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Bottlenecks in Knitwear and Knitted Bottlenecks

Knitwear Production with 3D Technology in Finland

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The objective of this research was to look into integrated seamless knitwear production, also known as 3D. The latest developments in knitwear production like 3D were supposed to change the whole industry but nevertheless changes are happening slowly. As a technique, it is unique in clothing production while the machine can knit a complete sweater in less than an hour. The integral knitting technique to make seamless knitwear has many advantages but also some obstacles and limitations and in this research, those will be looked at more carefully. This was carried out as an action research by co-operating with one local producer Kutomo Holopainen in Finland by investigating knitting samples and prototypes and testing the possibilities with 3D.

There is a very limited amount of garment production left in Europe and in Finland. New 3D production methods and printers are expected to bring industries and jobs back from the Far East and, therefore, the reasons for global sourcing and also future scenarios are discussed for textile and fashion industry for the EU by 2020.

The focus will be on the design of the products together with the 3D production. Good design should not only help selling the products but in this case also saves time and money in production. The production is run by a technician and one of the challenges is to have good communication between the technician and the designer. Knitwear together with 3D production should give excellent opportunities in finding interesting solutions in both what comes to the look of the products and the manufacturing.

Keywords	Knitwear, Seamless, Integral, Knitting, Design, 3D, Production, Profitability

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Tämän opinnäytetyön tavoitteena oli tutustua 3D:nä tunnetun saumattoman integroidun neuleen tuotantoon. Viimeisimpien kehitysten neuletuotannossa kuten 3D:n oli tarkoitus muuttaa koko teollisuutta, mutta muutokset tapahtuvat hitaasti. Tekniikkana se on ainutlaatuinen vaatteen valmistuksessa, kun valmiin neuleen tuotanto voi tapahtua alle tunnissa. Saumattomia neuleita valmistavalla integroidulla neuletekniikalla on monia etuja, mutta myös joitain haasteita ja rajoituksia ja tässä tutkimuksessa on tarkoitus perehtyä niihin tarkemmin. Tämä tapahtui toimintatutkimuksena Suomessa yhteistyössä paikallisen neuleyrityksen Kutomo Holopaisen kanssa neulomalla koekappaleita ja prototyyppejä ja testaamalla 3D:n mahdollisuuksia

Vaatetusteollisuutta on jäljellä enään hyvin rajoitetusti Euroopassa ja Suomessa. Uusien 3D valmistus- ja tulostustekniikoiden uskotaan tuovan teollisuutta ja työpaikkoja takaisin Kaukoidästä ja siitä syystä lyhyesti globaalin tuotannon syistä ja myös EU:n tulevaisuuden skenaarioista tekstiili- ja vaatetusteollisuudelle vuodelle 2020.
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Tutkimuksessa on keskitytty tuotesuunnitteluun yhdessä 3D tuotannon kanssa. Hyvä suunnittelu ei ainoastaan auta myymään tuotetta, vaan tässä tapauksessa myös säästää aikaa ja kustannuksia tuotannossa. Tuotantoa hoitaa teknikko ja yksi haasteista oli hyvä kommunikointi teknikon ja suunnittelijan välillä. Neuleella yhdistettynä 3D tuotantoon pitäisi olla erinomaisia mahdollisuuksia löytää kiinnostavia ratkaisuja tuotteen ulkonäköön ja valmistukseen.

Avainsanat	neule, saumaton, integroitu, neulonta, suunnittelu, 3D, tuotanto, kannattavuus

Contents

1 Introduction

The inspiration for knitwear has grown for the author from being both an eager user, a successful sales person of knitwear and finally a “maker” for knitwear. Knitted pieces of clothing are my wardrobe favorites, some of them never go out of fashion and can be worn almost anywhere. I can also consider myself lucky having had a chance to sell world famous knitwear brands in finest qualities. The feedback from customers was always positive and the products sold well. This experience made me start studying textile techniques and textile design. A school project where we designed knitted jacquard blankets that went into production at a local knitwear company, Kutomo Holopainen gave me another insight into knitting and the production methods. While we were knitting our blankets, one of their German Stoll Knit & Wear machines was knitting a 3D sweater prototype and I could not get that sweater out of my head. My background in fashion retail together with dress making education and a business degree made me wonder what this kind of technique could be used for. Finally, the opportunity to use Stoll industrial machines and latest technology to make knitwear prototypes in Borås Swedish school of Textiles convinced me to concentrate on knitwear.

Picture 1. 3D knitwear prototype production in Stoll machine.

The Stoll Knit &Wear trials and prototypes were made during the exchange period in Borås Swedish School of Textiles in Spring 2012, which consisted the background for this thesis. The technique allows great production possibilities costwise when considering the production time and the few processes it needs untill the garment is ready. Many of the labour intensive manual production stages are eliminated and, therefore, this could be also produced in countries with higher salary levels. It also gives new possibilities in design while the product is seamless and, therefore, the garment is very flexible and could be used inside out and upside down. New interesting shapes without resticting seams could be invented. It sounds like an ideal way of producing knitwear but is still used very seldom and not in any wider contexts in Finland. This left me with many open questions, as follows: why is this technology not used more in Finland? Is the issue designing integral knitwear? Or alternatively, is it the programming time or skills that form the bottleneck or what are the other reasons for not adapting this technique? Are the options in knitting too few or limited? My aim would be to find answers to these questions.

I consider knitwear a growing part of textile industry, new materials in yarns and new developments in production will bring new opportunities for knitwear industry. Especially a smaller scale production with a new technology in higher labour cost countries like Finland might be possible and even profitable. Local production could become an as important issue in fashion industry as in food industry. Customers are expected to be even more interested in the future in wearing small individual brand names with a local touch. Brand name fashion companies are getting bigger but the customer's choices are decreasing with the heavy mass production. Moreover, to be able to maintain at least some of the fashion and textile production in Europe is a future scenario that I strongly wish and believe in. Moving all the production to Far East would mean that soon there would be no raw materials nor any machinery available in Europe. New solutions for the production need to be invented at the same time as the price advantage of countries like China are disappearing and their own home markets in Far East are growing fast. The research, development and design functions in the textile and fashion industry should have a contact with the production. Therefore, the question arises would those also be soon transferred to Far East? Would only sales and marketing be left in Europe? At the same time, customers are getting more conscious of the environmental issues and want more sustainable ecological products. How meaningful are the long distance transports of fast fashion from Far East and

where will the lack of natural raw materials lead us to? How local or global do we want to the fashion to be in the future?

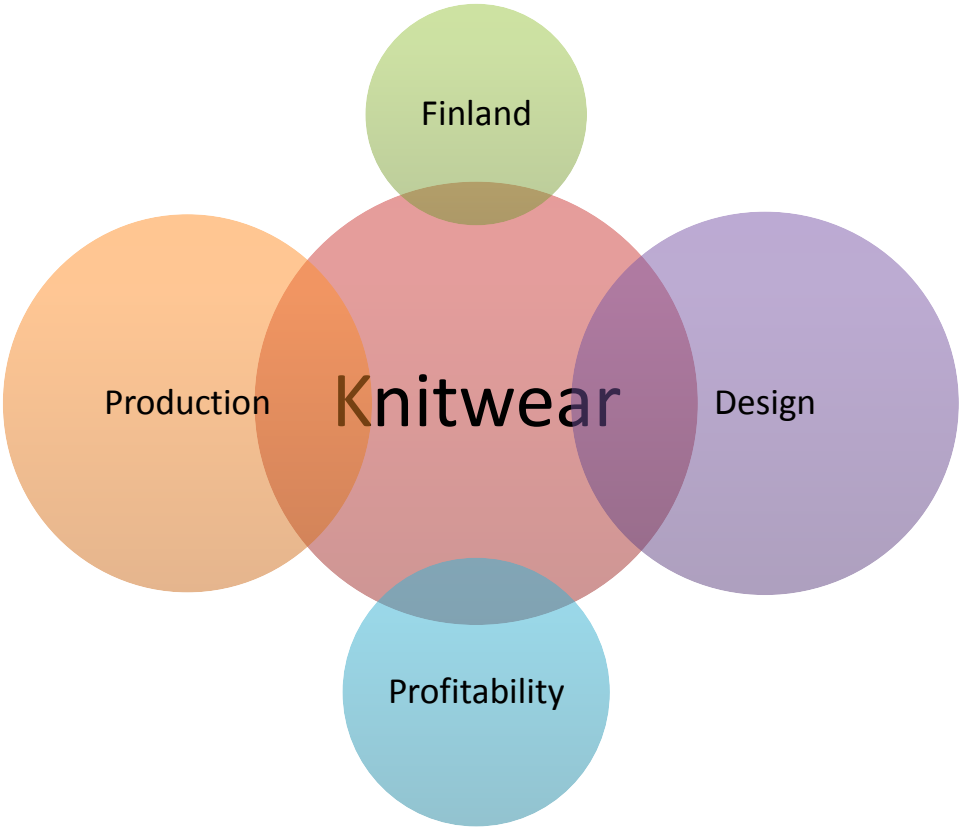
2 Research Objective

2.1 Research Question

The objective of this research is to combine knitwear design with 3D knitwear production technique. The 3D technique in theory offers great possibilities for fast and cost effective seamless production of knitwear but still majority of knitwear is produced in the traditional way by sewing knitted pieces together. This is the way production is carried out also in Finland despite of the high labour costs. The aim is to together with Kutomo Holopainen to look into the restrictions in 3D production and compare it with the other methods they are using. Action research method is applied while designing, programming and producing 3D prototypes. The Stoll Knit & Wear (K&W) machine can be used in several ways but in this research it will be used only to produce integral knitwear with no seams. The advantages should be many with this technique but the adaption has been slow. The questions to look read as follows: are the limitations when using this technique in designing the right kind of knitwear that suits this production method or are the limitations more technical? Alternatively, is the programming too difficult and/or time consuming so that there will be no advantages in using this technique? Are the limitations to be found somewhere else, and what are the bottlenecks in using this technique? In the end, the aim is to use this knowledge and the prototypes to develop a small collection of knitwear to be produced in Finland.

2.2 Reference Frame

The main focus in this thesis is on knitwear as can be seen in the reference frame in picture 2. The seamless integral 3D knitting production method is only available in industrial knitting machines and, therefore, I will look at the use and adaption of this technique together with a local producer in Finland. By designing 3D knitwear, I should gain an understanding of both the design process and the challenges in producing them. I will deal with the profitability aspects only in theory as this is a very complex as a whole.



Picture 2. Reference frame.

Knitwear is special in many ways and in Chapter 3 I will highlight the differences between knitwear and clothing manufacturing. Chapter 4 starts with a short presentation of Kutomo Holopainen followed by the production of knitted garments and the different techniques, especially 3D are explained. Production will be followed by the design of the knitwear in Chapter 5. In Chapter 6 profitability will be looked at and in Chapter 7 I will briefly go through Finland, Scandinavia and future scenarios for textile and apparel in the EU for year 2020. In Chapter 8, my own design process will be explained and after that in Chapter 9 some thoughts about the future are discussed. Finally, the conclusions of the whole process and lessons learned in Chapter 10.

2.3 Research Restrictions

The 3D technique will be tested with German Knit & Wear (K&W) machine by Stoll at Kutomo Holopainen. The use of 3D technique in knitwear is very limited in Finland. In this research, only seamless 3D technique will be used to produce the prototypes so that the limitations in design and production should stand out. I will concentrate more on finding the right forms and shapes of the garments rather than on different surfaces, structures or patterns in knitwear. The K&W technique already limits the options to use different structures together with 3D due to needle functions. The challenge is to maximise the use of technology and minimise the production steps. None of the ready programmed garments in K&W were neither used nor redesigned to get closer to the right shape. The aim was to start from zero with a tubular form and build knowledge based on what was learned while developing the pieces further, step by step.

