Jyoti Kalyanji and Frances Joseph

Machine-Crafted: Investigating form and aesthetics in the seamless knit environment as a sustainable textile design practice

Abstract

The introduction of electronic, seamless knit technology in the mid 1990s enabled a new mode of industrial textile production. Shaped three-dimensional knitted forms could be produced entirely by machine. While widely adopted by garment manufacturers for economic efficiencies, the design capability of this advanced machinery and its potential for more innovative and sustainable textile design and production practices has remained largely unexplored.

This unrealised potential is highlighted in a small, emerging body of literature which has begun to identify factors limiting design exploration. The complexity of the machinery and its interface, designed to reflect the specialised designer/technician roles found in industrial knit production systems, is recognised as constraining access to the technology's design capability. While cost initially limited this technology to commercial sites of production, more recently access and expertise to support education, experimentation and research into seamless knit design and applications has become available through centres like the Auckland University of Technology's Textile and Design Laboratory (TDL). This has allowed students, designers and researchers to develop a more hands-on approach, gaining a deeper understanding of the technology beyond the norms of design for mass production inherent to the available design software, to explore original, value-adding, sustainable, design opportunities

This paper reports on practice-led research focused on the integration of seamless knit technology into a small-scale textile design practice. The exploration focused on developing a practitioner's comprehension of the seamless knitting environment and on the acquisition of both design and technical skills. Immersion in a domain more commonly associated with a 'knit technician' allowed the capability of the technology to be better understood before being explored through a designerly, creative process, an approach akin to that of a digital craftsman. Along with developments in online manufacturing capability, the technology presents opportunities for more localised and customised design production, waste reduction and higher product value. Further, in the use of woollen yarn, a natural, renewable and biodegradable fibre that is produced locally is embodied in the design process.

The research resulted in a series of seamlessly knitted home interior product prototypes including soft furniture, couch squab covers, double ended chair covers, and cushion covers. The prototypes are composed of a complex assembly of three-dimensional constructs such as corners, shaping, closings and layers translated via two-dimensional knit diagrams. Extensive experimentation with stitch structures within the seamless environment allowed visual elements important to the on-going development of a South Pacific design aesthetic to be retained. This aesthetic has been applied through varying stitch combinations throughout the form, resulting in pieces that exhibit blended compositions of hue and texture within the fabric, producing a lasting appeal.

Establishing a deep knowledge of this advanced digital technology has allowed for innovative three-dimensional forms while maintaining the warmth and softness inherent in woollen knitted textiles in meaningful products that invite user interaction. As such, this research showcases possibilities for high-value, distinctive aesthetic expression through considered materials and process choices in machine-crafted knitted production.

The introduction of electronic, seamless knit technology in the mid 1990s enabled a new mode of industrial textile production. Shaped three-dimensional knitted forms could be produced entirely by machine. While widely adopted by garment manufacturers for economic efficiencies, the design capability of this advanced machinery and its potential for more innovative and sustainable textile design and production practices has remained largely unexplored. This paper argues that the understanding of three-dimensionality, distinct from the traditional two-dimensional to three-dimensional knit design approach, is key to innovation. Alongside this, a deeper technical knowledge of the seamless knitting environment and its interface, gained through a more hands on, designer/maker approach, will allow designers to envision and access these opportunities.

This paper addresses these issues through a detailed case study based on a one year research project concerned with developing a designer's understanding of the seamless knit environment with the aim of better integration so that the creative capability of seamless knit technology could be exploited in innovative, three-dimensional knitted forms. This inquiry led to the researcher being deeply embedded in the world of the knit technician, requiring a greater investment of time through cycles of discovery that unearthed new methods, outputs and areas for exploration.

Knitted textile design and production

Though industrial textile production has outgrown the craft discipline it originated from, the elementary skills and foundation of these practices are still relevant to the contemporary designer (Gale and Kaur 2002). Knitting techniques, whether by hand or machine, are still commonly learnt through verbal instruction. There are many tacit aspects to knitting, such as fabric handle and tension, which are difficult to articulate and best learnt experientially. Both learners and researchers also benefit from a wealth of printed resources due to knitting's survival as a domestic practice.

In both hand and machine production, the design of knitted textiles is considered a complex process. As a constructed textile,[1] visual and textural elements emerge from its fabrication, with designers synthesising knowledge of technical construction elements, such as stitches, tensions and yarn properties, along with creative design skills. Further, knit design often involves designing the construction of the fabric and the form of the end product in parallel – a process that requires simultaneous consideration of aesthetic, functional, two-dimensional and three-dimensional characteristics (Glazzard 2012; Challis et al. 2006).

