<td>Description</td>
<td>Percentage</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
<td>------------</td>
<td></td>
</tr>
<tr>
<td>A-Shape</td>
<td>The shape of dress resembles the letter A. The shape of dress is roughly quadrilateral, and fullest at the hem. The range of this silhouette may be from somewhat to very full at the bottom. The waist is unfitted and loose at the waist.</td>
<td>14 / 8.59%</td>
<td></td>
</tr>
<tr>
<td>Y-Shape</td>
<td>The shape of dress resembles the letter Y. The dress has a fitted waist with a relatively rich structural design in the shoulder or upper part.</td>
<td>3 / 1.84%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(“Get out of Your Skin”, 2014)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(“Arachne Collection”, 2013)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shape</td>
<td>Description</td>
<td>Percentage</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>------------</td>
<td></td>
</tr>
<tr>
<td>K-Shape</td>
<td>The shape of dress resembles the letter K. The dress has a tightly fitted waist with an apparently asymmetrical skirt part. And it has a relatively simple structural design in shoulder region.</td>
<td>2 / 1.22%</td>
<td></td>
</tr>
<tr>
<td>O-Shape</td>
<td>The shape of dress resembles the letter O. The dress has a fitted waist with a relatively rich structural design in skirt part. The skirt shape is like a circle or square.</td>
<td>3 / 1.84%</td>
<td></td>
</tr>
</tbody>
</table>

K-Shape

O-Shape
(Wearable Art by Catherine O'Leary, 2011)
After copying and moving all of the images in Group 2 to the Dress Silhouette folder, a new folder called Primary Final Application was created. Subfolders were created and given Primary Final Application tag. Next, each picture in Group 2 was copied and moved to each subfolder according to the Final Application tag name. Similarly, three subfolders for Primary Final Application category include all of the 163 images in Group 2 meaning each subfolder represents one Primary Final Application category. The three subfolders are: Primarily Decorative, Primarily Functional and Uncertain category. The table summarizes each category shown as follows:

Table 3.3 Results of the category of Primary Final Application

<table>
<thead>
<tr>
<th>Tag Name</th>
<th>Representative Images</th>
<th>Features</th>
<th>Quality / Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primarily Decorative</td>
<td>(“Wearable Art by Catherine O’Leary”, 2011)</td>
<td>Dress emphasizes the artistic effect shown by the garment, often sculptural fashion for exhibition or photography.</td>
<td>41 / 25.62%</td>
</tr>
</tbody>
</table>
Table 3.3 Continued

<table>
<thead>
<tr>
<th>Primarily Functional</th>
<th>Dress emphasizes wearability and function, often RTW fashion which can be commercialized for wearing in daily life or special occasions.</th>
<th>119 / 74.37</th>
</tr>
</thead>
<tbody>
<tr>
<td>(“Spring 2013 by Alexander Wang”, 2013)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.4 Developing Preliminary Categories

After classifying each image into each group, a catalog was created to help the researcher determine where the image belongs in the classification system. In this research, Dress Silhouette, Surface Pattern Effect, Primary Final Application are three main categories. The process of cataloging the images in Group 2 was three steps. First, images were sorted by dress silhouette, next by surface pattern effect, and finally by primary final application.
A new folder called Preliminary Categories was created. All Dress Silhouette
subfolders were copied and moved into the Preliminary Categories folder. In each Dress
Silhouette subfolder, subfolders were created and each of them was given a Surface Pattern
Effect name. Corresponding images in Group 2 were copied and moved to Surface Pattern
Effect folders according to the tag. Last, new subfolders were created and given a Primary
Final Application name. Then, each corresponding image was copied and moved to each
subfolder according to the Final Application tag. The number of total images in Group 2 was
163. Except for the 26 images in Uncertain Category for Dress Silhouette, the number of the
images in Preliminary Categories is 137. The results are summarized in Table 3.4 shown as
follows:
Table 3.4 Results of the Preliminary Categories

<table>
<thead>
<tr>
<th>Dress Silhouette</th>
<th>Surface Pattern Effect</th>
<th>Primary Final Application</th>
<th>Quality / Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-Shape Silhouette</td>
<td>Lace or Paper-cut Effect</td>
<td>Primarily Functional</td>
<td>5 / 3.65%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Primarily Decorative</td>
<td>0 / 0%</td>
</tr>
<tr>
<td></td>
<td>Hollow-out</td>
<td>Primarily Functional</td>
<td>0 / 0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Primarily Decorative</td>
<td>1 / 0.73%</td>
</tr>
<tr>
<td></td>
<td>Cutting and Recombining</td>
<td>Primarily Functional</td>
<td>6 / 4.37%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Primarily Decorative</td>
<td>2 / 1.46%</td>
</tr>
<tr>
<td></td>
<td>Laser Engraving</td>
<td>Primarily Functional</td>
<td>0 / 0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Primarily Decorative</td>
<td>0 / 0%</td>
</tr>
<tr>
<td></td>
<td>Hollow-out and Engraving</td>
<td>Primarily Functional</td>
<td>0 / 0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Primarily Decorative</td>
<td>0 / 0%</td>
</tr>
<tr>
<td>H-Shape Silhouette</td>
<td>Lace or Paper-cut Effect</td>
<td>Primarily Functional</td>
<td>29 / 21.16%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Primarily Decorative</td>
<td>6 / 4.37%</td>
</tr>
<tr>
<td></td>
<td>Hollow-out</td>
<td>Primarily Functional</td>
<td>12 / 8.76%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Primarily Decorative</td>
<td>2 / 1.46%</td>
</tr>
<tr>
<td></td>
<td>Cutting and Recombining</td>
<td>Primarily Functional</td>
<td>21 / 15.33%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Primarily Decorative</td>
<td>9 / 6.57%</td>
</tr>
<tr>
<td></td>
<td>Laser Engraving</td>
<td>Primarily Functional</td>
<td>2 / 1.46%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Primarily Decorative</td>
<td>0 / 0%</td>
</tr>
<tr>
<td></td>
<td>Hollow-out and Engraving</td>
<td>Primarily Functional</td>
<td>4 / 2.91</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Primarily Decorative</td>
<td>0 / 0%</td>
</tr>
</tbody>
</table>
Table 3.4 Continued

<table>
<thead>
<tr>
<th>X-Shape Silhouette</th>
<th>Lace or Paper-cut Effect</th>
<th>Primarily Functional</th>
<th>Primarily Decorative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hollow-out</td>
<td>Primarily Functional</td>
<td>2 / 1.46%</td>
<td>Primarily Decorative</td>
</tr>
<tr>
<td>Cutting and Recombining</td>
<td>Primarily Functional</td>
<td>3 / 2.19%</td>
<td>Primarily Decorative</td>
</tr>
<tr>
<td>Laser Engraving</td>
<td>Primarily Functional</td>
<td>1 / 0.73%</td>
<td>Primarily Decorative</td>
</tr>
<tr>
<td>Hollow-out and Engraving</td>
<td>Primarily Functional</td>
<td>0 / 0%</td>
<td>Primarily Decorative</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>K-Shape Silhouette</th>
<th>Lace or Paper-cut Effect</th>
<th>Primarily Functional</th>
<th>Primarily Decorative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hollow-out</td>
<td>Primarily Functional</td>
<td>0 / 0%</td>
<td>Primarily Decorative</td>
</tr>
<tr>
<td>Cutting and Recombining</td>
<td>Primarily Functional</td>
<td>0 / 0%</td>
<td>Primarily Decorative</td>
</tr>
<tr>
<td>Laser Engraving</td>
<td>Primarily Functional</td>
<td>0 / 0%</td>
<td>Primarily Decorative</td>
</tr>
<tr>
<td>Hollow-out and Engraving</td>
<td>Primarily Functional</td>
<td>0 / 0%</td>
<td>Primarily Decorative</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>O-Shape Silhouette</th>
<th>Lace or Paper-cut Effect</th>
<th>Primarily Functional</th>
<th>Primarily Decorative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hollow-out</td>
<td>Primarily Functional</td>
<td>0 / 0%</td>
<td>Primarily Decorative</td>
</tr>
<tr>
<td>Cutting and Recombining</td>
<td>Primarily Functional</td>
<td>0 / 0%</td>
<td>Primarily Decorative</td>
</tr>
<tr>
<td>Laser Engraving</td>
<td>Primarily Functional</td>
<td>0 / 0%</td>
<td>Primarily Decorative</td>
</tr>
<tr>
<td>Hollow-out and Engraving</td>
<td>Primarily Functional</td>
<td>0 / 0%</td>
<td>Primarily Decorative</td>
</tr>
</tbody>
</table>
Table 3.4 Continued

