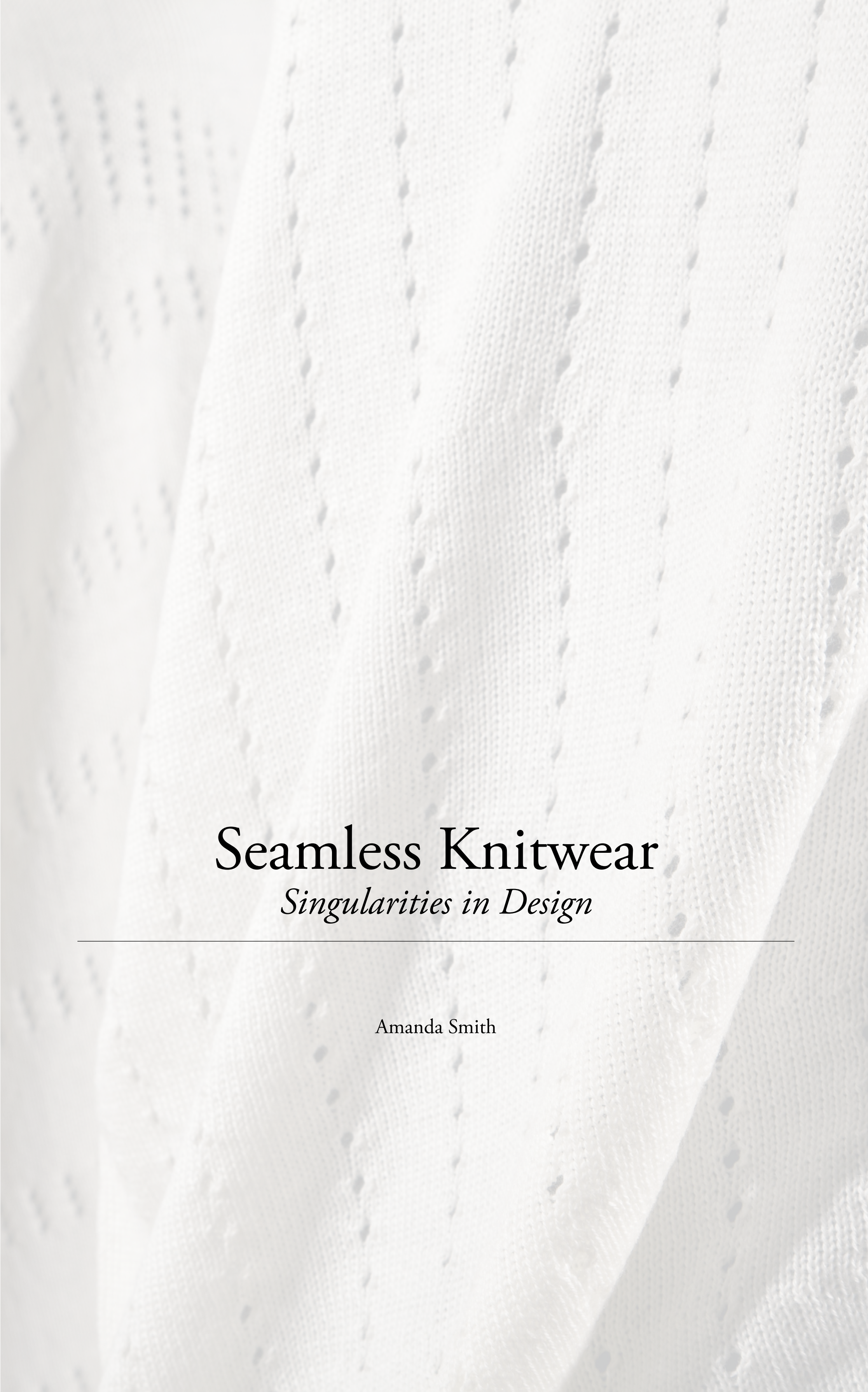

Seamless Knitwear

Singularities in Design

Amanda Smith

Seamless Knitwear
Singularities in Design

Amanda Smith

A thesis submitted to Auckland University of Technology in fulfilment of
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School of Art and Design

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Attestation of Authorship

"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning."

Amanda Smith

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Intellectual Property Rights

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Abstract

Seamless Knitwear: *Singularities in Design*

The 'hypothesis' of this practice-led research is that seamless knitwear processes, recognized as mass-production tools within a post-Fordist system of the mass-production of difference, may be rethought as design innovation processes for three-dimensional assemblage. This opens to a design-led rather than a production-led understanding of innovation. The thesis outcome is a collection of knitwear garments, each of which is singular though iterative; a collection produced as repetitive difference. Engaging with the computerized design capability of the Shima Seiki seamless knitwear system, this research opens critical approaches to an understanding of design, technology, garment, surface and form. Contexts associated with the work of the philosopher, Gilles Deleuze and the ethos of Wabi-Sabi ground the research questioning of production's relationship to form, materiality and the fashioning of things. The thesis outcome of a 'seriality' of singular garments is accompanied by an exegesis that engages the historical and critical contexts of the advent of seamless knitwear processes, and current research on seamless knit production and aesthetics.

Though now twenty years since its inception, its model of production does not realize the potential for three dimensional design-led capabilities, tending to perpetuate already established knitwear production models of two-dimensional symmetrical design processes that traditionally required seams. This research investigates the impact of whole garment knitwear technologies, particularly the role of design and its applications to production. The thesis suggests that the designer's ability to create singularities in knitwear design has been bounded by mass-production design and manufacturing processes, exemplified by current commercial applications of seamless knitwear techniques. When knitwear encounters the potential for a paradigm shift in its modes of production, there is also the potential to rethink design itself. *Singularities in Design* is a PhD research project that localizes such a paradigm shift in seamless knitwear processes. The research methodology works at the nexus of a triple engagement that of 'concept', 'affect' and 'function'. The thinking of Gilles Deleuze, particularly *The Fold,* informs this engagement and opens to a reflection on the designer's approach to her craft, invoking the tradition of Wabi-Sabi ethos and the broad technology imperatives of seamless knitwear and global techno cultural traditions. This research project aims at creating original modalities of understanding fashion other than with in traditional legacies of a science and art dualism.

Seamless Knitwear
Singularities in Design

1) Introduction - Three Fundamental Questions

The three planes, along with their elements, are irreducible: *plane of immanence of philosophy, plane of composition of art, plane of reference or coordination of science; form of concept, force of sensation, function of knowledge; concepts and conceptual personae, sensations and aesthetic figures, figures and partial observers.*
(Deleuze & Guattari, 1994, p. 216)

On the 9th of April I staged an exhibit of twenty knitted garments as the key component for examination of my PhD thesis focussed on seamless fashion knitwear. Though the exegesis that follows here was written prior to, and examined along-side this exhibition, it is the material semblance of the knitwear garment constraints that in fact give credence and finality to this writing. For that reason I want to introduce this exegesis where it also ends, indeed with what came after it, the exhibition.

The exhibition consisted of twenty garments that had been proceeds using seamless knitwear technology, five still photographs of stitch structure details and a film showing fifteen of the garments in movement on a model. The exhibition was divided into two parts; the first section showed process garment development, the film, photographs and five key garment forms. These five forms were developed initially as an illustration that seamless knitwear technology could be used to produce three dimensional forms that didn't conform to the usual and expected silhouettes as seen in mass-production outputs. The second section of the exhibition, housed the final fifteen knitted garments which described visually the exegetical content to follow. They were the result of an iterative design process which can be traced through each of the fifteen garments genealogy of development. This study being based in practice-led research means the research occurred through the process of making knitwear.

For over twenty years, my field of practice has been knitwear design and design research. This PhD marks a plateau from which I am able to survey the field from particular perspectives. The research engages with the development of a collection of seamless knitted garments using the very contemporary WHOLEGARMENT® technology developed by Shima Seiki Manufacturing in Japan. The research proceeds by embracing a particular conceptual field consisting of fashion, knitwear, questions of design, fashion and knitwear technologies, their design histories and processes. But the research also proceed by the methodical construction of knowledge, both in the sense that PhD enquiry requires the demonstration of its ground, and in as much as this research grapples with something essential to a technology in knitwear design that is transformative in the way we understand how knitwear fashion design functions. Thirdly, or perhaps initially and for the most part, the research proceeds by invention, by design as practices of composing a peculiar continuum of materiality and sensation. The garments so composed via Shima Seiki technology aim to move, and to affect, those who encounter them, in ways that are apart from the manner whereby such encounter evokes a consistency of concepts or a functioning of knowledge. We call this, perhaps, aesthetic consideration.

1.1 Aims and Objectives of this study.

The aim of this study is to explore the creative options open to knitwear designers using seamless knitwear computerised technologies. The objective of this is to ascertain if it is possible to fully engage with the notion of three dimensionality of creative knitted form-building using this technology. The intention is to accomplish this through a series of practical experiments using seamless knitwear technologies working from an experienced knitwear designer's perspective, but one which had little or no technical CAD training or knowledge. This lack of technical knowledge allows an un-premeditated approach to be taken when interacting with the technology, and thus has the potential to open up new ways of thinking about and making knitwear. This approach prevents the technology from dictating or supressing the creative design process. Taking a more open approach, allows for an adaptation of the standardised software to be integrated with an iterative design process. An open approach to the structured commercial design and production system of seamless knitwear technology enables the design process to be more creative and haptic as an integrated design strategy for production. The final goal is to produce a more distinctive and expressive seamless knitted garment collection which expresses a three dimensionality in its formation.

Just as the aim of the practice is to open a new space in which to re-think the traditional seamless knitwear outcomes as garment forms this study also aims to re-think the manner in which the design process is approached through invoking the aspect of maker as she connects with the materiality of the made. The incorporation of Wabi-Sabi, an ancient Japanese ethos as an approach to 'making', opens this interval creating a new way of entering the technical standardisation of seamless knitwear technicities. By evoking Wabi-Sabi as part of its design philosophy this study aims to re-incorporate the haptic elements of garment materiality and aesthetic nuance of creative detail, into a mechanised and standardised commercial practice.

With the opening epigraph to this PhD, there is the signature of particular conceptual personae, in particular the work of Gilles Deleuze, an important French philosopher of the late twentieth century. I want to emphasize from the beginning that this is not a PhD on Deleuze, or even a PhD primarily using Deleuze. Rather, and for good reason, this is a PhD that wants to experiment with particular Deleuzian understandings, that wants to go along with Deleuze in order to invent some new questions in the field of knitwear design and technology. I am not philosophically trained, and hence not equipped to plumb the depths of Deleuzian thought. Nor should this thesis concern itself with such plumbing. However, from the above, it is important to recognize how certain aspects of Deleuze's work have organized my processes and intersected with the design philosophy of Wabi-Sabi.

Deleuze offers a language with which to interpret the ethereal qualities of materiality and sensations evoked through a Wabi-Sabi ethos of making, forming linkages between the philosophical, the theoretical and the practical. This can be seen, through the three notions of concepts, functions and affects that, in a macro-structural way, have organized this exegesis: concepts in their consistency constituting a literature review; functions in their relations constituting the research methodology; and affects, along with percepts, developing a plane of composition, constituting the research process. The other key Deleuzian notion that I use comes from his book on the Baroque, *The Fold* (1993). Throughout this thesis I return to this slim book that eloquently concerns itself with the perplexing question of how matter and sense relate to each other, or how it is that with, for example, a knitwear garment you find in unison material sensations and signifying systems, matter and meaning. Somehow they fold.

1.1.1 **Contextual Framework of Study.**

This study is taking place in New Zealand and as such this was the first community of seamless knitwear design outputs to be analysed. Seamless knitwear had been developed and introduced by Shima Seiki in 1995 at the International Exhibition of Textile Machinery in Milan, Italy. Having observed seamless knitwear growth and technical developments since 1995 it was notable that New Zealand, like the rest of the world, had been very slow to introduce this technology. This reluctance to move to using whole garment technology was the focus of a three part feature series in Knitting International, entitled "Complete Garments – Evolution or Revolution" by Billy Hunter (Oct. Nov 2004 & Dec/Jan 2005) . These articles looked at the fact that seamless knitwear technology heralded as the future of knitwear manufacturing in 1995 had not been taken up as enthusiastically or as quickly as imagined. These articles looked at the technical issues that had slowed down the introduction of this technology. At the time of writing Hunter notes:

> 'Almost ten years ago at the 1995 ITMA in Milan, Shima Seiki made a presentation which dazzled the textile world. Complete garment knitting was finally to become a reality. However, it is only really in the last couple of years that we have started to see complete garments in the shops.' (Hunter, 2004)

Hunter went on to ask

> 'why has it taken so long to see this exciting technology being commercially exploited?' (Hunter, 2004).

There was a similar but even more extreme scenario in New Zealand. By 2002 there was only one knitwear company that had introduced this new technology to New Zealand, the Weft Knitting Company in Christchurch. In 2005 I co-authored, a grant application for the Growth and Innovation Pilot Initiatives (GIPI) fund, a government initiative which was funded by the Tertiary Education Commission (TEC) as part of a knowledge sharing and up skilling drive to improve NZ innovation and business capabilities. The grant was successful and saw the introduction of a WHOLEGARMENT® Shima Seiki knitting machine, a digital printer capable of printing on seamless knitted garments and a CAD design system; this technology, along with operational facilities and specialist staff, formed the basis for the Textile Design Laboratory (TDL), which was established at AUT University in 2006.

Since the establishment of the TDL and in part because of, many of the larger NZ knitwear companies have invested in similar technology. For example, Weft Knitting Company now has ten seamless knitting machines with various capabilities. However when garment production within New Zealand was analysed, it was found that this technology is primarily used for basic design outputs, using standard design and shape packages producing predominantly tourist wear and casual knitwear basics. This technology was not being used for designer knitwear in New Zealand.

There have been significant changes to the New Zealand clothing manufacturing sector since the introduction of seamless knitwear technologies in 2002. However these changes, such as woven textiles being increasingly produced off-shore, do not seem to have altered the way that the knitwear industry operates or what it is producing. This research situates the New Zealand knitwear industry in relation to its place in a competitive global design and manufacturing context.

This project assesses the relationship between knitwear design the potential of outputs and the adoption of rapidly changing technologies such as seamless knitwear technology. The development of four needle-bed knitting technology created the ability to produce WHOLEGARMENT® knitwear, as explained in Knitting International (1995):

> The sweater is knitted into a cylindrical configuration by first separately knitting the body portion from the waist and the two sleeves from the cuffs, respectively. When these three portions achieve a predetermined length, they are integrally knitted together at the lower portions of the armholes. The sleeve caps are inclined through progressive reductions in the width, and the shoulder portions are knitted thereafter. (Mowbray, 1995).

These significant technological developments have altered the way in which knitwear is now being manufactured and provides the production boundaries for the overall approach of the study. A primary theme within this production model is the move from knitted fabric pieces, which were cut and sewn, to the more cost effective, seamless knitwear capability. While this technology is already widely used overseas, its use is still growing in New Zealand, recognised by Shima Seiki, as the highest purchaser of this technology per capita in the world during the years of 2008/2009. The introduction of seamless knitting technology has manufacturing advantages, but these come potentially at the cost of design flexibility. The machines come with pre-installed design packages and, at this point, it appears that most companies in New Zealand either lack the design vision, the technical understanding or the need to develop their own internationally competitive designs which fully exploit this technology. Consequently, they tend to use ready-made programmes with limited design variation. This study proposes that a greater understanding of design-based technology in knitwear could be developed and used to create original designs for production and manufacturing. The New Zealand knitwear industry is well placed to develop a unique design aesthetic integrating high end technology with low end hand craft methods for niche market products that have a high price value.

The following three sections within this introductory chapter further explain how the exegesis revolves around the three key notions of concepts, functions and affects. Concepts in constituting a literature review; functions in their relation to the research methodology; and affects, developing the research process.

1.2 Concepts and their Consistency

1.2.1 What is consistency?

> There are no simple concepts. Every concept has components and is defined by them. It therefore has a combination. It is a multiplicity, although not every multiplicity is conceptual. There is no concept with only one component. (Deleuze & Guattari, 1994, p.15)

In a sense we all know what is meant by consistency. When things are consistent there is some kind of overarching order. If we speak of a collection of garments, there is something that defines its consistency. In *What is Philosophy?*, Deleuze and Guattari suggest an important relationship between concepts and consistency; concepts present us with the consistency of their components (Deleuze & Guattari, 1994, p. 19). In this sense, a collection is a concept. Concepts are not what we start with in order to think. Rather, they are what we invent in thinking. We invent new consistencies, new orderings. This thesis invents concepts with respect to questions of design, knitwear technology, fashion and an understanding of garment habitability. In doing so it draws from its own plane of consistency, its plane of concepts, which means drawing from a myriad of conceptual personae. Profiles are recorded in the reference section of this thesis. Some are encountered in passing, some are returned to again and again. The consistency is thickened by returning to particular personae. The concepts are component multiplicities of those of others, inventing new consistencies. Chapter Two, engaging with the literature of this thesis, details the processes by which the conceptual personae are assayed, mixed, returned to or forgotten.

1.2.2 Design's milieus

A plane of consistency establishes the milieu of one's thinking, which is to say, one's inventing with concepts. It defines the reach of one's enquiry. Again, a quick look at the reference list shows the reach of the conceptual personae drawn upon for my concepts. Looking again, it can be seen that my concerns are with design's milieus. The question of design and design's reach presents, perhaps, the first of our folds. In one respect, it can ask; what is not, ultimately, designed? Even design is designed. It could suggest that Deleuze and

Guattari's notions of concepts, functions and affects presents a good approach to design thinking, though I want to do something else. I want to ask how approaching a plane of consistency, a plane of functions and a plane of composition invents new concepts for design. This is particularly the case in this thesis, where the question of knitwear design wants to shift what we see as the literature's dominance to questions of form and process. I want that shift to be concerned more so with questions of force and intensity, with compositions capabilities to affect, rather than purely how form and function correlates. In this I hope to show how my thinking enacts the inventing of new milieus for design.

1.2.3 **The milieus of this research**

This research, through the process of creating a collection of knitted garments, questions current approaches to design and the designer's role when working with seamless knitwear. It aims to gain a greater understanding of design possibilities through singular outputs in seamless knitted garment forms, challenging current mass-production processes of repetition-of-the-same, to create a collection which, though iterative, enacts a seriality of difference. The thesis outcome of a seriality of knitted seamless garments is accompanied by an exegesis that analyses historical and current contexts of the advent of seamless knitwear processes, production, research, and design aesthetics. With the writings of Deleuze, the triple nexus of engagement with concept, affect and function is raised. These interconnecting notions underpin the exegesis throughout and form interrelated themes. Deleuze's *The Fold* informs the means to rethink the designer's approach to current practices. The *ethos* of the Japanese aesthetic of Wabi-Sabi evokes the question of affect, in Deleuze's sense of the term. The problem of seamless knitwear's global development and deployments is found in the articulation of Deleuze's understanding of function as that which defines a plane of relations (Deleuze & Guattari, 1994, p. 117).

This practice-based project questions the problematic of the creation of the "new" through the processes of designing using seamless knitwear technology (O'Sullivan & Zepke, 2008). Through tracing the histories of this technological development, it questions the technology of mass-production processes of seamless knitwear as a means to create design-led rather than production-led artifacts. The research is set in the milieu of knitwear design practices and within a boundary of knitwear's mechanised processual contexts, which have resulted in the advent of seamless knitwear technology, and stems from a questioning of current knitwear design practices from the viewpoint of a knitwear designer and educator within the design field of knitted textiles and their assembled products. As a hypothesis for this research, I suggest that *as knitwear design becomes more mechanised it appears to stultify design outcomes*. This research explores, through practice, the relationship between the milieu of knitwear production and the quality of design outputs currently being produced. It focuses on developing design praxis to create a movement away from static design practice that relies on traditional knitwear methods of design and development, to ask why it is, that nearly twenty years after seamless knitwear technologies were introduced in 1995, designers do not engage with them other than by following traditional methods of design, applying two-dimensional shaping and assemblage?

1.3 Functions and their relations

1.3.1 What are relations?

> The first difference between philosophy and science lies in the respective propositions of the concept and the function: in the one a plane of immanence or consistency, in the other a plane of reference. The plane of reference is both one and multiple, but in a different way to the plane of immanence. The second difference concerns the concept and the function more directly: the inseparability of variations is the distinctive characteristic of the unconditioned concept, while independence of variables, in relations that can be conditioned, is essential to function. (Deleuze & Guattari, 1994,pp. 125-126)

For the most part when designers use the notion of function, it is understood through its long modernist legacy in a binary with the notion of form. Just as I have suggested above that this design research aims to redress dominance in the literature on fashion and knitwear design that has a focus on form, so too, it aims to rethink, after Deleuze, the notion of function. Deleuze uses this notion particularly in the sense that it is used in mathematics, as with, for example, algebraic equations, or functions, that establish the regularity of variables, or the repetitions of variations [for example: $(x^2 + y^2 + 2xy) = (x + y)(x + y)$]. This research extends this notion of function to a more designerly one in the utilitarian sense of function. If a designed artefact functions, then it acts in a regular way within the milieu of its relations. If a tap functions, each time we turn the handle water comes out and when we turn it again, water stops. If a garment functions, its bodily habitability, with respect to its degrees of variation or variability, is *conditioned*, constituting a regularity of relations. The plane of reference constitutes the extent or reach of the variations or variability of relations that come under the jurisdiction of a function. This understanding of function extends, on the one hand, to how we approach the question of methodology and methods in this research. The research functions according to how methodology and methods condition the degree of variations afforded by thinking concepts and composing affects. But also, on the other hand, approaches the very question of how technology functions in knitwear design from the viewpoint of how a plane of relations is construed by the conditioning of lines of variations. As stressed in the epigraphic quote above, concepts and functions differ with respect to an understanding of the un-conditionality of concepts' lines of variation and the conditionality of function's lines of variation. This is seen in garment design when we ask the difference between how a garment works and what it means.

1.3.2 **Design's functions**

In a general sense in the above discussion, it broached the question of function with respect to design. If asked, though, in a general way, what the function of design is, we might lean towards the legacies of modernist precepts concerning the delivering of a future, in avant-gardist terms, or delivering a better world in humanist ethical terms. The function of design would then be to create, and in doing so to improve what has gone before in both a material and ethical manner. Designs need to be both effective and visually appealing, answering both form and functional need. But, because the act of designing is consistently looking to create the new, it is always looking to the future. A design only happens in its own future, though it emerges out of its current milieu. So, in this sense, design's function is to make the future and, for fashion to have a future, there needs to be new designs created. For knitwear to continue developing and not stagnate, it needs a new tomorrow.

If I am suggesting a rethinking of design's emphasis on form and function, this also emphasizes a shift in thinking on the new and the normativity of the better, or a complication of the givenness of these. Design's plane of consistency asks us to invent the unconditional potentials of variability as design becomes a differentiator of its milieu. But equally, for design to function, it necessarily has to preserve within the inventing of its own futures a line of variation that is conditioned, that performs its repetitions. This constitutes the gradient of design knowledge and the language of design methods. In as much as research is practised, it operates between the unconditionality of its plane of consistency and the conditionality of its plane of relations. Between such difference and repetition, this exegesis documents its research practice, which activates design as a process for this re-engagement and as a method for producing and understanding the *new* through designerly ways of knowing. It was Bruce Archer who first initiated such a methodology and its methods, and Nigel Cross who has developed them. (Archer, 1995; Cross, 2001). One aim is to assay how it is that the legacies or conceptual personae of Archer and Cross are able to go along with Deleuze and Guattari, in order to ask how best to proceed.

1.3.3 **How does this research function?**

Designerly research approaches and the peculiar approaches of Deleuze have construed a milieu of relations whose functioning emphasizes, on the one hand, the intimately personal processes or journey of a designer-researcher, researching through design, along with the impersonal, or a-personal approaches of Deleuze that see personae as so many effects of concepts, functions and affects. In this sense a self, or this self, folds into and outside of this research. It is my journey but it is, at the same time, a contribution to the field. Hence, it is through the nonlinear journey of this researcher/practitioner's transition, from a designer working in two-dimensional knitwear garment construction to one working in a three-dimensional mode, that this research functions. It moves between the inventing of concepts, to making things, to the thinking back to concepts, shuttling between unconditional and conditioned milieus. But what grounds this design is neither the lines of differentiation afforded by concepts nor the milieu of relations afforded by functions, but rather the plane of composition afforded by relays between the substance of materials with which to work and the force of sensations by which composing that materiality has its palpable affective engagements.

Thus the plane of reference for this research operates at the point where the concepts or contextual thinking and affects or sensations are created; this is revealed through enactment, that is, functional engagement. These relations can only be revealed through action. In this respect, the concept of the fold could only be interpreted and understood as it relates to designing and mechanized production methods, when encountered and re-encountered through processes of making. Likewise, the relations of the affective sensations of design embedded within the ethos of Wabi-Sabi speak to the lived experiences, the ethos of the researcher myself.

1.4 Sensations and composition

1.4.1 What is composition?

> In the first case sensation is realized in the material and does not exist outside of this realization. It could be said that sensation (the compound of sensations) is projected onto the well-prepared technical plane of composition, in such a way that the aesthetic plane of composition covers it up. The material itself must therefore include mechanisms of perspective as a result of which the projected sensation is realized not solely by covering up the picture but according to a depth. (Deleuze & Guattari, 1994, p. 193)

Composition, in the most general sense, infers an assembling of discrete elements according to some rule, or perhaps according to chance. Garments are generally assembled according to a design, or what we understand to be a prefiguring projection of what we intend to make. We see from the brief epigraph above, Deleuze and Guattari make a distinction between two notions of composition that elsewhere they insist should not be collapsed or confused. One is a technical plane of composition. The other is an aesthetic plane of composition. They suggest:

> Composition is aesthetic, and what is not composed is not a work of art. However, technical composition, the work of the material that often calls on science (mathematics, physics, chemistry, anatomy), is not to be confused with aesthetic composition, which is the work of sensation. Only the latter fully deserves the name composition and a work of art is never produced by or for the sake of technique. (Deleuze & Guattari, 1994, pp. 191-192)

It is recognized that all design knowhow, in whatever field, has its particular plane of techniques. And fashion design, in its composition, or knitwear design, in its technicities, clearly engages with such concerns. At the same time, there tends to be maintained a well-worn separation between fine arts and processes such as fashion or knitwear design. As seen in the epigraph above, Deleuze and Guattari are thinking of painting in the reference field they activate. What then, for this research, is the work of sensation that would bring a discussion of the work of art in play at all? Is aesthetic composition relevant at all, particularly, as intimated above, it is an essential ground of my concern? How are we able to locate, through the force of sensations, the consistency of (our) concepts and the regularity of (our) functions?

1.4.2 **Design's compositions**

So, I am suggesting that design has a two-fold compositing, one that follows variations defined by technical requirements, in some way or other reducible to a logic of sense or procedural knowhow. Such knowhow is precisely what this research wants to question in the field of seamless knitwear. The other fold concerns a logic of sensation. What are sensations? Deleuze calls them affects, how something encountered affects a self and becomes, in turn, affected or modified by that self; a relay between percepts and affects. Sensations should not be reduced to personal feelings or emotions. They happen when we are absorbed by something we encounter such that we lose our self. Our self becomes unimportant in the event of encounter. The thing encounters us in that sense; we are impersonal, moved by the sensation of colour, texture, surface, formation and deformation. This is why percepts are not perceptions, or what we in a sense know we encounter.

A depth opens in something that no longer concerns its technical realization or even its concept formation, its meaning or possible meanings. Deleuze suggests this is the condition by which art is encountered. In this sense, art is not what artists do, but rather what something is when encounterable on its plane of composition, when the thing is our 'becoming-impersonal'. A fashion collection happens as a block of sensations as much as it is relatable as a field of relations or functions, or a plane of concepts or meanings. Its processes of making happen between those two planes of composition, one a *faux*-plane of technicity, a plane of necessary relations, and one a plane of composition through and through:

> "…it is no longer sensation that is realized in the material *but the material that passes into sensation*" (Deleuze & Guattari, 1994, p. 193).

1.4.3 **How is this research composed?**

The design of seamless knitwear follows a linear development process as prescribed by an either/or selection continuum. To prevent design repetitions of the same, and to invent the new, a means to create an opening or space needs to be triggered. Habitual processes need to be recognized and broken down, allowing for new ways to encounter matter and a recombination of material elements. A new line of variation is composed when I, as a traditionally trained designer, had to move away from my traditional modes of design development, when working with seamless knitwear technology as a mode of design praxis for creating a knitted garment collection. As a designer, I became detached from the design process, due to the visualization configuration of the Shima Seiki computer programming, combined with a lack of technical training to understand it. This decentring force disturbed normal processual habits, allowing space and a reframing of possible directional futures to appear.

This *interval* became important to the design process of the ongoing project, allowing a gap between the *time of production*, or the making of garments, and creating a *production of time*, during which to absorb the sensations created by the realization of garments, before moving forward again. But because of this time-space or producing-interval, the "between" of a making and thinking, each garment was capable of taking on its own play of differences, its own nuance, composed from differentiated forces realized as its material makeup; a difference immanent to its own composition rather than a variation with respect to other garments in a plane of relations. These differentiated forces are composed in the continuum of differential modalities of the garments themselves, their internal elements becoming singularly diverse as they each encounter their own external folds and influences. It is through this differentiating development process that each garment within its series, and ultimately the collection, has been created. By starting with the individual garment, unifying factors emerge, creating exteriorities of a series or collection.

On the surface, this research is simple in formation; it is composed of seamless knitwear design as its *concept*, seamless knitwear technology as its *function* and Wabi-Sabi as its *aesthetics*. But, just as knitwear is rarely as simplistic as "knit one … purl one," and textural qualities are built through complications of knitted stitch structures, so this research is text-textured through its folds of composition: "The multiple is not only what has many parts, but what is folded in many ways" (Deleuze, 1993, p. 3). It is through the multiple layers and the folding of those layers that variation is actualized, through interconnections and intertwining. Thus the textural topologies are formed within this research. By complicating thought with doing, affect with concept, the inbuilt functions of the old design paradigm—that of a cut and sew process—are transformed into divergent possibilities of new mixtures. Seamless knitwear creates its own space and time or, as John Rajchman notes:

> Perplications thus are the foldings that expose an intensive multiple complexity in the fabric of things rather than a contradictory framed one; they unearth 'within' a space the complications that take the space 'outside' itself, or its frame, and fold it again (Rajchman, 1998,p. 18)

The Text-Textures of Seamless Knitwear

This research is composed of three component parts making up the whole; singular garment developments, a collection of garments, and a written exegesis. Each component part is interlinked to the others. Each has been created through a shuttling between the others. The *doing* of the one has enabled a *seeing* of the others. Knitwear, and an enquiry into the design capacities of seamless technology, formed the milieu from which this research emerged. This milieu was folded and unfolded to reveal new possibilities for creating meaningful design encounters which created new affective experiences, for both the designer and as encountered through a garment collection.

The practice initially involved the pre-installed programmes within the Shima Seiki WHOLEGARMENT® design system. These pre-installed designs follow a standardized format. Through systemized experimentation, the pre-installed shapes were used to test the limitations and possibilities of design within the set parameters. This was done through a series of developments that pushed the boundaries in the areas of size, shape, length and width capabilities of the design software programmes and the knitting machine capacity. It also discovered what alterations from the norm were possible, while remaining within the set pre-installed pattern programmes. This practice then moved to a more intuitive and experiential approach to develop less conventional garment forms. These reflected a more three-dimensional application that progressed the garment design away from a mass-market silhouette. I undertook this with technical support from a trained Shima technician, working within the Textile and Design Laboratory (TDL) at AUT University.

The final result of this experimentation is a collection of seamless knitted garments which would be commercially viable to produce and sell within a high fashion arena, or seen as examples of individuated design research practice outcomes. They also provide a model of design development process that is transferable for other knitwear designers to use in an industrial context. This knowledge provides a processual means to extend creativity and originality of design when using seamless technology.

In taking a different approach to the seamless knitting machine, from the inbuilt linear processes that dictate formulaic outputs, I have been able to research in a more experiential manner. This different way of *seeing* the machine is how this research functions. The collection of garments was formed from an iterative process of reflection and development, before the next iteration was produced. The process of folding this thinking with documentation and reflection helps create meaning out of the making. The collective garments embed a Wabi-Sabi *ethos*—not so much an applied style or aesthetic or look, but rather a method or way of being a researcher within this project. The peculiar functionality of the technology has limited the designer-researcher from knowing exactly what each programmed garment would be, until after it was produced. It has, however, also been the functionality of this technology, that has grounded this research within an exact regularity, which allows this project to be understood as research, and therefore repeatable. It is the introduction of Wabi-Sabi as an *ethos* that opens anexact qualities of the garments, and therefore moves the collection into one of a differentiated series (Lynn, 2004). It is this element of differentiation that allows this collection of garments to operate within fashion contexts and not remain strictly as a research datum.

My research focuses on the creative potential of knitwear outputs by rethinking how a designer interacts with seamless technology, through practice. It specifically focuses on what knitwear designers need to change about design processes that they have traditionally used, to enable them to be creative within this new technological framework. This creativity is being explored outside of commercial production frameworks and is specifically looking at three-dimensional formations and modalities of deformations; design possibilities that seamless technology offers to knitwear designers and is as yet under-utilised. The second chapter of the exegesis explores the field of consistency of this research, through an examination of relevant literature and the milieu from which this research emerges. There are three main points of focus to this chapter; the fields of fashion and, therefore, knitwear design; the technicities and operational influences on knitwear; and, finally, the aesthetic sensibilities of an engagement with the Japanese affective qualities of Wabi-Sabi.

The third chapter links the theoretical frameworks with practical research, through the experimental unfolding of seamless knitwear. The theoretical frameworks draw on Deleuze's notion of the fold that challenges my own previous approach to designing, as well as rekindling past experiences, as influential creative engagements. It describes how this journey has not been a linear one but has incorporated experiential aspects from my past, such as the traditional Japanese ethos of Wabi-Sabi, as well as incorporating experimentation during this research. Hence, the pathway was not prescriptive of what the final results could be. Deleuze's understanding of difference and differentiation has been activated to approach the human-technology interface as well as creative design practice. This research draws on Deleuze's notion of bifurcating paths, as a technique for exploring ways to move from a traditional knitwear designer operating in a two-dimensional design paradigm, to one who has developed a successful method for producing creative knitwear results within seamless knitwear's three-dimensional paradigm.

The research is a discovery through experimentation and exploration, akin to that articulated by Deleuze's engagement with the thinking of Henri Bergson. This allowed "events" to happen, for "intuitive" reactions to take place—adjustments to be made based on an assessment of results from a subjective point-of-view, with no predetermined final result in mind. It is through this process that the methodology for this research is grounded. As exploration takes place, a connection is made between the maker and the made which, though advanced through computerization practices, rekindles the affective sensations of composition. The fourth chapter outlines the design process, past and present, which has been used to engage with seamless knitwear. This chapter focuses on the changes that have had to be made to my traditional design practices to enable me to work with seamless knitwear in a creative way. It evolves around the relations of the aesthetics of garments and, the integrity of the force and structure of the knitted stitch, used to decentralise knitted forms, using a knitting system that is essentially built to design and make symmetrical flat forms. This process integrates research into and about design practice as affective force. The fifth chapter describes the iterative process of each garment development; the inter and cross connectivity, as rhizomatic connections developed. The closing section of this chapter shows the final garment collection in the gallery exhibition as the key component of this completed thesis. The final chapter identifies the areas of new knowledge that this research has created and where and how this knowledge is applicable. It shows how it relates to the area of knitwear design for the development of creativity, as well as ways other designers both within the knitwear arena and other computer driven design areas could apply this design process to increase originality and the production of the new.

Throughout my design career I have been interested in using knitwear or knitted fabrics in ways where the body forms a central core that is then wrapped, enfolded and cocooned by layers of fabric, using various points on the body from which material may fall, thus creating drapes that extend and distort its exterior. During the late 1980s, when I last undertook formal study, my practice-based project explored this concept, but from the standpoint of a trained fashion designer who worked with woven fabrics—cut patterns and constructed garments from pieces of fabric. In the late 1980s, knitwear was then, as it still is now, very two-dimensional. My Master of Arts project, attempting to wrap a body, creating asymmetrical space in areas between the body and the garment—thus altering the exterior formations, or 'becomings' of the garment—was considered counter to accepted knitwear norms. This, as well as the fact that these garments, though made from knitted fabrics, were constructed using methods that were traditionally used for woven fabric construction, was a new approach to design practice methods for knitwear at the time.

Figure 1:
Smith, A. (1989) MA Garment

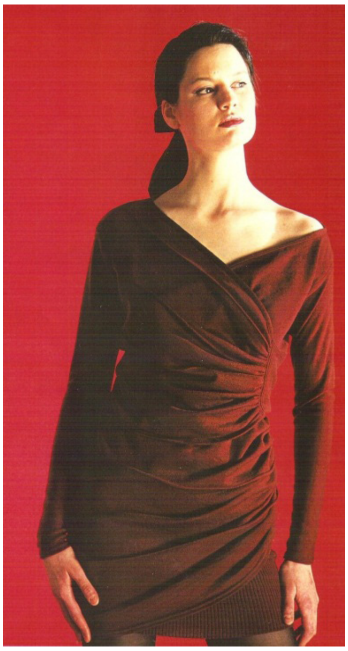

Figure 2:
Smith, A. (1989) MA Garment

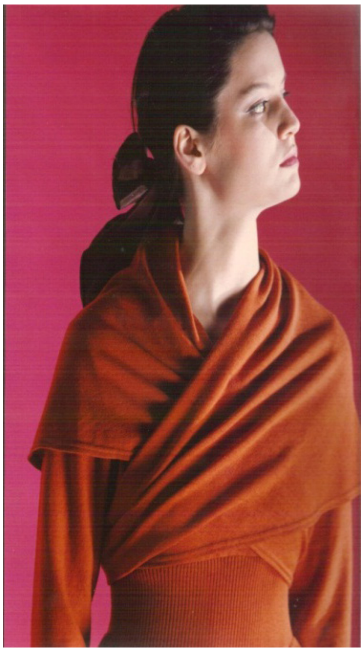

Figure 3:
Smith, A. (1989) MA Garment

This current research project, though polarised in principle to my previous study, has similarities in that both projects try to redress the norm. These projects are polarised because my earlier study came from a constructed knit avenue, cutting and adding seams, while this study is approached via seamless production. Both studies work to disturb the standardization of knitwear design practices and challenge design approaches from within the milieu of knitwear design. This current research differs from previous work through the increased tacit knowledge about knitwear processes and practices that I now have as a researcher. But, more importantly, it differs because design discourse has also matured and progressed, providing a language with which to describe design practice that was not recognised or fully formed in the 1980s, particularly in relation to a knitwear design milieu.

2) Conceptual Personae: Defining the research limits

This chapter engages with the key literature of the research, providing the contextual field out of which the research emerges and from which it sustains its supports. Concepts are what we invent in order to keep folding and unfolding our thinking as variations with respect to things that function and sensations brought about by engagement with things, with, respectively, functions as a plane of relations, and percepts and affects as a plane of composition. It is through this folding and refolding that we are able to see new perspectives on things or develop a different way of understanding things. This is not unlike the idea of folding a piece of fabric to reveal a new side or perspective of it. The virtual nature of concepts or idea generation means that there are multiple possibilities that could be accessed, activated or actualised; a plane of consistency mediating the chaos-to-order of our thinking, as we encounter things through functions and sensate becoming's.

2.1 Key Literature Fields

2.1.1 Forces from the outside

This literature review is structured around three broad arenas that intersect and, at the same time, delineate my research milieu. The initial arena I consider concerns a defining understanding of the fields of fashion and knitwear design as a preliminary and necessary orientation to my key concerns. However, the research is not a generalized engagement with knitwear fashion, but rather with a specific and current technological innovation in the field, the seamless knit technology of Shima Seiki Manufacturing. Hence, the second broad arena of literature concerns initially an exploration of design and technological innovation, including an understanding of the impact of post-Fordist industry models, leading to specific concerns with the development and implementation of seamless knit technology. This extends to an overview of literature and academic research that focuses on Shima Seiki WHOLEGARMENT® technology. The third broad arena of literature concerns the dimension of an aesthetic sensibility that underpins this research, in the Japanese tradition of Wabi-Sabi. In a rudimentary sense, the literature survey follows the schema introduced in Chapter One: approaches to fashion and knitwear design approximating the plane of consistency; engaging knitwear technologies inscribing the plane of relations; and the ethico-aesthetics of Wabi-Sabi suggesting the plane of composition.

2.1.2 The Silhouette as Image: From matter to memory

Fashion is concerned with economics, branding, and commerce. It is also about the identity of self; the community or cultures that you or I belong to. But it fundamentally concerns clothing a body in a creative and aesthetic way. As such, its concern is twofold; structure as form building and surface fold as texture. Fabrics or yarn as material substance, as matter, pass into a signifying system, into memory, into identity, community or culture. The structure-surface-yarn assemblage exists as garment only until worn, passing into becoming-clothing.

> A garment is not an independent, fully formed entity that is superimposed on the blank canvas of a woman's body. On the contrary, it exists only when it is in the process of being

> worn; when fashion is encountered in contexts other than the act of being worn, it can often evoke a sense of disquiet. (Bancroft, 2012, p. 2)

Fashion, equally explicable to menswear, has tended to be associated with women's wear, ever since Baudelaire (1995) wrote *The Painter of Modern Life* in the mid-nineteenth century, in which fashion was first identified as being related to the beauty of the feminine, rather than as an indication of social status (Bancroft, 2012; Lehmann, 2000). There is, perhaps, a perceived thought or hierarchy in fashion discourses that places women's wear in some way ahead of menswear and both ahead of knitwear. Knitwear appears to exist as a peripheral subset of fashion. If knitwear is mentioned, it is usually as an addition to the main components of a designer's wider collection. This means there is little in the way of literature from which I can draw. There are some notable exceptions, such as Sandy Black's *Knitwear in Fashion* (2002) and *Knitting: Fashion, Industry, Craft* (2012); Marnie Fogg's *Vintage fashion: Knitwear* (2010); and *Unravel: Knitwear in fashion*, edited by Emmanuelle Dirix (2011). The majority of literature written about knitwear focuses on the craft of hand or domestic machine knit and 'how-to-do' publications, such as *Knitwear* by Juliana Sissons (2010), or *The Handknitter's Handbook* by Montse Stanley (1986/1990). There is little, if any, focus on the machined or designer-led creative knitted form. Consequently, much of the fashion literature referred to within this research stems from the woven fashion industry, particularly focusing on the creation of garments as aesthetic form making in relationship to the body, form or function.

As I have intimated in Chapter One, an aim of this research is to open another kind of discussion on fashion design than one driven by concerns with form making and aesthetics as conventionally understood. Such an opening was made for me in the realization that the creation and analysis of fashion as a worn garment has close relationships with a body in much the same way as a body interfaces with and is surrounded by buildings. This has been noted in various influential publications, linking fashion and architecture, such as *The Fashion of Architecture* by Bradley Quinn (2004) and *Architecture: In Fashion* by Fausch and Singley (1991). The analysis of the inter-relationship of body and form, be it architecture or fashion, provided me with an introduction to the thinking of Deleuze. It was the initial reading of these connections and their further exploration that developed a greater understanding, beyond the obvious, of surface folds in architectural forms and fabric, both of which enfold bodies. A reading of the philosophical thinking to be found in *The Fold* (1993), ultimately underpins both the research practice and the exegesis. Concerning the emphasis he gives to surfaces as folds of interiority and exteriority, Deleuze suggests:

> As a general rule the way a material is folded is what constitutes its texture. It is defined less by its heterogeneous and really distinct parts than by the style by which they become inseparable by virtue of particular folds. … Hence texture does not depend on the parts themselves, but on strata that determine its "cohesion." (Deleuze, 1993, pp. 36-37)

Thus, for Deleuze, texture is not a surface quality in the conventional sense but rather how we come to understand a thing in the modifications of its consistency, how its materials are folded, how we most qualify what a thing is, what it can do and how it affects. It is this that Deleuze calls "style," and how we aim to encounter fashion in the image, or silhouette, of its styles or modalities of textures; the ways it can fold and refold its matter as that matter passes into sensation and sense. And, in this sense, what we name form making and aesthetics find their unison in the singularity of a garment's folds of matter.

There is also a geo-fold at work, a texture or style of the matter of place. The locale of seamless knitwear technological development, as well as a personal engagement with the country Japan, created a continuing interest in fashion emanating from there. Fashion produced by Japanese designers changed the accepted design aesthetic in Europe during the 1980s and has continued to provide the fashion industry with thought-provoking designs and influences. The work of designers like Rei Kawakubo, Yohji Yamamoto and Issey Miyake have consistently questioned, challenged and revolutionized mainstream fashion (Frankel, 2001; Holborn, 1995; Salazar, 2011). These, and a new generation of designers like Junya Watanabe and Jun Takahashi, have informed the fashion design literature reviewed during this research. In many instances they have looked backwards to move forward, incorporating cultural references or old techniques of making with new technologies, thus breaking with normal codes of practice (English, 2011). From this perspective, the literature has informed and influenced this research, within both the practice and its theoretical framework. Incorporation of craft practices or ways of thinking about making have been applied to the new technologies found in seamless knitting.

2.1.3 **Fashion's body semblances: Multiplications of the same**

Fashion is a term used to describe an object, an attitude or current taste, recognized by a group within society as being the accepted or popularized style at that time or moment. The term *fashion* is also applied to clothing, visually communicating a mode or form that is recognized as movement away from clothing as a practical body covering (Eicher, 2012). However, before there is clothing or fashion there is the practice of fashioning, styling or making. An influential factor that defines whether garments are considered clothing or fashion is how they are fashioned and from what material sources.

Textiles are two-dimensional materials, crafted from fibre or yarn either in a woven, knitted, crochet, lace or felted technique. Texture, in its conventional sense, is created from the directional movement of either fibre or yarn as it is woven or knitted into a textile material. The materiality of fabric emerges from the interlinking of yarns, forming the texture topology of the fabric, generally as a two-dimensional textile, with an inside and outside face. Deleuze sees texture in much the same way, not just as surface decoration. It becomes a way to understand how the event of folding parts together creates the materiality of something. Each textural encounter has a range of potentials or variations depending on the play of its consistency and the relations with other things it so forms; its function. The resultant textile expresses its affect:

> Everything is folded in its own manner, cord and rod, but also colours distributed according to the concavity and convexity of the luminous ray, sound, all the more strident where the trembling parts are shorter and more taut. Hence texture does not depend on the parts themselves, but on strata that determine its cohesion. (Deleuze, 1993, p. 41)

Clothing is created through the manipulation of two-dimensional textiles into three-dimensional structural surfaces that are, in turn, supported by and become visual extensions of a body. The materiality of textiles is folded, cut, manipulated, pieced together and sewn from a flat fabric to the third dimension in the semblance of a body's shape. An uncanny quality of clothing is the manner whereby it comes to relate to a body, how it functions, its body-semblance, its resemblance that at once makes doubly incomplete: the naked body and the empty garment:

> The creating (Latin *creare*) of material forms like clothing should be understood as a process from one material state into another, for example from the sheep's fleece via the woven piece of cloth to the draped or sewn item of clothing. An item of clothing is the result of a process constituting material and form. (Loschek, 2009,p. 17)

The process of making clothing has historically involved the cutting and separation of fabric into component parts that have then been reassembled, into forms that dress. Rissanen (2005) explains the different methods of patterning and construction for clothing, such as cut and sew, fully fashioning (knit) and jigsaw, a cut and sew technique that fits pattern pieces together like a jigsaw, thus reducing fabric waste. There are more recent fabrication innovations, such as *A-POC* (Holborn, 1995) and *Cradle to Cradle* (McDonough & Braungart, 2002), that search for ways to reduce the typical waste of fabric—from fifteen to zero per cent—using Western pattern making methods (Rissanen, 2005). Clothing moves beyond merely a protective covering or a way of retaining body temperature and becomes a means for making social or cultural statements, depending on the ways meanings are folded into the materiality of the textile and how the component parts are reconstituted into forms, which is to say, into cultural systems of meaning.

Designers such as Vionnet, McCardell, Kawakubo, Sybilla and Toledo, have focused on creating clothing for which the manner of cut and construction form a significant influence. This attention to signifying details that are also technical processes transforms clothing into the realm of fashion (Dresner, Hilberry, & Miro, 2008; Frankel, 2001; Steele, 1991; Steele & Mears, 2009). The way a textile is cut and composed or how flat material is constructed into three dimensions, where pleats, folds, tucks and darts are distributed, alerts us to the modal processes, or ways of modifying matter in its becoming-meaning. Fashions manifestations have been many. As Loschek states:

> Clothing is regarded as form, fashion as the medium. Since the form of clothing represents the foundation for the medium of fashion, fashion is form *and* medium. Whatever we see, it is form; the medium cannot be seen or rather the medium becomes visible only as the form of clothing. (Loschek, 2009, p. 25)

We need to recognise in Loschek's "form and medium" an essential concern with communicability and transmissibility, with the flows of matter and its expressions, or capacity-to-express. Form is a becoming-repetition of matter's expression at whatever scale; individuals, groups, a nation, the West, global fashion consciousness. Deleuze sees this expression as a force of affects created through the movement of events folding, unfolding and refolding, and creating the new: "Matter that reveals its texture becomes raw material, just as form that reveals its folds become force" (Deleuze, 1993, p. 40).

Fashion emerges as singular *couture*, socially attainable by a few, or as multiple mass-produced, accepted and attainable by many. The techniques of production vary from the individuated processes of couturiers, to producing patterns of component parts, enabling reproductions of the same, resulting in mass-production and standardization. Mass-production processes complicate the form and medium relations of fashion's semblance to, and differentiations from, clothing. Mass-production implicates quick and lean production methods, reducing time and cost. Yet time's expenditure enters a relationship with desire's aim for an ultimate range of garments: annuls time and energy for a collection requiring little or no construction processes, but which still expresses its flows of matter as fashion. This desire has inspired many designers. Yeohlee Teng's work has been driven by the idea of reducing seams to a minimum. Miyake and

Fujiwara developed *A-POC* ("A Piece of Cloth") using warp knitting technology to produce garments requiring no sewing but were cut out of fabric much like making paper dolls. Garment making techniques, initiated by Vionnet and Madame Grés, were the inspiration behind *Pleats Please* by Miyake garments of which also needed a body to complete its three-dimensional forms (English, 2011; Steele, 1991).

The development of seamless knitwear technology by Shima Seiki needs to be encountered in the realm of such a desire. It was seen as being one of the "most significant developments in knitwear manufacturing, which could have a major impact on the fashions we wear and on clothing production" (Black, 2002, p. 118). Seamless knitwear answered the production needs of less or no construction, no fabric waste, and the ability to produce mass or customised products, thus supplying clothing and fashion forms. Seamless knitwear does provide the "mystical dream" of fashion, as Roland Barthes once described it:

> On the one hand, we could say that in its profane way the garment reflects the old mystical dream of the 'seamless': Since the garment envelops the body, is not the miracle precisely that the body can enter it without leaving behind any trace of this passage? (Barthes, 1983, p. 136)

2.1.4 **Fashion: Affects and signs**

It was Barthes, perhaps before anyone else, who introduced an analysis of fashion to the science of semiology. His book, *The Fashion System* (1967/1983), was published in France in 1967. It is a complex application of his then current engagements with cultural artifacts and systems as modes of signifying practice. My aim here is not to engage with this comprehensive analysis in any depth but rather to acknowledge that fashion is, above all, and perhaps in the first instance, a field of significations and affects: concept formations as a plane of consistency in form making repetitions and aesthetic receptivity as blocks of sensations, expressions of those textures/styles/folds of fashion's materiality. In this sense, fashion happens at two levels; as a social construct and through sensory perceptions. As a social construct it questions society, cultural implications and connections as well as self and gender identity. As a sensory affect fashion can trigger emotions, memories, provocation and reflection, interior by nature, through the very questions that it raises (Bancroft, 2012).

Loscheck connects this to a limiting binary code of "in or out" of fashion, commenting: "The difference between form and medium leads to the fashion system of 'in' and 'out' (binary code).

The form/ medium distinction is one made by an observer" (Loschek, 2009, p. 25). However, one would want to add to Loschek to the extent that fashion is immanent to its lines of variation, and hence happens in its differentiations from itself. While there is an observer, there can be no observation from a point of view exterior to those differentiations. Observation, too, is immanent to fashion. Geczy and Karaminas recognize: "What the history of art since Marcel Duchamp has taught us is that art cannot exist without the elaborate protocols that register for the viewer that the experience of it is different, indeed something special" (Geczy & Karaminas, 2012, p. 5). Both art and fashion need a collective acceptance to be recognized as such, where that collectivity is itself constituted by what differentiates its singular constituents. Using Duchamp's example, the viewer "makes" art and the viewer "makes" clothing into fashion (Loschek, 2009), thus folding viewer/art/fashion each in its reflexive becomings.

Yet, fashion within social constructs works as a means of marking delimitation and noting extensions beyond what is collectively accepted. It constitutes normative valuations. Collections such as McQueen's *Highland Rape* (Autumn/winter 1995-6) and Kawakubo's *Dress Becomes Body Becomes Dress* (Spring/summer 1997) were both events that created an outcry and as such were rejected as being too deviant for collective acceptance (Bancroft, 2012; Clark, 2012).

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Figure 4:
Kawakubo R. (1997) *Dress Becomes Body Becomes Dress.* Retrieved December 10, 2012, from http://www.imamuseum.org

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Figure 5:
McQueen, A. (1995-6) *Highland Rape*, Retrieved December 10, 2012, from http://blog.metmuseum.org

Fashion in its normalising functioning becomes a signifying process that yet depends on how it is encountered. Its functions are folded with meanings. Often it acts as deviant when clothing becomes a spatial extension of a body, deforming, sculpting, and distorting space between skin and the matter of a garment. Baroque pleats and extensions, lacing, corsets, exposure of areas of skin, movement of necklines, the addition of multiples of sleeves, or the movement of sleeves to unexpected places all evoke reactions. The unexpected leaves us questioning, reflective and aware of an encounter with a deformation that is deeper than just a surface meaning. For Deleuze this is a "sense-event" that aims to account for a singular unison of matter's flows and its expression: "We go from inflection to inclusion, just as we move from the event of the thing to the predicate of the notion, or from 'seeing' to 'reading" (Deleuze, 1993, p. 47). Deleuze refers to the "pleats of matter" and the "folds of the soul," both infinitely complicating as immanent differentiations, yet finding a unison as a sense-event (Deleuze, 1993, pp. 7-8).

2.1.5 **Knitwear fashion: Twisting folded narratives**

Knitwear is seen as a subculture of fashion and crisscross's borders and boundaries found within fashion design, technicity, production and cultures. It has a duality in its modes of production: domestically perceived hand knitting and machined industrial production. The image of the domesticity of knitting remains embedded within the imagery of knitwear as a product, even though industrialized knitwear is now produced on some of the most advanced technology available for clothing production. Whether evoking a domestic romanticism embedded in knitwear history or emphasizing computerized knitwear technologies, knitted textiles are essentially fabricated in the same way, through the use of a single piece of yarn. The single thread is interlooped around itself to form a surface fold, a continuous line-becoming-garment, each stitch expressing its production and that of the garment that carries it. It is through this process of continuous yarn wrapped around itself, stitch interlaced to stitch, multiples of knit and purl, that the historicity of knitting is evoked through its evidential links to a craft context.

Yet, there is knitwear considered radical or termed "guerrilla knitting," making social, political, economic and gender commentaries, as explored through an exhibition held at the Museum of Art and Design in New York in 2007, *Radical Lace and Subversive Knitting*. In the book published from this exhibition, McFadden comments:

> Knitting and lace suggest a delicate domesticity that is belied by the imposing sculptural scale that they may assume, by the engaging and even perplexing complexity of their construction and by their often radical content, which may range from political manifesto to autobiographical revelation. (McFadden, Scanlan, & Edwards, 2009, p. 10)

This engages with a further subculture of knitwear as art, where knitwear moves from the realm of craft or industry production into the art gallery or museum, though such a categorization would need to negotiate the particular ways in which to engage art in the sense of a block of sensations on a plane of composition. This example leans more to art as a categorical *concept* and a mode of regularity or *function* continuous with the institutional spacing of a gallery or museum.

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Figure 6:
Robins, F. (2002) *Craft Kills*. Retrieved December 12, 2012, from http://freddierobins.com/work

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Figure 7:
Robins, F. (2000) *Headcase*. Retrieved December 3, 2012, from http://freddierobins.com/work

Freddie Robins has worked with seamless knit technology in an innovative manner, less as knitwear production, more as artworks making political or social comment, such as seen in the garments in figures 6 and 7 (Robins, 2012). One of the largest knitwear exhibitions, *UNRAVEL: Knitwear in Fashion*, was held in 2011 in Antwerp at the Mode Museum. It was a knitwear garment retrospective celebrating "the changing relationship between fashion and knitwear" (Dirix, 2011). Garments from Backlund, Westwood, Missoni and Kawakubo were included, demonstrating the moves that knitwear has made from the institutional locale of the domestic to the fashion domains of the fine arts. This was particularly notable through the use of historical garments, such as hand knit swimsuits, to an exquisite central exhibition piece by Sandra Backlund.

Knitwear's fashion design histories

Knitwear design moves between the *couture* or avant-garde, as seen from the Schiaparelli garments of the 1930s to the mass-products of companies like Missoni of Italy, design-expression being the garment's motive, and wearability a secondary consideration. Knitwear became part of fashion incrementally over many centuries, predominantly being worn as underwear and not becoming known as outerwear until the early 1900s. All knitwear garments and accessories, such as the knitted stocking, were hand-knit until the sixteenth century when, due to the demand created by the wearing of hose, William Lee developed the mechanized stocking-knitting frame. This produced a coarse knitted fabric, fashioned into a stocking, that heralded the beginning of industrialization of the knitting industry and the possibility of mass-produced clothing (Black, 2002, 2012). Many long standing knitwear companies were formed to manufacture knitted underwear, such as Jaeger, and John Smedley in the U.K. founded in 1784, later moving to producing outerwear (Fogg, 2010).

Knitwear has followed parallel journeys of hand-knit and mechanized production. Up until the 1950s, mechanized knitwear was limited by sheer mechanical capability, with hand-knit garments more sophisticated than those produced by machine. The 1950s saw the introduction of Dior's "New Look" and with it "the sweater girl" of Hollywood, which popularized the fitted twinset of sweater and cardigan (Fogg, 2010). It was at this point that the knitwear industry focused on making "machines go faster and increase patterning options" to increase production to meet the ever growing demand for fashion knitwear (Power, 2007). There were design innovations driven by knitwear designers and technologists alike during the 1950s and 1960s, such as McQueen patenting the Basque beret technique of *flechage* (1950s) as a technique to make outerwear, not just berets. Elsa Schiaparelli and Emma Pfauti had both developed ways of making individual hand-knit garments with no seams, whose principal concern was body-fit (Power, 2007). However, industrialized knitwear technology was not advanced enough to be able to duplicate these techniques. It has taken another seventy years for this to be achievable, as mechanization in the form of seamless knitwear technology.

Knitwear's technical perspective

When knitwear is discussed in books and academic papers (Brackenbury, 1992; Choi & Powell, 2005; Hunter, 2004-2005; Spencer, 2001), it tends to engage with either design outcomes or the technology developments that have produced it. Such literature has been concerned with technology advances progressing the capabilities of knitwear function. To date, limited material has been published that views the field from a design perspective.

Literature written with a technological or technician's perspective includes: *Knitted Clothing Technology* (Brackenbury,1992), *Knitting Technology: A comprehensive handbook and practical guide* (Spencer, 2001) and *Three Dimensional seamless garment knitting on V-bed knitting machines* (Choi & Powell, 2005). This literature focuses on the development of knitwear manufacturing, production capabilities and the creation of new machinery and technology that improve knitwear manufacturing technologies. One of the most notable is the book *Knitted Clothing Technology*, first published in 1992 by Tony Brackenbury. This book is used as a source of technical knowledge on the manufacturing and fabrication of knitwear garments. It is referenced in most academic writing about knitwear to date. However, it was written before the development of seamless knit technology, so provides little insight into this mode of production and has not been updated to include it. *Knitting Technology: A comprehensive handbook and practical guide* by D.J. Spencer was originally published in 1983 but the current third edition, published in 2001, has been updated to include mention of seamless knitwear technology. It contains images of technical machinery and knitted structures and gives a clear, though brief, history of machine knitting.

The books by Black; *Knitwear in Fashion* (2002) and the recently published *Knitting: Fashion, Industry, Craft* (2012); contain the best visual collection of influential knitted garments and textiles currently available to a researcher working in the knitwear arena. The key focus for these works is the development of knitted shape and its relationship to technological advances. Because these books include a recent historical focus, they have some of the most significant and relevant knitwear styles of the twentieth century. Garments included represent either a new technological capability or a new fashion statement by a noted fashion designer or company at a particular time. As sources of historical visual shapes and visual knit textile techniques, these publications are invaluable sources for knitwear designs from the recent past.

Another U.K. based researcher, Jess Power, traces the technological developments of industrial knitwear from the fifteenth century to the start of the new millennium, in her paper entitled *"Functional to Fashionable: Knitwear's evolution throughout the last century and into the millennium"* (Power, 2007). The topic itself is not new, but the reflection on the social environment and the interplay between changes in fashion and technological evolution of knitwear production are unique. Throughout history, fashion has influenced and driven industrial and technological developments but, equally, shifts in technology have also influenced changes in fashion. Power discusses the development of seamless garment technology and also notes that this first generation of WHOLEGARMENT® machines haven't had the initial impact on the industry that was originally predicted. In a similar vein, Hunter noted; "The whole garment technology within fashion has been evolutionary rather than the predicted revolution" (Hunter, 2004, p. 18). Power expanded on this point suggesting; "the product range capability of the first machine was too restrictive for the fashion arena" (Power, 2007, p. 11). Other industry experts (Brackenbury, 1992; Hunter, 2004-2005; Spencer, 2001) noted that the industry generally was not ready to embrace seamless knit technology. Such innovation had moved beyond the industry's mind-set and designers' understanding.

This thesis presents another thought-image. It recognizes the *timeliness* of developments in seamless knitwear and its utilization by knitwear designers. We see how the pull and push between these two, technology innovation and design innovation, are reliant on one another. They fold but often asynchronous, out of time with one another. This means they produce new time, which is to say, a future that is the new. Such folding is the new. Hence, this research raises the question of what is the current relationship between technology and design and investigates the slow uptake and use of seamless garment technologies within the designer knitwear industries for production that is not of a standardized nature. It is timely and important to be researching design possibilities and limitations using seamless knitwear technology, at a point when this technology is readily available but seemingly underutilized.

2.2 Industrial and Innovation Relationships

2.2.1 Fordism and Post-Fordism: Flexible specialization

The knitting machine was one of the first mechanized machines developed for production purposes, as early as the sixteenth century, setting the stage for the beginning of industrialization. The textile industry has found itself at the vanguard of industrialization from this time on. At the turn of the twentieth century, through the work of Fredrick Taylor and the introduction of scientific management, industrialized processes saw a separation of labour skills from mechanical knowhow, in a move to give management more control over production outputs. Jaffee cites Taylor in a discussion of this move: "The mass of rule-of-thumb or traditional knowledge may be said to be the principal asset or possession of every tradesman … a large part of which is not in the possession of management" (Jaffee, 2001, p. 51). Taylor's scientific management system reduced the labour process into a series of simple and repetitive physical motions that condensed an understanding of the whole process into a series of discrete and partial episodes, effectively reducing labour's control over production outputs: "Though workers depended on owners for employment, owners depended on the craft knowledge of workers for production to proceed" (Jaffee, 2001, p. 51). The breakdown of labour skills on the shop floor was mirrored in a development of production management roles, which controlled the process. Braverman notes: "The separation of hand and brain is the most decisive single step in the division of labour taken by the capitalist mode of production" (Braverman, 2010, p. 79).

This division of labour, both vertically and horizontally, is often attributed to Henry Ford and has become known as Fordism. Fordism is associated with the early American automobile assembly lines as established by the Ford Motor Company during the 1920s, which utilized principles of the scientific management system within its production and management infrastructures. The drive behind Fordism was to mass-produce goods that were identical as quickly and as efficiently as possible, thus reducing unit cost and enabling the masses to afford them, driving production needs upwards. Fordist mass-production, based on division of labour, introduced the moving assembly line with the same production lines maintained over long production runs, achieving economies of scale (Jessop & Sum, 2006). One of the issues with Fordist production that has been identified by Jessop and Sum was the focus on quantity rather than quality, changing the consumer market for developing mass-markets. It also developed new industries revolving around mass media, such as advertising, retail and consumer research. Because the products were being mass-produced, customer preferences needed to be established: “Since mass production meant standardization of products as well as mass consumption, it was associated with a whole new aesthetic and a commodification of culture” (Jessop & Sum, 2006, p. 65).

Particularly during the 1960s to 1970s, as markets expanded and products diversified, the demise of Fordism loomed, moving into what has become known as the Post-Fordist market of the 1970s and 80s. Manuel Castells noted:

> When demand became unpredictable, in quantity and quality, when markets were diversified worldwide and thereby difficult to control, and when the pace of technological change made obsolete single purpose production equipment, the mass production system became too rigid and too costly. (Castells, 1996, p. 154)

The Post-Fordist model of production is based on flexibility of manufacturing processes, labour forces, and product outputs. The idea of Just-in-Time production and Lean production methods were introduced as companies found producing one standardized product no longer sustainable, as well as no longer having the capital to stockpile materials. These changes were largely instigated and supported by the growing micro-electronics, information and communications industries, as well as being consumer driven by a growing demand for differentiated products, away from standardization.

There were, however, many differing versions of organizational transformations following Fordism. One of these, ‘Toyotaism’, is attributed to the Toyota automotive company in Japan from the 1950s onwards. It incorporated elements of Fordism but also retained many embedded cultural elements of traditional production processes. Toyotaism retained vertical communication links between workers and managers, therefore maintaining structures for sharing implicit knowledge and turning it into explicit knowledge (Jaffee, 2001). Jaffee suggests: “... the systematic and regularly scheduled communication between workers and managers, allows management access to a valuable form of information termed *tacit knowledge*” (Jaffee, 2001, p. 133). Tacit knowledge is a term introduced by Michael Polanyi in 1958 and is described as personal knowledge that has been acquired over time, but which is often difficult to pass on to others: “we can know more than we can tell” (Polanyi, 1967, p. 4). Tacit knowledge needs to be transferred through the practice of doing or showing, through community or social networks. This is able to happen within the Toyotaist system because of the organizational structures and communication networks built up by Japanese companies. “There is a broad sense of all organizational members as ‘corporate citizens’ with legal rights and obligations within the organisation, as well as social and recreational ties outside the factory" (Jaffee, 2001, p.132). Just as Fordism introduced the idea of mass production, by harnessing workers' tacit knowledge back into the development of a company's product output and design process, "Toyota became the model for quality and productivity" (Dohse, Jurgens, & Malsch, 1985, p. 117).

Tracing the lineage of industrial production organizations helps to explain the development of companies like Shima Seiki and products such as the seamless knitwear machine. They are both products of economic, consumer and cultural drivers. The company motto for Shima Seiki Manufacturing Limited is "ever onwards." A key factor within a Japanese company is its continuous striving for improvement, *kaizen* in Japanese (Shima, 2012). Other key drivers for Shima Seiki include a culture of customer orientation, which recognizes the customer's needs as a driving force for design and development and adoption of Just-in-Time principles. These have resulted in the development of seamless knitting technologies. Seamless knitting technology provides Shima Seiki's customer, the knitting industry, with the means to mass-produce its products quickly, with inbuilt possibilities of economies of scale and with a certain degree of flexibility in product design output.

2.2.2 **Design and Innovation.**

With mass-production came standardization of products. With the subsequent increase in modes of communication and the growth of a global economy came additional demands for flexible product design capabilities. This demand was market-led, with the consumer starting to look for products that were designed to suit her particular needs. A move towards industrialization and the capacity for mass-production created the need for a design industry. In "Craft verses Design," Cardoso comments: "The perfection of mass-production technology signalled a new perfectibility for industrial artefacts; and designers would henceforth play the key role in ensuring that machine work was as attractive as it was efficient and cheap" (Cardoso, 2008, p. 327). This is a significant paper, which notes the current growing relation of craft practices with industrial bespoke products and closer relations between the producer and the consumer emerging. This industrial paradigm shift has been enabled by technology developments that have allowed greater refinement of design within products, giving consumers more choice.

The introduction and use of flexible manufacturing procedures, such as Just-in-Time and Lean manufacturing, enabled cost-effective production runs that were shorter and more flexible in outputs. The growth and improvement in digital technologies, not just for design but primarily for communication purposes, has empowered both consumers and producers, providing a means of producing products on demand.

> Design is no longer a one-way system, in which manufacturers impose products on a market without a choice. There is an unprecedented degree of reversibility to many manufacturing processes, in which consumer input is seen as a factor conditioning production (Cardoso, 2008, p. 328)

The introduction of choice in this way has been called "mass-customization" where consumers are able to make decisions from a prespecified range of options, such as selecting from a list of criteria. Piller, Reichwald and Tseng have been researching the organizational changes that manufacturing companies need to make to successfully introduce customization practices, also described here as "co-design": "Co-design activities are performed in an act of company-to-customer interaction and cooperation" (Piller, Reichwald, & Tseng, 2006, p. 161). The improvement in digital technologies for manufacturing, designing, communication and infrastructure have allowed an individualization of design process and making which, if analysed, looks much like that of the master craftsman before industrialization. "The boundary between design and craft … is porous. In a changing world of work, technology and consumption, some practitioners may want and be able to exploit this porosity, while others will continue to work within recognisable traditions" (Rees, 1997, p. 135).

Over the past twenty years there has been a growing concern about over production, the damage caused by production of and disposal of goods. This has resulted in a consumer driven push for sustainable production and companies being held accountable for the environmental impacts their products may have. Sustainability and environmental impact have become part of design. The fashion and textile industries have been particularly at fault and slow to react to ecological impacts. Many of the ways that textiles are produced cause massive environmental problems. Raw materials are farmed unsustainably; water use and contamination issues, and the use of harmful chemicals and incorrect disposal of chemicals used in treatments on fibres, have all been identified as issues created through production process. Other environmental issues, such as over-production of cheap-chic products, the unethical working conditions and social practices of manufacturing companies and the heavy use of fossil fuels for manufacturing and distribution of products, have in many cases meant that fashion and textile companies are having to rethink the way they do business (Bide, 2012).

The technology of the Internet has made communication and information about new design and innovation techniques as well as old techniques such as "up-cycling" accessible to the consumer. They can choose whether they want the "fast," "slow" or "up-cycled" version. Designers have had to incorporate this kind of thinking into the ideology of their design processes, responding through interactive design, participatory design and emotional design for experience. They now have to take the entire lifecycle of a product into account when developing it, not just the initial design-to-market stage of a product's life. This shift in the design and consumer paradigm has led to the rebuilding of a community that revolves around the producing and ongoing use of products, not unlike the relationship that existed between craft makers and clients before the industrial revolution. Cardoso sums up this paradigm shift:

> With the advance of flexible models of industrial production, the designer as aesthetic autocrat would seem to be a thing of the past. Artefacts are increasingly suited to the changing experiences of a fluid community of users, and less to the predetermined designs of any one individual. Human psychology makes product differentiation desirable. Better machines and engineering make it possible. The old paradigm of mass production is on its way out; a new paradigm, the individuation of experience, arises in its place. (Cardoso, 2008, p. 331)

The increase in the demand for a personalized product has raised awareness of the possibilities that new digital computer design practices, processes of on demand production and communication, have availed to the designer and the consumer for an individualized product, heralding a swing away from standardization of production.