Traditionally knitted clothing and products have been created through manipulation of two-dimensional fabric into three-dimensional forms. This manipulation may include actions such as folding, cutting, sewing and bonding; essentially the piecing together of a flat fabric into a three-dimensional shape relating to the body or product form. Previously, there were two common methods for construction of three-dimensional garment forms. In the first, 'cut, make and trim' the front, back, sleeves and trims for a garment are cut from lengths of knitted fabric using flat-pattern making techniques and are then linked or sewn together.

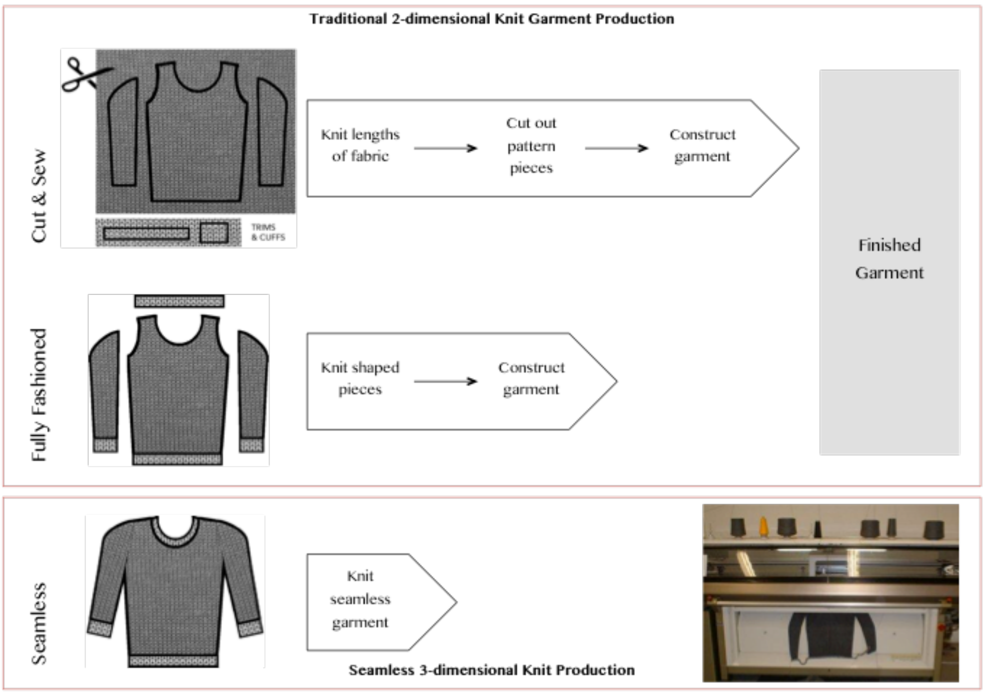

Figure 1. Kalyanji, J. (2013). Knitted textile garment production.

This method is labour-intensive, with numerous steps in the construction phase and considerable fabric waste. The second method, 'shaped' or 'fully-fashioned' knitwear design, involves knitting garment panels to the exact pattern shape required and then linking them together. This approach produces less waste, but often requires more time and technical skill in the programming and production of the shaped pieces. With both these methods, the seams produced when joining the various knitted pieces together add weight to the garment and affect their stretch, drape and comfort.

Seamless knitting technology

The introduction of computerised seamless knitting technology in the mid-1990s enabled a new mode of production. Using a tubular knitting technique, shaped, seamless, three-dimensional forms could be produced direct from the machine with minimal finishing required. Under development for over 40 years,[2] the advanced capability of this knitting technology results in one of the most sophisticated computer-controlled textile production processes used in high fashion (Black 2002). It offers a new platform able to produce ready-to-wear clothing with little or no post-production make up necessary, in the form of seamless knitwear. With few or no seams, the garments produced generate no fabric waste and are lighter, more flexible and more comfortable than seamed garments. Further, labour costs of traditional knitwear construction are reduced or eliminated, offering considerable savings to the knitwear manufacturer. This aspect is key in allowing local manufacturers to compete against low-cost, offshore production.

Seamless knit technology comes to the market via two leading manufacturers[3] and is being adopted by garment producers globally for its economic efficiencies. However, the standardised way in which this advanced machinery is used has generally reduced the degree of design sophistication in the products being produced. Despite the opportunity this technology offers for form and shape innovation its potential has remained largely unexplored, primarily due to complexities associated with its use and the subsequent difficulty designers and manufacturers face in understanding and integrating this complexity into their practices (Hunter 2004a; Black 2002; Challis et al. 2006).