2.4 Vocabulary

In this research, I will use the words integrated, seamless and 3D knitwear to describe the same thing. To simplify it *integrated* knitting technique is used to produce *seamless* knitwear that is *3 dimensional*. 3D as a term is very popular now due to the new 3D printers while integral and seamless more opens up what this is about. Parts like *back*, *front*, *sleeves* and *collars* are knitted simultaneously and, therefore, integrated into knitwear without seams. In some literature, the actual technique is called Complete Garment. German industrial knitting machine producer Stoll calls their technology Knit & Wear and Japanese Shima Seiki has their WholeGarment system and because they are both brand names and registered trademarks this technology is sometimes just called simply *complete garment* (Peterson 2012, 26). Both techniques are used to produce 3D knitwear but with slightly different needle technique but in Finland we have only some Knit& Wear machines and no Shima Seiki machines that I would be aware of.

3 Knitwear

In this chapter I am going to discuss more in detail what makes knitwear so special and why it would be suitable for this kind of high tech product by comparing knitwear and garment manufacturing.

"The essence and beauty in knit lies in the fact that the designer invents everything from scratch; he creates the stich, the handle, the weight and chooses the colour, deciding on texture and shape at the same time, mastering his own finishing and detailing."

Li Edelkoort
(Sissons 2010, 65)

The knitwear designer has many options but also many open ended questions to answer during the design process like stated above. More than in a clothing design process, a knitwear designer really starts from zero with just a piece of yarn. In knitwear, the yarn forms the stich and the stiches form a surface that then get a shape during different processes, based on the production method. Some of the methods to process knitting into garments are similar to clothing manufacturing but in this research, I will concentrate on the latest integrated technology in knitwear production. In Chapter 4, I will briefly explain about the other methods in knitwear production and go more into the details of the 3D production technique.

3.1 Manufacturing

In clothing manufacturing, the processes follow each other in separate steps while in knitwear the processes can happen simultaneously. The latest technology makes it possible to proceed from yarn to a readymade knitwear in one go in less than an hour. In clothing manufacturing the yarn is first made into fabric and the design process often starts first after the designer has found the right fabric. The fabric is then cut into a correct shape with patterns and then sewn together according to the designer's wish. Clothing manufacturing is more divided into different steps and, therefore, more people are often involved. These people can have different skills like pattern making, cutting or sewing and these steps made in the right order make in the end a garment. Parts of the process or makers can be changed anytime to change or improve the quality or the look of the product. In 3D knitwear the readymade and finished piece can first be observed. Finishing includes that the knitted piece has to be also washed and steamed so that the yarn gets back to its normal shape after been in extremely stretched position in the machine. Any changes to improve the quality or the look of the knitwear have to be carried out after the whole process and a new piece needs to be knitted and finished for the results to be seen. All changes will have an unknown effect on the integrated

process and on the final result. This makes the manufacturing of 3D knitwear compared with clothing production so different and that has its effect on the design process. The 3D knitwear designer has to have good knowledge in variety of fields while the processes happen simultaneously. Mastering the process will take time and several trials have to be made to get even one acceptable design. Changing the yarn or the stich size makes you begin from zero again. Knitwear is a challenging field and more so the 3D method but at the same time very exciting and rewarding.

3.2 3D Knitwear

The new technology in knitwear gives new possibilities not yet available in any other garment production and that makes the knitwear unique. It also improves the quality of the product while only few or no seams will be needed and at the same time fewer steps in production. The quality of the knitted garments reflects all the processes it has passed and the number of possible faults increases with the number of processes. (Brackenbury 1992, 169.) On a stretchy material seams are often the weak part because the seams are very difficult to make as stretchy as the rest of the material. Therefore the seams might both limit the stretching and also stick out from the surface.

The choices of yarn and how to use it are almost unlimited in knitwear; your imagination might be the only limit! At the same time, that is what makes it very challenging while your design is not based on the quality and property of the fabric but on what you imagine and wish the yarn will look like once knitted. You can use different thicknesses, use the yarns single, double, triple or more and combine different qualities and different colours. You can create your own yarn. The thinner the yarn is the more in different ways you can use it. You can knit many different structures or patterns in industrial machines but in 3D they are more limited to one bed options. Testing and samples should be done beforehand by hand knitting or with domestic machine as it is then easier for the technician to help adapting that to industrial machines.

Picture 3. Knitted test samples in plain and rib, single, double and triple.

In picture 3, knitted square pieces made for testing the plain and rib in different thicknesses. Industrial knitting machines have certain gauge i.e. number of needles per inch and that gives limitations on yarn thickness. Kutomo Holopainen K&W machines use gauge 12 and when using every other needle gauge 7. 3D technique needs more needles in action while knitting the whole piece in tubular in both beds and that gives limitations on knitting jacquard or certain structures that would need needles to transfer stiches like in cable knit.

3.3 Bottlenecks

Only a certain more limited range of knitwear will be looked at in this research, in this case casual ladies tops, tunics, cardigans and capes. Knitwear often makes a part of a collection or is as an addition to a collection, but seldom forms a whole collection. This suited my purposes well while I could concentrate on fewer pieces. The main area in the knitwear I was looking at was the area around armhole, shoulder and neckline. This is where the bottleneck in knitting a jumper is and this area happens to look like a bottleneck too! This area can be done in 3D without seams but finding the right form and shape is challenging. Once you find the right settings but you would like to make it in another size, colour or use another yarn you might have to start from zero. Stoll K&W production technique is fast in production but the programming time and the flexibility to make certain even minor alterations to designs can be very time consuming.

Grading to different sizes is time consuming when all parts need to be first graded separately. Also a different colour of the same yarn can change the 3D format so that a new grading needs to be done with another colour. Black yarn might be thicker due to dyeing process and therefore it needs new programming so that S size in all colours would be the same size. This might limit the size and color range. The closer fitting the knitwear is the more sizes and programming is needed. Therefore, in my own design process I was keen on looking at this area and tried to find more “one size fits all” solutions and alternative ways for armholes and sleeve construction. Even tighter pieces might allow you to move your arms enough if the armhole is placed correctly. We do often have a traditional view on where and how the sleeve should be based on garments made of fabric but that does not have to be the case in knitwear.

Collars and trimmings are often sewn to the knitted pieces and these seams might change the whole look and touch of the knitted garment. However, in 3D these can be integrated. Fastenings form another challenge in knitwear, traditional solutions like buttons with button holes or zippers used in clothing made of fabric might again not offer the best solutions in soft knitwear. Some alternative solutions like belts, straps, hooks, brooches and buttons with loops could better fit to casual knitwear without seams.

4 Production and Techniques

“It is a freedom to be able to make your own fabric while working. For me it is the absolute challenge.”

Sandra Backlund
(Sissons 2010, 9)

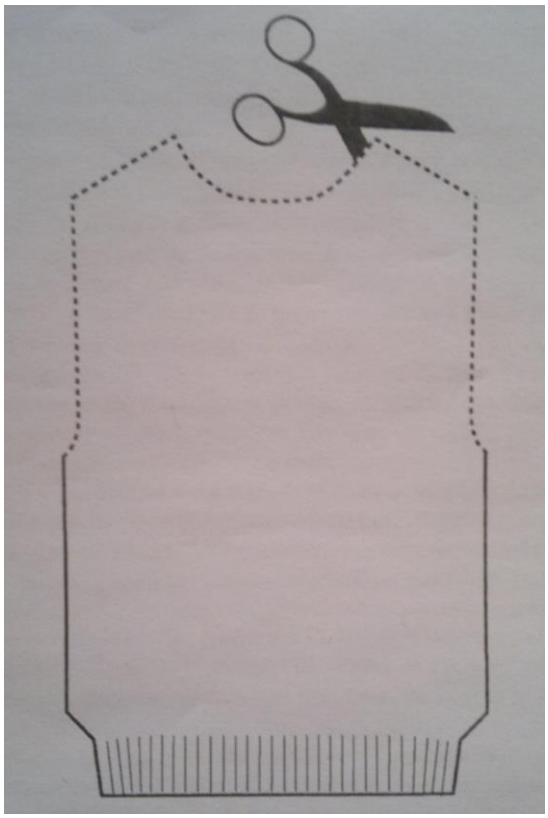
The traditional techniques used in Knitwear production are Cut, Make and Trim (CMT), Fully Fashion and Complete garment, all in use still today and also by Kutomo Holopainen. I will first shortly present Kutomo Holopainen, then introduce the techniques and finally concentrate on 3D and more specifically at K&W. And last but not least I will shortly present the material I chose to use.

4.1 Kutomo Holopainen

Kutomo Holopainen was grounded 1964 by Pauli Holopainen. The company started with Rascal machines and knitted mainly scarves and socks. 1974 a production of knitted jumpers and cardigans mainly for ladies and children started as new flatbed machines were introduced. In 1975 brothers Matti and Pentti who had been helping occasionally joined in and the company became a stock company (Osakeyhtiö). At the time, they abandoned the sock machines as cheap mass produced socks were imported to Finland and they concentrated on ladies knitwear. Kutomo Holopainen made their own collections for wholesale customers and had their own sales representatives to visit retailers. Around 1980s, the first customers to knit their own collections came along although customers could have made changes to existing models already earlier. 1986 first 3 Stoll CMS new technique machines were bought to Finland and the first one of them arrived to Kutomo Holopainen. Those machines gave the production a totally new perspective as they were both very fast and had many different functions like intarsia or surface patterns. At the end of 1990s, the K&W machines were introduced and Kutomo Holopainen acquired two of those. These machines can be used for many different production methods, not only 3D. In addition to own production under own label nowadays half of production is done to other brand names. (Intervue 5.3 with Pentti Holopainen)

4.2 Cut, Make and Trim (CMT)

Until mid-1990s industrial knitting machines were only used to produce knitted fabric and knitwear was made out of that in the same way as out of ordinary fabric. The knitted fabric was cut into pieces and then sewn together like any other garment. This method is called CMT or Cut & Sew. (Evans-Mikellis 2012, 45.) The starting point is the same as in clothing production as can be seen in Picture 4.



Picture 4. Cut, make and trim production starts with cutting (Evans-Mikellis 2012, 46).

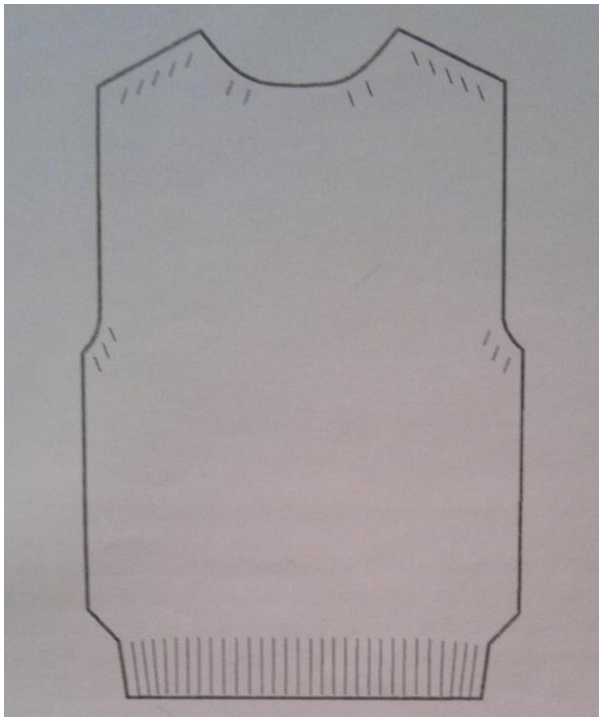
PRODUCTION STEPS: KNITTING->STEAMING->CUTTING->SEWING->FINISHING

This method is still in use in knitwear companies for several reasons. One of the reasons is that knitwear has been traditionally designed by fashion designers, who have treated knitwear in the same way as fabric, by cutting and sewing it to give shape. From a production point of view one of the reasons is that it gives a better control of the whole production. As mentioned earlier with clothing production the manufacturing steps can be stopped and changed at any time. According to Ari Holopainen, cutting the pieces out of a knitted fabric eliminates the different yarn related effects on measurements. One and same yarn can be slightly different sizes in different colours due to the dyeing process but also by using the pattern to cut the pieces makes them all the same size. The same garment can be made in different yarns with the same pattern and the shape remains. Grading is more “visible” with patterns than in 3D and the seams can also help the knitwear to keep a certain shape. The seams can also be used for other details like pockets. Parts are often sewn together with over locking as that finishes the raw edges at the same time, but gives also slightly bulkier seams. In my view, this better suits the fabric kind of knitting. Cutting the pieces of the knitted fabric means waste and both according to literature and Ari and Esa Holopainen the

waste is somewhere between 30-35%. If there is a quality problem in any of the pieces that piece can be changed, like for example a dropped stich in a sleeve can be replaced with sewing another sleeve in. The costs for smaller scale production are also acceptable according to Ari Holopainen while the following two methods need bigger quantities to be profitable.