2.2.3 Fashion Technology and Industry

Within the fashion industry flexible manufacturing has not necessarily resulted in differentiated products or seen a growth in the singular or the nuanced product embedded within the mass-produced. There have been some moves towards customization with experimentation of the mass-produced showing limited degrees of handcrafted qualities. However, the introduction of technologically driven processes within the fashion industry has had effects, one of the largest being that of increased globalised production processes, with many component parts of a company's collection being produced in many different countries and often offshore from the final destination of the products.

Globalisation within fashion has resulted in a shrinking fashion world, with many companies producing what looks like-the-same, and by decreasing the lead times from conception to delivery, the production of more-of-the-same. The ease of visual communication and increased globalisation of knowledge bases has given rise to a faster spread of information and images, increasing the standardization of fashion "looks" especially within fast-fashion arenas. Kiernander noted in the article "Ethical chic":

> Historically, fashion has always offered a highly accessible way of engaging with visual culture, but the 'cheap-chic' phenomenon means that individualism is seeping out of the style silhouette. In an era of mass-produced design, the fashion playground of colour, fabrics and shapes is now saturated with similarity. (Kiernander, 2007)

This phenomenon can be witnessed walking down any High Street in any large city around the world, with industry chain outlets such as Zara, H&M, Top Shop, Cotton-On, Pri-Mark, or their regional equivalents, all visually dominant and promoting a very similar product, resulting in similar looks. Turney noted in *The Culture of Knitting*: "A standardised 'World' style negates the significance of the role of fashion in the creation of personal identity" (Turney, 2009, p. 193).

With this in mind, new technologies used within the fashion industry have also been focused on the production of the mass-customized product, using technologies like body scanning as a means to reintroduce the individuated product back into the sartorial fashion framework. The jeans industry has introduced body scanning techniques to determine the best fitting jeans for a customer's body shape, as seen in Selfridges in London and Bloomingdales in the United States (BodyMetrics, 2012). In 2006, Nike Corporation introduced an on-line site for customers to customize a chosen predesigned shoe, with the colours of choice (NIKEiD, 2012). Both of these examples are of a mass-customization process, where consumer choice is limited to pre-set criteria of both shape and colour. Though this promotes the feeling of an individuated product, it is still produce able through a large-scale production line and still has an economy of scale built in. Tseng and Jiao, in Peterson et al., describe mass-customization as "technologies and systems capable of delivering products that meet a customer's individual needs with nearly the same efficiency as mass production" (Peterson, Larsson, Mujanovic, & Heikki., 2011; Tseng & Jiao, 2001, p. 6).

2.2.4 Seamless Knitwear as Customization: Research and industry

There has been much academic research interest in the use of seamless knitwear technology as a mode of production for customization. Some of this key research has been conducted in Sweden at the University College of Borås, where a Knit-on-Demand project was initiated. There are a number of papers and a dissertation by Jonas Larsson that disseminate this research (Larsson, 2011). The initial idea of Knit-on-Demand was to analyse how complete garment technology could be used in a customized outlet, where customers designed their own garments, and then how such a concept would impact on the organizational structure of the supply and management chain. Seamless knitwear modes of production were not available at the location of this research, so other arenas of knitwear manufacturing production were used, such as fully-fashioned and cut-and-sew methods. This research did conduct a simulated design-and-custom-make for seamless garments at the Wakayama *Factory Boutique Shima* in Japan. The findings from this simulation concluded that seamless knitwear technologies could be used for producing a personalized garment, but that to enable a crafted garment of a high standard some post-production fabrication would still be required. This is an extensive study of customization processes, the organizational systems requiring implementation and customer views on the process. It is unfortunate that seamless technology, as an initial driver for the research, was unable to be part of the project (Larsson, 2011).

The paper "Considerate Design for Personalised Knitwear: The Knit for Fit Project" also concentrated on creating a custom-made seamless garment, using the Stoll M1 Knit and Wear system. This project's aim was to create a garment that was personalized to customer fit-preferences. To do this, the client was body scanned and the data was used to create two garments, one using a fully-fashioned production method and the other using seamless garment technology. The two production methods were compared for comfort of fit, production time and costs involved. The conclusions noted:

> The ability of the complete garment seamless knitwear production method to deliver a cost-effective business model for personalisation is yet to be proven, however satisfaction was found to be high after development of the project samples personalised for fit. (Black & Watkins, 2010).

It was the high costs involved in the programming and then prototyping to get the garment to a level of fit and quality that was acceptable that seemed as yet prohibitive (Black & Watkins, 2010).

Commercial uses of seamless knitwear technologies

The idea that seamless knitwear could be suitable for customized knitwear processes may have been stimulated by Shima Seiki, the manufacturers of WHOLEGARMENT® technology. In

1995, shortly after the first seamless knitting machine was launched, Wajima Kohsan Ltd opened its first *Factory Boutique Shima* in Wakayama Japan. This was attached to the Shima Seiki manufacturing plant and used seamless knitwear technology to provide a semicustomized product to consumers. *The Factory Boutique Shima* is still in operation today and is now located in the Fusion Toys and Knit Museum in Wakayama. A similar design-and-made-to-measure operation was launched as a commercial venture, to promote seamless knitwear as a superior mode of production, to customers in Takashimaya department store in Osaka in 2009. The idea of "seamlessness" has been used globally by a number of companies trying to market knitwear via its mode of production. In the United Kingdom, Marks and Spencer, Oasis and John Smedley used seamlessness as a promotional tool to differentiate their knitted products from others.

Commercially, companies like John Smedley, an old established knitwear manufacturer in the United Kingdom, have transferred some of their production capability to seamless technology. In 2006, John Smedley started to change to seamless knitwear with a focus on Shima technologies. This was a significant transformation for a company that had been producing knitwear in its original premises since 1795. Though the designs produced by Smedley remain within a traditional shape, that of basic sweaters and cardigans, they have been using seamless knit technology to differentiate their product from other knitwear producers in the United Kingdom. In the 2009 catalogue for their "One" label, the marketing focused exclusively on seamless knit technology and the company's craft based heritage:

> The beauty of fine, lightweight knitwear is its sleek simplicity and refined elegance. These qualities can now be further enhanced by the use of new technology in knitting to create a truly seamless garment ... John Smedley 'One' styles are produced using these whole garment machines, which knit the garment all in one piece. ... John Smedley continues to evolve and advance into the future. It is a brand with a heritage which spans two centuries, a reputation for fine quality knitwear which utilises the craftsmanship and skills learnt through time but with sights set firmly to the future. (Smedley, 2009)

This knitwear company has a huge international reputation for producing quality knitwear, which though now partially produced on seamless technology, has remained within a traditional shape paradigm as can be seen in figure 8.

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Figure 8:
Smedley, J. (2009). '*One*' styles, Retrieved November 12, 2009, from http://www.johnsmedley.com

Seamless knitwear is now being used for commercial, mass-production internationally by a number of companies. Many of the heritage knitwear companies in the United Kingdom, like *Pringle* and Jaeger, producing high-quality garments using high-cost yarns, such as cashmere, have moved to using seamless knitwear. Many of these companies are producing classic knitwear not dissimilar in shape to New Zealand tourist-wear products. In many of these mass-production arenas seamless knit technology has been used as a marketing and branding tool with swing tags informing the consumer of this mode of production. Marketing promotes it as having better fit and improved comfort for the consumer, due to its seamlessness. How successful such marketing has been and whether the consumer even understands this branding message is doubtful, with most consumers not interested in knitwear modes of production. In a personal communication with Smedley in 2012, it was intimated that trading on seamlessness for promotional purposes has not been successful. Buyers, retailers and customers were more interested in colour, style and feel.

Researching the market for seamless knitwear, it was found that there are few designer companies that have used seamless knitwear in any more innovative ways than it has been used within the mass-market production areas. Most have used it within a standard shape such as a crew neck cardigan. Though, what is of note is the attention to details such as fit, shoulder shaping, trims and the luxury yarns from which these garments are made. One such example is from the *Jill Sander* 2011 Spring-summer range. It is a very basic-shaped three-quarter sleeve cardigan made in one hundred percent cashmere as seen by the researcher in Takashimaya, in Ginza, Tokyo in 2012. Others I also observed were from *Comme des Garçons*; long sleeveless tunic shapes, with blue and white stripes that had been distorted by three double-bed horizontal lines of a tighter tension, running though each body piece.

Looking at the Shima Seiki and Stoll Web sites, all of the literature promotes the three-dimensional aspects of this technology and its potential for three-dimensional garments (Shima, 2012; Stoll, 2012). Yet it can be seen that the majority of companies using this technology are doing so to mass-produce garments which stem from a traditional two-dimensional cut and sew design and production model. Though this technology promotes new capabilities and three-dimensional design and production potentials, designers and designs remain entrenched within the confines of a traditional model for knitwear design and manufacturing. As yet seamless knitwear technology as a means for producing customized garments has not been proven as a sustainable business model, other than by the manufacturing company Shima Seiki in Wakayama, where it may be assumed that there are commercial benefits to be gained by the company in having a working centre in which to display its latest technologies in action.

2.2.5 **Knitwear technology: Shima Seiki Wholegarment®**

This PhD research has focused on Shima Seiki flatbed knitting machines for two reasons. In New Zealand, where this study is taking place, there are very few Stoll machines and no seamless Knit-and-Wear Stoll machines. Most New Zealand companies have invested in Shima Seiki flatbed knitting machines, as there is a Shima support system in place. It is for this reason that the Textile Design Laboratory (TDL) at AUT University purchased a Shima Seiki SES-SWG-14 gauge knitting machine, therefore providing access to Shima machines for this practice-led research. The second reason was the ability to extend this study to incorporate design training at Shima Seiki headquarters in Wakayama, Japan. My previous design experience, working and living in Japan in the late 1980s and early 1990s, gave me an understanding of how large Japanese corporations operate and how incorporation of internal operating processes may have been influential in the design and development of seamless technology.

Shima Seiki Manufacturing Limited was established in 1962 by Dr Masahiro Shima, in Wakayama, Japan. Wakayama is a port city and from the Edo (1600 -1868) era through the Meiji (1868 -1912) era was involved in the production of textiles (Watson, 1981). It is also very close to Osaka, which was a main supplier of textiles. It is known that at least one knitted product factory was set up there as early as 1872, by the Governor of Osaka (Takeuchi, 2006).

Masahiro Shima, having been born in 1937 in Wakayama, would have been brought up surrounded by the traditional textile "putting out" system embedded in the traditional *ie* culture of production, which continued in parallel with the introduction of larger Western factory systems, especially in the craft orientated products sector, such as knitwear. This, together with the developmental structures of Lean Manufacturing that were being adopted, as seen incorporated into Toyotaism, form the basis for many Japanese corporations like Shima Seiki. This form of structural management of a company created what Nonaka and Takeuchi called a "knowledge creating company" (Nonaka & Takeuchi, 1995). It had both a vertical and horizontal structure of communication inbuilt: *Kaban*, a horizontal communication system, focuses on a lean production process, minimizing raw materials and parts and made to order; and *Kaizen* focuses on a vertical communication system of continuous sharing of knowledge to improve products and processes. *Kaizen* is particularly applicable to Shima Seiki because it emphasizes the notion of "learning by doing" so that "the production process is continuously, or incrementally changed and improved" (Jaffee, 2001, p. 136).

Masahiro Shima would also have been exposed to the latest knit technology, which had been imported into Japan since 1868. It is reported that early technology transfer within the knit industry had occurred from Switzerland in the form of Dubied knitting machines (Chircop, 2011). There is currently housed in the Fusion Museum Knit and Toys in Wakayama, a knitting machine dating from 1868 called the Ishikawa-Type glove machine, showing that technology transfer was not only happening but also adapted and manufactured within Japan. The Fusion Museum, set up in 2009 by Shima Seiki, records the growth and development of knitwear production prior to and after the establishment of the company. It includes the rib knitting machine and elastic yarn insertion device that Shima developed in 1954, at the age of seventeen (Shima, 2012).

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Figure 9:
1868 Ishikawa-Type Glove Machine at Fusion Museum Wakayama Japan – Retrieved November 10, 2011 from http://www.knitmelbourne.com

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Figure 10:
1954 Rib Knitting Machine at Fusion Museum Wakayama, Japan – Retrieved November 10, 2011 from http://www.knitmelbourne.com

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Adaptation of technology by Japanese companies was taking place in many of the craft orientated industries, which had maintained small family centred businesses and made up a large proportion of the Japanese economy. “Small and medium-scale firms were not in a position to use the most advanced models of machinery. To compensate for this they worked to accelerate adaption of the machinery they did have” (Takeuchi, 2006, p. 14). This adaptation and improvement on technology by Masahiro Shima, which started with the development of the elastic yarn insertion device, was the beginning of many such technological developments for Shima Seiki.

There are remnants of past cultural influences still present within the modern Japanese business world. Junichi Murata argues:

> The characteristics of modern technology are sometimes considered to be universal and context independent, in contrast to traditional technology, which is considered to be embedded in a local cultural context. However, without an environment provided by traditional technologies, modern technologies cannot be transferred and introduced into other contexts. (Murata, 2003, p. 250)

Such traces of cultural influences, such as *ie* and the flexibility of small production businesses, are now being accepted as having played a significant role in the success and speed of Japanese industrialization. *Ie* in Japanese refers to the traditional family structure or household and was until the end of the Second World War used as a legal unit. *Ie* is often associated with a Japanese sense of collective, where the group is more important than the individual. Therefore traditional production systems relied heavily on the selflessness of the individual, who worked for the betterment of the family or group.

However, this combination may also have created an environment where, in the case of design, the group is stronger than the individual, where technical developments, such as the development of the WHOLEGARMENT® machine become the result. At the point of such a radically new development as the WHOLEGARMENT ® machine, the group, in this sense, becomes the embedding of a Western hierarchy within the knitwear industry, that of a technical and design divide. There might have been an opportunity to do things differently. However, what resulted, at the core of the WHOLEGARMENT® system, was a computational division between design and technical functioning, rather than creating a new folding of craft-artisan modes of community and design knowledge in conjunction with the new computational technologies. Though technically advanced, seamless knitwear's design capability remains within a standardized alignment of the mass-production silhouette, and replication of the same is promoted. Such a huge technical advancement needed to also have had a new approach to design methods, to rethink the potential design possibilities of this technology. There was an opportunity with the development of seamless knitwear and the improvement in computational design knowledge, to have created a revolutionary shift to three-dimensional design and production. This has not been the case and both design and production remain within the same alignment of past industrial mass-production Western (now global) cultures and practices.

Seamless Knitwear processes

Seamless knitwear technology is the result of many evolutions of knitting machine development. It produces knitted garments that are essentially ready-to-wear, with little or no assemblage process necessary, post-production. This has many cost advantages for manufacturing companies, because of reduced yarn wastage and lower labour post-production costs (Choi & Powell, 2005; Spencer, 2001; Underwood, 2009; Yang, 2010). Prior to seamless knitwear, all knitted garments required some post-production assemblage, with many companies having a large part of their premises used by cut, make and trim procedures. A higher use of seamless technology can see a large reduction in space usage and thus overheads for a company. Previous methods of knitted manufacturing include fully cut, make and trim, partial cut, make and trim, or fully-fashioned, make and trim.

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Figure 11:
Shima Seiki Manufacturing. (2009) Cut and Sew Knitwear – Retrieved November 12, 2009 from http://www.shimaseiki.com

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Figure 12:
Shima Seiki Manufacturing. (2009) WHOLEGARMENT® Knitwear – Retrieved Novemeber 12, 2009 from http://www.shimaseiki.com

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The development of seamless knitwear has proved to be the first major production swing away from traditional manufacturing processes since the industrial revolution, when knitted garments moved from being hand-knit on-the-round to being mechanized (Black, 2002). My argument is that though seamless technology is a remarkable achievement, providing the first means to produce three-dimensional garments, its main focus has been on technical capability, referred to in Chapter One as technical composition, in distinction to aesthetic composition. The rudimentary design systems developed for WHOLEGARMENT® technology lack all but the simplest capabilities for difference for the designer.

Traditional knitwear design processes are based on the fabric development of a textile swatch, which is then knit to size to produce a front, back, and two sleeves. The required shapes are cut from this fabric using flat-pattern making techniques. Integral knitted trims may have been knitted on to the body (front) and sleeves but further knitted trims are then required for collars or cardigan fronts, which would be attached after the garment has been assembled (Brackenbury, 1992; Choi & Powell, 2005; Eckert & Stacey, 2000; Spencer, 2001). When a designer works with the design system developed to interface with the seamless knitwear technician programme, Knitpaint, and therefore the seamless knitting machine, it continues to promote the above traditional two dimensional knitwear design process. It does this through continuing to follow a scripted standardized design process, which is used within the commercial knitwear environment and has continued to be taught within knitwear design courses (Sayer, Wilson, & Challis, 2006). It continues to promote this two-dimensional process through the computerized imagery used to programme the knitwear on a flat front, back and sleeve shape as seen below (figures 13 & 14).

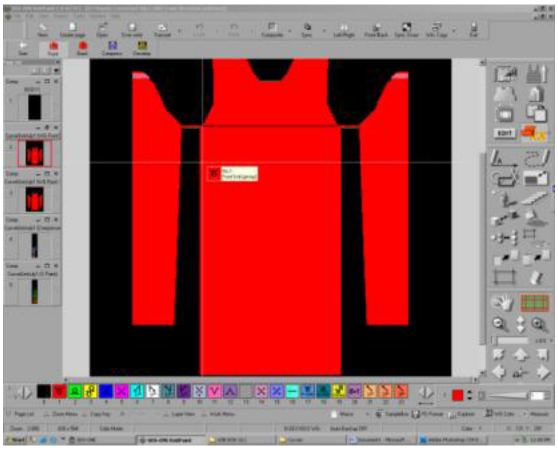

Figure 13:
Smith, A. (2010) Front of shape initialisation in Knitpaint

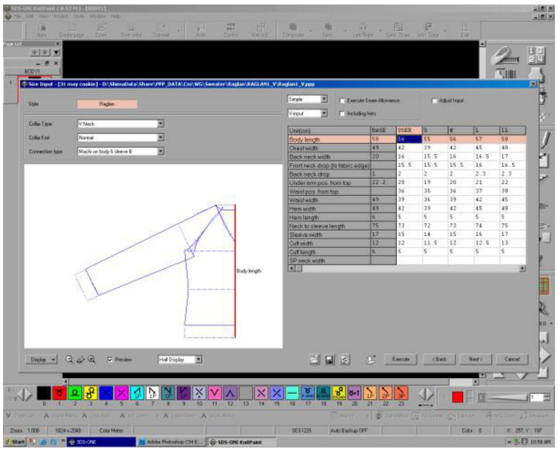

Figure 14:
Smith, A. (2010) Size specification in Knitpaint

It is difficult to imagine these garments as anything other than versions of traditional mass-produced replicas of knitwear seen in our closets for decades. The flat block-like shapes, along with the designer's stitch selection options, where the designer can pick from ready-designed texture or basic colour patterns, all result in a design system at once cutting edge technology from a technical perspective, and yet nothing but a designer's colouring in tool. My research suggests that seamless knitwear technology is successful for mass-production and global markets, where design has become synonymous with preprogrammed shaping, embellished with surface decoration, colour or texture. Yet, there is little support for the designer who wishes to explore the three-dimensional aspect of shape or form differentiations within knitwear. Much of the advertorial and promotional material for seamless technology promotes the view that it operates within a three-dimensional paradigm. For example, in an interview with Mowbray, for *Knitting International*, Shima states: "WHOLEGARMENT can provide a number of advantages over the conventional cut and sew techniques of knitwear manufacture, especially in the construction of 3D fabrics, shaped goods and patterning possibilities many of which we have not yet fully explored" (Mowbray, 2002, p. 5). The uninitiated, such as myself before embarking on this research, have subscribed to this promotional material and believe that innovative three-dimensional garment designs are possible with this technology. This research explores to what extent three-dimensionality is possible and what changes would need to be made to current design methods to enable the designer to participate within a three-dimensional paradigm.

2.2.6 Key research on Seamless knitwear:

Ever since the advent of the role of designer made its way into the knitwear industry in the 1930s (Power, 2007), there has been a technical and design divide. This divide has been both a gender and occupational one, which has been central to a number of academic papers over the past ten years (Eckert & Stacey, 1994; Sayer et al., 2006). The modern European knitwear industry is a result of the industrial revolution and was originally a male-dominated occupation. As women moved into this workforce, primarily after the Second World War, they moved into various roles within the knitwear industry, but that of knit technician remained a male-dominated role. The role of knit technician was, until recent computerization, an occupation that required physical strength as well as needing engineering or machine mechanic skills. Thus the role of knit technician, though now mainly executed at a computer, still remains male-dominant, while women predominantly engage in the role of design.

This gender divide is not, however, the main issue. It is only exacerbated by the different training procedures that designer and technician historically have had. Knitting companies generally train their technicians in-house; designers usually complete a university design degree, or previously a polytechnic or technical college qualification. They thus have very different knowledge bases (Eckert & Stacey, 1994). This historic model of occupational roles within the knitwear industry has formed the basis for the development of the human interface with seamless knitwear technology. There are two separate programming systems, one for the technician and one for the designer. This can be seen through the evolution of design systems for seamless knitwear, which for Shima Seiki culminates in the latest SDS-ONE APEX-3 design and programming system and for Stoll in the M1Plus design and programming system for Knit-and-Wear garments. It was noted by Power (2007) that, throughout the history of knitwear, there has constantly been a "push and pull" between the development of technology and the designer wanting to be able to have more flexibility of design. Power notes: "[I]n this techno age technological developments lead, followed by a period where design explores the boundaries of the technology and then the cycle repeats" (Power, 2007, p. 12). It would appear that this is the current situation with seamless knitwear technology. It is promoted as having endless design possibilities but the reality is that there is still a manufacturing and production focus on technical abilities.

There is currently a culture where knitwear companies send technicians for specialist training with Shima but it is less likely that they will send designers for comparable training. There continues to be a focus by both the knitwear industry and the manufacturers on technical developments and training for technicians as opposed to the design aptitude of both the technology and the designers. This has exacerbated the ever increasing gap between technology and design, which has raised questions about the way that designers continue to be trained within higher education curricula (Power, 2007; Sayer et al., 2006). With the introduction of seamless knitwear technology globally, the urgency for designers to be able to engage creatively with this technology is becoming crucial to the ongoing future of design within the knitwear field. Mowbray stated in 2004: "What we must remember is that fashion sells knitwear as opposed to bulk textile products. … If we do not keep fashion fresh then knitwear will lose market share to other technologies" (Mowbray, 2004, p. 42). Currently the design and programming systems for seamless knitwear replicate and renew established approaches to design and production, remaining entrenched within traditional industrial models for knitwear design and manufacturing, through having two CAD programming systems, one for technicians and one for designers.

Academic Research: Seamless knitwear

There have been a number of international academic research projects, papers and doctoral studies that have focused on the use of seamless knitwear. Much of this research has had a technical or historical focus. Papers such as "Functional to Fashionable: Knitwear Evolution throughout the Last Century and into the Millennium" by Power and "Three Dimensional Seamless Garment Knitting on V-Bed Flat Knitting Machines" by Choi and Powell, cover the broad history of knitwear development and the more specific developments which led to the production of seamless knitwear technologies. The Choi and Powell paper undertakes an in-depth evaluation and comparison between the two leading producers of seamless knitting, Stoll and Shima Seiki, and is a useful source for technical development and process for both companies (Choi & Powell, 2005; Power, 2007).

One of the leading academic studies into seamless knitwear techniques was completed by Jenny Underwood, in Melbourne, Australia in 2009. Her doctoral research, *The Design Study of 3D*

Knitted Shape Preforms, investigated 3D knitted shapes, capable of being used as pre-forms for reinforced composite structures as applicable to industries such as aerospace, automotive, industrial design or architecture. These shapes explore structure and form possibilities within the technical boundaries of seamless knitting, as well as exploring those that could be produced on traditional flatbed knitting machines. From this technical perspective, Underwood investigates the possibilities and limitations of this technology as a 3D form-manufacturing mode. A further focus of Underwood's study concerned the potential for this technology to create a paradigm shift for the knitwear designer from being primarily a 2D surface designer to a 3D structure designer, who integrates surface and form for applications other than clothing. Though Underwood mentions the difficulties faced by designers using seamless design software and its limitations for visualising or designing 3D garments on it, she does not take a garment design perspective within her study. (Underwood, 2009).

One of the other main academic research studies, also conducted as a doctoral thesis and also in Australia, was by Yang, in 2010. It is titled *A creative journey developing an integrated high fashion knitwear development process using computerized seamless v-bed knitting systems*. Yang's research focused on the three main roles identified as important in the production of computerized seamless knitwear: the knitwear designer, knitting technician and knitting machine operator. This identification was with a view to redefining these roles, giving the knitwear designer a more inclusive position within the development of high-fashion knitwear as knit "designer-interpreter." Yang uses a theoretical framework of socio-technical systems, as they are applied to the human roles, technical interface, and work-flow processes within the commercial production environment of the knitwear industry, when working with seamless knitwear technologies. There are many areas within Yang's work that overlap with this research, mostly in relation to the technicalities of using seamless knitwear technology. Yang's research does explore ways for the knitwear designer to be more creative with this technology, but her approach is from a systematic, process, work-flow analysis perspective (Yang, 2010). Where this research differs from Yang's is primarily in my approach as a knitwear designer, whose creative interaction with the technology focuses on the potentials of design differentiations immanent to the technical modalities already available, though closed off by the current design software system.

There are two other doctoral level projects that have researched seamless knitwear technology: *Inclusive design for womenswear through advanced knitting technology*, (Radvan, 2011) and *Crafting the Technological: Gansys and wholegarment knitting* (Shaw, 2009). They both use seamless knitting technology to make garments but with differentiated boundaries from the research discussed so far and one another's research. Radvan's research focuses on using seamless knitwear as a production technique to make garments that work outside of the normal shape silhouette for clothing. Using geometric shapes as starting points for designing, traditional pattern cutting techniques are avoided and an integrated shape is created by increasing fabric where darts or shaping would normally exist and an exaggeration of folds become incorporated into garments. Radvan has investigated this as a means to clothe the disabled as well as the able-bodied, in garments that have integral fit and design embedded within their conceptual grounding (Sissons, 2010).

Shaw works across the technology-craft nexus and creates body blanks in the form of seamless knitted Ganseys that have then been embedded with various cultural contexts, drawn from the fishing communities along the northeast coast of Britain. The Gansey has been traditionally hand-knit, and in-the-round. Using the mass-production techniques of seamless knitwear removes the usual embedded memories of the Gansey's maker, but through post-production craft processes, these emotional connections between the garment and maker are re-established (Shaw, 2009). There are interesting overlaps between these doctoral studies and my research, with similarities in deformation and formation and then with the craft-technology interface, both of these elements are central to this practice-led research.

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Figure 15:
Shaw, A. (2010) *Gansey, Deep-fried,* Retrieved November 12, 2012, from www.artdes.mmu.ac.uk/profile/ashaw

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Figure 16:
Shaw, A. (2010) *Gansey, Fortune Teller*, Retrieved November 12, 2012 from www.artdes.mmu.ac.uk/profile/ashaw

2.3 Design's Folded Encounters

2.3.1 The folds of fashion: memory and matter

I have earlier introduced, from Deleuze, a notion of folding of matter and memory, or the materiality of things and how they have meaning. I have suggested that with his notions of texture and style, Deleuze refers to the myriad ways that matter folds and refolds such that it shows what it is capable of becoming. The Deleuzian theorist, Brian Massumi, discusses this relation of matter and thinking in terms of emergence, how something becomes what it is. He refers to a Deleuzian understanding of the virtual, as a plane of immanence, or the sheer capacity for emergence as such, and actuality, when concept formation and function relations come to self-recognition. Massumi notes in the introduction to *Parables for the Virtual* (2002), concerning the positioning of affect:

> Emergence, once again, is a two-sided coin: one side in the virtual (the autonomy of relation), the other in the actual (functional limitation). What is being termed affect … is precisely this two-sidedness, the simultaneous participation of the virtual in the actual and the actual in the virtual, as one arises from and returns to the other. Affect is this two-sidedness *as seen from the side of the actual thing,* as couched in its perceptions and cognitions. Affect is *the virtual point of view.* (Massumi, 2002, p. 35)

Knitwear is worn stretched. It takes on bodily shape and memories of events, and is constantly becoming itself. Deleuze borrows from the French early twentieth century philosopher, Henri Bergson, the notion of "nuance" (Bergson, 1946) in order to understand how a thing constantly becomes itself (Deleuze, 2004, p. 25). The nuance of a thing is not how it differs from other things but how, in the duration of existing, it has a capacity or capability for alteration. Bergson makes no distinction between the substance of a thing and its capability for alteration, and its duration. Nuance is how a thing is capable of differing from itself, an immanent power of a thing to change. As time is folded, past into present into future, memory is the manner of a knitted garment persisting. It is affected by a body but in turn triggers affects for the wearing body. Gregg and Seigworth further elaborate Deleuze's notion of affect in their introduction to *The Affect Theory Reader* (2010):

> … affect in the midst of things and relations (in immanence) and, then, in the complex assemblages that come to compose bodies and world simultaneously. There is, then, a certain sense of reverse flow between these lines of inquiry—a certain inside-out/outside-in

> difference in directionality … affect as an entire, vital, and modulating field of myriad becomings across human and nonhuman. (Gregg & Seigworth, 2010, p. 6)

The notion of permanence is destabilized, as the material and the immateriality of the object and the subject are affected time-over-time. Stratifications of event and experience build and change. In introducing the praxis of an artisanal approach to design and through introducing nuance as immanent capability to a mass-production process, the linear design process of seamless knitwear is disrupted, an event creating an "affective force that is active, intelligible, and has genuine efficacy: it is both moved and moving" (Thrift, 2010, p. 292). It is in *A Thousand Plateaus* (1987) that Deleuze and Guattari discuss the artisanal in relation to production. They particularly use the notion of "following," in artisanal practices, as in following the flows of matter:

> The artisan is *the itinerant, the ambulant*. To follow the flow of matter is to itinerate, to ambulate. It is intuition in action. Of course, there are second-order itinerancies where it is no longer a flow of matter that one prospects and follows, but, for example, a market. (Deleuze & Guattari, 1987, p. 409)

Through the introduction of craft making, designers are given back options for continued creativity within a mechanized domain. Creation becomes "a force that generates sensory and emotional gratification. It is a force that produces shared capacity and commonality. It is a force that, though cross-cut by all kinds of impulses, has its own intrinsic value" (Thrift, 2010, p. 292). The force of affect emphasizes the haptic over the scopic, disclosing a question of fashion as other than the superficialities of consumerist mass-production, creating blocks of sensation as prehensive encounter, recouped as memory and time in-folded. We have already referred to the *personae* embedded within the memory-works of Shaw, where garments are an expressive bearer or support for forces of wear-and-tear tide-washing (figure 18) or the becoming-image of her grandmother (figure 17).

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Figure 17:
Shaw, A. (2010). *Gansey: Image of grandmother.* Retrieved November 12, 2012, from www.artdes.mmu.ac.uk/profile/ashaw

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Figure 18:
Shaw, A. (2010). *Tide-Washed.* Retrieved November 12, 2012, from www.artdes.mmu.ac.uk/profile/ashaw

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2.3.2 Living one's fashioning: Wabi-Sabi and Japan's affective powers.

I have already briefly introduced Wabi-Sabi as an essential aspect to my research. It is more than a style of design, or an approach to making in the conventional sense of an aesthetic affect. Wabi-Sabi is lived before it is practised. Or, rather, it is a way of living rather than something one applies to particular things. In this sense, it is closer to Deleuze's understanding of style as that singularity by which matter folds and unfolds in its nuanced duration. It is closer to Deleuze's understanding of affect as reciprocity of matter and memory, affect and being-affected, as the opening of things to becoming what they are. Importantly, Deleuze understands this reciprocity, from the German philosopher Spinoza, as the foundation to an ethical life; to maximise one's capability to affect and to be affected. I want to briefly give some background to Wabi-Sabi as an ethos, or an ethical-aesthetic practice.

The twin ideas of evanescence and the ephemeral embody the Japanese aesthetic known as Wabi-Sabi (Inouye, 2008). Wabi-Sabi is an aesthetic ethos, having its beginnings in Zen Buddhism. It is an art form reputed to have been developed by Zen Buddhist monks in the thirteenth century. It was used as a means to decorate their austere dwellings when entertaining, using organic forms that were readily available from the surrounding environment, while still reflecting Zen precepts of simplicity, humility, restraint, naturalness, joy and melancholy as well as the defining element of *impermanence* (Juniper, 2003). Because of its Zen philosophical roots, Wabi-Sabi is a difficult term to fully describe and one which Japanese scholars find elusive. In the essays on Japanese beauty written by Sōetsu Yanagi, a collector and expert on Japanese craft-based pottery, he notes:

> *Wabi* is the objective for which we all strive—literati as well as laymen. But to expect its full comprehension by all people would be asking too much. For the idea cannot be demonstrated by physical sense; it must be conveyed by formless spirit. (Yanagi, 1972, p. 184)

Founded in Zen Buddhism and the endeavours of the monks to use art and craft forms as a means to reach an enlightened mind and therefore spirit, the essence of Wabi-Sabi is associated with many traditional art forms. At Wabi-Sabi's simplest, it is seen represented by the tea ceremony, painting, flower arranging and Noh dramas, with common links between these areas of a naturalist form, space, serenity and irregularity being prominent. At its more complex, it is representative of a way of being which strives to return to an intuitive response of the focused but "emptied" mind, to nature. "The artists must make themselves 'slender' so that the object can lead the artists toward grasping and identifying with its essence" (Saito, 2003, p. 130). It is perhaps in this sense of "leading" that we may recognize a resonance between the Deleuzian artisan who follows the flows of matter and the Japanese artist who makes herself "slender."

Wabi-Sabi is a combination of two words, Wabi and Sabi, which have similar but different meanings. Wabi is a three-sided pyramid of simplicity, irregularity and austere beauty, while Sabi is described as old or faded, but in a naturally withered way: "one of quiet harmony and peace" (Haga, 1995, p. 54). They come together to form an ethico-aesthetic sensibility that often describes traditional Japanese craft and art products. It has become known throughout the Western world as an "aesthetic", though bears little relation to the emergence of this term within Western scholarship since the late-eighteenth century. It is seen to represent a certain quality of craftsmanship and a design philosophy, which has been adapted and transferred into architecture, interiors and textiles, as well as painting and objects for home use. It is, at once and without differentiation, everyday and singularly remote and ritualistic.

Wabi-Sabi is the art of *impermanence*, perhaps what Deleuze might term, becoming-imperceptible. It relies on matter's processes of degradation through change as an object is made and ages, expressing an object's nuance in a Bergsonian sense. It expresses the organic nature of matter as the designer or artist works with material, responding to the flows of matter as an object is formed. This transient, fragile nature of Wabi-Sabi is constantly changing and is therefore never complete, again echoing Deleuze's understanding of constant becoming, and that forces–affects or sense-events constantly reform or make their mark on an object or person, creating a singularity of form in a unison of matter–memory. Wabi-Sabi's impermanence, inconsistency and incompleteness recognize the im/perfection of all things, and that whereby the hand of the artist is expressed. It thus rejects perfection and a uniformity seen with mass-production processes, creating a singularity of affect connecting an artisan and the way of making. Creating in this way leaves room for a designer to respond intuitively to the emerging materiality of forming.

This creates the *interval*, which allows the designer to move outside of her known experience and an intentional object, to develop beyond representation as repetition of itself. "… only those who have transcended the boundaries of dualism, who have succeeded in stopping their internal dialogues, who are able to perceive the world in its 'is-ness' are able to be creative in the truest sense of the word" (Juniper, 2003, p. 95). Andrew Juniper recognizes that Wabi-Sabi challenges what is seen as a learned norm for the beautiful or the ugly. Because it lacks symmetry, lacks order, and utilizes that which is essentially organic and, as such, is so by differentiation, the "is-ness" of Wabi-Sabi is difficult to categorize using past learned experiences of beauty—usually synonymous with completeness, order and symmetry:

> … wabi sabi is not in the realm of learned ideas of beauty and ugliness, it lies in an intuitive, non-intellectual feeling toward objects that can bring about the wabi sabi experience. The real beauty that we can enjoy in true and pure aesthetics is neither beautiful nor ugly. It is the magical state that happens before any of the concepts have found voice in the intellect. (Juniper, 2003, p. 111)

This is the point of fold and refold, between subject and object, between past, present and future, between the virtual potentials of a differentiated actual. It is the prehensive block of sensation on a plane of composition that sets a self in motion, as the thing that affects so opens a self to its capacities: how can I relate to things? How can I comprehend things?

Wabi-Sabi provides a method of making for this research project. Because of Wabi-Sabi's opening to temporal instability that seems polarized to seamless knitwear's standardizations, it opens a way of asking anew what this machine is capable of becoming: how can I relate to it differently? How can I comprehend it differently? Wabi-Sabi is not a "look" that I was seeking in machine outputs. It was a way of artisanal-following the flows of matter as they became assembled in the modulating capabilities of a WHOLEGARMENT® machine. Wabi-Sabi provides an asymmetrical fluidity to form building through the yarns I used and my response to these and their materiality. Wabi-Sabi has pushed the garments away from a known structural model, accessing further potentialities of de/formation. As each garment emerged, the reciprocity of affects–being affected happened in the expression of the flows of matter: intuition in action, as Deleuze says. I came to understand the nuances of the machine, the nuances of the yarn and the nuances of their relations and potentialities. I developed a style, in Deleuze's sense, a way for matter to become texture, to find its own nuanced expression. Deleuze says it better: "Whether active or passive, derivative forces of matter refer to primitive forces which are those of the soul. But always the two levels, their harmony, and their harmonization." (Deleuze, 1993, p. 42)

A Wabi-Sabi design process incorporates the unfinished, the flawed, or the incomplete, which every designer would recognize as that feeling at the end of a project where all imperfections stand out or the idea that didn't get trialled resurfaces, leaving you wondering … what if? For Wabi-Sabi and for Deleuze there is no finished product. All things continue evolving, changing, becoming, moving from the virtual to the actual and actual/virtual, continuing to create differences through these perpetual movements of folded matter and spirit:

> The inside and the outside: the infinite fold separates or moves between matter and soul, the façade and the closed room, the outside and the inside. Because it is a virtuality that never stops dividing itself, the line of inflection is actualized in the soul but realized in matter. (Deleuze, 1993, p. 39)

Wabi-Sabi things are never completed but continue to develop and evolve as time makes its marks on them, through stains, shrinkage, stretching or tarnishing. The life of a garment continues to differentiate itself in production, through wear, through organic processes of degradation and disposal, a never-ending encounter of becoming itself.

2.3.3 **West into East: Japanese fashion design and global markets.**

> Wabi is a very intimate premise that comes from within. A personal philosophy that is found in the interior of the soul. A totally individual way of seeing, feeling and thinking. There are no boundaries, no borders, no beginning, no end. This means there are no hard-and-fast rules, dogma, or convictions. (Vervoordt, 2010: 11)

Characteristics of Wabi-Sabi are attributed to influencing fashion created by some of Japan's most important designers: Rei Kawakubo of *Comme des Garçons*, Issey Miyake, and Yohji Yamamoto in particular. This cultural Japanese aesthetic was noted when they first emerged on to the European fashion scene in the 1980s, and not in a positive vein. Harold Koda published an article about Rei Kawakubo, the founder and designer of *Comme des Garçons* in 1985, titled "Rei Kawakubo and the Aesthetics of Poverty" (Koda, 1985). Other press-releases at the time described their fashion as rags, World War III survivors, or bag-ladies (Steele, 2010). This initial backlash towards the Japanese designers was due to a lack of understanding of the new silhouette and styling that was shown in their collections when they first arrived in Europe; Miyake in 1973, Kawakubo and Yamamoto in 1981 (Kawamura, 2004). At the time, European fashion was body-conscious and form-fitting. The Japanese showed garments where cultural clothing influences could clearly be seen, even exaggerated, in shapes that resembled Kimonos, in fabrics that were rustic, and in colours of predominantly black on black. These garments were loosely fitted, with layer-over-layer, wrapped and overlapped, covering the body and creating an androgynous silhouette. They challenged the European ideal of fashion with a look that had cultural identities embedded within it.

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Figure 19:
Kawakubo, R. (1982). *Comme des Garçons lace sweater.* Retrieved November 8, 2012, from http://collections.vam.ac.uk/item/073390/jumper-kawakubo-rei.

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Figure 20:
Yamamoto, Y. (1983). *Blended wool coats and integrated bags*. From Yohji Yamamoto, Editor Salazar, L. (2011). V&A Publishing, London.

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designers were becoming. Through cultural aspects of Wabi-Sabi, these designers used asymmetrical layers, unfinished hems and edges, deliberately created holes, moved the placement of arms and neck holes, thus displacing and disturbing garment norms as perceived in the West. Steele cites Koda on Rei Kawakubo:

> … she has been influenced by a thousand-year-old canon of aesthetics according to which there is a beauty in poverty and simplicity no less than in richness and ornamentation. Imperfection itself can add to an object's beauty because it reminds us of the frailty and transitory nature of things. (Steele, 1991, p. 186)

Many of these garments were made from fabrics that also challenged the norm. Issey Miyake used Japanese utilitarian cloth, traditional farmworker or *sashiko* quilted cloth. He noted: "This tough cloth for working garments and *kendo* and *judo* outfits was softened and adapted for industrial manufacture" (Holborn, 1995, p. 30). One of *Comme des Garçon*'s most famous garments is the *Lace Sweater* from 1982, pictured in figure 19. It is reputed to be the result of a deliberate disruption of the machine to create the holes, adding an irregularity and elements of a handmade or craft imperfection to the fabric, though this sweater was actually hand-knit. Kawakubo suggested, concerning this sweater:

> The machines that make fabric are more and more making uniform, flawless textures. I like it when something is off—not perfect. Hand weaving is the best way to achieve this. Since this isn't always possible, we loosen a screw of the machine here and there so they can't do exactly what they are supposed to do. (Steele, 1991, p. 186)

These processes of rethinking tradition and reconfiguring technology have continued to be the *modus operandi* of many Japanese designers. They work with traditional textile manufacturers within Japan to develop new fabric forms and technology adaptations, which incorporate elements of craft and craft-making techniques. Following these *personae*, this research-through-practice has reinterpreted the high technology process of seamless knitwear shaping, incorporating traditional knitwear knowledge and techniques to rethink the possibilities of knitwear silhouettes produced via mass-production methods but having a designer's artisanal following of material flows. As Miyake suggests: "Traditional hand-craftsmanship all over the world must continue to be appreciated by all people, not just the chosen few. The only way to achieve this is by making tradition modern through technology" (Holborn, 1995, p. 104).

Miyake's Spring/summer collection of 1989, *Cicada Pleats*, incorporated the technology of heat-pressed pleats on polyester fabric inspired by the Japanese semi-transparent paper *Aburi-Gami*. Final forms were translucent shells, reminiscent of the cicada shell (figure 21). Cicada in Japanese is *utsusemi*, and expresses the temporality and fragility of life throughout Japanese literature. Its relevance is believed to predate Buddhism and to have been embedded within animist doctrine. *Utsusemi* is discussed throughout Inouye's study of Japanese aesthetics, *Evanescence and Form* (2008), with Inouye noting: "As an early image of evanescence, *utsusemi* affirms life's brevity and fragility—the active summer that ends with the death of fall" (Inouye, 2008, p. 13). The significance of the cicada in Miyake's collection of 1989 is just one culturally embedded example that folds his work with the spiritual, whilst acting on the organic, from insects, shells, rocks and the bark on trees (Figure 22). The pleating process was developed through new techniques, mixed with elements of the known. Holborn notes, concerning Miyake's process:

> Unlike the conventional method of pleating polyester with heat and then cutting the fabric to a design, Miyake reversed the process by designing the shape first and pleating the finished form. The pleating press became the experimental focus. … The initial graphic effect was of horizontal and vertical lines, but by turning the un-pleated garment and feeding it into the pleating machine at an angle, diagonally pleated clothes were produced. (Holborn, 1995, p. 82)

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Figure 21:
Miyake, I. (1989). *Cicada Pleats.* Retrieved from Holborn, M. (1995). Issey Miyake. Published by Taschen. Photo by Albert Watson for British Elle

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Figure 22:
Miyake, I. (1985). *Shell Knit Coat*. Retrieved from Holborn, M. (1995) Issey Miyake. Published by, Taschen. Photo by Gilles Tapie.

designers had been actively working within Japan for over ten years before they emerged on to the international scene, and few had heard of them outside of Japan. It was only after these designers were launched in Paris in the 1980s that they were recognized as designers worth noting both in and outside of Japan (Kawamura, 2004).

There remains a Western predominance to globalized fashion, in the sense that this is discussed in Niessen et al's *The Globalization of Asian Dress: Re-Orientating Fashion* (2003). Many Asian designers struggle to strike a balance between a local cultural identity and a global fashioning, while others struggle to remain neutral to both and attempt to create some other identity (Niessen, Leshkowich, & Jones, 2003). Many of the large Japanese corporations have for decades successfully supported Western designers, with Onward Kashiyama having rights to many designer brands within Japan, such as Calvin Klein, Ralph Lauren and Sonia Rykiel, as well as licences to Jean-Paul Gaultier and Paul Smith (Kawamura, 2004). It is interesting to note that this has been happening with Japanese corporations since the 1960s but it has only more recently started to happen in reverse, with Western companies collaborating with Japanese designers. John Smedley has started to work with Japanese designers to produce capsule collections on a seasonal basis. The most recent collaboration is with Junya Watanabe for *Comme des Garçons*, who designed a menswear capsule collection for Spring/summer 2012, knit by Smedley but indigo-dyed in Japan. This illustrates a technologically orientated mass-production method, in conjunction with a craft-based, expressing the nuance of a fabric's style (Smedley, 2012) (figure 23).

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Figure 23:
Watanabe, J. (2012). *Comme des Garçons for John Smedley*. Retrieved August 22, 2012, from www.ldnfashion.com/menswear/john-smedley-junya-watanabe-capsule

> For Western designers, the Japanese market provides a great commercial opportunity but, for Japanese designers, it is not a country where fashion is produced. While Japanese companies entice foreign designers, Western companies entice Japanese consumers. There is no place for Japanese designers … Japan became a fashion leader not in fashion production but in fashion consumption. (Kawamura, 2004, p. 110)

This "paradox," global in its geo-localising, may help to define some of the issues that have already been addressed in relation to Shima Seiki WHOLEGARMENT® technology, in its adherence to Western production models. I needed to look at other Japanese *personae* and some of the ways that Japanese designers, such as Miyake, have been successfully breaking codes with new technology by using artisan techniques as starting points. This is seen with the *Pleats, Please* range, with *A-POC* and more recently with *Origami* and the new label, *132 5*, referencing the one-dimensionality of fabric, the two- and three-dimensionality of a garment, and the fifth dimension constituting bodily interactions with a garment (figures 24 & 25).

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Figure 24:
Miyake, I. (2010). *132 5*. Retrieved January 29, 2011 from http://www.2121desightsight.jp/en/program/reallab/works

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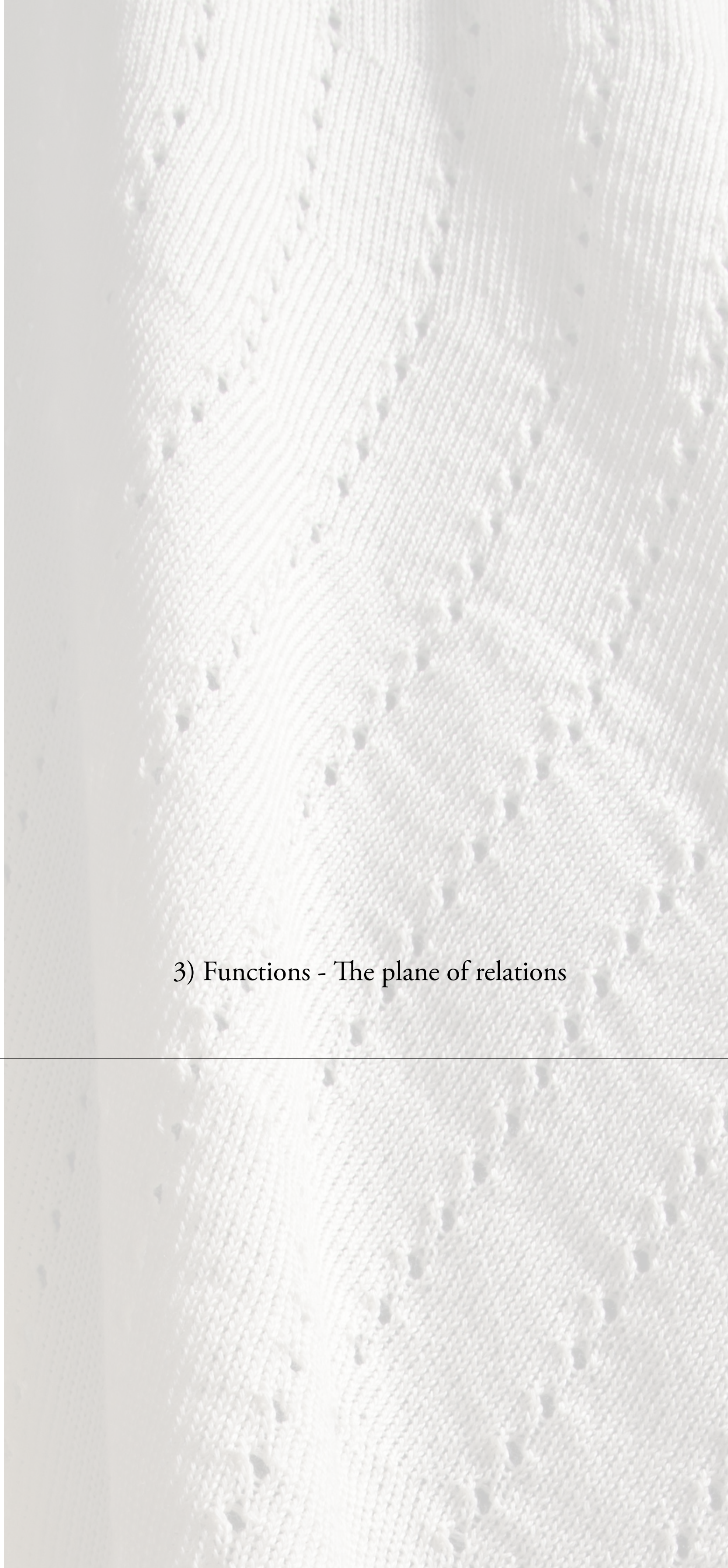
Figure 25:
Smith, A. (2011). *132 5 store in Omotesando, Tokyo, Japan*

At this point, seamless knitwear technology works, but designers are not able to invent at a level that the technology may yet allow. Seamless knitwear technology has the capability to produce garments not previously possible. Knitted structure and texture may be incorporated without postconstruction. Seamless knitwear is a fast production mode, capable of three-dimensional shells with innovative shape. To enable this to happen it is necessary to re-access how the designer interacts with seamless knitwear technology. This means seeing the machine itself, in what it can do, from the point of view of its modal essences: what its powers of transformation are and how the limits to those modes, which is to say, the degrees or powers of modification, can be thought otherwise. This happens from the bottom up, initially by prospecting and following the flows of materials, by understanding yarn, its continuities and capacities for lines of variation. This primarily concerns a new approach to understanding function, what something can do, as the how of its relating, and the degrees of freedom afforded by its conditioning capture of variations. In what follows, in Chapter Three, I look at function, how things happen, both in terms of how this research process happens but also how a new designer-led process happens with WHOLEGARMENT® technology.



3) Functions - The plane of relations

3.1 **Methodological Relations**

This chapter engages with the key methodological frameworks and methods of procedure. As I have noted already, functions are concerned with what things do, and can do, and hence how they interpret relations with other things in their agency. Thus this chapter examines how this research happens, how it is done and how it develops relations between a concept milieu and a field of affects, and so, what can be made or invented. Functions concern regularities and repetitions. A function is what can repeat itself, and thereby develop a stable order of relations with a milieu. Hence 'methods' prescribe procedures for regulations in doing.

3.1.1 **Practice-led research: Research approaches and approaching research**

This practice-led study is an enquiry into seamless knitwear processes and design possibilities. It seeks to ask and answer questions about seamless knitwear's design limitations and potentialities, to build on the current body of research conducted in this field and add further awareness, through practical knowledge creation.

Research generally is conducted to gain a greater depth of understanding of the physical and theoretical worlds we inhabit. Through research and this greater understanding, we aim for knowledge creation to be transformative within the social, cultural, material and theoretical domains that are our becoming. Research is often characterized under the broad umbrellas of scientific and humanities traditions, with each category falling into further and further subcategories and, in some cases, straddling both traditions. Each research paradigm has its own methodologies and methods of interrogating its discipline, always under construction, never completed.

Design research tends to find itself in an "Interpretivist / Constructivist" paradigm, as described by Mackenzie and Knipe:

> The interpretivist / constructivist researcher tends to rely upon the participants' views of the situation being studied and recognises the impact on the research of their own background and experiences. Constructivists do not generally begin with a theory … rather they

> ‘generate or inductively develop a theory or pattern of meanings’ throughout the research process. (Mackenzie & Knipe, 2006, p. 197)

Broadly, this research follows an interpretivist model of research practices, inductively developed in the sense just mentioned. It was Donald Schon who first mooted the idea that the field of design research is an interpretivist activity in *The Reflective Practitioner* (1983). Through Schon’s work a practice-based epistemology has been developed. Swann notes: “Schon formulates an epistemology of practice based largely on an examination of the way in which practitioners reflect on their actions during and following their work. Reflection ‘in action’ and reflection ‘on action’ are key concepts in Schon’s scenario” (Swann, 2002, p. 50).

Development of these ideas has resulted in Action Research being recognized as a valid methodology for design research, with practice-led research, such as this study, one of the subcategories of this methodology. I will discuss more fully the strategic methodological deployment of Deleuze below, though note in passing the emphasis placed in these references above, and generally in design research literature to epistemology as a key concern. What marks Deleuzian thinking is its emphasis on ontology rather than epistemology, as the general correlationist framework for epistemological concerns—subject, object and correspondences, whether idealist or realist, constructivist or rationalist—are seen as secondary or derivative problems to more originary considerations with existents and their existence. Nonetheless, epistemology cannot be ignored as it is the referential milieu of most design methodologies in one way or another.

3.1.2 Methodology as a cohering of variations

Design is a twentieth century innovation and has its roots in the original guild and craft practice traditions (Friedman, 1997). Friedman notes:

> Intelligent designers are moving beyond craft skill and vocational knowledge to professional knowledge. They do this by integrating specific design knowledge with a larger range of understandings. This includes understanding the social, industrial and economic circumstances in which the act of design takes place. (Friedman, 2000, p. 13)

Crouch and Pearce note: “The designer practices in an ecology that is both material (to do with production and objects) and ideological (to do with ideas about the purposes of production and objects)” (Crouch & Pearce, 2012, p. 3). Both the cultural and the social environments in which knitwear designers are immersed, influence their design decisions, their design practices and outputs. This is also true of the design researcher. With this study, the cultural, social and employment experiences of encountering Japan had significant influence on the development of this research.

This point of view, that is, my becoming-myself, needs to be recognized and acknowledged as the nuance or style, the text-texture of this research. One of the ways that a researcher in design can do this is through "reflexivity," a social science method of self-conscious awareness of social, cultural or political influences that a researcher may carry (Crouch & Pearce, 2012). This self-awareness, or recognition of one's own self-becoming, and its inseparability from methodology and methods, for they happen in the same milieu, are a distinguishing difference between a knitwear designer and a researcher working in the domain of knitwear design. Gui Bonsiepe proposed two ways of approaching research in design, which he called "endogenous research" and "exogenous research." Endogenous research is that which emerges from within the act of designing, whilst exogenous research is design observed from outside the practice of designing (Bonsiepe, 2007). In this sense, my research would be endogenous. Its findings fold into the seamless knitwear design body of knowledge and knitwear design milieus. Through working within a design research or practice–led approach, knitwear design researchers can start to link thinking-about-design with the actions-of-design. It is in this way that knit design researchers can acknowledge what came before in the field of (knit) design, what processes they are following to create knitwear and what new solutions result for knitwear design practices, thus contributing to growth and new knowledge within the knitwear design field: "Practice is not just doing but also thinking about actions" (Crouch & Pearce, 2012, p. 39).

Acknowledging each of the issues raised when conducting research in the domain of design, helps to select a methodology that supports a valid and reliable practice-led research study. A chosen methodology needs to resonate with the manner whereby a designer works. As already briefly mentioned, one methodology that supports practice-led investigation, taking an interpretivist worldview, is Action Research. It is encompassing of solution-focused strategies that involve an action-reflection cycle of acting and thinking. It also recognizes the researcher's points of view, brought into play via previous experiences or knowledge developed when engaged with design research study.

3.1.3 **Forces not forms: The enigma of the silhouette**

Methodology orders what is variable or open to variation and thus chaotic. It conditions, and therefore makes necessary what would otherwise be contingent. In this sense, methodology functions, or is that which brings about functioning, which means the determinable relations between things otherwise scattered and indeterminate. Swann described this in a design milieu: “Design deals in human interactions with artifacts and situations that contain a great deal of uncertainty. Design research is tied to a domain that derives its creative energy from the ambiguities of an intuitive understanding of phenomena” (Swann, 2002, p. 51). It is the designer’s intuitive leap, possible when moving between the known and the unknown, as experienced through doing things when habitual practices are removed.

This “intuitive leap” has been encountered in Deleuze’s mention of an artisan prospecting and following the flows of matter. Deleuze calls this folding of affects, concepts and functions a “sense-event”, which creates textural nuances of potentialities understood intensively as force, rather than extensively as form. In addressing Deleuze’s notions of intensities and differentiations of force for the creation of knitwear, I recognize Swann’s “intuitive leap” more as the enigma of a silhouette, shadow as a thing’s semblance, than as its form. This enigma-shadow-silhouette swarms on a virtual plane of potentialities, a field of forces before it actualizes within the concrete modalities of its material possibilities. Such a Deleuzian methodology is not at odds with the epistemic drivers of design methodologies. Rather it folds their concerns into a prehensive and intensive concern with the opening of matter and memory to stratification-formation itself.

Force works at two levels; between percept (the prehending of sensations, how they fold with this body) and affects (what sensations do to this body, how they modify it). This is the virtual opening of a body-thing couple for actualization and creation of the new, by moving the designer to concrete forms and finalized functions. In this sense, I encounter seamless knitwear technology and the yarns used as forces to reckon with, intensively, before they become extensive: so much unformed matter (what is this yarn capable of becoming?) and non-finalized functions (in what manner and in how many ways can this machine couple with matter and bodies?). They create differentiated movements immanent to the conditioned relations so formed. These forces settle into the finality of garments, formed matter and finalized functions. Knitwear can be created through holding certain areas while knitting others, creating areas of intensities, playing-off areas of extensities. As a body moves, these intensive/extensive plays fold and unfold, as movements of sensations or affects are encountered as body passes into garment and garment into body–the sense-event of knitted style (Deleuze, 1993).

3.2 Relations of Methods

3.2.1 Action research: What is reflection?

It was Bruce Archer who stated:

> There are circumstances where the best or only way to shed light on a proposition, a principle, a material, a process or a function is to attempt to construct something, or to enact something calculated to explore, embody or test it. (Archer, 1995, p. 11)

To enable a better understanding of seamless knitwear processes and functions this is what has had to happen during this study. Drawing on "Research through Practice," I needed to make garments using seamless knitwear technologies to enable a reflective process to take place, eliciting an active response to what was observed (Archer, 1995). The directional effects of a play of forces, called "vectors," become discernible only through the creation of each garment. It was through observation of how a finished garment draped or twisted, or how internal movements became apparent, that the collective series of garments was progressed. Designing in this way became very personal, though curiously non-personal as well, in as much as my point of view by which observation and inductive reasoning could be mustered was itself intrinsically also under construction. Who or what am I when struck by sensation, when it is neither a subjective whim nor objective validation that rouses an indescribable affirmation, an intuitive leap and acceptance of what has seemed to happen as if I was looking on? As such, a reflective process of progression becomes important to this study, such as that found within Action Research. Though, perversely, it is as if, when everything that has happened does happen, I am strangely and radically passive; a sense-event that engulfs me and leaves me behind as a self who can only then see what has happened. I am always catching up to my own becomings.

Action Research has been used across many different domains of enquiry and therefore has a variety of interpretations and applications, some more structured than others. Swann (2002) discusses ways that designers can apply Action Research to practice–led research. Swann recognizes design as an interpretive mode of research, rather than a positivist mode:

> Interpretive research accepts data and findings as containing bias and that it is inevitable that many human cultural values are embedded in the interpretation of phenomena. This is much closer to the designer's personal interpretive analysis of problems, and the creation of potential solutions based on individual insight. (Swann, 2002, p. 51)

This recognizes that the practitioner/researcher *is* a point of view to the research process. As Archer states: "Action Research is almost always situation-specific … its findings only reliably apply to the place, time, persons and circumstance in which the action took place" (Archer, 1995, p. 12).

Swann argues that the design processes followed during the action of designing are very similar to those followed during Action Research: "I suggest that action research and the action of designing are so close that it would require only a few words to be substituted for the theoretical framework of action research to make it applicable to design" (Swann, 2002, p. 56). Swann's interpretation of the design process is "problem/ research–analysis–synthesis–execution–production–evaluation," which does resemble the "plan–act–observe–reflect" description of Action Research by Zuber-Skerritt (1992):

> In brief it is a spiral of cycles of action and research consisting of four major moments: plan, act, observe and reflect. The plan includes problem analysis and a strategic plan: action refers to the implementation of the strategic plan; observation includes an evaluation of the action by appropriate methods and techniques; and reflection means reflecting on the result of the evaluation and on the whole action and research process, which may lead to the identification of a new problem or problems and hence a new cycle of planning, acting, observing and reflecting. (Zuber-Skerritt, 1992, p. 56)

Any designer or professional practitioner can relate to Action Research cycles as seen above. The added element of reflection and documentation of processes would not normally be so formally executed within a professional design environment, but they do occur. The practice component of this research follows an Action Research model using design processes. However, this cyclical process that resembles design practice processes is only one of the features of Action Research. For design to follow an Action Research methodology other conditions must be met. The research must be concerned with fostering change in practices. In the case of this research, this could be seen as "practice to improve practice" (Bowen, 2009). This happens through the evaluation of the impact of seamless technology on the designer's role and the global implications that this technology is having on knitwear design outputs. The third condition is its participatory nature. With this study, this is a harder condition to adhere to. As I am the researcher/practitioner participating in the design process as well as the one reflecting on the outcomes, the researcher is in this case also the participant. Much of this research relies on development of technical knowledge which, when applied to a garment outcome, creates an opportunity for reflective practice to take place within a broad industry milieu.

3.2.2 The pre-theoretical and the re-encounter

> Memory is not constituted after present perception, but is strictly contemporaneous with it, since at each instant duration divides into two simultaneous tendencies, one of which goes toward the future and the other falls back into the past. (Deleuze, 1991, p. 118)

I have already mentioned how Deleuze borrows the notion of nuance from the philosopher, Henri Bergson. It is Bergson's understanding of the continuum of matter and memory, their differentiations constituted in how we encounter duration that reflects on this project's approach to the temporalizing of design, its research and the duration of garments themselves (Bergson, 1911). For Bergson, as for Deleuze, intuition presents itself as a return—what is rediscovered in the movement that takes us from matter, as the congealing of movement, to memory as that which retraces the sensations by which matter was initially encountered. That movement is duration itself. In duration, the past is not behind us but contemporaneous; to be unfolded and refolded, constituting the present of its movements.

I have tried to maintain these notions of matter, memory, duration, past and future with this project. It was advanced through a reliance on past knitwear design knowledge to initiate designs using seamless knitwear technology, though such a "past" is subliminally contemporaneous. My initial garments needed to be made out of the points of view that consisted as my design knowledge and the material relations of my knowhow—intuitive prospecting with yarns and pre-theoretical encounters with the seamless knit technology. A garment arrives, and for the first time I am able to retrace from this congealing of movements that constitute the formed matter, to the intuitions-in-action that opened the plane of immanence. This constituted the momentum of a repetition-in-difference, the shuttling of duration's pastness and futurity, but also its virtuality, its intensive forces and its actualization, its extensive forms and formations. This process of reflective development worked both inside and outside of the internal seamless knitwear design system, by combining the functional processes of the technology with intuitive responses to each garment's affective qualities with design memories.

Hendrix explains Deleuze's concept of the fold through the architectural structure of the spiral found in the Baroque period:

> Leibniz conceives of a continuous physical unfolding of matter with continually changing points of view. Aggregates of individual substances are interwoven in an infinite number of ways, wherein the position and interplay of the substances is constantly changing. The

> coincidence of opposite spatial relations, horizontal and vertical, produce a spiralling effect, as in the Baroque, of movement and change. (Hendrix, 2003, p. 118)

It is through the encounter followed by the re-encounter with each cycle of reflection and action, as an Action Research methodology is applied to the process of making or doing, that the living situation is always approached for the first time. It is through the re-encounter that reflection is possible, giving the "space" to see things with acuity. In the case of this project, the re-encounter elucidates the play of forces virtually constituting each garment expressed in the flows of material and followed by a prospecting itinerant maker. Deleuze's Bergson, in *Bergsonism* describes this reflective-space-time movement as the "interval" or "duration" (Deleuze, 1991).

Working with a technology which has repeatable functions inbuilt, it is possible to replicate the same, but due to the 'interval' in time during which a reflection, or reflexion (as it is more corporeal as affect than it is intellect, or at least a fold of the two) manifests, the next iteration will always differ from itself. Iteration is constructed, each time, with a new consistency of composition. Rajchman describes this aspect of Deleuze's philosophy in "Connections" as a "conceptual trip" or "voyage":

> There are different conceptual 'bits', each initially introduced in relation to a particular problem, then re-introduced into new contexts, seen from new perspectives. The coherence among the various bits shifts from one work to the next as new concepts are added, fresh problems addressed; it is not given by 'logical consistency' among propositions, but rather by the 'series' or plateaus into which the conceptual pieces enter or settle along the web of their interrelations. (Rajchman, 2001, p. 21)

When re-encountering a garment through reflective processes, its composition or interiority contains its singular memory, though externally each garment contains its own exteriority. Thus each is differentiated from itself through its embodied duration.

Because knitwear is created from a single yarn (or in the case of machined knitwear several cones of yarn) each yarn used incorporates its own memory, becoming intertwined and differentiated through the process of knitting. In fact, knitting is, perhaps, exemplary as a Deleuzian rhizomatic processual becoming. Each structure, each garment created would be "different in kind" from any other as each builds and combines differentiated memories in its always incomplete becoming itself (Deleuze, 1991). The technology of seamless knitwear programmes (algorithmic functions) allow a regularity to be accessed, as the conditioning of variables, or modal structures permitting degrees of freedom for modifications. Folding creates a differentiated series of garments, a swarm as collective force of modulations, with each related through external conditions but always individuated, as there continues to be a differentiator immanent to a garment's singular modal becoming itself.

3.2.3 **Writing actions**

The design researcher needs to make clear the processes of engagement, such as needed in a practice-based study through the thinking and making of garments. This process entails a constant movement backwards and forwards through doing, reflection, documentation/memory reflexion, and then doing again. Through these loops and detours between thinking and doing, there are constantly shifting intersections so documentation is needed to map these intersecting directions as a time–process–thought cartography. These interior and exterior movements of the conscious/preconscious self, need to be explained. This happens in this research through the visual documentation of thoughts-images through sketching, as well as intersecting with written notes or theoretical engagements which return me into the making process.

This movement can be a very linear one such as seen in the Design System within the seamless knitwear programme. Or it can allow events to unfold, to create and influence an experimental thinking process which is constructed, dismantled, re-constructed; as parts co-exist, linking backwards and forwards through documentation and memory. An Action Research spiral has allowed a process of developmental stages within this research to be illustrated, with new points of view or design knowledge being incorporated into each cycle. This idea can usually be used to chart design development processes using a designer toolbox: drawing, illustrations, rough sketches, toile or modelling on a mannequin, and specification drawings. All of these become visual communications, as the result of practical-led engagement with a problem or idea. Due to visual indeterminacies between computer interface and resultant garments when using seamless knitwear technology, the progression of design ideas had to rely on more intuitive processes.

Through the doing/making, I have shuttled between percepts and affects, where percepts are not perceptions and affects not affections: not intentionality but more so prehending thought or action, affirmed before a "why" is considered. These "charts of affects" or "diagrammatics," these visual images convey a thought-image, instinct, intuition, ordering, linking, folding, unfolding, complicating, experimenting towards a design outcome, avoiding folding too soon into formalization and finalization. The doing and thinking is an experimenting with experience, during which a constant selection or diversification process of shuttling to and fro, builds towards this collective garment outcome but more in the way a swarm thickens than in the sequencing of, for example, building a wall one brick at a time. Stefan White describes this, in *Thinking: Objects*, via a product design process:

> This process of thought is what enables us to look beyond our own experience, and test and challenge our habits of thought—to create the new. Deleuze refers to this testing mode of thinking, and all the external expressions made which attempt to interrogate beyond our direct experience, as 'diagrammatic'. He does not mean a particular type of drawing, but all potential ways of thinking (non-representationally). (Parsons, 2009, p. 153)

These abstract diagrams or way of thinking allow relations and effects of an interiority to be revealed, not just exterior effects, whose modality happens in a binary with "cause." Less predictable and multiplicitous linkages and possibilities can be seen as rhizomatic in structure. A rhizomatic structure can open new ways of encountering things which can be complementary to more linear design processes and forms of expression (Deleuze & Guattari, 1987 pp. 3-25). Deleuze and Guattari oppose rhizomes to the arborescent structure of trees, with their linear flows, hierarchy of branches and logical ordering. Rhizomes are chaotic in comparison. If the designer is aware of being immersed in an experimental experience, expressions of the thought–action process can be visual but would be less predetermined, as each rendition is singular in nature and, though related, would always be differentiated from itself, in itself. Therefore writing actions can only be a method of documentation of a time-of-production, before movement is interrupted, congealed, reconnected and moved forward into its future.

3.3 Relations of Concepts

3.3.1 The fold as theory: Deleuze

> A soul always includes what it apprehends from its point of view, in other words, inflection. Inflection is an ideal condition or a virtuality that currently exists only in the soul that envelops it. Thus the soul is what has folds and is full of folds. (Deleuze, 1993, p. 24)

Deleuze's way of looking at life, his ontology, or logic of Being, found in *The Fold*, allows me to draw on past experiences while exploring new zones of design process and experiences. By looking at time and living as a constant path of differentiation, experience is the contemporaneous existing of a past/future as virtual plane. With each actuality, all possible futures change. This ontology resonates on many levels within this research as I have come to realize it. This singularity of a viewpoint, what Deleuze especially borrows from Leibniz in *The Fold*, in terms of the *monad*, is the point of inflection of my past-becoming its realized future possibility. This passage takes place on two levels, much as Deleuze talks about interiority and exteriority as a fold enclosing over other folds within itself, whilst simultaneously unfolding and opening up new surfaces/textures elsewhere. So the artisan-journey-woman of this research has been prospecting-discovering within her practice. Linkages are created within my context, connecting openings and closings, exterior actions that have influenced interior ones or new theoretico/practical thought-images or diagrams: "The best of all worlds is not the one that reproduces the eternal, but the one in which new creations are produced, the one endowed with a capacity for innovation or creativity: a teleological conversion of philosophy" (Deleuze, 1993, p. 89).