The current constraints of seamless technology are not fixed. Traditional craft and design practices have often been disrupted by the emergence of new technologies. In other areas, new digital design and manufacturing technologies have led to radical shifts, disrupting what were previously highly specialised, mass production and distribution systems. Strategies such as customisation, participatory design and on-demand production, evident in areas such as digital textile design and printing, are challenging older production methods, economies of scale and their associated environmental impacts (Joseph, Fraser and Cie 2010). Maker movements and open knowledge systems are giving designers, artists and hobbyists access to new design and productions systems that are no longer reliant on technical specialists and industrial scales of production. Associated with these developments are new aesthetic and conceptual possibilities that are being explored through deeper understanding and experience gained in the craft or skills of designing and making with such technologies.

However, with seamless knit technology, the development of proprietary knit systems for commercial garment manufacturers has driven a focus on the time and labour saved in standardised production rather than enabling design innovation. Similarly, industry's adoption of the technology for cost reductions in high volume garment production has restricted user access for research, development and innovation. The limited research that has been conducted is largely technically focused on aspects such as quality and comfort.

Design in the seamless knitting environment

This paper reports on an alternative approach to the use of seamless knit technology, focusing on those aspects that have a significant impact on the knitted textile designer's ability to access the creative capability of the technology.

The existing divide between knitted textile designers and technicians is exacerbated in the WHOLEGARMENT™ environment. Though this is a radically new technology its software structure echoes the old industrial roles of knit designer and knit technician. A lack of shared knowledge or common language between these roles leads to ambiguity in ideas and instruction when translating design into production. In the commercial environment, a designer's limited time and inability to problem solve often results in technicians resolving discrepancies, which can leave a designer's intentions unrealised and subsequently contributes to standardised outputs from the technology. This communication gap was observed throughout this research, where continued correction and confirmation was required in communication between the textile lab's technician and external clients (both students and industry).

Occasionally, the client would develop the product alongside the technician, and this generally produced a more favourable result, but it became obvious that a shared understanding of the seamless environment would be beneficial in achieving an innovative, design-focused product. There have been varied suggestions to remedy this situation, ranging from intelligent design support systems (Eckert 1999) and increased technical learning in academic institutions (Challis 2006) to changing or merging the traditional technician/designer roles in industry (Yang 2010). Generally these solutions share an expectation that a designer's increased technical knowledge as well as a common language between a designer and technician lead to improved design outcomes. This expectation is central to the approach adopted for this research. Acquiring technical knowledge was a key part of the research practice, and is considered to impact directly on a designer's ability to realise expressive design outcomes. This shift in a designer's skillset has been seen across the design discipline as practitioners seek to take advantage of the continued onset of advanced technologies (Kettley 2012).

Shima Seiki's WHOLEGARMENT™ user interface is built around established approaches to knit design and production, remaining entrenched within traditional industrial models. Eckert (1999: 6) notes that the software has proved restrictive for designers and that, 'Despite marketing claims to the contrary, these CAD systems are mainly built for knitwear technicians to program the knitting machines, rather than as design tools for designers. Using these systems requires considerable understanding of the technicalities of knitwear design.'

The specialised nature of this software, expensive licensing restrictions and limited learning resources make it difficult for designers to attain the experience and knowledge required to effectively use the design interface. Shima Seiki acknowledge this complexity with continued revisions to simplify the interface and improvements to their help menus and user guides. However, a trade-off of a simpler, automated user system is an increasingly inflexible and modular garment set-up that, in turn, restricts access to the technology's vast design capability.

Though the technology itself, accessible through the technician interface, has enormous potential to be used for new spatial, structural and textural configurations, its design interface is based on pattern libraries of standardised garment shapes and uses traditional two-dimensional cut-and-sew visualisation of front, back and sleeves. It follows a scripted design process of swatch, stitch structure and colour-way development added onto these flat, two-dimensional silhouettes. Newer features, such as three-dimensional simulations, show stitch movements and knitting techniques and can also visualise the final product. These simulations are effective as learning tools, but are insufficient for showing drape, volume and texture in a form useful for design decisions.

There is significant potential to extend beyond these software limitations to explore and develop radically new three-dimensional garment shapes, product applications, textile aesthetics and systems of production. In this paper we argue that, pending future software redesign, this innovative potential can be explored by knit designers taking a more craftsman-like approach, engaging with both the technical and design dimensions of the technology and distributing this knowledge to enable further innovation, accessibility and change.

As with many new technologies, initial use of seamless knitting merely replicated basic knitwear forms and constructions (Black 2002). Philosophers of technology refer to this pattern, whereby new technology is initially recognised for the ways in which it can imitate or perform the familiar functions of established technologies, before eventually gaining recognition for their new and unique capabilities (Baron 1999). In the case of seamless knit technology, this 'diffusion of innovation' (Rogers 1962) is in its infancy.