4.3 Fully Fashion

In fully fashion the pieces of knitwear are knitted into shape and no cutting is needed. Pieces must still be sewn together. The garment forms its shape and fit from the stretch properties of the knitwear. (Evans-Mikellis 2012, 45.)



Picture 5. Fully Fashion with “birds eye” details that give the shape (Evans-Mikellis 2012, 47).

PRODUCTION STEPS: KNITTING->STEAMING->SEWING->FINISHING

Scottish cashmere brand names like Pringle and Johnston use fully fashion while it gives a more finished look to their products; they both fit better and are more durable because the stiches have not been cut along the sides. Fully fashion knitwear can be recognized by the small “bird’s eyes” along the seams, usually around armholes and shoulder like seen in Picture 5.

Kutomo Holopainen knits fully fashion mostly to their partners. According to Ari Holopainen, fully fashion can be expensive to make due to the programming time. All parts need to be programmed separately and if there are in addition several sizes and different colours, it will certainly take time. Also the knitting time is longer because all parts are both knitted and steamed separately. However, it has advantages like many different shapes can be made and different techniques can be used on the parts, also cable or jacquard. Because no cutting is needed, there should be no waste of the material either but still approximately 5-10 % waste can be calculated due to knitting mistakes. While knitting with the 3D technique in K&W machines complicated pockets and collars can be made integrated in the fully fashion pieces. It has more needles to use because it is not knitting the whole garment at the same time like in 3D. Sewn together usually with chain stiches on either a linking machine or a cup seamer, gives slimmer and more elastic seams than with overlocking.

4.4 Complete Garment Technology or 3D

In integrally knitted seamless 3D technique, the machine knits tubes which are interconnected and the entire garment is made at the same time as the fabric created as can be seen in Picture 6. The knitwear comes off the machine complete without seams. (Evans-Mikellis 2012, 46.)

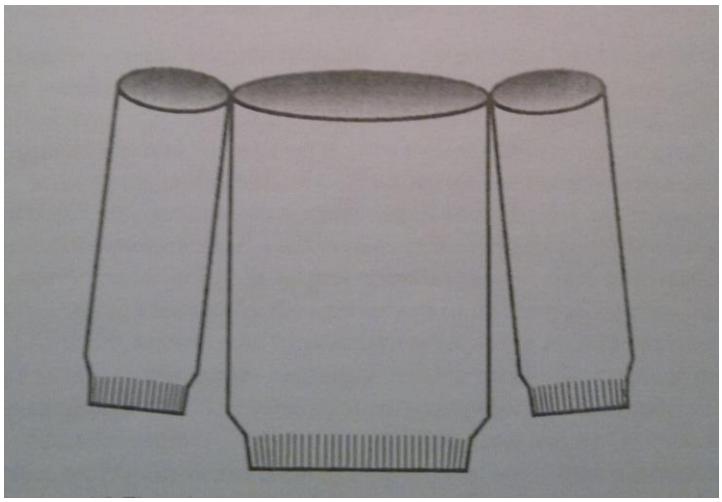


Figure 6.Complete garment technology sweater (Evans-Mikellis 2012, 47).

PRODUCTION STEPS: KNITTING->WASHING->FINISHING

Eliminating the seams means no need for cutting and sewing and this means saving time and money on manufacturing. Eliminating the seams makes also more comfortable and better fitting knitwear. (Evans-Mikellis 2012, 48.) Complete garment technology gives the possibility to use extra thin materials that earlier in combination with over locking in CMT made the products weak and aesthetically poor. Also certain other materials like loose mohair or certain knitting structures like lace can be now used in more ways without restrictions. Summer knitwear and evening wear could be areas to use this seamless knitting technology. One really interesting possibility is a reversible knitwear that without seams gives a real choice for the customer to use their knitwear upside down and inside out. That gives also the designer an ultimate challenge in using all the possibilities this technique allows, both in surface and shape. (Evans-Mikellis 2012, 50.)

In practice, K&W is not as simple to use as in theory written and therefore neither so widely used. Kutomo Holopainen reasons for not using it are partly the same as for fully fashion i.e. long programming time, especially when wider size and colour range. The bigger quantities you make, the more profitable it gets. 3D knitting means no waste like in Fully fashion but usually at least the first 2 pieces are trial ones due to all kind of technical reasons and several pieces have to be knitted to follow the design accurately. In addition, when mistakes like dropped stiches happen or some of the stiches are knitted front and back together, the whole garment is damaged. Esa and Ari Holopainen counts on 10-15% waste. There are more limitations on patterns and surfaces than in fully fashion, as the majority of the needles are used for integral knitting. The knitting time is also longer as the tubular knitting takes more time.

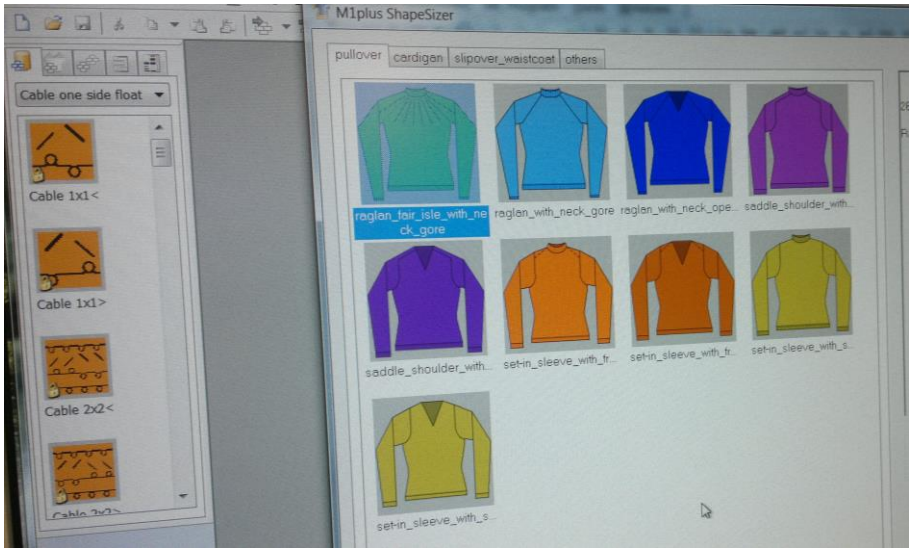
4.5 Knit & Wear Machines

Stoll Knit & Wear technique has its limitations concerning what kind of a 3D format you can make. For example, increasing stiches is more restricted compared with decreasing stiches. This might not give too many choices in which way to knit the product, from neckline to waist or from waist to neckline. As well restricted is the way in which way to make a split or holes like armholes or pockets in the knitwear, they have to be vertical. Horizontally creating new stiches i.e. adding width is restricted while adding length is quite simple. The amount of needles gives you the maximum width of the product. If the design is wider like some of my “one size fits all” solutions the sleeves

will not fit in and therefore cannot be integrated. The tension is important as it affects the look of the stich and the feel of the knit. Knitting technique sometimes forces you to tighten or loose the stiches so that knitting runs smoothly in the machine. Yarn has to be a high quality yarn on a cone and enough stretchy so that it does not broke while under tension during production.

4.5.1 Programming

While programming a garment with K&W you can start with having a look at what patterns the K&W machine already has, some examples in Picture 7. There is a limited amount of basic ready-made patterns from Stoll available like pullovers, cardigans, slipovers and leggings.



Picture 7. Pullover alternatives in Stoll K&W machine.

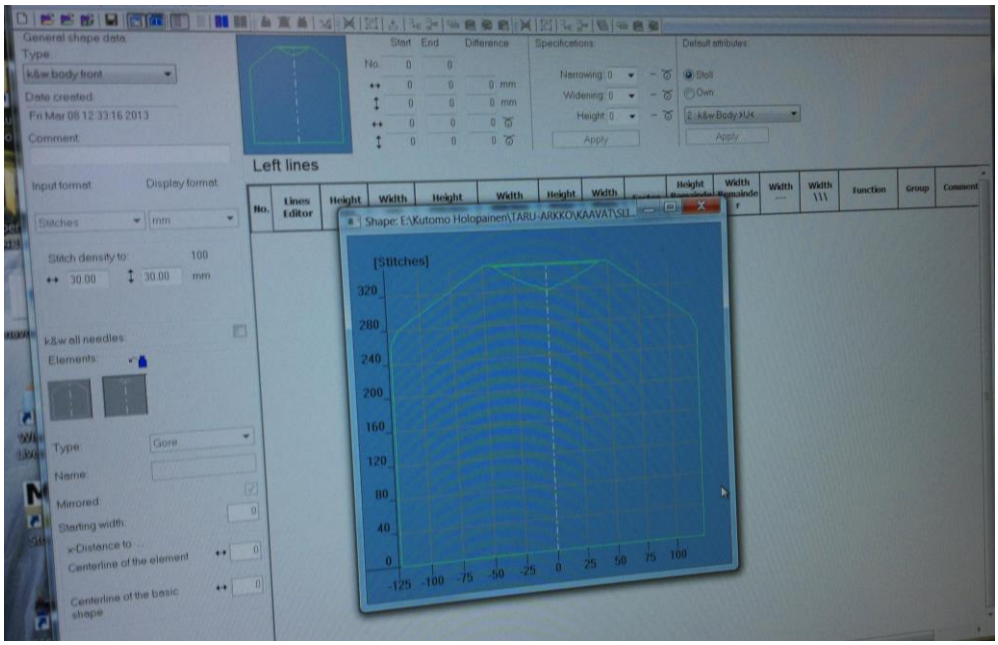
Knitting a ready programmed sweater with your own measurements and settings you get knitwear that you can start forming and make alterations. This is often the fastest and easiest way to start with when making a sweater with sleeves according to Ari Holopainen. I tried this in Borås but it was still very time consuming, a simple basic roll neck with cable knit in front took us two days to program and 6 samples until we got it somehow acceptable. You can also program your own patterns depending on how complicated they are. While some of the alterations mean that you have to start from zero, I conducted in this research and chose to start from a simple cape in tubular and making gradual development with this piece into a more integrated and complex piece.

Knit & Wear technique needs several samples until you get what you want due to the difficulty to know how the knitted material behaves as a garment.