Seamless technology is currently operating as a representational model. It has re-packaged what has gone before, but it does have the potential to be a catalyst for change, with its ability to create three-dimensional products and garments. To truly enhance this, a move away from traditional, current processes embedded within the design software attached to seamless technology is needed. This software is currently perceived to be preventing knitwear designers from being able to work intuitively and therefore creatively because of its very systematicity and prescription (Sayer et al., 2006).

3.3.2 Bernard Cache: The frame and the curve of the surface.

There are a number of design arenas that have engaged Deleuze's work, particularly architecture and product design. Of interest to this research are the writings of other design practitioners who have been influenced by Deleuze and the concept of folding. Greg Lynn, an architect, and Bernard Cache, a furniture designer, have both used folding to develop design theories (Rajchman, 1998). As with Leibniz's original premise of the *monad*, that each being contains its whole universe as immanent differentiator, Deleuze argues that it is folding that constitutes life's existence. The concept of the fold describes ways in which the outside folds as our interior. Clare Colebrook describes this as an away move from a binary notion of an inside/outside as separate entities, to a notion containing both inside and outside simultaneously within each being:

> Each act of thought, perception, action or life creates a border between inside and outside. We often think of the inside or 'interiority' of minds that represent or picture an actual or 'outside' world. This would give us a simple binary between inside and outside, subjects and objects or the virtual (representations) and the actual (the world). But Deleuze argues that the distinction between inside and outside depends on specific events within one single plane of being. (Colebrook, 2002, p. 52)

Bernard Cache, in *Earth Moves* (1995), uses the notion of the frame as a means to access the fold and therefore the inside/outside, or as a means to move from the virtual to the actual. Cache draws from Deleuze and Bergson and works within the areas of geographic topology, architectural structures and furniture design. He engages with Bergson's ontology of images through the use of literal visual documents such as sketches, architectural plans or geographical drawings, as well as with abstract diagrams (Cache, 1995). Cache uses the "art of the frame" as a means to "construct frames that function as folds rather than rigid boundaries between outside and inside" (Harris, 2005, p. 39). The surfaces of the fold permeate the frame, thus allowing the movement of abstract images between the virtual and the actual. This process became relevant to this research as I engaged with design via the visualization software attached to the Knitpaint programming system of the Shima Seiki WHOLEGARMENT® machine. Because the visualization graphics were not closely related to the final knitted outcomes, they did not so easily fall into a representational model of abstraction and, in fact, asked to be thought of differentially, as framing devices for what would eventually be produced, limited by the frame of the software parameters, what it allows to be done. Cache emphasizes that framing (or folding) is a "bottom-up" process, rather than a top-down imposition. This suggests that the software programming be no longer thought of as an imposition to design but as a power or capability; as long as it was thought from the point of view of what Cache calls "aggregates of succession," in the iterations building towards a final collective assemblage. As iterations of a garment happen, exterior matter and interior memory frame variations of composition within it. Anne Boyman, in her introduction to *Earth Moves*, explains this moment of the frame:

> … where the whole is not given but [is] always open to variation, as new things are added or new relations made, creating new continuities out of such intervals or disparities. … images are therefore no longer defined by fixed divisions between inside and outside … as outside forces cause internal variations or as internal variations create new connections with the outside. (Cache, 1995, p. ix)

Cache's idea of the frame, with the fold moving between the virtual and the actual, provides a way of approaching the design development process followed and used to develop and decentralize garment outcomes. Garments are designed using a design-imaging system that, due to its diagrammatic format, gives no consolidated idea of the final garment, until produced via the modalities of the knitting machine. These garments are analysed, in terms of what Cache calls their "interval," by which he means how we come to understand distributions and arrangements (in this case of knitted yarn) in terms of vectors, or forces by which those arrangements came about. Only in this way can we adjust the framing either in terms of the materiality of yarns or in terms of the degrees of freedom afforded by the modal essences of the machine, the modifications it allows. Thus the design development process passes through the frame freely, from exterior to interior and back again, with each design modification. As it does so, external events and internal affects function as garments.

3.3.3 **Greg Lynn: The exact, anexact and inexact as design's degrees of freedom**

Greg Lynn, in *Folds, Bodies and Blobs* (2004), explores Deleuze's understanding of differential thinking and challenges some established rules of architectural practice: those of symmetrical, right angled gravitational constructions. By applying a curvilinear and more organic approach that reflects and reacts to the topography of the land, volumetric buildings are created with curvilinear support structures, creating a new principle of curvilinear folded or blob-like architecture (Lynn, 2004). Paul Harris comments on this move to folded architectural design: "Folding architecture creates continuities between site and structure, implementing conceptual designs that entrain perception to follow patterns that connect outside and inside" (Harris, 2005, p. 37).

Folding architecture develops a move away from deconstructivist architectural practice, challenging structural design, space and context, to create a new way of thinking about the blending of complexities of the physical, cultural and social within and without its forms (Lynn, 2004). Lynn refers to Husserl's *Origin of Geometry* (1917) and Husserl's term "anexact" to describe the kind of methodological rigour one requires in producing blob architectural proportions and forms as opposed to the "exact" proportions found, for example, in classical architecture (Derrida, 1982). In geometric terms, anexact form cannot be wholly simplified but sections adhere to a rule set, whereas exact forms are completely reducible and identically reproduce-able. Exact rigour produces the same in each iteration or repetition; anexact rigour produces singularities of difference in each iteration or repetition; for inexact rigour there can be no iteration or repetition. The inexact is formless and "cannot be fixed or reduced because their contours cannot be described" (Lynn, 2004). Deleuze and Guattari discuss these notions in *A Thousand Plateaus*:

> Husserl speaks of a protogeometry that addresses *vague*, in other words, vagabond or nomadic, morphological essences. These essences are distinct from sensible things, as well as from ideal, royal, or imperial essences. Protogeometry, the science dealing with them, is itself vague, in the etymological sense of 'vagabond': it is neither inexact like sensible things nor exact like ideal essences, but *anexact yet rigorous* ("essentially and not accidently inexact"). (Deleuze & Guattari, 1987, p. 367)

Anexact forms are more open but still contain rigour, where parts, but not the whole, are reducible. It is through this mixture of closed whole but open possibilities for re-arrangement of parts that the anexact moves from the replication of the same to a repetition of difference. Lynn has used computational design programmes to create anexact architectural designs. Computational visualization allows generic parameters to be offset by individualized topological forces creating deformations of surfaces and singularities in blob architectural structures. There are connections that can be made between the computer design systems as used for creating folded architectural buildings and the design system used to create seamless knitwear.

The seamless knitwear machine programme, through its mass-production pre-installed shapes and linear programming parameters, is designed as a producer of exact iterations—repetitions of the same. With this project, seamless knitwear has been approached through anexact design approaches—that of iterative difference. The parameters of the computational design system create a structured process and design restraints are present due to pre-installed programmes, packages and knitting machine capabilities. This is the enclosed whole. The design task is to work with the open parts, to manipulate the variable internal modes, the forces of which cause deformation of surfaces and thus differentiations of the whole. There has long been comparisons drawn between architectural practices and fashion design; seamless knitwear could be seen as one of the first forms of whole garment construction methods able to reflect folded architectural practices. However, for knitwear design, there is already a mode of production for such garments whereas folded architectural design has been criticized for having the computational interface but not the building methods for production (Frichot, 2005; Harris, 2005). Harris goes as far as questioning the use of Deleuze's philosophical concepts of space, as extrapolated via folding, within the work of Lynn:

> This application of philosophical concepts in architecture raises interesting methodological issues. Inflected by philosophy, folding architecture's techniques operate top-down, in that they move from philosophical spatial concept to designing abstract diagrams to implementing them in plans and projects. There is a certain irony in this, given that the central concepts of folding architecture are all founded on bottom-up principles. In other words, folding architecture has discovered how to design bottom-up concepts, but not how to practise bottom-up building procedures. (Harris, 2005, p. 39)

With seamless knitwear technology the means are there to manufacture using a bottom-up process; this research facilitates knitwear designers to access this and to integrate a bottom-up design process.

3.4 Relations Folded

3.4.1 Design research methods: The method of folding

Fashion and knitwear design have been described as cyclical in nature; the past gets re-interpreted in the present:

> Fashion repeatedly returns to old forms, as is illustrated particularly in wearing-apparel; and the course of fashion has been likened to a circle. As soon as an earlier fashion has partially been forgotten there is no reason why it should not be allowed to return to favor and why the charm of difference, which constitutes its very essence, should not be permitted to exercise an influence similar to that which it exerted conversely some time before. (Simmel, 1904, p. 152)

Interpretations of past fashions do get revisited but they are always separated from the originals, due to changes in exterior forces such as social environment, fabric developments or new ways of styling. The idea of the past being folded into the present thus changing the future, such as Deleuze describes throughout the fold, is a closer reading of the fashion cycle: less a cycle more a fold. Lehmann discusses this in the introduction to his book, *Tigersprung* (2000), particularly in relation to Simmel's ideas on the characteristics of high fashion: "In order to become new, fashion always cites the old—not simply the ancient or classical, but their reflection within its own sartorial past" (Lehmann, 2000, p. xx). This enfolding of past design nuances the personal. For me, each decade as an active designer has folded experience into my design knowledge and increased the influential potentialities. Tacit design knowledge is built up and draws from eras of design styles or design personae. Influences from the past are contemporaneous with and make up my present, becoming my future simultaneously. Some decades become more influential than others and the folds go deeper. The 1980s, and particularly the emergence of Japanese designers on to the European fashion scene, is one such decade. Holding a strong personal fascination, it affected me in travelling to Japan in the late 1980s. This event created a divergent life path. This fold was to continue to fold, unfold and enfold events and influences, including many elements of this research project. As Deleuze aptly suggests:

> If inclusion is extended to infinity in the past and the future, it is because it concerns first of all the living present that in each instance presides over their division. Because it includes what I am doing right now—what I am in the act of doing right now—my individual notion

> also includes everything that has driven me to do what I am doing, and everything that will result from it, all the way to infinity. (Deleuze, 1993, p. 80)

3.4.2 The Collection is a swarm

The seamless knitwear technology is designed to produce replicated knitwear for mass-production, losing the quality of craft and the nuance of designed details within garments. Through the linear production processes, which are inherent within the design system, repetition of the same is generated, again losing the craft detail that differentiates one product from another via individuation. By working with a bottom-up design process, it's possible to reintroduce an element of this nuance of detail back into the mass-produced without resorting to individualized customisations. By using an experiential thinking process I have cited as "anexact," I moved backwards and forwards through documentation of process, production of garments, analysis and reflection, combining design memory and ways of creating differentiated garments using technology designed for mass-production. By starting with the individual bottom-up process, rather than a universal top-down process, garments that are singular in design were created.

However, the aim of the project was to create a collection of garments. Within fashion, the universal understanding of a "collection" or "range" of garments is not the singular but a collective that belongs through similitude, be that fabric, colour, silhouette or design detail. This method of working, through a process of differentiation, relied on difference rather than convergence to produce a series of garments or a collection. From one point of view there is but a single garment whose becoming is its immanent capability to differ from itself, with the collection so formed a becoming-swarm of this iterative virtuality. The anexact computational processes allow a series of garments that contain singularities through internal differentiated forces, interconnected to one another through their compositional make-up. Each garment is a singularity-creating-multiplicity as each referenced its successor.

3.4.3 The Method of Becoming: Wabi Sabi as an affective becoming

Incorporating Wabi-Sabi within this practice emerged especially after my travel to Japan for Shima Seiki design systems training, in 2011. I revisited some of the places that I had frequented when living there during the 1990s. The passage of time, the affects that living in Japan had on my existence and how it had shaped who I had become, all became apparent. Wabi-Sabi is the way to describe this. On reflection, all of the areas chosen to revisit were of old-style or traditional Japan: temples, old buildings, traditional craft stores and exhibitions; the very antithesis of the Japan seen and experienced through the media, on the streets of Tokyo, during the Shima training, and through the Wholegarment® machine engaged with in this practice. This dualism of the modern and the traditional was a focus of Watsuji Tetsuro, a Japanese philosopher who wrote about Japanese culture and philosophies in the 1960s, and more recently analysed by Graham Mayeda: "The response involves the co-existence within Japanese culture of tradition and innovation, and the difficult process of dealing with the critique of traditional culture which accompanies the adoption of any innovation" (Mayeda, 2006, p. 55). Tetsuro states: "In Japanese culture, the relational nature of human existence is manifest in two ways: the necessity of distinct and different roles for each person in society, and the interplay of interiority and exteriority" (Tetsuro, 1971, p. 57).

Wabi-Sabi as a Japanese ethos embodies the antithesis of mechanic, ordered culture. Inouye notes:

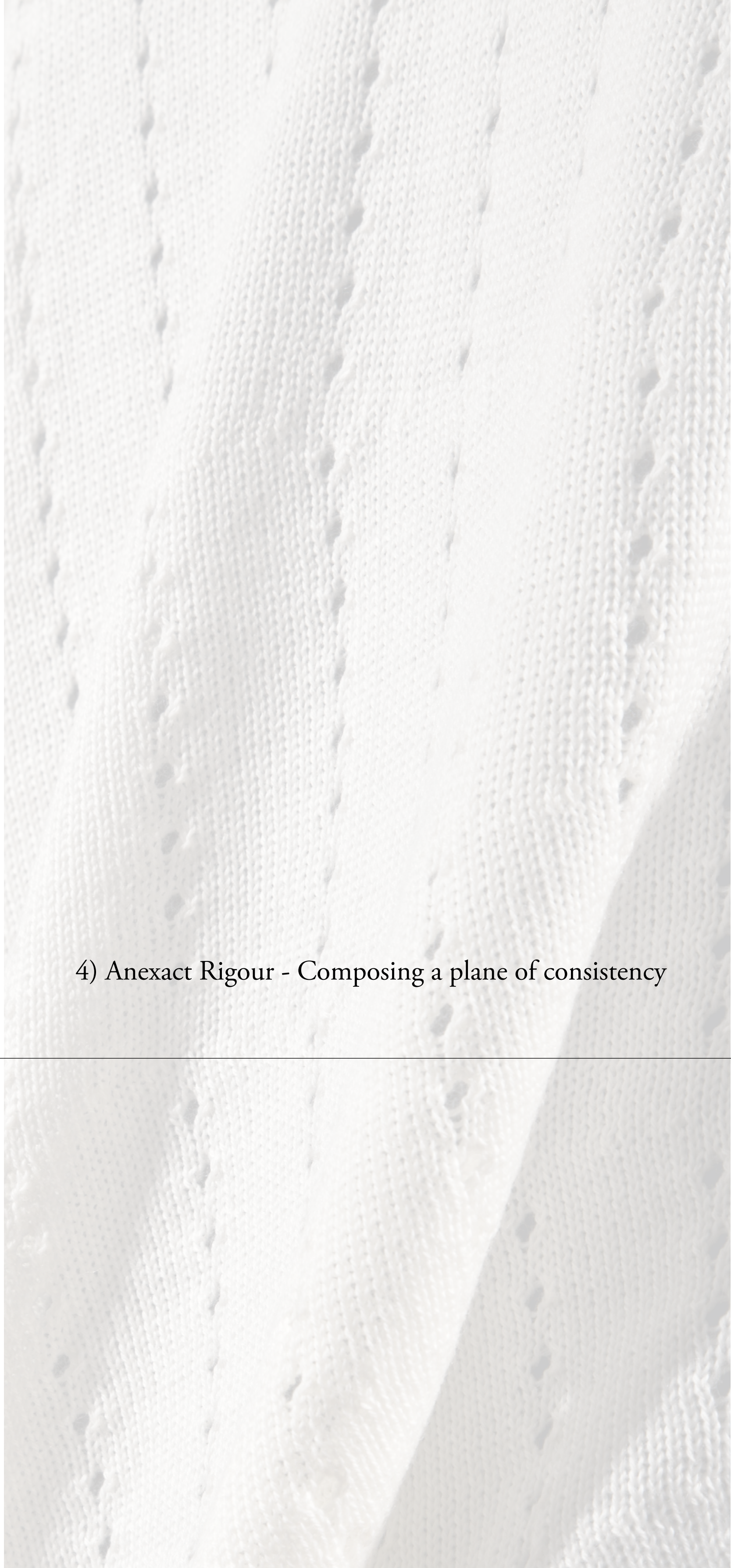
> … what is relevant to our analysis about essences is the claim that emotion, not reason, is the better measure of reality. This surprising assumption follows from what we have come to understand about propriety as a formal response to evanescence. The order of the here-and-now requires there to be an emotional response that is both lyrical and predictable at the same time. (Inouye, 2008, p. 83-84)

In evoking Wabi-Sabi when using seamless knitwear technology, it opens a method of approach, which reintroduces the nuance, traditions, fragility and essences of the maker within the resultant interior garments. Traditional Japanese craftsmen were trained "to make themselves slender" or to relinquish all material, bodily thoughts and past works and allow the material to be worked on to dictate the final form (Saito, 2003). The ways of working in this project adopted a Wabi-Sabi ethos to making, allowing the materiality to lead the making through a process of rhizomatic connecting, aiming for incompleteness, imperfections, and impermanence, creating singular differences in each process and garment. I follow the flows and forces, which means relinquishing a top-down intentionality as designer. I become impersonal or a-personal to the process, in a way unconscious to it. Deleuze puts it this way:

> The perceived as a 'being of imagination' is not a given, but possesses a double structure that allows for its genesis. Macroperception is the product of differential relations that are established among microperceptions; it is thus an unconscious psychic mechanism that engenders the perceived in consciousness. (Deleuze, 1993, p. 108)

Thus each progressive stage has relied on perceptual foldings of developments, one after another, with time and events of the process embedded within: “Tiny perceptions are as much the passage from one perception to another as they are components of each perception. ... These are ‘pricklings’, or little foldings” (Deleuze, 1993, p. 99). While involved in the tradition of making using Wabi-Sabi, Japanese artists and craftsmen followed Zen or Buddhist doctrines. These doctrines encouraged the artist to “enlightenment through engagement, both bodily and mental, with the world … so that the object can lead the artists towards grasping and identifying with its essence” (Saito, 2003, p. 130). There is an element of the spiritual, of enlightenment and of harmony with oneself and the world, within Wabi-Sabi’s philosophy of making, which may be related to Deleuze’s understanding of natural harmony through the Baroque fold and as a means of being creative: “.... this continuity of the arts, this collective unity in extension, goes out beyond, towards an entirely different unity that is comprehensive and spiritual, punctual is indeed… conceptual” (Deleuze, 1993, p. 142). The creative process of Wabi-Sabi is open to interpretation, drawn from parallels with Deleuze’s writings within *The Fold*; no path is the wrong path but each choice will lead to the next event or fold to be discovered to unfold, refold or enfold.

While this chapter has outlined my key methodological orientations, a folding of Action Research and Deleuze’s ontology of folding, we have yet to encounter what I actually did in this research, given the plane of consistency I outlined with its conceptual personae in Chapter Two, and the plane of relations enumerated with respect to the functioning of the research, in this current Chapter Three. In what follows, I provide a thick description of my processes, experiments, and thought-images in order to draw on and draw out the nuance of my research’s concern with its own plane of immanence, or how it folds the matter of research into the tangible actuality of a collection of things.



4) Anexact Rigour - Composing a plane of consistency

4.1 Design as Compositional Structure

4.1.1 Knitwear Technology: Immersion in the Shima Seiki Wholegarment® machine

It was through immersion within the technicalities of seamless knitwear that this research found its sites of practice. The problematic became more defined after engagement with the SDS-One Design System, attached to the Shima Seiki WHOLEGARMENT® machine: why does the design system remain within a two-dimensional design approach? How may this study be an exemplar for other modes of approach to design outcomes? Through engaging with the functionalities of the design system, the approach to this study was clarified: engagement via a non-linear process.

As a designer working with a three-dimensional computerized design system, it would be presumed that the design system would have a visual three-dimensional aspect to it, that the designer would be able to work on a form much like an animated movie—to stretch, morph and add detail to form. In my naivety, this was how I had projected the WHOLEGARMENT® design system—building stitch structures on a three-dimensional framework, adding details such as ribs and trims, shape increases and decreases until a three-dimensional garment was created. This knitted form would then be converted to a technical programme that interfaced with the knitting machine, enabling it to be knit. This projection was built upon my experience as a hand knitwear pattern writer. One designs a basic garment idea, knits a swatch of fabric for tension, and then builds the panels for the garment based upon the stitch and row count, stitch-by-stitch. In hand knitting it is possible to knit a whole garment in-the-round in this manner. This method of hand knitting has historically been used, and is still currently used, to create socks, hats, gloves, through to whole garments; the most notable are from the Highlands in Scotland—traditional Fair Isle and Guernsey patterned knitwear (figures 26 & 27) (Fogg, 2010; Stanley, 1986/1990). The three-dimensional image used by Shima Seiki on promotional websites (as seen in figure 28), reinforces the idea that the Design System has a means to create such virtual whole garments.

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Figure 26:
Fair Isle Knit on Round. Retrieved July 23, 2012, from Shetland Museum http://photos.shetland-museum.org.uk

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Figure 27:
Girl Wearing Fair Isle. Retrieved July 23, 2012, from Shetland Museum http://photos.shetland-museum.org.uk

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Figure 28:
Shima Seiki Manufacturing. (2011). Apex 3D image. Retrieved November 22, 2011, from http://www.shimaseiki.com/product/design

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However, the design training at Shima Seiki in Japan, and then further experimentation with the SDS Design System on my return to Auckland, proved that a three-dimensional design of this sort was not available to the designer or, in fact, the technician. The three-dimensional imagery is only possible after the garment has been created and a shape-image scanned into the system. This image then needs to be mesh-mapped before covering with a knitted textile. This is a lengthy process and unless a basic shape was being repeated season after season, with only a change in the textile colouration required, it would not be worth doing, when a photograph of the finished garment could be used instead. This discovery led me initially to undertake an analysis of what the Design System could do and how it could be of benefit to a designer as a design process tool. I also decided to investigate what it was *not* able to accomplish, that a designer would require. The Shima SDS Design System comprises of two major functions, Design and Knitpaint. In a normal production situation, the designer activates the design component of the Design System, and the technician utilizes Knitpaint. Initially I explored the potentials for using just the design component of the Design System. Within the design component, it was possible to pull up many pre-installed stitch structures as well as create stitch structures on a virtual fabric swatch (as seen below, figures 29 & 30).

Figure 29:
Smith, A. (2011). Virtual swatches from Design training at Shima Seiki Manufacturing

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Figure 30:
Shima Seiki Manufacturing (2012). Stitch Structures, Retrieved December 3, 2012, from http://www.shimaseiki.com/product/design

The variety of stitch structures is endless and easily transferred into the technical Knitpaint programme, to add to pre-installed knit garment shapes. Within the design programme, multiple colour-ways of knitted swatches could be created and coordinated fabric swatch ranges developed. These are also transferable to selected basic pre-installed garment shapes. However, this was as far as the design component of the Design System could be used. From this point, processing needs to be continued in the Knitpaint programme, for registration of the garment to enable knitting on the machine. Within the Design System, there are other tasks a designer can complete but these relate to producing promotional information, such as the “line” or “look-book”, selling sheets with garment design and colour-ways or posters with fabric and garments on models (as seen below, figures 31 & 32). These elements are all part of a designer’s role and encompass a major part of it, especially in the mass-production side of the knitwear and apparel industry.

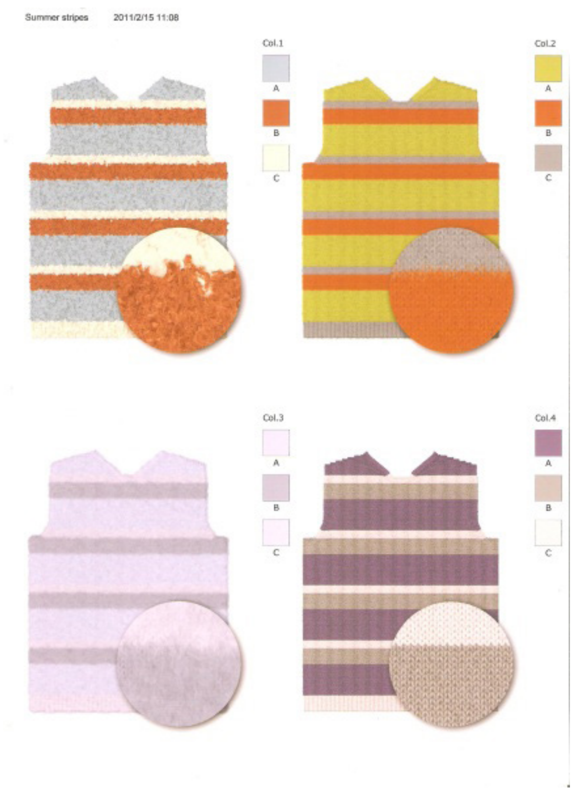

Figure 31:
Smith, A. (2011). Swatch colour-way samples, from design training at Shima Seiki Manufacturing

Figure 32:
Smith, A. (2011). Poster created at design training, Shima Seiki Manufacturing

The area found within the programming of the Design System that was not very flexible was the choice of the shape or silhouette of the pre-installed garments. This realization, along with the fact that all work was done on flat pattern shapes of separate front, back and sleeves, reinforced the notion that the Design System was based on a standardized, two-dimensional cut, make and trim process, with post-knit assemblages of component parts of the garment still needed, when working within the designer's System of this programme. If these designs were to be knitted in a seamless manner, they would have to be handed over to the technician for adaptation within Knitpaint, before they could be knitted as seamless garments. If these were basic designs, then there is no issue with this. However, if a designer wants something that is more complicated and outside of a normal standardized shape format, there are risks of the design being compromised for a number of reasons. Because the Design System is not capable of being used for anything other than a standard shape, designers have no means to draw up, or otherwise project, the design diagram within this current system. This may complicate communication issues between designer and technician, resulting in unintended design outcomes or attenuations by the technician due to complexity of programming (Cross, Johnson, & Eckert, 2000; Underwood, 2009; Wynn, Eckert, Clarkson, & Black, 2008; Yang, 2010).

This implies that currently the design component of this software programme is lacking in functionality for the designer. This prevents them from fully engaging with not only the seamless knitwear arena but also with the cut-and-sew arena, unless they remain within a set group of shapes, as defined by the manufacturer. This may have been developed to prevent damage to the complex knitting machine or may be because the complexities of linking the design tools to the knit capabilities are technically difficult. However, further investigation proves that neither of these is valid. The technical Knitpaint software has a very robust check process attached to it, which alerts the technician to any programming faults or clashes when it tests the knitting programme virtually before knitting, thus preventing damage to the machine. The Knitpaint system is very complex and incorporates the means to do alterations to standardized shapes as well as the means to build original shapes from scratch, stitch-by-stitch, row-by-row, just as a hand-knit pattern would be worked out. This Knitpaint system, however, has been formatted in such a way that it is not accessible to the knitwear designer, even with years of technical background and understanding of commercial practice. Yang comments on this:

> The computerized seamless V-bed package software in SDS-ONE® KnitPaint is conceptually impregnable to a fashion designer. This is unusual because Japanese products are known for their easy-to-follow instructions … it was unusually complicated and technically required engineering rather than fashion design education. (Yang, 2010, p. 171)

My analysis of the Design System has identified that the designer needs a more comprehensive design tool to allow him or her to work more creatively within the SDS Design System, a tool with capabilities comparable to the technical component of Knitpaint. It would need to be in a format that knitwear designers are able to recognize, as opposed to the current format of Knitpaint, and one that reflects their ways of working. The other major finding at this point was the lack of flexibility of the shape component within the system, and the limitations to its modification or variability. This was also one of the areas identified by Yang as needing further research at the conclusion of her study: “There is much still to explore in relation to silhouette shaping in high-fashion knitwear using this technology. The finding in this case is the need for further research in creating design methods for silhouette shaping” (Yang, 2010, p. 139).

These findings also show that designers without technical Knitpaint training have to rely on technicians to programme designs to complete the knit process unless they are of a standardized nature. As previously emphasized, this can lead to mis-communication, re-interpretation of design as well as production issues. A technician producing a sample garment infers taking machine and technician out of production, which may be seen as none productive time by a company. I have found that this can slow the design process time down considerably and places pressure on both designer and technician to complete sample ranges on time.

4.1.2 **Orthodoxies of Knitwear Design**

Knitwear designers have historically worked in a linear design process, exemplified in the development of the Design System component of the computerized system for production of seamless knitwear. Linear design processes, historically followed by knitwear designers, has been the focus of research by Claudia Eckert and her colleagues, using knitwear design as a means to understand how designers use sources of inspiration within an industrial environment (Cross et al., 2000; Eckert & Stacey, 2000, 2003). My own professional experience concurs with their findings, that there are three main stages in developing knitwear design: research, design, and sample making. Each stage has multiple activities that take place within it, and each of these stages has been replicated within the SDS One Design System to complete a virtual knitwear collection. The research stage comprised of themes, new garment shapes, and fabric ideas can be created using the Design System to produce virtual design research boards. The design stage, where ideas generation of fabric swatches, garment shapes and details happen, can also be produced via the Design System, creating flat virtual garments of limited shape variation that include colour and stitch structures. The sample making stage can be converted to the Knitpaint programme if the designer has been working with the Design System, and then knitted by the designer if they have enough technical knowledge, or passed on to the knit technician to programme and knit.

This process is so narrow in its capacity that it is capable only of exact repetitions of the same. The Design System eliminates many of the creative processes that designers traditionally engage with when developing garments. A design process of sketching ideas and working through to final shape development is not available, though obviously this can be done outside of the Design System. A technician would then be needed to programme the garment from scratch and shapes developed would not easily fit into the fixed shape paradigms that are currently available to the designer within this system. The designer is also removed from tactile aspects of knitwear design, the fabric or textile development process. This can be one of the most rewarding aspects of knitwear design, working with different yarns and developing new textile combinations; the more complicated the textile structure or yarn complexities of behaviour, the less likely it is that they could currently be simulated through a digital computer generated image. Peter Dormer makes the observation: “Materials have flaws, and in real life these flaws have to be worked on or worked around but on a computer the material remains imaginary and flawless" (Dormer, 1997, p. 147). The designer will often respond to the haptic qualities of a fabric, to stimulate a final design idea or knitwear collection. Designers are removed from these spontaneous events and therefore removed from responding to the material sensations or affects of such discoveries during the process of making.

These qualities or aspects of design are somewhat removed from this three-dimensional seamless knitwear technology. In their place are all of the conveniences of prefigured shape structures of a limited and standardized range that offer a small degree of variability and whose logic is based fully on two-dimensional pattern forms that are traditionally cut and sewn. This Design System functionality, precisely because of the clear logic of its conditioning of variables, in effect conceals the three-dimensionality of the technology and its design capabilities, or what we might call the unconditionality of design thinking as the inventing of new shape-structures.

4.1.3 **What the Shima Seiki cannot do (and thus what it does)**

On completion of the study of the basics of the Design System, and identifying some of the issues found when using it, I moved on to the WHOLEGARMENT® function of the Design System within the SDS One programme. This was when I realized that there is only one *seamless* pre-installed product template on this system for the designer to access: the glove. There are no pre-installed templates for garments within the design component of the seamless programme, as there had been within the Design System using the older format of fully fashioned knit and assemble. This was significant. I had simply not thought this limitation existed, and seriously asked if the project comes to an end here. This research has worked with the premise that I would be able to explore three-dimensional formations, working with a design praxis offered by the seamless knitwear technology. The discovery that there are no pre-installed designs for the designer to work with within this system, apart from the glove, created a computer interface void, which locked me out of the project I had planned.

Discussion with the AUT Textile and Design Lab technician, Gordon Fraser, and the Shima Seiki support agent confirmed the fact that there are no pre-installed seamless templates in the design system for designers to use as basic design shapes. The only way to work with the pre-installed shapes was within the Knitpaint or technical system. After further investigation I discovered that I could move a template from Knitpaint to the Design programme, add stitch structures or patterns, and then move it back to the Knitpaint programme. But this required either indepth understanding of both systems or good collaboration with a technician. This was a disjointed way of proceeding and led to some consideration of how, as a designer, to move forward with my research. This suggests that any designer working with seamless knitwear design has to be working with a technician, passing on two-dimensional schemas and maybe a fabric swatch; or the designer and technician is one and the same person; or the designer needs to learn Knitpaint to enable her to design and programme in this technical format. During 2012, I was able to visit the John Smedley factory in the U.K., to discover that some designers were not even aware that the SDS system had a design component. Designers worked with technicians to do all of the programming, using two-dimensional drawings to convey ideas, or purchased predesigned garments from Shima Seiki's design database.

This starts to explain why designers are not interacting with seamless knitwear in a creative or high fashion design mode. There is not an access route for designers within the SDS Design System, leaving designers reliant on technicians to programme for them, or the predesigned Shima Seiki garments as seen at their design centre in Tokyo. The only flexibility of design capability within the SDS Design System is accessed through the technical programme, Knitpaint. My options then became: to use the technical programme on the SDS Design System; to design with the help of a technician for programming or to complete a non-practice orientated study documenting the history and use of seamless knitwear technology. As a designer, the driving force of this research has been to design with this technology. This juncture clarified the focus of the study; to continue with practice, with an emphasis on developing a way for the designer to interact with seamless technology in a more original way. For this to happen, further basic knowledge of the technical programme Knitpaint was needed, in order to find a means for working in a designerly way with the technology by utilizing the basic operative skills acquired, along with my tacit understanding of knitwear creation. This was one of the major bifurcating moments within this research journey. Deleuze might comment: "The predicate is an event, and appears in the subject as a change of perception: the event is voluntary when a motive can be assigned, such as reason or change of perception" (Deleuze, 1993, p. 79).

4.2 Problematic Encounters

4.2.1 Seamless diversions

There were three routes that I explored at this juncture. The initial route led me to prospecting other three-dimensional computer design programmes, such as those successfully being used in spatial and architectural design fields. The second route led me to surveying traditional pattern-cutting techniques for woven garments, while the third route accessed the only pre-installed seamless garment in the SDS Design System, the glove. The area of parametric computer aided design (CAD) was explored and the software programme RHINO trialled. Though positive, in that a three-dimensional design for knitwear could be simulated, it could not be made compatible with seamless knit technology interfacing. While it produced three-dimensional design results, it still needed to be translated into the Knitpaint system for knitting. This did not progress the research in a direction of developing a new understanding of design methods for seamless knitwear.

There has been a vast amount of research and development done in the area of creative patternmaking (Nakamichi, 2011; Rissanen, 2005). This was the second avenue investigated as a means for developing three-dimensional form structures to programme into a knitted garment. A toile or calico is used as fashion and knitwear's three-dimensional, pre-final fabric, design system. It is used for drafting and testing out ideas in a three-dimensional structure before finally making the garment in its actual fabric. In this process, expensive fabric is not wasted during the testing phase of design development. This form of prototyping mostly requires darts, tucks, gathers and, more importantly, seams to enable the toile to fit a body (Rissanen, 2005). Obvious working with these modalities, incorporating seams, would not be easily transferable to seamless technology. All toiles would need seams or areas of fabric manipulation to create fit (figure 33 & 34). Even if made out of jersey knit fabrics, they would still be difficult to replicate on seamless technology, because it is impossible to exactly predict what the machine will do and what the final form and fabric will look like when departing from the Design System's pre-installed shapes. The computer design visualization has three flat two-dimensional images of a garment. The mechanized forces, which manipulate the yarn into a garment's three dimensions, cannot be previewed as a three-dimensional vector-form on the computer screen. It is not until a garment is actualized that three-dimensionality is revealed and the modal play of internalized forces becomes apparent. Initiating with toiles becomes pointless, other than as a means to create preliminary design ideas in three dimensions. Again, at the John Smedley factory, it was found that some of the complex garments that had been achieved using seamless knitwear had been processed using this as a method of realization, with a technician translating into Knitpaint the parameters of garments developed through toile processing.

The third exploration took me back to the SDS Design System and the glove. The glove was easily programmed in the design component of the system. A stitch structure was added to the glove, transferred to Knitpaint, and knitted. This is a method of programming closely resembling training I undertook in Japan and had continued to explore on returning to the TDL. The process followed the Design System development of garments using the pre-installed Shima shapes and adding stitch structures or patterns to them. The technician then checked if the programme was correct and ready to knit, without doing harm to the machine, via the Knitpaint auto-simulation programme. The glove can be seen in figure 35. This took thirty minutes to programme, but because there are no other pre-installed seamless garments within the Design System, it is the only one able to be tested and realized in this way. This method of creating a seamless garment was very easy to achieve and it would be of benefit to designers if more pre-installed base garments were available. This would allow designers to use the seamless component of the Design System independently, in a commercial environment. Because many of the seamless garments being produced within the current industrial framework are very simplistic in styling, designers would be able to use the pre-installed base shapes and add colour or texture from the stitch structure options available. Thus they would be able to initialize garments ready for first sampling without technical intervention.

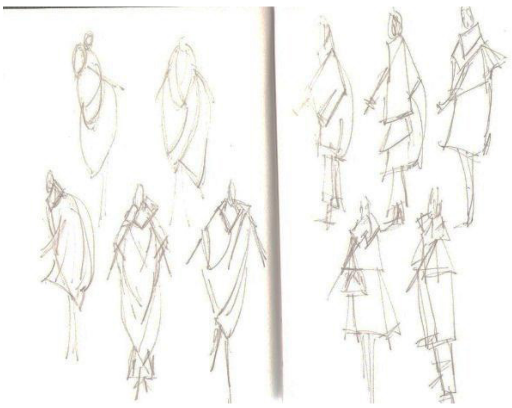

Figure 33:
Smith, A. (2010). Three methods: Sketching

Figure 34:
Smith, A. (2011) Toile using knit fabric

Figure 35:
Smith, A. (2011) Seamless glove in 'Design' SDS-ONE Design System, Shima Seiki Manufacturing

With further exploration of Knitpaint, I recognized similarities to knitting stitch and shape formations used in more traditional knitwear constructions. Having spent most of my working life translating knit design ideas into either stitch structure instructions or on to specification sheets in such a way that others are able to understand them, I came to realize that Knitpaint is only another version of these scripted instructions. To enable this research to continue, the use of the pre-installed shapes working within the Knitpaint programme needed to be mastered. I needed to find a way to design within the confines of the technical parameters and boundaries of this technology. A new problem field for this research emerged through these experimentations; in mastering basic operations within Knitpaint, it would be possible to see if there is a way for a designer to have an adequate degree of freedom, without the ongoing requirement of a technician.

4.2.2 Dimensional boundaries

I orientated the project to "modulations of difference," the modal parameters that defined the functioning or conditioned lines of variations, as boundaries to pre-installed shapes within Knitpaint. I needed to understand what the parameters of this technology were and what was achievable with them. I had previously identified that three-dimensional formations were currently impossible to create using the design component of the SDS Design System, so working with Knitpaint became the main focus of this exploration. The parameters investigated were delineated by the pre-installed Shima shapes within the WHOLEGARMENT® knitpaint programme. The experimentation trialled each basic pre-installed shape as it was before any changes were made to measurements. Then each base shape was altered via changing measurements to establish limits to size and shape boundaries, which were dictated by the knitting machine process capabilities. The investigation was to establish what gradient influence, or vector differentiations to shape possibilities, could be created within the boundaries of the technology's modal capabilities. It also established how singular a designer could be when using the pre-installed garment shapes and how variation through modalities of differences could be created without doing any technical programming to change them.

There are two ways of accessing the pre-installed garments within the SDS One System, one is through the Picture Dictionary and the other is by making a basic shape choice followed by measurements. The Picture Dictionary visualizes in an array the pre-installed shapes in the Knitpaint seamless programme, for initial choice prior to sizing (figure 36). The second approach is via diagrammatic shape, simulating more conventionally a designer's mode of operation when working in an industry environment—working with diagrammatic size specification sheets (figure 37). Garment size measurements are entered, and the diagrammatic drawing then alters, responding to the measurements entered. A designer experienced in technical specification sheets would be able to read-off and assess if the shape was adequate or if further adjustments were required.

Figure 36:
Shima Seiki Manufacturing (2012). Pre-Installed shapes in Shima Seiki Knitpaint. Retrieved from: Help File of 'Knitpaint' Shima Seiki Manufacturing

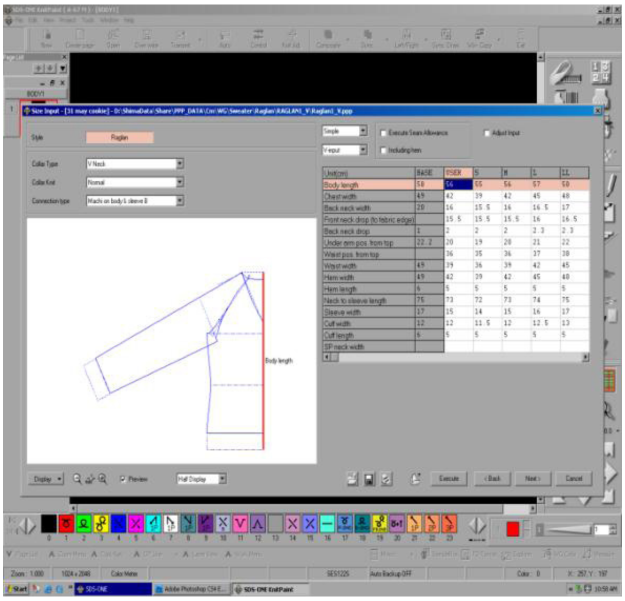

Figure 37 :
Shima Seiki Manufacturing (2012). Size Image in Shima Seiki Knitpaint Retrieved from: 'Knitpaint' Shima Seiki Manufacturing

As can be seen in (figures 36 & 37), the pre-installed garment shapes within the WHOLEGARMENT® system are very basic and display a simple array of knitwear garment shapes. It is not surprising that designers have been uninspired by this technology and that there have been few designers who have managed to create difference with it. This technology was questioned by Sayer, Wilson and Challis (Sayer et al., 2006). They asked if this method of manufacturing of “predefined garment modules” was even designing.

Modulated Possibilities

Using one of the basic pre-installed garment shapes, I investigated what could be done with it and how far the garment shape could be stretched from its base starting point. It was a very easy step-by-step process to follow the Knitpaint programming menu for registering a garment up to the “knit-ready” stage. Initially I had to be shown how to follow these steps by the TDL technician, but I was able to memorize them quite quickly, even though at this time I was generally unclear as to what lay behind these procedural steps. In particular, the garment diagram for the three-dimensional shape, when flattened to two dimensions, was initially hard to decipher.

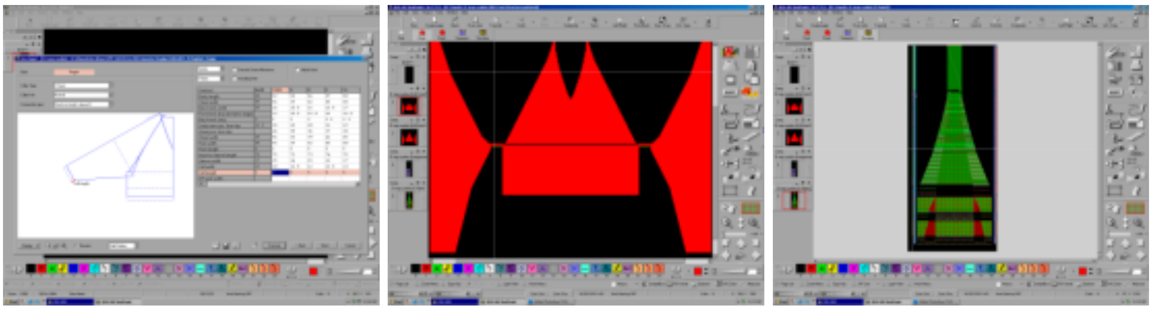

Figure 38:
Smith, A. (2012). Three stages of development for garment initialisation in Knitpaint. Source: ‘Knitpaint’ SDS.ONE®, Shima Seiki Manufacturing.

Figure 38, depicts three of the four stages of development for a basic raglan garment. The first depicts entering the garment size; the second shows the “peeled out” shape of the front; and the third is the same garment when it has been programmed and ready for knitting (figure 38). Figure 39 shows two garments made from the same shape—one is a basic sweater with rib structure added, and the other is a basic cardigan. Both were created from the same shape measurements (figure 39).

Figure 39:
Smith, A. (2011). First seamless garment tests –
Cardigan and Rib sweater created from the same shape.

Other garments programmed using the pre-installed garment shapes were: set-in-sleeve sweaters, cardigans, parachute sleeve sweaters and singlet vests. All of these garments were unknown—what I referred to earlier as the *enigma* of the silhouette—until after production on the knitting machine. It was hard to predict from the "peeled out" two-dimensional computer image the look of these garments when knitted. The "unknown" was primarily the measurement of the final garment. Test swatches had been performed, so measurements should have been accurate but, due to the cyclical nature of the knitting, some areas proved unpredictable. Areas of the garment difficult to predict most noticeably were necklines, which pulled outwards without stabilizing seams to hold shoulders securely. I saw this in terms of plays of forces, flows of matter within the garment composition that were disturbing garment formation and causing unpredictable movement. Coupled with this were the unpredictability of fabric movement and the resolution of knitted structure.

After a series of iterations of seamless garment correlations of size and proportion, that compared actual garments and how they were visualized on the "peeled out" computer diagrams, I found there to be a lack of correlation, with unpredictable and inexplicable movements. The computer software was not able to offer a predictable measure of resultant garments or map the multiple plays of internal forces at work in the modulations and modifications set in train. Pulling and stretching at certain points of the garment, especially the neck, shoulder point and under the arms, resulted in deformations to the texture, or style of a garment, as the mode by which all of the folds infold to constitute the garment's milieu and its singular nuance within that milieu. Such a "milieu" includes a normative appraisal. In short, the garment looked "cheap," poorly finished. Finishing may be added via extra programming, and would be needed to improve a seamless garment's finished "look." A certain degree of shape movement was possible using the pre-installed garment forms, but mostly limited to length and width of a garment, neck trims and depth of the neck line, as well as depth and position of the armholes and sleeves.

With increased experimentation, better correlations were developed between the peculiar diagrammatics of the Knitpaint garment shapes and actualized garments coming off the machine. This allowed me to start to build a systematic array of differential units, a pattern-language of sorts, as a translating nomenclature between the two-dimensional diagram and three-dimensional garment. From material modulations to a memory-trace system of differential units, marking the singularity of nuance or style, these design linkages started to create new design memories for the researcher, and as such built a design repository that is also a technique or knowhow, as a way of creating knitwear using seamless knitwear technologies. Through this shape lexis or lexicon, limitations and capacities for modal differences were discovered. This lexicon was the building of a system of design signifying elements, a sign-system for the researcher to access, through the assemblage of these differential material elements.

A major modal limitation was the conditioned symmetry of the technology. All garment variations conformed to symmetry. For example, cardigans had no front trims; they just butted to one another, making it impossible to have any overlap to garments. Additional trim finishes are required for production purposes. Symmetry implies a technology designed for the repetition of classical forms of an unchanging and static nature, the exact. The inability to achieve symmetrical variance suggests the difficulty for such a technology to be productive of the anexact, or singularities of repetitive differentiations. The design lexicon also has limitations imposed on it by the exterior functionalities of the machine capabilities. One of these limits is the overall width of a garment. The width of all machined knitwear is limited by the size of the knitting bed and the number of needles available at any time. With seamless knitwear, the sleeves and body are being produced simultaneously. Thus the garment width is less than for cut-and-sew or fully-fashioned methods. With a cut-and-sew or fully-fashioned garment, each panel can be knitted separately; therefore a wider garment can be created, and the extra fabric can be used to create overlaps for fronts of cardigans or additional layers and flaps when secured into side seams. Due to the modulating forces of movements of the knitting machine, producing multiple parts of the garment simultaneously, as the machine merges the sleeves and body together to form a garment, Shima advise limiting added stitch structures on the body to below the arm, for ease of knitting. This limits the flow of the textural materiality of a garment formation and creates a line of variation across the body. With this experimentation, garment preforms were standard. If I tried to move shape outside this norm, the technical check at the end would find programming faults, which would prevent the garment being knitted.

These findings confirmed that this system of manufacturing knitwear was designed for mass-production of symmetrical garments. However it also confirmed that a designer may quickly learn how to process these basic shapes through to a finished garment using Knitpaint. This raises some questions about the process of development of the Design System within this technology. Have designers been consulted in its development? Is there a way to redevelop the Design System to move the shape modulations, and therefore the final forms, outside of currently imposed technical parameters? The technology was user friendly, and had technical checks in place to prevent unknittable garments from getting to the knitting stage. However, it promotes a gap between creative capabilities and versatility that craft knitwear has over machine knitting. Rather than increasing design capacity and potential of this three-dimensional knitwear, it is currently limited to sequential predetermined movements and standardized forms.

4.3 Research Practice

4.3.1 Process and Analysis

As part of an upskilling process to enable my practice-led component of this research to further develop, in 2011, I travelled to Wakayama, Japan, to Shima Seiki to undertake training on the SDS One Design System. Prior to this, I had seen demonstrations of the software but had very little knowledge of how it worked. A weeklong programme of study had been compiled by the Shima staff, which focused on the Design System within the SDS One software. All the training that I completed was on the designer's side of this software. I was not introduced to the technician's side, Knitpaint.

The sessions were very structured with little movement from the set lessons for the day. Each day was planned step-by-step, following the Design System process. It covered all of the basic tools within the software and, after three days, the training completed all of the knitwear basics such as stripe, jacquard, intarsia and stitch structures. All of these basic colouring-in tools were applied to flat pattern shape options within the software with optional choices for sleeve shapes, raglan or set-in-sleeve and optional choices for necklines, such as crew or V-neck. This was followed by yarn and knitted swatch development, where yarn was scanned in, colour matched and then virtual swatches were developed. Also a full-knitted swatch was scanned in and recoloured with new yarn and colours, creating a virtual copy of an already knitted swatch. The second to last day of the training covered mesh mapping of a preregistered three-dimensional garment on a mannequin, which was then wrapped with a knitted swatch from the Design System. This was the first aspect of the training that covered the three-dimensionality of this design programme. However, it is impossible to do this with anything other than the preregistered garment shapes within the design system. If an original garment is wanted, it has to be made into a toile. An image taken of it then has to be scanned into the system before being mesh-mapped and the textile of choice added to it. This is a long process, with the only advantage being that you have a virtual three-dimensional garment created with no knitting machine time being used and no yarn wastage. The only point of divergence from the set weekly schedule of training involved attempted distortions of the preregistered mesh-mapped garments, to see if an original garment shape could be created from the pre-installed one. There was a small amount of movement possible, as can be seen by the comparisons of the two garments in figure 40, but it was minimal. Note the thickening of the waist area on the second garment.

Figure 40:
Smith, A. (2011). Mesh-Mapped Garments with knitted textiles from Shima Seiki Design training

This, along with the ability to create virtual sample books with colour ways, virtual swatches with colour ways and finally poster-like layouts which incorporated all of these aspects, indicates that the designer's component of the Design System primarily concerns virtual production of standardized knitwear for promotional purposes or for "Look-Books" for selling to mass market customers, prior to knitting. In so using this design system, it removes a designer from the tactile processes that have been central to knitwear design. It would also be possible to train someone who has never been involved in knitwear design to use this software to design.

While in Japan for training, I was invited to visit the Shima Seiki Design Centre in Tokyo. At the Design Centre, I was able to look closely at the garments on display and from these chose garments from which I might want image-prints. These came with programme numbers, related to the technical information for knitting the garment. This seems to be the way that designers are using this Design System, viewing garments that are already designed and then purchasing the knitting technical programme from Shima. The Italian designer, Saverio Palatella, produced some of the most interesting garments shown at the Design Centre, in 2009/2010 (figure 41). Many of the other garments were very interesting from a technical perspective but were uninspiring in overall design movements.

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by the author of this thesis for
copyright reasons

Figure 41:
Shima Seiki Total Design Centre. (2011).
Designs selected from Shima Seiki Total
Design Centre, Tokyo, Japan

4.3.2 Garment-to-garment: Researching from the bottom up

If knitwear designers are to utilize seamless technologies, they need to do so outside of the restricting limitations of the Design System's pre-installed shape structures, and the translation difficulties in modifications made in shuttling from Knitpaint to the Design System and back to Knitpaint. The seamless knit Design System has been approached from a top-down design paradigm. It has taken the basic elements of mass-production fashion needs as its first design premise; repetition of basic design as quickly and as economically as possible. Top-down development continues, as this technology is adapted. For example, since this research was commenced, there has been a new pre-installed basic shape, the Bolero, added to the programme. However, in the development of this technology, it is only recently that the designer has become part of the technological equation. The designer was only recently acknowledged with the introduction of the SDS One Design System, which included a designer's interface with this technology (Choi & Powell, 2005). This interface currently still excludes the designer from designing seamless knitwear, unless she is able to use the technical interface designed for technicians, in Knitpaint. I have approached the linearity and rigid hierarchies of the Design System / Knitpaint relationality in applying Deleuze's understanding of rhizomatic movement as opposed to the arborescent. This is a "bottom-up" process for designing garments in the sense Harris mentions: "Because it proceeds bottom-up, consolidation is always creative, always beginning over again at each operation; but because it is an emergent process, it also always creates consistency" (Harris, 2005, p. 40). At this divergent moment each design has multiple potential outcomes depending on which virtual potentiality is actualized. Bergson describes this as the "interval" (Deleuze, 1991), Cache as "hysteresis" (Cache, 1995) and Leibniz as "the line of inflection" (Deleuze, 1993). All relate to the primary image or the point when the fold of thought hovers between the inside and the outside of virtuality and actuality. It is the point of movement between percept and affect, the designer's leap of faith. Deleuze uses architectural imagery to illustrate this moment of movement between the known and the unknown:

> The facade-matter goes down below, while the soul-room goes up above. The infinite fold then moves between the two levels. But by being divided, it greatly expands on either side: the fold is divided into folds, which are tucked inside and which spill onto the outside; thus connected as the high and the low. (Deleuze, 1993, pp. 39-40)

It is this movement between the interior and the exterior that moves the designer outside of habitual modes of designing, and thus transfers them away from representational thinking and designing (Jeanes & De Cock, 2005). In the case of this project, this happens when the designer works with the computerized imagery that is installed on the Knitpaint technical system. Its "representational" imagery is so removed from the actual materiality of knitwear garments that designers are removed from their normal modes of visualization or expression. This disturbs the typical process of designing and creates a complex interaction between the designer, the computerized visualization of designs, the seamless knitwear machine, the yarn, fabric development and garments produced. Deleuze suggests:

> The extrinsic character of movement is mixed up in the very condition of bodies or of material parts, as a relation with a surrounding, a successive determination, a mechanical linkage. But all movement that goes, according to the law, to infinity under the force of exterior bodies none the less possesses an inner unity without which it could not be ascribed as movement. (Deleuze, 1993,p. 133)

These component elements that compose the whole of a process for making a singular garment each become interior *and* exterior to one another. These linkages all require force and movement to be applied via sense-events, as well as each creating a singular force and movement which develop and move the process of designing outside of habitual repetitions and towards the production of singular variabilities.

4.3.3 **Exact and anexact compositions: Shima Seiki and exact composition.**

Findings from the "modulation of difference" project established that there were no pre-programmed seamless shapes within the design component of the SDS One Design System for the designer to work with, other than the glove, resulting in a move to working with the technical programme Knitpaint. Limitations that I established related especially to the extent to which the basic shapes available to the designer within Knitpaint could be moved from the original pre-installed programmes. The basic shapes of a sleeveless tunic, sweater, skirt or pants are the only pre-installed programmes available to work with. These can be manipulated to form a cardigan or a waistcoat, with a round, 'v' or polo neck, which can be further manipulated to form an open collar, if a slit is added. There is a range of sleeve shapes that can be selected: parachute, raglan or set-in. The set-in sleeve can be straight or have sloped back-shoulders.

All garments can have basic measurements altered: the neck-drop and width; the armhole-drop and width; horizontally, the garment shoulder, bust, waist and hem widths; and vertically, the garment length from shoulder-point to hem and waist-point to hem. Alterations of the waist length and width to shoulder, bust and hem width can produce garments varied in shape from a rectangle, to a triangle, to an hourglass shape. All of these shapes are limited to the width of the knitting bed capacity, in this case 1000 needles. If a garment has sleeves and a body to consider, this can be limiting. The length of a garment is only limited to the programming capability which, in theory, is limitless. All garments use a mirror image of left and right within the pre-installed programmes so no asymmetrical designs can be made and all garments butt together. If cardigans or waistcoats are made, trims need to be added postproduction. All of these pre-installed programmed shapes were easy to achieve, using the Knitpaint programme, but they produced very mass-production orientated shapes.

This practice concerns the three-dimensionality of seamless knit technology, to a large extent a mythical design-production concept. It can be achieved if a technician programmes a garment from beginning to end in Knitpaint, but can take many hours and trials to achieve. This would be outside a designer's normal practice, unless she has also trained as a technician. This was the route that Yang took in her research, which resulted in a designer/interpreter role which encompassed both technician and designer within one role (Yang, 2010). This research questions whether there are ways for the designer to be able to create, alter shape and work with three-dimensional modular formulas using the pre-installed shapes that are provided within the SDS One Design System. I am asking what a designer 'becomes' with these changes, and if it is possible to 'be' a designer still.

There are a number of ways of creating excess fabric in the form of drapes or folds. Points of inflection can be incorporated into knitwear through pleats, folds, gathers, tucks or darts. Many of these create forces, surface intensities and differential movement, which need to be secured into a structural (non) seam to be held in place. To create garment zones that activate folding forces, directional changes in force need to be an integral part of the knitted structure. The addition of shape creation to the pre-programmed rectangular bodies in seamless knitwear needs to be knitted within the original form, creating points of inflection and extrapolation and thus folding forms. One way of creating directional changes, or vectors, within knitwear, and thereby altering the directional forces of internal structures, is the use of the knitting technique *flechage*: short-row, partial-knitting, or integral-knitting. This method of knitting is a little like making a dart in a fabric garment but is accomplished as the garment is knitted. It is the basic method used for turning-the-heel on a sock or creating the traditional knitted beret. *Flechage* knitting involves holding back one part of the knitting while another continues to be knit, thus creating a wedge shape, where one side becomes longer than where the knitting has been held. This technique was trialled as a method for incorporating directional forces, folding matter-through-function, to create volumetric dis/tensions revealing forces of movement.

4.3.4 **Experimental matter**

Initially I started to design using orthodox methods of concept development: sketching initial ideas and trialling three-dimensional toiles on a mannequin. However, it quickly became apparent that neither of these methods was easily transferable to seamless knitwear technology. It was not possible to mime the technical functions of seamless knit technology when drawing or toiling, therefore complicating an ability to know how these initial ideas would be actualized. It became obvious that the design development had to be done on the CAD system attached to the seamless knitwear machine. This was the sole way to explore shape development having the same technical parameters or behaviour, as a 'whole' garment without seams structuring the volume. Because of its seamlessness, the surface dispersions of intensities of the garment develop according to the plays of a structural absence, or void. Formations and deformations become programmable within the surface textures of garments via the modal essences of the seamless technology's functions. The initial garment experiment used the basic tunic as a starting shape and through using partial knitting on one side deformed the rectangular shape into a curve which, when worn on a body was reinterpreted in movements around the body, its materiality creasing, causing it to drape and fold, opening to a play of signifying possibilities.

To create this de/formation, the TDL knit technician created two new "Packages" that were placed on to the basic tunic template, when developing the garment and registering it ready to be knit. Each pre-installed garment within the Shima WHOLEGARMENT® has numerous Packages, up to a hundred in some, which are the step by step technical instructions for how to knit a garment. These are linked to the "Option Lines" which run on both the left and right sides of the "Compressed Garment" images and the Package instructions. The Option Lines are the control centre for the knitting of a garment. They contain the instructions for how each section of the garment will be knit. For example, they determine and instruct which area needs to be repeated, and how many times, or which yarn carrier to use, and when. Here Option Lines can be seen, as well as basic Packages for a tunic and final knit programme (figure 42 & 43).

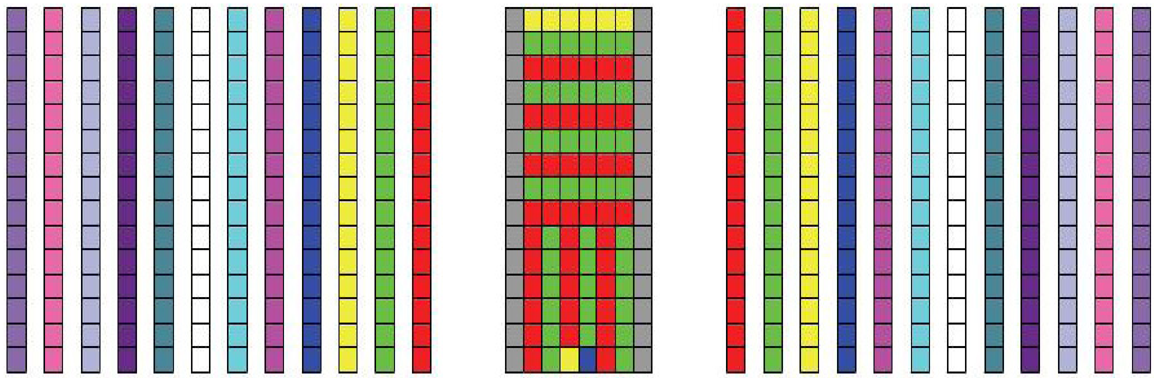


Figure 42:
Shima Seiki Manufacturing (2011). Option Bars used for programming in 'Knitpaint'. Retrieved from Help File of 'Knitpaint' SDS ONE®

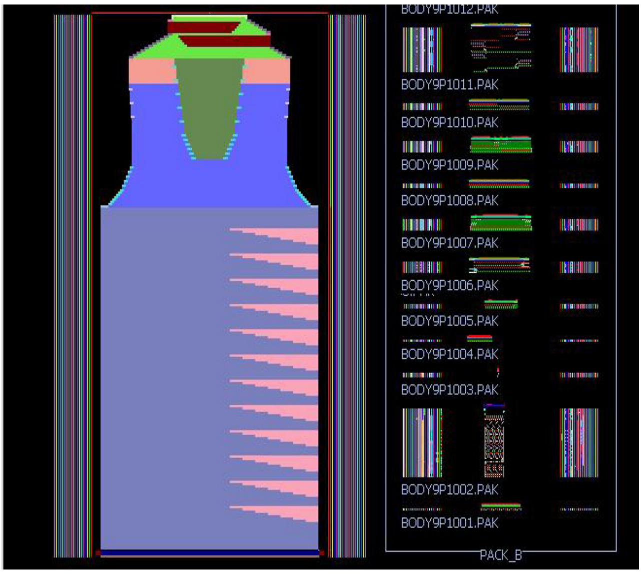


Figure 43:
Smith, A. (2011). Option lines and basic packages for tunic.
Source: 'Knitpaint' Shima Seiki Manufacturing

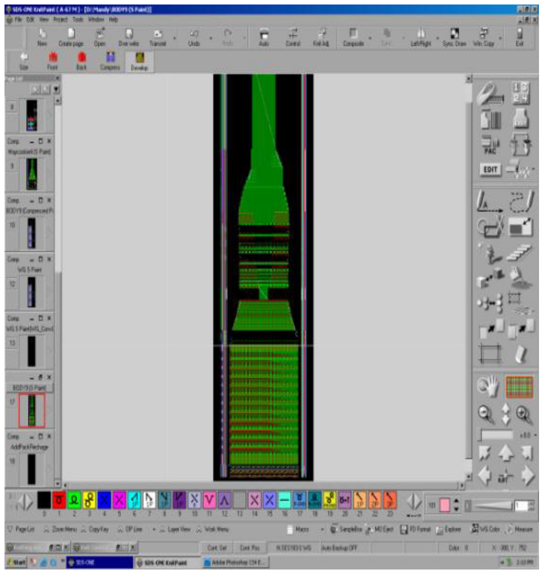


Figure 44:
Smith, A. (2011). Final knit programme of tunic.
Source: 'Knitpaint' Shima Seiki Manufacturing

To alter the basic tunic shape a new Package, or pac, had to be introduced, initially developed by the technician at the TDL. The imagery for where the pac will be used is drawn on the overall, front and back two-dimensional images at compressed-garment stage of registration. It can be seen here on the tunic above, in pink wedges (figure 43). These become the areas of movement, caused by directional forces being introduced to the basic form. The pac is then registered through a Package Development process and the new pac is then incorporated with the other pacs that make up the basic garment structure. After executing the Package Development, a green image of the garment appears that incorporates the knit programme instructions (figure 44). This programme can be checked using the Knit Simulation and Knit Assist process to check that there are no faults in the knit programme and that it will knit successfully. If no "ERROR" is found, then it means the garment is ready to knit. See Appendix A for the Package Development description.

The first few garments programmed, though knitable, were programmed at a tension level that was too tight, where the garment was holding or partially knitting. This resulted in burst stitches, creating holes down one side of the garment. The intrinsic forces were too intense in this modified form. Once the modulating forces were reduced in extension, and tensions loosened, the garment knit without boundary rupture. A series of garments were developed from this, all based on the basic sleeveless tunic shape and using a variety of wedge shapes placed on the garment using the two Packages developed by the technician. Through this experimentation, a range of points-of-inflection was trialled. Each garment was developed, knit, analysed and incrementally altered. With each garment, improvement notes were taken and garments placed on mannequins to observe the lines, proportion and the way that the garment draped. In this way a shape lexicon was developed. With each variation, a series of differentiated modulations were elicited, creating a contextual order of differences, building a signifying system of meanings. Below are some of the compressed garment developments. The first has symmetrical wedges on both front and back (Appendix E - pac 1 WEDGES); the other four are variations of diamond wedges placed through the main body of the garments on the front only (Appendix E - pac 2 CENTRE) (figure 45). Note the difference in colour of the two shape programmes. The first is pink, directly placed on a purple background. The others are green, placed on a pink stripe, on a purple background. These are Shima registered colours from the base Package software colour 180 (Purple) and 101 (Pink), with an additionally developed WG Package in 102 (Green) and in 101 (Pink).

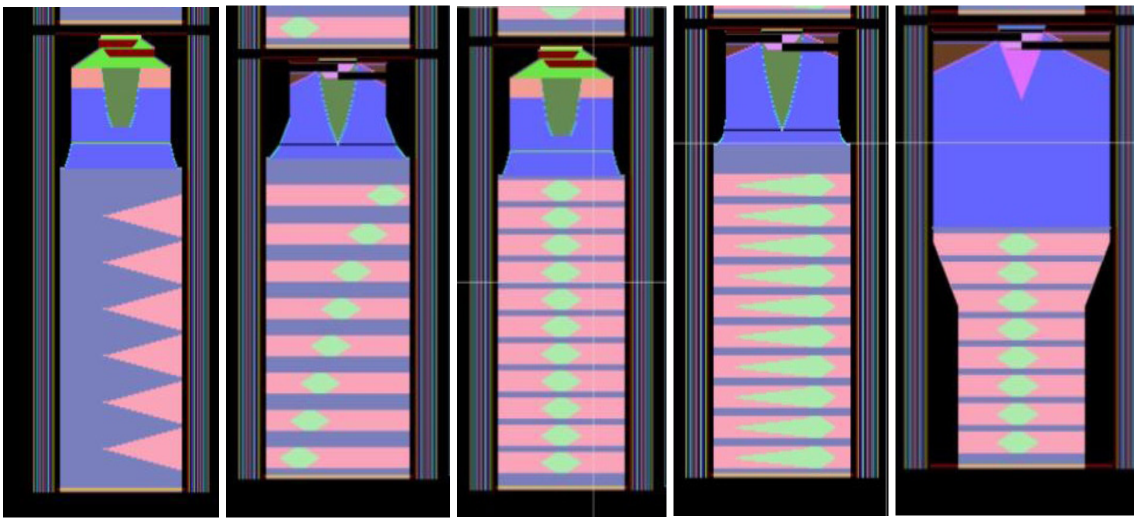


Figure 45:
Smith, A. (2011). Five tunic designs each with a different use of one of the two developed 'packages'.
Source: 'Knitpaint', Shima Seiki Manufacturing

Figure 46:
Smith, A. (2011). First of garments developed using 'Tunic' pre-installed shape using one of two developed 'pacs'

The garments above are some of the results from using just two additional pacs, the wedge and the diamond wedge, on a basic tunic shape (figure 46). Modifications were more distinct when used on both back and front of the garment, as seen in the first garment on the left, or when used in a vertical line through the centre of the garment, as seen in the last garment on the right. As already emphasized, it is not possible to predict what a knitted garment will look like when processed and knitted from the two-dimensional imagery in the compressed form. This is a format most closely resembling something that a designer would recognize. It is possible to move the design at this point to the Design System, but because the CAD software is not able to reconstruct the movement of stitches, or wales, it cannot represent this shaping visually in stitch structure form (figure 47). Where wedges were placed on a standard tunic shape, the resultant garment is curved, but the stitch structure image remains symmetrical and rectangular in format.

Figure 47:
Smith, A. (2012). Stitch Structure of additional pacs in 'design' format. Source: 'Design', SDS-ONE Design, Shima Seiki Manufacturing

There were a number of findings relating to shape modification and three-dimensional form building, uncovered from the first seven or eight garment developments. When a garment has differential forces applied to both front and back, an asymmetrical hemline with diagonal drapes folds through and around the body. This same garment, when seen lying flat, has such intensive movement that the forces twist and fold the body, displacing the neck and armhole openings on to a diagonal line. All of the garments had such intensive modifications, created through forces applied using diamond wedges through the front of the garment. Differentiated results were achieved by using different configuration formats, but all had hemline distortions. The modification of the hemlines differed from asymmetrical to symmetrical, depending on the degree of movement caused by forces created by the diamond wedges. Deformation was more exaggerated the further the inflective forces were placed away from the central vertical point of the garment. It became obvious that armhole placement was limiting the degree of drape that could be added to garments. When applied to an earlier version of garment five seen in figure 45 and 46 above, only three diamond wedges could be added. This garment had lower armholes. This insight brought the realization that all garments could only be altered easily up to the armhole point. Further findings were that the depth and length of the wedges created a more or less defined fold, depending on the increase or decrease of intensities, which ran through and around the garment body. All garments had to be read as flat two-dimensional shapes. It was not until they were worn that intensities of movement could be seen acting and counteracting forces around a body, taking on a third dimension. These forces multiplied, folded and refolded, changing shape and formation which changed again when a body moved.

At this point I realized that further pacs would need to be developed for similar movements to be accomplished within garment basic pre-installed programmes. For a sweater and a cardigan format, each pre-installed format would need separate pacs for the left, right or central wedge. This would bring the number of pacs developed to nine. The TDL technician developed all of the pacs; but once this was completed, it was possible to apply and work with these pacs independently, to create garments. As a designer, the more that was achieved and fed into a cycle of building design capacities through design lexicon memory, the more a designerly process was being developed and understood, intrinsic to the technological capabilities. Initially, working on the basic pre-installed sweater and cardigan, with round-neck and set-in sleeves, wedges were added to the garments through the centre front, as seen in figure 48.