In addition to seamless capability, WholeGarment™ technology also offers new scope in its ability to shape three-dimensional forms – which may or may not be seamfree. Recently, both researchers and practitioners have started to explore the three-dimensional aspect of the technology and the design possibilities this allows. Challis et al. (2006: 41) note that seamless technology 'forces a conceptual shift in the way knitted garments are designed and created', requiring an understanding of three-dimensional design concepts. Research in this area has taken varied approaches: some have explored new design processes, recognising that the traditional flat fabric panels devised for seamed construction are no longer a necessity, while others focus on achieving variation in form through stitch structures, volume or design features (Yang 2010; Evans-Mikellis 2011). The most inventive and accomplished three-dimensional work in garment form is often created for exhibition, or through collaborations reflecting the expert technical knowledge needed to realise such innovation. For example, Shima Seiki have provided extensive technical support for selected international designers such as Yoshiki Hishinuma to showcase the strengths of the technology for the high-end fashion sector. More recently, Kotoba has been established in the US as a knit collective promoting Shima Seiki Wholegarment™ technology in local design and production of high-end garments.

Examples of non-garment three-dimensional applications are rare and often limited to one-off, customised designs or art-based works. It is significant that much of this work is in single colour, plain stitch fabrics. The tubular knitting technique for creating shape and three-dimensional forms has proven particularly restrictive with regards to the design of the textile itself (i.e. fabric colour, pattern and texture). However, Dr Shima argues that vast patterning possibility does exist, and that this is an area of Wholegarment™ that has not yet been fully explored (Mowbray 2002).

Exploration of the technology's potential has begun to gain momentum in recent years with some sophisticated applications in highly technical or artisanal design outcomes beginning to emerge from textile research centres, often in collaboration with industry. These outcomes are generally underpinned by the expertise of knit technicians, engineers and industry funding. Perhaps the best example is Nike's use of seamless technology in its revolutionary Flyknit running shoe.

The Nike Flyknit shoe (2012) and the newly released Free Flyknit shoe (2013) have used seamless knit technology to rethink sports shoe-making. Nike has developed a light, one-piece knitted upper that not only simplifies construction and minimises waste (by an average of 88%) but provides an extremely comfortable 'barefootlike experience', in part through the minimisation of seams but also through engineering the knitted textile to correspond to different areas of foot pressure and stress. Nike's designers used data from pressure mapping technology to inform the knit structure to zones on the top of the foot to enable areas of natural flex along with tighter stitch structure at the perimeter to stabilise the forefoot and heel. The use of knit has also allowed for the introduction of startling and highly distinctive new colourways. However, the design and technology development took Nike many years (reflected in the current price of these shoes). The complexities of the seamless environment still prove prohibitive for smaller scale, design-driven experimentation and outcomes.

Situating the research

While the investment cost of seamless knit technology initially restricted its use to commercial sites of production, more recently access and expertise to support education and research into seamless knit design and applications has become available through centres like the Textile and Design Laboratory (TDL) at the Auckland University of Technology, where the research reported in this paper took place. The TDL was established in 2006 with funding from the New Zealand government to support capability development and innovation through design and new textile technologies. Investment in digital knit and print technologies, supported by specialist technical and management staff, is accessed by academic researchers, postgraduate students and industry. This has allowed designers and researchers to develop a more hands-on approach, gaining a deeper understanding of the technology beyond the norms of design for mass production inherent in its design software, to explore original, value-adding, sustainable, design opportunities. These industry and educational initiatives have in turn supported internal research capability, reflected in a growing interest in three-dimensional knit shape development for knitwear (Smith 2013) and for homewares (Kalyanji 2013).

This research also references the small-scale knitted textile designer and considers whether computerised seamless knitting technologies could be integrated into a creative, design-focused practice to support innovative and affective outcomes. Such outcomes are not only concerned with expressive and creative product, but also economic feasibility and the sustainability of the designer's practice. Cochrane (2007) acknowledges the limited size and isolation of the Australian and New Zealand domestic markets and suggests that a sustainable practice for small-scale designers and craftsman could result from focusing on a higher-value product, one that can be produced by machine in small batches for a particular discerning customer either locally or internationally. Similarly, Livingstone (2002: 41) proposes that the survival of crafted product in the twenty-first century is reliant on transition to a 'craft' relationship with batch production, and Kettley (2012) notes that a number of small design practices have emerged, bringing 'craft' and new technologies together to appeal to consumer values with a more feasible business model than 'traditional' craft allows.

Such adoption of seamless technology by small-scale knitwear designers is in part demonstrated by their engagement with the TDL. Commonly these designers commission the laboratory to produce small batches of garments; however, these are usually in standardised shapes. Often, their product is differentiated through the use of luxury fibres such as alpaca and possum and is targeted at a tourist market.