<table>
<thead>
<tr>
<th>Y-Shape Silhouette</th>
<th>Lace or Paper-cut Effect</th>
<th>Primarily Functional</th>
<th>1/0.73%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Primarily Decorative</td>
<td>2/1.46%</td>
</tr>
<tr>
<td>Hollow-out</td>
<td>Primarily Functional</td>
<td>0/0%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Primarily Decorative</td>
<td>0/0%</td>
<td></td>
</tr>
<tr>
<td>Cutting and Recombining</td>
<td>Primarily Functional</td>
<td>0/0%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Primarily Decorative</td>
<td>0/0%</td>
<td></td>
</tr>
<tr>
<td>Laser Engraving</td>
<td>Primarily Functional</td>
<td>0/0%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Primarily Decorative</td>
<td>0/0%</td>
<td></td>
</tr>
<tr>
<td>Hollow-out and Engraving</td>
<td>Primarily Functional</td>
<td>0/0%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Primarily Decorative</td>
<td>0/0%</td>
<td></td>
</tr>
</tbody>
</table>

3.5 Refining Categories

From Table 3.4, some subgroups represent a very small proportion, so there was a need to further analyze the preliminary categories. On the one hand, those groups which have small proportion need to be intensively studied. On the other hand, those images which belong to the Uncertain Category need to be analyzed one by one.

In the Uncertain subcategory of the Surface Pattern Effect category, two groups were classified: Group A includes the images that are difficult to tell apart from Lace or Paper-cut Effect and Hollow-out Effect, Group B includes the images that are difficult to tell apart from Hollow-out Effect and Cutting and Recombination.

In Figure 3.4, image (a) is a typical example for lace effect, (b) is a typical example for paper-cut effect, (c) and (d) are typical examples for hollow-out effect. Images (e), (f), (g),
and (h) are in Group A. The cut patterns of images (e) and (f) have similarities to the paper-cut effect but also have similarities to the hollow-out effect. In other words, the complexity of the cut patterns of the image (e) and (f) is moderate with floral shape but the portion of exposed part is larger than that of image (a) and (b). The cut patterns of the images (g) and (h) have similarities to the hollow-out effect but also have similarities to the lace and paper-cut effect. In other words, the cut patterns of the images (e) and (f) are geometrical but the portion of exposed part is smaller than that of images (a) and (b).

Because the perception of patterns is often influenced by subjective factors, the solution is to extend the scope by merging the Lace or Paper Effect category and the Hollow-out category into one category: Lace and Hollow-out Effects.
(a) (“Threeasfour at New York Fashion Week Spring 2014 (3)”, 2014)

(b) (“Laser Cut Dress”, n.d.)

(c) (“Dissect 2013 Fashion Collection by Minette Shuen (2)”, 2013)

(d) (“Morticia skull laser cut dress black”, 2015)

(e) (“Laser Cut Dress by Christopher Kane S/S 2014”, 2014)

(f) (“Valentino Couture”, Fall 2013, 2013)

(g) (“Laser Cut Fashion - Graphic Black & White Laser Cut Seahorse Dress”, n.d.)

(h) (“Black Laser-Cut Crepe Dress”, n.d.)

Figure 3.4 Image examples and Group A images in the Uncertain subcategory of the Surface Pattern Effect category
In Figure 3.5, images (a), (b), (c), and (d) are four typical examples for the Cutting and Recombining category. In image (a), the designer cut part of the graphic pattern on the fabric so that the cut pieces remain attached to the fabric, which gives a feeling of thousands of leaves on the dress. In image (b), the designer cut the petal pieces and assembled them, which created the flowering shrubs around the garment. In image (c), the designer cut strips on the top back and transformed them into a new structure, which is dimensional. In image (d), the designer cut the fabric apart into the specific shapes and reattached them on the dress, which creates a collage. Images (e), (f), (g), and (h) are in Group B. In image (e), it is easy to misclassify it to the Hollow-out Effect category, however, it should belong to the Cutting and Recombination category. The designer cut the strips and built a structural skirt, which has a large exposure. Actually, the Hollow-out Effect category has one requirement: the effect must be created by the laser cutting itself. In other words, the exposure is the result of the skirt structure. In image (f), it can be mistaken for the Cutting and Recombination category. However, after closely observing, it should belong to the Lace and Hollow-out Effects category. This is because Cutting and Recombination requires the laser cut work be recombined on the laser cut piece. In image (f), the laser cut piece combined with a knitted fabric which has no laser cutting. In a similar way, image (g) also has features of the hollow-out effect. However, the designer used several cut pieces to create the skirt, which give a strong feeling of structure. In the other words, the cut pieces which have hollow-out effect
are combined together to create the dimensional design. So the image (g) belongs to the Cutting and Recombination category. As for image (h), it resembles pieces in the Lace or Hollow-out Effect category. However, after further scrutinizing, it can be found that the black pieces around the garment are cut firstly and stuck or stitched secondly.
(a) (“Christian Dior Spring 2014 Couture Collection (10)”, 2014)

(b) (“Textured Embellishment by Noir Kei Ninomiya”, n.d.)

(c) (“Twisted Laser Cutting Idea”, n.d.)

(d) (“Anne Hathaway Met Gala 2015”, 2015)

(e) (“Conceptual Fashion by Charlotte Ham”, 2014)

(f) (“Laser cut leather with chunky knitted textures by Jessica Hope Medlock”, 2014)

(g) (“Wearable Art by Catherine O'Leary”, 2011)

(h) (“Black Laser-Cut Crepe Dress”, n.d.)

Figure 3.5 Image examples and Group B images in the Uncertain subcategory of the Surface Pattern Effect category
Therefore, the refined Surface Pattern Effect Categories are four: Lace and Hollow-out Effects, Cutting and Recombining, Laser Engraving, and Combination of Hollow-out and Laser Engraving. The number of total images used for Surface Pattern Effect category is 355. The new Surface Pattern Effect category is detailed in Table 3.5.

Table 3.5 Results of the refined category of surface pattern effect

<table>
<thead>
<tr>
<th>Tag Name</th>
<th>Representative Images</th>
<th>Features</th>
<th>Quality /Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lace and Hollow-out Effects</td>
<td>(“Crazy for Laser Cut Clothing”, 2014)</td>
<td>Lace and hollow-out effects emphasize the surface pattern and may feature lacy, openwork or paper-cut design effects, or larger voids and holes in the fabric.</td>
<td>214 / 60.28%</td>
</tr>
<tr>
<td>(“Laser cut top by Roger Rich (“FHM Collections Germany”, 2009)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cutting and Recombining</th>
<th>(A Passion for Lasers, Jolka Wiens’ Graduate Collection (2), 2013)</th>
<th>Cutting and recombinig effects may utilize cut parts or garment sections. Recombining cut pieces to create structural and dimensional effects also fits in this category.</th>
<th>118 / 33.24%</th>
</tr>
</thead>
<tbody>
<tr>
<td>(“Nieuwenhuys worked with pieces of plywood”, 2011)</td>
<td>Laser Engraving</td>
<td>Laser engraving adds ornamentation by changing the fabric color, texture or both through a burning process that alters the fabric surface. Multitonal effects can be generated on the fabric surface.</td>
<td>7 / 1.97%</td>
</tr>
</tbody>
</table>

Table 3.5 Continued
From Table 3.2, it can be found that K-Shape Silhouette, O-Shape Silhouette, and Y-Shape Silhouette represent a very small proportion in the image database. Therefore, all the dress images in these categories needed to be restudied.

In the original silhouette category, images Y1, Y2 and Y3 (Figure 3.6) belonged to the Y-Shape silhouette. Images K1 and K2 (Figure 3.6) belonged to the K-Shape silhouette. Images O1, O2 and O3 (Figure 3.6) belonged to the O-Shape silhouette. Images X1, X2 and X3 (Figure 3.6) are three typical X-Shape silhouettes. Images H1, H2 and H3 (Figure 3.6) are
three typical H-Shape silhouettes. Images A1, A2 and A3 (Figure 3.6) are three typical A-Shape silhouettes.

