

# Creating Textured Knit Using Industrial Knitting Machine and Knitwear Design

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## 산업용 니팅머신을 이용한 니트조직과 니트웨어 디자인

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(2007. 9. 17. 접수; 2008. 2. 2. 채택)

### Abstract

니트웨어가 가지고 있는 신축성은 우븐 페브릭으로 제작한 옷과 비교했을 때, 옷을 입었을 때의 편안함과 관리의 수월함을 제공하며, 이러한 니트웨어의 특성은 현대의 라이프 스타일에 맞는 경쟁력을 가지고 있다. 현대인의 생활은 단지 일에만 치중하며 사는 것이 아니라 여행, 사회적 참여 그리고 운동 등을 하며 개개인의 삶을 더욱 중요시 여기는 형태로 변해가고 있다. 따라서 손이 많이 가고 관리하기 힘든 옷을 위해 쓰는 시간은 점점 줄어들고, 캐주얼이나 정장에 관계없이 편안하고 관리하기 쉬운 옷을 선호 하며 살아가고 있다. 이러한 경향은 패션산업시장에 직접 반영되어 관리하기 쉽고 입기에 편안한 니트웨어는 패션 시장 안에서 점점 더 많은 부분을 차지하고 개발 되어지고 있는 실정이다. 하지만 현재 니트웨어시장은 니트조직을 개발하고 표현하는 데에 있어 공장의 기술자 중심으로 이루어지고 있어 제한된 스타일의 니트조직이 대부분의 시장을 차지하고 있는 실정이다. 이에 창의력을 가진 니트 디자이너와 현대인의 감수성을 만족시킬 수 있는 니트 조직의 개발은 현대 패션시장에서 매우 중요한 과제로 남아있다고 할 수 있다. 또한 CAD를 사용하는 산업용 니팅머신은 독특한 텍스처를 가진 니트웨어의 대량 생산을 위해 꼭 필요한 아이템이라고 할 수 있다. 이러한 시대의 요구에 맞추어 연구자는 이번 연구를 통해 현재 니트웨어시장에 나와 있는 조직과는 차별화 된 4가지 니트조직을 CAD로 디자인하고 산업용 니팅머신을 사용해 현실화하였으며, 니트웨어디자인에 적용하여 실제의상으로 제작해 보았다. 이 연구를 통해 얻어진 결과물이 현대인의 감수성을 만족시킬 수 있는 새로운 제안으로 현재 패션시장에 받아들여졌으면 하는 바람이다.

**Key Words:** 니트웨어(Knitwear), 질감(Texture), 산업용 니팅머신(Industrial knitting machine), 니팅 기술(Knitting technique), 대량생산(Mass production)

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## I. INTRODUCTION

Texture development is crucial, and industrial knitting machines are necessary for the development of textures that can be mass-produced. In the course of this research, I created four distinct knitting structures that are both attractive and affordable to produce with industrial knitting machines.

### A. Importance of Developing Texture

There are two major reasons to develop knit texture. First, it will create a new look for the fabric. Most companies in the knitwear industry use industrial knitting machines to create only the most basic jersey or cable patterns. Unlike woven fabrics, there are various different construction techniques possible for knitting. However, these techniques have not been used creatively and the end result is that knit's potential has remained unrealized. Even more important is the ability to apply these new textures to garment making in order to reduce the cost of mass-producing garments. To manufacturer better knitwear, new construction techniques for knitwear must be developed.

If the fashion industry desires to satisfy their customer's increased demands, both visually and functionally, it is crucial to create new fabrics; therefore, accelerating the development of textured knit fabric ought to be a priority within the fashion industry. Textured knit fabric can make garments appear unique, and of higher quality. These characteristics are more important than ever since simple and linear beauty is emphasized in the current fashion trends. Presenting texture fabric in garments would be one strategy for surviving in the current fashion design market. For these reasons, creating textured knit fabric is required in modern fashion industry.