Project methodology

Bye (2010) has observed a loss of tacit knowledge and skill in the clothing and textile field resulting from the displacement of traditional apprenticeships. Further, with increasing use of technology, details and nuances of design and production processes are being hidden in CAD systems, along with the opportunity to understand their value and impact. To emphasise the importance of retaining the unique knowledge of this field, Bye (2010) offers a framework for the establishment of a clothing and textile knowledge base. The research from which this paper draws was conducted as a one-year practice-led project for a Master of Art and Design degree and falls within Bye's (2010) conception of 'research through practice', whereby the 'research is initiated based on a problem or question that is derived from practice' and 'practice is the main method of discovery' (Bye 2010: 214). As such, the researcher is directly involved in establishing connections and shaping the research object.

Reflective practice has a significant impact on how far designs are progressed, reinforcing the need for constant engagement across the design and production processes. Initial work produced at the TDL revealed that a compromise often resulted from designs being produced without a strong feedback process between designer and technician. It was difficult for the designer to see the production choices being made or to offer any input, and an early iteration of the product was generally regarded as acceptable. By contrast, maintaining engagement throughout, and gradually developing a more hands-on approach, enabled reflection during design and production and an ability to continuously modify and steer the development of products through many reflective, iterative cycles to develop design outcomes further.

Central to critical reflection is tacit knowledge, an intrinsic part of a designer's practice, linked to their ability as a creator. The extent of tacit knowledge in the knitting process became clear when learning from the technician. Dormer (1994) suggests that learning by instruction, demonstration or written word is limited to what can be articulated. When the technician was unable to articulate an explanation, or the researcher unable to understand the reasoning, the aspect in question was investigated by attempting to design or produce it. In the process of doing this, the researcher would inevitably access the tacit, experiential knowledge that addressed the issue. In the seamless environment, tacit knowledge often relates to the three-dimensional characteristic of knitted forms. With forms being programmed and constructed in a two-dimensional space, it is difficult to explain or understand how the third dimension of the form is produced between two parallel needle beds only millimetres apart.

The research framework

The researcher's design practice was informed by a four-year apprentice-style learning approach. Design skills and knowledge of knitted textile construction had been acquired through the act of making, initially under the guidance of those more skilled and knowledgeable – in this case AUT design lecturers and knit technicians – and later through self-directed practice. Throughout this practice, different types of knitting machinery had been explored, starting with domestic flatbed, then manual V-bed Dubied and Shima Seiki's electronic V-bed and, for this research, Wholegarment™.

Although working with progressively more industrialised and automated technology, a direct relationship with the design and production of the work had developed by exploring the machinery's potential before narrowing the exploration into a textile collection. This engagement is a key aspect of the researcher's practice and places them as a designer-maker within Gale and Kaur's (2002) four categories of textile 'types'.