To reassess the dress images in the K-Shape Silhouette, O-Shape Silhouette, and Y-Shape Silhouette categories, each dress silhouette was outlined from the waist to the skirt using red lines. Except for all of the A-Shape silhouettes and the type of H2 silhouette, there is one similarity: they all have a relatively tight and fitted waist region. The red lines in the images Y1, K1, K2, O1, O2, and O3 are similar to the red lines in the images X1, X1, X2. At the same time, the red lines in the images Y2 and Y3 have similar features to the red lines in the images H1 and H3.

Therefore, the images in the K-Shape Silhouette, O-Shape Silhouette, and Y-Shape Silhouette categories can be classified into the X-Shape Silhouette and H-Shape Silhouette categories.
Figure 3.6 Typical examples of each silhouette in the original silhouette category

Image Y1 ("Arachne Collection by Malgorzata Dudek (1)", 2013)
Image Y2 ("Arachne Collection by Malgorzata Dudek (3)", 2013)
Image Y3 (Threeasfour at New York Fashion Week Spring 2014 (1), 2014)
  Image K1 (Marchesa SS 2011 Collection, 2011)
Image O1 ("Papercut Dress by Beatrice Coron (1)", 2013)
Image O2 ("Wearable Art by Catherine O’Leary”, 2011)
Image O3 ("Papercut Dress by Beatrice Coron (2)", 2013)
  Image X1 (Marchesa Fall 2012 Collection (1), 2012)
Image X2 ("Marchesa Spring 2010 RTW Laser-Cut Floral Stencil Dress”, 2010)
  Image X3("Arachne Collection by Malgorzata Dudek (2)", 2013)
Image H1 ("A Passion for Lasers, Jolka Wiens’ Graduate Collection (2)", 2012)
  Image H3 ("Ezra Couture 2016 RTW”, 2016)
  Image A2 ("Get out of Your Skin”, 2014)
  Image A3 ("Laser Cutting Fashion Product (2)", n.d.)
Also, all the images in the Uncertain Category needed to be closely observed and analyzed. First, each dress silhouette was outlined from the waist to the skirt using lines with different colors. The red line meant the actual outline of the dress from the waist to the skirt. The Yellow line meant the part that required further assessment. The blue circle meant the details that should be considered. Compared with the typical dresses in the A-Shape Silhouette, H-Shape Silhouette, and X-Shape Silhouette (Figure 3.6 X1-X3, H1-H3, and A1-A3), these uncertain images needed to be classified.

Group A (Figure 3.7) was challenging because the dress silhouettes of 3.17 (a) and (b) are very similar to the H-Shape silhouette (see yellow lines). However, after further scrutinizing, the silhouette of the dress in Image 3.17 (a) is the same as that in image O1 (Figure 3.6) and the silhouette of the dress in Image 3.17 (b) is the same as that in image O3 (Figure 3.6). Therefore, they should belong to the X-Shape Silhouette.
Group B (Figure 3.8) was challenging because the silhouettes of the dresses in Image (a)-(d) are also very similar to the H-Shape silhouette (see yellow lines). However, after drawing the silhouette of each dress using red lines, they should belong to the X-Shape Silhouette. Even if the skirt is not flared apparently, two red lines still are radial.
Figure 3.8 Group B Group B images in the Uncertain Silhouette category

Group C (Figure 3.9) was challenging because the silhouettes of the dresses in images 3.9 (a)-(d) are hard to distinguish. The solution is exploring all the possible silhouettes using professional knowledge. For images 3.9 (a), and 3.9 (b), the sleeves are close to the side of the skirt, which hides parts of the skirt. Therefore, there are two possible dress silhouette: one is drawn by red lines and the other one is draw by the yellow lines. The silhouettes drawn by red lines are most likely to be correct. For images 3.9 (c) and 3.9 (d), the cut pieces also hide
parts of the skirts, so there is a need to zoom in the image and carefully find the actual skirt silhouette using red lines. According to the red lines in images of Figure 3.9, images 3.9 (a) and 3.9 (c) belonged to the H-Shape Silhouette, and Image 3.9 (b) and 3.9 (d) were classified into the X-Shape silhouette.

(a) (“Anne Sofie Madsen SS14”, 2014)  
(b) (“Iris Van Herpen Couture SS13 Collection (4)”, 2013)  
(c) (“Iris Van Herpen Couture SS13 Collection (3)”, 2013)  
(d) (“Iris Van Herpen Couture SS13 Collection (6)”, 2013)  

Figure 3.9 Group C images in the Uncertain Silhouette category

Group D (Figure 3.10) was challenging because the determination of the dress silhouettes was affected by the attachment to the dress or an extra skirt. If the skirt of the dress has a surface effect using laser technology, there is no need to consider the attachment.
Images 3.10 (a) (b) and (c) (see Figure 3.10) belonged to this situation. If the skirt of the dress has no surface pattern effect using laser technology, but the attachment or the extra skirt part has it, there is a need to consider the attachment or the extra skirt part. For image 3.10 (d), the skirt has no surface pattern effect, but the attachment has the surface pattern effect and it is flared skirt. Thus the shape of the attachment should be considered when determining the dress silhouette. If a dress has an extra skirt, and both skirts have surface pattern effect using laser technology, the solution is finding and confirming the integral part of the dress. For image 3.10 (e), the flared skirt is very short so the silhouette type depends on the midi skirt. According to the red lines in the images of Figure 3.10, images 3.10 (a), (b), (c) and (e) belonged to the H-Shape Silhouette, and image 3.10 (d) was classified into the X-Shape silhouette.
In Figure 3.11, Group E is challenging because the silhouettes of the dresses in images 3.11 (a)-(e) are very easy to be mistaken for the H-Shape silhouette type after drawing the silhouette of each dress using red lines. However, there is an important detail: gathers and pleats should be noticed when determining a dress silhouette. In comparison, it can be found that the gathers in image 3.11 (b) are more than those in image 3.11 (a).
Therefore, image 3.11 (a) belongs to the H-Shape Silhouette while image 3.11 (b) belongs to the X-Shape Silhouette. Similarly, the gathers in Image 3.11 (c) and Image 3.11 (f) are more than those in Image 3.11 (d). The pink lines refer to the skirt outline if it was unfolded.

(b) (“Laser cut Leather Dress Product”, n.d.)
(c) (“Laser Cut Skirt”, n.d.)
(d) (“Carven Fall 2012”, 2012)
(e) (“Black Laser-Cut Crepe Dress”, n.d.)

Figure 3.11 Group E images in the Uncertain Silhouette category

In Figure 3.12, Group F is complex because the silhouettes of the dresses in images 3.12 (a), (b) and (c) are similar to the A-Shape Silhouette. Image 3.12 (a) is easily mistaken for the H-Shape Silhouette. Actually, the inner white dress has no laser surface effect.
Therefore, the silhouette of this dress should depend on the outer dress which is made of strips. After drawing the silhouette using red lines, image 3.12 (a) should belong to the A-Shape Silhouette. Image 3.12 (b) is easily mistaken for the H-Shape Silhouette. Actually, the dress bottom is wider than what H-Shape silhouette should be, which is shown by the yellow line. So image 3.12 (b) should belong to the A-Shape Silhouette. Image 3.12 (c) is easily mistaken for the X-Shape Silhouette. Actually, image 3.12 (c) belongs to the A-Shape Silhouette. This is because of the fitted part is below the chest, however, the fitted part of the X-Shape Silhouette is at the waist.