### B. Why Use the Industrial Knitting Machine?

In terms of mass-production, using industrial

knitting machines would be cost-effective, since industrial knitting machines can knit faster than humans. Also, industrial knitting machines have more needles and technical capabilities, which allow the construction of textured knit fabric. With an industrial knitting machine, it is possible to create unique or "new looking" texture. Nevertheless, it is hard to find a knitwear company that uses industrial knitting machines to their full potential. Only one or two companies are working on developing knit construction. My goal is to create innovative textured fabrics using industrial knitting machines and to use these fabrics in garment design to show the fashion industry the unlimited ability of expression possible.

## II. BACKGROUND

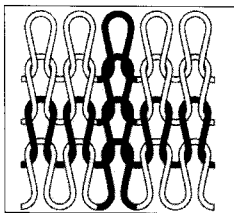
### A. Definition of Knit and General Terms

Knitted fabric may be described as structures produced by the interlooping of yarn. In actual construction of the fabric, loops are formed; new loops are then drawn through those previously formed [loops]. The continued addition of new loops creates the knitted fabric. A knitted loop is usually referred to as a stitch when it is pulled through another loop. Stitches are produced with knitting needles. It is the loops that give great crimp to the resulting fabric.

*Wales*: Vertical columns of stitches in a knitted fabric are called wales. Wales run length-wise through the entire fabric, and in that sense they are similar to the wrap in a woven fabric. The number of wales-per-unit width of fabric (expressed as wales per inch) is dependent on the density of needles or the needles per inch. The use of thinner needles can result in high wales per inch because there can be more needles per inch.

*Courses*: Horizontal rows of stitches are called courses. Courses run width-wise, from side to side, and in that sense are similar to the feeling in a

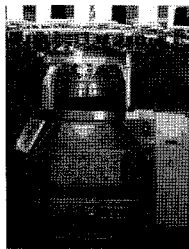
woven fabric. The number of course-per-unit length (expressed as course per inch) of fabric is dependent on the height of the stitch loop. This in turn depends either on the distance the needle pulls the yarn when the loop is made or the amount of yarn fed and wrapped around the needle. When small loops are formed, the fabric has a large number of course per unit length. Wales and courses per inch contribute to the fabric weight, hand, insulation, shape retention, drape-ability and cost<Figure1>. Note the wales (vertical) and courses (horizontal).<sup>1)</sup>



<Figure1> Wales and courses

## B. Introduce Knitting Machine

a. Industrial knitting machines allow production of a complete row of loops at one time instead of only one loop at a time, as with hand knitting needles. Each machine may hold from several hundred to several thousand needles. These needles are substantially different from hand knitting needles. The formation of the stitch is also somewhat different in that only one needle is required to make a stitch rather than two, as with hand knitting. Each wale of the fabric in machine knitting is produced by its own needle<sup>2)</sup><Figure4>.



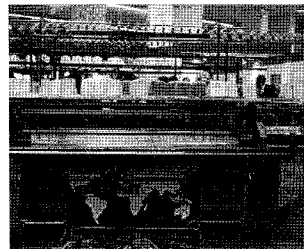
<Figure2> Circular machine

Knitting machines are divided into two main categories: circular knitting machines and flat knitting machines. Circular knitting machines look like cylinders and produce tubular knit, such as socks and t-shirts<Figure2>. Flat knitting machines have the knitting needles in a straight line, thus producing open width or flat fabrics, similar to a woven fabric. The flat knitting machine has a width that range from about 12 inches to over 200 inches and has double beds<sup>3)</sup><Figure3>.

b. Computer-Aid Design (CAD) - The most modern system for creating texture in knitted fabric consists of electronic and computer-controlled adaptations of the methods and stitches that will be discussed. Computer controlled industrial knitting machines have had a profound impact on the knitting industry. They permit the designer to conceive a new design and to produce samples of the fabric within a few minutes.<sup>4)</sup> The computer-aided design (CAD) and the industrial knitting machine to which the CAD is connected reduce from several weeks to several hours the time required to conceive and make fabric samples. The CAD system has become a very important tool to the knitwear designer. Knitwear designers must understand the capabilities and limitations of the machines that are used to produced the desired fabric.