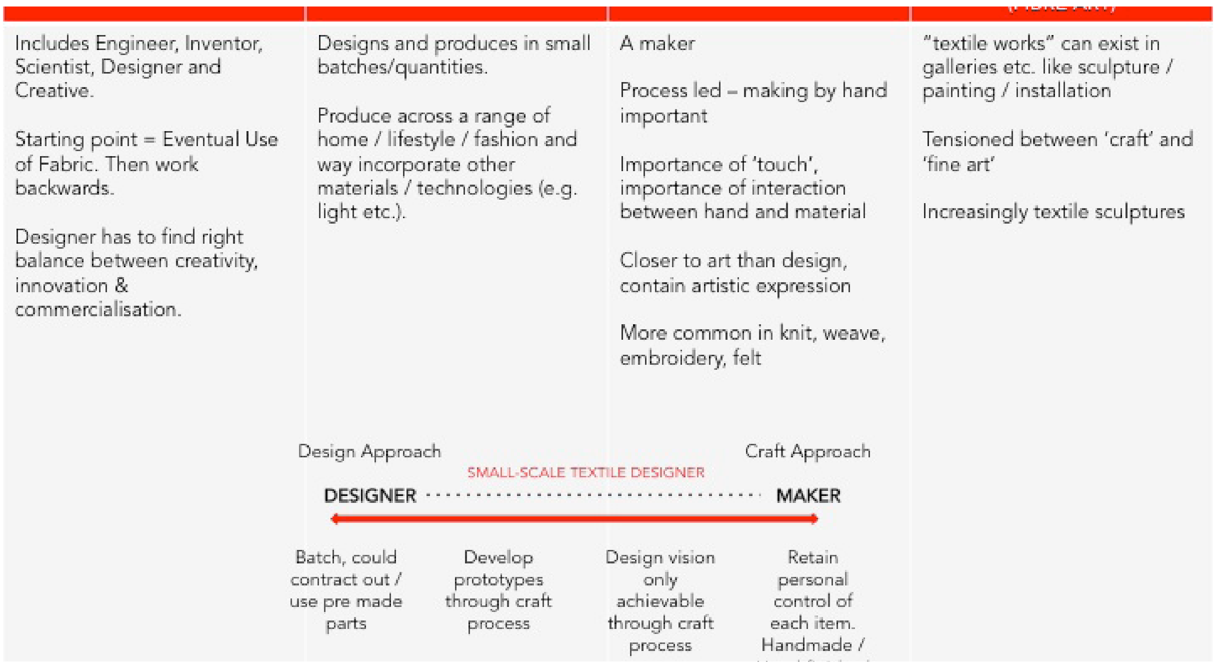

Figure 2. Kalyanji, J. (2013). Four roles of textile design, adapted from Gale and Kaur (2002).

Alongside production knowledge, established aesthetic values that leant towards those of a craftsperson were established. Particular importance was placed on visual and haptic experience, with an intention to produce expressive, unique and engaging fabrics that invite viewer interaction. Further, techniques were adopted that allowed for some variability and, subsequently, a uniqueness in each piece.

The project was focused on developing a practitioner's understanding of the seamless knit environment with the aim to integrate the technology into the researcher's design practice so that the creative capability of seamless knit technology was exploited in innovative, three-dimensional knitted forms. The approach was informed by findings from across the design discipline, where the use of industrial technology and the prevalence of CAD/CAM interfaces has been seen to result in a designer's detachment from design and production processes. A number of issues can result from this detachment, including a loss of exploratory process and an inability to realise original intentions (Kettley 2012; Cochrane 2007; Smith 2013). This detachment can be addressed by approaching technology in a more craftsman-like way, so that its use is accompanied by a deep working knowledge of materials and making processes (Cochrane 2007). It is also suggested that improved understanding of design and production processes enables the designer's hand and associated creativity to be applied more directly throughout the entire process. For this research, the TDL provided a facility where engagement with design and production processes could be supported. Exploration of the technology was focused in three areas: the textile's *surface* design resulting from yarn and stitch composition, the textile's *form* relating to its shaping and volume, and the textile *product* which combines *surface* and *form* to create a seamless, three-dimensional artifact. The project aim was to explore creative capability in each of these areas, with an intended outcome being knitted object prototypes for the home. The choice to focus on non-garment forms for this research encouraged its exploratory aspect. With such forms falling outside the modular garment shapes offered by Shima Seiki's automatic software, learning and the use of the technology were pushed beyond common approaches, requiring a broader exploration of Wholegarment™ capability.

The project focused on innovative and crafted high-end design, aiming to meet Cochrane's suggestion that a sustainable practice is achievable through focusing on higher-value product for a discerning global consumer (Cochrane 2007). Craftsmanship is difficult to define owing to its use in varied contexts, debate surrounding the essence of craft, and subjectivity in assessing craftsmanship. This research recognises that craftsmanship contains authenticity and individuality – aspects often cited as being lost in the transition from handmade to machine. There is a common perception that both the identity and integrity of the maker and the uniqueness of the product are lost in machine production. Niedderer (2009) has recognised that attention and care are needed in producing craft and that 'through this care, which is put into a craft object to achieve its integrity, we encounter something of the maker' (p. 169). This suggestion aligns with Zaccai's notion of 'visionary generalist' and the approach underpinning this project, whereby maintaining a direct relationship with the work during design and production allows care to be applied throughout the entire process. Further, the small-scale batch production possible through this digital knit technology supports product individuality, which can be achieved by varying set-up and production methods. Uniqueness can be introduced through manual interventions to alter set-ups or by actions such as allowing yarns to mix and feed randomly, resulting in natural variations in the textile. Small adjustments can also be made on multiple parameters of the design through the CAD interface, ensuring uniqueness.

The project

Full engagement in design and production processes required a deep understanding of the seamless knit environment. To acquire this understanding, the project first focused on the acquisition of technical knowledge through immersion in a domain that is more commonly associated with a specialised knit technician. This progressed through two paths of replication. The first path involved a repetitive process of working through the Shima Seiki user interface to explore the making of a variety of the three-dimensional garment forms on offer. By repeating the computerised development phase for a single garment, with varied design parameters in each repetition, an understanding of seamless knitting techniques was developed alongside the language describing these techniques and their impact on the shape produced.

The second path involved replication of another practitioner's work. Jenny Underwood's PhD thesis (2009) includes high-level documentation of selected shaping techniques alongside programming directions. Guided by these directions and with assistance from the labs technician, knit programs were written and shapes replicated, assisting the acquisition of basic programming skills. These paths of replication resulted in a small collection of shaped seamless samples, and greater understanding of the environment and medium of seamless knitting.