(a) (“Cutting Class: Conceptual Fashion by Charlotte Ham”, n.d.)
(b) (“Christian Dior Spring 2014 Couture Collection (32)”, 2014)
(c) (“Christian Dior Spring 2014 Couture Collection (17)”, 2014)

Figure 3.12 Group F images in the Uncertain Silhouette category
Also the X-Shape Silhouette and the A-Shape Silhouette were renamed Calabash Silhouette and Trapezium Silhouette because the characteristics changed after refining the categories. The number of total images used is 163. The new Dress Silhouette categories are described in Table 3.6 shown as follows:

Table 3.6 Results of the refined category of Dress Silhouette

<table>
<thead>
<tr>
<th>Tag Name</th>
<th>Representative Images</th>
<th>Features</th>
<th>Quality / Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-Shape Silhouette</td>
<td>(“Giles at London Spring 2013”, 2013)</td>
<td>This shape of dress resembles the letter H. The silhouette is slender, with a roughly straight-line outline and straight skirt. The waist is loosely fitted if at all. Above the waist, it can be a structured, natural or strapless.</td>
<td>99 / 60.74%</td>
</tr>
<tr>
<td>Calabash Silhouette</td>
<td>(“Marchesa Spring 2010 Laser-Cut Floral Stencil Dress”, 2010)</td>
<td>The dress shape is tightly fitted and snug at the waist and flared in the skirt. This silhouette emphasizes the curves of the body. And it has a relatively simple structural design in shoulder part.</td>
<td>47 / 28.83%</td>
</tr>
</tbody>
</table>
3.6 Developing Refining Categories

After refining the category, a catalog needs to be created so that it can help the researcher to determine where each image belongs. In the refined classification system, Dress Silhouette, Surface Pattern Effect, and Primary Final Application are three main categories. The number of total images used is 163 and the result of cataloging is displayed in Table 3.7 shown as follows:

Table 3.6 Continued

| Trapezium Silhouette | The shape of dress is roughly quadrilateral, and fullest at the hem. The range of this silhouette may be from somewhat to very full at the bottom. | 17 / 10.43% |

104
Table 3.7 Results of the Refined Categories

<table>
<thead>
<tr>
<th>Dress Silhouette</th>
<th>Surface Pattern Effect</th>
<th>Primary Final Application</th>
<th>Quality /Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapezium Silhouette</td>
<td>Lace and Hollow-out effects</td>
<td>Primarily decorative</td>
<td>1 / 0.61%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>primarily functional</td>
<td>5 / 3.07%</td>
</tr>
<tr>
<td></td>
<td>Laser Engraving</td>
<td>Primarily decorative</td>
<td>0 / 0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>primarily functional</td>
<td>0 / 0%</td>
</tr>
<tr>
<td></td>
<td>Combination of Hollow-out and Laser Engraving</td>
<td>Primarily decorative</td>
<td>0 / 0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>primarily functional</td>
<td>0 / 0%</td>
</tr>
<tr>
<td></td>
<td>Cutting and Recombining</td>
<td>Primarily decorative</td>
<td>0 / 0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>primarily functional</td>
<td>0 / 0%</td>
</tr>
<tr>
<td>H-Shape Silhouette</td>
<td>Lace and Hollow-out effects</td>
<td>Primarily decorative</td>
<td>9 / 5.52%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>primarily functional</td>
<td>48 / 29.45%</td>
</tr>
<tr>
<td></td>
<td>Laser Engraving</td>
<td>Primarily decorative</td>
<td>0 / 0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>primarily functional</td>
<td>2 / 1.23%</td>
</tr>
<tr>
<td></td>
<td>Combination of Hollow-out and Laser Engraving</td>
<td>Primarily decorative</td>
<td>0 / 0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>primarily functional</td>
<td>4 / 2.45%</td>
</tr>
<tr>
<td></td>
<td>Cutting and Recombining</td>
<td>Primarily decorative</td>
<td>10 / 6.13%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>primarily functional</td>
<td>26 / 15.95%</td>
</tr>
<tr>
<td>Calabash Silhouette</td>
<td>Lace and Hollow-out effects</td>
<td>Primarily decorative</td>
<td>12 / 7.36%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>primarily functional</td>
<td>26 / 15.95%</td>
</tr>
<tr>
<td></td>
<td>Laser Engraving</td>
<td>Primarily decorative</td>
<td>0 / 0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>primarily functional</td>
<td>1 / 0.61%</td>
</tr>
<tr>
<td></td>
<td>Combination of Hollow-out and Laser Engraving</td>
<td>Primarily decorative</td>
<td>0 / 0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>primarily functional</td>
<td>0 / 0%</td>
</tr>
<tr>
<td></td>
<td>Cutting and Recombining</td>
<td>Primarily decorative</td>
<td>4 / 2.45%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>primarily functional</td>
<td>4 / 2.45%</td>
</tr>
</tbody>
</table>
3.7 Development of Evaluation Tool

To validate and examine the classification system, and to assess the need for further refinements of the system or the characteristics of specific categories, a survey of participants with professional and relevant knowledge was conducted. Before the survey, a brochure describing each category of dress silhouette, and providing visual examples of dresses in each category was prepared (see Appendix A: Brochure Description for Survey). The brochure was divided into 3 parts: Dress Silhouette, Surface Pattern Effect, and Primary Final Application. A survey was designed as the evaluation tool for the visual research (see Appendix B: Evaluation Tool for Survey). At the same time, one set of 20 images were selected. Images were numbered from 1-20 and then the images were organized into four different random orders using a random number generator (http://andrew.hedges.name/experiments/random/) into presentations. One of the four randomly ordered sets was presented in Power Point format to each participant. Images included 17 existing images selected from the image database and 3 original fashion designs. There were two conditions considered when choosing the 17 existing images. First, images that could be considered typical examples in their categories were selected. Second, images that could be easily mistaken for other categories were selected. There are two reasons for these choices: the first was to validate and examine if the participants understood each category’s description in the brochure; the second was to tease out whether there could be a
need for adding characteristics for further refinements of specific categories. All 17 images had detailed information so that the expected responses could be credible and relatively certain based on the information. The intent of including 3 original designs is to represent a situation that otherwise would not have been present in the image database. For example, in the original designs, two designs used two different surface pattern effects which could be mistaken for others. Because the description of each category and the categorization system were developed by the designer of the original garments, the designs were attained through application of the description and system. So the accurate excepted responses for these three designs was certain in the classification system.

After preparing the images for evaluation and the brochure, and acquisition of IRB approval, the survey was conducted. The participants were invited due to expertise in fashion and textile design, textile technology, and textile product development. This was important to the research because a professional background with relevant knowledge was expected to help participants easily understand the brochure and the responses enhancing the researcher’s confidence in the results. After completing the informed consent, participants were given a brochure and introduced to the brief purpose of the survey. Next, participants were given a survey and seated at a computer. Participants were asked to complete the survey in response to 20 images previously selected and presented in one of four random orders. Digital images of the designs were used to prompt the participants in completing the survey. After reading
the brochure, the participant evaluated the 20 dress designs shown one at a time in Power
Point. Each subject was asked to respond to questions about the silhouette of each garment,
the surface pattern effect, the primary final application of each dress and feelings associated
with each dress. After participants finished the survey, it was returned to the researcher. For
each dress design image, the answers were compared to the category given by researcher in
the analysis.

3.8 Analysis of Response Data

There were a total of 25 research participants including 3 professors, 17 graduate
students and 5 undergraduate students with experience in fashion and textiles. The major or
research areas for participants were in fashion and textile design, textile technology, and
product development. The level of education was collected as references for future study.
Because the survey was based on validating and refining results of visual research, and the
results can be understood with knowledge of basic textile and fashion product development,
the expertise in the field is more relevant than level of degree for the remaining results of the
survey. The number of professors and undergraduate students is much less than the number
of graduate students, no comparison among degrees is possible.

After collecting all of the surveys, they were distributed into four groups according to
the four random image orders that participants had evaluated. Then each survey was
reviewed and responses that differed from the expected response were marked. Responses for each group were collected and integrated, and the results are summarized in Table 3.8 (1), (2), (3), and (4).

After integrating the data, responses of the four groups for each image were integrated again and the Table 3.9 and Table 3.10 were developed. Based on the Table 3.10, three bar diagrams (Figure 3.13 (a), (b), and (c)) were developed showing the percentage of responses as expected for each category. Images with responses that had 85% or less agreement with the expected response were discussed.