Figure 48:
Smith, A. (2011). First seamless garments using basic pre-installed sweater and cardigan shapes – with additional pacs

These created a certain amount of drape, but due to the tightly fitting shape of the garments, the drape was being held closely to the body and therefore remained as a conventional-looking form. The garments were also very symmetrical because of the placement of the wedges through their centres. The main disturbance of the shape can be seen on the cardigan, which has a void through the centre front. How to achieve the development of trims around the neckline had yet to be discovered. Thus, both garments have finished edges but no trims at the neckline. Both garments have the same measurements and differ only in that one has been "selected" as a cardigan, when initially registering garments, and different pacs had to be used for the cardigan (Appendix E – pac 5 Diamond Cardigan), from the ones used for the sweater (Appendix E – Pac 4 Diamond Garment); see figure 48. From the analysis after producing these garments, further vector movement of material force was needed. So garments needed to be longer and wider, thus moving the fabric further away from the body line, creating in theory greater acting and counteracting of movement when worn, creating more mobility around a body in a three-dimensional directional flow. It was again noted that, for an asymmetrical garment, the forces needed to be applied off-centre or to be moving directionally across a body. A basic sweater-shape was developed that was wider and longer. I also ascertained, at this point, that if the basic sweater shape with a turtle neck is selected, then the turtle neck can be shortened and thus provide a neck trim on the garment. The neck trim structure has some basic options to choose from: a plain-knit purl structure, one-by-one rib, a two-by-two rib or a three-by-three rib. The first garment had long ribs programmed on the sleeves, which limited how far down the wedges could be placed, and therefore how much shape distortion was created through the garment (figure 49 – left image). By reducing the length of the rib-trims on the sleeves, it was possible to increase the depth of the movement and therefore increase the drape and folds around a body, as seen in the second image below (figure 49 right image).

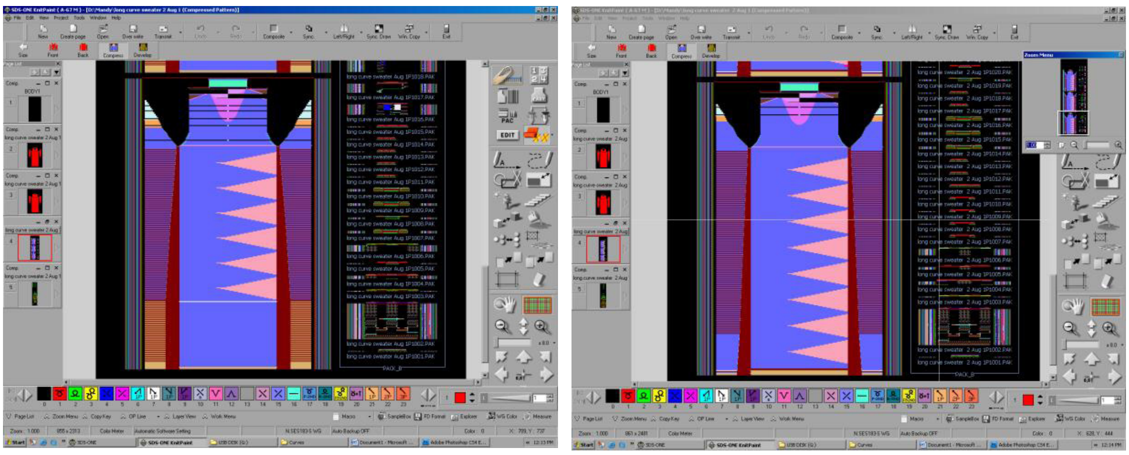


Figure 49:
Smith, A. (2011). Comparison of drape possibilities, with and without, long rib on sleeves. Source: 'Knitpaint', SDS-ONE, Shima Seiki Manufacturing

The two garments can be seen side-by-side in the images in figure 50. From the front, they look very similar. But from the back, the drape disappears on the garment with fewer wedges applied. The second garment retains drape and folds around the body. Each angle of the garment gives a different view, which is ever changing. The second garment, when successfully knitted, resulted in a difference of fifty centimetres in length between its left and right side, thus twisting it forty-five degrees off its vertical central point. This was the first of my experimental garments that started to move the shape and form decisively away from a flat two-dimensions, while yet creating drape and movement around a body as dictated by immanent forces of the structural components (figure 51).

Figure 50:
Smith, A. (2011). Comparison of knitted garments with sleeve ribs at different lengths

Figure 51:
Smith, A. (2011). First garment for base shapes

Advancements were made with developing design parameters of the project but also building up a praxis knowledge with the technical programme, Knitpaint, in a developing understanding of the translating capabilities of, for example, altering the garment from a sweater to a cardigan, change of collar structures, hem type and sleeve rib-trims. The basic sweater preprogrammed shape has gathers on the sleeve head. This can be seen on the centre image of garment at the front, but not on the far garment. To alter the basic pre-installed programme, from a gathered sleeve-head to a flat sleeve head, the knitting ratio has to be altered when initializing the outline during registration of the initial garment. A knitting ratio of 2:4:2 over 16 courses needed to be selected under the “Setin” option when initializing the outline of the garment. Further designs were completed using both the sweater and cardigan basic pre-installed programmes, with the pacs that had been developed added to them in a variety of configurations. As can be seen in figures 52 and 53, the visual CAD imagery remains very similar in each garment configuration, but the three-dimensional form of the garment when knitted out differentiated with each iteration. It was only possible to gain a design knowledge of three-dimensional results through making, when working with this technology. Each garment incrementally grew from the previous garment, as did both technical and design outcome knowledge.

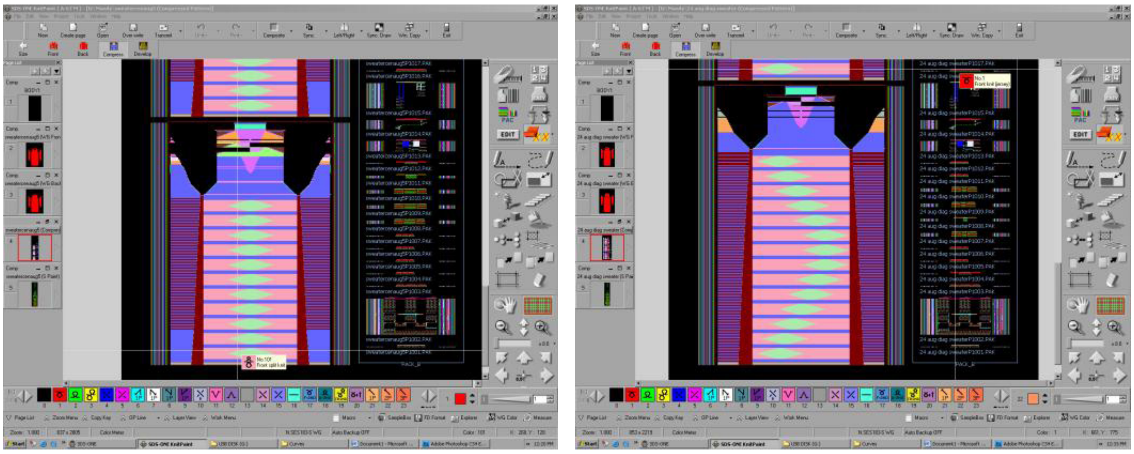


Figure 52:
Smith, A. (2011). Comparison of computer images for two garments – visually look similar
Source: ‘Knitpaint’ SDS-ONE, Shima Seiki Manufacturing

Figure 53:
Smith, A. (2011). Comparison of two knitted garments from computer images as seen in figure 52

Figure 54:
Smith, A. (2011). Comparison of two cardigan shapes on computer image. Source: 'Knitpaint', SDS-ONE, Shima Seiki Manufacturing

Figure 55:
Smith, A. (2011). Comparison of two cardigan shapes in knitted form of computer images seen in figure 54

The imagery of the CAD system within Knitpaint remains very removed from the reality of the garment produced but, because the designer is working in an incremental way, or from the bottom-up, each time a garment is produced she is able to interact with it through visual and touch sensory responses, the physicality of the garment. I am more an itinerant prospector than a designer-manager. The garment's matter becomes folded into the development process, maintaining designer-design tactility, enabling a response to findings as they emerge.

Further development was made using the sleeveless tunic, the sweater with setin sleeves and the cardigan. All of these shapes were developed using pacs placed on both sides of the garments. Up until now all developments had been achieved using just a single pac, but by doubling the number of pacs used in each garment further intensities of force were affected, increasing degrees of rotation away from a standardized shape. The pacs developed a double twist within the garment, creating a dual force of movement, through the garment's verticality as well as around the horizontal plane. Again, the Shima CAD imagery was unable to depict these forces and resembled the original images of the pre-installed programmes. The forces and counterforces of movements, instigated through vectors of the seamless knitwear assembly process, created directional differentiations of the actual knit structures away from the horizontal/vertical - fabrication and seamlessness of the construction processes - axes of the garment. All create directional movements, acting and counteracting against one another, creating variations of directional forces. Currently the CAD image interface is unable to depict these movements of variable differentials.

The three-dimensionality of the actual garment seemed to "increase" when becoming in a whole garment form—the lack of seams within a garment *allowed* the garment to achieve its fullest three-dimensionality or the highest degree of its capability—as if the flows of matter were in some way unimpeded by joins. This affect, as a block of sensation, was unexpected. It was the nuanced style of seamlessness, and surprisingly these movements were not evident on the initial CAD system diagrams.

Figure 56:
Smith, A. (2011). Seamless garment developments created using 'knitpaint' shapes and one or two additional pacs

A variety of garments achieved through the addition of no more than two pacs to any one garment from the pre-installed garments within the standardized Shima Seiki software shapes are shown in figure 56. I created and programmed all of these garments with limited technical knowledge and limited required intervention by the Shima Seiki technician. The design process and incremental development of the garments was achieved through iteration and reinterpretation, which combined the developing technical knowledge, the most recent garment created, the designer's tacit understanding of knitwear, knitting techniques and garment-body interactions. My design lexicon, or array of differential parts, construing the developing of meaning-structures, gathered themselves around a discrete series of parameters or modal essences that could constitute the degrees of modification capable with each garment iteration. These were, firstly, the key frameworks of Wabi-Sabi—impermanence, incompleteness and asymmetry; secondly, the three-dimensionality understood as the highest degree of the expression of matter's flows, as the nuance of seamlessness; thirdly, the intensive force/counterforce of rotational movements of standardised shapes and forms becomes the method of return each time to the modal capabilities of the Shima Seiki technology. The fourth parameter aimed at creating singularities within a serial repetition, as a crucial recognition of a garment as essentially matter that differs from itself as the duration of its impermanence and incompletion. Yet, collectively, the garment series formed another body with an altogether different nature, that of a swarm. Five key shapes seem to emerge and settle as if through a distillation of experimental processes, chance encounters and the above concerns with modal capacities as seen in figure 57.

Figure 57:
Smith, A. (2011). Five seamless knit base shapes for collection

4.3.5 **Defining the affect: Fold, unfold and refold**

Though three-dimensional forms had been established, I aimed for even further exaggerations of directional forces of movement, by looking to formations of stitch structures. This required further technical knowledge within Knitpaint, or knowledge of how to create stitch structures within the design component of the Design System that could then be incorporated with the garment programmes in Knitpaint. Using three of the established shapes, all sleeveless tunics, small presser-foot tucks were developed and added to these shapes. The first garment had multiple groups of tucks placed randomly on the garment. The tucks were too close together, resulting in the structural knit forces becoming too heavy to maintain the folds and drapes, creating a gravitational downwards pull on the garment (figure 58). The idea of adding stitch
Though three-dimensional forms had been established, I aimed for even further exaggerations of directional forces of movement, by looking to formations of stitch structures. This required further technical knowledge within Knitpaint, or knowledge of how to create stitch structures within the design component of the Design System that could then be incorporated with the garment programmes in Knitpaint. Using three of the established shapes, all sleeveless tunics, small presser-foot tucks were developed and added to these shapes. The first garment had multiple groups of tucks placed randomly on the garment. The tucks were too close together, resulting in the structural knit forces becoming too heavy to maintain the folds and drapes, creating a gravitational downwards pull on the garment (figure 58). The idea of adding stitch structures to the garment was to fold a further texture into the overall texturology of the matter, to further emphasize the movement of the garment as it folded forces around a body. The next garment placed rows of tucks horizontally between the forces created by the wedge pacs (figure 59).

These were easily programmed and did create movement in the same directional flow as the garment folds. However, due to the added weight of the tucks, the material now drew out the drape and the garment became very flat and two-dimensional again. With a third experiment, by reducing the horizontal tucks to two lines, I hoped to also reduce the weight of the knit, to prevent the garment from being dragged down and returning to a flat plane. This was done on a diagonal twist-wedged garment, where the wedges moved from one side of the garment to the other and then back again. When knitted, this garment was again too heavy from the additional weight of the tucks to maintain its drape and three dimensions. It did, however, create a visual movement throughout the garment that was unpredictable and, as fabric structure, it revealed forces colliding and being counteracted, pushed and pulled, with different directional flows becoming apparent. It was not successful as a garment within the design parameters of this practice, having been reduced to a flat tubular shape with no directional flow around a body (figure 59).

Figure 58:
Smith, A. (2011). Drape garment with added tuck texture

Figure 59:
Smith, A. (2011) Horizontal lines of tucks added to base shapes

To move the design development forward, I needed to reflect on all of the garments with surface structure added to them, along with the project parameters and the other garments created thus far. The aim of adding surface structure to the garments was to emphasize and exemplify garment three-dimensionality and vector movements around a body. It was also to discover what surface structures did when added to a garment that had its standardized form translated. Because the flat two-dimensional shape had been transformed, it interrupted the surface structure that becomes part of the force and movement transposed around the garment. One of the traditional ways of adding texture to a surface, but without adding additional weight, is to take away rather than apply on top of an existing structure, to create structural voids. With knitwear, I could achieve this via lace structures or by deliberately knitting holes into a garment. Lace holes would make a garment lighter and maintain drape and three-dimensionality. They could be applied in a similar way to the tucks and would create further redistribution of the play of forces, as the holes would also create forces of movement and become part of the divergent qualities within the texture of the garment's infolding matter. Further shapes were used and a variety of lace hole structures were applied to garments. The lace holes had to be added to the front and back image of the garment before registration of the pacs for the wedges. It was necessary to work out which Shima colours would replicate the holes on both the front and the back of the garment. For the holes to be the same there had to be mirrored movements; for example, the garment in figure 60 used Shima colours 7 and 40 on the front and 9 and 50 on the back (see Appendix D).

Figure 60:
Smith, A. (2011). Front, Back and Side of seamless sweater with horizontal lace lines added

This garment maintained the drape and the fluidity of movement and the addition of the surface texture emphasised the directional movement around a body. The texture radiates out from one side of the garment around a body, and then reverts to its starting point again without being interrupted by side seams or joins. Each point of view of the garment changes as it is worn, folding, unfolding and refolding with movement (figure 60). Through incremental development and exploration of a variety of lace hole structures, I found that if they were placed on either horizontal or vertical lines within the CAD diagram, unpredictable movements occurred. This was due to the distortion of the garment away from its standardized format and away from the wales running parallel with each other. As already emphasized, actual garments didn't resemble the CAD imagery used to programme them. Hence I needed the iterative process of actualised garments leading me to the next experiment with CAD visualization. I had to make myself "slender," following the flows of matter into their translatability into computational processes. It was impossible to predict what each garment would look like until it was knit and became tangible matter.

Using this incremental design development process also allowed me to develop technical abilities, as the design process progressed. All of the designs achieved have only had stitch structures added up to the start of the armhole or sleeves. At the point where the armholes start or the sleeves start to join the body of a garment, there are many technical knitting challenges for the production of seamless garments. It is generally recommended that any structural additions do not go beyond this point. Figure 61, below, shows the stitch structures stopping at this point.

Figure 61:
Smith, A. (2011). Three garments with stitch structures added

Figure 62:
Smith, A. (2011). Two garments with stitch structures going above armhole

It is not a difficult process to extend the stitch structures beyond the armhole or sleeve point. I was able to do this by using the same structure numbers, but changing the background colour and number. This was the same process used for taking the wedges beyond the armhole point, which was discovered when trying to extend the stitch structure to the top of the garment. Two garments can be seen in figure 62, where the stitch structure has been extended beyond the armhole, towards the neck. It was noticed during this process that the CAD imagery for any additional stitch structures are all "fronts." Even the image representing the back is a visual of the front. Stitch structures only went as high as the front neck, on the back of the knitted garment. This can be seen in the garment on the left of figure 62. Extending stitch structures through the vertical and continuing the differential forces of the wedges, through the garment beyond the armhole point on the horizontal, greatly increased the drape and continuity of design. Both of these extended techniques can be seen on the garments in figures 63 to 65. The first image depicts the original shape that was possible to achieve, only taking the wedges to the armhole (figure 63). The second image shows the wedges applied (figure 64); and the third is with wedges and horizontal structure added (figure 65). This is a good illustration of my incremental design development as I gained technical knowledge, as well as having had time to absorb results and question how to extend the design parameters and further push boundaries of the technology. A full explanation of the registration process and the technical instructions are included in appendices at the end of this exegesis (see Appendix A, B, C, D, E and F).

Figure 63:
Smith, A. (2011). Three versions of garment with drape to armhole point

Figure 64:
Smith, A. (2011). With drape above armhole point

Figure 65:
Smith, A. (2011). With horizontal lace lines added

Figure 66:
Smith, A. (2011). Images of final garments as a collective

4.4 Research Affects

4.4.1 Deforming spaces: Percept and affect

Seamless knitting, through its very mode of production, challenges any simple binary division between interior and exterior. Its seamlessness enables interior to become exterior if garments are inverted, with little else other than the stitch structure changing from knit to purl. Its method of making in circular motion renders the joins invisible and therefore enabling the interior to be the exterior with minimal transformation of the final form of a garment. The usual knitted object has a defined inside and outside, as do most conventional textiles or textile objects. An inside manifests the connections of parts, revealing the manufacturing processes (Turney, 2009). Seamless knitwear merges the inside with the outside just as the knitted stitch is formed by the yarn passing from the front to the back as it loops around itself to form the face and the reverse surfaces of the fabric simultaneously. The seamless garment when worn on a body becomes an exterior with the body interior. Due to seamlessness and merging of interior and exterior, when worn the garment capacities for forming/deforming the space between it and body become realized without interruption.

Seamless garments, as with all textiles, may be thought of as resultant actions/reactions to forces of manufacture, which have been distributed throughout the garment in an intentional manner by a designer, plying with "interference" of construction techniques. The garment and the interior body are able to react with one another to redistribute the *fullness*, or highest intensive degrees, created by internal movement of fabric structures, distorting garments and nullifying standardized forms. This deforming of subject-space, through redistribution of exterior fabric around a body, creates garments that envelop the wearer in folds—drape, fold/unfold, form/re-form—constantly changing, actuality to virtuality and back again, touching potentiality, affect being the point of expression/emergence (Massumi, 2002). The intrinsic structure of the seamless garment and additional structural forces added by the designer through the registration of the partial knitting pacs, create internal movement of the knitted wales away from the parallel. This disturbance off-the-parallel intensifies the force of movement around a body which, when doubled and tripled, from double pacs being applied, or when forces collide from opposing sites of a body, complicate the exterior formations of a garment: "Complication involves an intricate assembly of these extrinsic particularities into a complex network" (Lynn, 2004, p. 120).

The resultant garments (figure 66) use a body as central core, and pivotal points on the body support the structure of the garment. Due to internal garment forces created by movement around the body, the garment deflects away from its *nature*; the "natural" bodyline recreating an individualized three-dimensional form. The differential forces in each garment create singularities of design that, though machined, are not of a standardized shape. *They are singular though entirely replicable*. They move around a body, creating asymmetrical lines away from the parallel, course to warp lines creating organic forms. Each interpretation of a garment changes with its point of view. The distorting course to wale creates curvilinear shapes, inflective surfaces and, due to the absence of seams, enables free rotation. There is an affect; the sensation of an excess of fabric that drapes. Its sensate matter seems to form body-spacing's peculiar to its garment flow, asymmetrical, fragile, and impermanent.

Drape and asymmetry are intensified through texture, the folds of matter enacted in linear stitch structures. Garments with twists and double twists create movement and multiple movements throughout their three dimensions. These movements distort the linear stitch structures away from the horizontal or the vertical, mimicking and emphasizing the force of movement happening throughout the garment. The resultant collection is composed of singular garments of organic three-dimensional de/formations, challenging the standardized output normally created using seamless knitwear technology. This has been achieved by allowing the designer to become central to the design process, by reinstating a rhizomatic designer–fabric–garment assemblage, at odds with the Design System/Knitpaint arborescent hierarchy. A designer more familiar with body–garment–space assemblages has connected to the interior processes of designing that were always already there in the mechanical assemblages of Shima Seiki technology, but required a particular point of view in order to reveal the genuine modal essences of that technology. She, the designer, has thus become enabled by the technology and not excluded from it. This has been a bottom-up process: material fibres, following the flows of matter, prospecting inside the technology, movements, intervals, affects, which have allowed time for rhizomatic connections to be made between each sense-event of production. Each garment contains a memory; each is a singularity. Each reveals the differentiator immanent to its line of variation. There is a single garment, in effect, though its silhouette is an enigma, what precisely requires the work of exploration, prospecting, unconcealing.

4.4.2 The Sensations of Wabi- Sabi: Fibres, textures, surfaces and colours

During the initial development stage of shape experimentation and the "modulation-of-difference" project, any yarn was used that was available from accumulated yarn stock. It quickly became clear that a uniform yarn needed to be sourced to ensure consistent findings in experimentation. The initial shape experimentation had been completed in a dark yarn, which actually made visual acuity of three-dimensional garments difficult, with their internal stitch, drape and shaping details (refer to figure 46). I decided on a neutral or lighter colour, to make analysing these details more accessible. This became a first research function, or regulating condition; a light-coloured yarn, to enable a uniformity of design outcomes, the results of which were visible when knit.

Because New Zealand is well known as a producer of exceptional quality Merino wool, it was a fibre to investigate for this practice. However, and somewhat ironically, I found that most high grade Merino wool is exported to be spun into yarn and used for woven fabric or knitted garments produced overseas in high-priced niche quality products, such as John Smedley garments and Baruffa yarn (Baruffa, 2012; Smedley, 2012). There is very little Merino fibre now spun and used in New Zealand garment products. Where New Zealand companies such as Icebreaker do use it, the yarn is spun overseas before being manufactured into garments. New Zealand wool is known to be of the finest quality and is marketed as such by overseas companies such as John Smedley when using it in their products. It is used as a component of craft history, and is used as a branding tool, relating the narrative of yarn, from sheep to farm to final garment (Smedley, 2012). The success of New Zealand Merino fibre overseas has, however, made it difficult to source within New Zealand, especially in small quantities such as needed for this practice or by a niche market knitwear designer. The majority of yarn still spun in New Zealand is for the carpet manufacturing industry, with only two commercial spinning companies providing Merino yarn for the garment knitting industry. One required large minimum quantities and both had minimal colour ranges. It is possible to order yarn via an import agent from yarn companies overseas, which gives a much broader yarn and colour selection, but there are also issues of large minimum quantities. Because of the locale of this practice, it was important to me to source a yarn locally.

It was possible to source an undyed 2/28-wool yarn from the largest yarn spinning company in New Zealand, Woolyarns (Woolyarns, 2012). There was a minimum quantity of twenty kilograms for undyed yarn, which would make forty average sized knitted garments. For any of the pre-dyed yarns, there was a minimum quantity of forty to sixty kilograms, which would make eighty to one hundred and twenty garments. This was excessive to this practice's requirements. Undyed Merino yarn was the best option for garment experimentation. The yarn answered further design functions or regularities: locally sourced, thus readily available; light coloured, revealing stitch structure and surface details. The undyed yarn also allowed for colour to be considered via dyeing the garment post-production. The 2/28-wool was used for all of the design experimentation, developing three-dimensional processing and incorporating vertical and horizontal stitch structures into garments. Using the same yarn throughout this development process enabled the rigour of consistency necessary for repetitive analyses of garments, with yarn characteristics as a base constant. Neutrality of tone eliminated colour preference as a modal variability, allowing sensate affects to concern nuanced texture, structural variations and stitch architectures. Again, ironically, the monochromatic effects of the uniformity of material substrate eventually became one of the most striking aspects of the collection; a complicating "minimalism" that simultaneously maximizes the sensate modalities of variances of knit.

After structural determinants of the garments had been established, other yarns were considered for producing final garments in alternatives to the undyed Merino wool. The ethos of Wabi-Sabi was important and in its underlying concerns affected how I proceeded. It emphasized an organic, process of emergence and decay, fragile hues, irregular finishes, impermanent finalities, incomplete processes. Within New Zealand there are a number of smaller producers of protein yarns, from organically farmed sheep to Alpaca yarn producers. Both of these options were investigated. Alpaca yarn was suitable for use on the seamless knitting machine but came in chemically dyed colours that were very limited in range, and conflicted with my Wabi-Sabi ethos. Un-dyed organic Merino wool spun utilising the natural colours found in sheep and produced in small but balanced colour ranges, was another option. The company, Treliske, produces organic wool, primarily used for hand knitting. Some of their eight-ply yarn was considered fine enough to knit successfully on the Shima Seiki SDS machine (Treliske, 2011). The yarn came in small quantities, so there was no issue with minimums of one colour. However, because of the very niche market and boutique quality of this yarn, it is expensive and could only be used for small quantities of garments. A garment was produced using the organic Merino wool but the eight-ply yarn proved to be too heavy for the knitting machine, resulting in a garment that was solid and lost much of the organic movement seen in the undyed 2/28 Merino garments.

Because of the undyed state of the process development garments, it is possible to garment dye them. This can be done using chemical dyes via a commercial dyeing company, or it could be done in small quantities using chemical dyes within a home environment. It is still easy to source both of these options within New Zealand. I have looked at this as an option for adding colour to the garments, though decided it would not be used unless all other avenues were exhausted. This seemed too far removed from the ethos of Wabi-Sabi, from the points of view of the consistency of my concept milieu—what it is able to invent unconditionally; the regularity of my processes, how variations are conditioned in repetitions; and the play of affects—how sensate being encounters these garments in their fragile movements.

Natural Dyed Affects

Over the summer break of 2011/2012, I initiated an AUT University-funded Summer Studentship research project, in collaboration with a Fashion Honour's student, Oliver Church. The research project investigated natural dye processes as a method for incorporating colour into seamless knitwear. We ran a series of experiments to determine the amount of stretching or shrinkage movement a seamless garment had, when going through the many processes that are needed to dye a garment using natural dyes. We also determined the effects that dye solutions have on the textural qualities of a garment and fabric handle. Two garment shapes were used to measure the movement and effects of the dye process. Each garment was knitted at four different tensions. Measurements were taken for each, and then put through a natural dye process. This was to determine if the garments shrank or stretched during the dye process that, at times, involved simmering garments in hot dye solution, as well as a scouring and mordent solution process to encourage the dye take-up on the garment. After the dye process has been completed, the garment has to be thoroughly washed to remove all remaining dye solution. The complete dye process could involve the garments being submerged up to five times in water.

Figure 67:
Smith, A. & Church, O. (2012). Four of the natural dyed garments

The findings from this Summer Studentship project established the occurrence of a small amount of movement in the overall garment, particularly at points where there would normally be seams for stabilization, such as shoulders and necklines. This resulted in garment sleeves and necklines "growing," as well as areas where there was a longer length running down the side of a garment, due to the asymmetry of the garment. However, movements were minimal on garments knit at the standard tension I had maintained for those garments developed for my practice-research project. The garments with a looser tension had the most movement during the dye process. The fabric handle changed during the dye process. In some cases, it became harder or more brittle to touch. With garments that used henna as the dyeing agent, the fabric remained as supple as before the process. The henna dye also added a luminous quality to the fabric, which helped to reflect light and therefore emphasized the three-dimensional quality (figure 67). This process of dyeing the garments postproduction added a further element of uncertainty. It is difficult to predict exactly what the final outcome will be, regarding colour, density, intensity and consistency (figure 68). This combination of processes of production has incorporated the innovative technology of seamless knitting with a craft process of organic dyeing. Concerning this fold, Turney suggests:

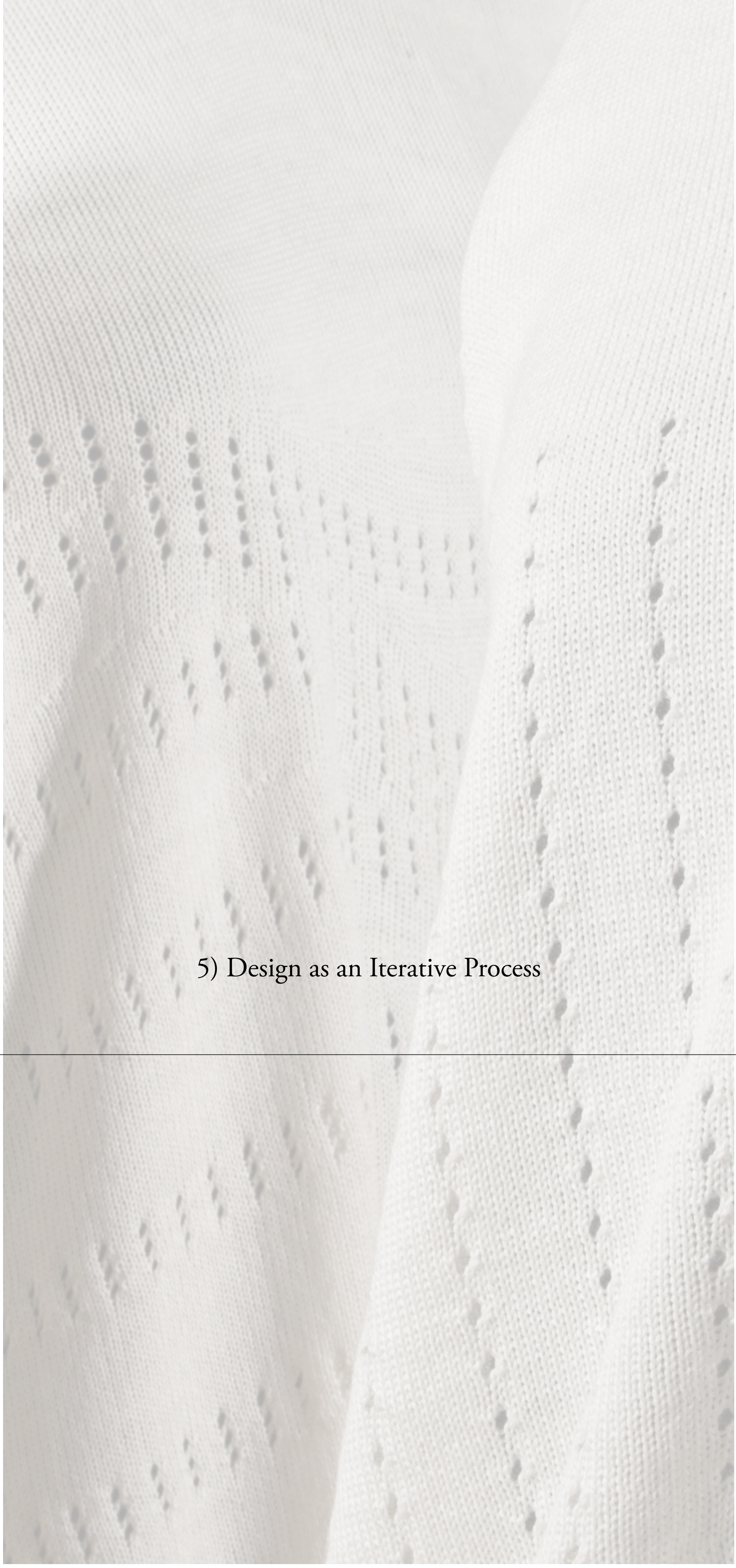
> … talking about artists, designers and crafts people investigating the relationship between old and new techniques and the methods of production, which aim to challenge and extend the boundaries of production and objects. One way of doing this is by creating a dialogue between the handmade and the industrially produced. The inter-relationship between two seemingly disparate practices firmly places knitting at the forefront of technological innovation, creating objects potentially suitable for mass manufacture as well as small-scale production. (Turney, 2009, p. 82)

Figure 68:
Smith, A. & Church, O. (2012). Group of natural dyed garments in two shapes – Tunic and Sweater

4.4.3 **Impermanence and asymmetry**

> Simplicity is at the core of things' wabi-sabi. Nothingness, of course, is the ultimate simplicity. But before and after nothingness, simplicity is not so simple. (Koren, 2008, p.71)

The fragility of the garment collection's evolving singularity creates an "encounter" with impermanence, evoking the temporality of its materiality, and fashion as an immanent becoming. This is not the Wabi-Sabi of the decayed or faded but of an irregularity and the transformational, indicating impermanence through the subtleties of formation, of fold/unfold. Wabi and Sabi evoke the function and affect of this project. Responding to Wabi, I take in the materiality of constructing in the composition of garment making. Recognising Sabi, I evoke the affective sensate becoming that garments have, and the quality of response to them, becoming a-personal in their midst. Memories of making are traced within the work, inflecting affective excess, thinking's inventing and a thing's functioning-motion through incorporeity. Material objects connect across their interiority/exteriority. This quality of a delicacy *aroused* by the thought-image of the garments exemplifies the fragility of fashion through its ethereal nature of folds and forms, constantly in flux: a-collective, unfinished and undyed, continuing to become-itself, transient and impermanent by its nature. I realize and I am realized by an asymmetry and irregularity of structured surfaces, an organic, intrinsic material forces, irregularity of forces creating at times awkwardness of forms, irresolute and unresolvable, yet with intimate, understated trace-like structural veins. The time of a garment is encountered in another way, as it folds, unfolds and refolds. This *time* of a garment, its duration as immanent becoming of its matter as memory, is the connectedness made between viewer and object, object and maker, maker and viewer, interconnected and ever changing, transient in nature as relations constantly change. "In Zen Buddhist thought all things exist only in relation to one another and are subject to change as those relations change, which prevents the phenomenal world from possessing any enduring permanence" (Flowers, 2011, p. 5).



5) Design as an Iterative Process

5.1 **The Creative Process**

The creative process followed a rhizomatic connective-ness which was unpredictable in nature and could only be reflected on at the completion stage of the research. Documentation of research during the creative stages of practice is crucial for accessing the journey and the nature of the design development process. It is through reflection on the documentation within sketch books, technical notebooks and through photographic evidence the route and its bifurcations can be revealed. The following descriptions of design processes and developments are drawn from these sources to clarify and clearly articulate the processes and iterations involved in the design and creation of the final collection of garments.

5.1.1 **Modulations of Difference**

Initial findings about some of the limitations and possibilities within seamless knitwear software emerge through testing the parameters of some of the basic pre-installed shapes within the 'Modulations of Difference' study.

Stage One: Working in the 'Knitpaint' programme, with pre-installed basic shapes.

On first opening up the Knitpaint programme a selection pane will appear. It is here that the WHOLEGARMENT® option needs to be selected(see figure 69). To work on the size or measurement chart to create the shape of the garment, the option 'Size' needs to be selected. Because the garment will be knitting as a whole garment the 'Half gauge' needs to be selected. This can also be seen in figure 69.

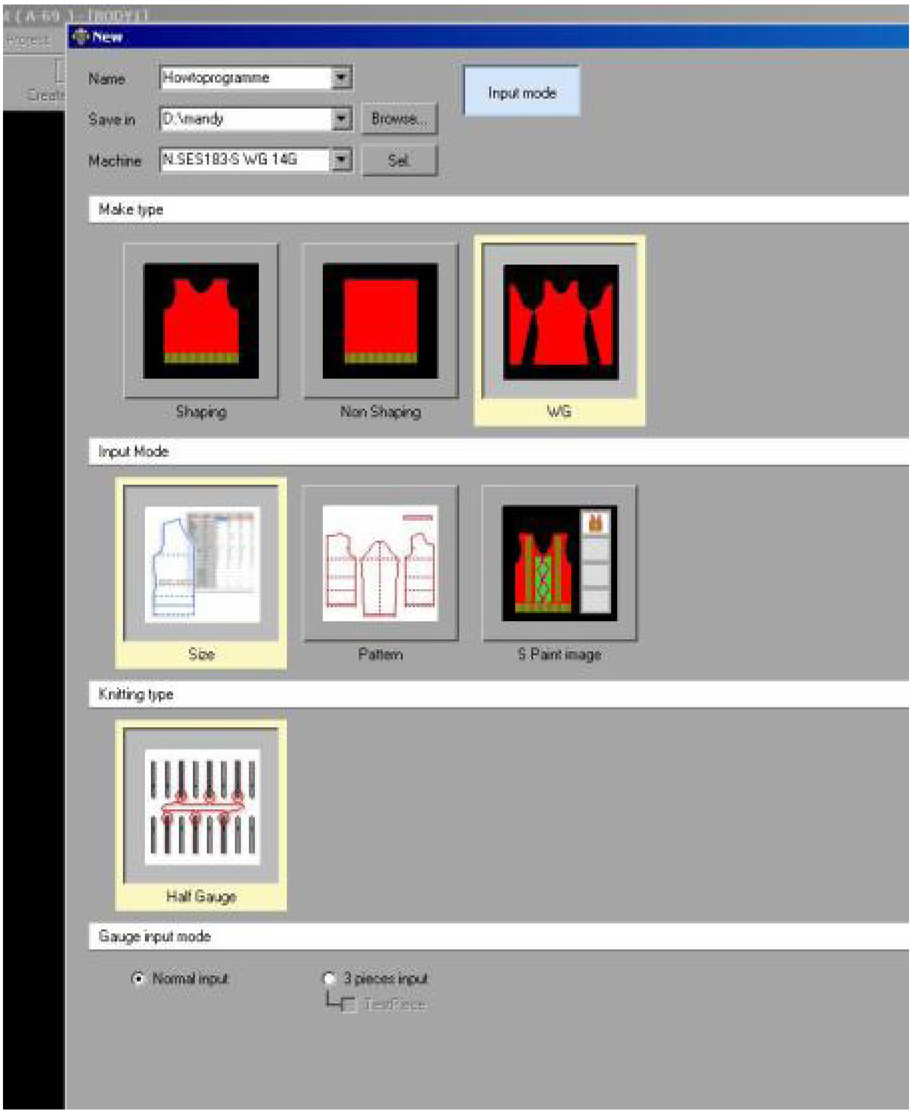


Figure 69:
Smith, A. (2011) How to select WHOLEGARMENT input option. Retrieved from 'Knitpaint' Shima Seiki Manufacturing

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The first stage of initialising the design programme happens after deciding on the garment shape. Figure 70, shows the pre-installed shapes that can be selected from a sweater, sleeveless or bottom (skirt or pants). If selecting a sweater, there are then sleeve and neckline options to select from. The sleeve types vary from parachute, raglan, setin, epaulette to horizontally knitted bolero styles. The neckline options vary from U-neck (round), V-Neck or turtle. The turtle neckline needs to be used for adding a trim on the garment neckline in order to finish it.

Figure 70 Smith, A. (2011). Seamless shape selection. Retrieved from 'Knitpaint' SDS.ONE. Shima Seiki Manufacturing.

Then the wale and course count need to be entered for each part of the garment (figure 71). This is calculated after doing a wale and course tension test on the knitting machine. These numbers are calculated over 100 centimetres for each component part. The pane also needs the direction of the mirror image selected. This is calculated from the centre line of each component part and can be seen in figure 71.

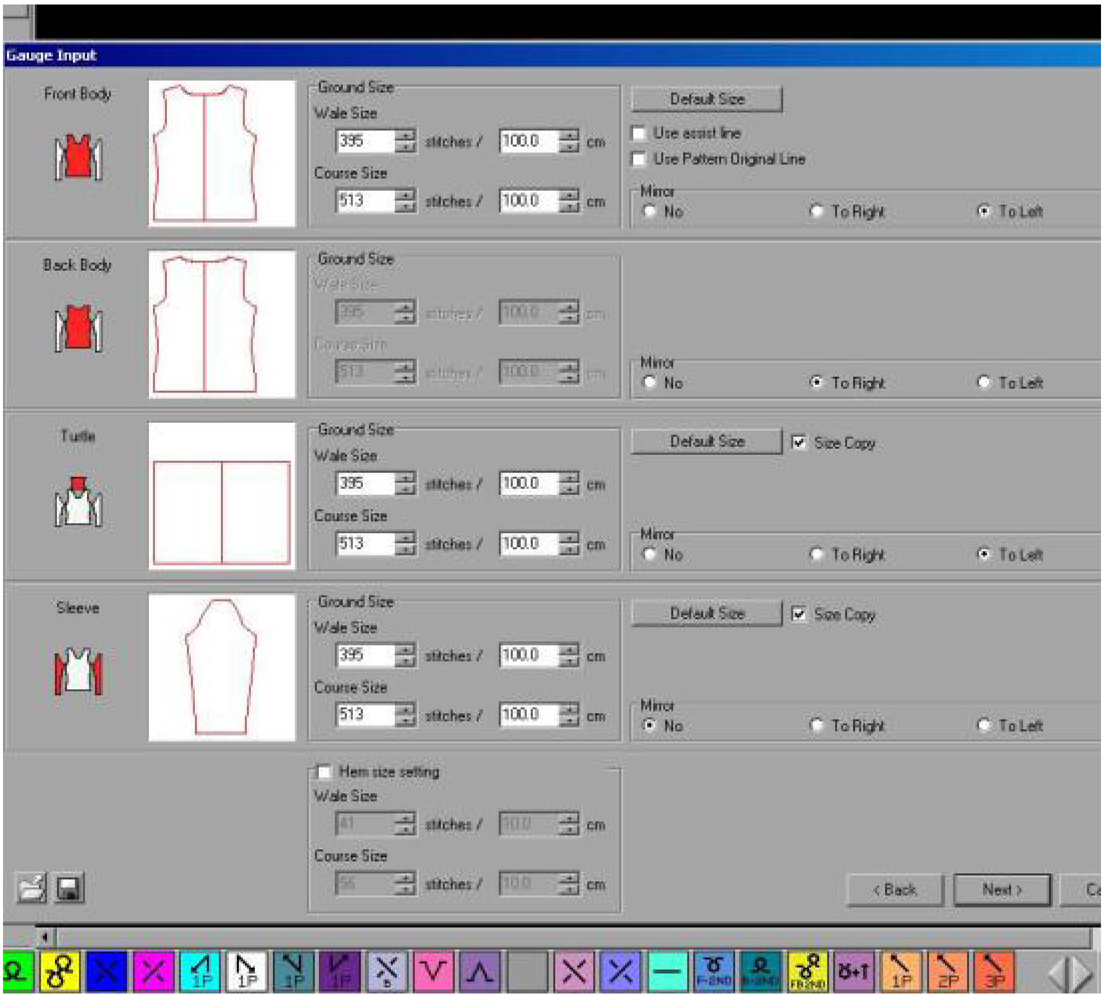


Figure 71:
Smith, A. (2011). Gauge input. Retrieved from 'Knitpaint' SDS.ONE, Shima Seiki Manufacturing.

The basic shape and standard measurements of the garment selected will appear in the next pane (figure 72). By entering new measurements the garment shape can be altered from the basic shape lexicon into more developed silhouettes and styles. Through experimentation at this point it was possible to start to understand the possibilities and the limitations imposed from the top-down designed Shima Seiki software on the silhouettes and styles that could be achieved by changing the basic measurements of the pre-installed shapes.

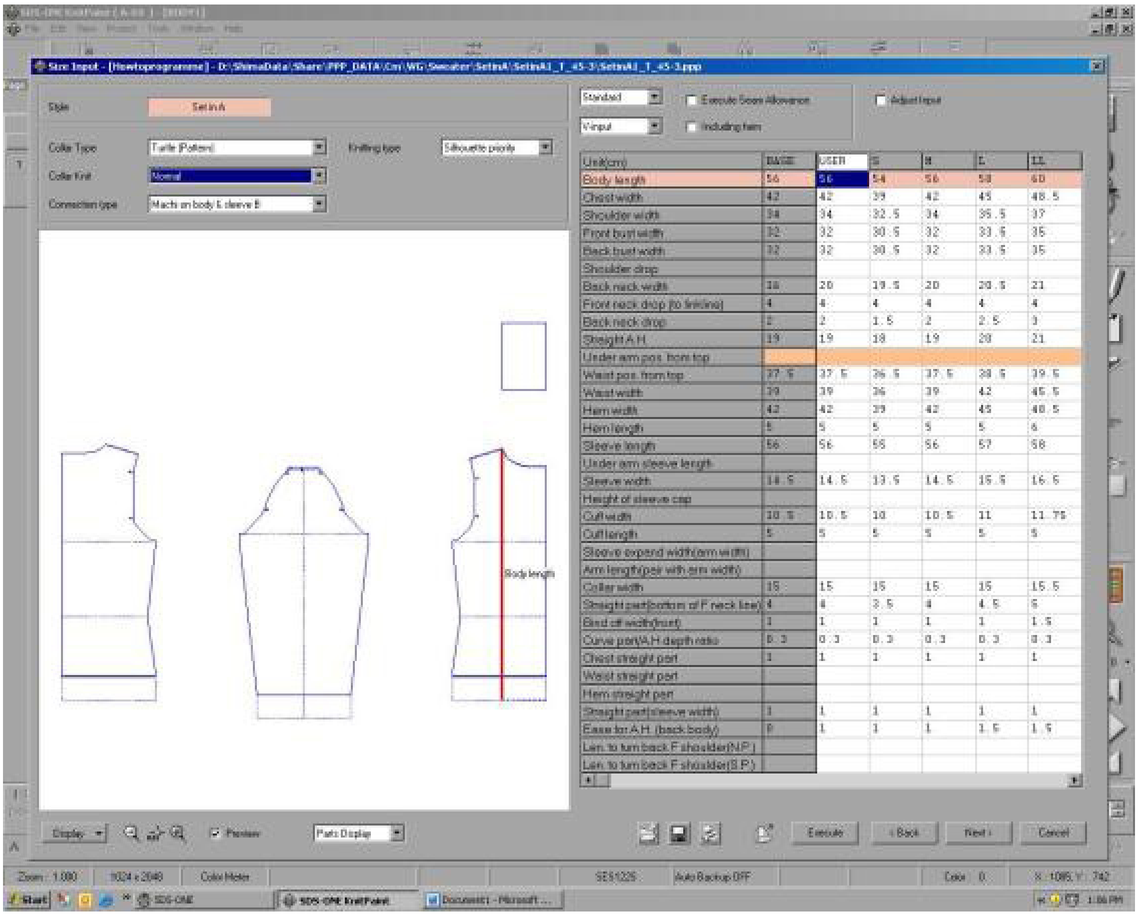


Figure 72:
Smith, A. (2011). Size Input. Retrieved from 'Knitpaint' SDS ONE, Shima Seiki Manufacturing.

Possibilities for minor alterations to the silhouette of the garment are endless figures 73, 74 and 75 show three basic raglan sleeve sweaters all of which have been altered by changing the measurements entered on the basic size input pane.

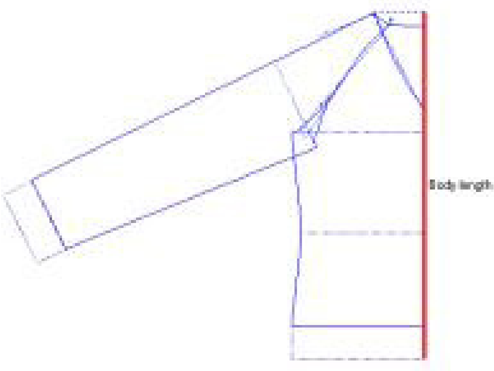


Figure 73:
Smith, A. (2011). Raglan Sweater 1. Source 'Knitpaint' SDS ONE, Shima Seiki Manufacturing.

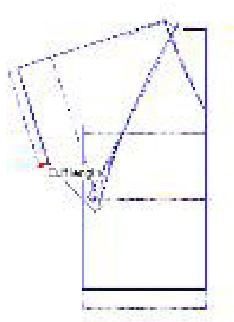


Figure 74:
Smith, A. (2011). Raglan Sweater 2. Source 'Knitpaint' SDS ONE, Shima Seiki Manufacturing.

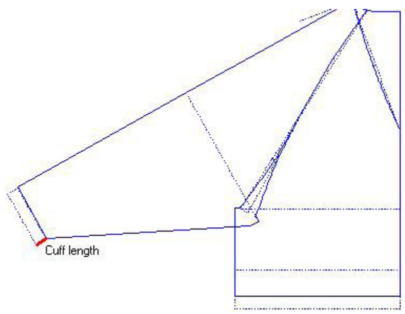


Figure 75:
Smith, A. (2011). Raglan Sweater 3. Source 'Knitpaint' SDS ONE, Shima Seiki Manufacturing.

Stage Two: Wholegarment Structure Pattern

By changing the measurements under 'USER' the silhouette of the garment can be changed. Changes can be made to the sleeve length and width, the body length and width and the neck shape and depth. Through experimentation of shape alterations a silhouette lexicon of possibilities and the limitations started to build. Some extreme changes to the basic shapes could not be successfully programmed, for the following reasons: garments were too wide and there were not enough needles on the knitting bed; the sleeves and body were not merging successfully or designs was having to hold over too many needles for machine movement to be achieved. Raglan sleeved sweaters were the most problematic to programme, due to the splicing movement of the sleeves to the body being un-even. It was also found that the raglan sleeved garment shapes, when spread out, could become very wide and required more needles than the knitting bed had available. An example of a raglan sleeved sweater that is programmed to stage two, the 'Wholegarment Structure pattern' stage can be seen in figure 76.

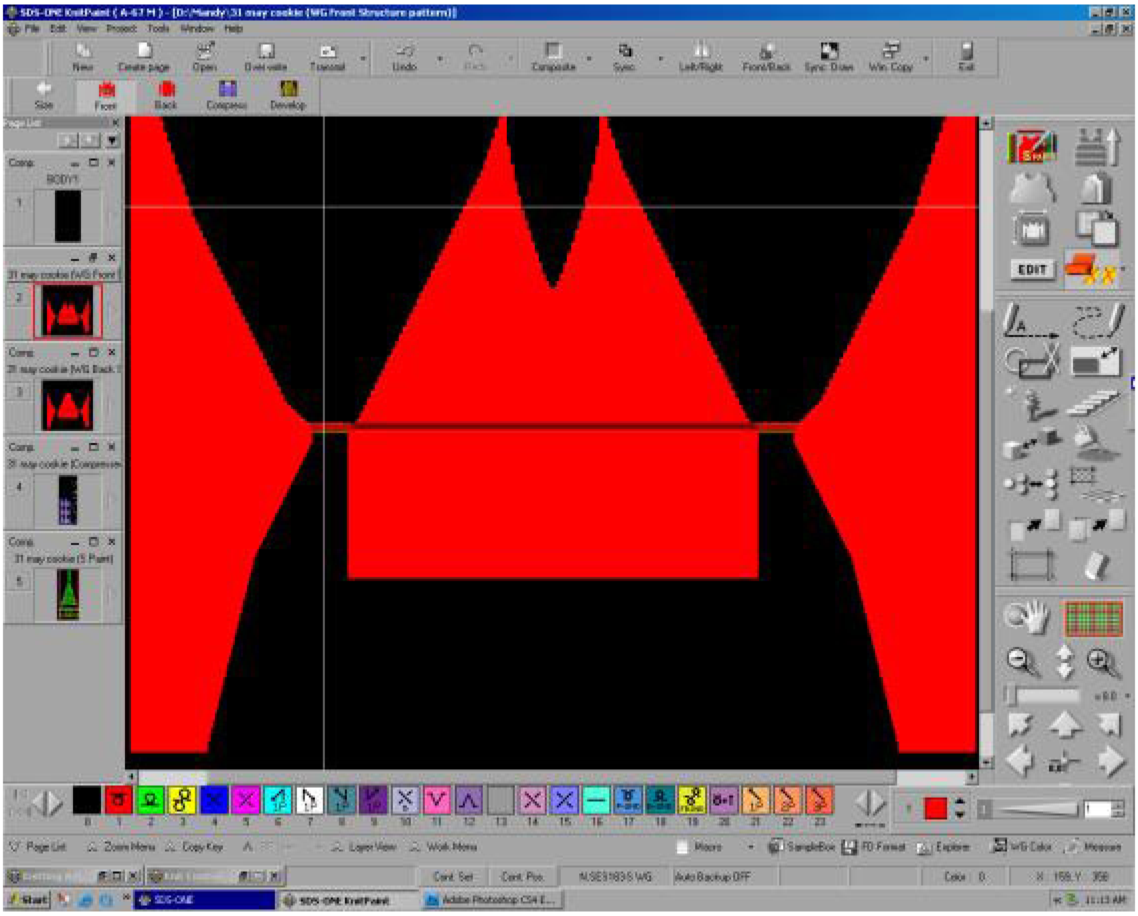


Figure 76:
Smith, A. (2011). Raglan Sleeved Sweater at stage 2. Source ‘Knitpaint’ SDS ONE, Shima Seiki Manufacturing.

Stage Three: Registering the shape into knit options lines and packages.

Stage three any additional machine movements to alter the shape or to add pattern structures need to happen. These can be done by moving pattern structures from ‘Design’ to ‘Knitpaint’ or by adding additional packages to create machine movements within the basic shape structures. This is done by using the colour-coded options created by Shima Seiki Manufacturing. These can be seen at the bottom of the screen shot in figure 77. Alternatively one may create package options developed in ‘Knitpaint’ if multiple machine movements are needed. Both the Shima Seiki Manufacturing stitch structure options in ‘Knitpaint’ and the basic pre-installed packages for a raglan sweater can be seen in figure 78.

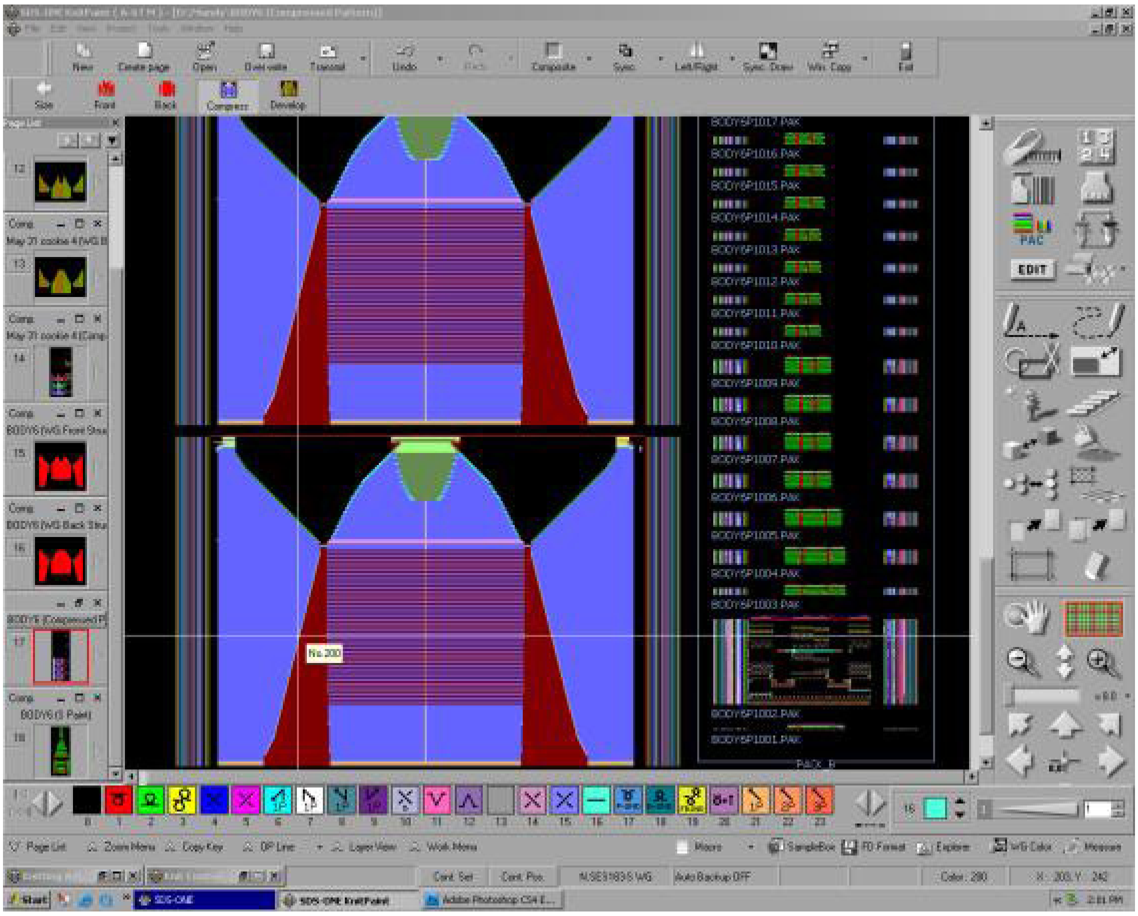


Figure 77:
Smith, A. (2011). Raglan Cardigan at Stage Three. Source ‘Knitpaint’ SDS ONE, Shima Seiki Manufacturing.

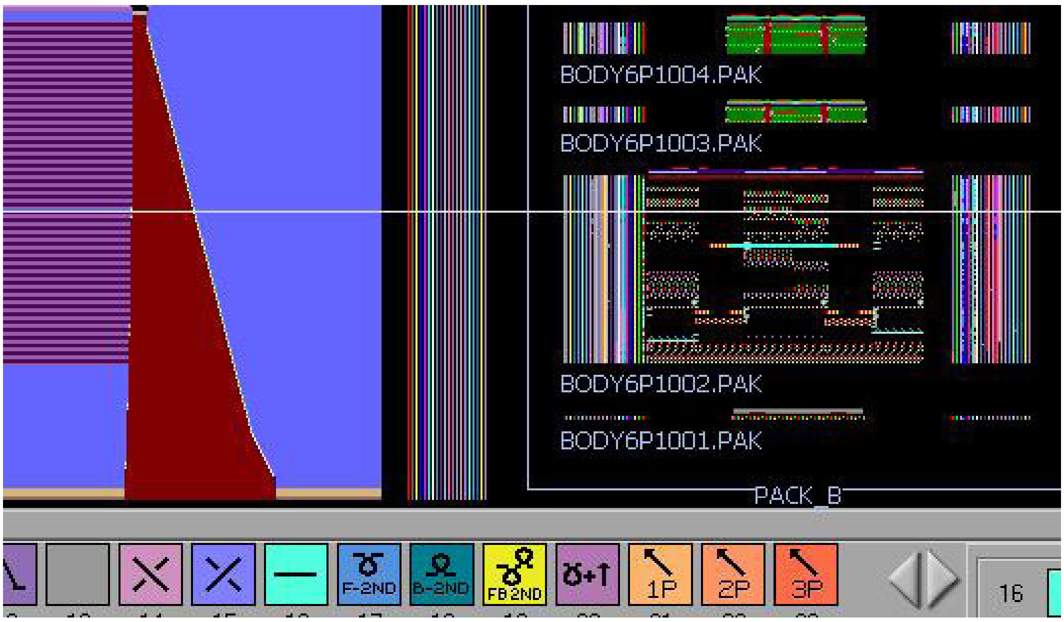


Figure 78:
Smith, A. (2011). Pre-installed Shape Packages and Machine movements in ‘Knitpaint’. Source ‘Knitpaint’ SDS ONE Shima Seiki Manufacturing.

Stage Four: ‘S Paint’ the technical instructions for knitting.

The fourth stage for registering a pre-installed shape in ‘Knitpaint’ is called ‘S Paint’. This is where the garment shape is translated into a course-by-course, wale-by-wale technical illustration of knitting instructions for the knitting machine. At this point that the garment shapes becomes unrecognisable in having any relationship with the final garment to be knitted. It becomes difficult to visualise how the seamless garment will look when knitted, as can be seen in figure 79, which shows the technical ‘S Paint’ visualisation next to the original stage two and three imagery.

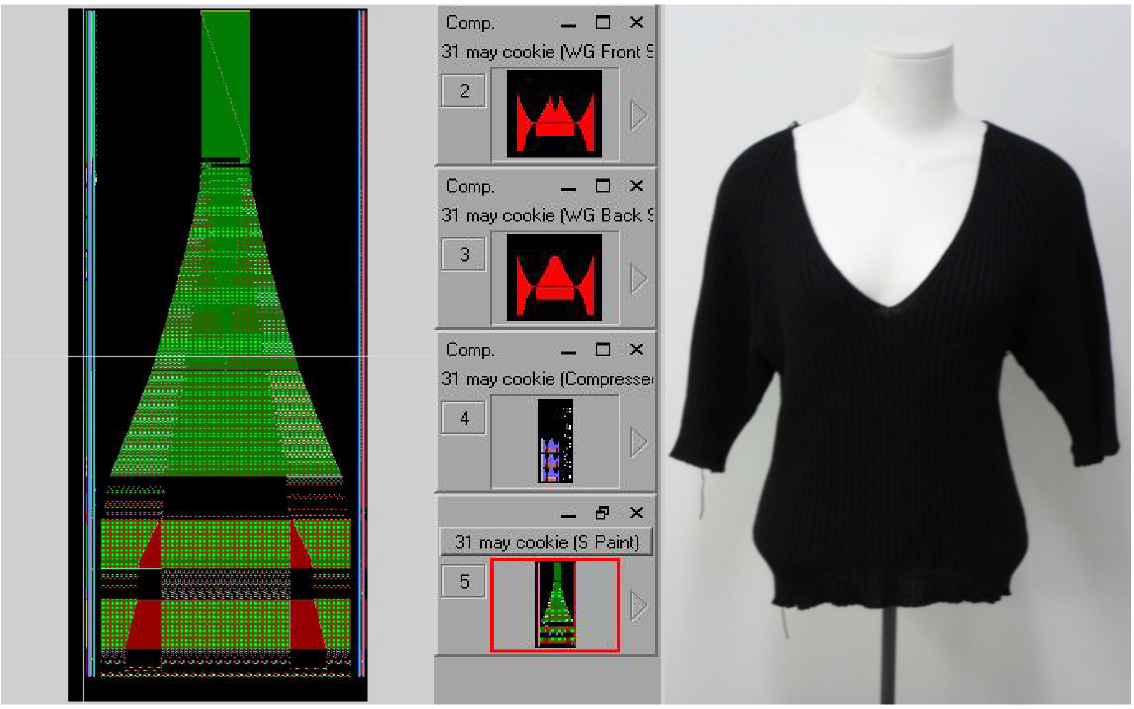


Figure 79:
Smith, A. (2011). S Paint Technical Instructions for Raglan Sweater. Source SDS ONE, Shima Seiki Manufacturing.

Discoveries of Limitations and Possibilities for Shape manipulation from 2D to 3D.

Discoveries made during the 'Modulation of Difference' study made me question if I was going to be able to achieve a three dimensional garment design process using seamless knitwear technologies. There were many technical limitations to the pre-installed garment shapes and seemingly very few possibilities for manipulation or disruption from the set pre-installed shape options. The main issues identified were: (i) width of garments especially if in a raglan format can be too wide for the needle bed on the knitting machine and (ii) the depth of the waist position in relationship to the sleeve depth can cause programming issues for raglan sleeved garments. The waist position needs to be lower than the sleeve depth for programming to be successfully completed. If programming cardigans the fact that no overlap can be created needs to be taken into account. The programme works in a very two dimensional format which is dictated by the software and promotes two dimensional garment silhouette outcomes. The visual representation works to promote this two dimensionality by continuing to work on flat images of the front, back and sleeve shapes. This imagery also makes it very difficult to project the final garment outcome, when realised in its knitted form.

The round neck, set-in sleeve garments proved to be more consistently successful and easier to programme. For this reason I continued to work with the set-in sleeve option while working on further design developments. I also realised that if I was going to alter the garment silhouette from two dimensions to a three-dimensional contour, a means to incorporate the shaping *forces* of the garment needed to be integrally incorporated into the pre-installed formatting process, before it was translated into the 'S Paint' technical diagram. This created a focussed direction for development of new shapes: what means could be incorporated integrally through knitted structures as the seamless garment was being knitted? Drawing on tacit knowledge of knitted structures and techniques, a mind-map of known stitch structures that influenced directional changes to knitted forms was completed, as can be seen in figure 80. Through discussion with the TDL technician some of these techniques had to be dismissed as impossible to apply while knitting in a seamless mode. This was because the techniques needed both knitting beds to be realised. These knitted shaping techniques were not possible because both knitting beds are needed to knit the garments in a seamless manner. Techniques such as knitted pleats need the structure to be formed on a double bed fabric or if produced as a single bed fabric, would involve needles being used on the back bed simultaneously with the front bed, which is not possible whilst knitting seamless garments. Discussion and further analysing of fabric structures led to the testing of integral shaping such as 'turning the heel' of socks or in short row knitting in a traditional beret.

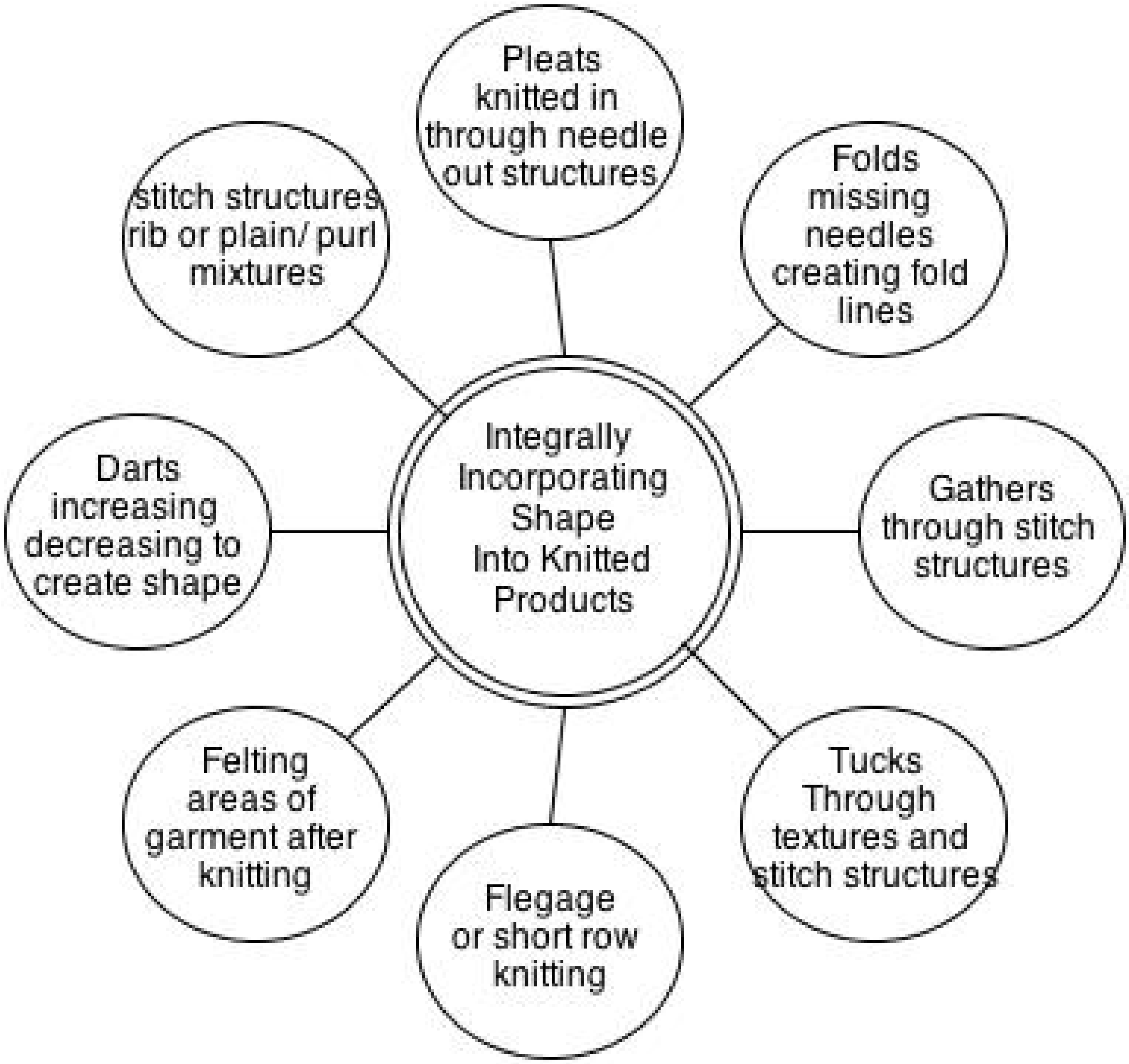


Figure 80:
Smith, A. (2011) Mind Map of How to Integrate Shape in Knitted Forms

5.2 **Design Ethos**

Through sketchbook developments and an unfolding connection to Wabi-Sabi emerging through the development of a theoretical and philosophical underpinning of the practice, a general design direction emerged. This had a 'naturalistic' feel of unstructured forms, incorporating drape and softly folding asymmetrical lines untethered by seams or structure, but with movement and disturbance of silhouette as the forms folded around the body. This design *feeling* was further developed through sketchbook drawings and the compilation of a Wabi-Sabi theme board (seen in figures 81, 82 & 83). Figure 84 shows the knitted notation developments to interpret the Knitpaint visual imagery into ideas of what the final seamless garments might look like when knitted.

