A DIGITAL-CRAFTING APPROACH TO KNITTED SURFACE TERRAINS

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Abstract

This practice-led research investigates digital-craft creation methods to generate knitted surfaces. This practice utilises traditional woven twill patterns combined with digital inlay knitting technologies. Inlay knitting is a technique originally developed on domestic knitting machines which combines the layering of a knitted stitch and horizontally inlaid yarn. The built surfaces in this research utilise the inherent material properties of knit-purl or links-links stitch structures to disrupt traditional weave-inspired inlay patterning. Subtractive design methods further increase the inlay pattern fragmentation allowing the knitted ground to dominate the surface movements. The inlay yarn navigates pathways which are revealed and concealed amongst the knitted surface folds. This research engages with two-dimensional and three-dimensional making environments where the technology and maker inform a collaborative design approach, each an active participant in the knitted surface aesthetic. Through a series of virtual-physical processes, a mode of making emerges that interprets photographic images of my grandmother's farm in the Coromandel, New Zealand, into a series of knitted panels. The landscape photographs provide a base to build sectional positioning of layered knit design elements. Surface planes disrupt through assemblage of scaled pattern repeats and combinations of different stitch structure material performances. These knitted surfaces utilise a pick-and-mix design approach which blends digital and physical aspects of making, to generate programmed material shifts. Compositional positioning of design components fosters fragmentation of surface patterning. Material agency generates haptic encounters informing tactile knitted surfaces, where physical engagement reveals hidden surface patterning through touch. Knitted surfaces become vehicles to articulate the method of making and knit knowledge as built terrains. This research offers a new approach to knitted surface design and encourages interdisciplinary designer engagement with complex digital knitting technologies.

Introduction

This paper discusses the development of a method of making for knitted surfaces. The research practice uses digital knitting technologies to explore how a structured and controlled surface generation process can be applied to exploit the material agency inherent in links-links and inlay knitting. The research aims through exploitation of these textile creation methods to produce visible and invisible material agency informing knitted surface aesthetics. This practice translates hand to machine knitting techniques and traditional weave patterning opening up possibilities for new designs (Haffenden, 2018). Hybrid crafting (Golsteijn et al., 2014) generates digitally knitted surfaces that look to the past to reinvent the future (Turney, 2009).

Inlay is a knitting technique that involves merging knit and weaving components in one constructive process. In inlay knitting, a horizontal strand of yarn is positioned across selected knitted loops, although never knitted into the stitch. Also known as knit-weaving (Guagliumi, 1996, p. 98), "the secondary weaving yarn laces through the background fabric to create texture." Weave and knit are both textiles constructed in a grid-like formation allowing similar programming approaches to design. However, due to variations within the construction methods, the knitting techniques links-links and inlay exhibit opposing material behaviours. Singular surface points influence neighbouring points and alter surface dynamics. Knitted loops stretch with vertical and horizontal elongation, whereas weft inserted inlay yarn increases surface stability.

The programmed material forces allow the surface to become multiple arrangements of itself. Author Richard Sennett (2008) discusses a material consciousness where the designer allows the material to guide the design. Due to the extreme difference between two-dimensional coded knit structures and their three-dimensional knitted representation, physical prototyping is crucial to realise material behaviours. Bodily experience and tacit knowledge (Dormer, 1997) embed in the knitted surfaces during the making processes. Each knitted surface has an individual persona imbued by interactions between the links-links structures, inlay patterning, materials, technology and practitioner-researcher. Techniques, material forces and knowledge, are layered in virtual coding materialising as patterning disruptions in the physical knit. Through this digital-crafting approach, an alternative mode of making for knitted surface emerged, converting landscape photographs into knitted stitch movements.

Methodology

The overarching methodological framework utilised in this research aligns with action research (Schön, 1983; Swann, 2002) and the sub-category, practice-led research (Gray and Malins, 2004). This research is not a scientific or mathematic investigation of knit; it is a tactile, haptic exploration informed by intuitive design responses. Furthermore, a hybrid crafting (Golsteijn et al., 2014) methodology investigates the dichotomy between craft and technology, combining virtual and physical production methods. The creative process followed three key phases of practice; Generating Surface-building Blocks, A Mode of Making and Building Multiple

Terrains. A series of reflective feedback loops informed subsequent digital-physical knitted surfaces.

The making process emerged as a collaborative performance between the maker, technology and materials (Ingold, 2013; Lawrence, 2018). This practice utilises a digital-crafting or hybrid crafting approach where "both crafting process and result will include both physical and digital elements" (Golsteijn et al., 2014, p. 594). Practice discovered boundaries between virtual and actual, design and technical through crafted design outcomes. As author Peter Dormer (1997, p. 140) notes, "it is craft not as 'handcraft' that defines contemporary craftmanship, it is craft as knowledge that empowers a maker to take charge of technology." The knitting technologies become a design collaborator, combined with the research-practitioners' designerly knowledge influencing the physical outputs (Cross, 2006). Tacit knowledge (Dormer, 1997) acquired through interaction with digital and physical making imparted a deeper understanding of the limitations and potentiality of knitting technologies, techniques and materials (Philpott, 2011).