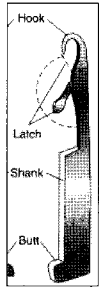
## C. Knitting Stitches

In the industrial knitting machine, stitches are made by knitting needles. Though there are three

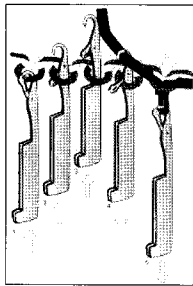


<Figure3> Flat knitting machine

types of needles used in industrial knitting machine –latch, spring beard and compound–, this thesis will only focus on the stitches made with latch needles<Figure4>. To form the knitted stitches, the needle raises and the previous loop opens the latch and slides down onto the needle shank. As the needle begins to descend, a new yarn is fed onto the needle hook. As the needle continues to descend, the previous loop slides onto it and causes the latch to close. The needle continues downward and the old loop slides off the needle completely. As a result, it becomes interlooped with a new loop, thus creating the knitted fabric structure<Figure5>.



<Figure4> Latch needle



<Figure5> Knitting process

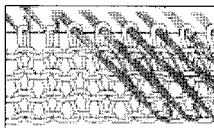
needles do remain “live” and can resume knitting whenever they are moved back into the working position. While needles in the holding position stop knitting, any other needles on the knitting bed that are still in working position continue to knit, and these stitches continue to accumulate rows and thus length [of fabric]. Therefore, by moving groups of needles into the holding position at various times, a fabric can be divided into various sections that are knitted independently of one another. This allows for greater variation in structure and design. Putting needles into the holding position is always done manually with a hand knitting machine; however, this can be done automatically on an industrial machine.<sup>5)</sup> A single needle, or a group of needles, can be put into hold. When a group of needles is to be held, the needles can be moved into holding position all at once or gradually. As seen in <Figure6~9>, the portion of the fabric in which the needles were held has fewer rows, i.e. larger loops, than the portion of the fabric in which the needles were not held.

a. Holding Technique (Stitch)

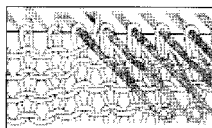
The holding technique is used to change the number of stitches or to divide the knit fabric in order to add a different color or texture, or to knit more rows. When a needle or group of needles is placed into holding position, the needles in holding position stop knitting the stitches, although the

b. Transfer Lace Stitch

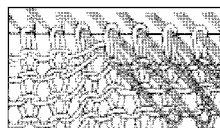
A lace stitch is used to make a little hole in the knit fabric. In a knit fabric, a hole (a button hole, for example) cannot be “cut” after the knitting is complete. Since the knit fabric is made using one strand of thread, the hole would cause the fabric to “run.” The hole must be made during the knitting process. A lace stitch is made by stitch transferring: taking one stitch from a needle and transferring it



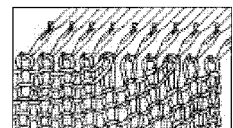
<Figure6>



<Figure7>



<Figure8>



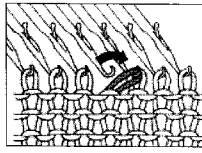
<Figure9>

<Figure6> Putting designated needles into holding position

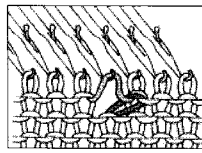
<Figure7> With the next pass of the carriage, new stitches form on working needles, while yarn passes over needles in the holding position

<Figure8> Loop that forms on first held needle will be knit together with the existing stitch when held needles are put back into working position.

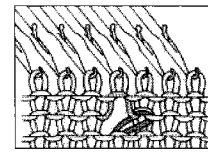
<Figure9> Feature of the knitting construction after partial knitting using the holding technique.



(a) Place one stitch onto its adjacent needle

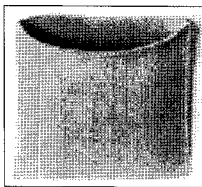


(b) Knit one row so that a hole is formed

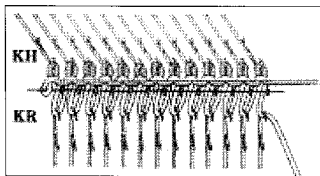


(c) Continue to knit, and hole is created.

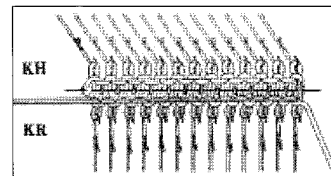
<Figure10> Transfer lace stitch making



<Figure11> Circular knitted fabric.