Figure 81:
Smith, A. (2011) Initial Form Gathering Process

Figure 82:
Smith, A. (2011). Wabi-Sabi Ethos Gathering of Images

Not obvious; Unbounded
by convention; Free; tranquility; Dark
Austere beauty; Imperfection; ethereality

Figure 83:
Smith, A. (2011). Sketchbook

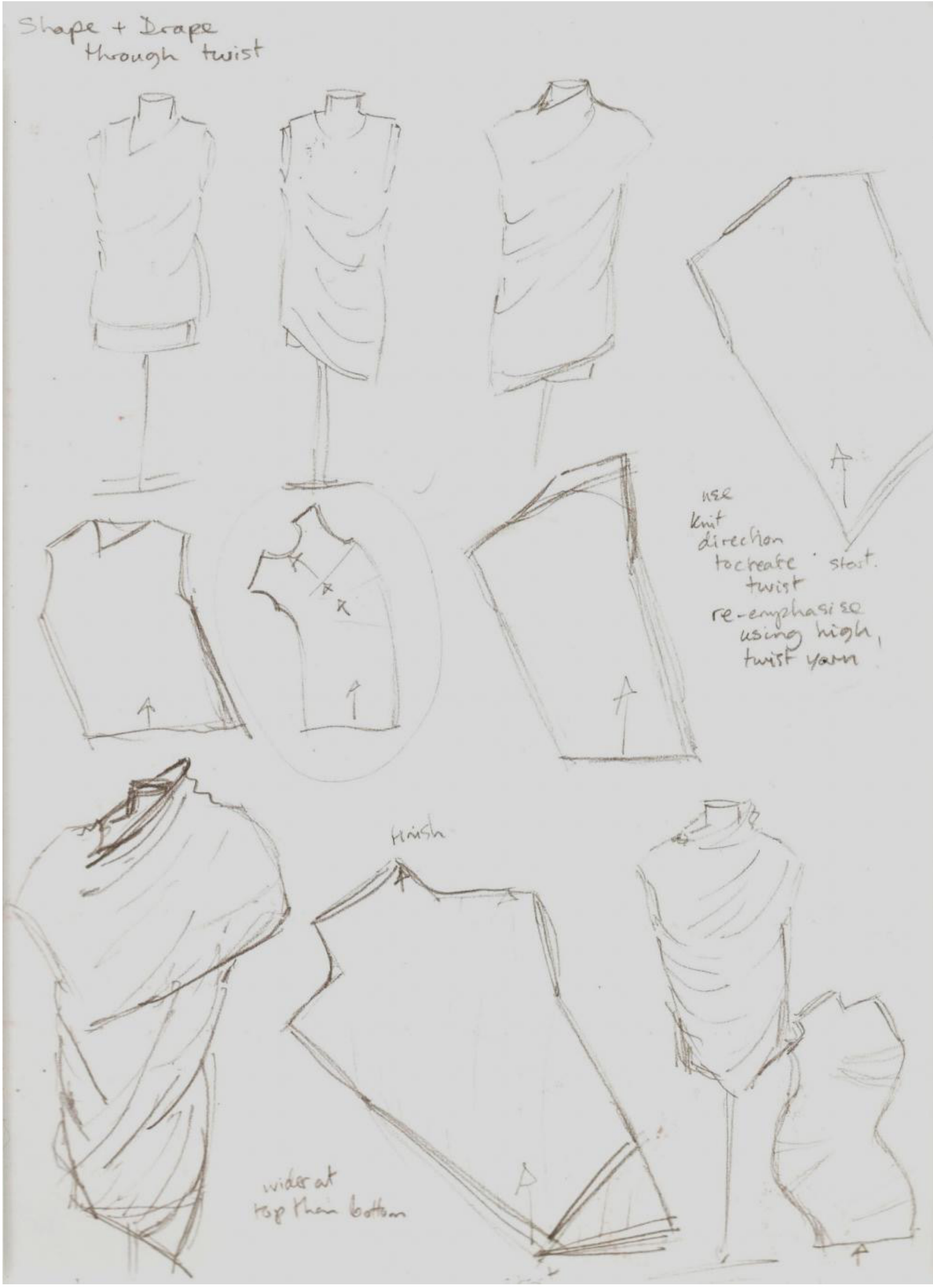


Figure 84:
Smith, A. (2011) Sketchbook

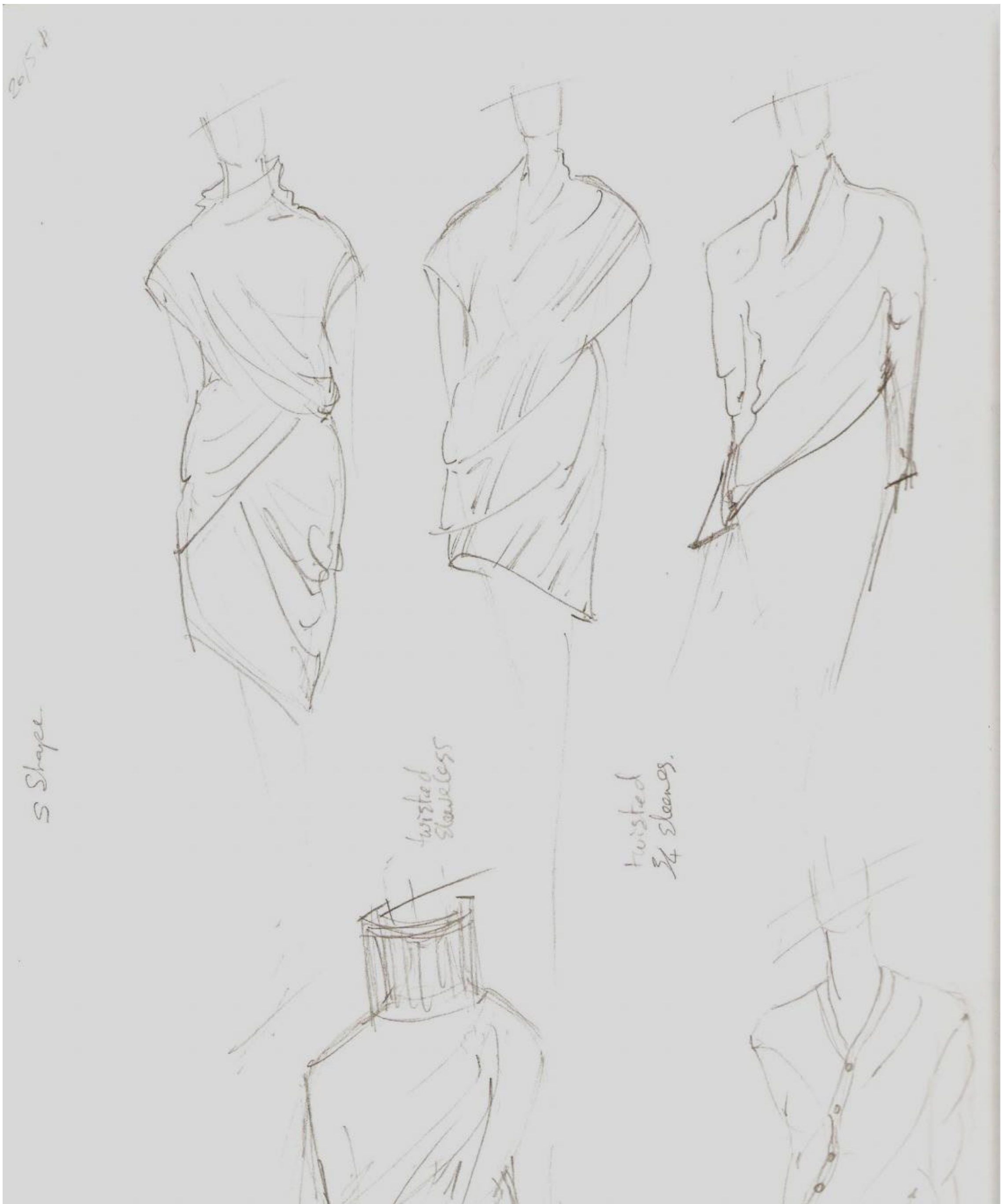


Figure 85:
Smith, A. (2011) Sketchbook

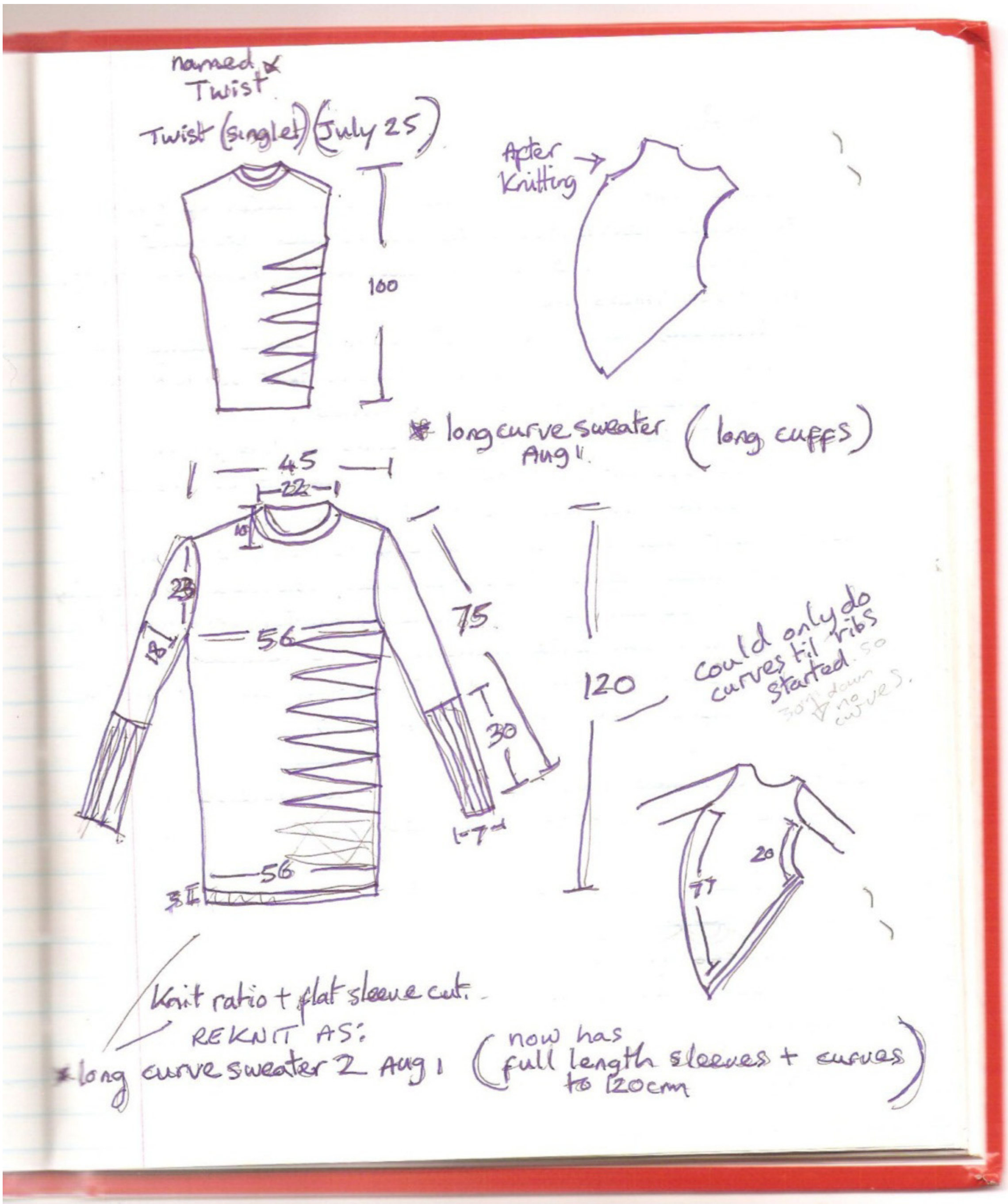


Figure 86:
Smith, A. (2011). Technical Notebook

5.3 **Creative Design Process**

The first garments that I developed worked from the idea of creating a twist to the basic pre-installed shapes with the design premise that movement would be created around the body and drape increased within the garment form. By introducing a 'wedge' shape to the basic pre-installed shapes, fabric was taken away from the rectangular form in designated areas of the garment body. The wedges work much like adding darts into a fabric garment, but could be programmed into the garment at 'stage three' of the development process when using Knitpaint. The first garments designed used the basic singlet which had been lengthened and made wider. The wedge shapes were then added to the garment using a 'Package' (pac) to create the machine movement needed. This was developed by the TDL technician after an explanation of the type of knitted structure and movement required. Results from this experimentation can be seen in figure 87.

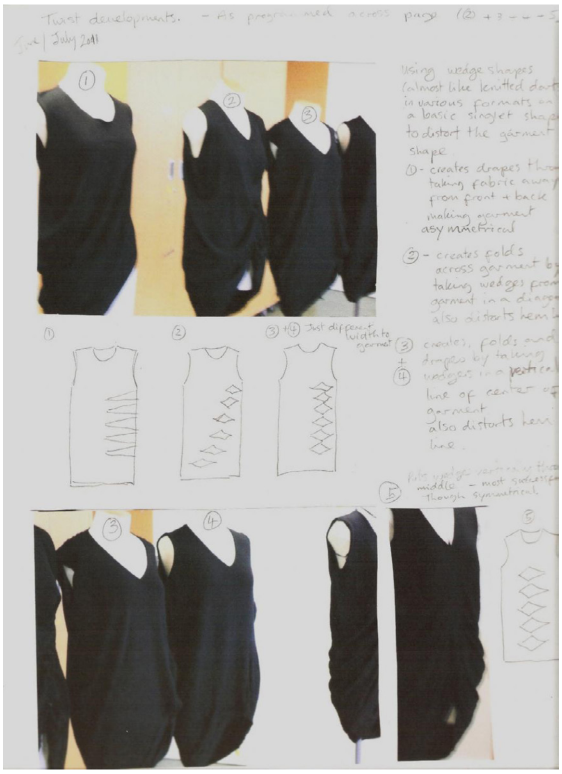


Figure 87:
Smith, A. (2011). Sketchbook of First Garments Using Additional Packages.

Design results showed that if the wedges were placed at the side of both the back and the front of the garment, a distortion of the garment which gave an asymmetrical hem line and curved the body away from the vertical occurred. Other findings included: a distorted garment resulted from placing the wedges off the central vertical line, the further away from the centre the more disturbances to the final form in an asymmetrical manner. If the wedges were placed on the vertical line the disturbance to the garment had the most impact, but the garment itself remained symmetrical.

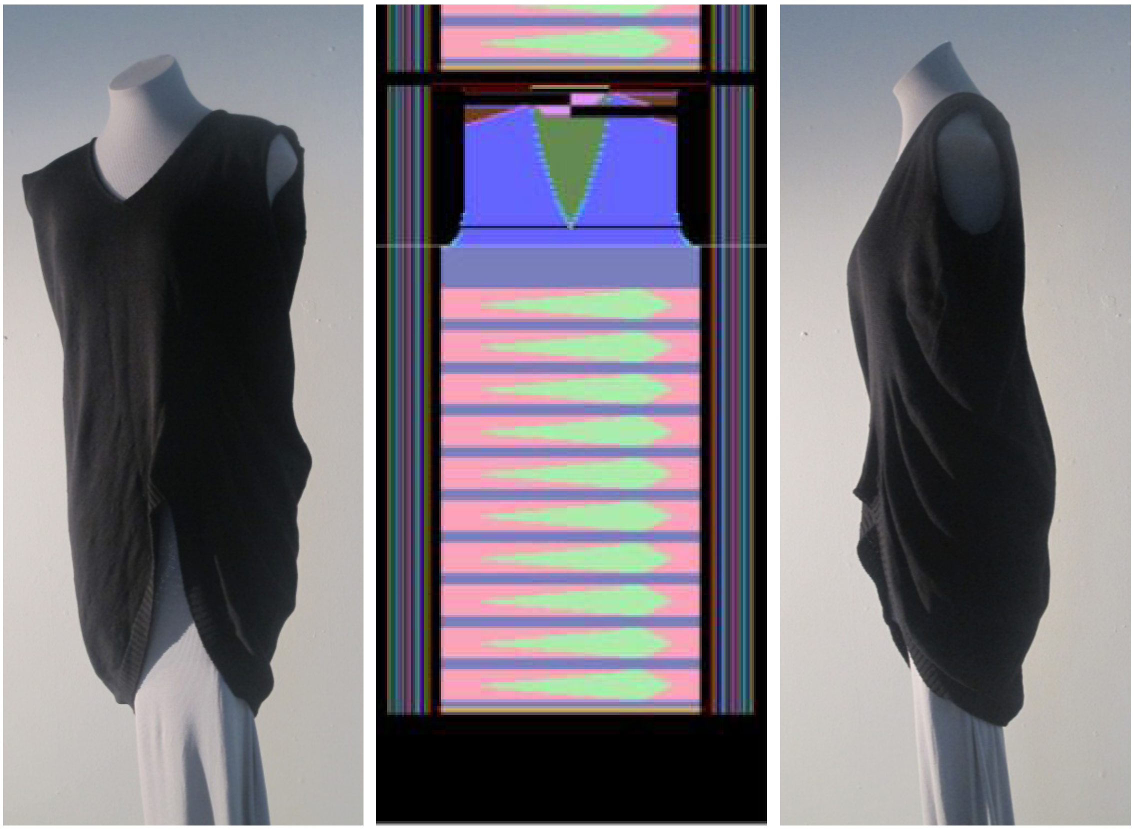


Figure 88:
Smith, A. (2011). Garment with Wedges Off Centre, Actualised and Virtual Programme.

Figure 89:
Smith, A. (2011). Garment with Wedges Placed on Front and Back, Actualised and Virtual Programme.

Further garment shapes were developed working with the singlet as the base pre-installed shape. By extending the shoulder line and dropping the waist point, new silhouettes which distorted the singlet shape away from the initial pre-installed software shape Started to emerge. This was further distorted when new wedge shape pacs were added two examples of this this process can be seen in figures 90 and 91.

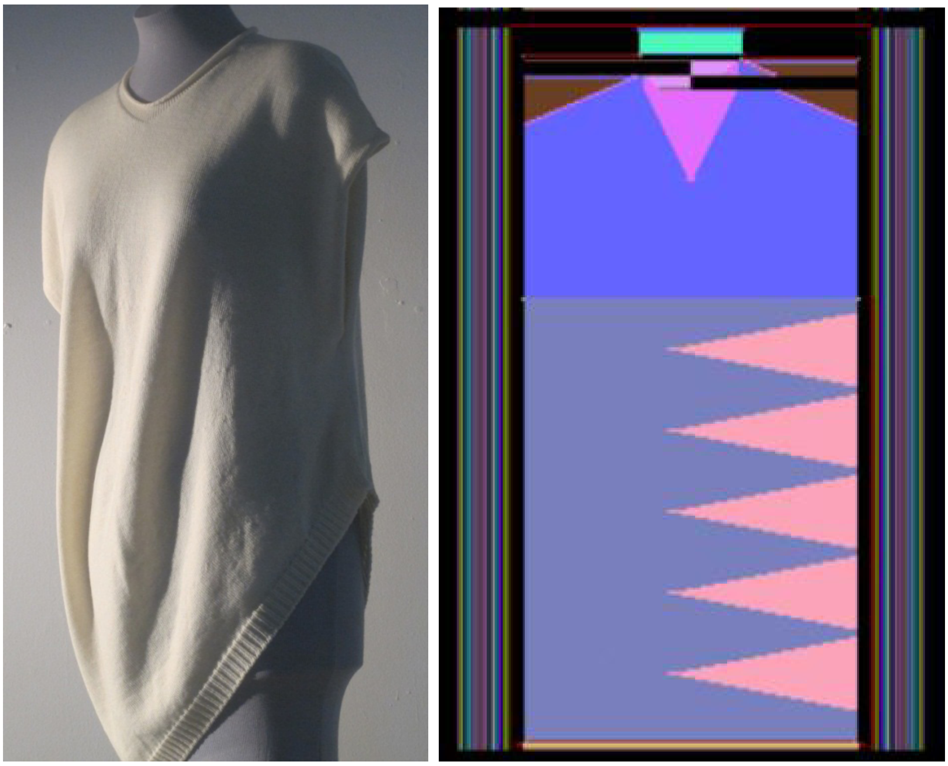


Figure 90:
Smith, A. (2011). Singlet with Extended Shoulders and Side Wedges on Front and Back of Garment.

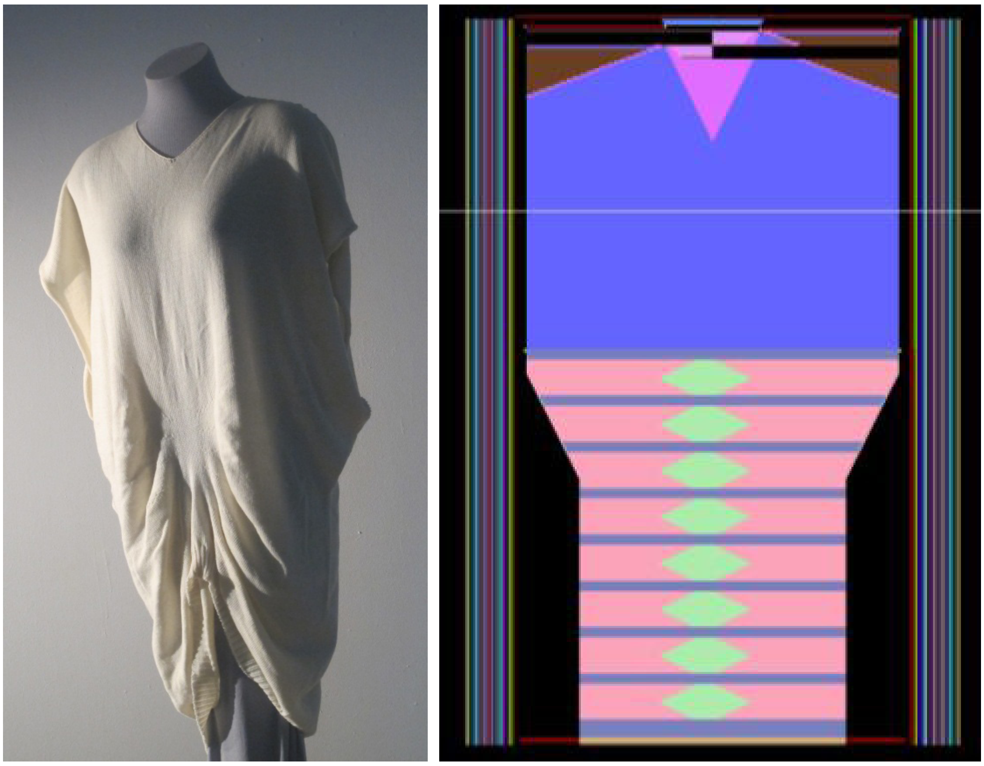


Figure 91:
Smith, A. (2011). Garment with Shoulders Extended and Centrally Placed Wedges.

The experimentation into additional pacs proved to be a successful strategy in creating movement of garment silhouettes away from the pre-installed Shima Seiki shapes. The technical knowledge to register the new pacs was easy to memorise (see Appendices B and C for details on registering pacs). All experimentation had taken place on the tunic pre-installed shapes. To move the idea forward onto other pre-installed shapes, further pacs had to be developed. These pacs had to create the same stitch structure movement but had to work within the garment format for a set-in sleeve sweater and a set-in sleeve cardigan. Please refer to Appendix E for the additional pacs developed for use on the 'Tunic', 'Set-in Sleeve Sweater' and the 'Set-in sleeve cardigan'. The development of these further pacs opened up multiple design options across a range of garment shapes. Some of the first sweater and cardigan garments developed can be seen in figures 92, 93 and 94.

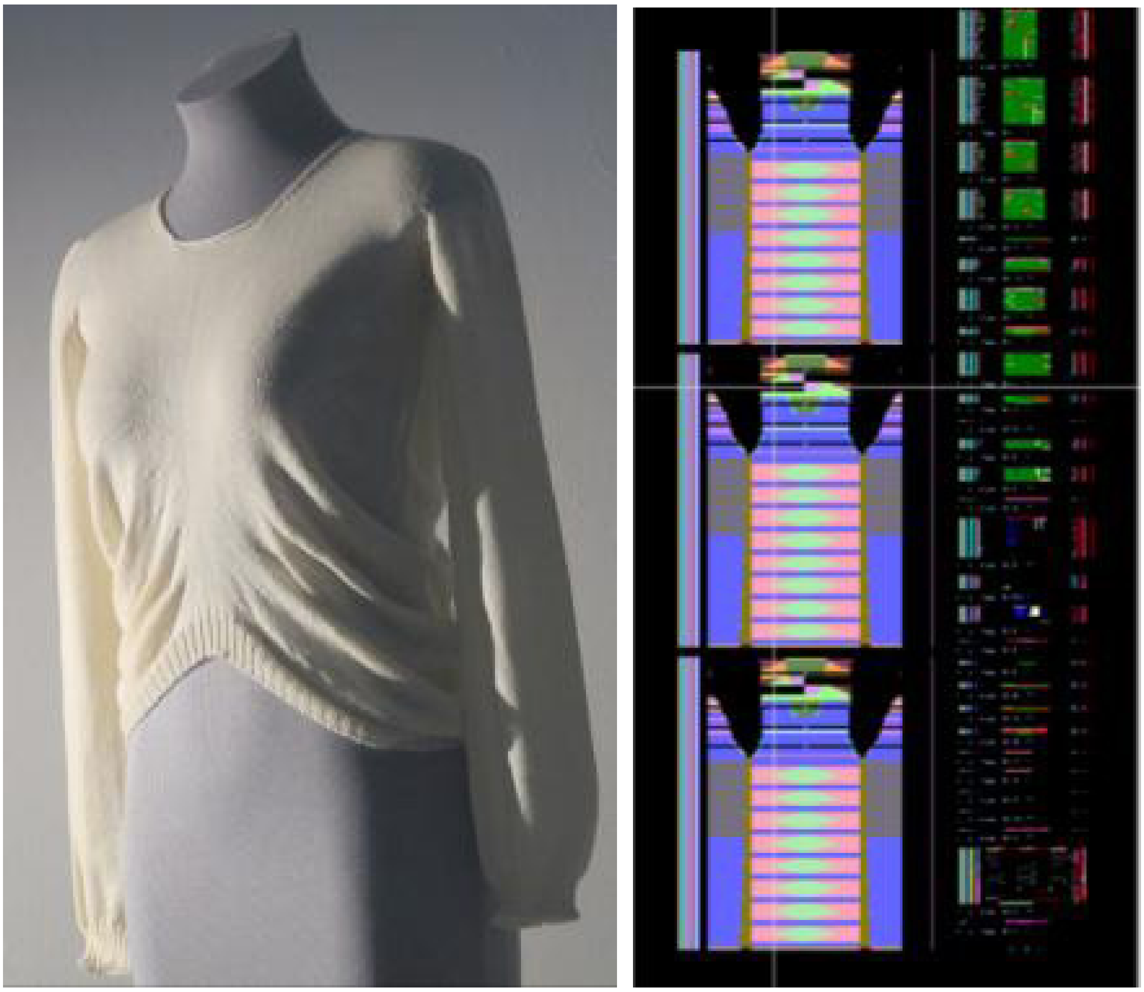


Figure 92:
Smith, A. (2011). First Sweater with Added Pacs.

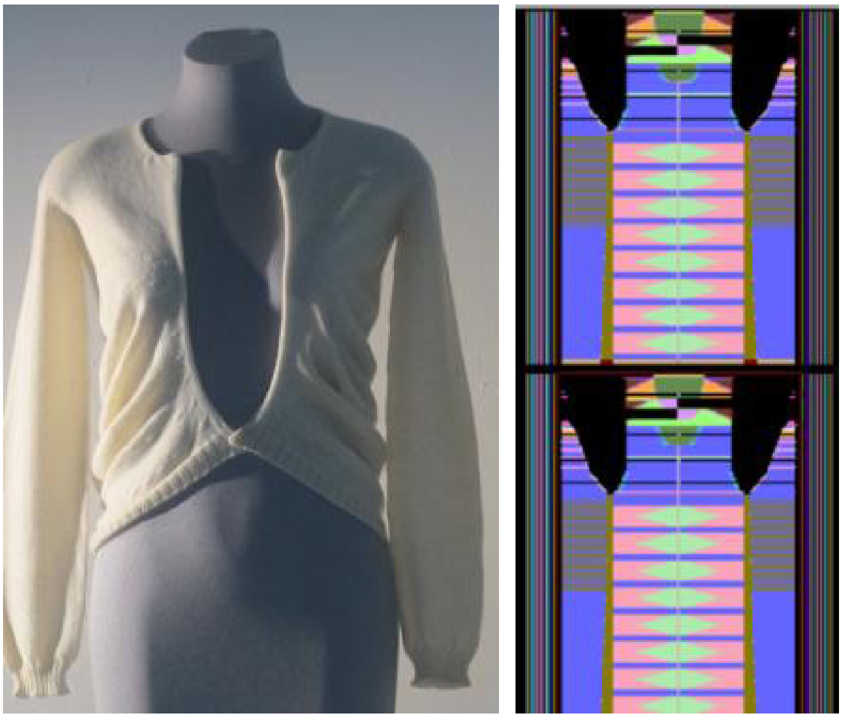


Figure 93:
Smith, A. (2011). First Cardigan with Additional Pacs Added.

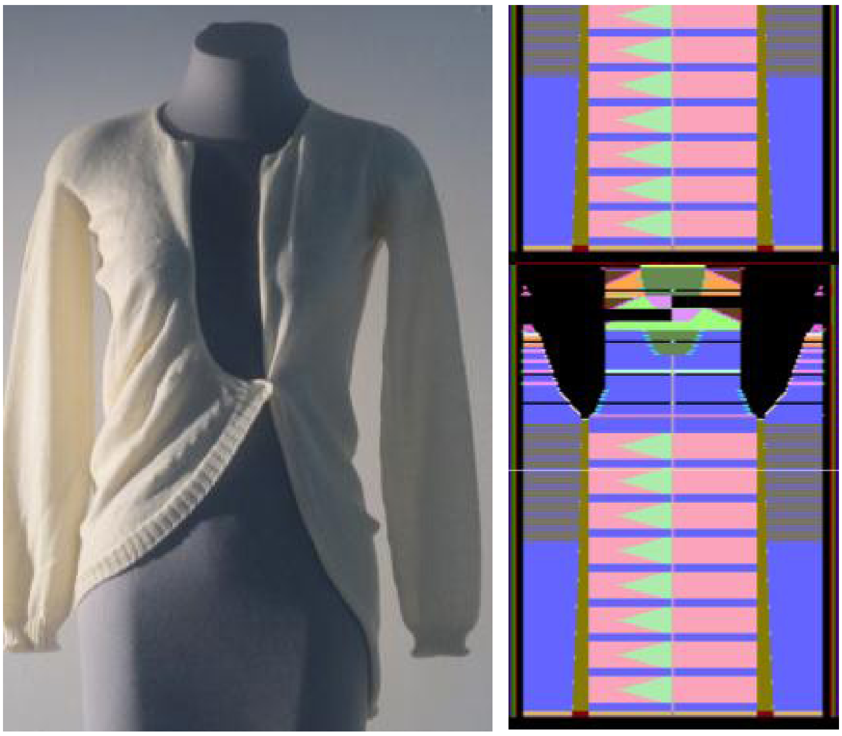


Figure 94:
Smith, A. (2011). Second Cardigan with Additional Pacs Added to One Side Only.

At this point it became apparent that further design development processes would take on an iterative nature because the diagrammatic imagery and actual garment forms when knitted did not resemble one another. In Figures 92, 93 and 94 the computer-based imagery generated by the Shima Seiki software programme remain rectangular in body shape, but each garment when knit takes on very distinct silhouettes with an individual movement of form around the body. The design development process started to work in a 'bottom-up' way with garment iterations developed from the previous ones and in some cases by cross-connections of a rhizomatic nature. In this manner five base garment forms were developed and settled on (see figure 95).

Figure 95:
Smith, A. (2011). Five Base Shapes.

These five base shapes were developed using single and double pacs, placed to create the most amount of movement around the body, whilst forming drape and excess fabric distending the silhouette from that of a flat two dimensional shape seen in the pre-installed Shima Seiki formats. These five base shapes were chosen because they covered the normal elements of a knitted garment collection, by including a cardigan, a long and short singlet and a long and shorter sweater silhouette. They were also settled on because through their variation of directional forces, they created a complexity of movement which was reflective of my aims within this research of creating three dimensional forms.

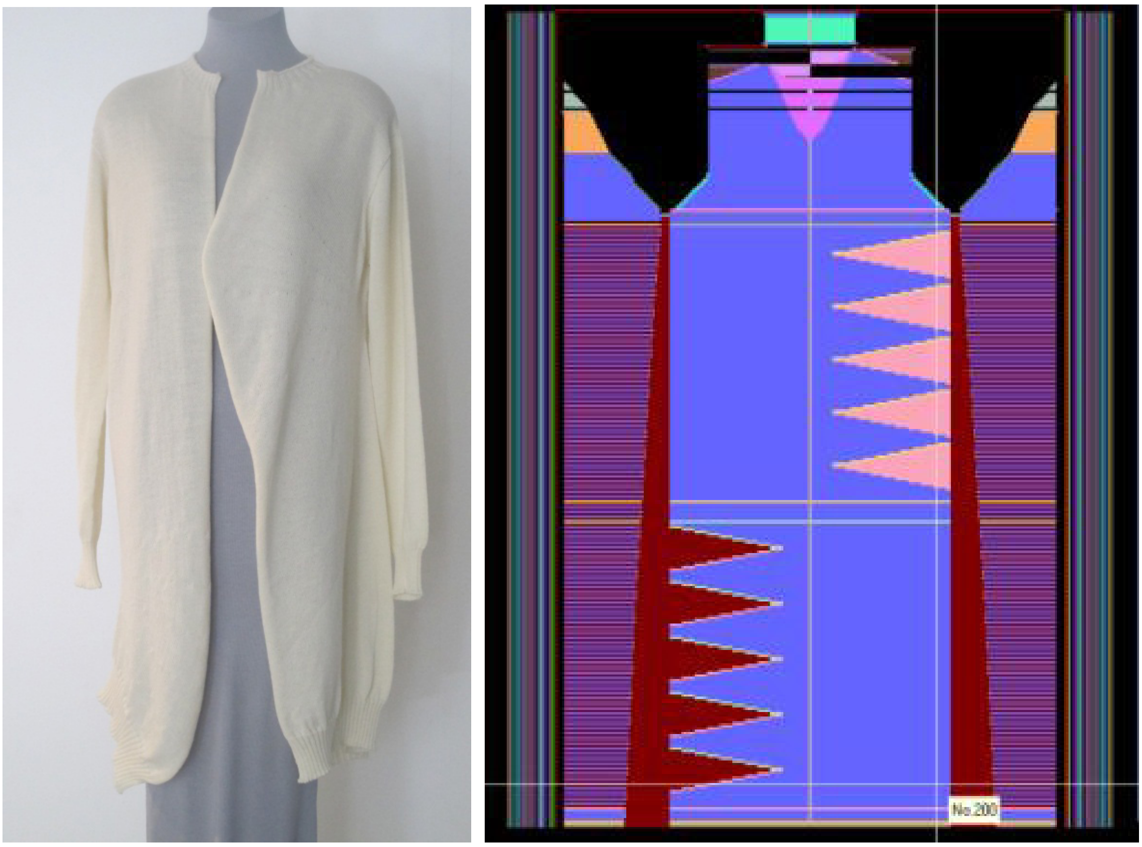


Figure 96:
Smith, A. (2011). Double Sided Cardigan, Two Pacs Added.

The garment in figure 96 used two pacs placed on opposite sides of the basic cardigan with a set-in sleeve. The measurement of the cardigan was extended in both the length and width to move the garment further away from the natural body fit. The additional pacs created opposing curves on the front central line of the garment. The *force of movement* through the garment caused the underarm 'sides' to curve both in and out but in different positions down the body length.

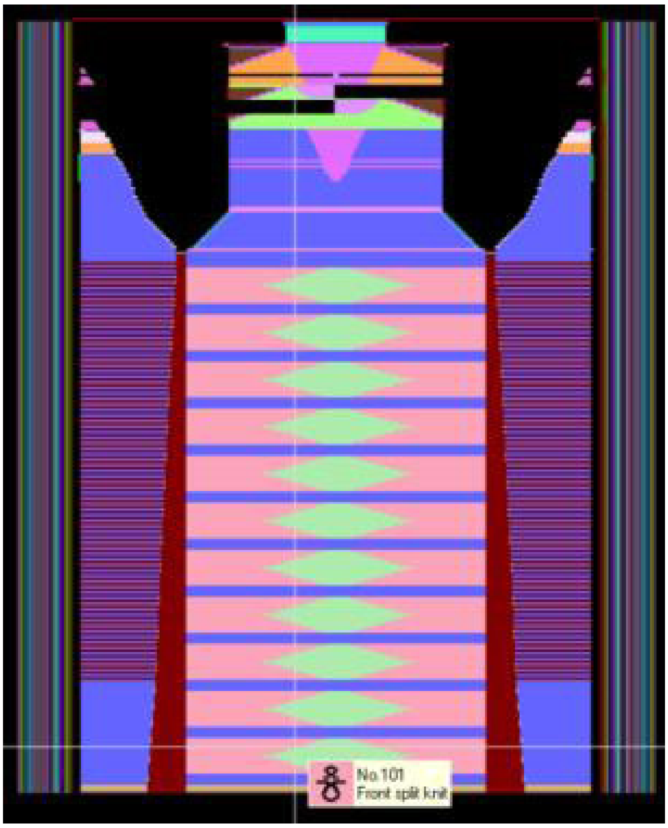


Figure 97:
Smith, A. (2011). Set-in Sleeve Sweater with One Additional Pac Added Through the Centre.

This garment used the basic pre-installed set-in sleeve sweater shape. The garment measurements were extended through the length and width of the shape, to allow movement around the body when the shaping pacs were added. The additional wedge shaped pacs were added through the centre of the garment, which held the knitting through the middle of the garment whilst still knitting the sides and back. This created natural drape down to the sides of the garment which continued around to the back of the garment.

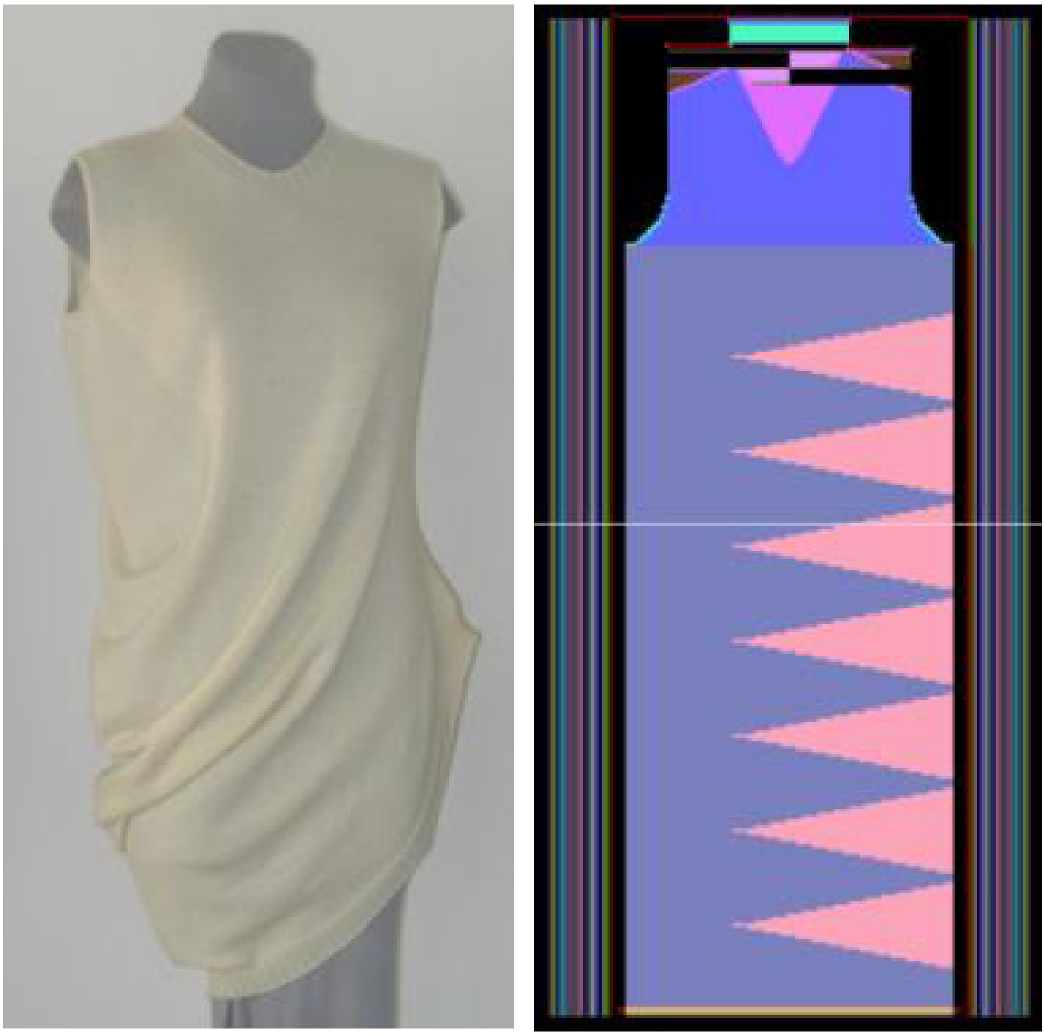


Figure 98:
Smith, A. (2011). Tunic with Single Wedge Pac Added to Both Front and Back of Garment.

This garment used the basic pre-installed tunic shape, the length and width of the garment was extended. When the additional pac was added to both the front and the back of the garment on the same side, the knitting was held on this side, whilst all other areas of the garment continued to knit. The resultant garment has one side which is much shorter than the other in this case by fifty centimetres. This creates drape which moves around the body from front to back as well as creating an asymmetrical hem line. The drape movement travels undisturbed by seams around the body, with front and back opposing movements visible within the garment silhouette.

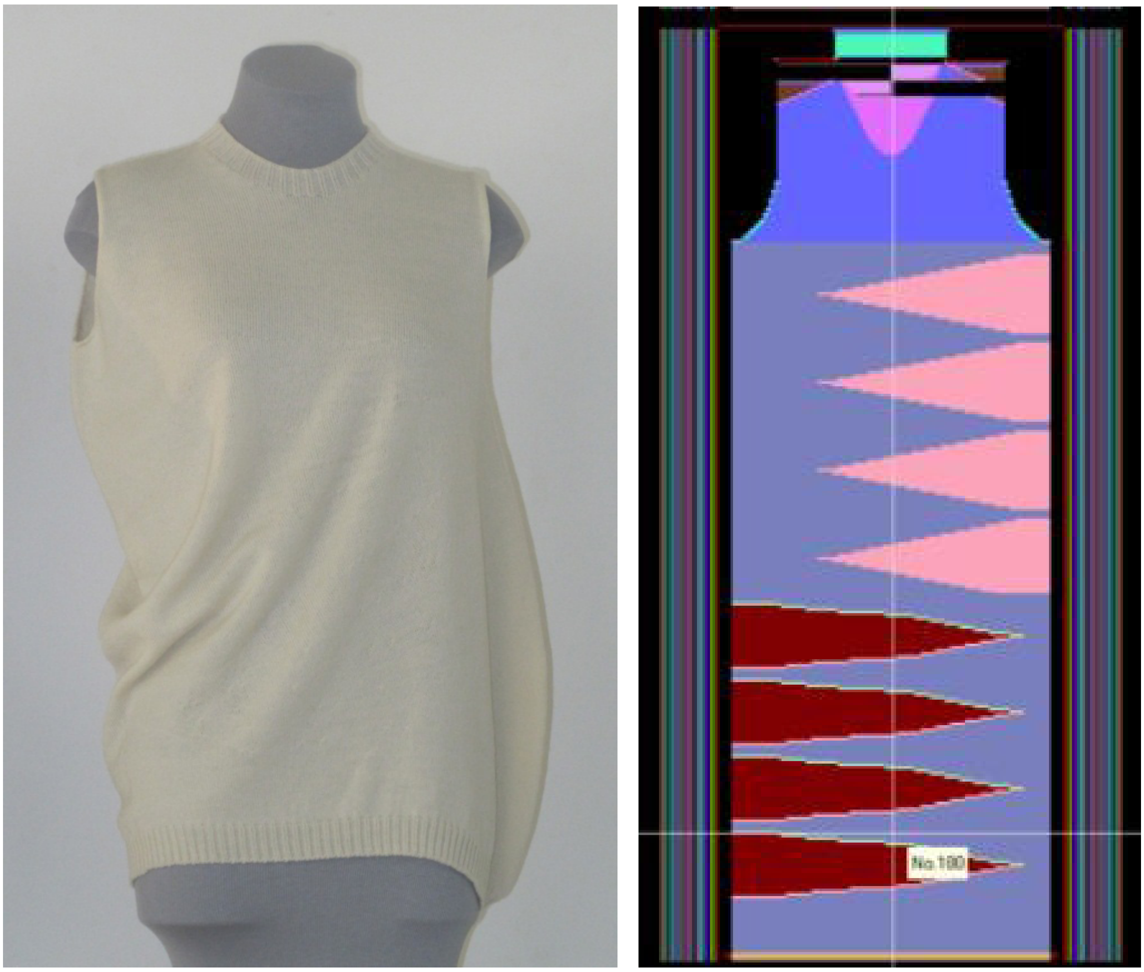


Figure 99:
Smith, A. (2011). Tunic with a Double Pac Added to Both Left and Right of the Garment.

This garment used the tunic basic pre-installed programme, with two pacs added, on the left and right and front and back of the garment. The force of knitted structure movement created opposing forces within the garment, causing it to twist through the middle and to distort along the sides of the garment, both at the top and the bottom of opposing sides.

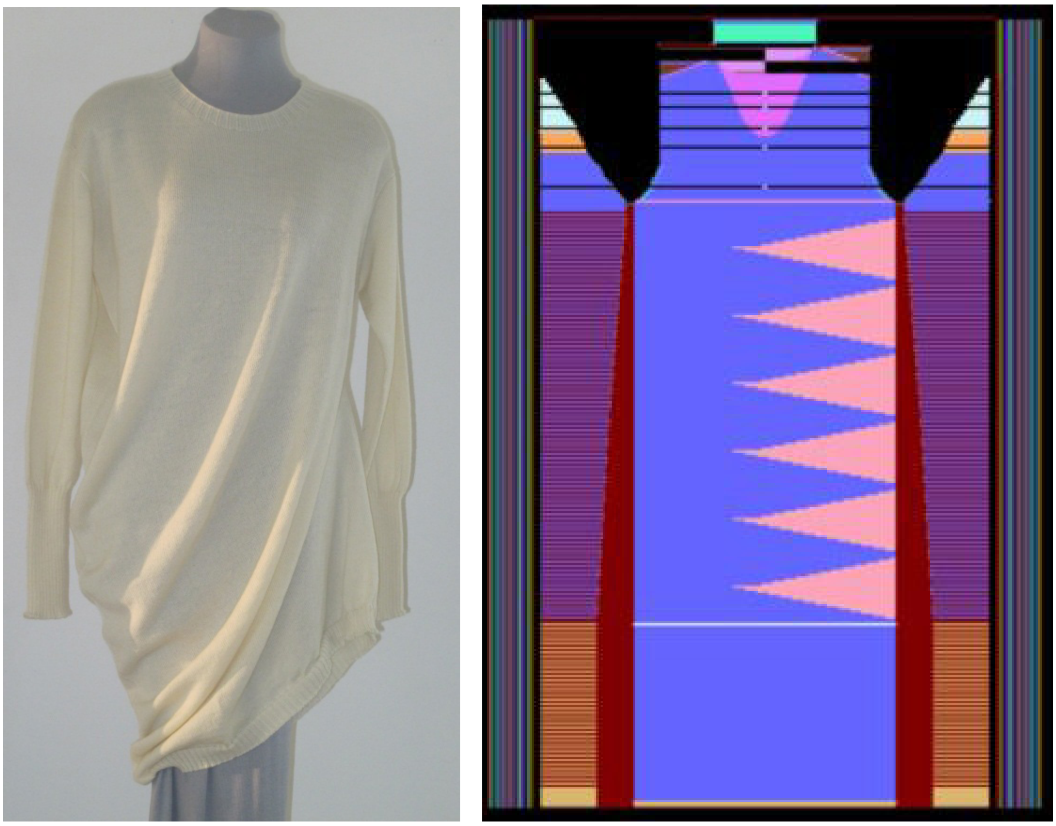


Figure 100:
Smith, A. (2011). Set-in Sleeve Sweater with One Additional Pac Added.

The garments in figures 96, 97, 98, 99 and 100 were chosen as the five base styles to be developed further. They were considered to be the five garments that most successfully demonstrated a silhouette movement away from the two dimensional flat pre-installed shapes to one that started to recognise design possibilities for three dimensional creativity in knitted forms. These garments exhibited asymmetrical three dimensional forms which were counter to the normal garment shape produced using seamless technology, of flat two dimensional proportions which remain very symmetrical in structure.

The force and energy of the machine movements remained visible within the garment, with one side opposing the other creating a distorted, twisted form. This distortion should make the garments imbalanced but the overall affect is one of harmony. As a garment is viewed from different angles, no view remains static, but the balance of fit, flow and an elegance of form remain evident.

The design development process moved from form building to incorporating stitch structures within the garments which would emphasise the three dimensionality of the form, without distracting from the integral drape and silhouette.

5.4 **Design As: Textural force and movement.**

Having established five basic forms, the design process moved to thinking about how to include texture and stitch structures within the base shapes, which would add to the three dimensional forms as well as emphasising the elements of drape created. This process drew on previous knitwear knowledge of knitted stitch structures and ways of incorporating textural surface into garments. The unknown element of the computer design system outcomes as seen in the initial virtual imagery, created some unpredictable results. Rhizomatic connections started to be made between garment developments as computer outputs were merged with tacit knowledge in an iterative manner. Knowledge from each garment produced became inter-twined with the next iteration, which also developed and defined its own design boundaries through the process of development and making.

The first textural trials used pin tucks to add texture to garments. These were added in a horizontal liner way to the garments. Figure 101 shows some of the developing notation for additional pacs and textural stitch structures.

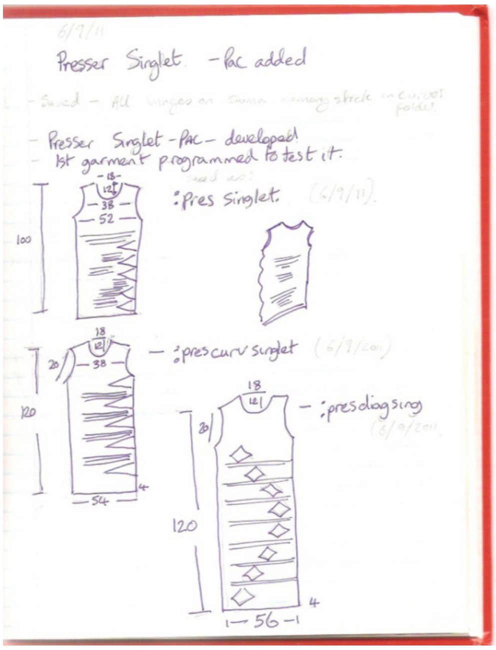


Figure 101:
Smith, A. (2011). Technical Notation of Additional Pacs and Horizontal Tuck Structures.

The integral forces of movement within the garments cause some unexpected results when textural horizontal lines were added, as seen in figure 102.

Figure 102:
Smith, A. (2011). First Garments with Pin Tucks Added, with Some Un-expected Results.

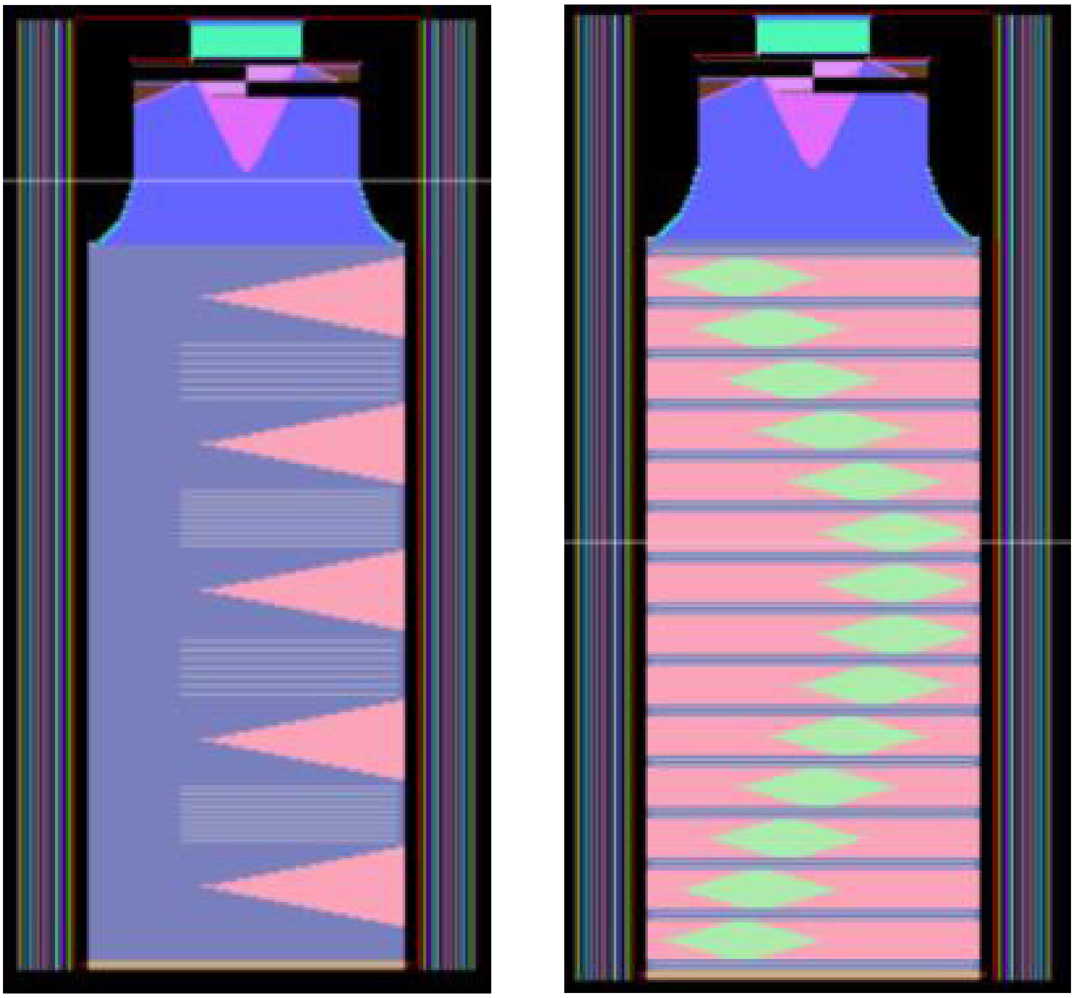


Figure 103:
Smith, A. (2011). Technical Knitpaint Programme of Garments in Figure 101.

The first garments with added pin tucks used the base tunic shape with side wedges and a lengthened version of the double twist tunic. The double twist tunic produced the most unpredictable textural affect with the horizontal lines merging and diverging as the diamond wedges travelled across the garment, creating and mimicking the intensive integral forces of knitted movement and holding formations. However in both cases the added pin tucks created extra weight in the garment. Though this was effective in developing textural quality, it did not allow the garments to hold their form or drape qualities. The pin tuck weight flattened out the garment, reverting back to two dimensional shapes, with the sense of three dimensionalities being lost.

This experimentation demonstrated the possibilities for adding textural elements to the seamless garments and also elicited some results which could not have been realised without knitting the garments. They could not have been predicted from the visual technical imagery as seen in the Knitpaint programming in figure 103. However, what I now needed to develop was a process for adding textural effects without adding extra weight to the garment.

Lace or lace holes are a means of adding texture through the negative mode of material subtraction rather than addition. They can be placed horizontally, vertically or randomly. Therefore they would be able to replicate the pin tuck effect. Working on the tunic curve base shape, horizontal lines of lace were added across the body of the garment. It was possible to continue the lines around the body and very close to the long edge of the side of the garment. Issues with bursting stitches when holding and adding lace on the shorter side, resulted in having to place the lace holes further into the garment, relieving stressful forces causing the burst stitches.

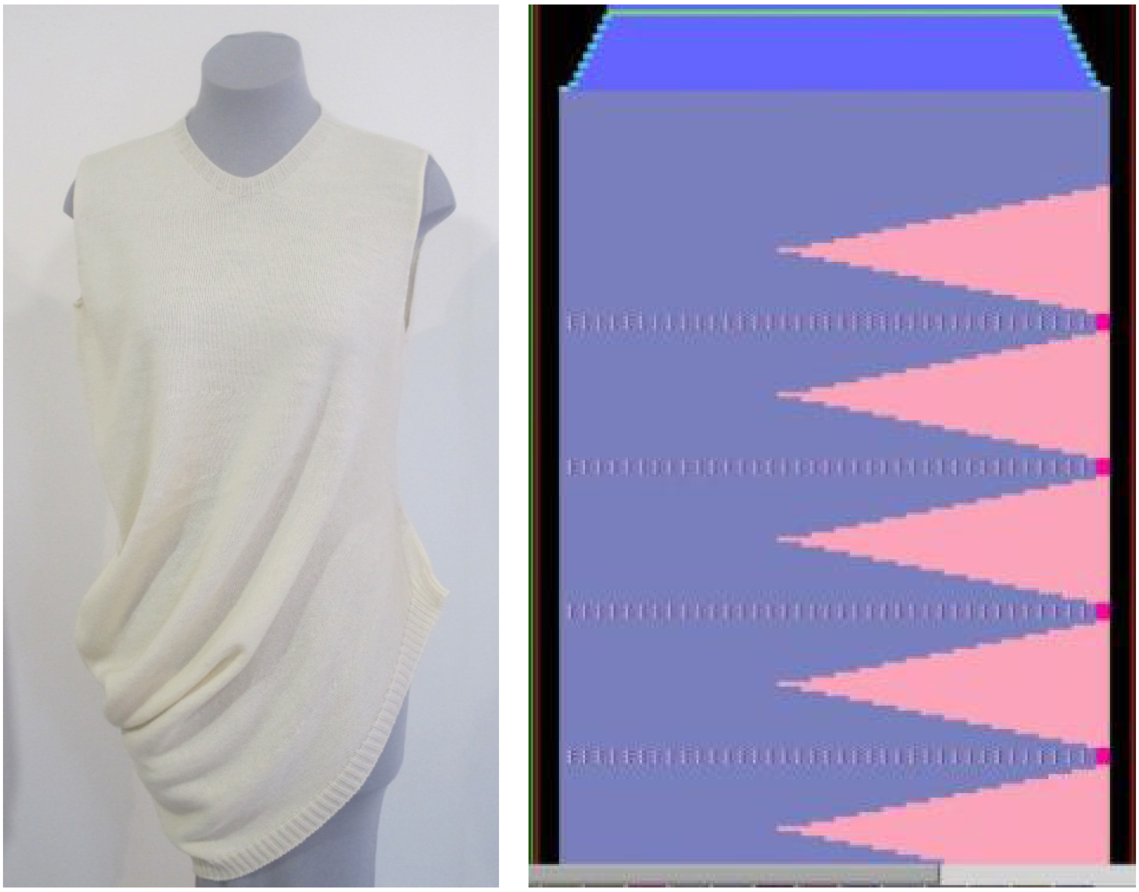


Figure 104:
Smith, A. (2011). Base Curve Tunic and Lace Knitpaint Programme.

Figure 105:
Smith, A. (2011). First Lace Structure Garment. Close Radial Affect Opening to Wider Movement Around Body.

Figure 106:
Smith, A. (2011). Close-up of Radial Effect on Short Side of Garment.

The application of the horizontal lace lines to the Knitpaint programme emphasised the feeling of movement and structural force around the body of the garment. The lace pattern did not affect the drape and silhouette of the garment but reinforced its movement. The side where the knitting machine movement is minimal due to holding courses, created a radial effect on the lace structure, which opened out as the lines moved around the body. See Appendix D for details of the process of adding the additional lace structure to the pre-installed Shima Seiki shapes, along with programming the additional pacs for garment movement

The three rows of horizontal lace were then added to the long sleeved set-in sleeve sweater, developed as a base shape. The base shape had been altered to extend the application of the wedge pacs further down the length of the garment by reducing the depth of the sleeve rib from the original base shape.

Figure 107:
Smith, A. (2011). Comparison of Base Sweater Shape with Sleeve Rib Difference.

Figure 108:
Smith, A. (2011). Sweater with Horizontal Lace Added.

Figures 107 and 108 demonstrate the additional developments of the basic one side drape sweater. The garment's three dimensionality was further developed by reducing the sleeve rib length and thus enabling more wedge pacs to be added to the basic shape. This resulted in deeper and further exaggeration of movement around the garment form. The additional lace structures added in a horizontal format across the body of the garment and further emphasised this movement when knit in a seamless manner. The lines contracted and opened as they moved around the body meeting perfectly at both sides of the garment. The drape of the garment was not interfered-with but was emphasised by the movement of lines in rhythm with the three dimensional form. This led to further experimentation of other techniques and stitch structures based around stitch movement and lace structures, which would further enhance three dimensionality of forms and movements.

5.5 Garment Genealogy

The design development process of the seamless garment collection, worked in an iterative mode as both technical knowledge and design understanding expanded through each iteration (see figure 127). The garments formed rhizomatic connections as each referred to a garment already created and in some cases connections made between more than single garments. The process was not linear in nature but did rely on past garments as well as the designer's tacit knowledge of knitwear. One garment would be made and reflected on, whilst another was being programmed and knit, this created multiple crossovers of design ideation. Because of this the genealogy of each garment is complex and involves multiple linkages. Alongside the development of stitch structure progress, garment shapes were being influenced and incrementally progressed, moving further and further away from the initial pre-installed Shima Seiki shapes.
The following images re-trace the development process of each of the final garments that make up the final seamless knitwear collective.

The Cardigan:

Figure 109:
Smith, A. (2011). Development of the Cardigan.

Figure 110:
Smith, A. (2011). First Three Cardigan Shapes with; Two Central Pacs Added, One Central Pac Added and with Body Length and Width Increased.

Figure 111:
Smith, A. (2011). Plain Cardigan With Double Pacs On Opposite Sides; with Horizontal Lace Applied and Overlap Option.

Figure 112:
Smith, A. (2011). Cardigan with Wedges Added on Both Sides of Front and Back Plus Horizontal Lace Added.

The Curved Tunic:

Figure 113:
Smith, A. (2011). The Curved Tunic Development from Right to Left.

Figure 114:
Smith, A. (2011). The First Three Curved Tunic Form Developments.

Figure 115:
Smith, A. (2011). Curved Tunic with Added Horizontal Lace and High Neck Collar on Small Curve Tunic.

Figure 116:
Smith, A. (2011). Curved Tunic with Vertical Lines Added and Vertical Lines Developed to Follow the Flow of the Drape Around the Body.

The Double Twist Garment:

Figure 117:
Smith, A. (2011). The Development of the Double Twist Singlet and Sweater from Right to Left.

Figure 118:
Smith, A. (2011). Double Twist Tunic; Short and Long Plain and Vertical Lines Added to the Shorter Garment.

Figure 119:
Smith, A. (2011). Double Twist: Long Tunic with Vertical Lines, Plain Sweater with Added Pacs on Sleeve, Double Twist Sweater with Horizontal Lines and Added Pacs on Sleeves.

The Centre Front Drape:

Figure 120:
Smith, A. (2011). The Development Process of the Central Front Drape Tunic.

Figure 121:
Smith, A. (2011). The First Three Developments using Diamond Wedges in a Central Position on Standard Sweater, Loose Sweater and Extended Shoulder Tunic.

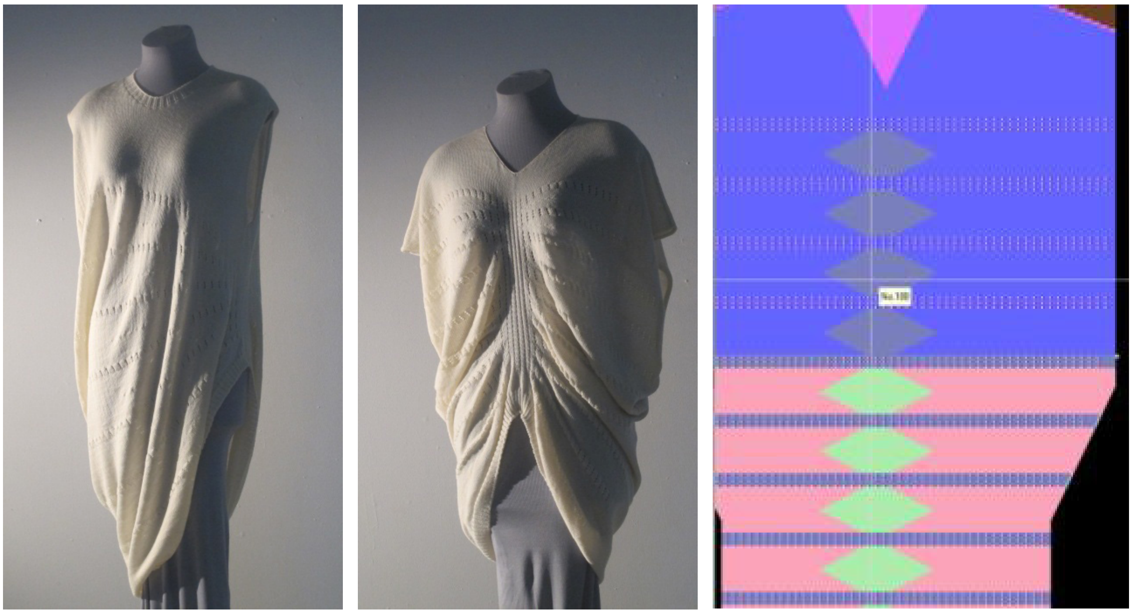


Figure 122:
Smith, A. (2011). Development of Extended Tunic with Horizontal Lines: First Garment With Horizontal Lines, Extended Tunic with Horizontal Lines and Central Diamond Wedge Pac Knitpaint Programme.

The Ripple Sweater Development Process:

Figure 123:
Smith, A. (2011). The Ripple Sweater Garment Development Process.

Figure 124:
Smith, A. (2011). First, Two Sweater Shapes and Original Singlet with Diamond Wedges moving through Garment at an Angle.

Figure 125:
Smith, A. (2011). Plain Sweater with Additional Pacs moving from One Side of Garment and Back Again, Ripple Pressure Tucks on Tunic with Same Additional Pac Movement.

Figure 126:
Smith, A. (2011). Horizontal Lace Applied to Curve Tunic, Horizontal Applied to Ripple Sweater Creating Random Flow of Movement Across Garment.

Garment Genealogy: Rhizomatic Connections.

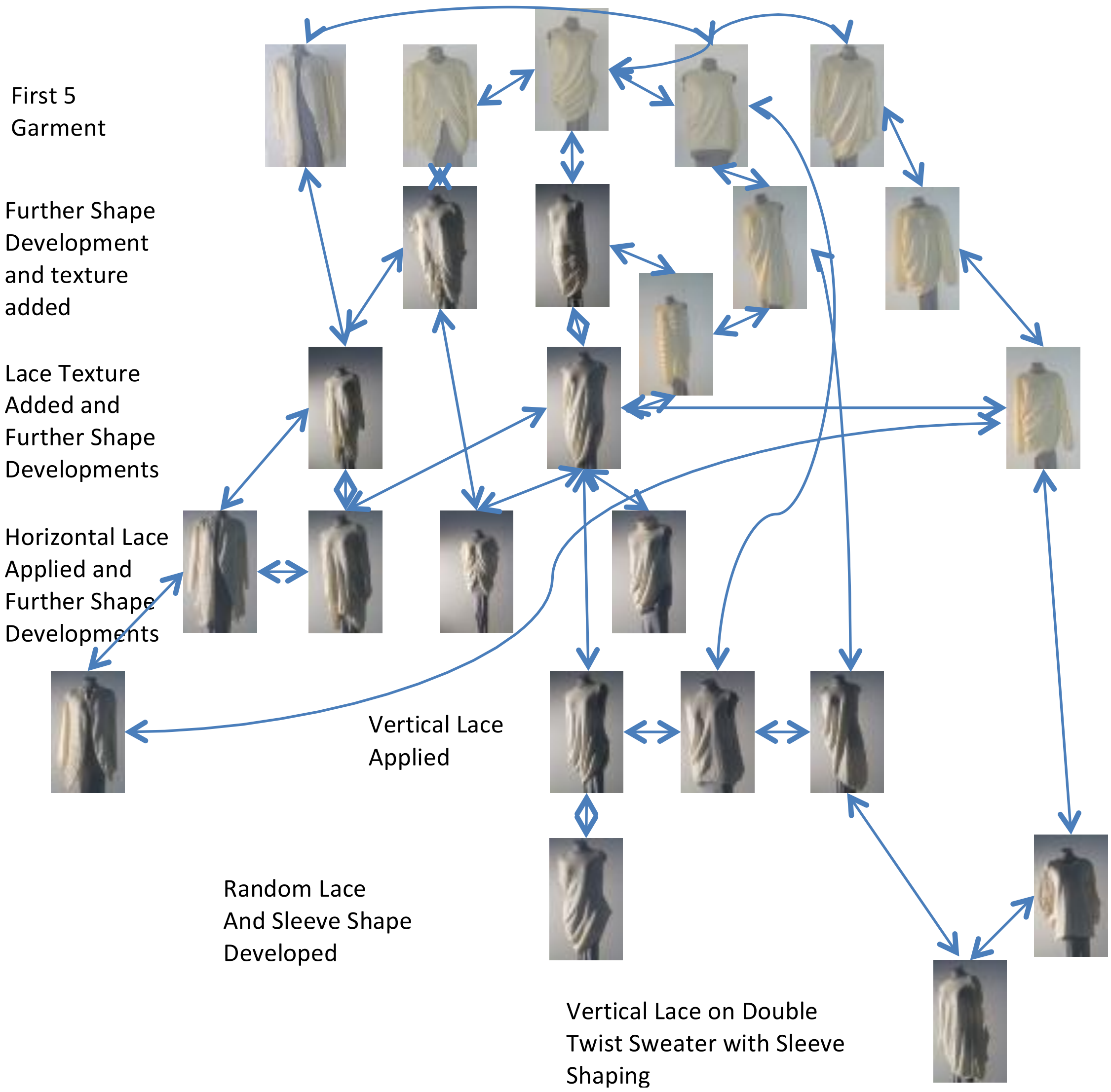


Figure 127:
Smith, A. (2011). Design Process.

The Final Garments as a Collective:

Figure 128:
Smith, A. (2013). The Collective.

5.6 The Exhibition

The garments were exhibited in two exhibitions: One at The Cloud on the Auckland harbour water front in New Zealand, as part of the Campaign for Wool exhibition Shear Brilliance in November 2012.

Figure 129:
Smith, A. (2012). Shear Brilliance Exhibition. The Cloud, Auckland Harbour Front.

The second exhibition was held as part submission for the Degree of Doctor of Philosophy and was held at Gallery 3, St. Paul Street Gallery, 39 Symonds St. Auckland, New Zealand (2013). After seeing the garments exhibited at The Cloud exhibition a decision was able to be made about how to exhibit the garments in the final exhibition for the practical component of this thesis. Whilst the garments were still un-dyed, experiments to over-dye them had taken place. But when colour was added to the garments, initial reactions were about the colour rather than silhouette formation.

On seeing the un-dyed garments at The Cloud, it became clear that the garment forms held an enigmatic quality of their own, exemplified rather than diminished by their rawness. Having decided on this affective material quality, other details such as mannequin covers, photography and film making were organised.

The decision to make a twelve minute digital film loop of the garments being worn to include in the final exhibition of this work was raised after re- reading the thesis text and viewing the images within it. There were disconnections between the words and the images, in that many descriptions of the garments referred to movement and fluidity of form which reacted to the body in movement. However all of the images included in the text and the exhibited garments themselves were static. A film of the garments in motion was made to include in the exhibition to address these issues. Stills from the film can be seen in figures 130, 131 and 132. The video is included as Appendix G.

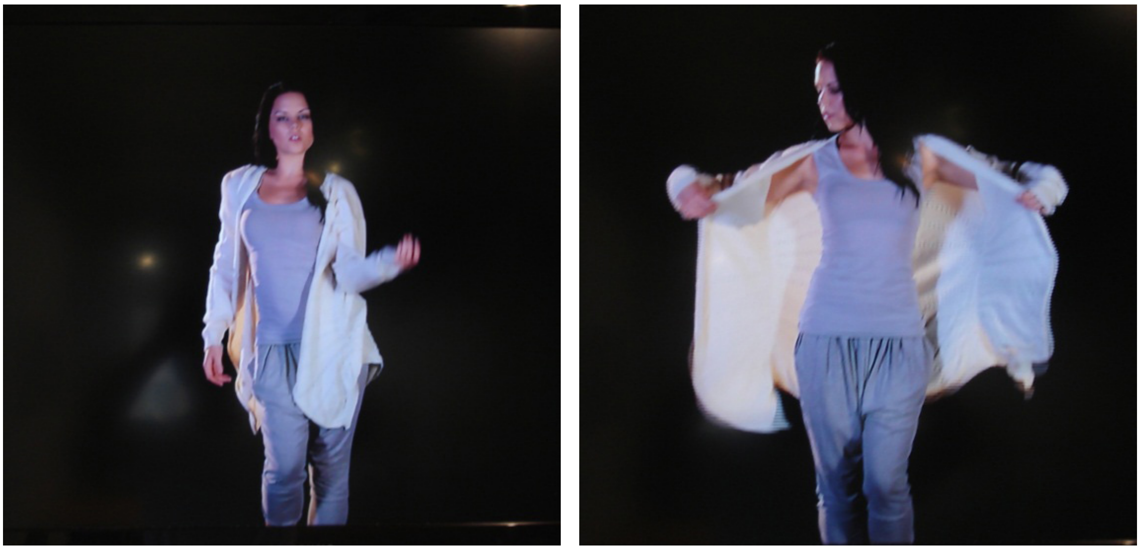


Figure 130:
Smith, A. (2013). Film of Seamless Knitwear. Filmed by: Denton, A. Jackson, M. (2013).
Model, Hannah Tasker-Poland.