The process of converting selected samples into large-scale finished products prompted a second phase of experimentation and learning, focused on developing three-dimensional forms and aesthetic expression. Stitch structures and yarn combinations were explored to determine feasible options. Also, these forms required closures. With nothing to replicate, it was necessary to generate knit programs in order to test ideas. This was a time-consuming process involving a great deal of trial and error. Most often, knit programs were tested in production to determine whether they worked as intended. This ability to prototype through iterative development cycles, and the experiential knowledge gained from each cycle, was significant in progressing the project. The knitted forms could not have evolved to the same extent without this direct engagement and growing knowledge base. It is difficult to write effective knit programs without an understanding of such aspects as needle movements and carrier arrangement and it was through this phase of the project that a deeper understanding of the mechanical operation of the machine was gained – essentially relating programming instructions to the physical action of the machine. This also involved exploration of techniques for better understanding these aspects. In some instances, recording needle and stitch positions in a notation similar to that used in hand-flat machines was the most effective means of comprehension.

Forms were initially produced on a small scale. The programming and production of large-scale prototypes generated another area of learning relating to the manual operation of the machine. These large-scale pieces often used the full width of the needle bed and all needles. In this phase settings and mechanical adjustments that could be made at the machine to encourage effective knit production were essential. As such, this phase was more sensitive to the materials being used and understanding the impact of aspects such as the weight of a yarn or the take-down applied during production. These phases combined to a point where procedural knowledge was combined with tacit knowledge and a deeper understanding of the seamless environment. In the earlier stages ideas were derived from what had already been seen. Now ideas could be generated from understanding what was possible. This was highlighted in the development of knitted corners – something that had not previously been explored or even imagined possible.

In synthesising the research findings, the relationship between the designer and the technology was reframed through greater technical understanding of its capability, and of how this capability could be utilised to develop original seamless forms – essentially designing to the creative potential of the technology to produce a series of seamlessly knitted, three-dimensional home interior prototypes. More specifically, exploration in surface design was initially focused on textile designs that would be difficult to produce using other knit technologies. Domestic flatbed knitting allows for considerable versatility in stitch manipulation, and resources for this machinery are often used as inspiration. A pile fabric documented in Lewis and Weissman's (1986) book, *A Machine Knitter's Guide to Creating Fabrics*, was investigated. This is a textural fabric that can be produced on a handflat machine through use of a specific attachment.

Figure 3. Kalyanji, J. (2013) Variations of 'pile' fabric (L) and comparison of non-felted and felted versions (R).

Through experimentation, knitting instructions and the function of the attachment were translated into a Shima Seiki program for application on a tubular form. Although this fabric was technically challenging to produce it added weight to claims that patterning possibilities within seamless existed but have not yet been adequately explored.

The aesthetic of these pieces was influenced by the on-going development of a distinctive 'South Pacific' design aesthetic. Stitch combinations were varied throughout the form and different coloured yarns were used in single row striping, resulting in pieces that exhibit blended compositions of hue and texture within the fabric. Producing pieces with a distinctive and subtle aesthetic that sits outside of trends and seasons and can fit into multiple interior settings has been a key goal of the project; the intention is for the pieces to have lasting appeal, with the quality of product and its distinctive aesthetic creating a strong bond between the artefact and the owner. This will help ensure sustainability. Other surface aspects explored include the fibre composition and treatment. Woollen yarn was preferred both for its properties as a natural, renewable and biodegradable fibre which could be sourced locally and for the warmth, flexibility and softness inherent in woollen knitted stitches. This allowed for the creation of fabric which was inviting to touch – an important factor in producing objects intended for human interaction. Further, a small amount of elastane was included to aid in fabric recovery. Machine felting after production was found to produce a denser, more durable fabric.

Form development was focused around shaping, volume and structured features such as corners and closures. As knowledge and understanding increased it became easier to generate design ideas for which feasibility could be determined prior to programming, though determining effectiveness of the idea would require production. For the most part, shapes and closures paralleled existing patterns from cut and sew production. Significant opportunities with seamless technology were suggested by features that are difficult, or not possible, to produce within traditional, two-dimensional cut-and-sew methods – for example, forms containing curves, volume and tubular joins that could lead to innovative product shaping. These areas are the focus of ongoing research.

Figure 4. Kalyanji, J. (2013). Shaped samples for prototype development.

The shapes for the final product forms evolved from parallel developments in surface and form, with the products intended to showcase a range of features. Essentially, the collection represents a complex assembly of three-dimensional constructs such as corners, widening, narrowing, curves, closures, and layers designed and translated via two-dimensional knit diagrams. The products include soft furniture, couch squab covers, double-ended chair covers, and cushion covers.

Figure 5. Kalyanji, J. (2013) Product prototypes for couch squabs and soft furniture.