The percentage of responses as expected for Dress Silhouette category is shown in Figure 3.13 (a). As can be seen, 3 dress silhouettes were 100% evaluated as expected; 7 dress silhouettes were 96%; 3 dress silhouettes were 92%; 4 dress silhouettes were 88%; and 3 dress silhouettes (Figure 3.14 (a), (b), and (c)) were below 85%. All of the dresses that have 85% or below 85% evaluated as expected responses were further analyzed and discussed.
Table 3.8 Results of Group (1)-(4)

<table>
<thead>
<tr>
<th>Image Number</th>
<th>Silhouette</th>
<th>Surface Pattern Effect</th>
<th>Final Application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
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<tr>
<td>8</td>
<td>4</td>
<td>1</td>
<td>4</td>
</tr>
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Table 3.9 Integrated results of each Image

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Table 3.10 Expected response for each category

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<th>Percentage of Responses as Expected</th>
<th>Expected Response for Surface Pattern Effect</th>
<th>Percentage of Responses as Expected</th>
<th>Expected Response for Primary Finally Application</th>
<th>Percentage of Responses as Expected</th>
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<td>76 %</td>
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<td>56 %</td>
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<td>Cutting and Recombining</td>
<td>100 %</td>
<td>Primarily Functional</td>
<td>76 %</td>
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<td>H-Shape Silhouette</td>
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<td>Cutting and Recombining</td>
<td>96 %</td>
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<td>56 %</td>
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<td>Cutting and Recombining</td>
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<td>7</td>
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<td>80 %</td>
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<td>64 %</td>
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<td>96 %</td>
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Figure 3.13 Percentage of responses as expected for each category

(a) Percentage of responses as expected for dress silhouette

(b) Percentage of responses as expected for surface pattern effect

(c) Percentage of responses as expected for primary finally application
Four participants thought image 3.14 (a) belonged to the Calabash Silhouette category (Table 3.10). Actually, the skirt is not flared (see red lines) and the challenging part (see yellow lines) belongs to the top. So, it should belong to the H-Shape Silhouette according to the category description given. Five participants thought image 3.14 (b) belonged to the Calabash Silhouette category (Table 3.10). Actually, the flared part does not start from the waist (see red lines and yellow lines). It should belong to H-Shape Silhouette according to the description given. Seven participants thought image 3.14 (c) belonged the Trapezium Silhouette category and two participants thought it belonged to Calabash Silhouette category (Table 3.10). According to the description given by the brochure, the waist of trapezium silhouette dress should be very loose (see yellow lines). The waist of this dress is not closely fitted and the skirt of this dress is not flared. After observing carefully, it can be found that waist of this dress is loosely fitted (see red lines), and the skirt has roughly straight-line outline so it belongs to the H-Shape Silhouette category.
Image 3.15 (a) and image 3.15 (b) are also challenging for participants. Three participants mistook the silhouette of image 3.15 (a) for H-shape silhouette and three participants mistook the silhouette of image 3.15 (b) for Calabash silhouette (Table 3.10). Gathers and pleats should be noticed when determining a dress silhouette (Figure 3.15 (c) and (d)). It can be found that the gathers in image 3.15 (a) are more than those in image 3.15 (b). Therefore, image 3.15 (b) belongs to the H-Shape Silhouette while image 3.15 (a) belongs to the Calabash Silhouette.
Figure 3.15 Example images

The percentage of responses as expected for Surface Pattern Effect category is shown in Figure 3.13 (b). As can be seen, one surface pattern effect received 100% evaluated as expected responses; eleven surface pattern effects received 96%; eight surface pattern effects
(Figure 3.16 images (a) - (h)) received below 90%. All the dress images that have 85% or less evaluated as expected responses were discussed.

Three participants considered the surface pattern effect of image 3.16 (a) belonged to the Lace and Hollow-out Effect category (Table 3.10). In fact, the visually hollow-out effect is recreated by cutting strips on the top back and transforming them into a new structure. One criterion of laser and hollow-out effect is that the cut fabric should be used intact without creating additional structural or dimensional effects. So the surface pattern effect of image 3.16 (a) belongs to the Cutting and Recombining category.

Two participants considered the surface pattern effect of image 3.16 (b) belonged to Cutting and Recombining category and two participants considered it belonged to the Combination of Hollow-out and Laser Engraving category (Table 3.10). The dress in image 3.16 (b) is a sculptural fashion design which can’t be worn to move conveniently and the hollow-out rectangles resemble a brick wall, which give a visual effect that the dress is dimensional. Actually this effect is created by a hollow-out pattern rather than by recombinining the hollow-out fabric part. So the surface pattern effect of image 3.16 (b) belongs to the Lace and Hollow-out Effect category.

Five participants considered the surface pattern effect of image 3.16 (c) belonged to the Lace and Hollow-out Effect category (Table 3.10). Similar to the image 3.16 (a), the visually hollow-out effect is recreated by cutting strips and transforming a hollow-out
structure rather than by cutting the hollow-out surface pattern. So the surface pattern effect of image 3.16 (c) belongs to the Cutting and Recombining category.

Six participants considered the surface pattern effect of image 3.16 (d) belonged to the Lace and Hollow-out Effect category (Table 3.10). Similar to the image 3.16 (a) and image 3.16 (c), the visually hollow-out effect is recreated by cutting the fabric and turning over the cut pieces to create a dimensional texture rather than by cutting the hollow-out surface pattern. So, the surface pattern effect of image 3.16 (d) belongs to the Cutting and Recombining category.

Four participants considered the surface pattern effect of image 3.16 (e) belonged to the Lace and Hollow-out Effect category and three participants considered it belonged to the Cutting and Recombining category (Table 3.10). Observing the engraved lines is important. When carefully observing the floral pattern, a clear outline is found adding more details to the flower pattern. In other words, the engraved lines and cut pattern appear together in one pattern design. So the surface pattern effect of image 3.16 (e) belongs to the Combination of Hollow-out and Laser Engraving category. The structural leather part has no treatment of laser techniques (the lines on the brown leather are made by stitches), so even if the waist design is structural and dimensional (see Figure3.14 (a)), it is irrespective with cutting and recombinining effect.
Seven participants considered the surface pattern effect of image 3.16 (f) belonged to the Lace and Hollow-out Effect category and one participant considered it belonged to the Cutting and Recombining category (Table 3.10). In image 3.16 (f), the dress is cut but all cut pieces are attached to the dress, while the Lace and Hollow-out Effect requires all the cut pieces are separated from the fabric. In image 3.16 (f), the engraved pattern and cut pieces appear together in one pattern and the fabric is used intact without creating additional structural or dimensional effects. So the surface pattern effect of image 3.16 (f) belongs to the Combination of Hollow-out and Laser Engraving category.

A dress may use more than one surface pattern effect image 3.16 (g) and image 3.16 (h) are original designs by Weiqi Zhang, and each design used two surface pattern effects. There are two surface pattern effects applied to the dress in image 3.16 (g): lace and hollow-out effect and cutting and recombining. The lace effect pattern is clear, and the shoulders are dimensional and structural by combining several layers of cut pieces, which belongs to the Cutting and Recombining category. Among all the participants, nine participants chose these two effects together. The rest of sixteen participants only chose the Lace and Surface Pattern Effect.

The dress in image 3.16 (h) also featured two surface pattern effects: lace and hollow-out effect and laser engraving. Only two participants chose both. The other two participants also chose two types of surface effects but they were cutting and recombining and laser
engraving. The rest of the fifteen participants considered the surface pattern effect belonged to the Combination of Hollow-out and Laser Engraving category. It is easy to mistake the laser engraving and lace or hollow-out effect for the combination of laser engraving and hollow-out effect. After further scrutinizing, the laser engraved pattern is separate from the cut pattern. The laser cut pattern is geometric pattern while the engraved pattern belongs to a repeatable floral pattern. According to the description of the categories, the combination of laser engraving and hollow-out effect requires the engraving part and hollow-out part belong to one pattern. So, even if the pattern of lace and hollow-out effect and the pattern for laser engraving are made on the same dress, they don’t belong to one pattern. The Combination of Hollow-out and Laser Engraving category requires that the engraved pattern and cut part appear together in one surface pattern. After carefully observing, the visually hollow-out effect shown by dress in image 3.16 (h) is displayed by cutting the hollow-out surface pattern, which is unlike the dress in image 3.16 (d).
Figure 3.16 Images of surface pattern effect below 85%

(a) (“Coat Design by Dion Lee: Fabric Manipulation for Fashion”, 2013)

(b) (“Wearable Art and Sculptural Fashion”, n.d.)