After first knitting samples using right yarn to find out correct adjustments like tension the steps in programming are

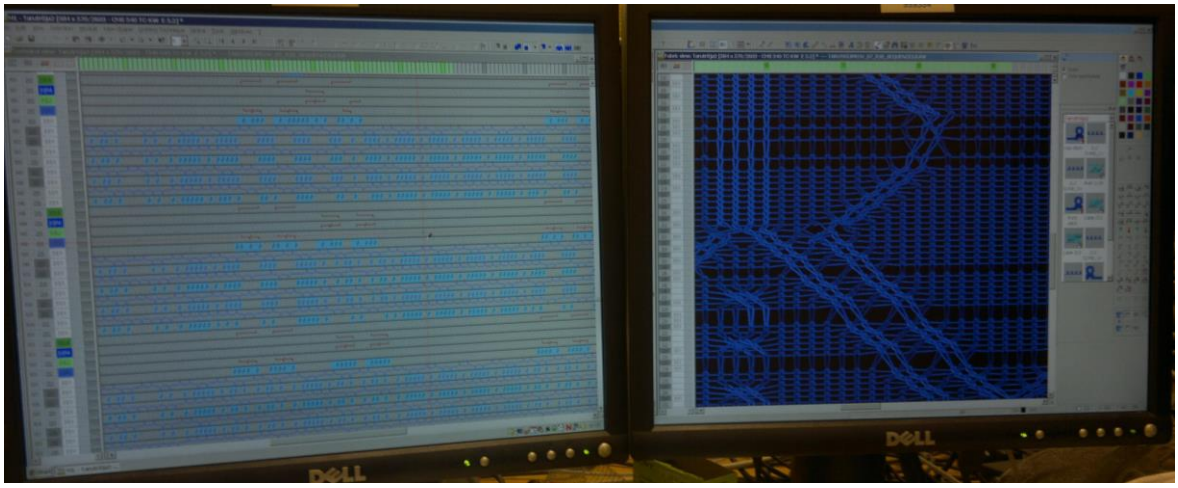
- installing the technical details like how many stiches per centimeter based on samples
- making the pattern for each piece like front, back etc. or using an existing one with desired alterations and details
- integrating garment pieces to one
- integrated pattern is placed on top of the chosen knitwear structure
- computer makes the program for the 3D garment knitting
- transferring the program to the knitting machine

The programming is completed on the computer with two screens. The pattern for the knitted piece is done first, separately for the front, back and any other parts like sleeves. When they have the correct measurements and detailing the parts will be integrated and form just one knitwear.



Picture 8. Pattern making

In Picture 8, the pattern for the cape is done with correct measurements and details like the right angle in shoulder line and partial knitting at front neckline.



Picture 9. Programming cable knit, both technical and visual view in use

The screens show different views during the programming and in Picture 9 the left one shows the technical view with signs and the right one the visual look i.e. how the stiches will look like on the surface. Trained technicians are used to read the technical signs on needle functions on the left screen to find faults and problems easier and the more visual side on right makes more sense often to a designer. The programming process might be challenging depending on how complicated the model is and how well the parts have been originally designed to fit each other. A toile or mock up made of fabric and/or very detailed measurements help at this stage in addition to the knitted samples in the correct yarn and tension. Even small hand knitted pieces would be helpful for the technician to clarify what the designer is after.

After the whole programming process, a knitted prototype needs to be made to see if the idea works at all. A waste yarn can be used but that should be really close to the chosen yarn. If the details are very fine and measurements very precise, the correct yarn should be used because in 3D even minor differences in yarn will have an immediate effect on the result. With that first sample alterations can start and several samples might have to be done. More about the development process explained in Chapter 9 on my own design process. There are no other way than knitting the samples and making step by step the alterations because everything is integrated. Changing one proportion has an effect on the other proportions as they are all connected. The elasticity of knitwear is challenging in 3D design. One could say that it adds one more unpredictable dimension to the whole. But the final shape the knitwear gets according to the wearer, slightly different on everyone!

4.5.2 Technician

The technician's role in integrated knitting is very important. In this case when the design process leads directly to a finished product, a skilled technician is at least as important as the designer. The technician translates the design into stiches. If and when the technique is new to the designer the technician can clarify the technical restrictions and solutions that are available. There are no immediate answers to all questions but the technician can also try to program a trial and see if the machine accepts the programming. The computer will not finish the programming if there are solutions that cannot be produced. However, it does not tell where the problem is and, therefore, understanding of all the steps is essential. Not all the alternatives one could make are either tested so there will be many exciting challenges for those working with this technique. Stoll is all the time updating and developing the programs and one can also be in touch with them about technical solutions. Twice a year Stoll makes a collection to give inspiration for the season. Sometimes this production method is more suitable for the fashion being. Technicians tend to use solutions they know and are used to and in my mind it is the designer's role to challenge the technique. The more the designer works with this technique the more interesting it gets. Limitations often forces one to be more innovative and creative and in this case there are opportunities for many innovations and creations!

A good co-operation and communication between the designer and the technician is essential. The designer works with the form and the shape of the garment and knows the trends, materials and colours that will sell. The designer could be said to represent the customer while the technician makes the designs to come true. The technician should have good technical skills and need to be interested in trying something new. Knowledge of clothing or knitwear production with any technique is good base and knitting as hobby would be additional plus. Although the technique has been available for a several years there is still quite few experienced in using it in Finland. The technicians do not use 3D if there is no demand for it and the designers do not use it if they do not know about it or think it is complicated. Building knowledge all the time is important, the more you work with this the better you get.

Complete garment technology offers obvious cost savings along the production but only buying a new machine and then trying to adapt it to existing production and business systems will not automatically give the best results. This technology is likely to be

one of the future production methods in knitwear production but it will need the production system and supply chain to support the use of it. New technology takes time and the whole chain might have to be adapted. (Peterson 2012, 26.)

4.6 Material

Alpaca seemed like an interesting material based on previous experience with it and thin non dyed 100% Baby Alpaca from Peru was found in Nm 2/28 yarn count. This yarn had the right properties like the softness and lightness I was looking for in this kind of products. The yarn was on cones suitable for industrial knitting machines and in addition the good news was that the neutral colours I was looking for were the natural colours of the alpaca. After the shearing, the alpaca wool is manually sorted out by hand according to the colours. That means the yarn is less processed and, therefore, more ecological and the colours should stay. The baby alpaca is from the first shearing and, therefore, extra fine and soft. Alpaca is a mammal related to Camel and it is living in South America in the Andes, a baby alpaca shown in Picture 10.

Picture 10. Baby Alpaca (La Alpaca Brochure)

The weather conditions are rough at 3000-5000 metres above the sea level and, therefore, the alpaca has grown soft and thick wool. Hollow and long hair gives excellent insulation and protection against cold, moisture, and sunlight. The fibre is strong, durable, elastic and soft and will not irritate the skin. It will not feel cold when wet because absorbing fibres transfer moisture away from skin. Alpaca has the same kind of self-cleaning ability as wool and, therefore, regular airing means less washing and makes alpaca products environmentally friendly. (La Alpaca Brochure)

5 Design

"Design development allows you to make mistakes; without screwing up once in a while you can't ever move forward."

Alexander MCQueen
(Sissons 2010, 39).

Designing means trying something new and that includes always risks, something might not work out but you learn on the way. Some of the "mistakes" might be really "lucky" ones and some useful first later on.

5.1 Knitwear Designer

A knitwear designer both designs the garment and the material for it so that one could say that knitwear designer has to be both fashion and textile designer. Knowledge of both fields is important.

KNITWEAR DESIGNER = Fashion designer + Textile designer

Knitwear is often considered a minor part of fashion design and, therefore, there is not much education in knitwear design. Fashion designers usually have very little technical training and that goes for knitwear design and techniques too. Traditionally, the technicians have been trained by knitwear manufacturers and knitting machine manufacturers with little creative or commercial fashion elements with regards to the design aspects. This might have been one of the reasons why knitwear design is often based on using traditional CMT way of production. If the knitwear is just considered and treated as "stretchy" fabric then all the advantages of knitwear and the production methods are not fully explored. With 3D production method the knitwear should be more considered like a shape and the big question is how to transform the shape into knitwear with the possibilities 3D knitting machines allow and that needs both designer and technician participation. (Evans-Mikellis 2012, 62.)

When Wholegarment machine by Shima Seiki was launched it was an entirely new approach to knitwear design and production, the manufacturing point of view is in use

but the design potential has not yet been fully explored. There is huge potential for new design thinking in this 3D format when shape can now be built into what used to be just flat fabric. There are opportunities in this “shape engineering” where the fabric and the shape of it are developed at the same time and lead to new uses and products in knitwear. There is a need for changes in training and in the working methods of knitwear designers so that the new technology in seamless production and CAD for knitwear can be fully used. (Evans-Mikellis 2012, 62-63.)

Comparing hand knitting, domestic knitting and industrial knitting machines the structure in hand knitting is sometimes closer to 3D knitting. The hand knitted pieces can be built up in a three dimensional format while in domestic knitting machine the pieces are built up more in two dimensional format. The possibilities in 3D knitting will not be fully explored if industrial machines are used in the same way as domestic knitting machines. Experience and knowledge in hand knitting helps to understand 3D knitting. Ability to see the form and the shape is important. Basic knowledge in pattern making is a benefit so that one knows how the human body can be transformed in to 2D pattern but only to help in understanding how to use this information in 3D format.

5.2 Industrial Designer

In the following text based on an article in TEK magazine, an industrial designer explains his approach to design and technical knowledge and this could well be adapted to the integrated knitting. In case using more advanced technology in production even a textile, fashion and knitwear designer needs to know more of the technical side of the production. Using a high tech production needs more co-operations between the persons involved. Otherwise too many decisions are left to the technicians without designer education and knowledge and then the technical solutions might ruin the whole design concept. Production methods and possibilities should also inspire and challenge the designer.

Industrial designer Hannu Havusto has co-operated with a Finnish paper machine manufacturer for a long time in improving product development. Designing has played an important role in industrial products while it helps companies to differentiate from competitors, build a recognized brand, improve the quality impression and the look of the product and create innovative solutions. Design helps improve the use of the product and can affect also on the costs. Savings are made with new kind of structures and

putting functions under same components. Hannu Havusto says that the designer has to understand how the materials behave, production processes, what customers want, what the end users are doing and how to maintain the products. A designer is needed during the whole product development process. It all begins with setting the targets and ideas for the functions and the visual look of the product. He likes to talk about design that transforms the strategy. To find new ways of doing things that will change company's strategy. Companies should put more effort on long time planning. A designer's job is to visualize the readymade products although not all the technical details are solved. An engineer's job is to find the problem areas and find the solutions. The engineer and the designer aim both to develop a good product which is cost effective and easy to produce. But bringing design into product development can be painful if company is not willing to change anything. (Karjalainen, Aku 2013, 37-38.)

The same things could be valid in a designer's role in high technology clothing manufacturing like in 3D knitting. Adapting a new technique might mean that the whole strategy of the company needs to be looked at. Also the co-operation and the roles of the designer and technician are as important as in this paper machine case. The production is executed by a machine and the technician is the link between the designer and the machine. 3D knitwear design process is closer to what an industrial designer does in what comes to taking the production into consideration. This is more production oriented and the costs for even prototypes are high. It needs to be considered what production method to use, 3D offers great possibilities but depending on the design other methods might be more cost effective. Knitwear is a special field and it needs special knowledge.

6 Profitability

As a fashion designer I was always aware that I was not an artist, because I was creating something that was made to be sold, marketed, used, and ultimately discarded.

Tom Ford
(Hopkins 2012, 47)

Being profitable is essential as challenges in fashion industry are many and quite much has to be invested before the season even starts. The further away the production is the earlier the design process and ordering has to start. This involves risks as it is very difficult to anticipate what customers want, even 9-18 months ahead. First, in this chapter I have summarised the theory of some of the most important calculations as the calculations are the tool for profitability and then something about global sourcing as this is very common in fashion business. 3D knitting and other high tech production methods might bring some of the production back to Europe and therefore the reasons for global sourcing needed to be included.

6.1 Costing, Pricing and Budgeting

Costing and pricing are critical functions in any company and also designers should be aware of them. Cost means the cost to produce and manufacture a product and price is the money customers pay for the product. Price is also in fashion world often an indicator of quality. Profit is what is left after taking the cost from the price. (Jeffrey & Evans 2011, 4.)

PRICE = COST + PROFIT or rather PROFIT = PRICE – COST

To be able to sustain the business all companies need to make a profit. Businesses have their own margin and mark-up policies based on their company's strategy. There are high turnover "fast fashion" businesses as well as lower turnover designer labels. Turnover is the volume of business over a certain period, usually a year. Break-even point is achieved when the total sales volume generates just enough money to cover for all the costs. The profit margins are often slim in clothing manufacturing and therefore cost control is very important. Cost control process means measuring, recording and comparing costs to ensure the profitability. Main reason for being in a business is to make profit because that is the only way to provide a living for those running the business and those employed by it. (Jeffrey & Evans 2011, 4.)