<Figure12> The carriage moves from left to right. The carriage only knitted on one side of the bed (KH).



<Figure13> The carriage is moved from right to left after the upper knitting. This time the carriage only knits KR, and makes a tubular shaped fabric.

to the next needle.<sup>6)</sup> It is possible to transfer every other stitch onto their adjacent needles and align the empty needle in the working position. Afterwards, by moving carriage to knit, a small hole will be created in the fabric due to empty needle skipping one row and starting a new stitch (cast on) after transferring<Figure10>.

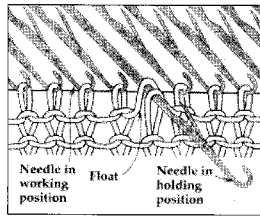
c. Circular Knitting Technique (Tubular Knitting Technique)

Circular knitting is used to create tubular shapes without seams<Figure11>. The size of the tube depends on the number of needles used.<sup>7)</sup> A stocking that is knitted on both knitting beds at once is an example of circular knitting. The machine is set so the carriage moves in one direction on one bed <Figure12> and in the other direction on the other bed <Figure13>. It is literally knitting in a circle. This type of construction is useful for edgings, the inside bag of a pocket, waist bands, seamless socks and string, or for waist knitting for ribbing and trousers. Stitch patterns can be knitted on this setting. Circular knitted fabric forms a tube

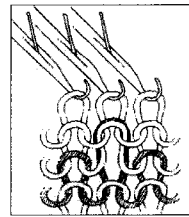
shape and has no seams. It is dual-sided as shown in the picture below.

d. Tuck Technique (Stitch)

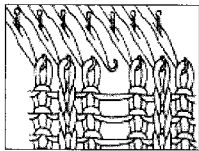
The needles on the bed that form the tuck stitch are sent to the holding position. The needles in holding position don't knit; rather, yarn is simply laid over the needles with each pass of the carriage. When these needles are returned to the working position, all the loops on the needle knit in a single stitch, resulting in a textured fabric. Only one strand of yarn per row is used, although the yarn can be swapped on any row for some interesting color effects. Eventually, the needle must be allowed to knit again because as the floats <Figure14> accumulate, they affect the tension on the adjacent stitches and can cause the neighboring needles to knit improperly<sup>8)</sup> <Figure15>. The main difference between the tuck and holding techniques lies in the needles sent to the holding position. In creating tuck stitches, every other needle can be sent to the holding position, while in the holding technique, multiple



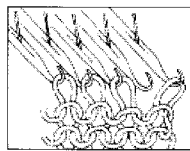
<Figure14> Yarn Float



<Figure15> Tuck stitch



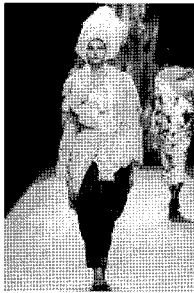
<Figure16> Skip stitch



<Figure17> Bringing stitch from the adjacent needle.

adjacent needles can be sent to the holding position. In terms of the effect on the fabric, the tuck stitch is mainly used to create texture, while the holding technique can be used to increase or decrease the

number of stitches and to divide the fabric by color.



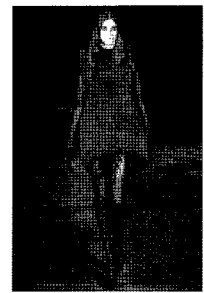
Fall 2007 Ready-to-Wear Vivienne Westwood - Runway



Fall 2007 Ready-to-Wear Alberta Ferretti - Runway



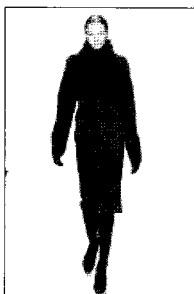
Fall 2007 Ready-to-Wear Vivienne Westwood - Runway