(c) (“A Passion for Lasers, Jolka Wiens’ Graduate Collection (2)”, 2013)
(d) (“Iris Van Herpen Couture SS13 Collection (9)”, 2013)

(e) (“AW 2010-11 Dress Design by Haider Ackermann”, 2011)

(f) (“Collezioni Primavera Estate 2013 by Carven (1)”, 2013)

(g) Designed by Weiqi Zhang

(h) Designed by Weiqi Zhang
Another finding is that some participants mistook other techniques for the laser engraving effect. For example, in figure 3.17, besides choosing lace and hollow-out effect, one participant also classified the surface pattern effect of the dress into laser engraving. The floral pattern on the dress top is made by embroidery. If closely observing the details in the picture, it can be found that the floral pattern is stitched. Apparently, the embroidery pattern is mistaken for the laser engraving pattern. Also, one participant classified the surface pattern effect of this dress into the Combination of Hollow-out and Laser Engraving. The reason may be because the participant mistook the embroidery pattern for laser engraved pattern and it appeared with lace effect pattern together. Even if the floral pattern is made by laser engraving, it still has no relation to the Combination of Hollow-out and Laser Engraving category: the cut pattern is a repeatable floral pattern but the other one is engineered floral pattern.

Figure 3.17 Example Image (Designed by Weiqi Zhang)
The percentage of responses as expected for Primary Final Application category is illustrated in Figure 3.13 (c). As can be seen, four dresses have 100% evaluated as expected responses; three dresses have 96% evaluated as expected responses and five dresses have 92% evaluated as expected responses; two dresses have 88% evaluated as expected responses and six dresses (Figure 3.18 images (a)-(f)) dresses have less than 85% evaluated as expected responses. All the dress images that have 85% or lower evaluated as expected responses were discussed.

Six participants considered the primary final application of the dress in image 3.18 (a) belonged to the Primarily Decorative category. In fact, the dress in image 3.18 (a) is not revealing and has possibilities to be worn in special occasions. So, it can be classified into the Primarily Functional category.

Seven participants considered the primary final application of the dress in image 3.18 (b) belonged to the Primarily Functional category. The dress in image 3.18 (b) is very revealing (see the green circle). Besides, the structure of the dress is very complex and delicate so that it is easily damaged when worn. Therefore, it can’t be classified into the Primarily Functional category.

Nine participants considered the primary final application of the dress in image 3.18 (c) belonged to the Primarily Functional category. Similar situation to the dress in image 3.18
(b), the chest part is easily exposed (see the green circle). What’s more, the strips are very delicate so that it is easy to get damaged when worn, so it is better for this dress to be classified into the Primarily Decorative category.

Eleven participants considered the primary final application of the dress in image 3.18 (d) belonged to the Primarily Decorative category. The dress in image image 3.18 (d) is not revealing and all the private regions are covered and protected by using black lining inside. It has possibilities to be worn in special occasions. So, it can be classified into the Primarily Functional category.

Eleven participants considered the primary final application of the dress in image 3.18 (e) belonged to the Primarily Functional category. Even if the dress in image 3.18 (e) is not revealing and has no exposed region, the structure of the dress is very complex and delicate so that the dress is easy to get damaged. So, it can be classified into the Primarily Decorative category.

Thirteen participants considered the primary final application of the dress in image 3.18 (f) belonged to the Primarily Decorative category. The expected response for this dress is the Primary Finally Functional category, because the cut part in this skirt is not revealing and can be worn in special occasions. However, thirteen respondents illustrate it can be classified into the Primarily Decorative category. The reason is that the top of the dress is
revealing (see the green circle) and it is hard to move conveniently wearing the dress. For this situation, more information about the dress is needed. Because the perception of the final application to a dress is often influenced by environment and presentation.
(a) (“Anne Hathaway Met Gala 2015”, 2015)
(b) (“AW 2010-11 Dress Design by Haider Ackermann”, 2011)
(c) (“A Passion for Lasers, Jolka Wiens’ Graduate Collection (2)”, 2013)

(d) (“Iris Van Herpen Couture SS13 Collection (9)”, 2013)
(e) (“Wearable Art Dress by Yiqing Yin”, 2013)
(f) (“Laser Cut Dress”, n.d.)

Figure 3.18 Images of primary final application below 85%
Through the analysis of the survey data, more characteristics for each category were explored and added to the features of each category. Image 3.18 (f) was moved from Primarily Functional category to the Primarily Decorative category. The other 19 image remain as categorized.
CHAPTER 4 RESULTS AND DISCUSSION

4.1 Surface Pattern Effects

Laser technology can expand designers’ creative options. According to analysis of visual research and survey data, primary applications of laser technology to fabrics can be categorized into four primary categories based on visual effect: Lace and Hollow-out Effect, Cutting and Recombining, Combination of Hollow-out and Laser Engraving, and Laser Engraving.

4.1.1 Laser Engraving

Laser engraving changes the fabric color and texture through the burning process, and can modify the fabric surface. Various tones can also be created. Details can be shown very clearly with laser engraving. Dresses that can be classified into the Laser Engraving effect category, need to meet all of these requirements listed below:

1. The engraving pattern has no laser cut elements;

2. The engraved fabric is used intact without creating additional structural or dimensional effects;

3. No engraving and cut-out effect appears together in one same pattern design, but they can appear separately in different patterns on a dress.
4.1.2 Lace and Hollow-Out Effects

Lace and hollow-out effects refer to the effect created by laser cutting fabrics. It emphasizes the design of the surface pattern and it may feature lacy, openwork or paper cut design effects, or larger voids and holes in the fabric. Placing the cut pattern is crucial because the cut section can affect the durability of the fabric. Also, if the fabric becomes too soft, it will affect the dress structure. This effect can demonstrate a strong sense of modern and unique fabric texture with precise details. Furthermore, designers can create lace effects or hollow-out effects on materials besides lace fabrics or knitting fabrics by laser cutting. In other words, use of laser cutting expands possibilities for dress design.

Dresses that can be classified into the Lace and Hollow-out Effect category, need to meet all of the requirements listed below:

1. The fabric is cut and all the cut pieces are separated from the fabric;
2. The cut fabric is used intact without creating additional structural or dimensional effects;
3. No engraving effect appears together with cutting effect in one same pattern design, but they can appear separately in different patterns on a dress.
4.1.3 Cutting and Recombining

Cutting and recombining effects also utilize laser cutting technology. Cutting and recombining effects may utilize cut parts or garment sections. Recombining cut pieces to create structural and dimensional effects also fits in this category.

There are some differences between the Laser and Hollow-out Effect category and the Cutting and Recombining Effect category. Lace and hollow-out effects emphasize the design of surface patterns and how to place the pattern in the right region on the fabric. While cutting and recombining highlights how to utilize the cut pieces and combine them together to create an innovative, structural and dimensional design. For some lace and hollow-out patterns, it is hard to achieve a good effect by hand cutting. Also, it may require excessive time to cut an intricate pattern by hand. However, cutting and recombining can often be accomplished with traditional manually cutting. However, compared to manual cutting, two advantages to use laser cutting is the high speed and the smooth cut edge of the fabric. In addition, designers can explore unique inspirations and creative ideas to achieve an innovative, structural and dimensional design.

Dresses that can be classified into the Cutting and Recombining Effects category, need to meet all of the requirements listed below:

1. The fabric is treated with laser cutting;
2. The cut pieces are combined or cut region is recreated to yield a structural and dimensional effect;

3. Laser engraving or hollow-out pattern maybe appear on the cut pieces, but the visually dominant effect is that of cutting and recombining effect.

4.1.4 Combination of Hollow-Out and Laser Engraving

The combination of hollow-out and laser engraving effects use both techniques to create more details. For some surface patterns, lines cannot be cut out but can be engraved. If a pattern has too many details to cut successfully, the combination of hollow-out and laser engraving effect is a good choice to create an intricate pattern.

Dressed that can be classified into the Combination of Hollow-out and Laser Engraving category, need to meet all the requirements listed below:

1. The hollow-out and laser engraved fabric is cut while the cut pieces don’t need to be separated with the fabric;

2. The hollow-out and laser engraved fabric needs to be used intact without creating additional structural or dimensional effects;

3. Engraving and cutting must appear together in one pattern design.
4.2 Dress Silhouettes

According to the analysis of visual research and survey data, there are three dress silhouette categories which can provide a classification for all of the dresses in the image database: Trapezium Silhouette, Calabash Silhouette, and H-Shape Silhouette.