Budget is a financial plan for the company for the future, normally for the year ahead. Budgeting is the process of achieving the plan, i.e. a plan of action. It includes targets for sales and production in terms of money. Separate budgeting is done across the business but it needs to be integrated so that the sales budget fits with the production budget. The plan of the business cash flow is crucial to the whole business operation. It

shows the planned incoming money and the outgoing money month by month. (Jeffrey & Evans 2011, 93-94.)

Systems and methods of manufacture and sourcing are constantly changing and being improved. High tech methods of manufacturing, component manufacturing and systems like just in time (JIT) have been introduced. This is leading into new demands on measuring the changing costs and costing methods. (Jeffrey & Evans 2011, 111.)

The new 3D technology will give several benefits and savings on manufacturing when considering production time, stages and flexibility, the need of less labour, machinery and space and should improve quality. However, those savings need to be calculated correctly, especially while comparing with the “old” methods. There will be additional costs on programming and allocating those costs needs to done accurately. Correct counting methods during the whole process are very important.

3D production is relatively cost effective but the rest of the process not. It was extra interesting to have something to measure and calculate as soon as I had something completed . Already the weight of the product gave me material cost that together with the production and finishing time, gave me a starting point to calculate the cost and the approximate price. Numbers are often business secrets and they will in this case also be secrets but also because my designs are still prototypes. The possibility to produce several products at the same time of a certain design was also going have an effect on the price, the machine hours will be the same but the washing and finishing process can be “mass produced” and the cost divided. How to divide the programming time was going to be difficult as in my case one programming led to another one. So should programming time be equally shared with the amount of approved prototypes or with the amount of produced pieces? Products would need a price before they could be sold while the volumes that affect the price are unknown. So the starting point is costing and pricing but as soon as you start selling your products you need to include budgeting to be able to have enough money to get the products made and delivered to customers.

6.2 Global Sourcing

The production has been moved to countries with cheaper production costs and global sourcing is everyday life to all of us and not just in clothing. In Chapter 7, I will more look at Finland and Europe and some of the reasons why some of the production

should be kept here. Many of the reasons are based on profitability and therefore the production was originally moved to Far East.

The high street is driven by customers looking for latest fashion from catwalks with just a fraction of the price. The global sourcing strategy is an answer to find and evaluate manufacturers abroad to meet sales targets and increase profit margins. There is a capacity to mass manufacture. With today's information technology, global sourcing is easier than ever. Overseas, low labour production costs have increased profitability and offered a wider product range to customers. Some of the obstacles are the cultural differences, long distances with different time zones, travelling, freight and shipping costs, legal and administrative costs and the risk of copyright issues especially when dealing with brand names. There is a pressure for even smaller retailers to find all the time cheaper sources of supply although not all have the negotiation power in the form of economies of scale with the buying power. There is a rising interest among customers on "green fashion", fashion which is ecologically sound, uses organic materials, pursue fair-trade and is sustainable and ethical. (Jeffrey & Evans 2011, 61-62.)

Customer's awareness on ecological issues is one of the steps that might lead the production to move back to Europe but also the fast raising salary costs like in China. Local 3D knitwear production would in my mind be ideal for "green fashion" but also because it should be cost effective and, therefore, profitable. With the complete garment technology the processes a product goes through during manufacturing will be reduced or eliminated and this will shorten the lead times and the product will be made as efficiently and inexpensively as possible without affecting the quality of the product (Peterson 27). Moreover, the shorter the lead time the more accurate your products are for the market and the season.

7 Finland, Scandinavia and Europe

We have long traditions in clothing and textile industry in Europe and so does Finland with other Scandinavian countries. Mostly, the production has been moved long ago to other countries with cheaper labour costs but as a business it is still important. In Sweden, it is considered a growing business and the government plan is to support its growth and to double the turnover in near future. To be competitive, certain functions like sales, marketing and design are kept local while production is done elsewhere. I

will start with a comparison on Scandinavian countries and Finland and then present the EU commission report on the Future scenarios of the branch for 2020. The Future scenarios' report is a very long and detailed report but also a very interesting reading to anybody working in the business. It states where we are now and what the options for the future are divided in 3 different scenarios. I have picked up what are in my mind the most important issues in the report and present what I think will be the most probable scenario.

7.1 Finland and Scandinavia

Finnish clothing export was in 2011 worth 293 million euros. Our leading export country was Russia with 33% followed by Germany with 14%. Biggest trader in fashion business in Nordic countries is Denmark with an export worth 4 billion when including textile export. Fashion alone made 3,2 billion and Germany was main export country with 25%. Textile and fashion export from Sweden amounted to 2 billion euros where fashion made 1,3 billion. Finland is their biggest export country with 26%. (Sajari 2012.)

The common factor with Sweden and Denmark is that they have built very strong commercial brand names to answer a very wide demand. In the same article Satu Mehtälä, managing director of Finatex (The Federation of Finnish Textile and Clothing Industries) says that Finnish clothing industry would have very big potential to grow. Making Finnish brand names known abroad would be essential. Denmark and Sweden export to their neighbor countries while Finland has an advantage in the growing Russian market. Knowledge of the actual fashion business and putting emphasis on it is less in Finland than in the two other countries. Finatex is working on finding new ways of networking with other organizations, schools and international contacts to improve the business. (Sajari 2012.)

In another newspaper article, Satu Mehtälä says that to be able to grow, Finnish fashion companies should be able to add such value adding qualities to their products that customers would be ready to pay the high cost of Finnish labour. This kind of value adding qualities in a product would be as follows: high quality; fitting well for the purpose; having the right look; fitting well and being durable. The question remains if we have any more people willing for factory work like sewing if the production would also be kept in Finland. China is the world's clothing factory but is becoming more expensive all the time. That is why some of the work has moved back to Europe to low cost

countries like Estonia, Turkey and Bulgaria. Today's clothing manufacturing is divided into two: the ownership, administration, marketing, design, production management and logistics are in the homeland but the actual work, in this case sewing, is done in low cost countries. (Suomalainen 2012.)

We are falling behind of our Scandinavian neighbours in what comes to clothing and textile industry and there are no reasons why we would or could not compete with them. In my view, we would need a better understanding of production to be able to know what, where and how to produce. Design and production should go hand in hand. That would give a base for many different kinds of fashion companies to grow. Moreover, we also need help to see the possibilities in what is now considered an "old fashioned dying industry" in Finland.

7.2 EU Scenarios for 2020

In the EU commission report *"Skills scenarios for the textiles, wearing apparel and leather products sector in the European Union, Final report"* , there are three different future scenarios for year 2020 for the branch presented. According to the report, there are four main drivers to effect the future; global competition, extension of the knowledge base, market changes, and environmental aspects. Based on these four drivers are the three different scenarios built up and they are shortly as

"**Globalization limited**" which concentrates on ecological and environmental issues due to climate change. This will have an effect on prices and set new priorities to consumers, governments and producers. Textile and clothing industries might become more European or even regional under these conditions.

• "**Asian dominance – European excellence**" is based on how emerging countries (in Asia) will be even more specialists in industrial manufacturing while the EU will strengthen its technological lead. Lots of production will disappear from the European textile and clothing industries but there will be a great demand for specialist skills in technology, environmental issues, chemistry and so on.

• "**Advanced New Member States**" is based on how EU and low cost production countries among the EU Members will defend the industrial basis in Europe. The task is to save industrial jobs in textiles and clothing manufacturing in EU and fight against the negative effects of globalization.

All three scenarios still result in a further decline of employment in the industry. All have something good and a mixture of scenarios would probably be the best choice.

7.2.1 Globalisation Limited

I believe and hope that this scenario will be the most probable scenario on what will happen by 2020. Therefore, I will present this scenario more closely and also because the 3D production method would suit well to this scenario. 3D production would fit "Asian dominance – European excellence" also as this is high tech production method, but I personally believe that being a top high technology performer needs a wider production to support the development. This presentation includes also my own opinions based on my experience in the fashion and retail business.

7.2.2 Environmental Aspects

Rising environmental and ecological issues are the main drivers in this scenario. Climate change is a fact and, therefore, a growing number of consumers are demanding ecologically produced sustainable products. Moreover, as the energy prices are going up, they will have cost effect on both production and transport of goods. So far the transport costs have not been too high from faraway places but in future the cost for these transports might get much higher. When the transports get less profitable that would partly compensate labor cost advantages. Also more energy efficient machines and production methods will be needed. Textile and clothing industry will be most certainly affected. The cost of climate change should be visible within the period until 2020. It is how the politicians address the climate change that determines the alternatives for worldwide growth and international trade.

Lack of material in the future should lead to much higher prices on raw material which should lead to a better use of materials. This would mean longer lasting products with a longer life time. This will put pressure on the design as well as the demand on the product to be reused and recycled. Some of today's mass production pieces are trash just after couple of weeks, not fashionable anymore, not worth reusing or recycling and will only pollute the nature.

If and when the fashion and textile products need to be re-used and re-cycled it is not worth sending them back to Asia but that needs to happen in Europe. Why not originally then have them made in Europe with a guarantee on reusing and recycling. Eco fashion could be a strong future trend and ecological processes and technologies will become more important. Consumer's knowledge and awareness of ecological issues are growing all the time.

7.2.3 Market changes and global competition

Economic growth might be mild in Europe due to southern European countries with big deficits and rising unemployment. Looks like most European countries keep up welfare that they cannot afford and will face problems. With the EU and use of Euro the problems will affect all EU countries one way or another. The Euro's value might sink with the problems in the European economies and, therefore, the import from outside Europe will automatically have a higher price in addition to all the other issues affecting price. Mass consumers behavior is dominated by high price sensitivity and retail systems based on cheap fashion products will be under threat.

Country of origin and "Made in Europe" should be highlighted and be something worth to achieve. This scenario believes in weakening globalization. Certain countries with greater knowledge in certain products like leather products "Made in Italy" would have an advantage because of the long traditions of making them there. Southern European countries have long traditions in fashion, textile and leather production. They still have the knowledge and traditions in making handcrafted individual products. Small sized network production like it used to be in Italy could be a solution to European production. Where something is made would be as important as the materials used.

Smaller companies and small scale production would lead to more individual products. This could lead also to new product innovations both in fashion and especially in textiles. Big ones are fast to copy but not very good at new innovations. Considering also the high forecasting error in fashion industry it would be smarter to have closer production with shorter lead times to have better accuracy in production. Having the production close by would also mean that transport costs and pollution to environment would be less. We would also know and have better control that rules and regulations on labor, production methods and chemicals are followed. There are social concerns about

labor conditions in developing countries and negative consumer sentiments about countries with poor environmental performance.

It would be sad if regional fashion and textiles would disappear in Europe, as we still have different ways of living based on the weather conditions and other circumstances. These will all have an impact on what we wear, as well as when and how. The choice of colors, materials, patterns and other details come from our surroundings. Some of us have four very different seasons during the year and need different clothes for all of them. The weather conditions might be very hard compared with some other countries where weather might be very mild all the year. Also how to spend your time off is different from one country to another, in some places people spend lots of time outdoors and have activities that need special clothes. The local knowledge is the best knowledge.

Arts and crafts have their roots in the each countries' cultural background and that is too valuable to be lost. Nowadays, both companies and products should have stories but mass produced products have no stories to tell. Europe should not be considered as one big country and clothing and textiles produced to us in mass production. A shopping experience in different countries would lose its meaning while you would find the same products in all countries.

Customers are interested in having more individual clothes. Style and fashion should be more of a way of expressing what you are and your lifestyle rather than following the latest trends. At least some of the products should be more long lasting, something to pass on to the next generation. Vintage is becoming more popular all the time and that shows us what good quality products are made of. Development of mass customized products is one step into the direction of more long lasting and individual production. Also the development and applications of E-commerce might change the whole market to a new interesting direction.