Figure 131:
Smith, A. (2013). Film of Seamless Knitwear. Filmed by: Denton, A., Jackson, M. Model: Hannah Tasker-Poland.

Figure 132:
Smith, A. (2013). Film of Seamless Knitwear. Filmed by: Denton, A., Jackson, M. Model: Hannah Tasker-Poland.

In addition to the film, still photographs of the knitted structures used on some of the seamless garments were hung. The still photographs were included to show the stitch structure, internal knitted movement and how the one affected the other, in close detail (see figures 133 and 134).

Figure 133:
Smith, A. (2013). Knitted Structure and Internal Movement. Photo by Kate Seller.

Figure 134:
Smith, A. (2013). Five Images Included in Exhibition of Close-up Stitch Structures. Photos by Emma Hughes

The final garment display consisted of twenty garments, fifteen of which were placed on the lower level of the gallery, whilst the five first garment shapes were placed separately on the higher gallery level, along with other process work. The following photographs show the garments as displayed at Gallery 3, 39 Symonds St. in the 'Seamless Knitwear: Singularities in Design' exhibition held in April 2013.

Figure 135:
Smith, A. (2013). Five Base Seamless Knitwear Shapes. Photo by: Kate Seller.

Figure 136:
Smith, A. (2013). Seamless Knitwear: Singularities in Design Exhibition. Photo By: Kate Seller.

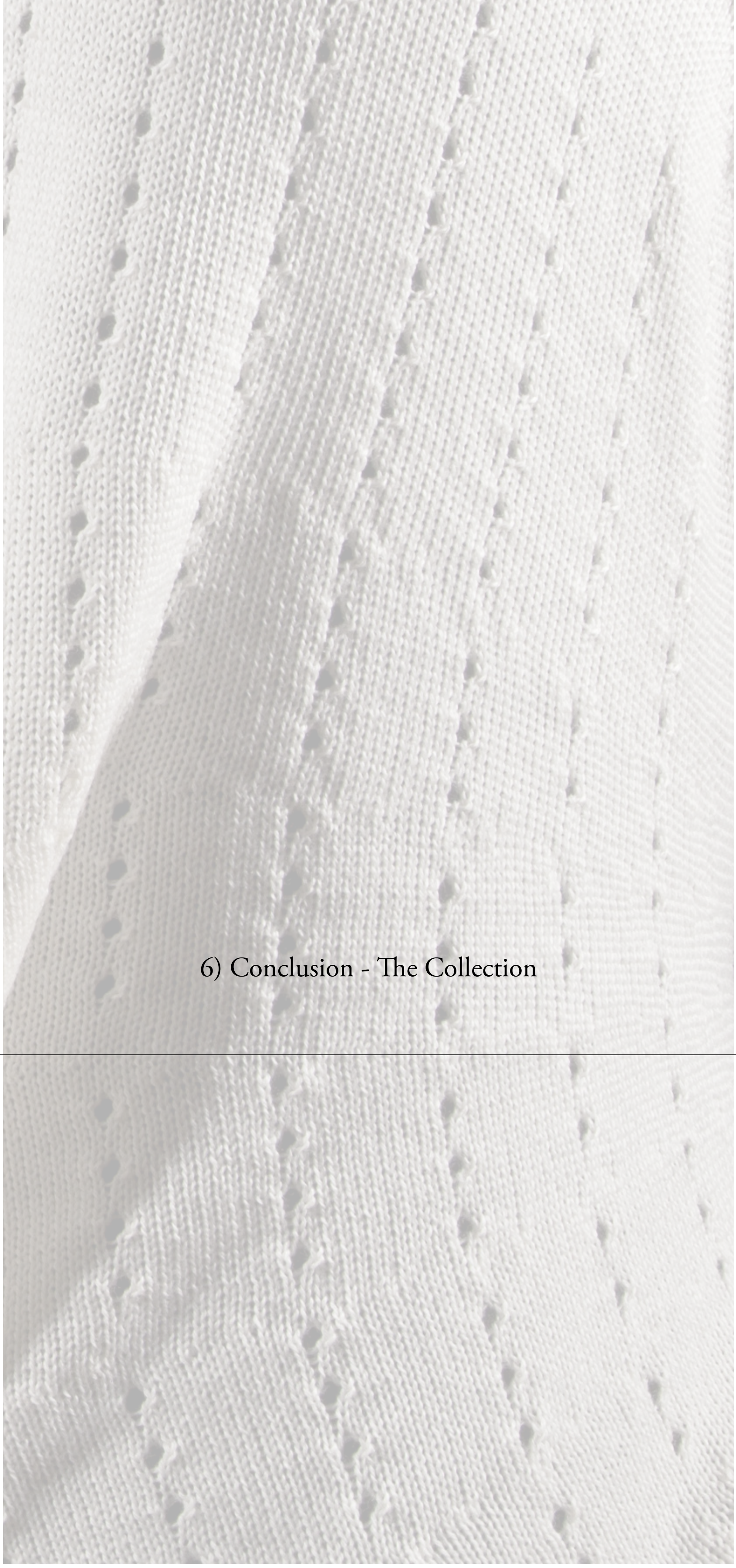
Figure 137:
Smith, A. (2013). Seamless Knitwear: Singularities in Design Exhibition. Photo by: Kate Seller.

This chapter has outlined the design process, iterative and rhizomatic in its inter-connectivity of knowledge and form building. The design process movements have been followed from the beginning of the study through to the culminating exhibition of this thesis as a whole.

The following concluding chapter summarises the knowledge gained from this study and areas that this new knowledge can be applied.

Figure 138:
Smith, A. (2013). Seamless Knitwear: Singularities in Design Exhibition. Photo by: Kate Seller.

Figure 139:
Smith, A. (2013). Seamless Knitwear; Singularities in Design Exhibition. Photo by: Kate Seller.



6) Conclusion - The Collection

6.1 Contribution to new knowledge

This study makes contributions to knowledge in three areas of the field of knitwear design research and practice-led design research. The first and most significant contribution is the garment collective, which embodies and illustrates the creative journey and the iterative nature that this process followed. The collective of garments, through their unique design elements also illustrate the second contribution to new knowledge. They provide evidence that it is possible to adapt a commercial design and production system developed for mass production and cost efficiency into one which becomes a creative design process with original, nuanced qualities and aesthetics. The third contribution to new knowledge is through the inclusion of both western (Deleuze) and eastern (Wabi-Sabi) philosophies into the design approach and process of making. This combinatory approach to the design process has moved the focus of the design outcomes from the final form, to the component movement of forces created by the production technicities of making, linking with the materiality of both the fibre and the fabric making. This approach has engaged with a language, a way of making and reading a garment in three dimensional forms, which moves this design thinking outside of the customary style used in fashion.

The following points enlarge on why and how this research has achieved these significant and original contributions to knowledge in relation to other research within the fields of knitwear, fashion and design paradigms.

6.2 A Collection produced on a Wholegarment® machine

This study engages with seamless knitwear from a design perspective with the aim of creating a collection of seamless knitwear garments, in order to develop the concept of three-dimensionality in knitted garment forms. The primary focus of this research was to initially analyse the designer interface with seamless knitwear technology, from a nontechnical vantage point. The research then assayed those changes a designer needed to make to the design process, to create non-standardized knitted garments, which have a high fashion design element to them. The documentation of this research, primarily through the exhibition of a garment collection, but also through this written exegesis, research notes and designer's workbook, makes the research findings available to commercial designers and researchers working within this field, as well as to the general public.

Current research completed in this field of study has primarily focused on the technical development or know-how of the technology, and not on the designer and designer-technology interface. Therefore, my research acknowledges and builds on extant work already completed, taking it to another locale. This research has applied this knowledge and created a method for designers to re-engage with the haptic qualities of knitwear design through an iterative process, pushing the use of the technology back into a designer's realm, without the need to entirely become a technician or amalgamating entirely the roles of designer and technician.

This research has identified a means for the designer to utilize the current software available for the development of seamless knitwear. Its current availability is predominantly via a technical format. Yet, this does not preclude access or require extensive technical training. Designers are able to work in a responsive manner with garment design outputs, altering and developing designs as they are created. Crucially, though, they stop engaging the technology in the linear workflow functioning for which it was designed. The technology takes on a different point of view and becomes other. This model of development would translate particularly well into an experimental educational learning experience, such as is needed to develop skills and knowledge of these "new" technologies of production methods, within a university environment, at undergraduate and postgraduate levels. Such an approach may help to fill the creativity vacuum which has been identified previously by Mowbray, Sayer et al., and more recently by Yang (Mowbray, 2004; Sayer et al., 2006; Yang, 2010). Due to the modular and "copy-and-sell" designations of the current software, designers have only been able to replicate the same through exact rigour, and not create difference through anexact rigour. This research has identified that there is a negative downward spiral of the quality of a designer's tacit and tactile knowledge as she has been removed from the haptic connectivity of her craft. This downward spiral needs to be reversed for designers to be able to re-engage with the nuance of difference within tactile knitwear environments. This can only be learnt through building design memories through haptic engagement. Current methods of training and their technology interfaces easily obstruct such learning directions.

The application of a bottom-up approach to seamless knitwear design and production processes realigns the designer with the haptic, while engaging technology. By creating a rhizomatic engagement with the software, rather than using the linear internal process, the designer is reconnected with the materiality and spatiality of the knitwear as it is produced, thus she is able to build design memory, the foundation for intuition in action, prospecting itinerancy of an artisan-designer-technologist. This has been achieved by analysing what was missing from the current technical framework. I identified that it was too standardized and lacked the opportunity for a designer to implicate its base frame, in order to fold it. The craft aspect was recognized as a means to reintroduce a randomising vector to the standardized format, inflecting surface structures as charged intensive fields of force. This research looked at past craft processes of hand-knitting shape-structure and form making, and established techniques for folding these as internal movements, to the technical conditions of seamless knitting. This starts to expand the possibilities for future directions for knitwear design, utilizing this mode of production. Though working within the current technical parameters, it starts to position the designer outside of the linear internal process and creates a means to explore the supposed three-dimensional capabilities of this technology, moving from practices of cut, make and trim.

6.3 **Relations: Technicities of Wholegarment® design**

The manufacturers of seamless technology need to consider the designer with new technological developments. Design Packages, within the technical parameters of Knitpaint, such as those developed for this research, would greatly facilitate designer involvement in the modal capacities of the technology for garment design modifications. Such packages would be used as an optional addition to pre-installed shapes for seamless knitwear. This would open up the flexibility of three-dimensional designs for designers to produce unique garment contributions to knitwear on a global scale. It would facilitate designers for further opportunities for design with this complex technology.

Designers need to be included in the technical parameters for making seamless knitwear. The technical capability is available, but it currently exists within the technician's Knitpaint system, and needs to be translated into a designer's language, or the format of Knitpaint needs to be made more accessible to designers, to understand and utilize. This is achievable through basic and operational designer training in the use of Knitpaint pre-installed garment shapes along with the addition of designer pacs. The latter would require illustration of their capability in stitch formation, and how to register extra pacs into a pre-installed garment shape. This would expand the designer's use of three-dimensional seamless knitwear design, exponentially. As design understanding of three-dimensional seamless knitwear develops, the designer is going to demand a means to develop these garment shapes on the figure. This suggests that further investigation into a three-dimensional graphics interface for designing will become necessary. Currently designing on the figure is difficult and slow and doesn't interface back into the knitwear software for production. It is only usable for visual documentation of a garment after the fact, and for publicity purposes. It is not a usable three-dimensional tool that interfaces with the technology or the way a designer would want to work with it.

6.4 Design as forces of production

Designers often aim to push boundaries, to be nomads rather than sedentary, in Deleuze and Guattari's sense, from *A Thousand Plateaus* (Deleuze & Guattari, 1987, pp. 351-423). The development of seamless knitwear, at this time, has been a massive technical achievement, resulting in the first opportunity to create garments that are wearable directly after production. It is now essential that the designer is integral to the next phase of seamless knitwear development. Seamless knitwear technology has integrated some traditional production industry models within its development, particularly a seeming divide between technical and design systems. It has focused on using a model of design that is modular in format, not unlike a manufacturing industry model of production found in aspects of post-Fordism or Toyotaism. Its focus is mass-production within a formulaic structure of design and production. This systemic rigour of exact replication has not been unassailable. My research process enabled a weave between the interstitial spaces of its technology, in order to reverse both of these guiding parameters. If seamless knitwear is approached differently, with a design focus rather than a production-capacity focus, it can move away from a standardized model towards differentiations of design output and complex design content embedded within it. This research has focused on one approach for a designer to push the technical outside of its linear model to achieve greater design capacities.

I needed to activate the technical programming of Knitpaint to access the design potential of seamless knit three-dimensional capability, demonstrating that limited technical knowledge is needed for the designer to operate the Knitpaint software successfully. This has opened up technical programming for designers to use with basic or little support from technicians, once the basic automatic functions of the software are mastered. My experimentation has shown that these basic operations function well and that, in most cases of programming, the designer doesn't need to know why or what is happening within the interior of the programming system to operate effectively. She does not need to be highly technically trained. This design method, in its iterative progression, is self-refining and allows the designer to be responsive to findings as garments are produced. It has reintroduced fabric, structure and surface-folds of a garment into the design process, rather than current seamless design processes that engage solely two-dimensional images on a CAD screen. The designer has to modify design methods predominantly used within industrial contexts, where designs are visualized, fabric swatches created and then garment prototypes created, refined or dismissed until a final collection is established. In this method of designing, the designer is able to visualize garment forms, fabric swatches and prototype garments in a singular form that, through iteration and reiteration, gradually builds a collection. Such a collection is one that the designer has been able to incrementally process, assess, improve and touch. This method allows the designer to be engaged in the whole cycle of design, in design decisions, which open up the possibility for creative dialogue with material flows. It creates the opportunity for reactions to findings which would have been unseen if the designer is removed from prototyping, as happens in the current industry model.

The seamless knitwear collection, resulting from this research, was grounded on a distorting or distending of the pre-installed garment shapes within Knitpaint. The Packages that were created are all for a similar movement or structure within a garment, that of integral shaping or partial-knitting techniques. These pacs were created with the help and support of Gordon Fraser, the technician within the TDL. A new pac had to be created for each pre-installed shape used and for each side of a garment if used on both sides of a garment at once. Once the pacs were created, they opened a powerful range of design permutations that I was able to apply. They increased design parameters, and created a much more flexible design environment. The collection is one example of using one such additional developmental possibility in a pac format, and is nowhere near exhaustive in its creativity or design flexibility. If pacs such as these, and others for various functions such as sections of rib-structures, groups of pleats, vertical darts or pintuck structures, were supplied, the designer would have genuine design flexibility when working with seamless knitwear. Further pacs could open the field of design outputs, and in this develop seamless knitwear capacities, as more designers push boundaries with them and demand more options. All of these developments, as well as the method of iterative and reiterative design, working against the grain of Shima Seiki's workflow model, would start to build a greater understanding of the three-dimensional capacity of seamless technology, which will push development and progress; designers' knowledge as well as technical know-how. Such application would need a different way of thinking threedimensionally, therefore designers would need a different point of view, and education systems would need to grow differently within the university sector and industry environments.

6.5 Consistency: New design processes

This practice-led research has engaged the thinking of Gilles Deleuze in order to interrogate the differences between ways of understanding design, addressing notions of materiality or matter, how we understand composition in terms of folding, and how we understand matter and memory as a continuum and not as two radically different things. I have emphasized, after Deleuze, artisanal following, as also seen in Eastern philosophy as the making "slender" of a designer as she follows the materiality of things. This is a bottom-up approach I applied to the production of knitwear using seamless knitwear technology. I have worked with Deleuze's notions of *concept*, *affect* and *function* as a means to develop a framework for viewing the historic, cultural and technological developments that have been influential for dislodging a predominantly representational model of garment construction that is the seamless knitwear technology model. This triple nexus of engagement stimulated a revisiting of past personal experiences, enfolding these past encounters into the present folds of this practice, construing a relaying infolding of the personal and a-personal. Massumi suggests: "Possibility is back-formed from potential's unfolding. But once it is formed, it also effectively feeds in…. Potential is unprescripted. It only feeds forward, unfolding towards the registering of an event" (Massumi, 2002, p. 9). The resulting serial array of individuated garments forms a collection of knitwear that enacts this bottom-up application to seamless technology.

I like to think that my activation of Deleuzian thinking to access a process for designing high-end knitwear, and therefore possibilities for fashion thinking, is a major contribution to new knowledge stemming from this research. *The Fold* and *A Thousand Plateaus: Capitalism and Schizophrenia* (Deleuze, 1993; Deleuze & Guattari, 1987) have been raided by others in order to develop practical works within the woven textile arena, (Darlaston, 2008; Dormor, 2012; Hemmings, 2012). Also, Otto von Busch used Deleuze to underpin his doctoral thesis, *FASHION-able: Hacktivism and engaged fashion design*, which explored artistic and fashion interventions through collaborative practices (von Busch, 2008). I accessed Deleuze as an entry-guide to the interior of the work produced by seamless knitwear technology, itself a product of mass-production, capitalist machinic assembly. This entry, a little forced though it may have been, aimed to create an alternate output possibility, that of singular, though iterative design with a high design integrity. This work opens to further possibilities for future research connections to be made via the rich terrain of Deleuze and Guattari with fashion plateaus, on a theoretical-practical basis.

6.6 Composition: Future research possibilities

There are three main areas that have emerged from these research findings as potential research opportunities for the future. They are, firstly, further design development within the functionality of seamless knitwear technology; secondly, further design practices utilizing a design process that incorporates rhizomatic connectivity; and, thirdly, development of further connections between the philosophical concepts of Deleuze and fashion design ethics, aesthetics and concept-building.

The functionality of seamless knitwear design software has many areas in which further research can be developed; the invention of additional pacs that can be easily utilized to improve three-dimensional capacity. These are, effectively, a designer's interface with the software. Coupled with this would be implementation of integrated three-dimensional modelling capability. This would give a designer flexibility within the Design System, and reconnect him or her with the design process in a way that is more easily operable. Both of these would improve a designer's capabilities to create more challenging design outputs that may explore three-dimensionality more fully.

Currently knitwear designers are educated on the traditional model of cut, make and trim, with the designer adding surface textiles to a flat two-dimensional shape, which is then assembled. This is still a valid educational schema for learning about the textile process of developing stitch-structures and assembling garments, as there are still many areas of the knitwear industry where these skills are needed. This method of learning also provides the basic building blocks for tacit knowledge, which are needed to understand knitwear tactility and the nuance of knitwear's singularity. However, ways to develop a better understanding of three-dimensional designing as well as operational techniques will need to be researched and developed to enable new designers to the knitwear industry to gain skills and experience with seamless design technology. The capacity for new designers to understand how to design in a three-dimensional format will need to be folded into current curricula. This is arguably what knitwear and fashion designers do all the time; but the methods of achieving this within the technical parameters of the technology and as a method of making, which doesn't involve seams within the structural framework of a garment, require a new process of design and development to be created. This research has developed a framework for approaching this but further investigation is needed to apply these findings more fully to an educational context.

The rhizomatic design process, outlined in this research, could be applied as a method for moving design processes forward to other areas within the fashion and textiles environment. It is a method that removes the designer from old habits and, through this, prevents her from repeating what has gone before, permitting her to work differentially. The process of changing methods described in this research could be used to access such differences in the many areas in which fashion and textiles are starting to use new technologies. Various technology-driven arenas have been developed from and now supersede older craft-based practices. I am thinking here of emergent technologies in digital printing, laser cutting, and three-dimensional printing. These are all zones where the roots of the technology have a craft base, but the nuance of material flows may become concealed, as technological parameters impinge on the process of making. Because this method of making removes the designer from a tactile and elemental exploratory engagement, but still allows the space for a designer to embed tacit knowledge, new possibilities of discovery may be initiated. There are many such areas within fashion and textiles for such application.

The arenas of fashion and textiles, and particularly their practices of making, have been late developers in arriving at critical approaches to their objects, questioning their conditions of possibility, their ontological ground and epistemic frameworks. While it has now largely been recognized that fashion cultures are considerably more than superfluous or frivolous societal excesses, but can be an access to understanding and critically engaging with something essential to the human, there has been less critical engagements with its methods of making. Fashion *practice* has only recently become recognized as having critical dimensions, through Journals such as *Fashion Practice*, having published its inaugural issue in 2010 (Black & Delong, 2010). This research, through activating Deleuze, aims at developing a language with which to interrogate the process of and product of fashion making. This has been primarily applied to seamless knitting, though further research into the application of and connections between Deleuzian philosophies and fashion and textile making processes could benefit the development of a language of making, as well as the understanding of methods of making within this still relatively young arena of academic research.

One of the unexpected potential areas for further research has been revealed through the application of both Western and Eastern foci within this research. Through Deleuze’s Western thinking and an Eastern ethos in Wabi-Sabi, many crossovers, clashes and convergences, both theoretical and practical have been revealed. These have only been marginally covered within this research. There is a rich area for a comparative study between Deleuze and Zen to be conducted.

6.7 How a future remains a question rather than a task to be completed.

This practice-led research has been transformational, through immersive participation in an iterative practice, and through the processes and concepts explored and developed, along with the residues of affective responses elicited through these encounters. Self-awareness has been renewed, grown and remains inquisitive. This research has opened up more areas of enquiry, just as it has answered questions. As new knowledge has encountered old, breaking old habits of practice and thought, new ways of seeing and reading have been triggered. I need to acknowledge the importance of the interval between percept and affect, the shuttling between thinking and making for any design process. This mediated space or slowing-down point allows for possibilities of differentiated creative responses from those that would emerge through habitual production methods.

Habitual design behaviour, as seen through seamless knitwear technology, ritualizes a mechanized reductivism, which can stultify design thinking and production into a series of linear steps. The introduction and use of a rhizomatic connectiveness in design acts as a means for “recalibrating of practices” (Teal, 2010). This practice uses both the “exact” (standardized pre-installed software) and “anexact” (additionally developed pacs) as a means to re-establish the nuance of the artisan-prospector into design thinking and the mass-production processes of designing seamless knitwear (Lynn, 2004). My use of the concept of folding has allowed interior forces of memory, built up through encounters of experiential and tacit knowledge within me as researcher, to become folded into the interior of this project through rhizomatic connections, as this research has developed. Rhizomatic connections have been built between the person, problem and process, as this research moved forward. These relations were ever-changing, developing in a continuous movement of varying complexities of discovery, stagnation, plateaus, action and response. The fold reveals that the inside is a fold of the outside and that the interior of a subject or object is also the exterior or a product of the influences and forces which generate movement and create affects and linkages which create change on the interior.

This research, through its many interconnections of hand and machine knit, of life lived in both Western and Eastern cultures, of designerly experiences, reveals the exteriority of my milieu infolding—what has shaped my subject-embodiment within the final garment outcomes of this research. This embodiment has been embedded within the interiority of a garment and influenced the development of the same garment outcomes, and thus the research itself. The fold, or modalities of folding, unfolding, refolding, has enfolded my materiality of bodily experience, through time and memory into a subjective topology of intensive contours, more a cartography than personhood, explored and intertwined into this research. The affects expressed within my subject, the experiences of an extended period of time in Japan, as a knitwear designer, of being an academic educator of design processes, have all inflected to the interior folds of development. This research has drawn out my affective self on to myself. The techniques of folding time, experience and memory reveal the production of self and subjectivity, created through these individualised and singularly unique aspects of being-becoming.

The frame, which is both the interiority and exteriority, central to this research has, curiously, become *Japan*. The experiential and influential forces contained within a subject's point of view, and without in an object's point of view, construct a singularity of locale—Japan, but a becoming-Japan in Deleuze's sense, such that Japan can itself become something other. The resulting collective of singularities of garments so designed, encompasses and exemplifies the ethos of this affective influence through the thought-image of Wabi-Sabi; elusive, allusive, undefinable, indefinite. The folding movements of time, memory, past and present have created and opened possibilities for a future to become, through new modalities of making and a different manner of approach for design language and design expression. Folding that which is outside, inside, and revealing the inside through the outside, exposes the development of subject and object within the continuously evolving texturology of this research. Through design process, garment, collection and designer, concepts, functions and affects have been folded and refolded opening to a new, an infinite combination of differentiated futures.

Questions of the *Fashion Collection* have been raised as a result of this research. When does a garment collection become a fashion garment collection? This garment collection has been created as part of a body of research, to explore both concepts and design thinking through the technological framework of seamless knitwear functions, which embody an ethos of Wabi-Sabi as an affective encounter. The finished material products which illustrate this remain undyed. If dyed do they remain a visual formative *illustration* of this research encounter? Or do they move into the realms of a fashion collective? Where are the frames of the interior of fashion located? Can this collection of garments be both interior to and exterior to fashion? Can they embody fashion at the very moment they critically assay and deny fashion its ground? Do they still exemplify the structural findings of this research when dyed, or are they falling outside of the frame of design research and becoming singularly fashion? Does the intrinsic value of the garment change through the addition or subtraction of colour or is it just another fold? The new continues to reveal that which can still be folded, creating new lines of creative flight………………………………………………………………………

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Glossary of Terms
Knitwear and Fashion Terminology

Compressed Garment Pattern –	A Shima Seiki term – A computer image of a knitted design programme which has been simplified into Shima registered colours
Course –	Horizontal rows of inter-looped stitches
Cut and Sew –	Knitted garment body lengths, which get cut to shape for a garment and then assembled
Design Programme –	The Design side of the SDS-ONE Design system for designing knit garments using Shima Seiki manufacturing technology
Fast Fashion –	Clothing produced using rapid design, manufacturing and distribution processes, generally used for mass-production garments which retail at an affordable price-point
First Sample –	The first garment that is knitted in final yarn to be used in final design
Flat-Bed Knitting Machine –	A weft knitting machine, with needle bed arranged in a horizontal format
Form –	A three dimensional shape, which is created through an understanding of materiality and vectored forces of composition.
Fully Fashioned –	Knitted fabric knitted to the shape required for each garment piece; these are then assembled into a garment with no cutting of fabric required
Gauge –	A term used for knitted machines and the measurement of the weight of knitted fabric produced on them. It represents the number of needles present over an inch measurement
Knit Paint Programme –	The technical side of the SDS-ONE Design system for programming knit garments using Shima Seiki manufacturing technology
Option Lines –	Shima Seiki term – Used to describe the computer notation codes which represent and control the computerized knitting process
Package –	Shima Seiki term – Knit programme instructions for knitting actions, to make each individual movement to make a knitting shape; these instructions have been condensed into packages or bundles of instructions

Programming –	The act of inputting design information or technical data in a language which the computer software can understand and translate into a knit programme format enabling a garment to be knit
Prototype –	Initial garment development into 3D form to trial ideas before moving to a more refined design
Registered Garment –	Shima Seiki term – for the expanded compressed garment pattern which uses registered Shima colours for each 'package' contained within the programmed garment
SDS-ONE Design System –	A Shima Seiki computer system which has been designed to programme mechanized knitwear products. It contains both the Design and KnitPaint systems
Seamless Knit Technology –	A knitting technology used to knit a whole garment in one manufacturing process and requiring no postproduction assemble.
Specification Sheet –	A communication sheet used in both the fashion and knitwear industry to identify a garment and all of the elements that it is made of during production
Stitch Structures –	Knitted stitches which have been used to create a fabric, texture or pattern
Wales –	Vertical rows of inter-looped knitted stitches
Weft Knitting –	Knitting where the yarn forms stitches which run horizontally across the width of the fabric, interlinking with the courses above and below them.

Glossary of Deleuzian Terminology
All terms referenced stem from: Understanding Deleuze by Claire Colebrook (2002).

Affect In its most general sense, 'affect' is what happens to us when we feel an event: fear, depression, laughter, terror or boredom are all possible 'affects'. Affect is not the meaning of an experience but the response it prompts. Affects are how doing something makes us feel, how our body reacts or feels as an affect created by an encounter through doing things with things. It is a sensate feeling.

Assemblage All life is a process of connection and interaction. Any-body or thing is the outcome of a process of connections, or things gathered together in a single concept.

Becoming Is a process of change or movement. It is the moving of one thing from an original function which creates new ones.

Concept For Deleuze, a concept is not a generalisation or a label that we use to name the world. Concepts are creations that testify to the positive power of thinking as an event of life. We create concepts in order to transform life. Concepts are what we invent with when we are thinking.

Diagram The diagram shows the flow of affect and the means used to affect, as function mixes with virtual tendencies.

Differentiated/ Differentiation The world we perceive is made up of differentiated things, distinct terms or objects. But in order for us to perceive a differentiated world there must also be a power of differentiation.

Function A function is used to describe how something works and what its specific use is for in a given situation. Things are understood through function, we build up a plane of reference through our understanding of things as we encounter them. A function can be repeated creating a regularity or way of regulating something.

Interval Is the space or point between intuition/concept and duration/percept, important movement point in design process.

Multiplicity At its simplest, a multiplicity is a collection or connection of parts. Deleuze uses the term in a number of ways but one of his most significant is his distinction between an intensive and extensive multiplicity, which also relies on the distinction between intensive and extensive difference. Extensive difference can be thought of as beginning from the extension of spatially distinct and bounded points. An intensive multiplicity is not a multiplicity of an identifiable measure; it is a substantive multiplicity. What it is is an effect of its connections (or becoming-multiple).

Rhizome/ rhizomatic Deleuze and Guattari explain these terms by first distinguishing between the 'rhizomatic' and the 'aborescent'. Aborescent, produces a distinct order and direction. Rhizomatic, by contrast, makes random, proliferating and de-centred connections. A rhizomatic method, does not begin from a distinction or hierarchy between ground and consequent, cause and effect, subject and expression; any point can form a beginning or point of connection for any other.

Virtual difference Difference should not be thought of as that which relates already distinct points or substances. Difference begins as the production of intensities from virtual tendencies. Some tendencies will not be actualised; there are all sorts of un-pursued paths and potentialities that are not actualised. Only if we consider those virtual or unfulfilled potentialities can we transform the present into a truly new future. A politics of potentiality or the virtual powers of life looks to all those non-actualised tendencies in order to question what we might become.

Appendices

Appendix A

How to Programme Garments using SDS-ONE Knitpaint

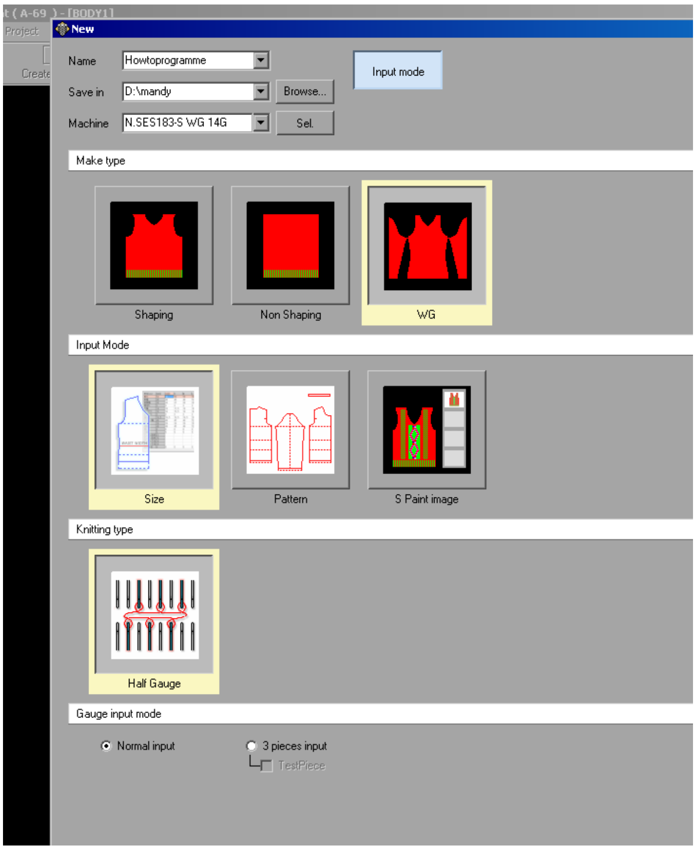
Click on New → Give garment name e.g.: Sept Sleeve

Select a drive to save in - D:\Mandy

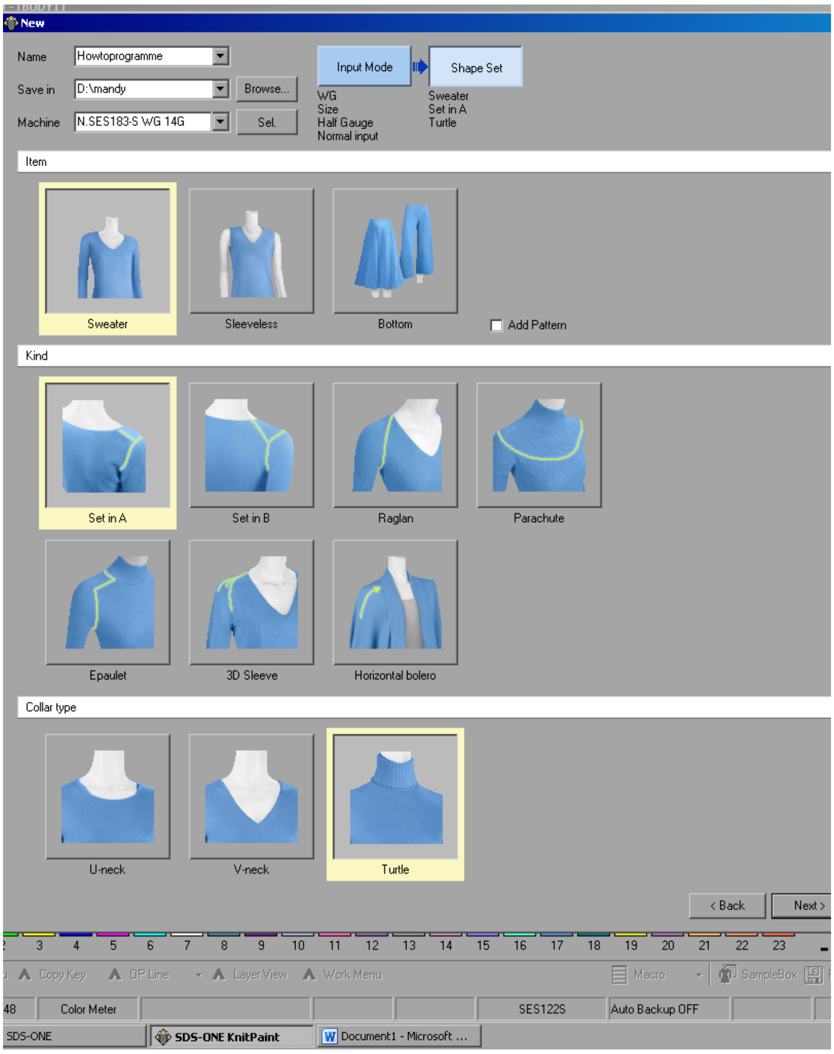
Select correct machine and gauge – N.SES183-S-WG – 14G

Select WG image - WG

Select Input mode – Size - Select Knitting type – Half gauge

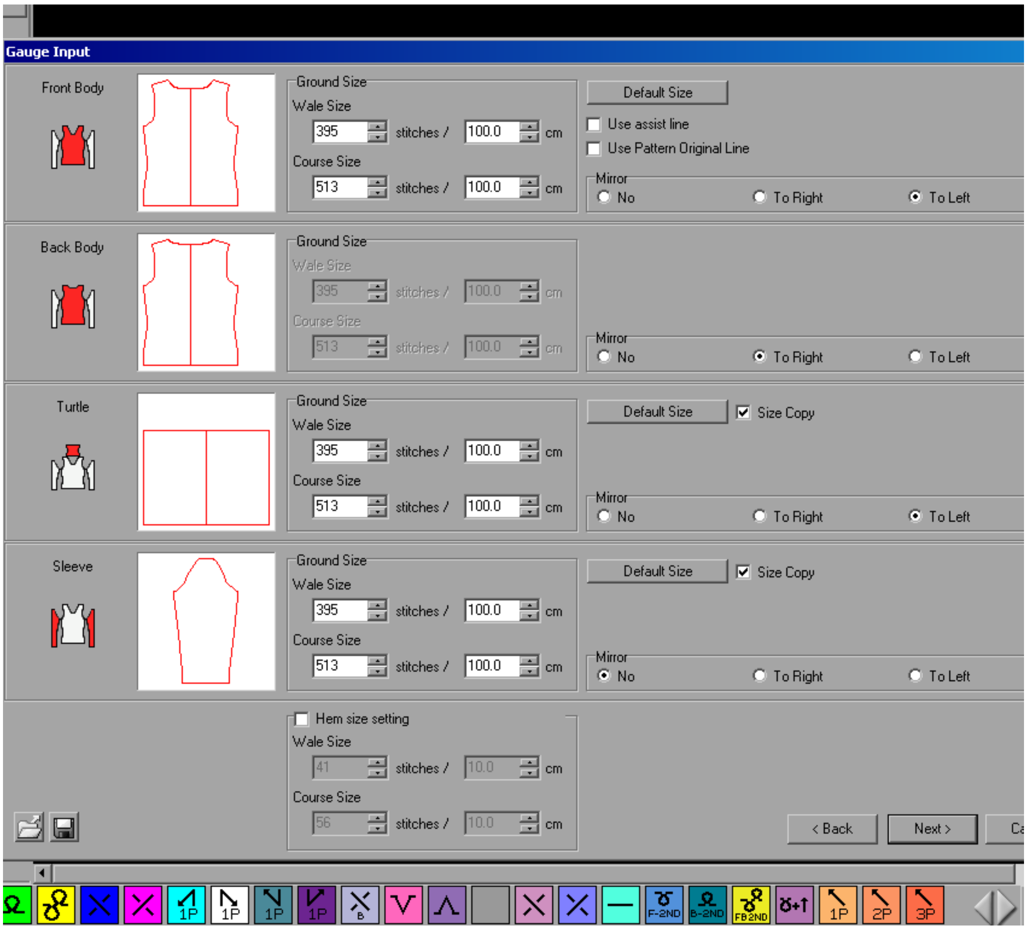


Select - Normal input and Click on NEXT

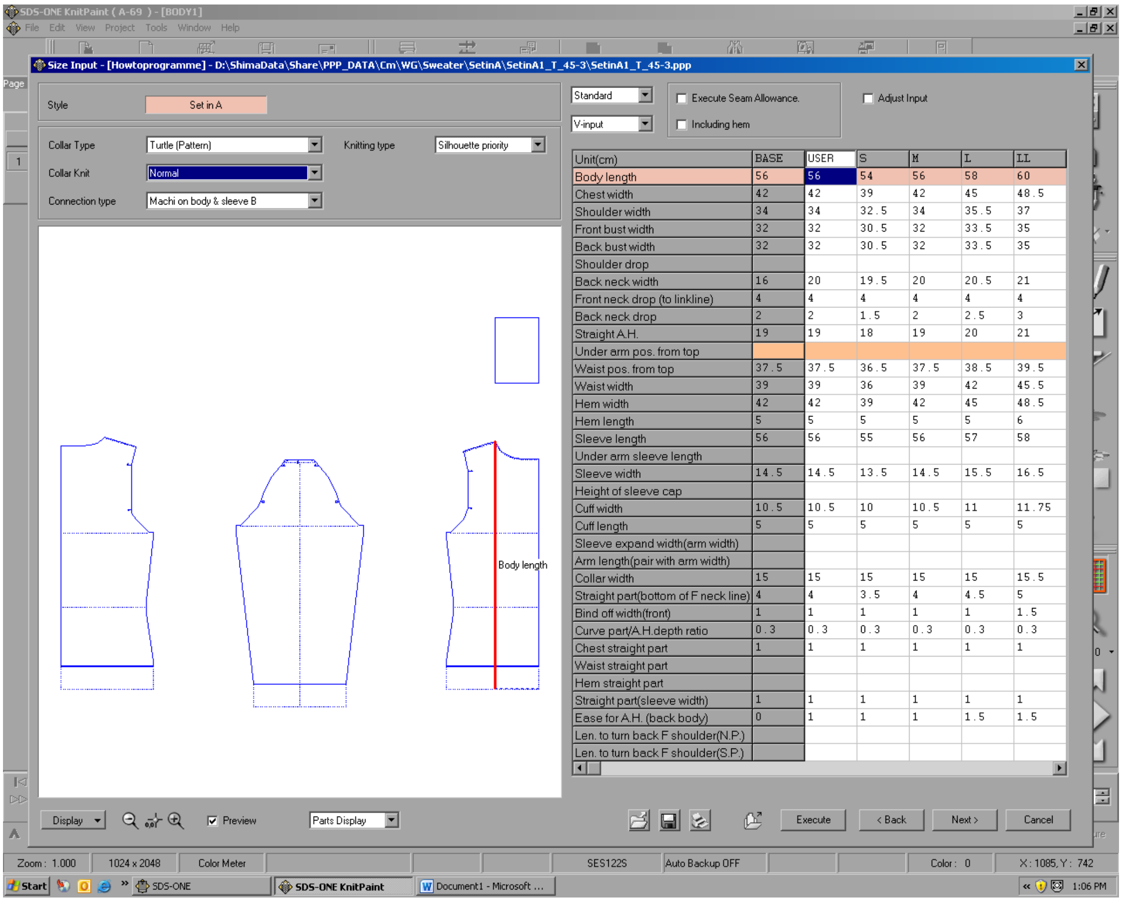


- Choose from Item: Sweater, Sleeveless or Bottom
- Choose from Kind: SetinA1, SetinB1, Raglan, Parachute, Epaulet or 3D Sleeve
- Choose from Collar Type: U neck, V Neck or Turtle NB. Use turtle for trims on garments
- Click Next

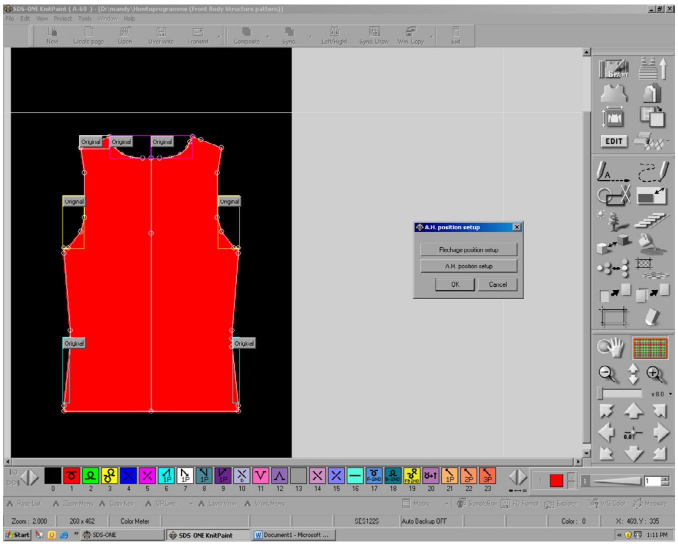
page 3



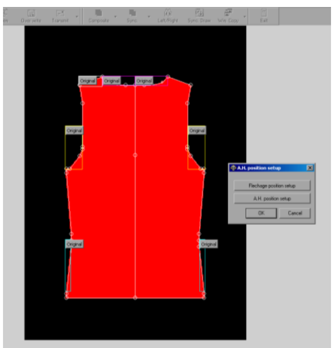
- Gauge Input – Is based on wale (stitch) and course (rows) measurements per 100 cm and needs to be swatch tested for the correct tension – prior to knitting garment
- The swatch test measurements are used here
- In Ground Size put – Wale (stitch) measurement and Course (row) measurement
- All other input on this page is automatically entered
- Click –NEXT

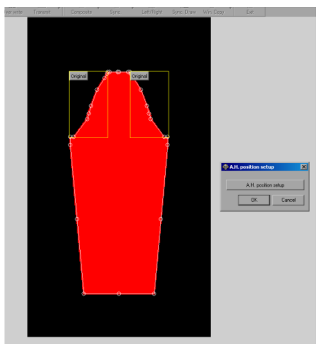


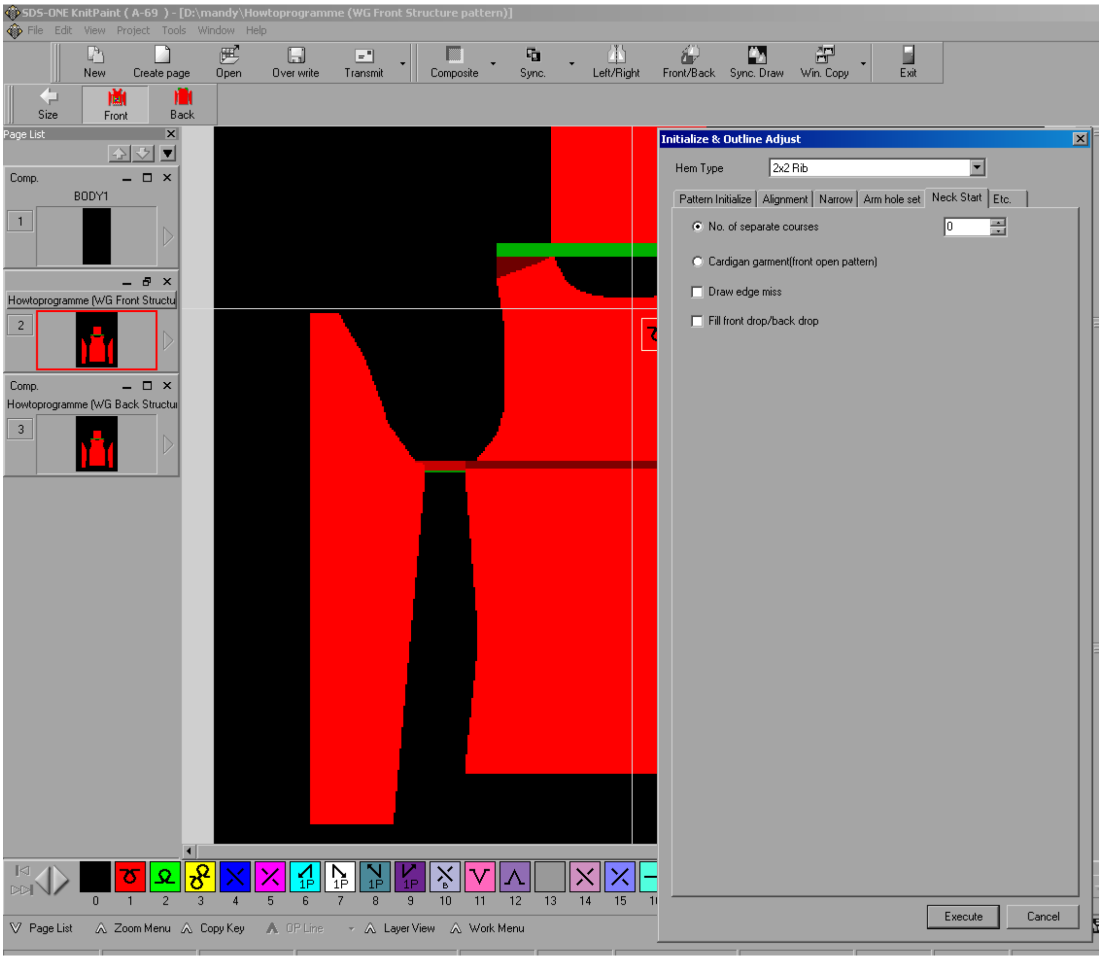
- Enter garment measurements under – USER line
- NB – Base measurements are already there but relate to Japanese sizes
- These size entries are a good guide to get to know relationship between measurements e.g. roughly 5 cm difference between sleeve width and arm hole width etc.
- Enter measurements
- Click – EXECUTE in bottom right of screen
- This shows a flat diagrammatic view of the garment
- If this needs to be modified – re-enter appropriate measurements then click – EXECUTE again
- If garment looks ok – Click – NEXT



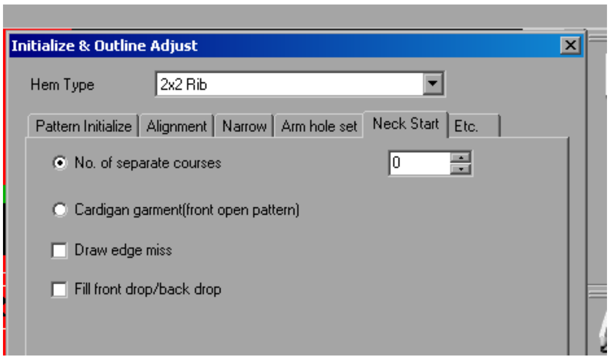
- A red drawing of FRONT garment will show
- It will have ‘A.H. Position Setup’ dialogue box next to it
- Click – OK
- A red drawing of BACK garment will show
- It will have ‘A.H. Position Setup’ dialogue box next to it
- Click – OK
- A red drawing of SLEEVE will show
- It will have ‘A.H. Position Setup’ dialogue box next to it
- Click – OK



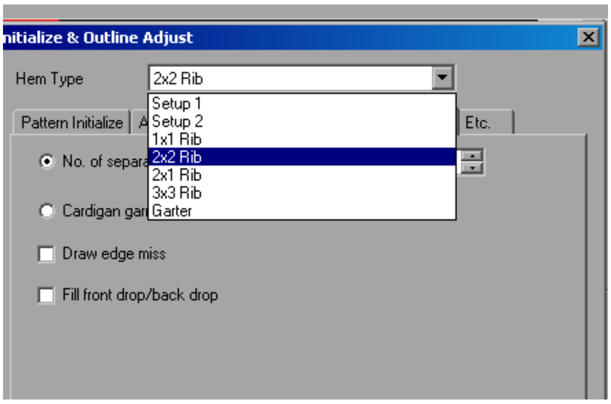




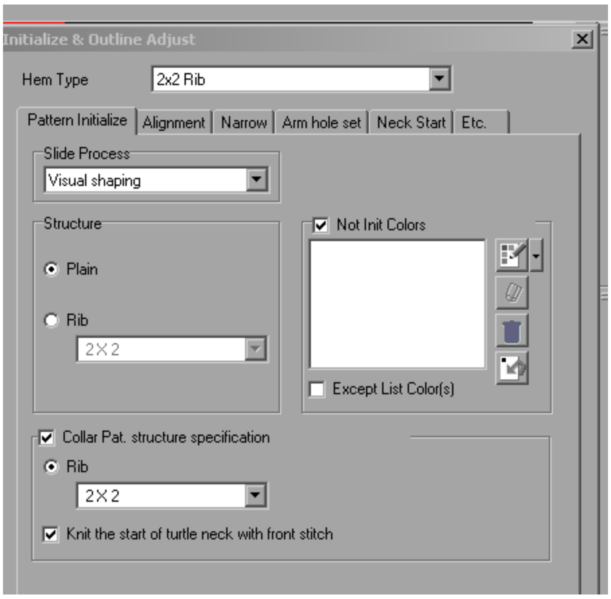
- A red flat drawing of BACK and FRONT will show in the left side bar on the Screen
- A Front shows on the main screen with INITIALISE and OUTLINE ADJUST in the grey box
- This is where garments can be made into:
- Cardigans
- Change collar structures
- Choose hem and sleeve trim structures
- For Cardigan – Click on CARDIGAN GARMENT – if finished – Click –EXECUTE



- For Hem – Scroll down in HEM TYPE – Choose from options
- Setup 1 is a three course tubular start
- Setup 2 is a five course tubular start
- Garter is plain knit start
- If finished – Click - EXECUTE



- For Collar structure – Click on – PATTERN INITIALISE
- For NO structure on collar – UN- Click – Collar Pat. Structure Specification
- For Structure on Collar – Click – Collar Pat. Structure Specification and Scroll down Rib selection panel directly underneath this to select rib structure required

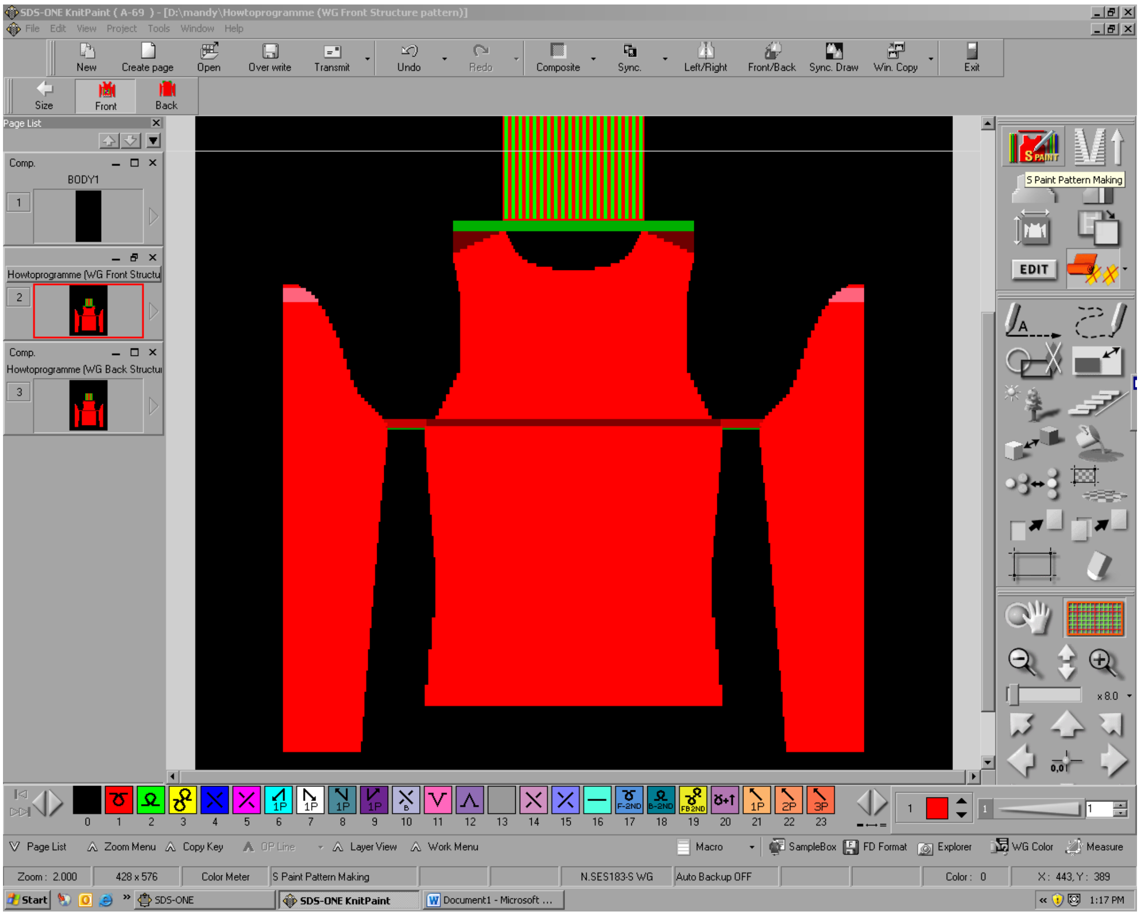


For basic rib structure on the body and sleeves of garment work on page above

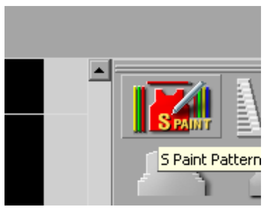
- Under Tab – PATTERN INITIALISE – in STRUCTURE
- Choose PLAIN – for no structure (flat knit on face and purl on reverse)
- For RIB – Click on RIB – and Scroll down rib selection for structure of choice

NB: All other tabs – Alignment, Narrow, Neck Start & etc. – This contains automatic set-up information and does not need to be altered.

- When finished – Click – EXECUTE

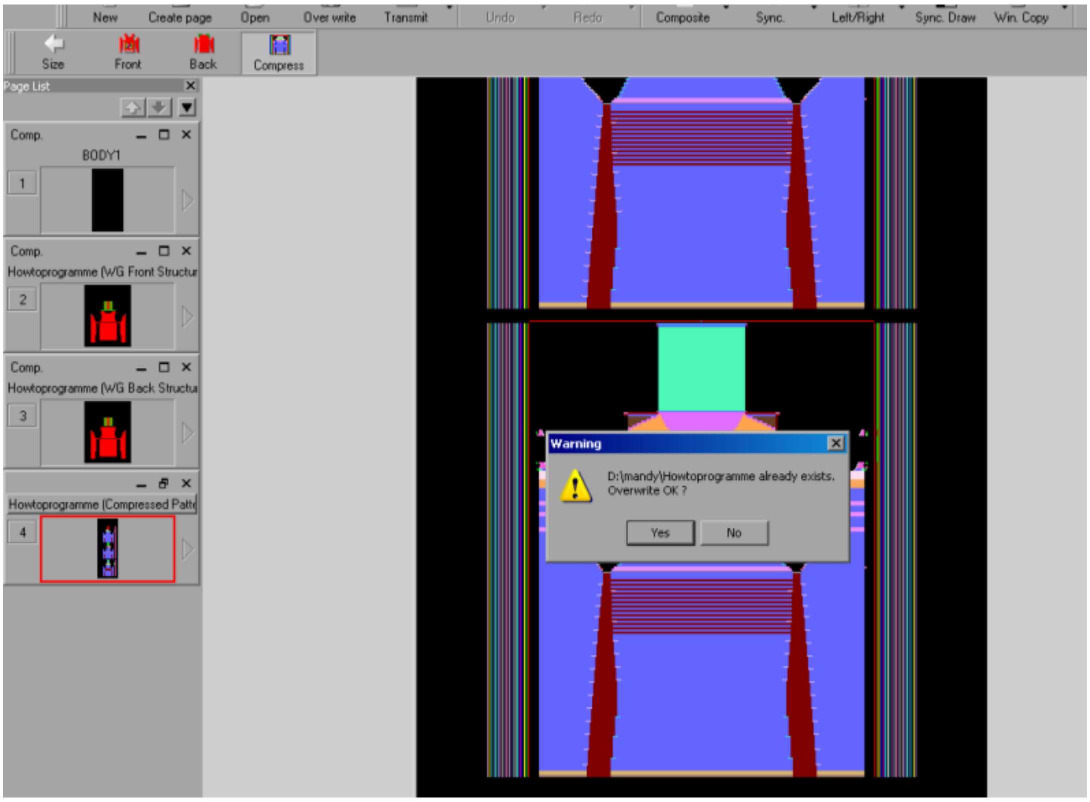


- A large red garment will appear

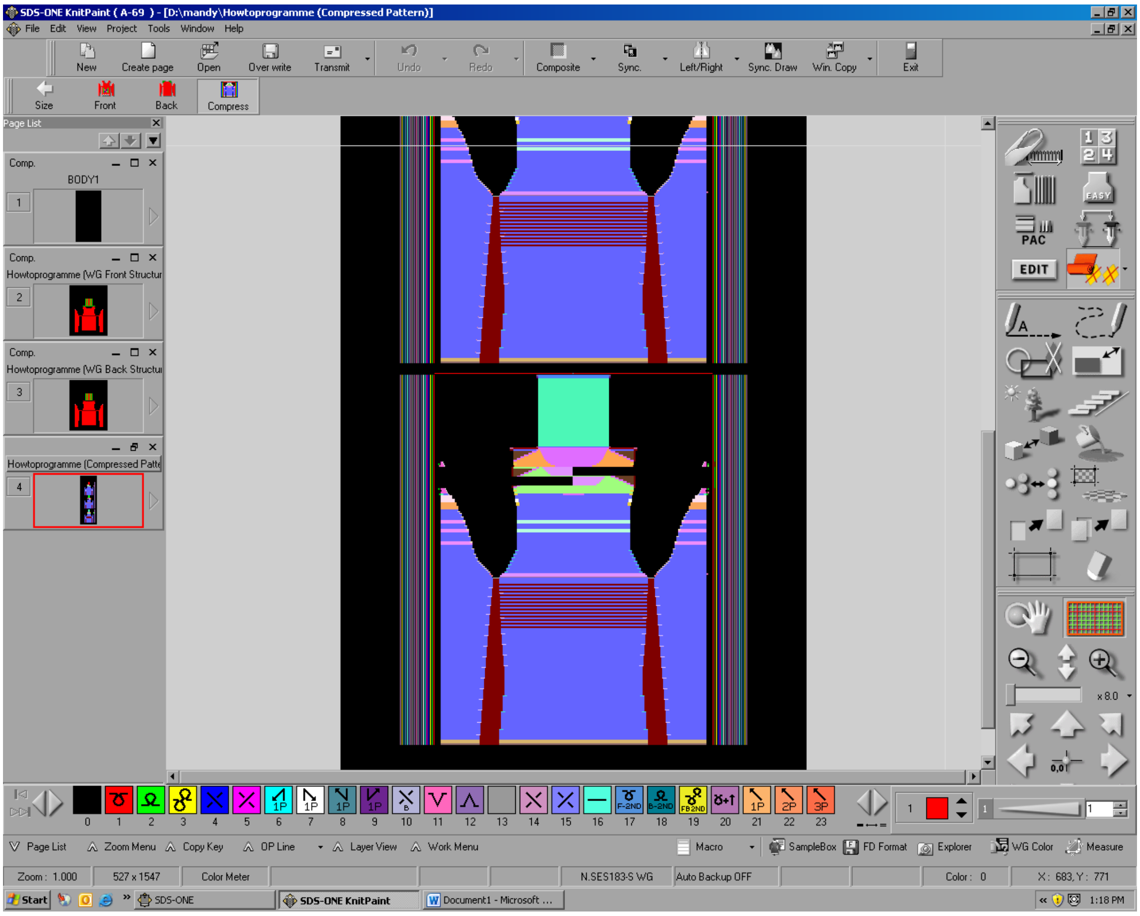


- Click - S PAINT Pattern Making button in top right of screen
- A PURPLE image of COMPRESSED garment will show on main screen and in left hand side bar

- NB: A 'WARNING' will pop up in the centre of the screen – asking you to OVERIDE OK? – Click YES



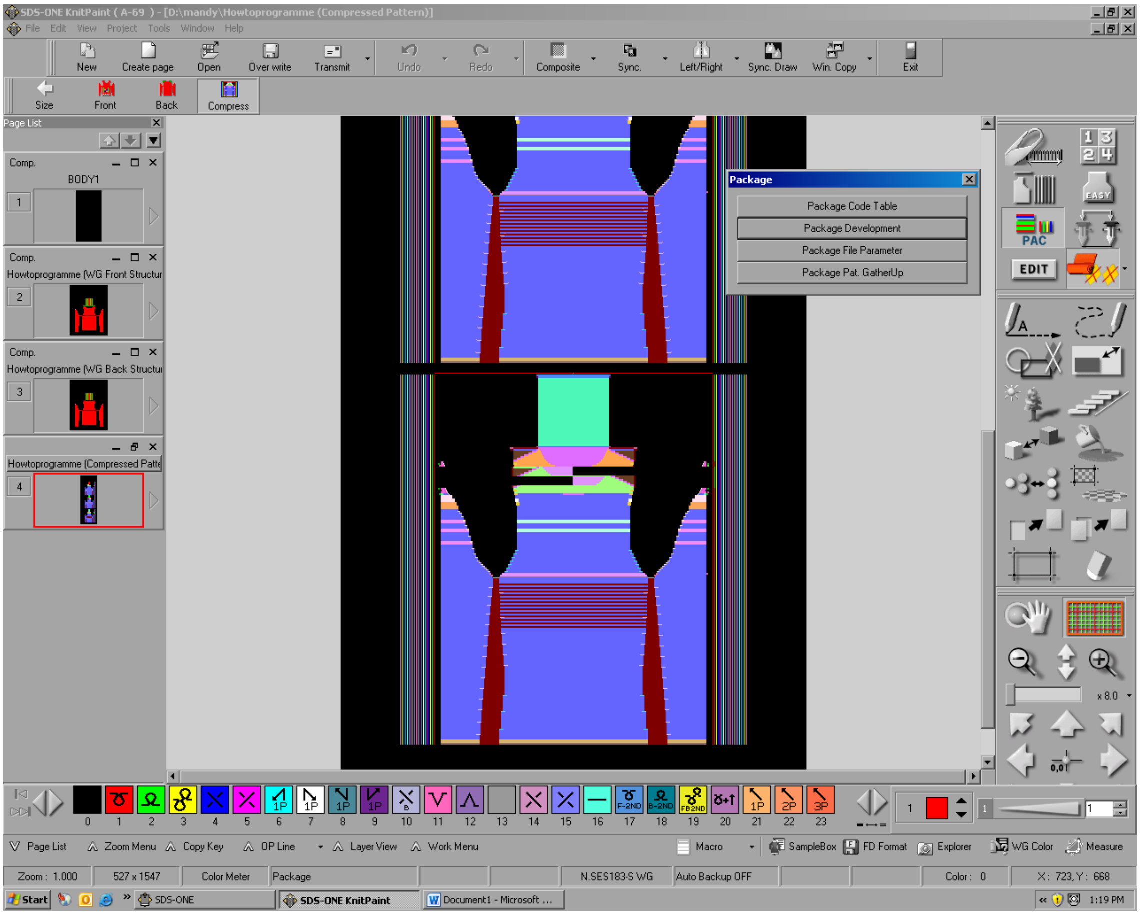
Page 8 – Compressed Garments



- Three Purple garments are now on the main screen – These are the Compressed garments
- All three garments can be seen when scrolling up - as indicated in the highlighted box on the left of the screen
- The first (bottom) garment represents – OVERALL garment registration
- The second (middle) garment represents – FRONT garment registration
- The third (top) garment represents – BACK garment registration

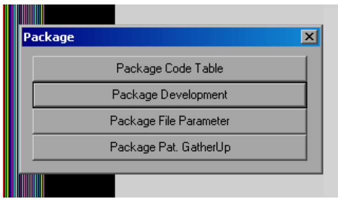
It is at this point where these garments can be worked on to add pattern structures or shaping details – such as those used in this study

- SHAPE – needs to go on all three garment registrations
- PATTERN STRUCTURES – Go on the front and back registrations ONLY – using the appropriate front and back stitch movement colours
- There are Shima Seiki stitch structure colours – which represent certain movements of stitches – these can be seen running along the bottom of the screen with visual symbols representing each machine movement
- Shima Seiki colours can be used from Knitpaint or stitch structures can be developed from Design and moved to Knitpaint



For PACKAGE DEVELOPMENT go to top right of screen

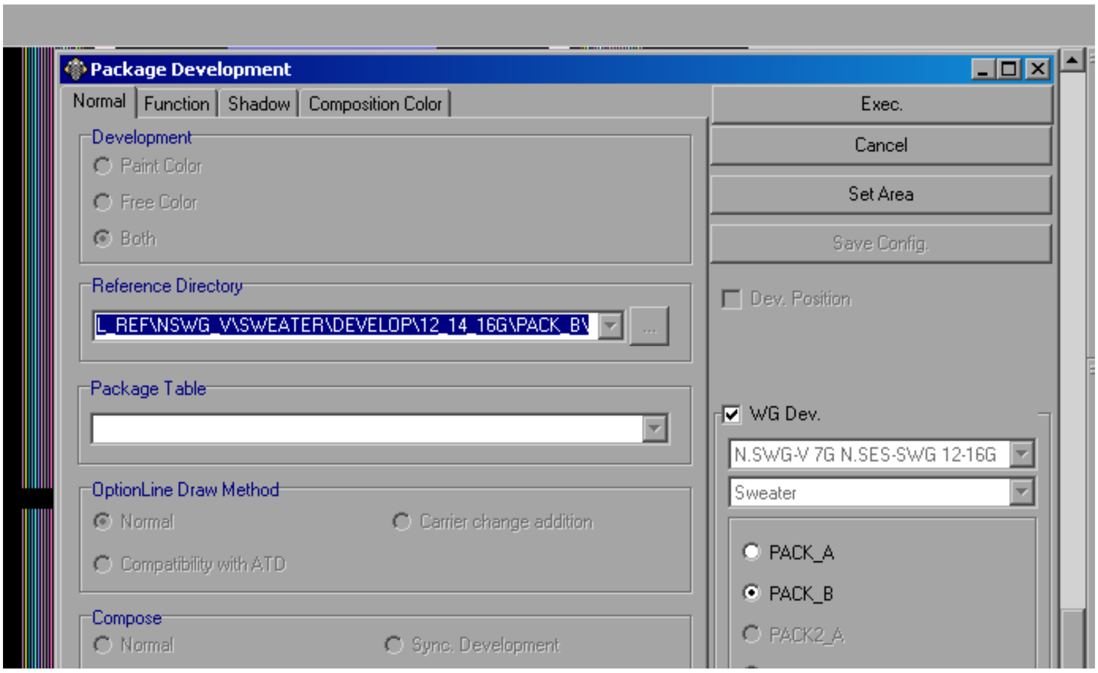
- Click on Package



- A Dialogue box will appear on screen
- If working with Shima Seiki basic garment packages with NO additions – Click – PACKAGE DEVELOPMENT
- If additional packages have been built by the designer or a technician – Click – PACKAGE FILE PARAMETER – Refer to Appendix B for more on additional package registration
- A new Dialogue box called – PACKAGE DEVELOPMENT will appear

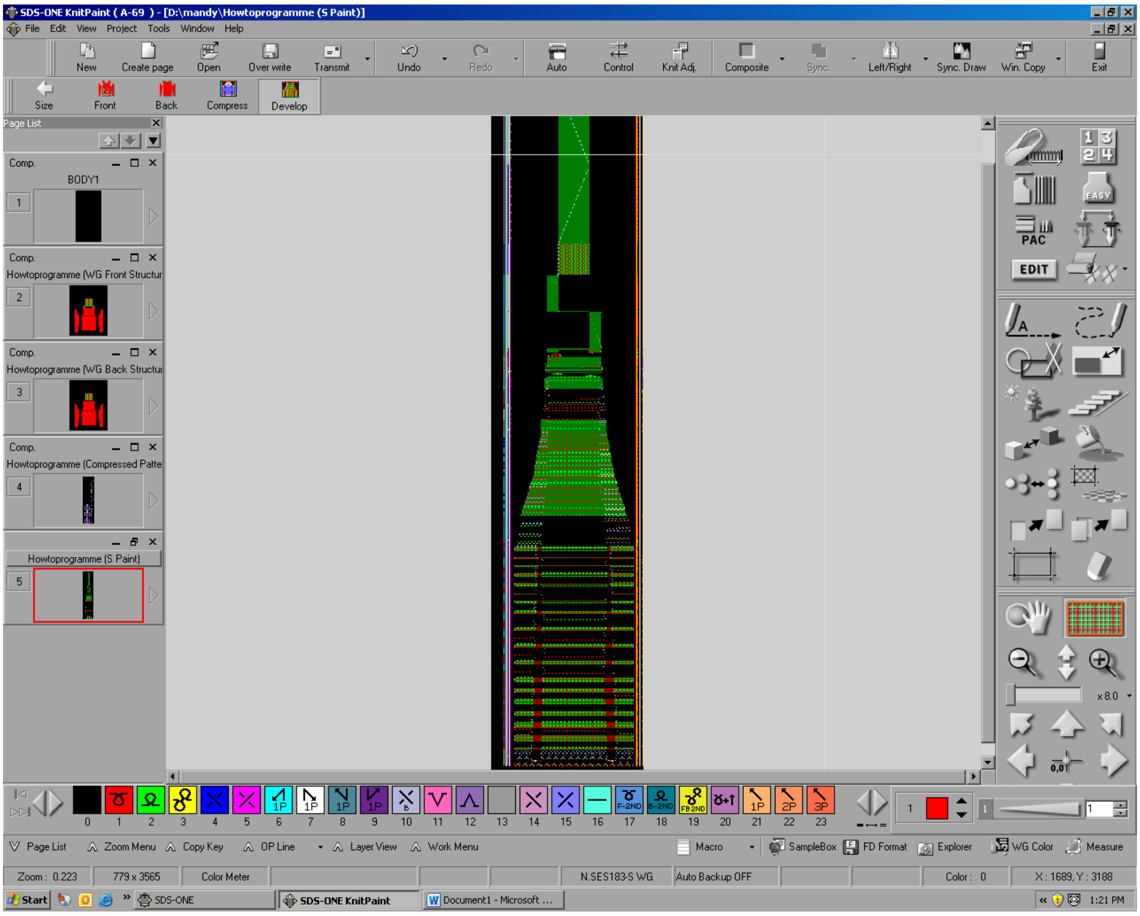
Package Development TABS show: Normal, Function, Shadow and Composition Colour

- Under NORMAL Tab – Check correct machine and garment are entered – it should be there automatically
- Then Click – EXECUTE – in top right hand corner

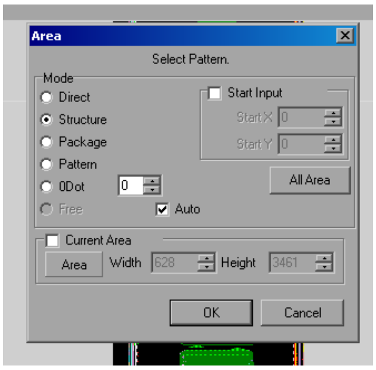


A Processed garment appears on main screen and on left hand side bar in green

This is the programme of the processed garment READY to knit

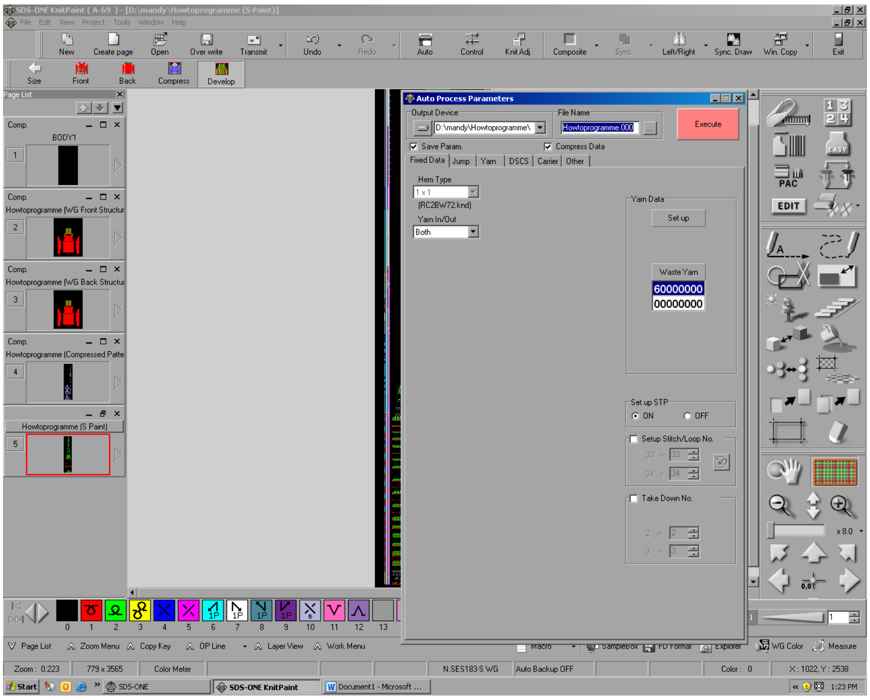


- To check garment programme has NO FAULTS Click -



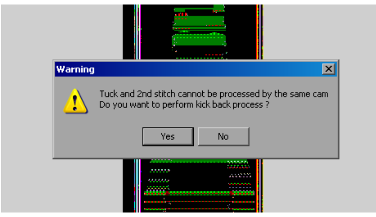
- AREA dialogue box opens – Click – OK -
- AUTO PROCESS PARAMETERS dialogue box opens -

Sometimes this will need to be checked by the designer or technician to make sure Yarn Carriers, etc., are correct – BUT if using automatic software this is generally OK.