4.2.1 Trapezium Silhouette

The shape of the Trapezium Silhouette dress is roughly quadrilateral, and fullest at the hem. The range of this silhouette may be from somewhat to very full at the bottom (Figure 4.1).

![Figure 4.1 Trapezium Silhouette model](image-url)
As daily wear, the shoulders of the trapezium silhouette dress are mostly simple with little extension, while the bottom part of the skirt can be very full and detailed. Lace and hollow-out effect patterns are very common to the trapezium silhouette dress (see Table 3.7 in Chapter 3). The pattern can be simple or relatively complex. Many trapezium silhouette dresses have a simple style. One reason is that a complex design in structure will interface with the pattern’s visual effects. With garment structure succinctness, the laser carved pattern can stand out and give a strong visual impact (see Figure 4.2 (a) and (b)). On the other hand, dresses that are designed as wearable sculpture are different. The skirt of the dress can be much more dimensional and complicated. In this case, cutting and recombining surface pattern effect is used a lot (see Table 3.7 in Chapter 3). The designer needs to figure out the balance between the garment shape and recombining region. How to combine the two elements together is highly significant so that the dress looks graceful and complex but not messy and chaotic (see Figure 4.2 (c) and (d)).
4.2.2 Calabash Silhouette

The shape of the calabash silhouette dress is closely fitted and snug at the waist and flared in the skirt (Figure 4.3). This silhouette emphasizes the curves of the body. By comparison, the trapezium silhouette is unfitted and loose at the waist. Similar to the Trapezium Silhouette dresses, Calabash Silhouette dresses are also common in fashion.
As daily wear, lace and hollow-out effects are also the main type of surface pattern effect used in Calabash Silhouette dresses (see Table 3.7 in Chapter 3). The surface pattern design can be either simple or relatively complex (see Figure 4.4 (a) and (b)). The waist of the calabash silhouette dress is mostly designed with simple pattern, while the top of dress and bottom part of the skirt can be very full and detailed. With garment structure succinctness, the laser carved pattern can stand out and give a strong visual impact (see Figure 4.4 (a) and (b)). When Calabash Silhouette dresses appear on important occasions, the design of the skirt part can be delicate and complicated. It can be dimensional, elegant, or the
designer can combine both characteristics (see Figure 4.4 (c)). To have a full skirt structure, Calabash silhouette requires stiffness in the fabric (see Image (c) and (d)). Because removal of too much material can add excessive flexibility to the fabric, the designer needs to figure out the balance between the garment shape and laser cutting or laser engraving pattern so that the garment can maintain the ability to achieve the full skirt structure. On the other hand, dresses that are designed as wearable sculpture are different. The skirt of the dress can be much more dimensional and complicated (see Figure 4.4 (d)). In this case, lace and hollow-out effects are used a lot (see Table 3.7 in Chapter 3). The surface pattern can be very delicate and intricate (see Figure 4.4 (d)). What’s more, the skirt mostly has a full skirt structure that can show much detail created by laser cutting.
4.2.3 H-Shape Silhouette

This dress shape resembles the letter H (Figure 4.5). The silhouette is slender, with a roughly straight-line outline and straight skirt. The waist is loosely fitted if at all. Above the waist, it can be a structured, natural or strapless.
Unlike Trapezium Silhouette dresses and Calabash Silhouette dresses, H-Shape Silhouette dresses are not as common but appear on special occasions. Lace and hollow-out effects are the main type of surface pattern effects that are used in H-Shape Silhouette dresses (see Table 3.7 in Chapter 3). The surface pattern design can be either simple or relatively complex (see Figure 4.6 (a) and (b)). Because the skirt of H-Shape dress is not flared, the laser cut pattern can be shown directly without being hidden by skirt gathers (see Figure 4.5 H-Shape Silhouette model).
Figure 4.6 (a) and (b)). A simple style of H-Shape silhouette dress can make a laser carved pattern stand out and give a strong visual impact (see Figure 4.6 (a) and (b)). On the other hand, dresses that are designed as wearable sculpture are different. The skirt of the dress can be much more dimensional and complicated. In this case, cutting and recombining surface pattern effect is used a lot (see Table 3.7 in Chapter 3). The designer needs to figure out the balance between the garment shape and recombining region. How to combine the two elements together is highly significant so that the dress looks graceful and complex but not messy and chaotic (see Figure 4.6 (c) and (d)).

(a) Romance Laser Cut Dress by Jovonna
(b) Laser-Cutting Satin by Elizabeth Fillmore
(c) (“AW 2010-11 Dress Design by Haider Ackermann”, 2011)
(d) Laser cut dress by Iris van Herpen (“Laser Cut Dress with Graphic Surface Patterns”, 2015)

Figure 4.6 Sample images of H-Shape Silhouette
4.3 Primary Final Applications

Primary Final Application provides a general direction for the dress designed using laser techniques. According to the analysis of visual research and survey data, there are two dress silhouette categories that cover all the dresses in the image database: Primarily Functional category and Primarily Decorative category.

Primarily decorative dresses emphasize the artistic visual effects shown by the garment. They are often sculptural fashion for exhibition or photography.

Primarily functional dresses emphasize wearability and function. They are often “Ready to Wear” fashion which can be commercialized. Primarily functional dresses typically can be worn in daily life or special occasions.

Almost all of the dresses have both decorative and functional characteristics. A conclusion must be drawn as to which is primary. The criteria for evaluating the primary application of a dress are listed below:

1. If a dress has an excellent visual effect, but can still be worn in daily life or for special occasions, it belongs to Primarily Functional category.
2. If a dress is too revealing, or it is hard for people to move wearing the dress, or the structure of it is very complex and delicate so that it is easy to damage when worn, it belongs to the Primarily Decorative category.

For some dresses, if it appears that it could be either in the Primarily Functional category or Primarily Decorative category, context becomes important. Because the perception of the final application to a dress is often influenced by environment and presentation. This can be factors such as whether the design is worn or mounted, or if it is seen in a store or on display in a gallery, for example.
CHAPTER 5 CONCLUSION AND LIMITATION

5.1 Conclusion

Dress designs made using CO2 laser technology were explored and classified in this research. In conclusion, there were four primary applications of laser technology to fabrics could be categorized into four primary categories based on visual effect: Lace and Hollow-out Effect, Cutting and Recombining, Combination of Hollow-out and Laser Engraving; there were three dress silhouette categories which could include all of the dresses in the image database: Trapezium Silhouette, Calabash Silhouette, and H-Shape Silhouette. There were two primary final application categories for dress designs using laser technology that covered all the dresses in the image database: Primarily Functional category and Primarily Decorative category.

The research methods used in this project included review and analysis through literature review, content analysis in visual research, and survey questionnaire responses, and subjective evaluation. In the research, an image database including hundreds of pictures of garments made using laser technology was established. Preliminary categories and refined categories were defined through visual analysis of the image database. According to the results, a brochure describing each category, and providing visual examples of dresses in each category was prepared. A survey was developed and used to gather data to validate and
examine the accuracy of the refined categories. Characteristics for each category were specified in the results after the analysis of survey responses.

The final results can guide the use of fabric laser technology for dress design. They also provide a foundation and framework for expanded study of laser application in the field of textiles and fashion. Results also delineated the impact that laser application has had on fabrics and textiles in the area of dress design.

5.2 Research Limitations

The research methods used in this project include review and analysis through literature review, visual research, and survey questionnaire responses, and subjective evaluation.

The literature review and analysis aimed at acquiring basic knowledge of the present situation of laser technology used in fashion and textile design, the existing challenges with the use of laser technology in fashion and textile design, and the possibilities of laser technology in fashion and textile design. However, the amount of works of literature about laser use in textile and fashion is limited. Currently, a large proportion of research about the application of lasers to textile and fashion fields is focused on fabric cutting, garment pattern cutting, and denim finishing (Hengyin, 2007; Yuan et al., 2012). Some research about sustainable design with laser engraving, as well as a few publications about the application of
lasers to the design of fashion, and challenges a designer may meet when creating a garment are available (Herva, et al., 2014).