Fall 2007 Ready-to-Wear Alexander McQueen - Runway



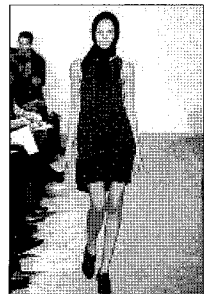
Fall 2007 Ready-to-Wear TSE - Runway



Fall 2007 Ready-to-Wear Calvin Klein - Runway

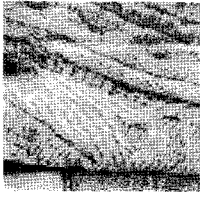


Fall 2007 Ready-to-Wear Oscar de la Renta - Runway

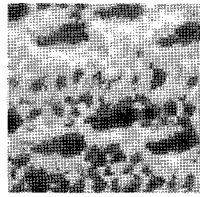


Fall 2007 Ready-to-Wear TSE - Runway

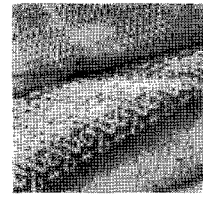
<Figure18>



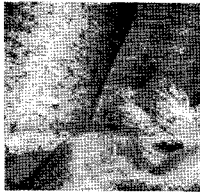
ZegnaBaruffa's new cashwool Super mélanges use new technology to achieve deeper color



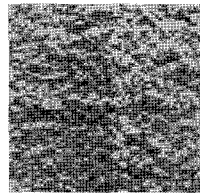
A mohair, wool and nylon blend from Igea



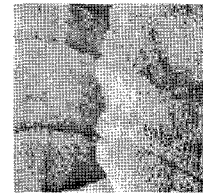
A selection of wool and silk blends by Grignasco



Igea's merino wool and Tactel blend



Manifattura di Sesia mixed sequins into a silk and nylon blend



A viscose and polyamide blend from Filpucci also incorporates metal.

<Figure19>

#### e. Skip Stitch (Ladder)

The process for the skip stitch is similar to that of the transfer lace stitch. As in the transfer lace stitch, one stitch is taken from a needle and transferred to the stitch on the adjacent needle. However, in the skip stitch, all empty needles are moved to the non-knitting position. The yarn floats over the stitch and on to the next needle. As a result, the carriage doesn't knit, by skipping empty needles that are in non-working position, and no extra loops of yarn are laid over the needles<sup>9)</sup> <Figure16>. The skip stitch is closed by bringing a stitch over from a needle adjacent to the empty needle <Figure17>.

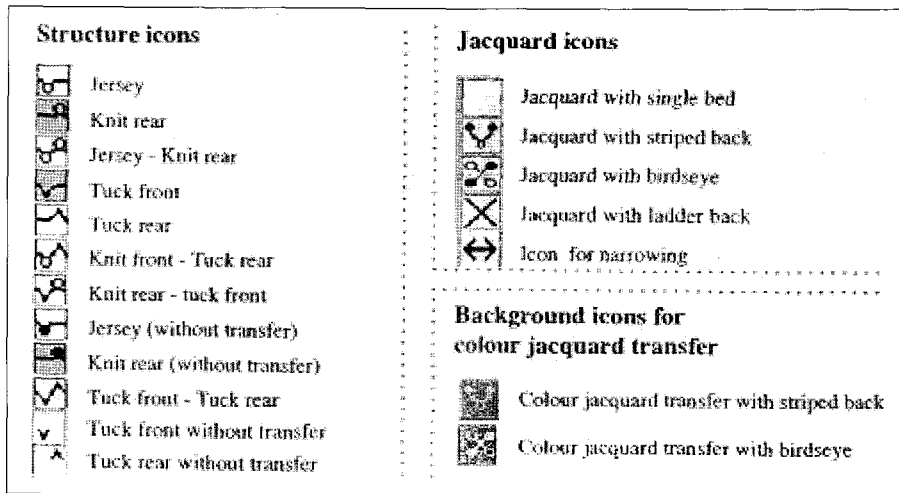
### III. RESEARCHING CURRENT STYLE OF KNITWEAR IN FASHION MARKET AND TRENDS

Recently, garments with simple silhouettes enhanced with textured fabric have gained popularity. Consumers

are increasingly focused on tactile sense and an extraordinary look. These tendencies are clearly shown in runway shows in Paris (ready to wear runway show) <Figure18><sup>10)</sup>, and the biggest yarn show in Italy (Pitti Failati June, 2007). This year's Pitti Failati show's keywords were "sober, superfine and sophisticated," and many yarn companies attempted to display the delicateness of yarns and tried to represent those yarns in textured knit fabric <Figure19><sup>11)</sup>. Yarn is the basic element of knitwear and also directly connected to creating textured knit. The images from this year's Pitti Failati show clearly demonstrate the value of developing this research.