Conclusion

Through this project the constraints of design software interface in seamless knit technology were overcome by deeper engagement with its technical interface to realise the aim of developing innovative three-dimensional forms for homewares and furnishings. Yarn and stitch selection and their effect on the visual and tactile aesthetics of the textiles were also important aspects of this project. The forms developed maintain the warmth and softness inherent in woollen knitted textiles in expressive products that invite user interaction. As such, this project demonstrates possibilities for high-value, distinctive aesthetic expression through considered materials and process choices in machine-crafted knitted production. This project highlighted some of the limitations of the technology in terms of software/hardware relationships, as well as identifying some of the fuller potential of knit design and production applications.

In relation to the three specific areas of inquiry – surface, form and product – the following conclusions were reached:

> **Surface**: Perceived constraints on textile design were addressed in the development of a range of textural and patterned fabrics in multiple colours, suggesting room for creative expression exists but has not yet been fully explored. A growing understanding of feasible stitch types in the seamless environment will lead to further exploration resulting in increased variation and expressiveness in the textile design of seamless or shaped product.

> **Form**: Shaping and three-dimensionality were explored through an experiential learning process. Understanding of this area progressed through different stages, moving from procedural knowledge focused on reproduction to an understanding of the environment and ability to self-generate

feasible designs. The practice considered application of shaped knitted forms in soft furniture and homeware. This work has accessed a limited aspect of the technology's shaping potential but has generated numerous ideas for further product development. The greatest potential comes from characteristics such as seamless curves, volume and tubular joins that are not easily constructed through other methods such as 'cut-and-sew'.

Product: The design and production of soft furniture and homewares in this project depended on existing forms or structures. Reuse (of old furniture or of existing forms such as cushions) effectively supported and set parameters for the early development and understanding of three-dimensional shaping. While the products in themselves were not innovative, the surfaces, forms and modes of production were highly original. Realising such products through this technology also recognised a cultural dimension. Kettley (2007: 5) has noted that 'Critical design is an approach that recognises the cultural roles of artefacts beyond their technological function, and in the case of novel computational technologies, there is a need to examine and critique the trend for innovation as an end in itself.' In the future, working collaboratively with skilled designers from other fields such as product and interior design will encourage the shaping potential of the seamless technology to be exploited more fully in developing innovative and meaningful forms.

The approach adopted for this project focused on the acquisition and application of technical knowledge as a method for retaining engagement in design and production processes. Cochrane (2007: 81) suggests successes can evolve from a designer's 'willingness to meet industry half way; to listen to and learn from those particular specialists and to respond to the mutual challenges that emerge as design ideas become objects'. This inquiry led to the researcher being deeply embedded in the world of the knit technician, requiring a greater investment of time through cycles of discovery that unearthed new areas for exploration. Two aspects of significance arise from this.

The first concerns the importance of this knowledge to the designer as designer-maker, with emphasis placed on their ability to realise designs. The tactile and haptic qualities of textiles suggest that the ability to touch and see the textile throughout the design and production process is significant to its development, and that requisite technical knowledge is necessary to retain this engagement.

The second concerns the amount of time invested in the learning process and that for most small-scale textile designers such an exhaustive investment of time would not be viable. Numerous iterations were required in terms of experimental and prototype development – these were vital for understanding software and hardware parameters. However, the sharing of this knowledge would be better supported through refinements in the designer software interface, more formalised teaching and learning pedagogy and better resources – like shape databases – made available in the seamless knit design area. This would require a shift from the closed proprietary model adopted by the technology's manufacturers to a more open, collaborative model.

In conclusion, this research suggests that design and production are heavily linked within the electronic seamless knitting environment and that, with technical understanding, the technology's creative capability can be accessed. While there is a risk that excessive technical concern can restrict creativity as designs are produced to fit within known constraints, realising the vast potential of seamless knit technology will require deeper technical engagement, understanding and knowledge sharing by designer/craftsmen. The understanding of three-dimensionality, distinct from the traditional two-dimension to three-dimension knit design approach, is key to such innovation. Alongside this, it is the technical knowledge of the environment and its interface which will allow designers to envision and access these opportunities.

Notes

1. By way of comparison, textile design processes such as print, dye and embroidery are applied to the surface of a constructed fabric and are categorised as surface design.

2. For an account of the evolution of computerised seamless flatbed knitting technology see Yang (2010: Ch. 3) and Hunter (2004a, 2004b, 2004c). Choi and Powell (2005) provide a detailed description of the seamless knitting process.

3. Computerised seamless garment technology is produced by two manufacturers; Shima Seiki and Stoll GmbH. The technology used in this research is Shima Seiki WHOLEGARMENT™ model N. SES 183-S WG.

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