Content analysis of visual materials was the main method used for this project. For exploring and classifying dresses made using CO2 laser technology, building an image database was critical. Through content analysis of the database images, categories were defined. However, because the image database was created by an individual, the number of images that could be found was limited. Also, due to all of the images being 2D format, it is not possible to see all around the dress as well as some details in one picture. In other words, the degree of a conclusion’s accuracy regarding to category depends on both the number of images in the image database and the content in each picture.

After content analysis was completed, several designs were created according to the characteristics of each category. At the same time, questionnaires were developed and used to gather data. So a limitation of this method is that one designer created all the designs. Therefore, the designs can’t entirely present the diversity of designs. In other words, there can be some designs by other designers that are quite different in style and aesthetic.

The last limitation is the subjective evaluation. Through the visual research, each category was defined by visual characteristics and the aesthetic properties. There is always some level of bias introduced in subjective evaluation.
CHAPTER 6 FUTURE RESEARCH

The research presented in this study provides a classification system for describing dresses made using laser technology. Future research could be performed in several areas related to this project.

More surveys are needed to reexamine the dress images that have 85% or lower evaluated as expected responses. The brochure for the survey also needs to be updated by adding more characteristics for each categories after analysis of response data. What’s more, the opportunity to conduct a survey with those who have expertise in laser cutting would provide additional insight into the reliability of the classification system of dress design using laser technology developed in this work.

During the content analysis of the image database, all the images in the database were classified into the defined categories. However, the quantity of images is limited. In other words, there may be still some dress design image that can’t be classified into any of the refined categories. So, there is a need to expand the image database in the future study.

The image database in this research is mainly used for exploring and classifying dress designs made using CO2 laser technology. In the future, the database can be used for further study. In the defined classification system, the researcher can analyze an image which has been classified precisely and explore more information about it. For example, to explore how
to apply each surface pattern effect to each silhouette, or how many considerations exist for a designer in placing lace and hollow-out effect pattern on the Calabash silhouette. A researcher can use visual analysis of images that are already classified in the database as a starting point. Another way to reuse the database with the help of computer science technology would be to design a searchable tool. It could be used by students and designers as an inspiration source.

In the image database, there is an opportunity to look at dates of the images through the information recorded. Additional research could be conducted to explore the introduction and adoption of laser technology by seeking evidence of adoption in different markets or over time, and changes over time in laser cutting application to dress design. These analyses could focus within the existing database or by expanding the database at some point in the future.

The results introduced three types of silhouettes and briefly talked about the application of surface pattern effects to each silhouette. Though not specifically studied, it is clear from the explorations and content analysis in this study that the impact laser treatment has on the hand of the fabric would influence silhouettes that could be achieved in dresses. Additional research should be conducted to explore how application of each surface pattern effect to each silhouette impacts resulting designs. One strategy for this work could be
through case studies. For example, how many and what considerations exist for a designer who wants to place lace and hollow-out effect patterns on the Calabash silhouette, or on the H-shape silhouette, and which regions of a dress cannot be treated with specific effects while preserving the silhouette.

The research project only covered dresses in terms of fashion products, so additional research is needed to explore other categories. There are many fashion products like coats, pants, accessories, bags, etc. that would use laser technology. Work established here in terms of classifying the surface pattern effect could be applied to other product categories. Methods developed for dress analysis can be applied to analysis of other products.

Education level of participants was mentioned in the analysis of survey part, but not discussed further because of the limited number of surveys. This needs to be fully examined to see if the level of education can impact the results.

This research presented a visual content analysis process and refined categories for dresses made using laser technology, but additional research is required to develop a completed and credible system illustrating the process of dress design using the refined categories. The system can be used for further research and academic study of lasers in design of textile based products. Beginners can design a dress using a clear guide by studying the classifications system and examples, and professional designers can gather ideas.
REFERENCES


[Sleeve detail with simple cuts to create texture by Maison Rabih Kayrouz Fall 2015].


Female outfit of digital pattern design system (PCAD) research and Application


O'Meara, K., & Keiffer, A. V. (n.d.). The pattern base: Over 550 contemporary textile and surface designs.


APPENDICES
Appendix A: Brochure Description for Survey

Table Appendix A (Dress Silhouette)

<table>
<thead>
<tr>
<th>Silhouette</th>
<th>Description &amp; Model</th>
<th>Representative Image 1</th>
<th>Representative Image 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapezium Silhouette</td>
<td>Trapezium silhouette: the shape of dress is roughly quadrilateral, and fullest at the hem. The range of this silhouette may be from somewhat to very full at the bottom.</td>
<td>![Image 1]</td>
<td>![Image 2]</td>
</tr>
<tr>
<td>Calabash Silhouette</td>
<td>Calabash silhouette: this dress shape is closely fitted and snug at the waist and flared in the skirt. This silhouette emphasizes the curves of the body. By comparison, the trapezium silhouette is unfitted and loose at the waist.</td>
<td>![Image 3]</td>
<td>![Image 4]</td>
</tr>
</tbody>
</table>
H-Shape silhouette: this shape of dress resembles the letter H. The silhouette is slender, with a roughly straight-line outline and straight skirt. The waist is loosely fitted if at all. Above the waist, it can be a structured, natural or strapless.
Table Appendix A (Surface Pattern Effect)

<table>
<thead>
<tr>
<th>Surface Pattern Effect</th>
<th>Description</th>
<th>Representative Image 1</th>
<th>Representative Image 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lace and Hollow-out effects</td>
<td>Lace and hollow-out effects emphasize the surface pattern and may feature lacy, openwork or papercut design effects, or larger voids and holes in the fabric.</td>
<td><img src="image.jpg" alt="Image" /></td>
<td><img src="image.jpg" alt="Image" /></td>
</tr>
<tr>
<td>Laser Engraving</td>
<td>Laser engraving adds ornamentation by changing the fabric color, texture or both through a burning process that alters the fabric surface. Multitonal effects can be generated on the fabric surface.</td>
<td><img src="image.jpg" alt="Image" /></td>
<td><img src="image.jpg" alt="Image" /></td>
</tr>
<tr>
<td>Combination of Hollow-out and Laser Engraving</td>
<td>Combination of hollow-out and laser engraving effects utilize techniques of both categories together in a design to create added detail and complexity.</td>
<td><img src="image.jpg" alt="Image" /></td>
<td><img src="image.jpg" alt="Image" /></td>
</tr>
<tr>
<td>Cutting and Recombining</td>
<td>Cutting and recombinating effects may utilize cut parts or garment sections. Recombining cut pieces to create structural and dimensional effects also fits in this category.</td>
<td><img src="image.jpg" alt="Image" /></td>
<td><img src="image.jpg" alt="Image" /></td>
</tr>
</tbody>
</table>
Table Appendix A (Primary Final Application)

<table>
<thead>
<tr>
<th>Final Application</th>
<th>Description</th>
<th>Representative Image 1</th>
<th>Representative Image 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primarily Decorative</td>
<td>Dress emphasizes the artistic effect shown by the garment, often sculptural fashion for exhibition or photography.</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>Primarily Functional</td>
<td>Dress emphasizes wearability and function, often RTW fashion which can be commercialized for wearing in daily life or special occasions.</td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
</tbody>
</table>
Appendix B: Evaluation Tool for Survey

Evaluation Form

Your Degree: Junior [ ] Senior [ ] Graduate [ ] Professor [ ]
Your Major/Research Area: ____________________________

Before the survey, you will be given a brochure describing each category of Dress Silhouette, Surface Pattern Effect and Final Application by providing visual examples in each category.

After reading the brochure, you will evaluate 20 dress designs shown in images. Start by writing to the left of each row the dress image number on the PowerPoint slide. Next, please indicate your categorizations for Dress Silhouette, Surface Pattern Effect and Final Application with “X” in the appropriate blank.

For example, for the picture 0, if you think it should belong to Calabash Silhouette in Silhouette Category, then you mark X in the Calabash Silhouette box. In a similar way, you mark an X in the appropriate category of Surface Pattern Effect and Final Application. Last, describe your feelings and thoughts in response to the dress.

<table>
<thead>
<tr>
<th>Image Number</th>
<th>Silhouette</th>
<th>Surface Pattern Effect</th>
<th>Final Application</th>
<th>Feelings &amp; Thoughts</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (Example)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Graceful, Elegant...</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Image Number</th>
<th>Silhouette</th>
<th>Surface Pattern Effect</th>
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<td></td>
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