### IV. METHOD OF STUDY

To create new textured fabrics, I have adapted the five techniques mentioned above: holding stitch, transfer lace stitch, circular knitting, tuck stitch, and skip stitch. For ease of understanding, I have named the different techniques and also attached a stitch icon diagram for CAD <Figure20>.



<Figure20> Diagram of stitch icon for industrial knitting machine

The diagrams of the fabric designs are shown below.

#### Fabric Design Explanation

Using five knitting techniques, I have created four advanced knit fabric swatches and applied them to knitwear design.

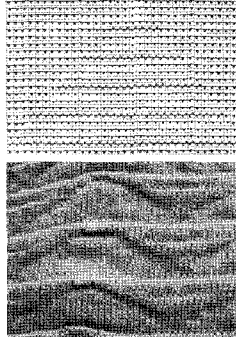
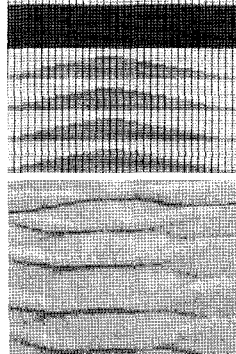
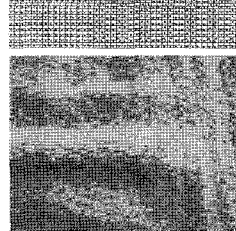
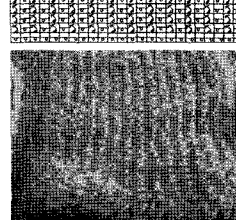
#### A. Swatches Development

a. Triangle holding - The holding technique is used for altering the number of stitches, dividing fabric by color, or making a slit. Due to the way stitches of select needles can be held while others knit, this technique offers many possibilities for the creation of new fabric designs. I used this technique to create a repeated triangular shape. This fabric construction, which I have named "triangle holding," was created by using the double bed icon at the first row of the triangle and following that with four rows of the holding stitch icon. This process was repeated until the triangle was finished. Basic jersey stitch was used for the background stitches in order to emphasize the triangular textures<Figure21>.

b. Triangle tubular - The circular knitting technique is useful for making socks, inside pockets, and trousers. However, if this technique is applied to a flat industrial knitting machine, and two differently-colored yarns are used between the front and back beds, the result is a reversible fabric with a front and back of different colors. In this case it would be used as a flat fabric rather than a tubular one. *Garments made using circular knitting are warmer since the fabric has twice the thickness.* To create the "triangle tubular fabric," the two layers of the fabric are attached at certain points with a triangular pattern. Where there is pattern the two layers of the fabric are attached automatically. Where there is no pattern, the two layers are not attached. The tubular jacquard icon was used to alternate between the triangular and plain areas<Figure21>.

c. Draped tuck - The tuck stitch collects several floated yarns and knits them all at one time. If the tension is adjusted properly, the stitch "projects" out, creating texture. Also, if this stitch is put only into some part of the fabric, that part will be shorter than the rest of the fabric, since tuck knits do not appear in every row. I applied this characteristic in my design, using the ladder stitch

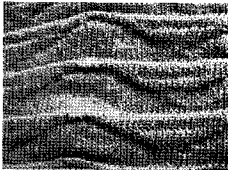

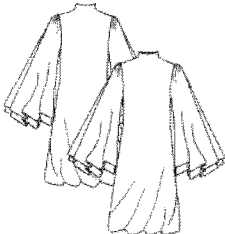

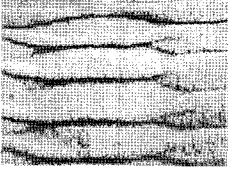

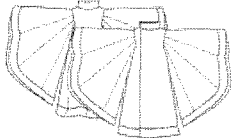
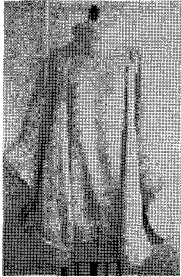
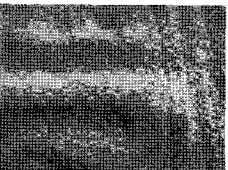