7.2.4 Extension of the Knowledge Base

Building new areas in high technology products in textiles still needs some basic industry around it, we can hardly have only one small high tech slice of the industry and develop that if no wider base to it in Europe. As labor skills we need three different sets of skills

- Technical skills for new innovations
- Traditional skills for craft related products
- Ecological skills for extended competences in repair and reusing

In addition, we need both eco-fashion designers and eco-engineers and a strong knowledge of past and future technologies. This will mean that retraining of labor force and training in environmental issues are among the most important. Forbidding certain chemicals and production methods in EU but then just producing with these chemicals and these methods with unfair labor conditions somewhere else does not seem morally right.

8 My Own Design Process

In this Chapter I will explain the design process of my 3D knitwear prototypes, the co-operation with the technician and the choices and decisions I made and the reasons behind them. I have been taught that “Designer is a master of decision making” and in knitwear, there seems to be great many decisions to be made. Like in many design processes, the result was unknown in the beginning and I was about to start an adventure. Although carried away sometimes by the many options, the reality was more restricted. But that still left me with so many choices and alternatives that some of them are to be explored sometime in the future because my time was running out. Keeping me focused on making the right questions while hitting the essential limitations was my main target.

8.1 Aim of the Design Process

What I wanted to test was how to use 3D in knitwear production. The aim was to use a 3D technique to be cost effective, innovative and still design oriented. I wanted to eliminate different sizes with “one size fits all” solutions, use only one yarn and very basic shapes. As a base for the programming, I wanted to start with a simple short bottleneck kind of cape without sleeves. The technique was going to exclude certain possibilities but still give options for other ones. I was free to follow the path because no precise decisions on designs had been made before the trial started. The overall look of the

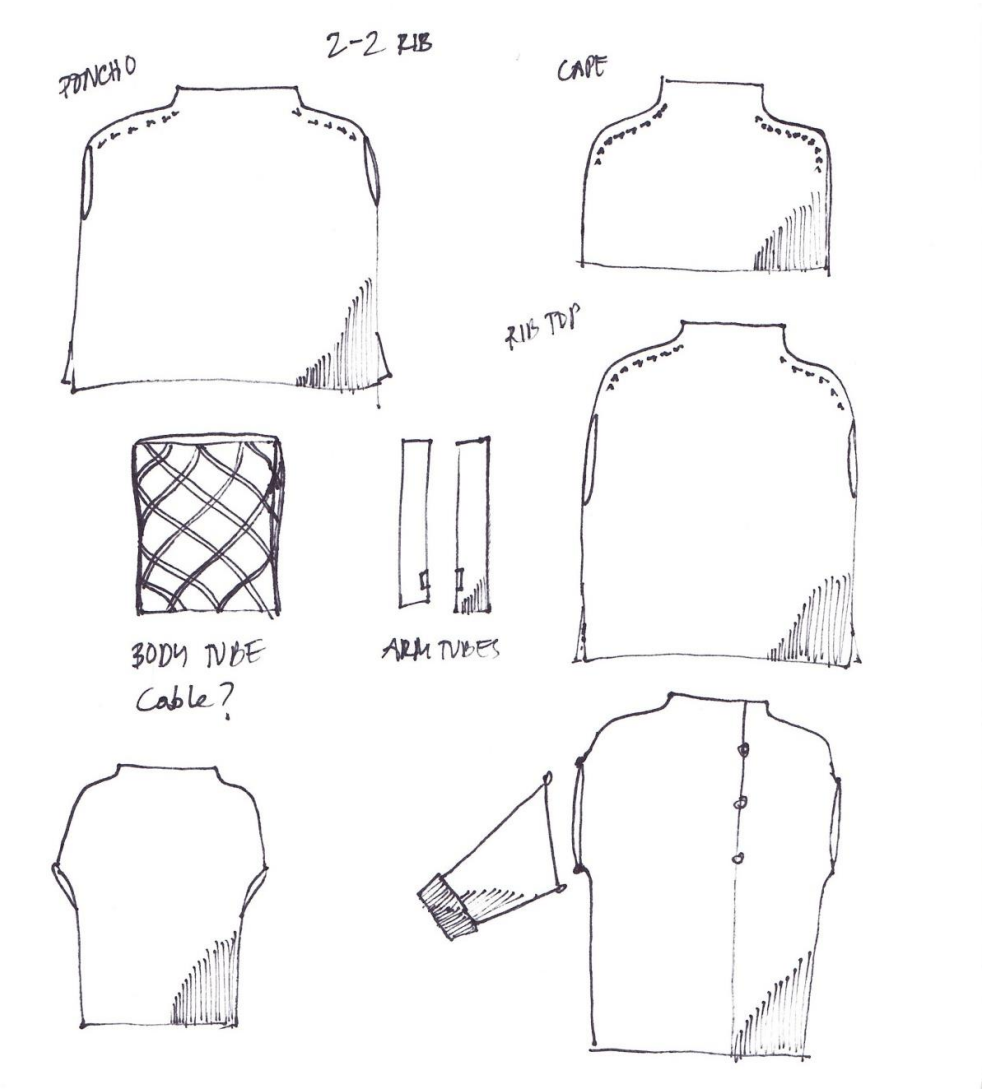
knitwear I was after was minimalistic, sparse and simple but still feminine. It had to be comfortable to wear and in addition hopefully the results would be ageless and long lasting. The minimalistic and simple look would need just one perfect detail to make the difference from being just simply bare or boring. To make it look stunning this kind of minimalistic items will need high quality materials and ultimate finishing. As the production was integrated, the chances for quality issues in production were minimal as long as the essential trials were done and programming was approved. How all this was going to work together with the technique remained to be seen.

8.2 Settings

Choosing the right yarn, structure and then testing them was important. We tried to keep the same yarn during the whole process because the effects of the yarn in dimensions are crucial in 3D. We started the process by knitting square pieces in alpaca in single, double and triple but did choose double and use only plain, rib and a combination of them. The aim was to have just the right kind of flexibility in rib combined with the weight of the yarn so that the pieces would fall nicely. I ended up using quite much rib because it is very elastic and ideal for “one size fits all” knitwear. The next step was to put the knitted pieces on the mannequin to see how they look, fall and feel on a body. I decided for a rib in double yarn made on every other needle in addition to plain knit. These would give me the best combination when I was after the shape more than anything else. Any patterns on surface made by colour or by structure would need to be fitted into the tubular system i.e. calculated how the pattern would flow from back to front, including even a possible sleeve and along the shoulder line. At this stage I was still more after shapes that would work best on this technique.

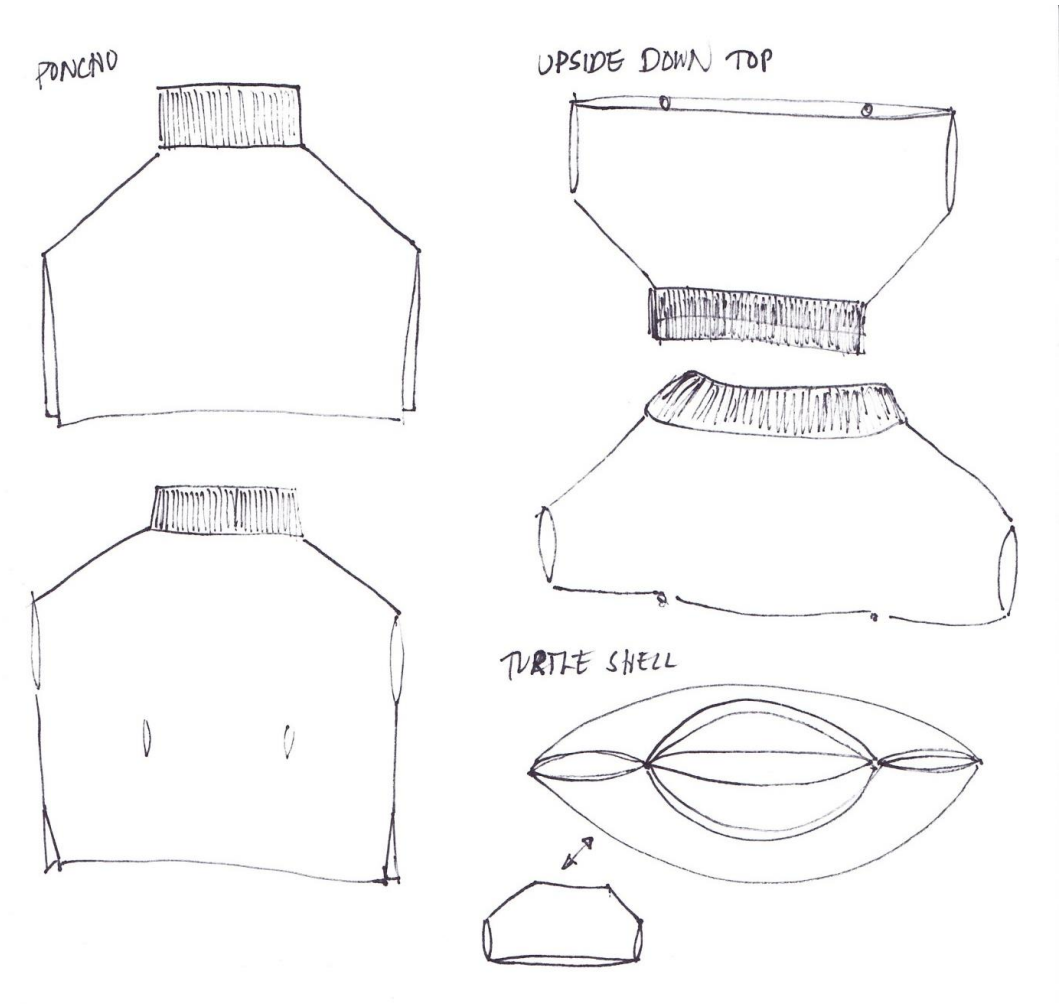
8.3 Sketching

The sketching process was going on all the time but certain shapes like the bottleneck was constantly turning up. Based on what I learned with every piece was developed further by sketching, usually I had to simplify them all the time but that was not only a negative thing.



Picture 11. Sketches for the bottleneck, poncho, rib top and body and arm tube.

I had started making knitwear sketches already a year ago in Borås during my exchange period. In picture, 11 some of the sketches made during the year for the cape and pieces that could be developed from that. Looking back at the sketches now makes me aware that certain details had stayed on my mind all the time. Some of the details like the cardigan had to be changed because impossible to produce with this technique.



Picture 12. Sketching for the Upside down multipurpose piece.

The multipurpose Upside down piece was a design that came out of the curiosity to try to get as many different pieces out of one shape that possible. Sketches of the Upside down top with additional pieces shown on picture 12, this time the poncho had details like the open sides that could not be produced.

I was drawing new sketches all the time with the knowledge I gained after every discussion with Ari and Esa Holopainen. Since last autumn I could bring them knitwear, a picture of one or sketches and get their feedback on how to produce a similar one. The experience from the 3D roll neck made in Sweden and these discussions with feedback built my knowledge about the technique already before we started knitting. In the sketches I tried to solve the limitations and there was often lot of thinking behind some very simple looking solutions. The programming time was so valuable so whatever was tried had to be for a reason. During the process, I received a frame within which to design 3D knitwear, sometimes it felt tight but on the other hand it challenged me. Some

of my best ideas have come out from having limited resources and this technique gave enough “limitations” for me. Being “profitable” in the production was important as well as the most important content learnt during the discussions with Ari and Esa Holopainen, which can be summarized as follows:

- Less sizes or rather only “one size”
- Same yarn in all knitwear
- Simple, timeless and innovative design
- Simple forms
- High quality elastic materials
- Less colour options or only white yarn and use the washing for dyeing also
- Bigger quantities, rather closer to 100 than 10 pieces to divide the programming costs

In my samples I was going to try to be as cost effective as possible and follow these “rules” except for the last one.

8.4 3D Knitwear

The design process started with the bottleneck cape but thereafter I was free to follow my instinct to develop that into a top, tunic and possibly to a cardigan. Other target was to try something with “upside down, inside out” but in that I also followed my instinct in where to start. Once I got started it just felt very obvious always where to continue.