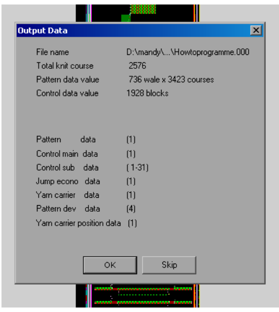


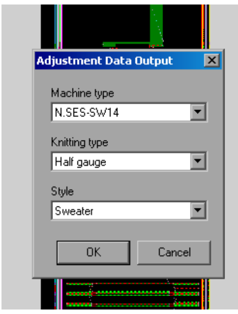
- Click – EXECUTE in right hand corner of dialogue box

Some 'WARNINGS' may pop up at this point e.g.

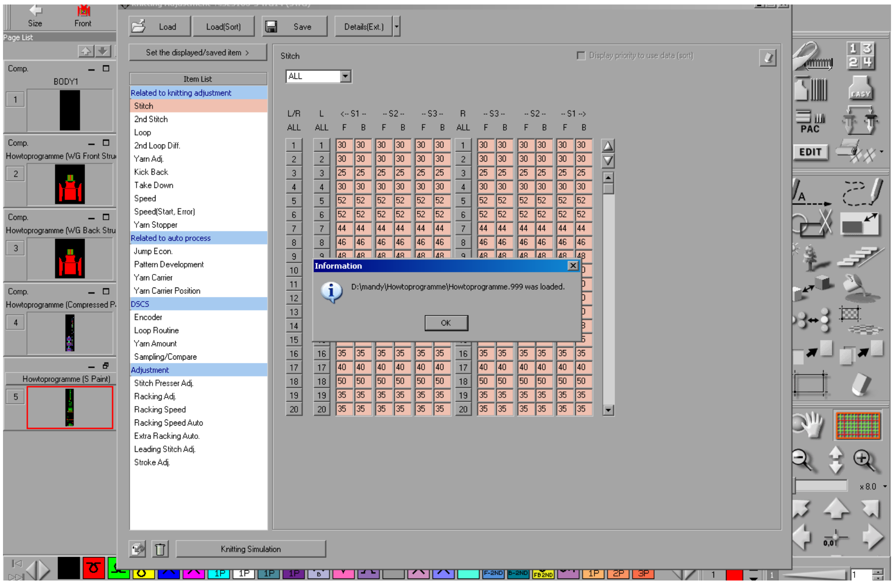


- Click – Yes
- OUTPUT DATA dialogue box – Click –OK
- ADJUSTMENT DATA OUTPUT dialogue box – Click – OK



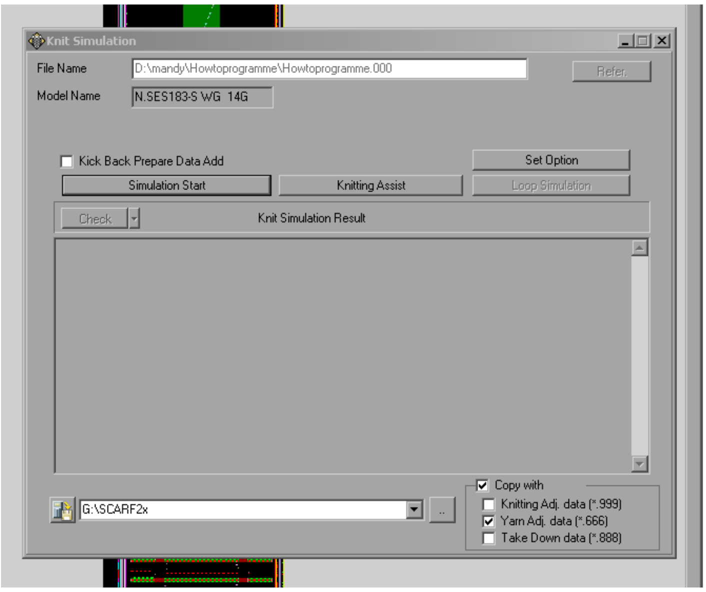


- INFORMATION dialogue box – Click – OK

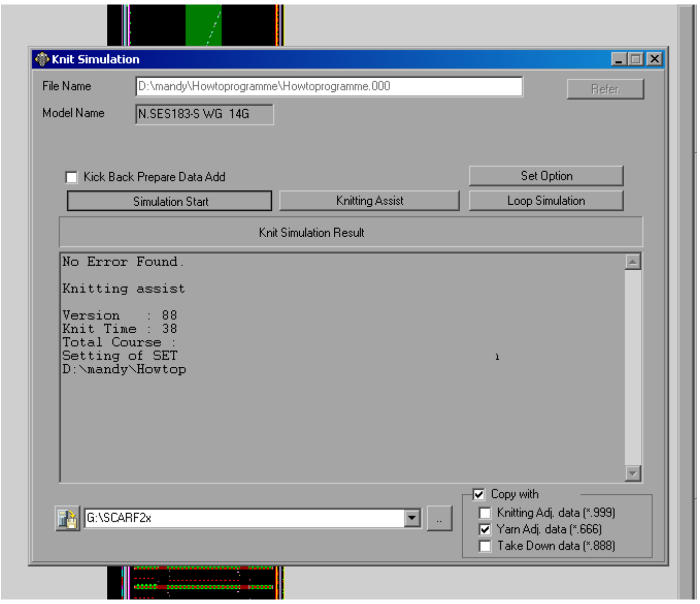


A KNIT SIMULATION dialogue box will appear

- Click – SIMULATION START



- Hopefully NO ERROR FOUND will be the result

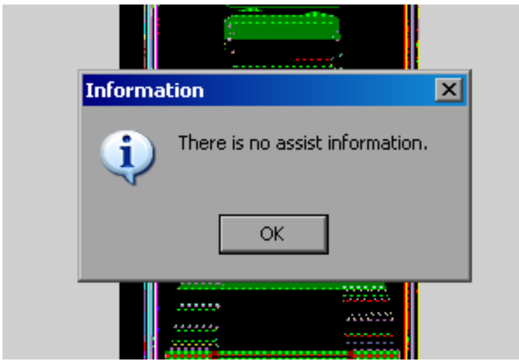


- In KNIT SIMULATION dialogue box seen above Click – KNITTING ASSIST

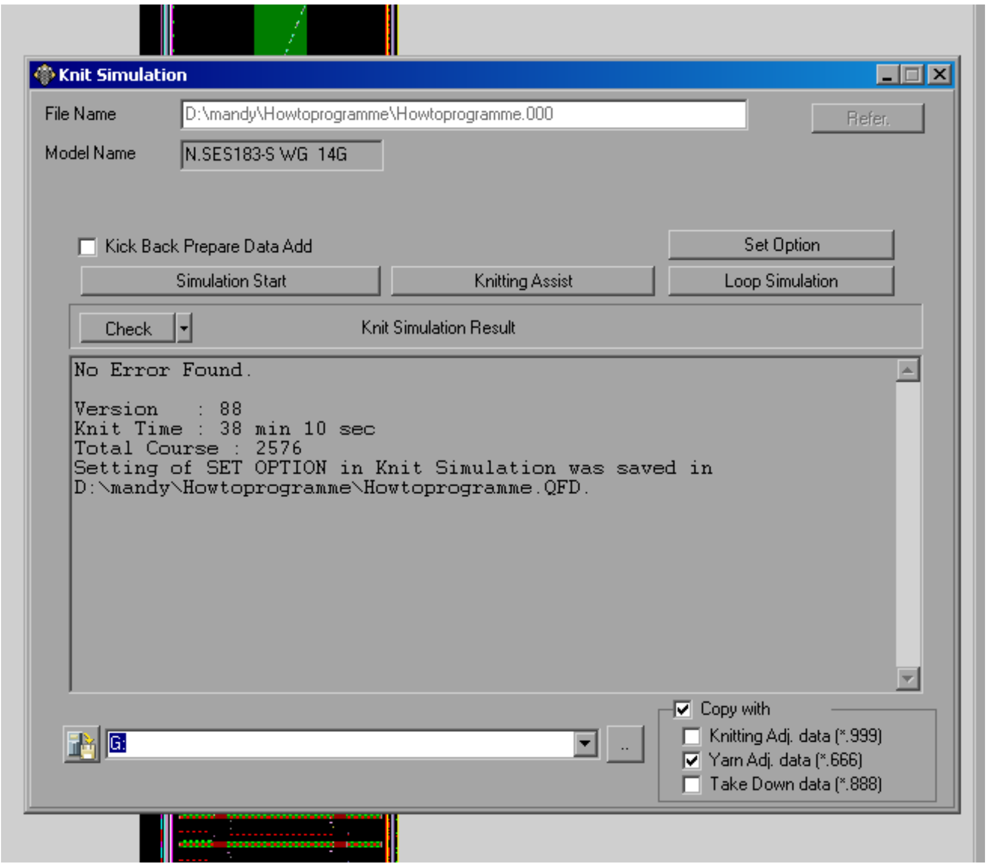
This does a more detailed check of the knitting process

- Occasionally even with the automatic software a dialogue box will pop up with ASSIST INFORMATION
- This means there is something wrong with the programme and it is not knittable – seek technical help

BUT if this doesn't happen – A dialogue box – THERE IS NO ASSIST INFORMATION will appear – Click – OK



If Knit Simulation dialogue box says - NO ERROR FOUND – The Garment is ready to knit



The above dialogue box shows:

- Total knit time
- Total courses in garment
- Where this garment is stored in computer
- In the bottom left hand corner of the dialogue box is the DOWN LOAD button to save in G: DRIVE to a USB stick to take to the knitting machine to be UP LOADED and knit.
- The garment is saved under the name that was initially programmed under at the beginning of processing e.g. D:\mandy\sept sleeve\sept sleeve.000

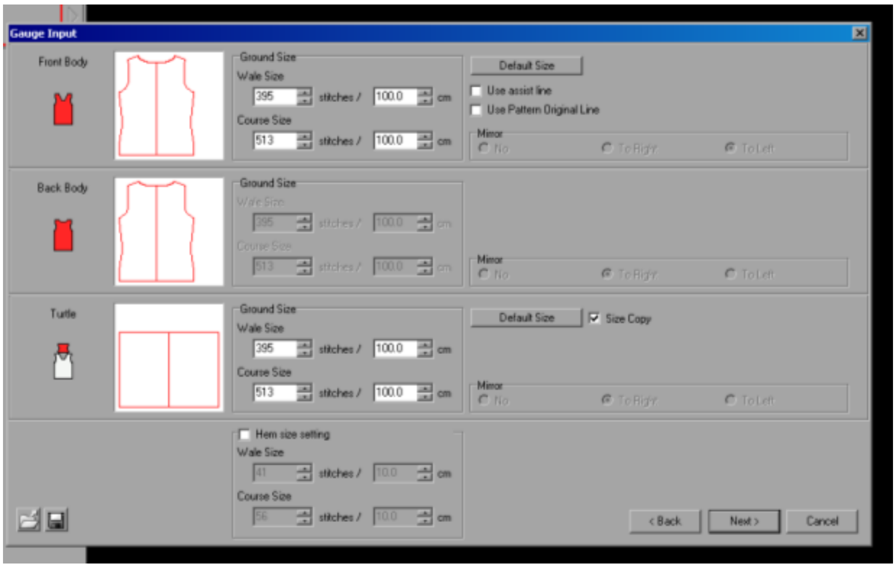
HOW to ADD SHAPE (Additional PACS needed)

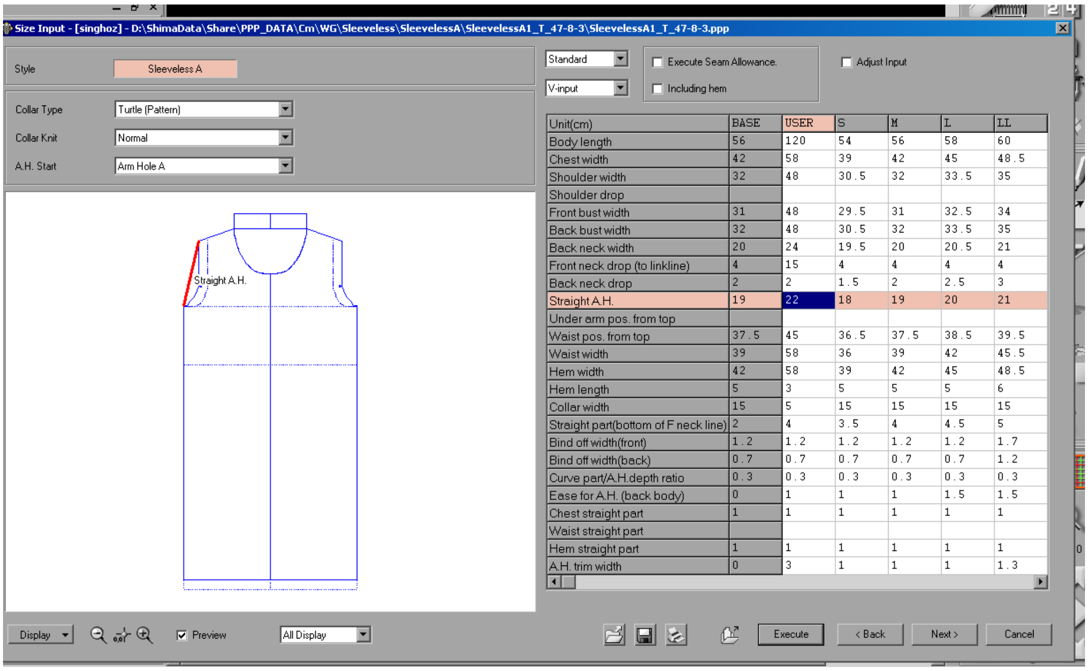
Follow above instructions to Compressed image stage

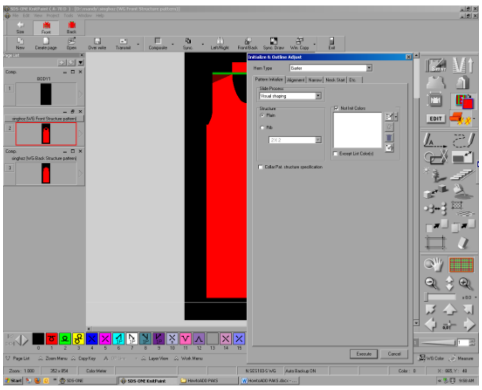
- It is advisable to process garment through to finish of above instructions to make sure that the garment is knittable without the additional 'pacs', sometimes even using Shima pre-installed shapes with no alterations ERRORs can occur.

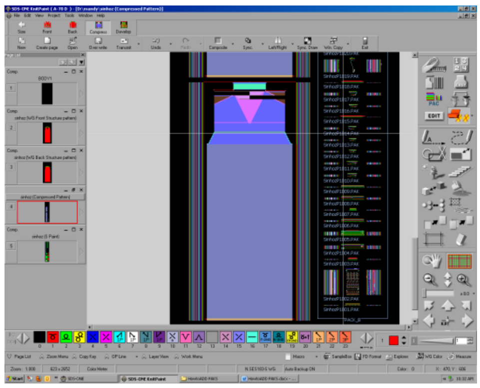
ADD SHAPE (Additional PACS)

These instructions have been completed for the TUNIC shape:



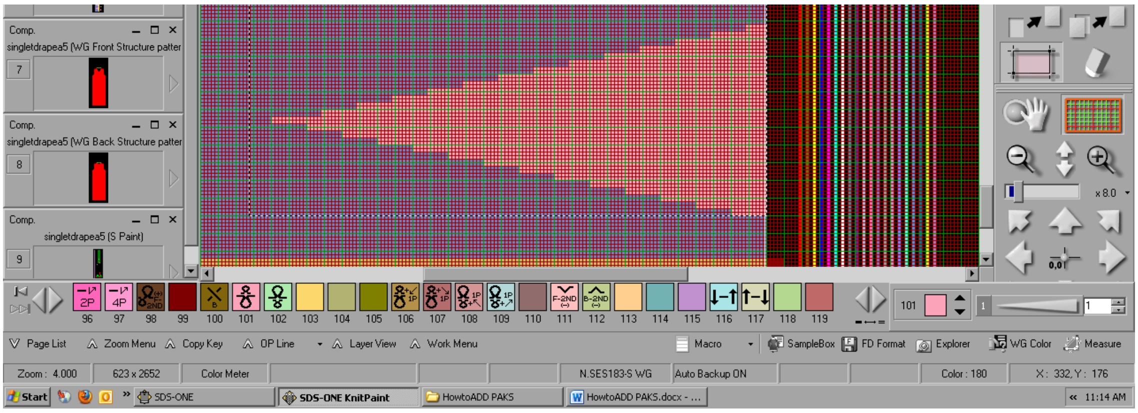


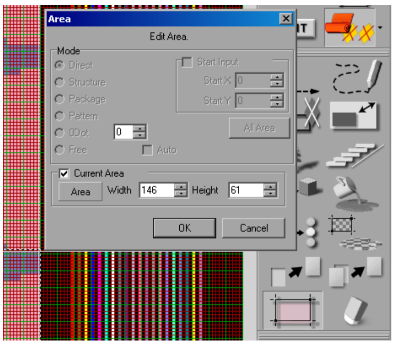


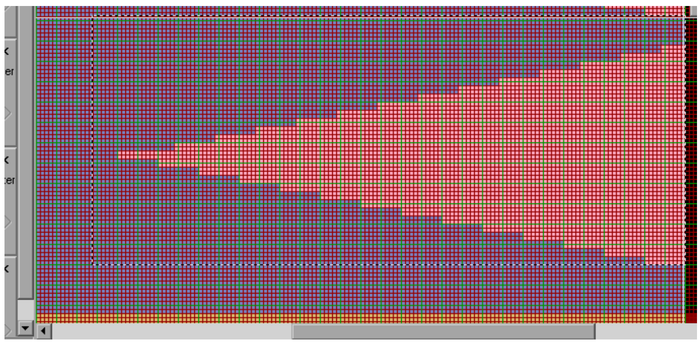


On COMPRESSED Garment image (Purple CAD images)

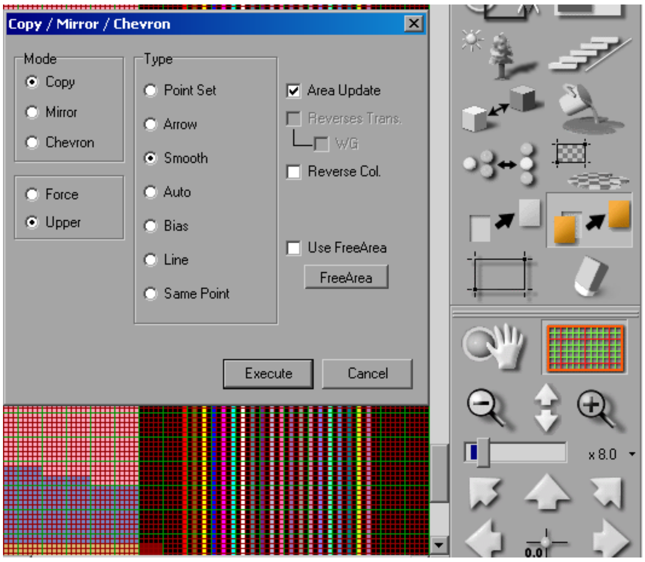
- Create wedge shape required on the first garment
- Using Shima colour 101 = Front Split Knit
- Create wedge shape to size required by selecting colour and drawing on first image
- Click on ‘AREA button – on right hand side of screen



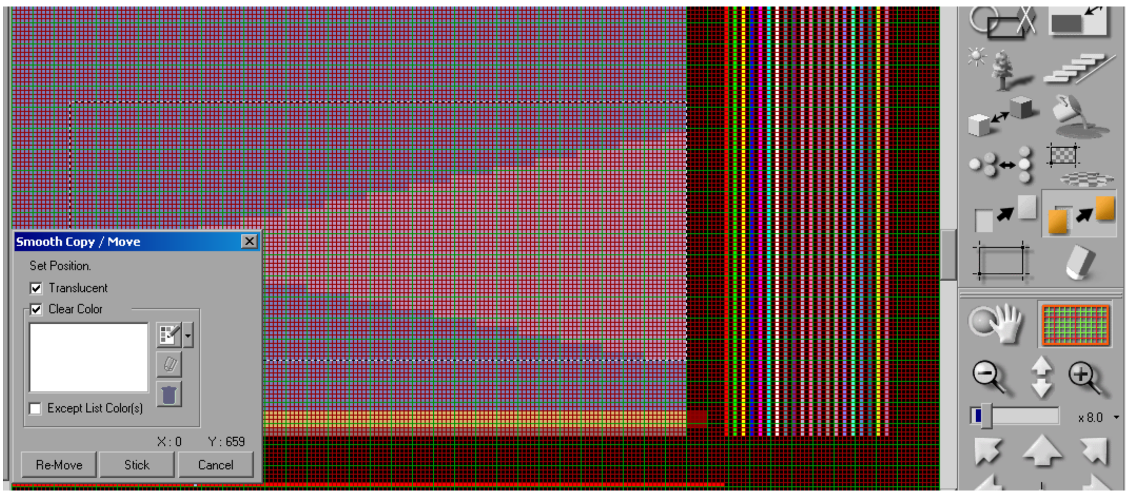




- Surround area to copy
- Click on copy button

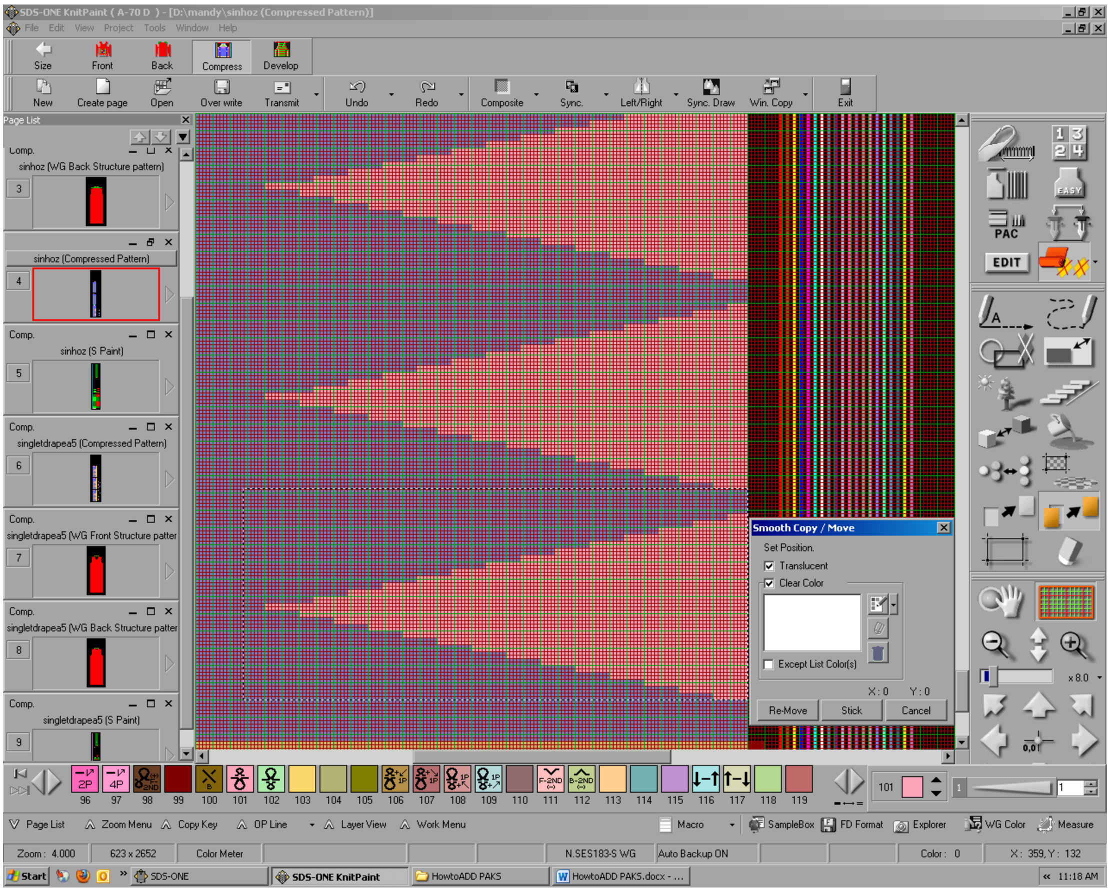


- Check – In MODE – COPY button on Check – In TYPE – Smooth button on
- Click – EXECUTE
- Smooth Copy/ Move dialogue box opens

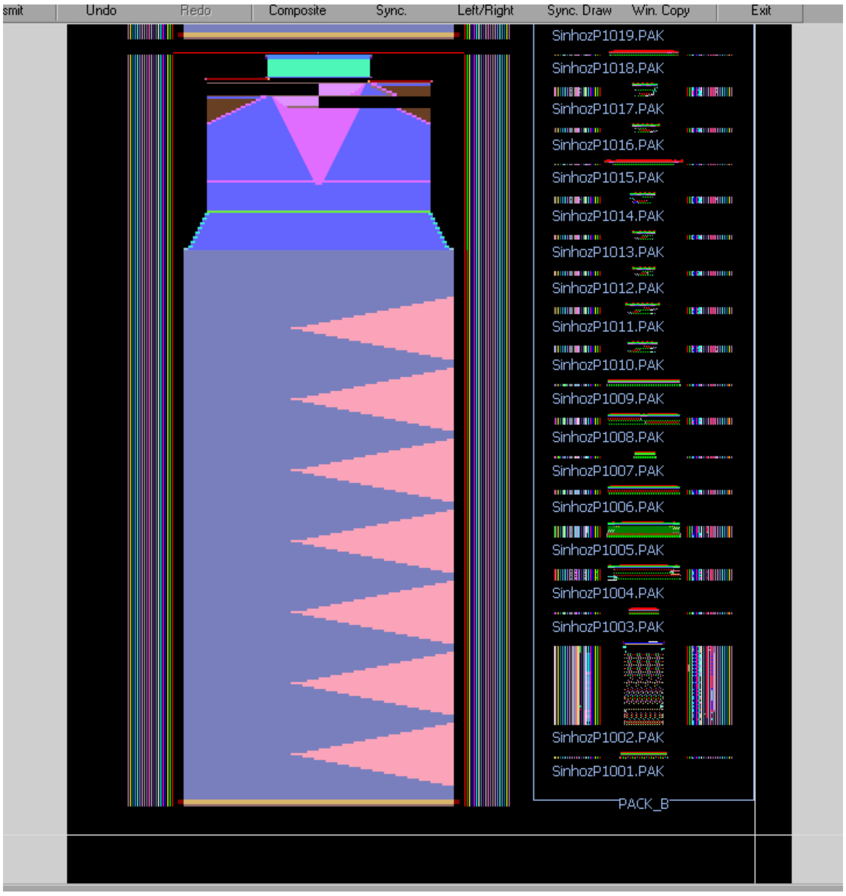


- * Click remove
- * Drag copy to place required
- * Click Stick

- Continue above * movements of remove – stick until all shapes required on garment are complete

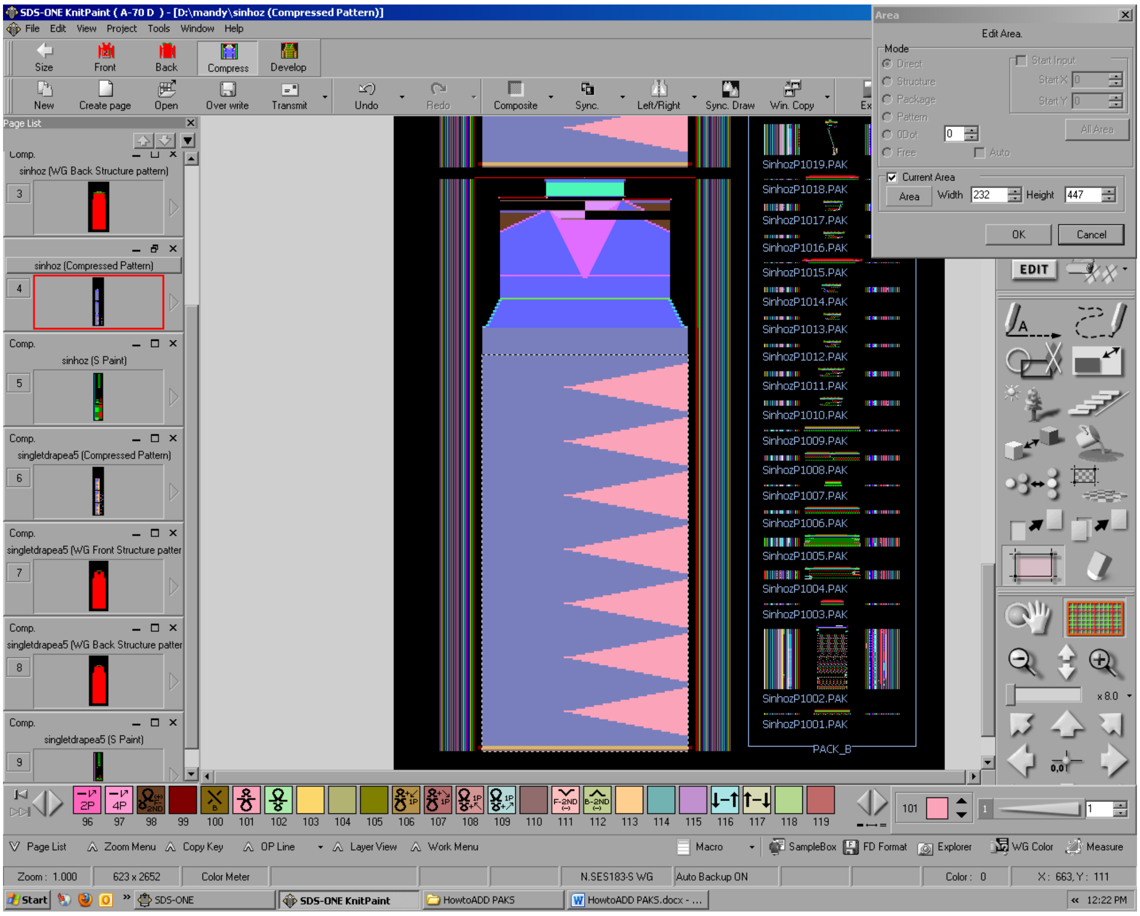


Garment will look like this:

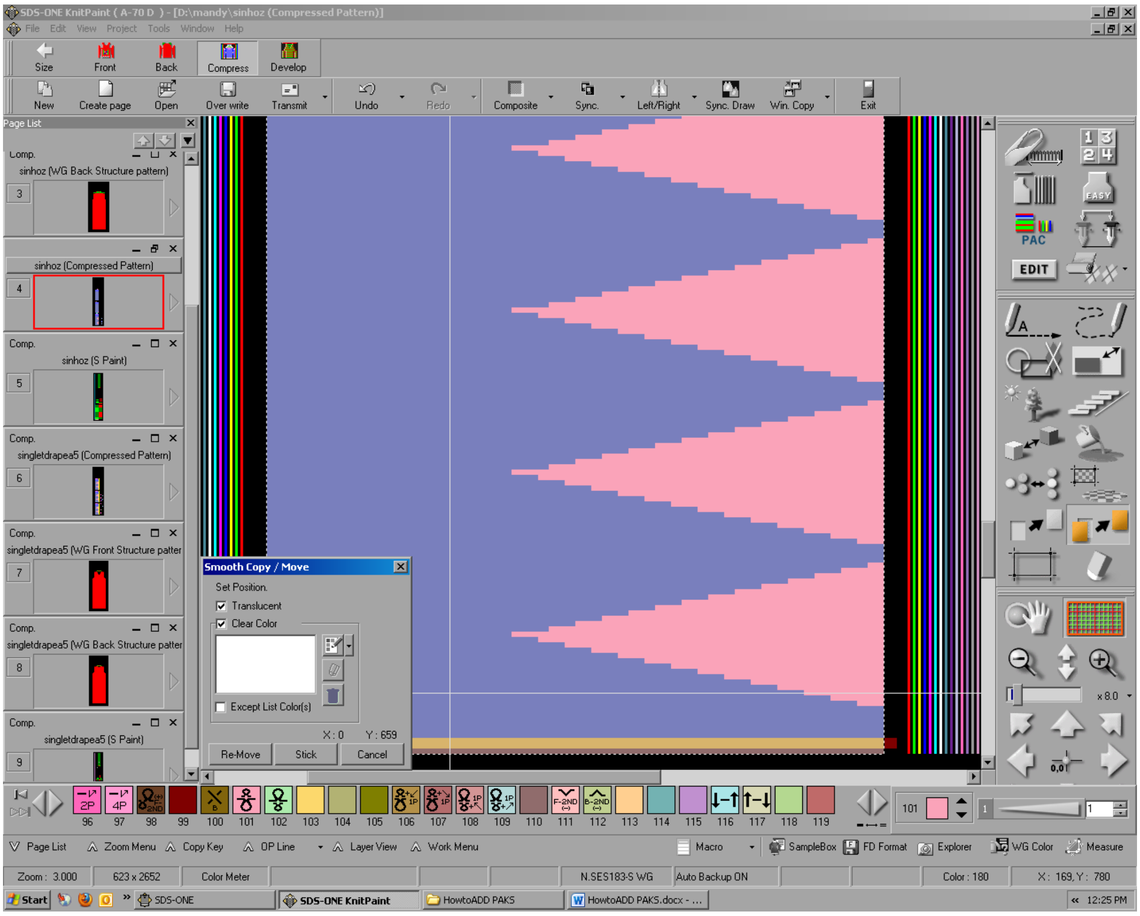


To Copy garment shapes from OVERALL compressed image to FRONT and BACK Compressed images:

- Click on AREA button
- Surround area on garment with wedge shapes

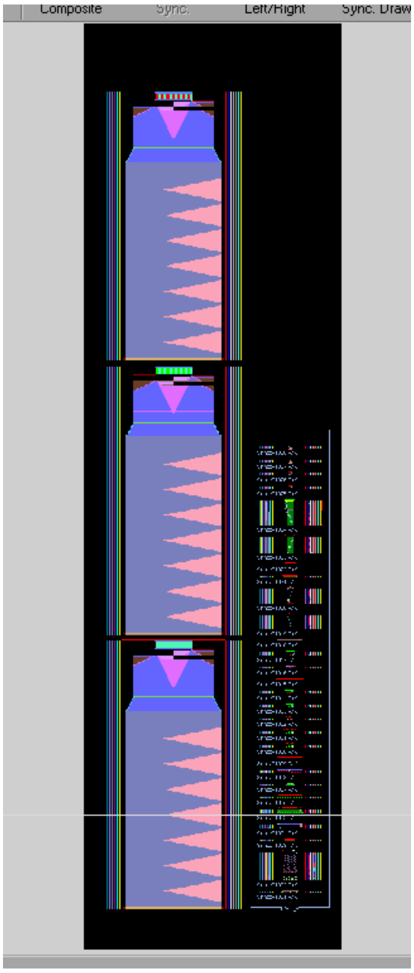


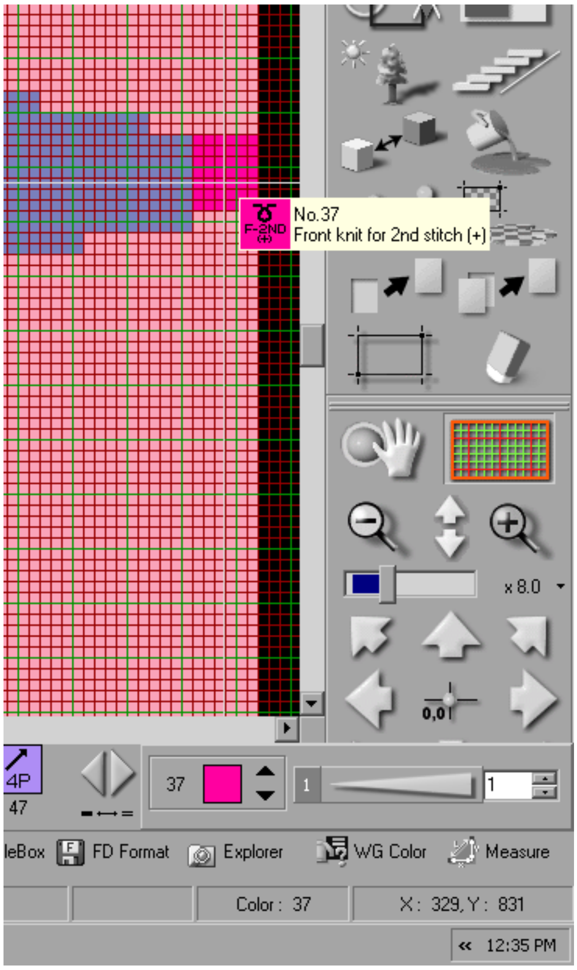
- Click on COPY button



- Click REMOVE
- Move copy up to FRONT Compressed garment image (middle shape)
- Match bottom of garment copy with bottom of garment FRONT
- Click – STICK
- Click – REMOVE
- Take up to BACK Compressed garment image (top shape)
- Match bottom of garment copy with bottom of garment BACK
- Click – STICK
- Click – Cancel & Cancel

All three Compressed garment images have wedge shapes on:

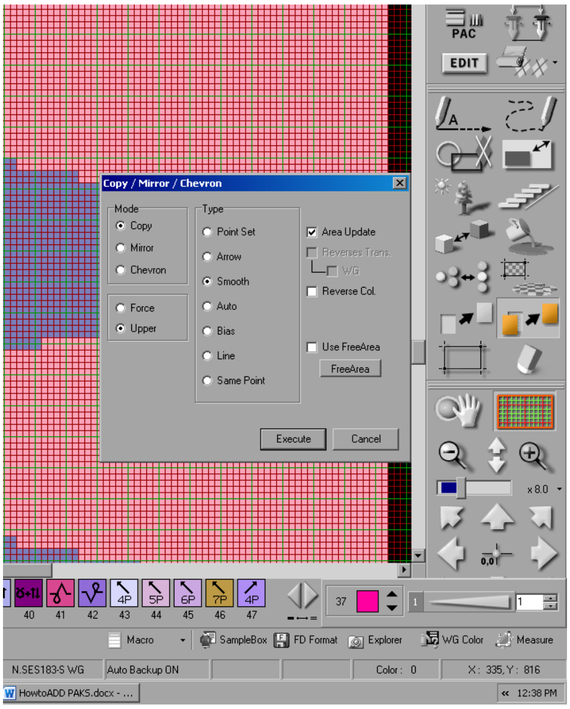


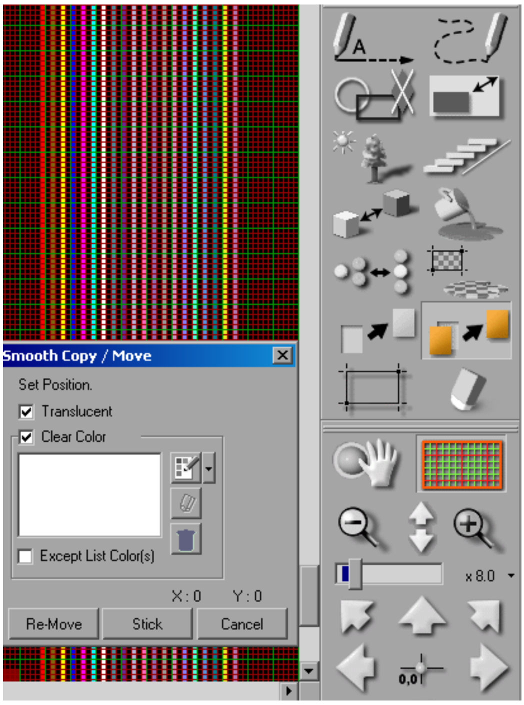


Due to this shape creating tension from holding at one side of the garment – some additional steps are required

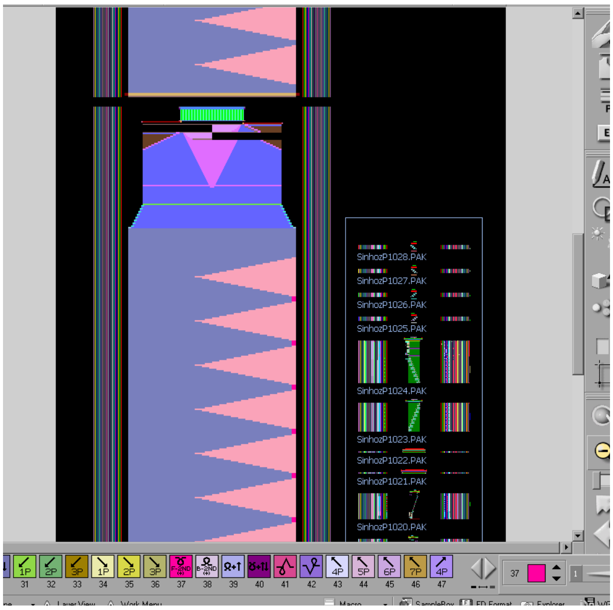
- Using Shima Colour 37 = FRONT KNIT FOR 2nd STITCH (+)
- Work on FRONT Compressed garment (Middle image)
- Fill in area of tension as shown – to loosen stitch tension here to prevent bursting stitches
- Click – AREA
- Surround stitch area colour 37

- Click – COPY – EXECUTE

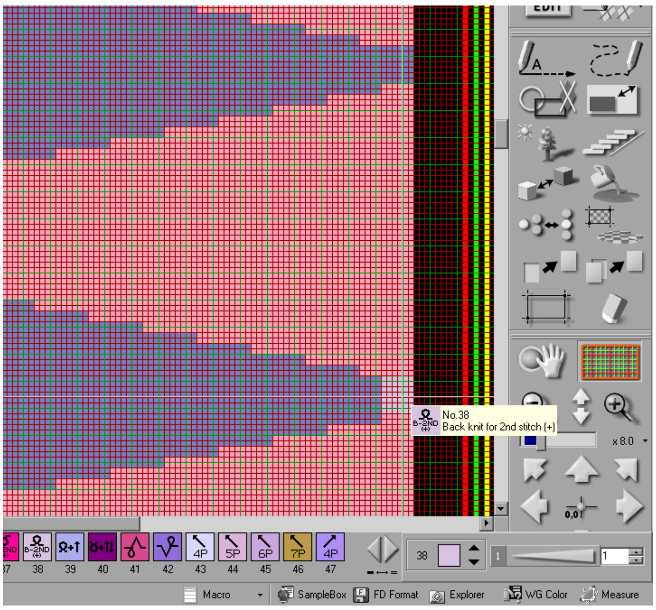




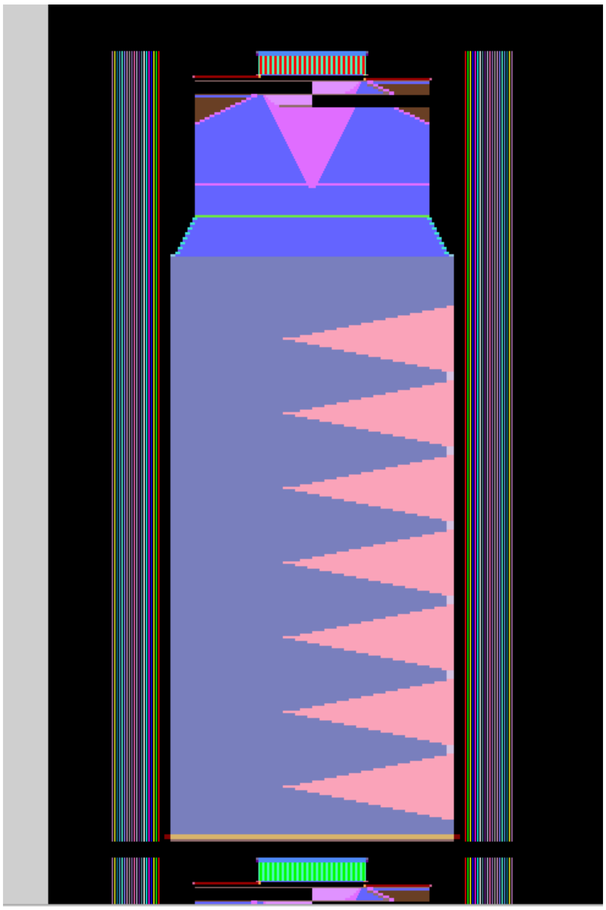
- *Click – REMOVE
- *Place between next set of shapes at area of tension
- *Click – STICK
- Repeat * until all shapes on FRONT have section of colour 37 between them

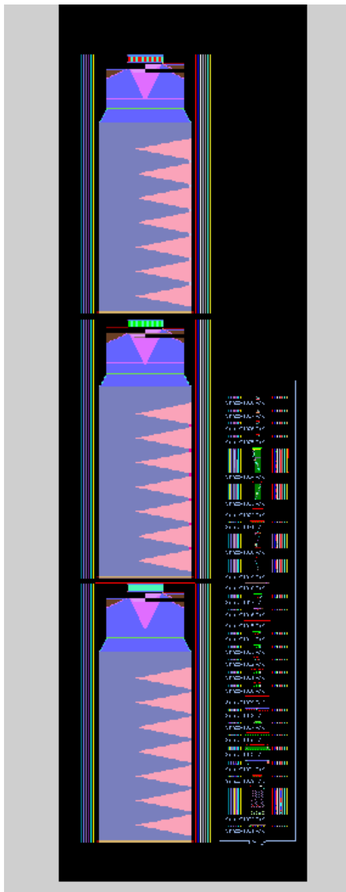


- Using SHIMA colour number 38 = BACK KNIT FOR 2nd STITCH (+)
- Repeat this on BACK image of compressed garment (Top image)
- Surround area, copy, execute, remove, stick



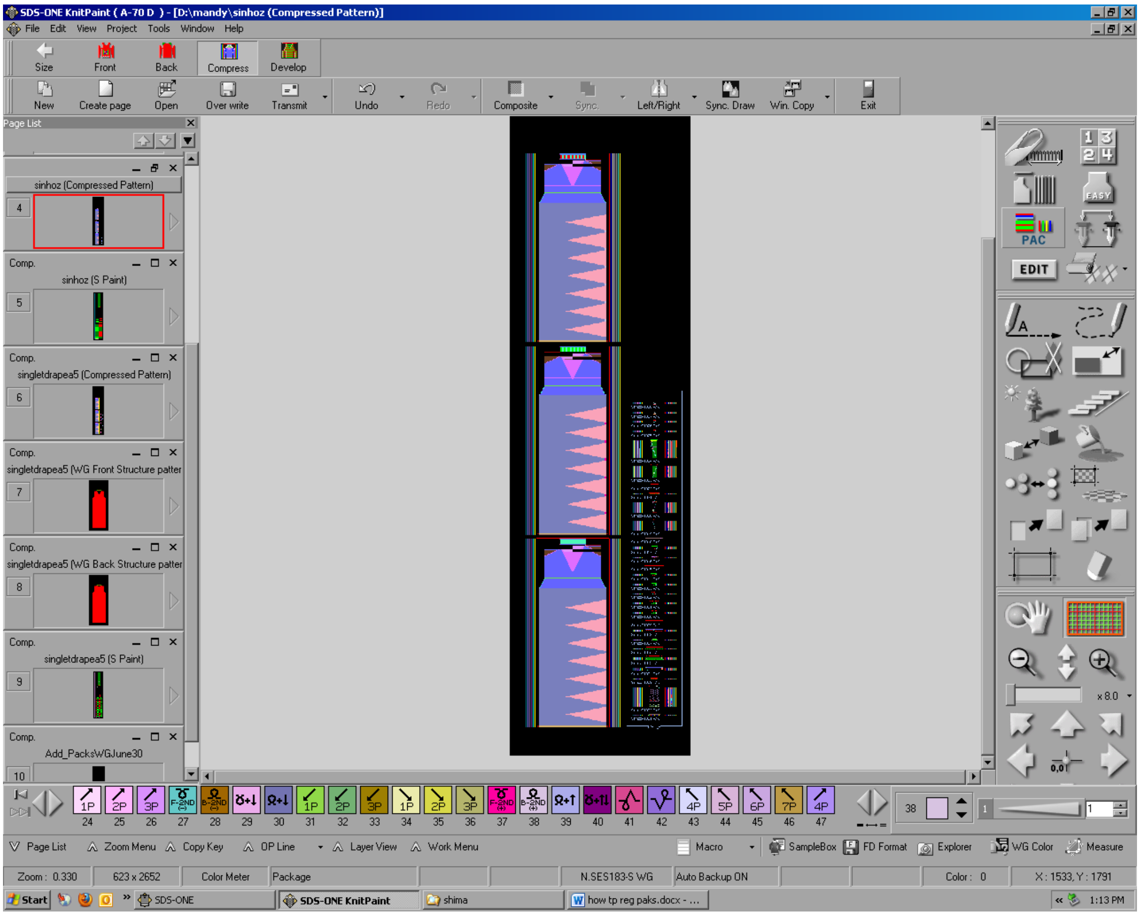
- Continue until Back shapes have section of colour 38 at areas of tension





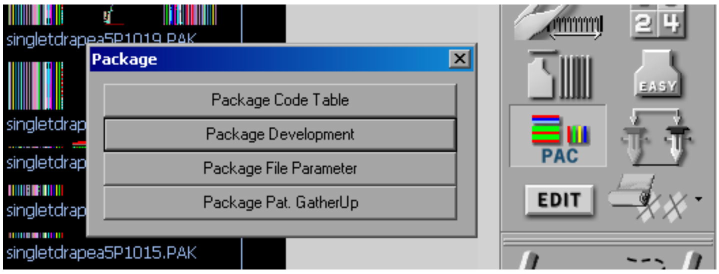
Now ALL three Compressed images are ready for – PAC registration

ADDITIONAL PACKAGE (PAC) REGISTRATION

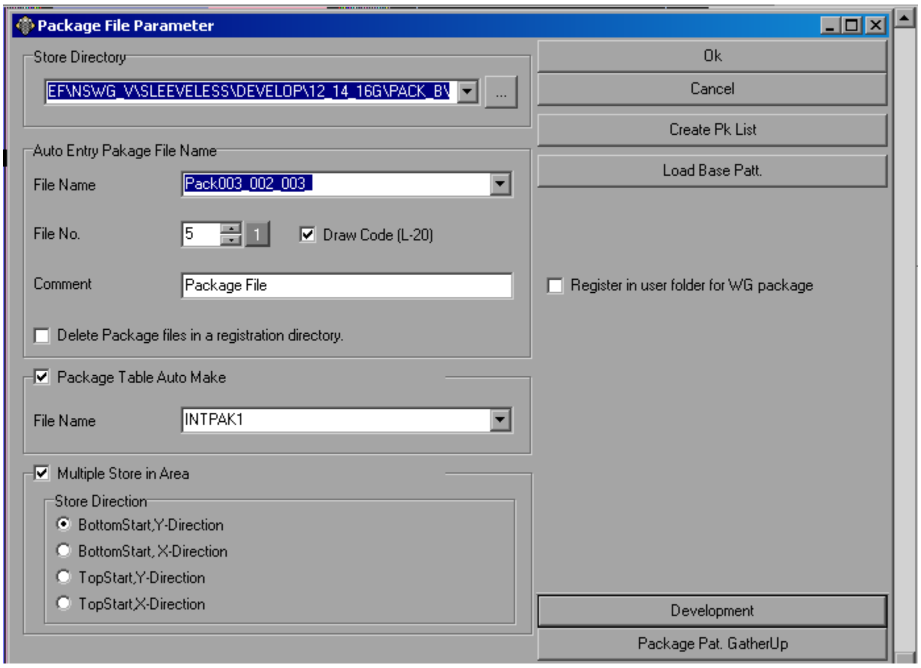


- On Compressed image page

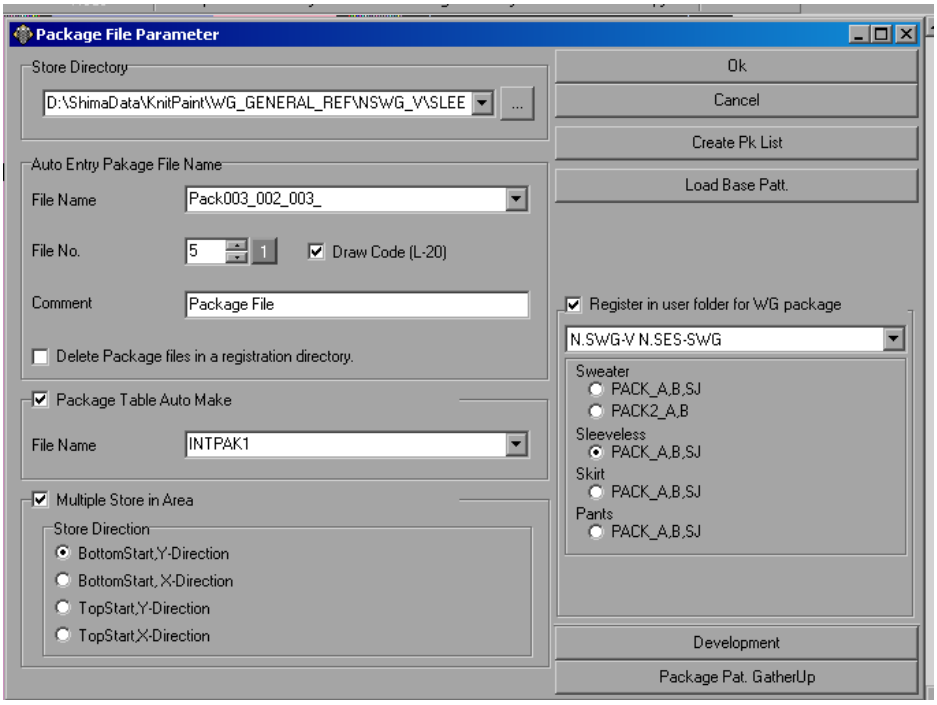
- Click – PAC button
- PACKAGE dialogue box will open
- Click on PACKAGE FILE PARAMETER button



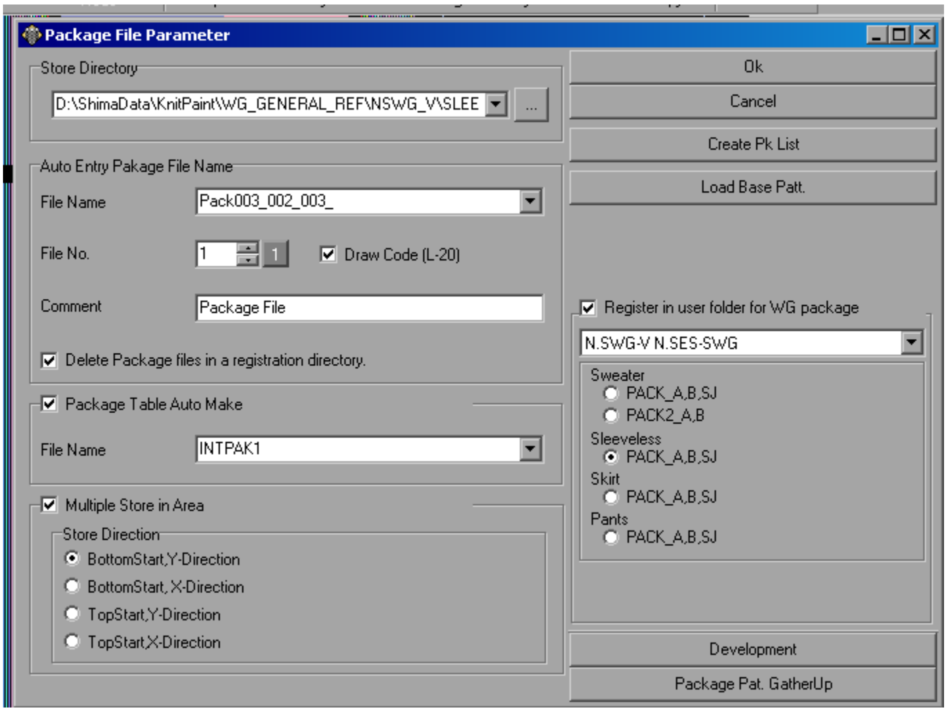
- PACKAGE FILE PARAMETER dialogue box will open



- Click box Register in user folder for WG package

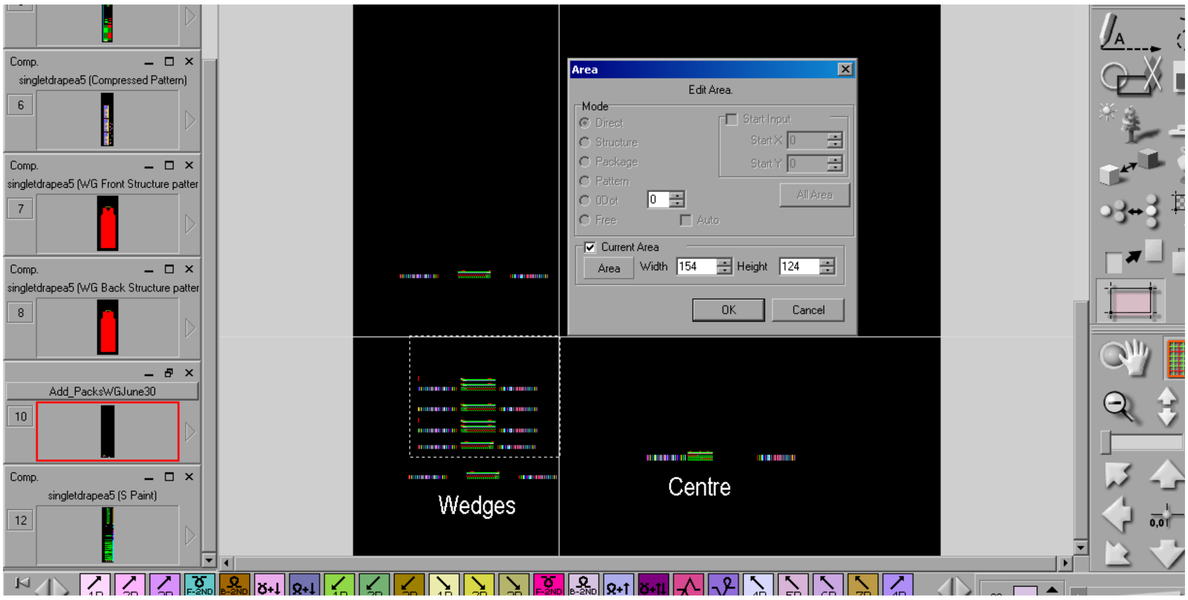


- Check – Sleeveless Shape is clicked (or sweater, etc. if working on other shape)
- Change FILE NO. to 1
- Check – Delete Package files in a registration directory is clicked

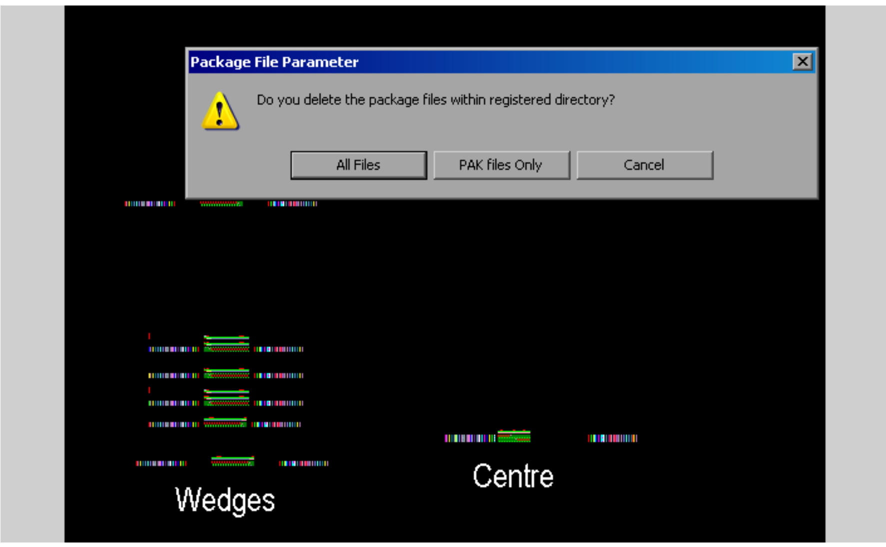


- When it looks like this – Click – OK
- Open page with 'Additional Packages' on

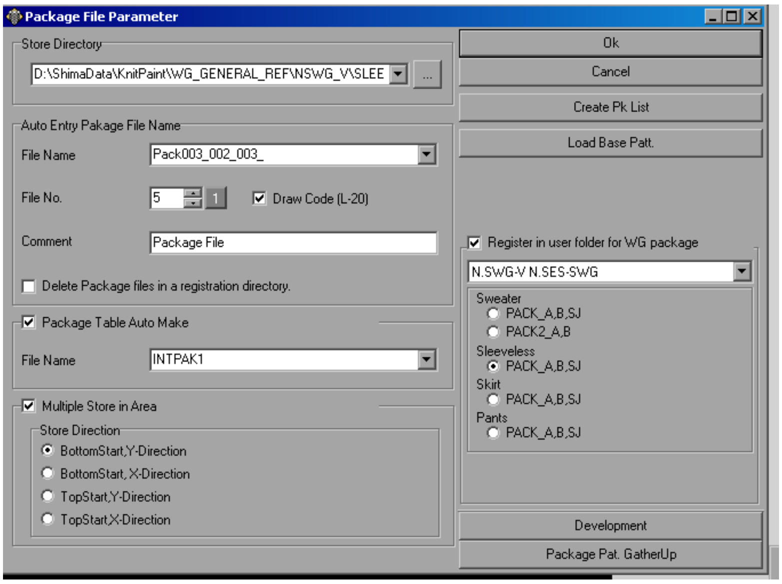
These would have to be created before starting to register shape – these were created by the Technician at the TDL



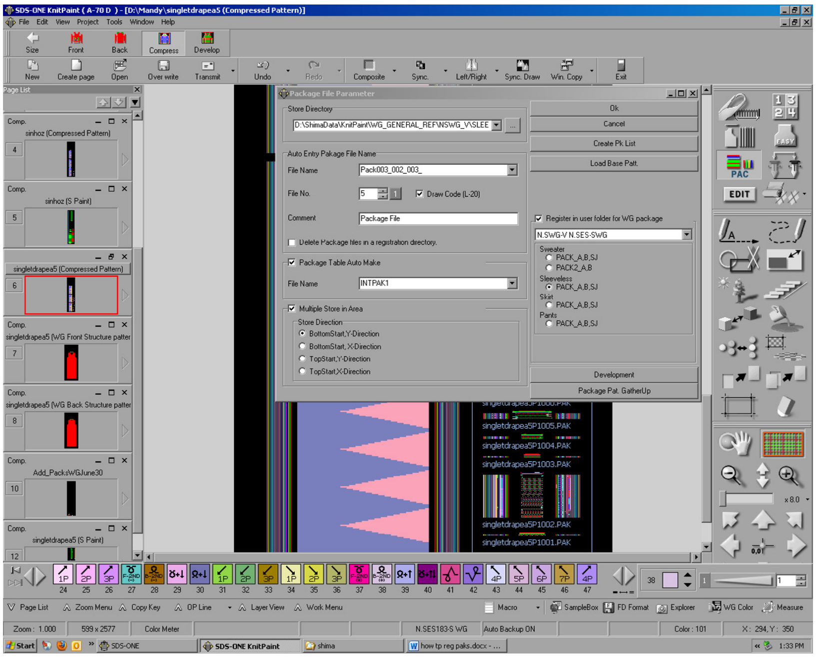
- Click on AREA
- Select area to be copied
- Click OK
- Package File Parameter – WARNING will open
- Click – ALL FILES

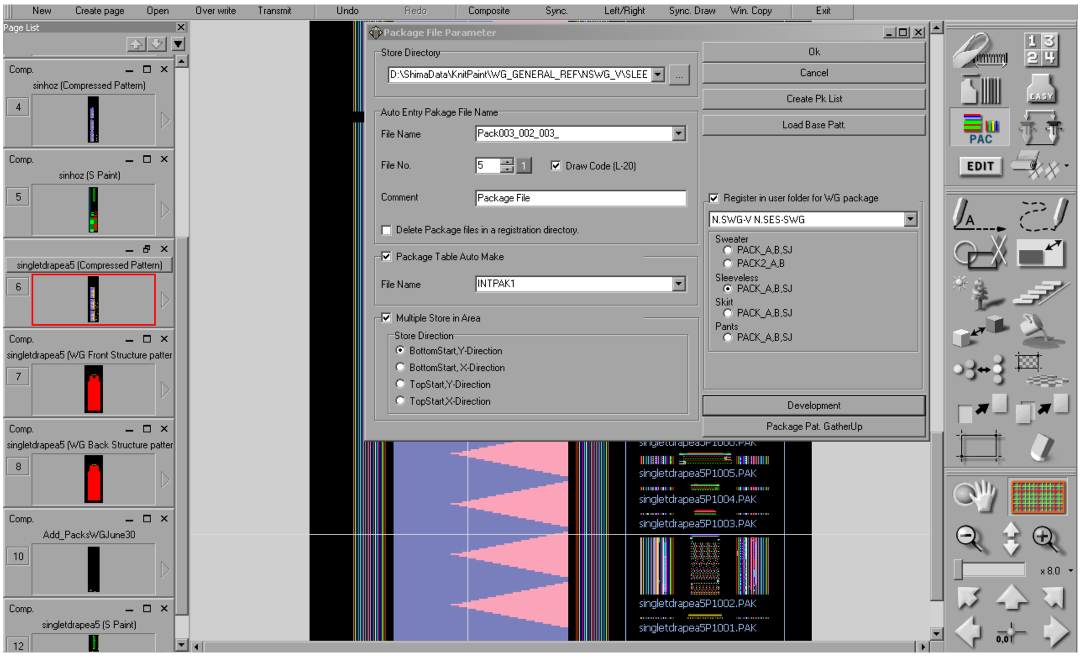


- Package File Parameter dialogue box will open



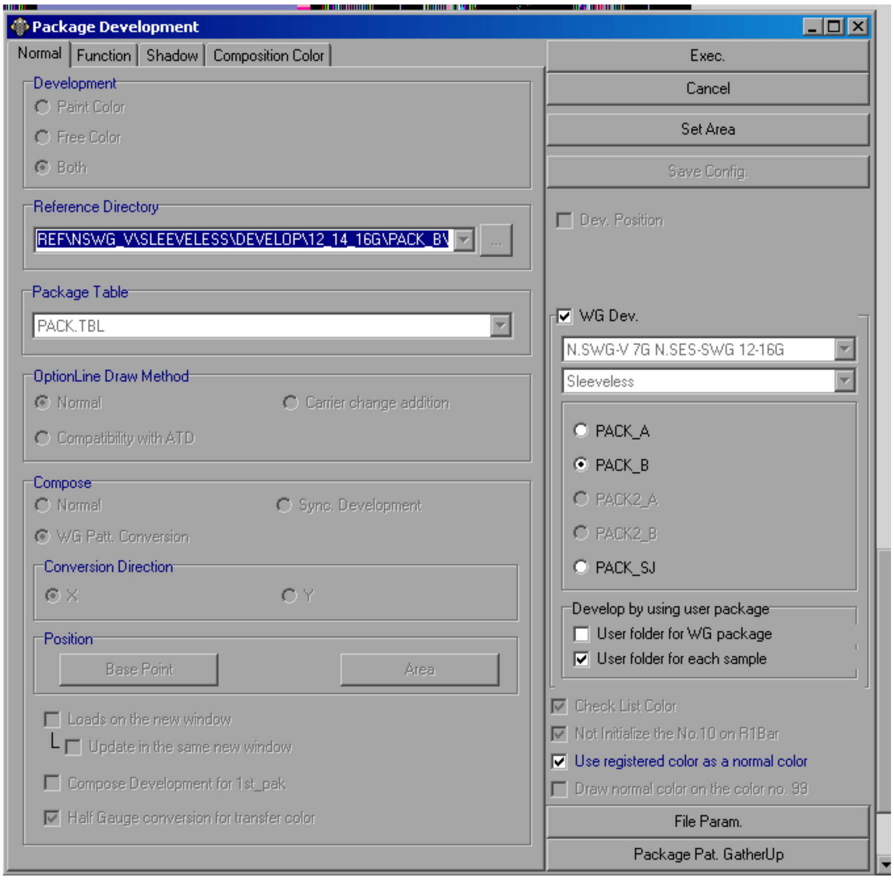
- Click – CREATE PK LIST in right hand corner
- Open Compressed garment image page