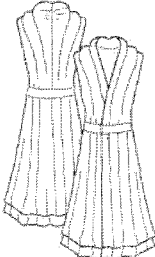

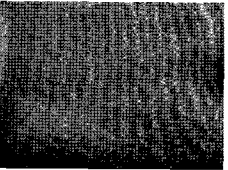


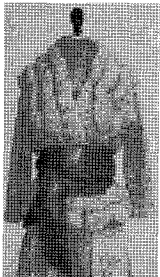


Names of knitting technique from this study	Technique Used	Yarn Used	Fabric design swatches & Image of the resultant fabric
Triangle holding	Holding technique	a. 84% viscose +16% nylon b. 54% rayon viscose +46% polyacrylic Used a and b in two-ply format.	
Triangle tubular	Circular knitting technique	a. 54% merinowool +23% angora +19% polyamidic +15% elastic b. 84% viscose +14% polyamidic +2% elastic White-area: a two-ply Grey area: b Black area: b	
Draped tuck	Tuck and ladder	a. 54% merinowool +23% angora +19% poyamidic +15% elastic b. 84% viscose +16% nylon	
Terry lace	Lace and tuck	a. 84% merinowool +23% angora +19% poyamidic +15% elastic b. 54% rayon viscose +46% polyacrilic Use a and b in two ply format.	

<Figure21> Name of “new” stitches and diagram of new fabric and their images

and the tuck stitch in the same row. These two stitches complemented each other well since the ladder stitch results in larger stitches, while the

tuck stitch bundles several stitches into one. The resultant fabric has long parts, where ladder stitches were used, and shorter parts, where tuck stitches

Fabrics	Rough Sketches	Flats	Garments
<p>Triangle holding</p> 			
<p>Triangle tubular</p> 			
<p>Draped tuck</p> 			
<p>Terry lace</p> 			

<Figure22> Illustrations, flats and garment pictures for new fabrics

were used. This created a unique and stylized-looking fabric<Figure21>.



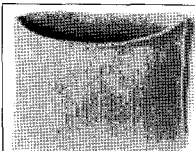
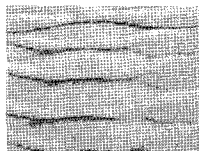
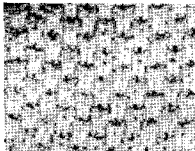

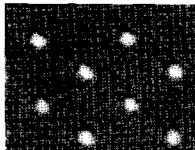
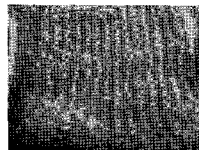
d. Terry lace - A major characteristic of fabrics made by the transfer lace stitch is that some stitches have bigger loops than others. The fabric also has holes from the knitting process. Using stretch and non-stretch yarn, I designed a textured fabric using this stitch. The texture was due to the differing rates of shrinkage of the yarn. Stretch yarn stretches farther than regular yarn during the final finishing step of "steaming." Therefore, by using stretch and non-stretch yarn while knitting with transfer lace stitches, strong texture was obtained<Figure21>.

**B. Applying New Knit Fabrics to Knit Garment Design.**

Next, it is necessary to test whether these newly-created fabrics are suitable for garment design—in other words, if they are capable of being mass-produced. To test this, I followed three steps: (1) draw rough sketches (2) draw flats and (3) make garments.

a. Triangle holding - To emphasize this textured fabric, I designed a simple dress and used jersey fabric for the sleeve. For nice proportion, I made the sleeve wider and flared to add an air of femininity<Figure22>.

b. Triangle tubular - This fabric was made by circular knitting, so it is thick and has strong texture. For effective expression, I designed a warm coat and used this textured fabric as a wide trim. Basic jersey fabric was used for the body to