8.4.1 Bottleneck Cape

The first piece was going to be the bottleneck cape and that was programed with the help of a mock up made by Brother domestic machine as Stoll had no pattern for a cape. The form was very simple and in plain knit it had a perfect fit. But moved to industrial machine, rib and to another yarn, we needed three trials until we got the width and the shoulder and neckline right. To get the neckline at front to fit better, we used partial knitting to make it lower than the neck line. The shoulder line was also challenging as the angle had restrictions on how closely the cast offs could follow. The final version of the bottleneck cape is shown in picture 13. The only details on the bottleneck were going to be the cast offs on the shoulder line (picture 14) and by a happy coincidence there was a programming error that made it look really fascinating. That “error” was going to be a permanent feature on the cape. All the prototypes were tested on a

mannequin with arms but the best alternative was to put it on and move your arms and body to see how it was fitting. This kind of knitwear has to be tested on a real person to see how the knitwear is functioning on a real body.


Picture 13-14: “Bottleneck” cape and the shoulder detail.

The simple bottleneck would be more useful with a body part and sleeves so I designed a separate body and arm tubes, seen on Pictures 15-17. To cover more your hands the arm tubes were made extra-long with a hole for thumb. All these pieces could be used separately or together in any combination.



Pictures 15-17. Body and arm tube with the cape.

8.4.2 Rib Top

The next piece was going to be a Rib top that was also one of the designs that was constantly on my mind. That could be used alone as a slipover or in combination with the separate sleeves. The cape shape was the starting point as we just cut the sides from below the shoulder line to make arm holes and added length to the bottleneck. The best way to have the proportions right was to measure whatever you had made and based on that estimate. Those were usually good enough as there usually were other changes also to be made to the prototypes so that the exact measurements could be fixed at the same time. The more you work with the pieces the better you get with the proportions and you learn to understand how the material behaves.

Pictures 18-19. Rib top with detail.

On picture 18 the rib top and in picture 19 a detail of the shoulder line with cast offs. This seemed to be a good starting point for tops.

8.4.3 Boat Neck

The next step was to use the rib top to make a plain knit version of it with a boat neck. The plain knit was behaving differently from the rib so we made several versions of it to get it right. The plain knit was challenging as it was less elastic, thinner and rolls easily. It also looked more interesting on the reverse side so that was going to be the “right” side”. We tried to use the “rolling” on details like in boat neck and in armholes to our

benefit as we could leave “raw” edges inside the rolls. In armholes, we added stiches to get a wider shoulder line to match boat neck and varied the right and purl stiches to make it roll in the correct directions. On picture 20-21 the plain rib top with shoulder and armhole details.

Pictures 20-21. Plain boat neck top with shoulder and armhole details.

The boat neck was an interesting and challenging trial that taught me how challenging moving from one structure and surface to another is.

8.4.4 Sleeveless Cardigan

Now I felt ready for some kind of cardigan next. The rib top was the starting point again in this case but now I seemed to get a real tight frame. All my ideas for details in cardigans seemed to be impossible to produce. First, I wanted two have two slits at side seems as the cardigan was supposed to be longer and if possible the front shorter than the back. But due to technical restrictions only one slit was possible and the pieces should all start at the same level, including front, back and sleeves. While knitting 3D the K&W machine cannot start knitting something later on like short sleeves, it has to cast on all the stiches at the same time for the whole piece. Adding on stiches gradually works if not too many and too quickly because all stiches need a pull and the pull is on the stiches knitted on previous rows. Only one slit was first a challenge but then it

made me really think where and how to use it and it turned into a valuable asset in my mind. As the front pieces can only be half the size of a back piece I was not going to have a wraparound cardigan either. And the width of the cardigan meant that due to only a certain amount of needles available in tubular knitting I could maybe only have one sleeve if any! Both with the slits and with the sleeves the answer Ari Holopainen gave me was first “can’t have it” but after a while “well, you can have one”! I became determined to use the “one” possible option in the best possible way. Finally, I found a solution for the one slit and solved the fastening at the same time. The slit was going to be quite long and used in front to give the slipover a cardigan kind of look. The top front that was in one piece would both hold the whole piece together (without any buttons) and keep the rib from “escaping” to the sides. It turned out to be very easy to put on and fitted well like seen in pictures 22 and 23. I added small holes to the sides for belt option and with the slit at the front the belt could be put on in different ways. The options in knitting from “front to front” with holes for belt and later for armholes had not been tested earlier but it worked fine. It did although need several cones of yarn for all the “separate” areas and the feeders needed to be checked to be on the right side when moving from one area to another. Otherwise the machine could continue knitting without a yarn.

Pictures 22-23. Sleeveless Cardigan.

Two sleeves would not fit in and this did not look to me like a piece that would benefit from only one sleeve so the possible sleeves for all the sleeveless ones needed to be solved later on. Ari Holopainen recommended using Stoll ready programmed options

for integrated sleeve constructions. Getting from armpit to shoulder would be an area where front, sleeve and back needed to fit in stich by stich every row and that would need high level programming. I guess a week might not be enough for programming and testing something not very basic. That area was a real bottleneck as the ready-made options would need reprogramming as well. The programming starts from the hem line and decisions have to be made with how many stiches to start the body part and the sleeves. Those would then need to be calculated to meet in the armhole area. There are different integrated sleeve options like raglan and saddle sleeve in Stoll that might be easier to combine in your own designs while they also partly include the shoulder area. Knitting the shoulder line in the saddle sleeve was difficult as knitting sideways is challenging, all stiches need to be pulled downwards for the knitting to proceed and knitting sideways could mean dropped stiches or stiches knitted together like in my saddle sleeve knitwear from Borås. The knitwear could not be very wide as the sleeves might not fit in and a more fitting narrow pullover with narrow sleeves would need grading to fit to different sizes. More programming would be needed in that case also. As Ari Holopainen said the 3D does not give you sometimes enough of options to make what you wish or what is in fashion. I was getting an idea of where the bottlenecks were.

8.4.5 Cardigan Dress

I got carried away with the slit at front and got an idea of a much longer version, more like a long cardigan dress based on the cardigan. Ari Holopainen suggested making the hemline wider as the piece was getting longer and you would need space for walking. The anticipated width was divided evenly from hem to waist. The waist width was to remain as it used to be as the cardigan was already made wider due to being a piece worn over other garments. The first prototype of the cardigan dress turned longer than expected due to the weight of the long piece but otherwise perfect, it was either a lucky guess or we had learned a thing or two during the process!

Pictures 24-26: Cardigan dress.

In pictures 24-26, the Cardigan dress with the long slit and small openings at the sides for a belt option. That piece had become from a bottleneck shape to what it was step by step and that was something I had not designed beforehand but it was rather based on what I had learned and ideas that came along the process. I adapted to what the technique allowed me to do and I was both positively surprised and very happy with the result. This gave again ideas to many more pieces like dress, tunic, skirt etc. using the shape that seemed to work so well and looked good. One path to follow was just to start with a very simple shape and let it lead the way with the ideas and opportunities that came along. Not a bad idea!

8.4.6 Upside down Top

I was eager to move forward and test the possibilities with the inside out and upside down solutions this technique allowed me to do. This piece had its origin in a 2D piece made with domestic machine in Borås, a tunic that could be used upside down either as a longer tunic or a shorter penguin sleeve top as seen in pictures 27-29.

Pictures 27-29: Upside down 2D tunic made in Borås.

This in combination with a T-shirt with very wide sleeves my colleague at work had worn gave me ideas for a multipurpose top. I would then also get a piece with sleeves and not only sleeveless options with separate sleeves. I started with draping on mannequin (pictures 29-32) to get closer to the right shape and then draw a pattern. In addition I made a miniature in tissue paper to be able to turn it around in my fingers to observe the volume from all angels. Some of the measurements had to be adjusted to fit a real multipurpose piece as I got more ideas how to develop that form further.

Pictures 29-32. Draping trials on mannequin for the Upside down top.

On the first upside down prototype, the measurements seemed to work fine. We still had to work with some of the other details like the starting row alternatives, the width of the rib etc. This would be too thick in rib so we worked again with plain knit. The knitting had to be started at the widest end as it was easier to cast off than cast on. Worn the widest part at top the shoulder was kept together with only two buttons and the width formed sleeves that could be worn in two different ways as shown in picture 33, the other more like a sleeveless option.

Picture 33. Upside down top shown with the two sleeve options.

In pictures 34 and 35 details of the two sleeve options, it looked good both ways and gave more variety to how to wear it.

Pictures 34-35. Details of the sleeve options in Upside down top.

This multipurpose piece could be also worn upside down more like a penguin sleeve version, shown in pictures 36-37. The different ways of wearing one piece would make it both more wearable with different outfits but also to suit more customers. The penguin sleeve version could be drawn further down for an open neck look like in picture 36 or the rib double as in picture 37.

Picture 36-37. Upside down “Penguin sleeve” option.

This was a piece that might be best in other material than alpaca as the wide open neckline makes it more suitable for summer or as evening wear. Although several options how to use it this kind of knitwear might be difficult to sell without assistance or clear instructions.

8.4.7 Turtle Shell

This upside down piece was still going to be developed further to “inside out” and that was going to be some kind of a turtle shell as shown in pictures 38-40 with details. The piece was in fact turned inside out for a more interesting surface on the reverse and the rib part was going to be “cut” off and that end knitted together. This was a demanding shape to get it right because it became easily too wide or too narrow and the back part too bulky. On the reverse surface we used elements that we had developed in the boat neck like alternately right and purl stiches to get an interesting detail where casting off (originally shoulder line) for the shell shape as seen in picture 39.

Picture 38-40. Turtle Shell with details.

To get the right kind of a round shape at the back would need still more work, round shapes horizontally are not easy.

8.4.8 Poncho

After the Turtle Shell, I went back to the penguin sleeve upside down piece and developed it further to a big poncho as we could again use the already programmed shape. We made it much longer with a wide rib at the bottom and the neck narrower with long-

er rib and as seen in picture 41-42. This could be also used with the separate arm tube as seen in picture 43. We used the plain right side and again the casting off detailing from boat neck shoulder line, this time on the right side.

Picture 41-43. Poncho with arm tube.

This became a big poncho to use outdoors over other garments and together with separate “sleeves” even more useful. This path to use a more multifunctional form and then see what all that could be turned into was also a great way to explore 3D knitting.

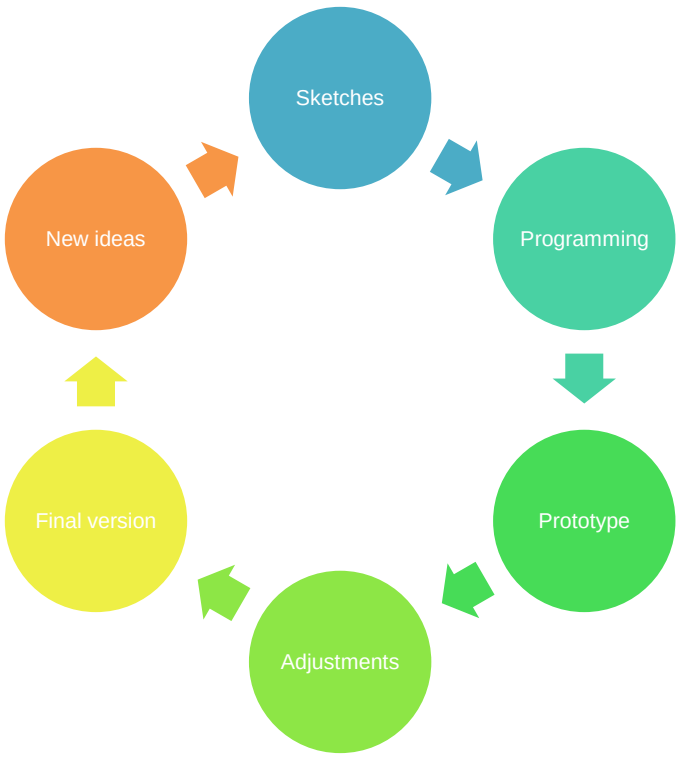
Picture 44-45. 3D roll neck cable knit jumper with saddle sleeve made in Borås.