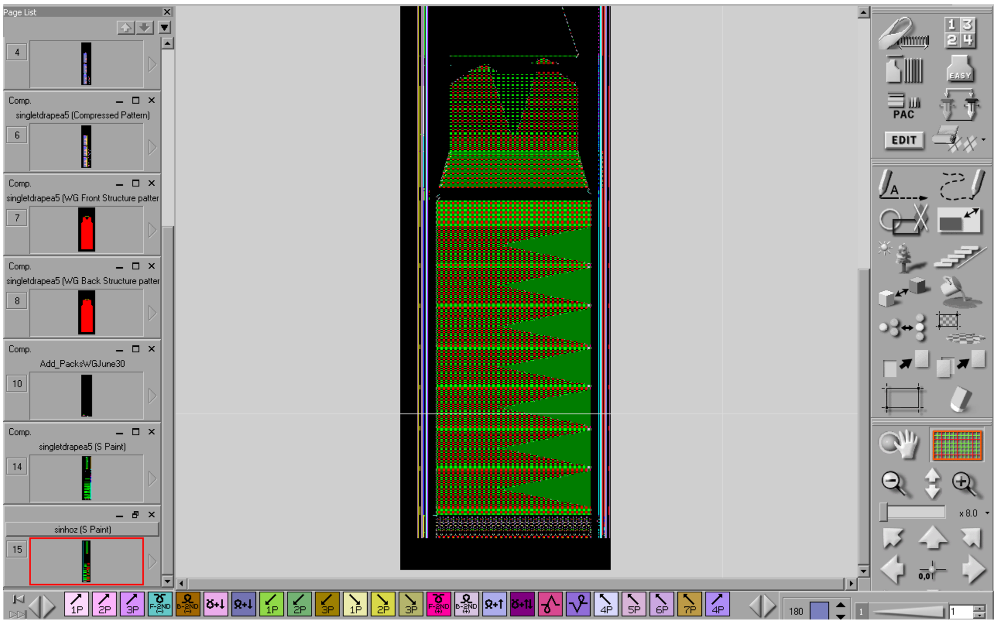


- Click on Compressed garment image page

- Check – REGISTER in user folder for WG package is on
- Click – DEVELOPMENT in bottom right hand corner
- New dialogue box opens – PACKAGE DEVELOPMENT



- Under –Develop by using USER PACKAGE
- Check – USER FOLDER FOR WG PACKAGE is on
- Click on EXECUTE



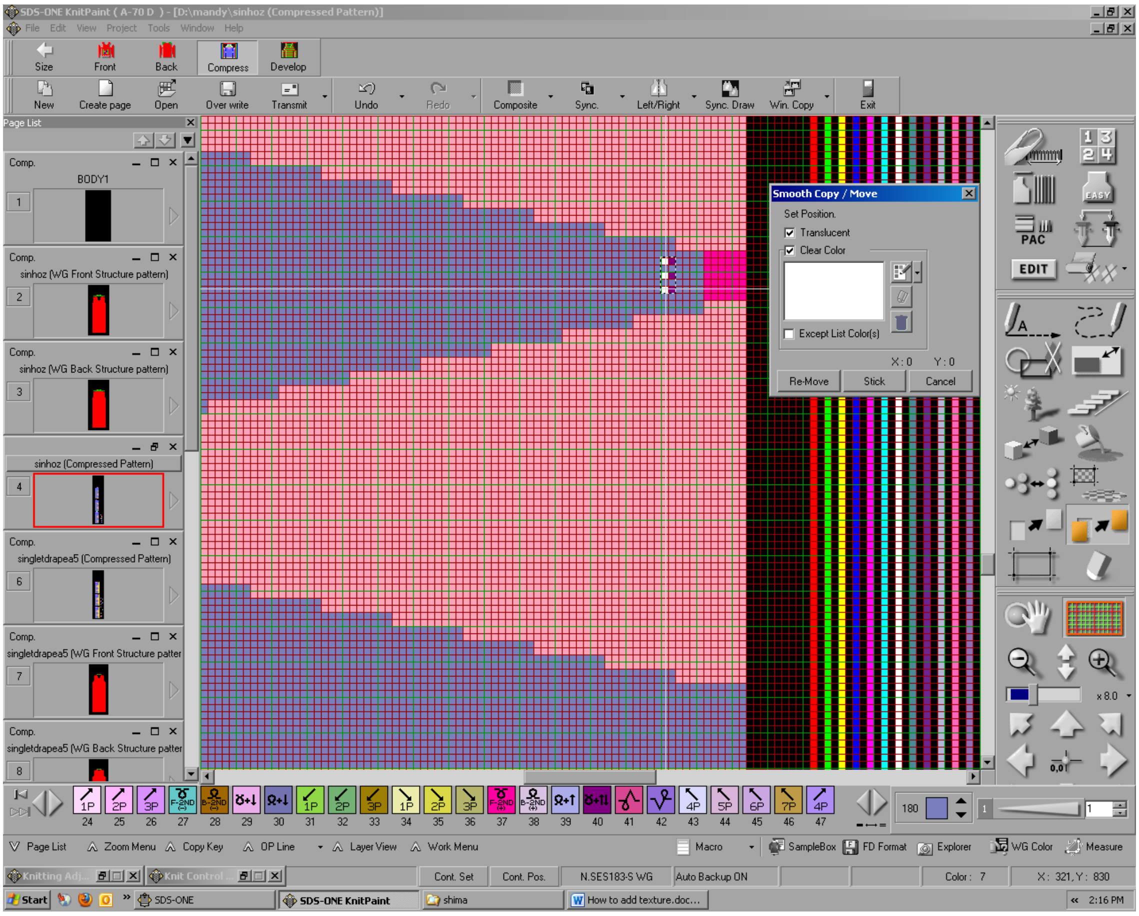
This should process and a green registered garment will open

- Check this through KNIT AUTO to make sure that it is OK to KNIT (see Appendix A for process)

HOW TO ADD PATTERN OR STRUCTURE TO GARMENT

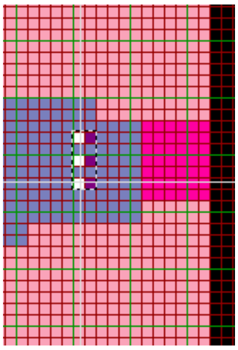
Work on Compressed garment CAD image (purple)

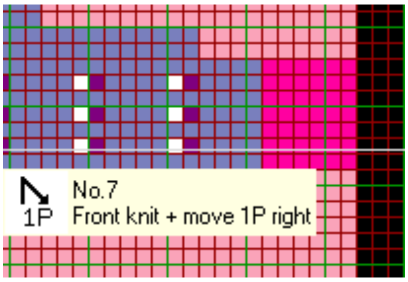
- Work on FRONT (middle image) Compressed garment

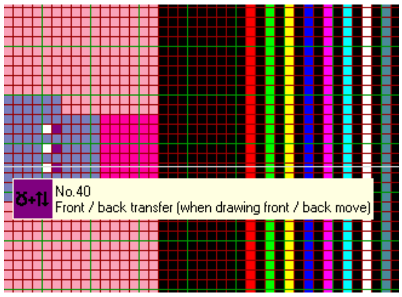


- Work out what stitch structure to add; NB: the 'Design' system in the SDS-One is good to find out what Shima numbers do

- Add chosen FRONT colours for front bed machine movements directly to FRONT (middle) compressed image



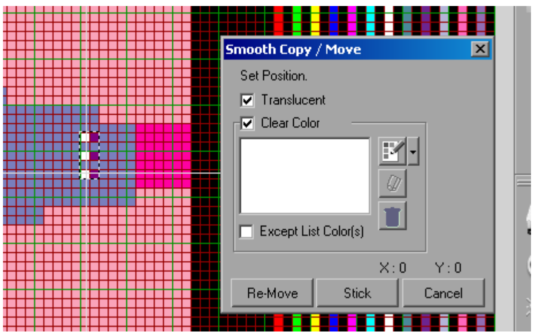


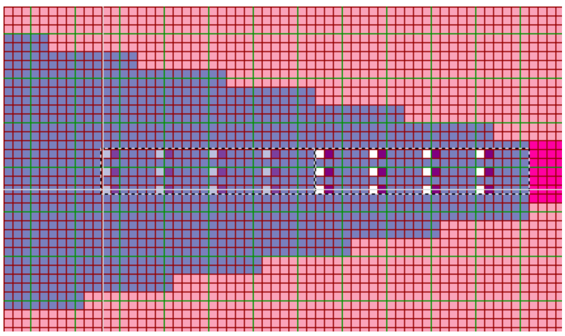


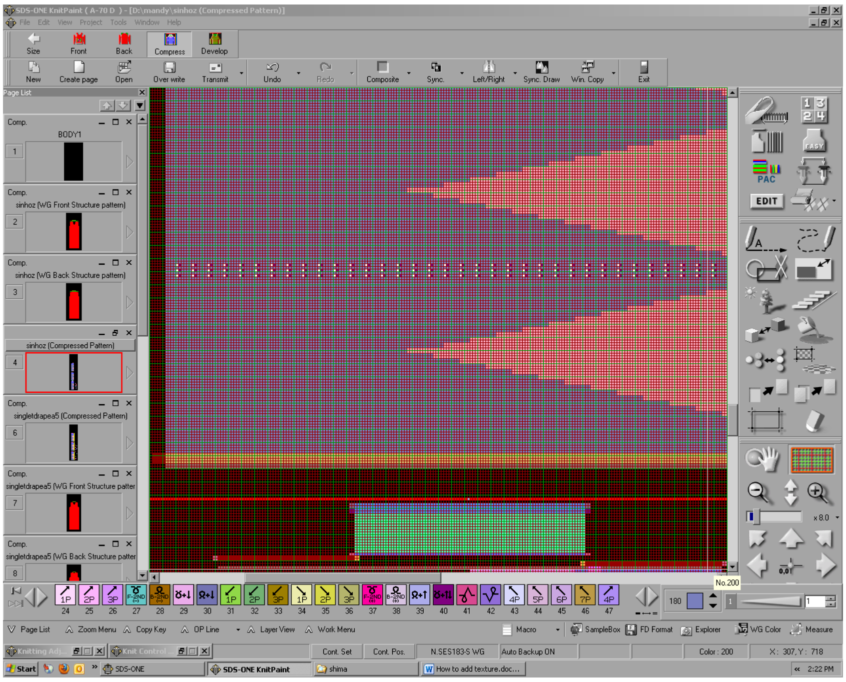
Seen here:

Shima number 7 = Front knit + move 1 P right (white)
Shima number 40= Front/back transfer (when drawing front/back move) (dark pink)
If making a repeat pattern of stitch structure

- Use AREA – surround area of repeat
- COPY – REMOVE – STICK
- Until area required is covered

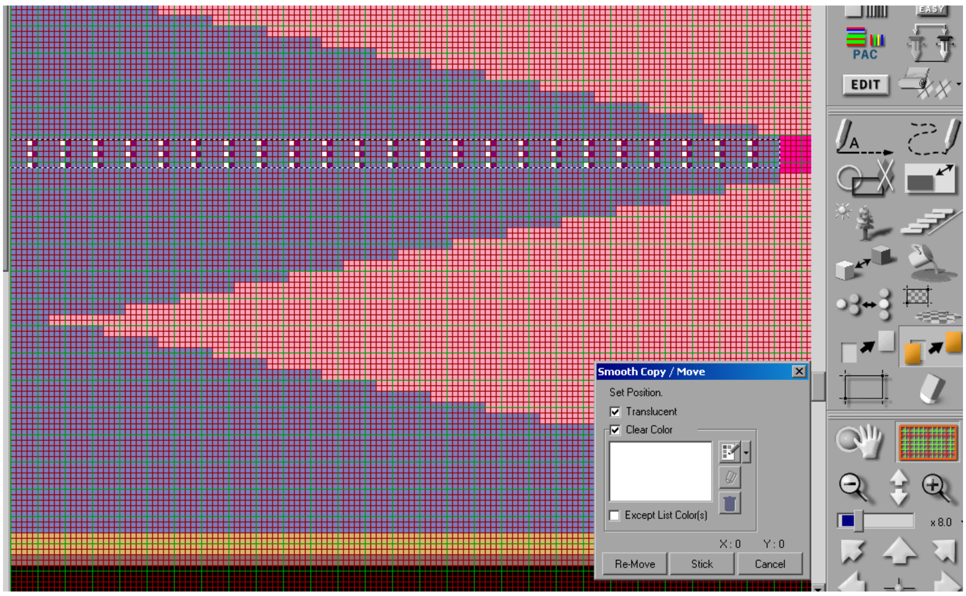


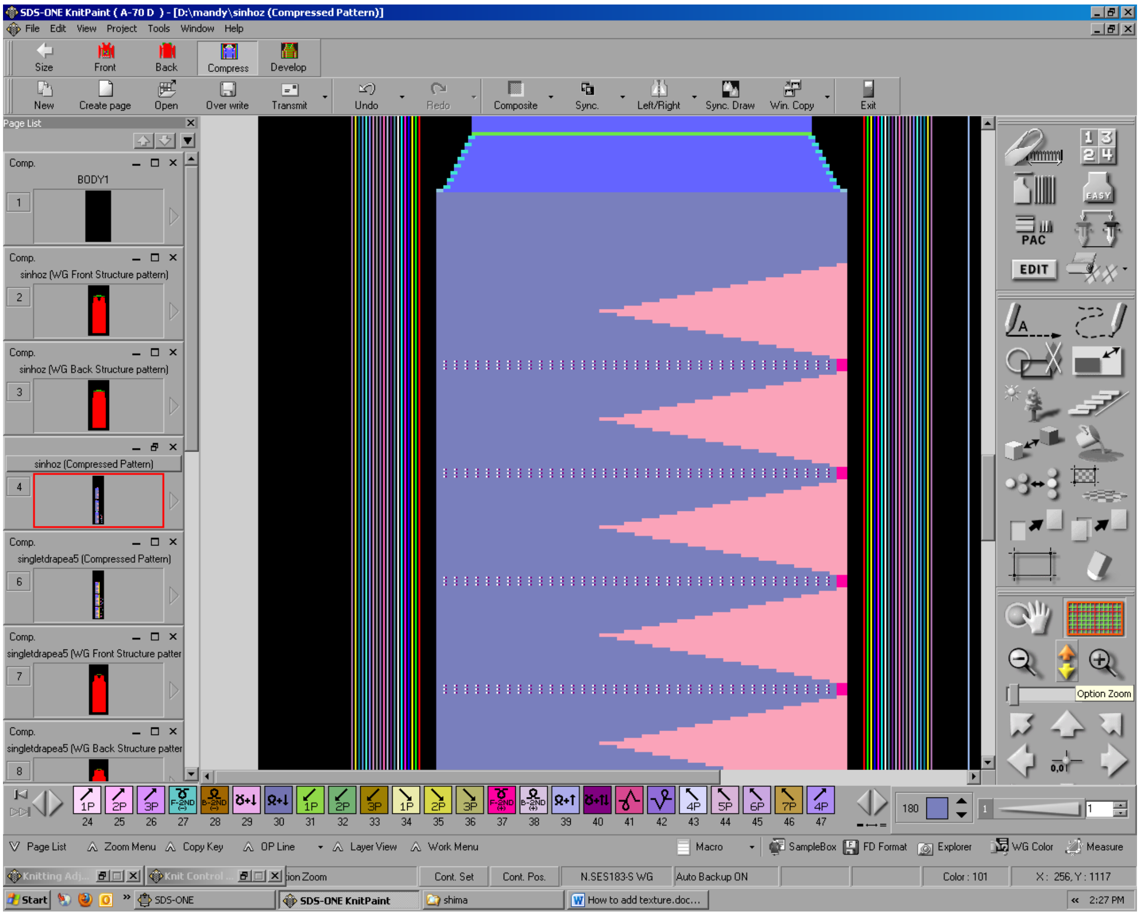




- Repeat pattern by using AREA – COPY – REMOVE –STICK

This can be repeated all over or placements made in areas of the garment





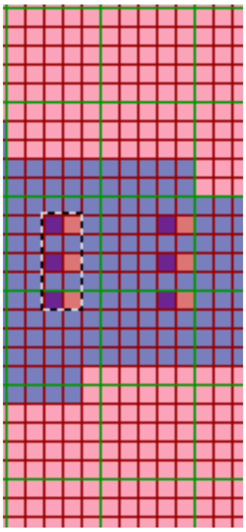
When FRONT compressed garment stitch structure finished

- The BACK (Top) Compressed garment stitch structure needs to be created
- For the stitch structure to look the same on the BACK of garment as the FRONT generally - mirrored stitch structures need to be used

BACK stitch structure uses:

Shima number 9 = Back knit + move 1 P right (dark purple)

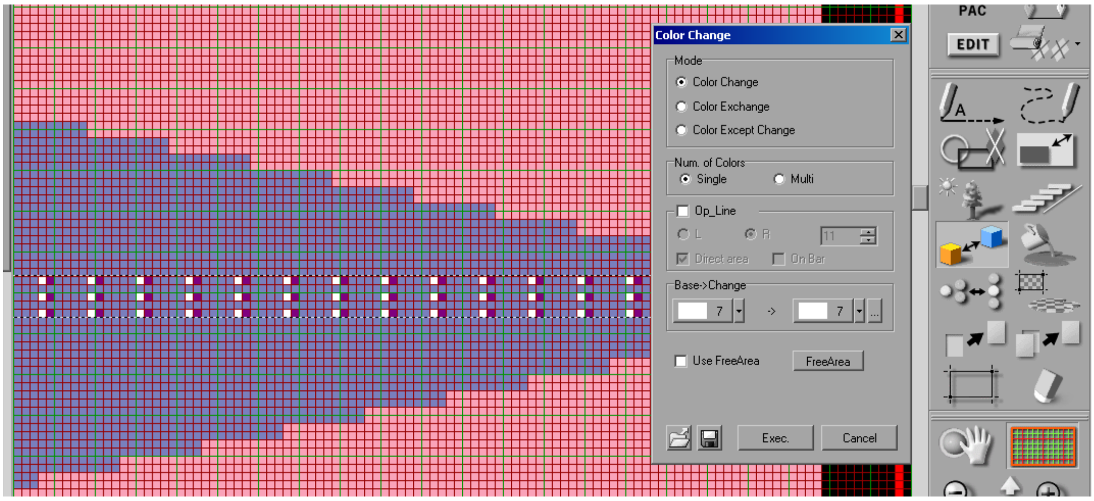
Shima number 50 = Back knit + transfer (brown)



- Back stitch structures can be created in the same way as the front was
- OR to make sure that the FRONT and BACK are the same
- Use AREA – COPY for whole of FRONT
- Surround AREA where there are stitch structures or shape on FRONT
- COPY – REMOVE
- Take copy to BACK compressed image and line up with bottom of image
- STICK

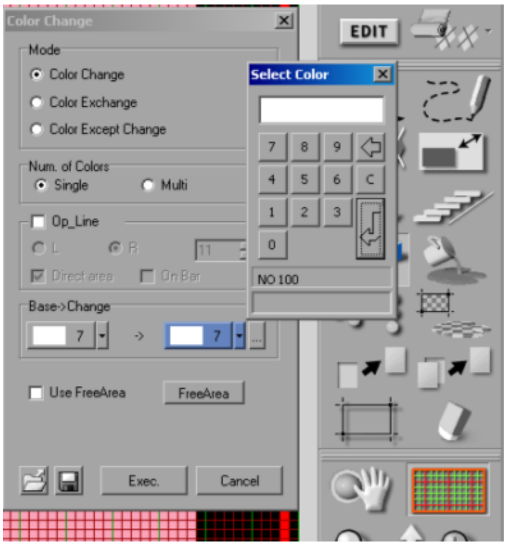
The stitch structures are now in the right place on BACK but with the FRONT colours

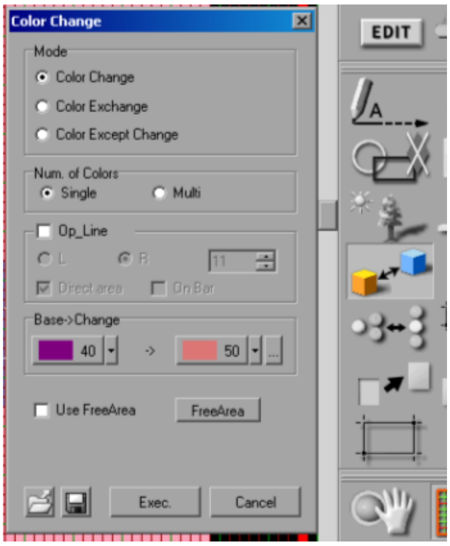
- Click on COLOUR CHANGE box on right hand side of screen
- A COLOUR CHANGE dialogue box will open



- Enter BASE colour to change e.g. 7 in first number box
- Enter Colour required e.g. 9 in second number box
- Click EXECUTE

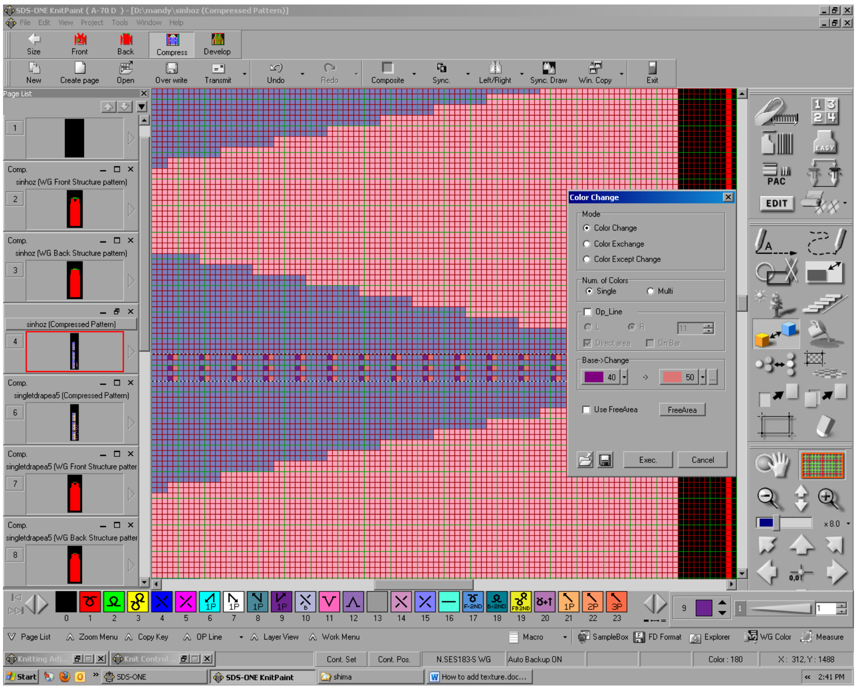
- Repeat for next colour to change



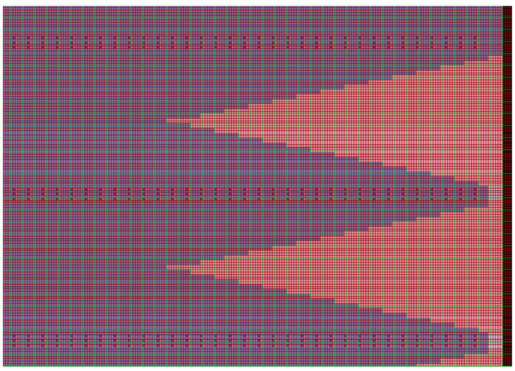


- Enter BASE colour to change e.g. 40 in first number box

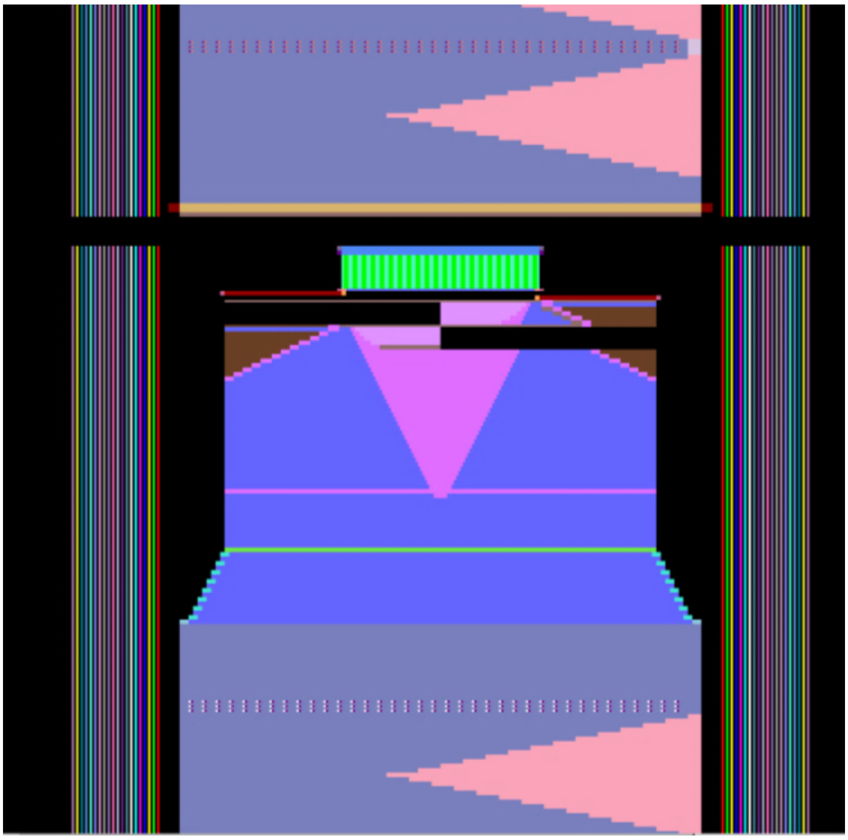
- Enter Colour required e.g. 50 in second number box
- Click EXECUTE



All FRONT colours will have changed to appropriate BACK colours all over structure



- Shima colour 7 has become 9
- Shima colour 40 has become 50



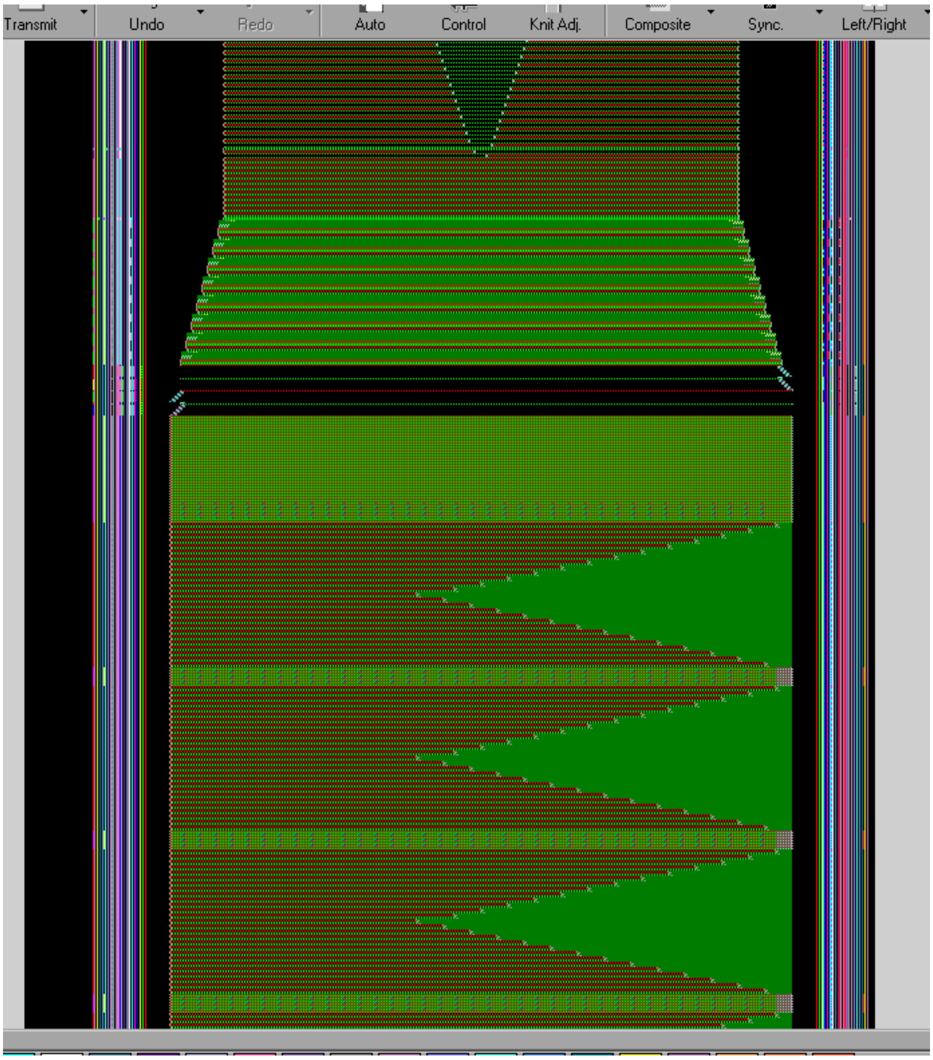
Above image shows FRONT and BACK compressed garment image with stitch structures applied

Compressed garment is now ready to process into Registered garment for knitting

- Process using PAC button as before
- IF using SHIMA colours – software recognizes instructions
- IF garment has ADDED PACs for shape and these have been processed when developing this garment – ADDITIONAL PACS have already been registered

SO:

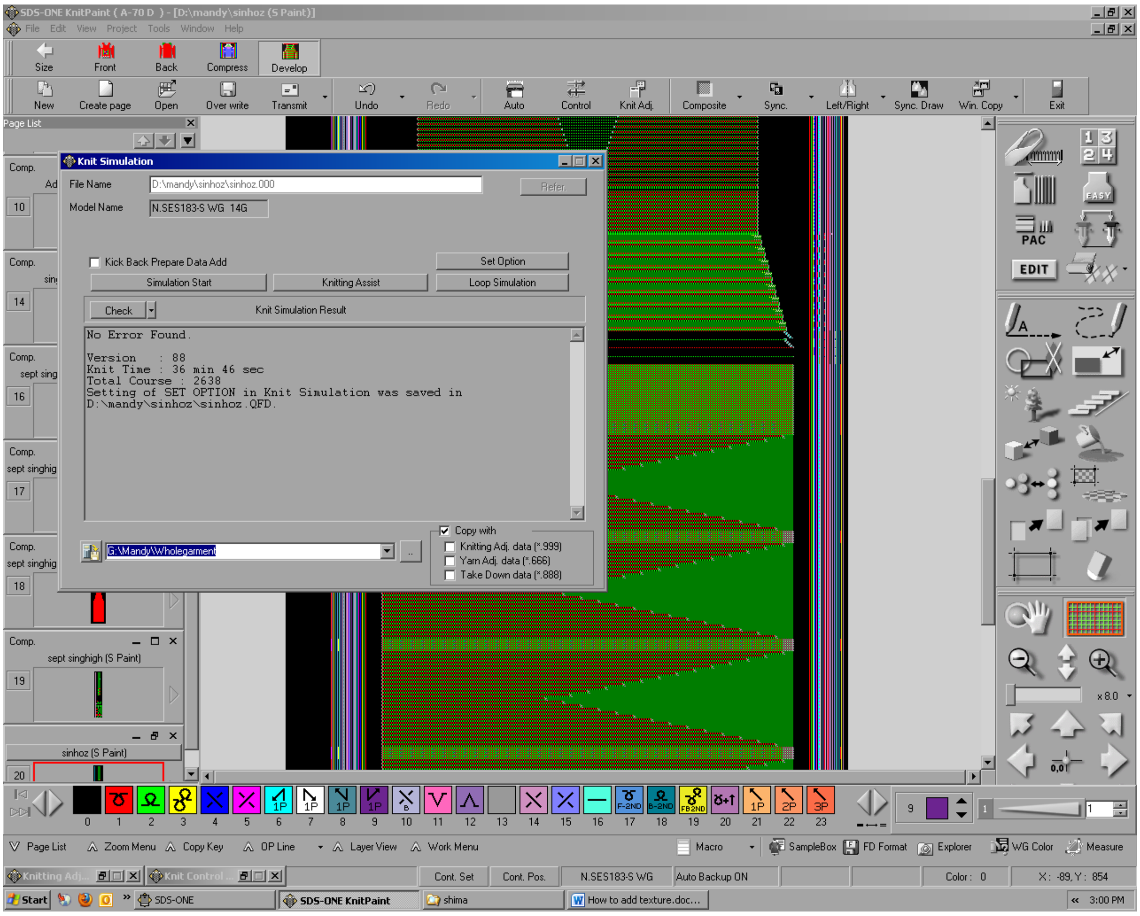
- Click PAC
- Click PACKAGE DEVELOPMENT
- EXECUTE
- A registered, processed garment (green) will open with shape and stitch structures evident



- Check garment is OK to KNIT
- Use AUTO check

If AUTO check and KNIT SIMULATION check – reads – No Error Found

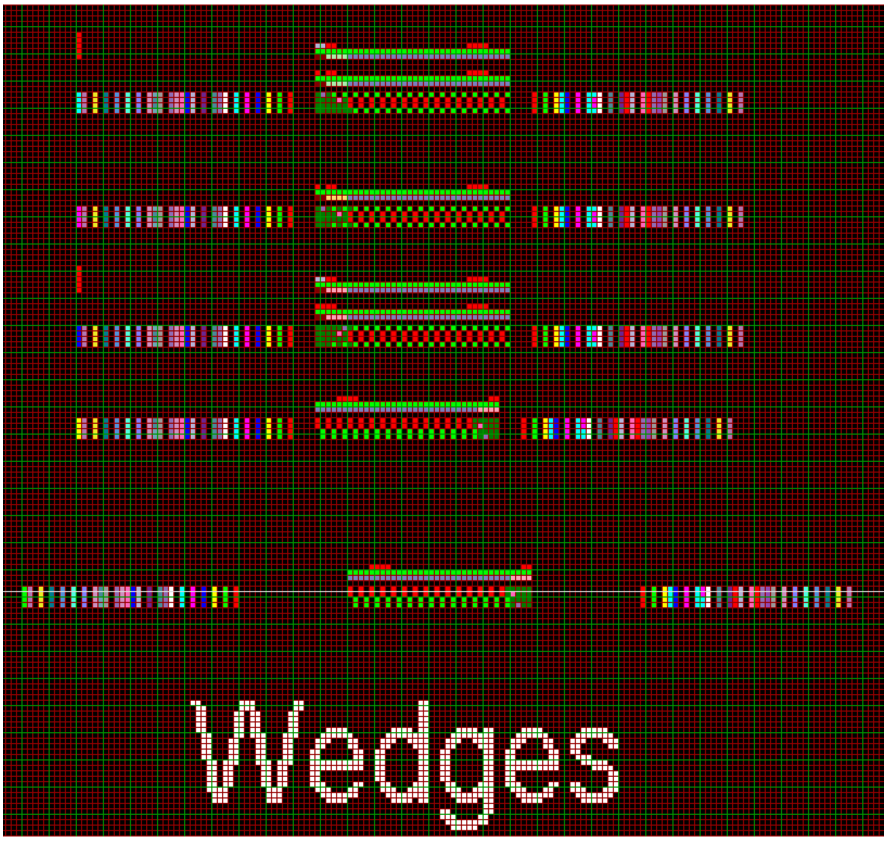
Garment is ready to knit



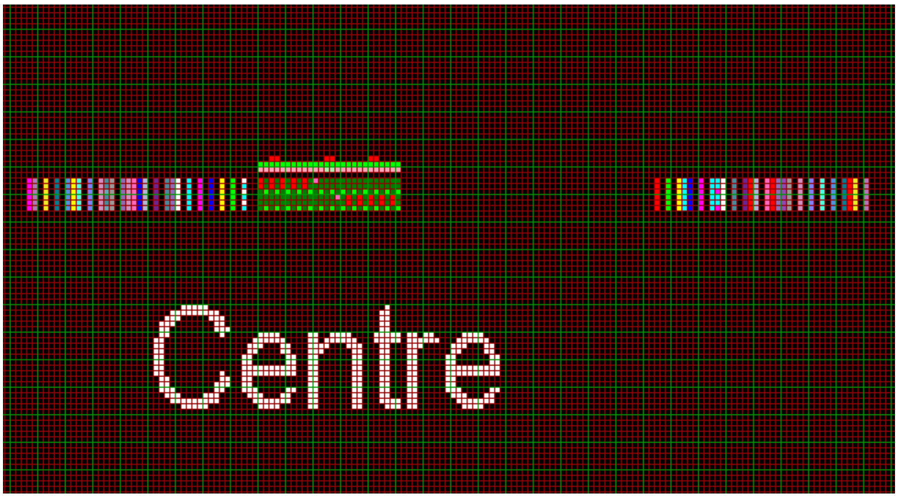
Appendix E

ADDITIONAL PACKAGES

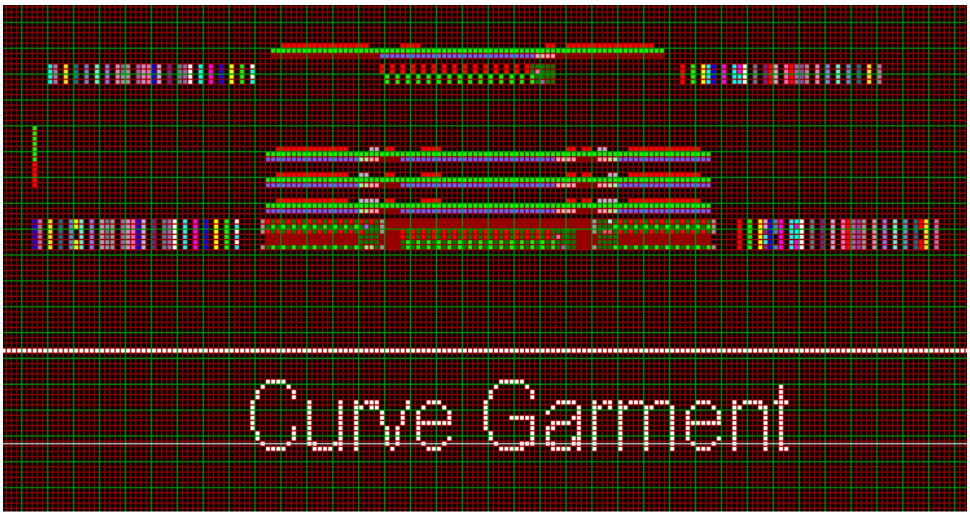
ALL additional packages were created by Gordon Fraser, the knitwear technician at the Textile and Design Laboratory (TDL), AUT University.



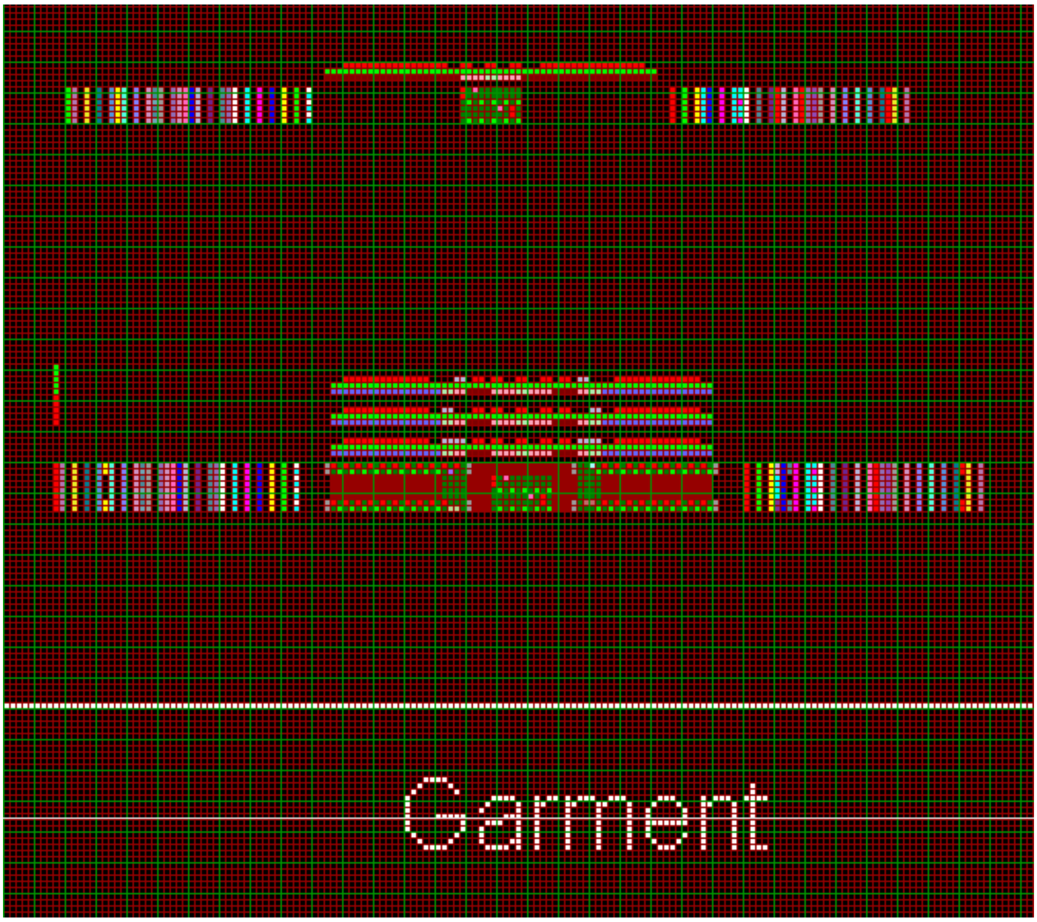
1. WEDGES – Packages for use on sides of Tunic Garment



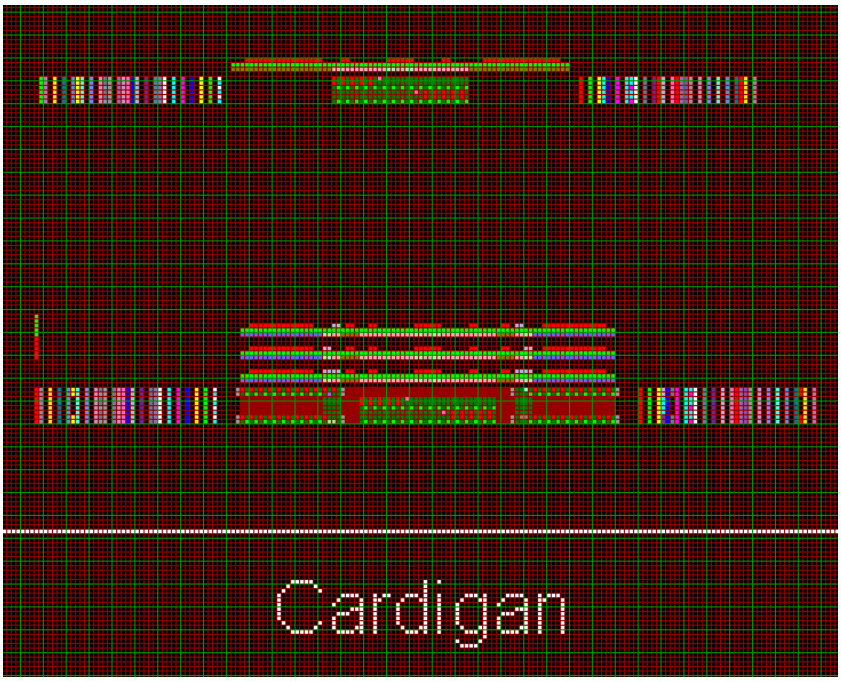
2. CENTRE – Package used for central diamond on Front Tunic Garment



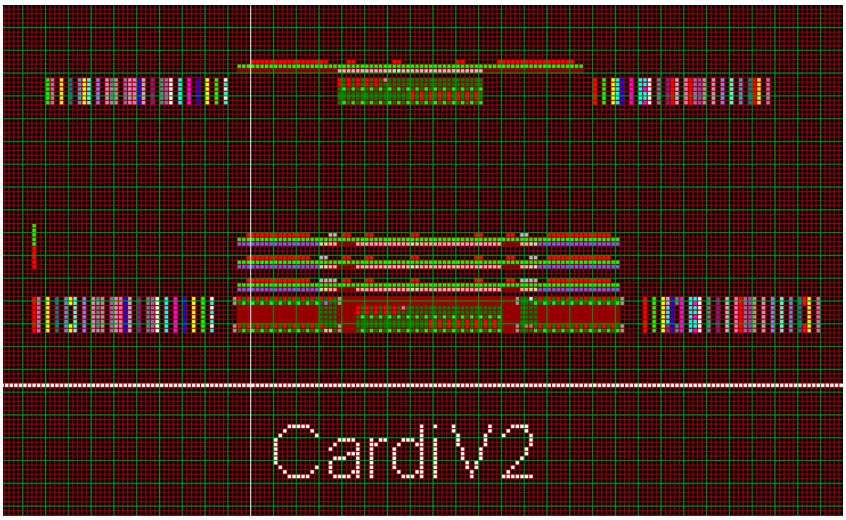
3. WEDGE Packages used on sides of sweater



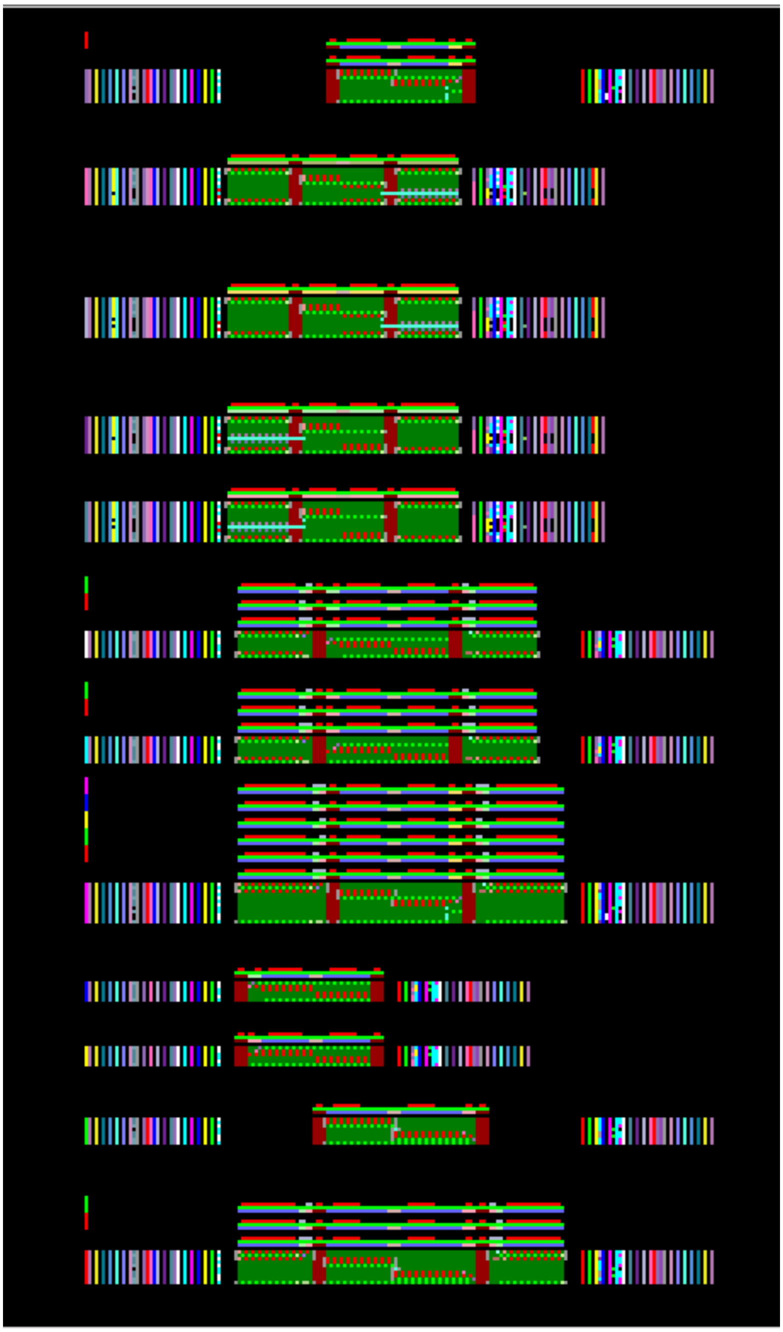
4. DIAMOND Packages used centrally on sweater



5. DIAMOND Packages used centrally on Cardigan



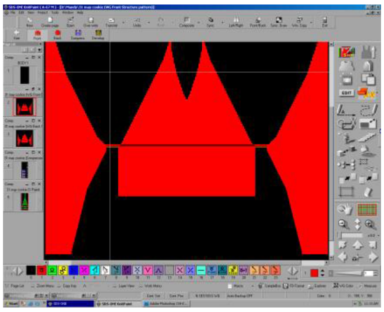
6. WEDGE Packages used on sides of Cardigan



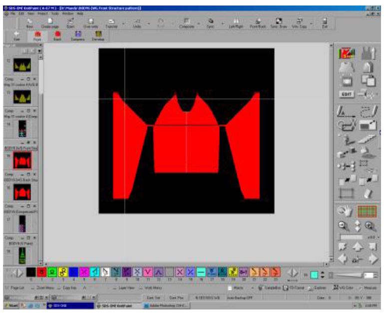
7. Image of All Twelve Additional Packages created for this study

Appendix F

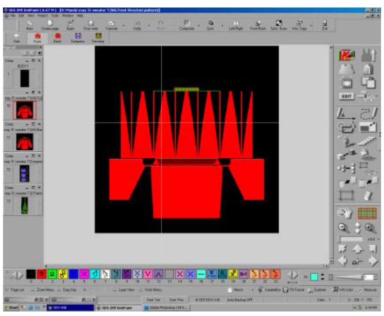
THE KEY GARMENTS PROGRAMMED FOR THIS STUDY

Ref: Figures 38, 39, 76 and 79

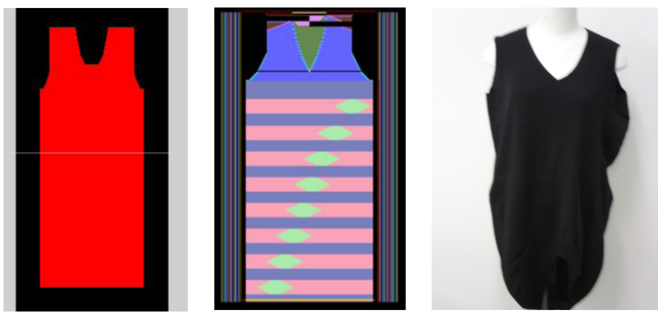
Ref: Figures 39, 77 and 78

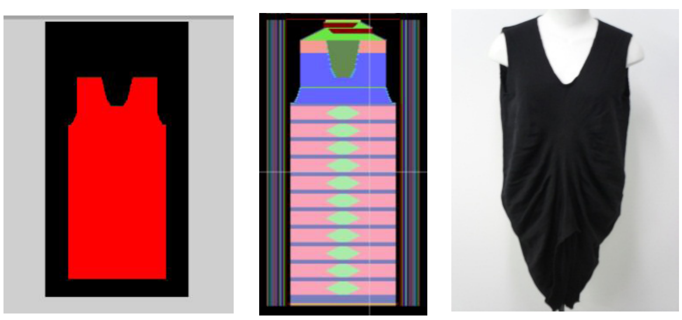
Ref: Page 152 This garment uses the full width of the needle bed

Pre-Installed Shima Seiki Shapes with Added Pacs:

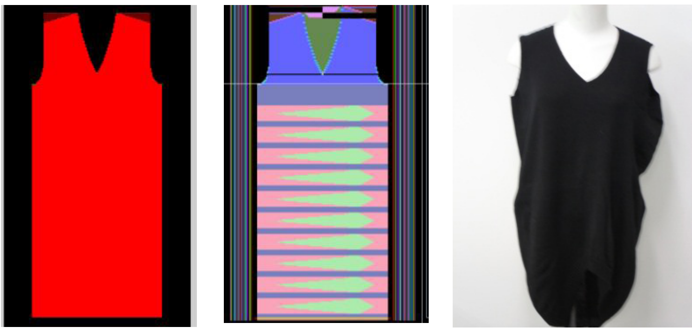
Ref: Figures 45, 46, 87, 89, 114



Ref: Figures 45, 46, 87, 124

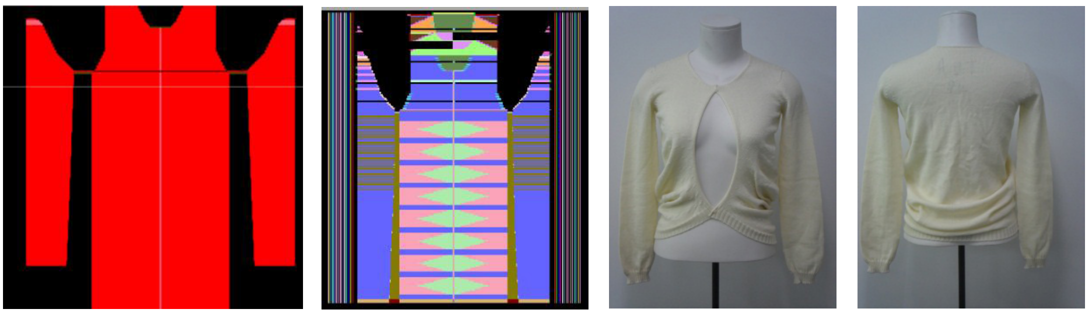


Ref: Figures 45, 46 and 87

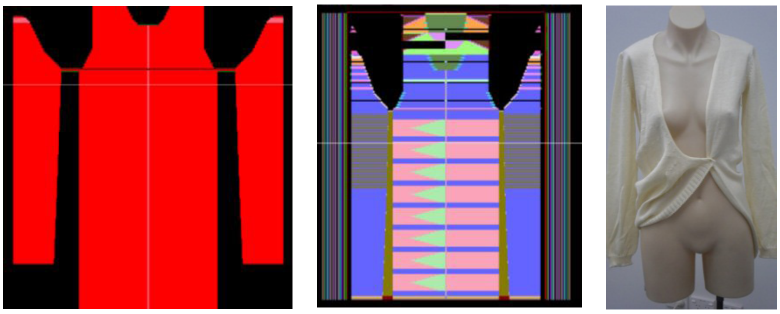


Ref: Figures 45, 46, 87 and 88

Ref: Figures 48, 92, 120, 121, 123, 124

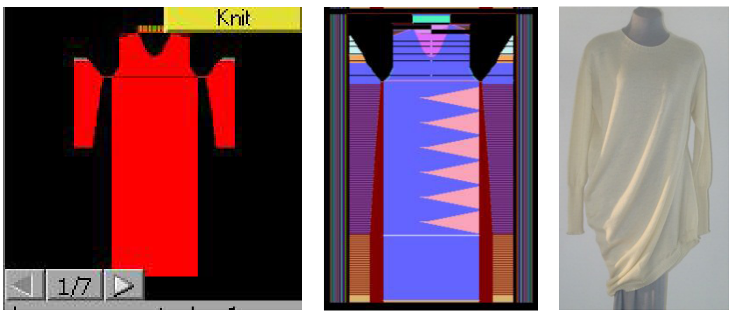


Ref: Figures 48, 54, 55, 56, 93, 109, 110

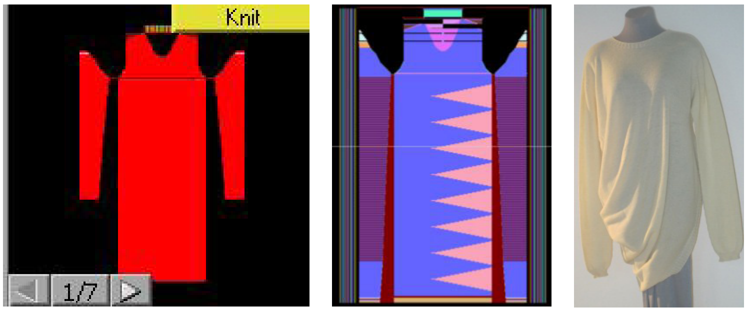


Ref: Figure 94, 54, 55, 109, 110

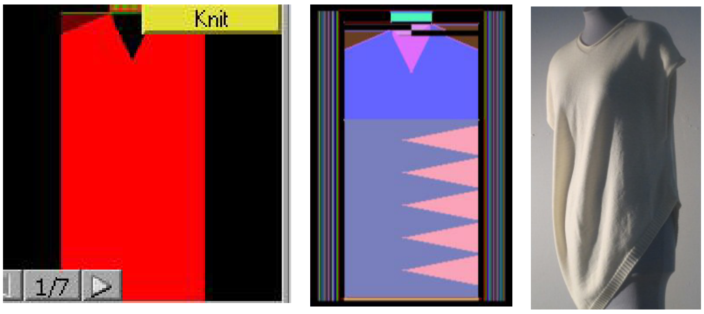
Ref: Figure 64, 91, 120, 121



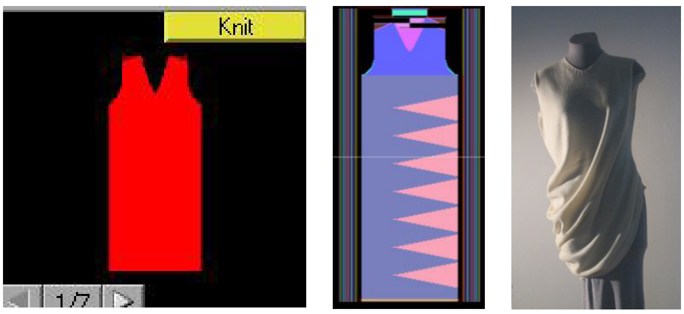
Ref: Figures 49, 50, 56, 95, 100, 107



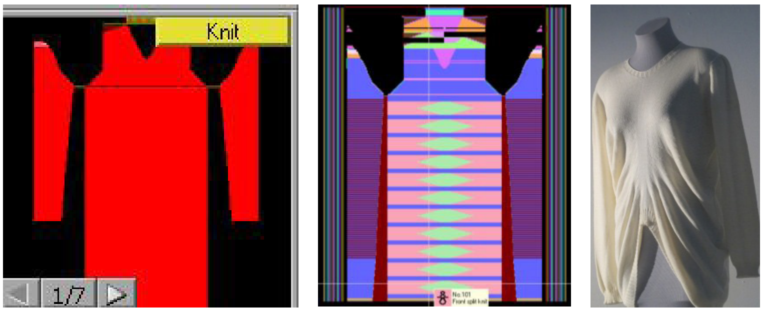
Ref: Figures 49, 50, 51, 56, 57, 107, 129



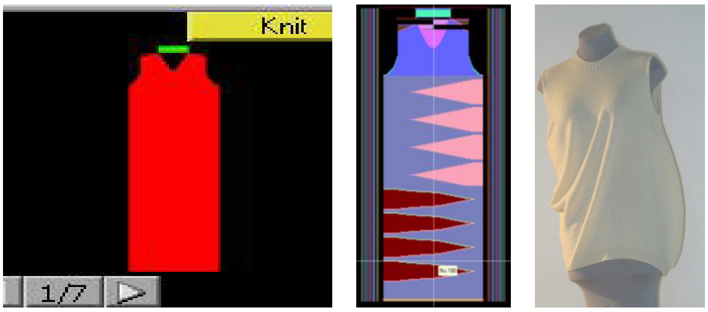
Ref: Figure 56, 113, 114



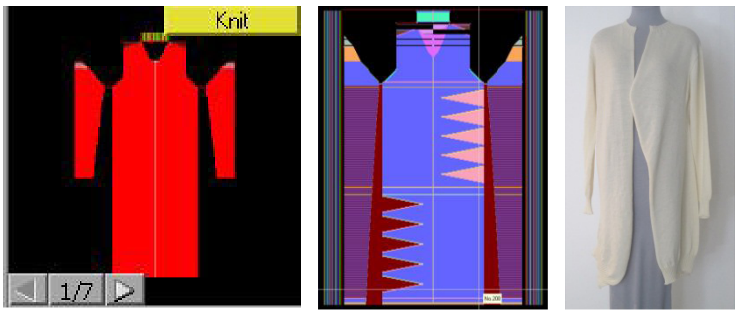
Ref: Figure 56, 57, 95, 98, 113, 114, 129



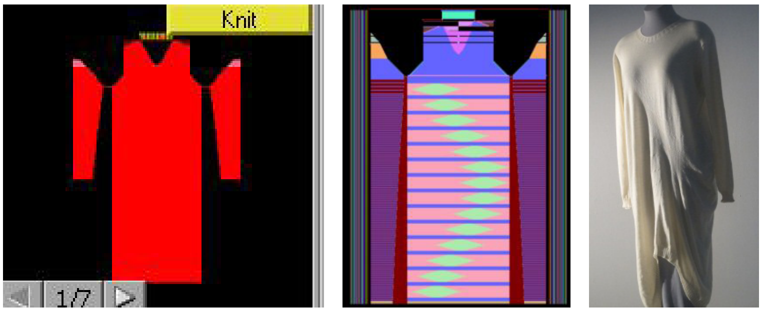
Ref: Figures 52, 53, 95, 97, 120, 121, 123, 124



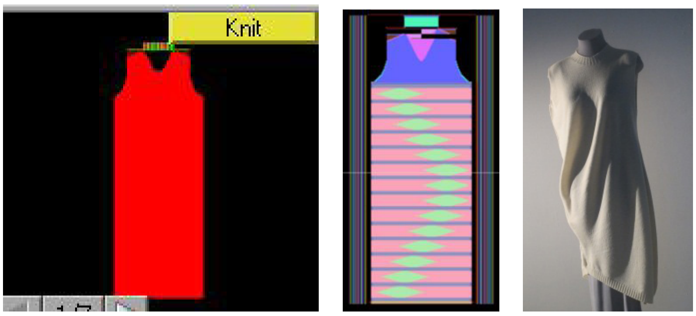
Ref: Figures 56, 57, 95, 99, 117, 118



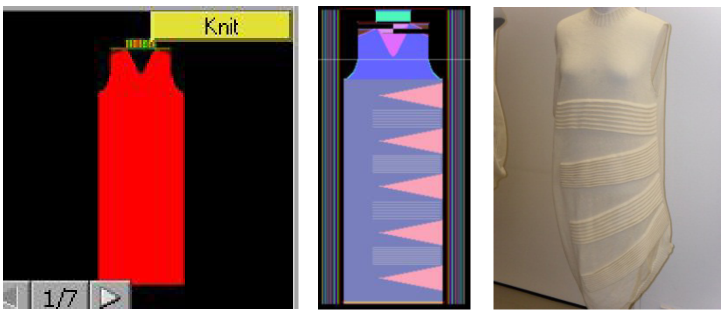
Ref: Figures 56, 95, 96, 111



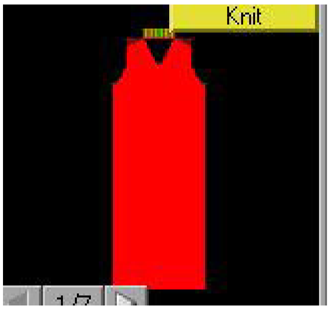
Ref: Figures 52, 53, 123, 125

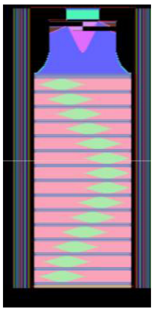


Ref: Figures 56, 57, 101, 117, 118

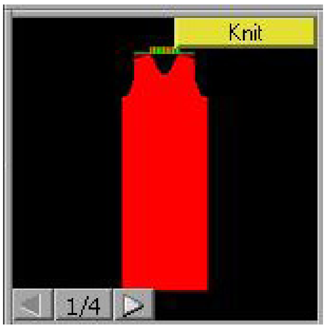


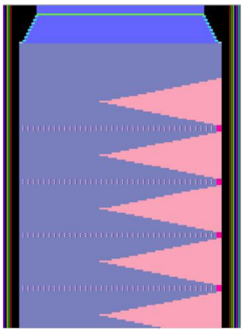
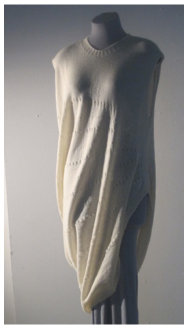
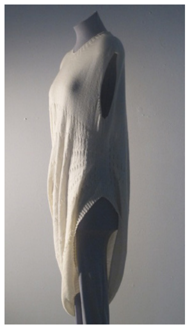
Ref: Figures 59, 102, 103



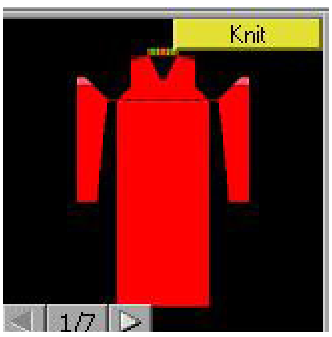



Ref: Figures 59, 102, 103, 123, 125

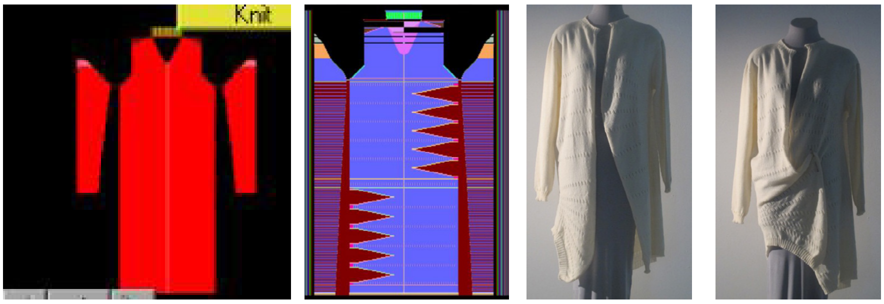


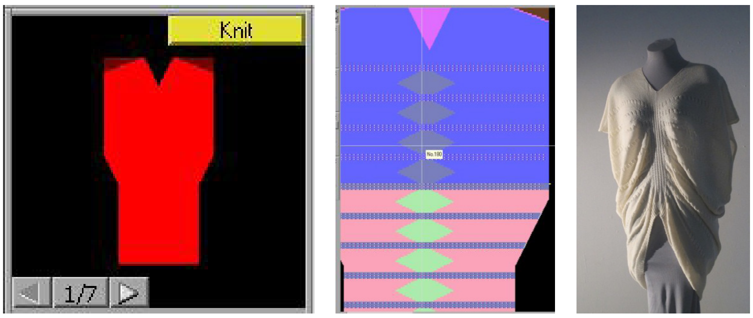
Ref: Figures 104, 105, 106, 113, 115, 120, 122, 126



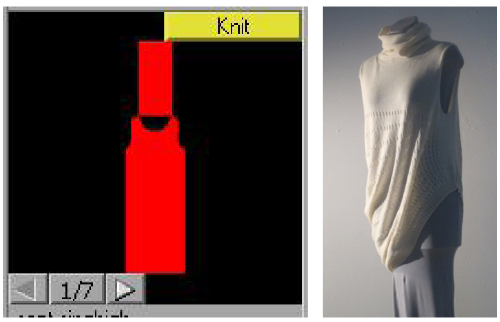
Ref: Figures: 61, 66, 123, 126



Ref: Figures 109, 111



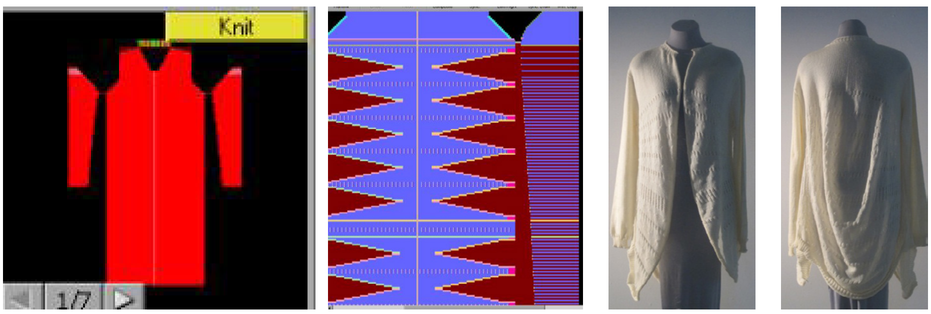
Ref: Figures 65, 120, 122, 129



Ref: Figures 61, 66 113, 115, 129

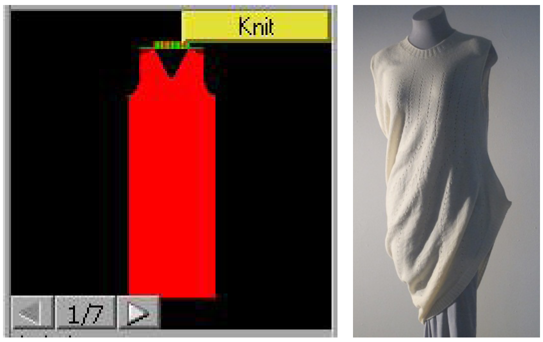
Ref: Figures 60, 66, 108, 129

Ref: Figures 62, 66, 117, 118

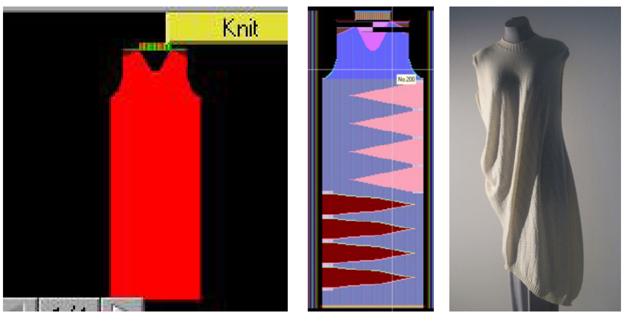


Ref: Figures 66, 109, 112,130, 131

Ref: Figures 113, 116



Ref: Figures 62, 66, 113, 116, 132



Ref: Figures 61, 62, 66, 117, 119

Appendix G

Digital film of: Seamless Knitwear: *Singularities in design*

The final garments produced through this study were digitally filmed in motion. This was part of this PhD. thesis exhibition of Seamless Knitwear: Singularities in design, held at Gallery 3, St Paul St Gallery, 39 Symonds St. Auckland, New Zealand, on 8th- 11th April, 2013.

Seamless Knitwear: Singularities in Design. Filmed by: Denton, A., Jackson, M. (2013). Modelled by: Tasker-Poland, H. (2013).