Regular Fabric	New Fabric	Analysis
		<p>Using the advantages of the holding technique, triangle holding created surface texture and a sophisticated pattern. The result was a fabric different from fabrics made with the traditional holding technique.</p>
		<p>Triangle tubular created strong textures from two layers meeting (triangular pattern) and not meeting. It is a modern-looking fabric and it also eliminates the tagging or sewing process that fixes the two layers (i.e. it doesn't need quilting). Triangle tubular is useful for creating texture, warmth and reversible qualities, but it did lose its tube shape.</p>
		<p>Draped tuck created a feeling of draping. The contrast of the fabric's loose part (ladder) and tight part (tuck) naturally gave an effect of ruches without the additional labor usually associated with making them. It was "fully fashioned" fabric, which can be applied to mass production.</p>
		<p>Terry lace created a feeling of terry cloth by using two different yarns with different stretch ability, rather than the typical big-loop device used in terry cloth production.</p>

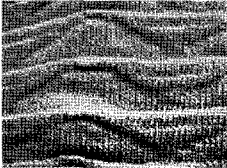

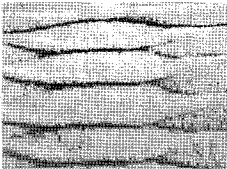
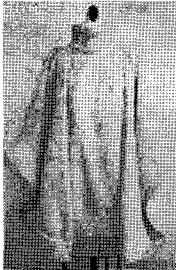
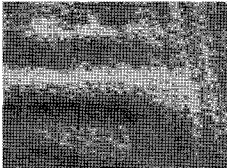

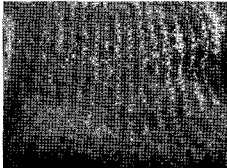

<Figure 23> Fabric design analysis

make the trim stand out<Figure22>.

c. Draped tuck - To use this fabric's advantage, I designed a coat that needed drape on its body. The coat is sleeveless, but the simple jersey dress

is to be worn inside to complement the texture of the coat<Figure22>.

d. Terry lace - I designed a jacket that would take advantage of this fabric by expressing the

New Fabric	Garments	Analysis
		<p>Applying strongly textured fabric into a simple dress silhouette lent the dress a unique, sophisticated air. The dress would be affordable and appeal to the current fashion knitwear market.</p>
		<p>Contrasting textured and flat fabric created a modern look. Applying textured fabric as trim added to the garment's clean finish and was visually extraordinary. Two layered triangle tubular knits were suitable for the winter coat, especially for the neck trim.</p>
		<p>Fabric made from the draped tuck stitch was used for parts that need draping. It created the needed effect without the labor associated with traditional draping, which means this knitting technique could lower costs when used for mass production. Also, this unique coat design from "fully fashioned" would open new possibilities in knitwear.</p>
		<p>Terry lace was used for this winter coat and suggests material that is reminiscent of terry cloth. Usually, terry cloth is not used for winter coats and its loop is smaller than terry lace. The garment from terry lace created a cozy and soft texture, and it would also be very warm.</p>

<Figure24> Knitwear design analysis

fabric's cozy feeling. Jersey knit was used for the sleeves. See below<Figure22>.

## V. CONCLUSION

Through careful research and experimentation, I was able to create four distinct knitting structures: as I analyzed in <Figure 23>: triangle holding, triangle tubular, draped tuck, and terry lace. These new fabrics are created from common knitting techniques, but could have new textures and structures that are from the knitter who has tasteful perspective. Furthermore, I adapted above created new fabrics into garment designs, and was capable to make unique and wearable knitwear by using industrial knitting machine as I showed in <Figure 24>. The continued development of such knitting construction is crucial in the field, since knit fabric has characteristics that are naturally different from those of woven fabric. Texture, appearance, and the soft feel of the fabric on the skin are all unique attributes of knitwear. However, heretofore most knitwear has been developed by fashion industry technicians rather than designers who are experts on the capabilities of knitting machines. It is time to expand knit garment design in order to satisfy modern customers, who are both fashion and budget conscious. The key to developing innovative knit texture for the mass market lies with industrial knitting machines since only industrial knitting machines allow efficacious mass production. Because the modern fashion industry demands the mass production of textured knitwear, fulfilling this demand will open doors and expand the industry. The possibilities will fuel creativity and may even affect the field of fashion design itself: the development of these new fabrics creates possibilities in the knitwear market that could lead to an expansion of designs and, eventually, to new fashions. The possibilities of knit fabric are limited only by the creativity of the knitter.

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