Comparing with the more traditional roll neck cable knit jumper made in Borås seen in pictures 44 and 45 the methods I used now challenged me more as designer and gave

me the feeling that I was developing something new. This really forced me to think of the shape, the proportions and the way how to integrate and what. The correct forms and details build a small “library” of 3D elements for me. This kind of elements would give the designer a base for designing and options to use the elements in almost endless combinations. Some of them are details that could give the customer a possibility to make her own combination and possibly lead to mass customized products. The further developments from the designer’s perspective should be quite simple to do; you already have a base for your collection while new “parts” and elements could be added according to season and demand.

8.5 Design Process

The steps in the design process followed each other mostly in the same order and a new round started often quickly, sometimes even before the final version was finished. The steps started with a sketch that was programmed. After the first prototype, the adjustments were done until I was satisfied with it and had the final version in my hands. All final versions usually gave me lots of ideas for further development so the process started from beginning again like in picture 46.



Picture 46. Design process chart.

I found it much more interesting to create a form of my own than taking an existing pattern and making adjustments. I learned more with each of my own designs and thus built up my knowledge. One could really get carried away with this technique once one is started. Therefore, it was important to stick to one yarn, to only very few stiches like plain and rib in this case and no manual details. An important aspect was also to find interesting multifunctional forms as the seamless pieces could be easily used inside out and upside down. With just a couple of shapes I could develop so many more pieces by just turning them around and around.

The overall design and production process went very smoothly as the co-operation with the technician Ari Holopainen was excellent. We seemed to talk the same language and had an immediate understanding and respect for each other's work. I challenged his technical knowledge and he challenged my designer capabilities. Together we were able to work around the limitations and maximize the use of 3D. We were able to create some really good "final" prototypes. These could still be processed further with more people involved; to see how the "one size fits all" knitwear really works they have to get feedback from potential customers in different sizes and different ages. And I would also ask them how they would use them, with what and when. Knitwear is similar to accessories and therefore there needs to be a connection to a wardrobe.

9 Future

To simplify the process from yarn to knitwear, one could say that manufacturers produce what designers have designed and that is based on what customers want. A real obstacle in Finland is the limited amount of technicians who know this technique and can use the machines. While other textile and fashion industry due to production costs have disappeared to other countries and other continents this kind of high tech production could be worth keeping in Finland. It would be a clear advantage for the Finnish textile and clothing industry to have at least some domestic production because the research and development in this field needs to be close to the production. We would need more engineers interested in the techniques in clothing and textile industry because there are so many interesting technical developments going on in the world.

For the moment, there is a growing interest in 3D because the 3D printers are the latest technique to have at everybody's home. This might both bring the awareness of what 3D means and the interest to explore 3D more. In January, the U.S president Obama visualized in his speech that the development in 3D printers will bring jobs back from China to U.S. (Pettersson 2013.) In the same article the future of 3D is expected to be from printing simple spare parts at home to highly personaliced self designed products that customers order and get printed in really high tech printers at "service points". This should be the start of a third industrial revolution. So far, there is a clear lack of programming skills and design softwear to transfer ideas to useful products. (Pettersson 2013.) As heard in "3D in Fashion" Seminar in Helsinki on 13th of March this year 3D is coming into Fashion business as well. In clothing production, the changes are expected to be similar, more customer involvement and the production could move closer in addition to new and faster processes in the excisting manufacturing like in design, pattern making, product development and also in marketing and sales. This would certainly help 3D knitting as there is a lack of other supporting processes to 3D production technique.

9.1 Customers

What do customers want? Design begins with the customer in mind and ends to the customer. In the future, customers are expected to want to spend more wisely and to get more involved in the design process. The new luxury products are products that need knowledge; customers want to know more about the raw materials, how it has been made and where. While buying will be much easier when you can order products from home and have them delivered home on the other hand customers want special service. Buying less with a higher price would probably lead to more demanding customers. (Niemelä 2012.) Would there be an interest among the customers to ask for 3D knitwear and what would the reasons be? I think that awareness of 3D among all people will bring the interest of 3D technique in different fieds, also in garment production and in this case knitwear. There are often new technical names that are used in marketing to sell new products, 3D might be the next "hot" one. Would we need something in addition to use the technique like better branding of the technique or the products or would really high quality or high tech materials in connection with the 3D production make it interesting enough? Or should it be design driven? Like stated in Brackenbury design has an important role in fashion: "In any market dealing with cloth-

ing, visual design itself is considered a quality. It must be recognized that hitting the right design for the market often overrides considerations by the ultimate customer of such factors as durability, fitness for purpose, neatness of makeup and other utilitarian factors. Good design must be considered a very important tool in the armory of quality assurance." (Brackenbury 1992, 175.) Designer's role in introducing new techniques and production methods by using them is important, not only in industrial design but also in fashion.

9.2 Designers

According to Ari Holopainen the 3D technique in knitwear is relatively unknown to knitwear designers. A real bottleneck is the lack of designers that concentrate on knitwear and would have the education and wider knowledge of knitting. The demand for 3D from manufacturers point of view has to come from the designer, she or he should have the vision on what and how to produce. Designers should challenge the technique so that it keeps developing. Knitwear designer is between textile and fashion design and working with 3D would make the job to be closer to what an industrial designer does in what comes to knowledge of the whole process and the technique. So there seams to be no short cuts to make this technique suddenly very popular among designers. But 3D developments in garment manufacturing will benefit knitwear production.

9.3 Manufacturers

Textile and fashion industry is an old industry with long traditions and that could be one of the reasons why changes are happening slowly. The production has been moved to low labour cost countries where manual processes are still cheaper and they are not technology driven as that should ad costs. The big business is in mass production to customers with high price sensitivity. But as that might be changing with the ecological awareness and the need of more individual products together with technical developments in the industry there should be a clear market for 3D knitwear. The advanced production technique is there in knitwear but looks like there is a missing part from design to 3D production. As with 3D printers there is a lack of supporting sophisticated softwear to help programming the shape to the industrial machine. If the programmming is time consuming and only few people can it a softwear for designers

could make it easier to use. There is a clear lack of technicians in Finland who master the programming and could operate the machines as there is no education for that. There are new interesting developments in fashion industry with 3D and those will help in all functions from design to manufacturing to marketing and sales. There might be something to adapt to knitwear. Smaller companies could be more innovative and therefore local smaller companies are important to have to be able to start with in a smaller scale. A good network of partners in knitwear field would benefit all participants in Finland.

The education in knitwear is very limited and only a part of the education for fashion or textile designers. We would need more education in knitwear design and production and that would need also close co-operation between the schools and the industry. If we do not have the knowledge we cannot keep the industry and if we do not have the industry how would we use the knowledge. The designer needs to work more closely with the technician and have better knowledge on the technology. The benefits of this technology will not be fully explored if the designer does not understand both the possibilities and the limitations. There are limitations but together with technician those can be solved. The technician alone cannot make this technique work while the designer has the vision and knowledge on what needs to be produced. The designer needs to work more like an industrial designer and know more of the production technique.

The challenge in having yarn as starting point actually gives flexibility in what kind of knitwear to concentrate on. The production method does not either give any limitations in concentrating on certain kind of customers. The actual production is high tech and mainly done by machine so the savings in labour costs would be minimal if the production would be moved to China. If necessary machines can be used 24/7 to produce this kind of knitwear and then the location of the factory is not that important anymore. Chances to use child labour or discard legal labour laws due to cutting costs are also minimal. There would be many benefits with having this kind of local fast production as long as the programming would be solved and the designers would be interested in getting more involved.

The potential to use textiles in different fields is almost unlimited while both the materials and the techniques are under constant development. Textile is taking big steps in many other fields than just in clothing or home textiles, in fields like health care, building and car industry etc. Intelligent textiles or smart textiles where electronics is com-

bined with textile are a crowing business and knitting is one technique to combine them. Finland has a reputation of being a high tech country but unfortunately many people think that textile industry is a dying industry with no future while the answer is totally the opposite!

10 Conclusion

The co-operation with *Kutomo Holopainen* was essential for me to be able answer the questions I had on my mind in the beginning. I found out that the use of 3D technology in knitting is very limited and so are both the machinery and the technical knowledge to use it in Finland. Even more limited than I expected. The limited amount of technicians forms a real bottleneck as this limits the programing possibilities and the maintenance of the machinery. There is a clear lack of education in the field of knitting in Finland as knitwear is a special field and would need special knowledge to keep developing. Technicians, textile engineers and designers just concentrating on knitting would be needed to keep the industry alive. New technical developments will not be used if they are unknown to designers as many decisions that affect the production are made while designing. The higher level of technique used the more co-operations between the parts is needed; designers, technicians and manufacturers should work more together.

The feedback from Kutomo Holopainen about using 3D in this research was that the designs made were different than what they used to produce. They gained new ideas of what kind of knitwear to use the 3D for and what new kind of shapes to make. 3D designs are not profitable if producing only smaller quantities. More 3D programming should be done but it is time consuming and therefore gets expensive. One design could lead to many more ideas of what to design although not everything could be programmed. (See Attachment 1)

I learned a lot about the knitwear production as well as about the 3D technique in Kutomo Holopainen. The use of the technique made me aware of the limitations but challenged me as a designer at the same time. Once we got started with the prototypes the process went as on autopilot and I felt comfortable in my role as a designer. I can now understand the reasons why it is not so widely used although I am very optimistic that it will still be a future method of production and has not yet showed the full potential of it. The limitations can partly be found in designing the right kind of knitwear that

suits this production because knitwear design is often based on clothing manufacturing methods. There are still some technical limitations on what all can be integrated at the same time and that affects the use of 3D but I am positive these will be solved one by one. All techniques have their limitations. Not all knitwear can and will be produced with 3D but for certain kind of knitwear it could be very suitable. There are clear advantages in using 3D in production, and thus it would be a real shame not to use this technique. The rest of the fashion world is now getting into 3D world in what comes to design, pattern making etc. and that could help knitwear while the production is already 3D. To be able to use the full potential of 3D knitting the whole production should be supporting the new technology. A step out of the world of making knitwear in the same way as other garments, from 2D world of clothing in to the exciting world of 3D knitwear. The 3D production is profitable only when the right elements meets like the cost of the production, the look of the product, the quality, the price and the material. That is when the customer comes in and gets interested. Only this way the knitwear can step into a new higher level.

I am really thankful for Finatex for the Stipendium that allowed me both to use the high quality alpaca yarn and spend time in Kutomo Holopainen and learn the whole 3D process. To Kutomo Holopainen, I will always be grateful for their time and effort in guiding me with knitwear production and especially with 3D technique. Their warm and friendly attitude made me feel really at home in the factory and part of the team. I have high respect for their knowledge and for their courage and stamina for staying in the business that has gone through a lot of changes. During the process, somehow all the pieces seamed to fall into the correct places and the prototypes became what I wanted them to be and in some cases even more. The minimalistic look with very few or only one detail showed out to be a very good combination with this production method. My thoughts about what to design and the 3D technique seamed to support each other and in addition the material proved to be the best possible. For me, the process was demanding but rewarding and I feel determinant to continue in the field of knitwear. I really enjoyed my role as knitwear designer. This is not an end but a beginning of something new.

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Intervue with Pentti Holopainen on 5th of March 2013.

Feedback from Kutomo Holopainen

Ari Holopainen 16.5.2013

Palautetta 3D mallien tekemisestä:

- Uusi materiaali (lanka) josta tehtiin mallisto.
- Mallit olivat erinlaisia mitä normaalisti valmistamme.
- Uusia ajatuksia mallien kaavoituksessa.
- Yksi malli poiki monta uutta ajatusta toteutta uusia malleja.
- Mallinteko ohjelma ja neulostekniikka eivät mahdollistaneet kaikkia ideoita mitä projektissa tuli eteen.
- 3D mallinnusta voisi tehdä enenmänkin, mutta se on hidasta ja sitä myöten kallista.
- 3D mallit eivät ole kannattavia pienissä sarjoissa.
- Näitä neuleita tehdessä sai uusia ideoita 3D tekniikalla toteutettavista neuleista.