Positioning the Research

Knitting Techniques

This practice-led research explores surface encounters between two knitting techniques: inlay and links-links using repetition and scale. There is limited research focussed on digitally knitted inlay from a design perspective; instead, the technique is explored predominantly from a medical therapeutic (Bera et al., 2016; Xiong and Tao, 2018) or an engineering perspective (Lee et. al., 2020). Although inlay as a textile technique has historical roots, digital knitting technologies have only recently integrated this construction method. In 2015, Shima Seiki Mfg. Ltd developed a weft insertion knitting machine in response to the growing knitted footwear market. The additional weave aspect of inlay responded directly to the athletic sector's requirements for strategically placing additional support through yarns and stitch structures. The inlay knitting technique allows "for the production of hybrid fabrics that feature knit and weave characteristics, suited to shoe upper applications that require form-fitting function, comfort, flexibility, breathability as well as strength and stiffening" (Shima Seiki Mfg. Ltd. email, Oct 30th 2019). The inlay surface exhibits amalgamated material behaviours inherited from the two textile parents; knit and weave.

The second knitting technique, referred to as links-links, combines front-bed knit and back-bed stitch structures. This practice builds on existing research of links-links in form generation (Philpott, 2011) and auxetic knitted textiles (Glazzard, 2014). Varying the arrangement of links-links knitting produces multiple self-folding knits (Knittel et al., 2015) with multi-directional material forces. Academic Linnéa Nilsson (2015, p. 8) discusses the importance of utilising new technologies to re-evaluate and "to fully realise the potential of both traditional and new textiles." Links-links is not a new stitch structure however this research uses the links-links knitting technique to demonstrate an alternative making approach to knitted surface. The links-links surface movements are positioned to denote land movements linking inspirational imagery to resultant knitted terrains.

Knitted Surface

In digital knitting, the coded terrain enfolds into the surface during the generative-making process. The yarn is a twisting strand that becomes a surface or ground through multiple interconnected single loops. The single stitch loop builds the multiple, generating a surface that is more than the sum of its individual parts (Kolarevic and Klinger, 2013). The term 'ground' is used in knitting to define the built structural base fabrication. Ingold (2013) discusses the ground in comparison to the page on which words are placed, highlighting the line of enquiry around surface value. What if the ground is what is important? Rather than what is under the surface? (Ingold, 2013). This practice views the knitted surface as a critical site of knowledge. The artefacts are "inputs of knowledge production and outputs of knowledge communication" (Nimkulrat, 2013) intended to encourage viewers to see the value of knitted surface.

Knitted textiles present two surfaces: a technical front and technical back. The two surfaces can look the same if the design is programmed symmetrically or illustrate alternative aesthetics if the design is asymmetrical. This research explores surface pattern fragmentations which attend "to textile materials and their entangling into surfaces" (Arantes, 2020a, p. 152). Visible design components meld with invisible material forces through the assemblage of link-links and inlay knitting techniques. In knitted surface "materials have agency. They move and act as if with a life of their own" (Moore, 2022, p. 30). The digital assemblage of codes affords alternative collisional arrangements of physical matter agency (Bolt, 2007). Pattern placements, machine and materials actively affect the pliant knitted matter, informing fragmentation of the knitted surface.

Design Practice

Phase 1. Generating Surface-Building Blocks

This research uses Shima Seiki Mfg. Ltd. digital knitting technology which contains automatic software specifically designed for inlay knit programming. The automatic software consists of separate pages which store coded information for the ground stitch structures, inlay patterning, colour and carrier preferences. The most common usage of inlay is "as an all-over, selvedge to selvedge" (Guagliumi, 1996, p. 100) layout (Figure 1). Initial practice explored the knitting technology in relation to programming constraints and the extension of inlay designs from all-over inlay to intarsia inlay with partial pattern placements (Figure 2). This included the translation of traditional weave patterning from gridded woven instructions into virtual codes.

Figure 1. All-over inlay

Figure 2. Intarsia inlay

In *The Culture of Knitting*, author Joanne Turney states:

> The past is a reference, a sign amongst many others, which is sourced as inspiration but developed rather than copied or reviewed into a new form. Knitting frequently refers to its own history and can therefore be understood as self-reflective. (Turney 2009, p. 61)

This research uses traditional weaves to provide arrangements for the programming of inlay floats and picks. Using weave layouts facilitated the juxtaposed appearance of a woven fabrication embedded in a knitted surface. Initial inlay knitting explored repeating patterns and variations of scale testing visual and haptic effects on knitted surface. Longer floats on a larger scale permitted more surface movement from the links-links material forces; however, as the scale of the inlay patterns increased, connections to woven aesthetics reduced.

Figure 3. Links-links vertical rectangle half-drop repeat in scales 100% to 500%

Additionally, links-links stitch structures explored geometric layouts using block, brick and half-drop repeating pattern layouts. Scaling up and down from the base unit size developed a range of material forces with variable visual and haptic knitted surface effects (Figure 3). On-screen links-links coding is static; however, in physical form interconnected knit and purl stitches shift surface. The links-links stitch combinations resulted in different compressional and tensional material forces. The knitted surface shifts and morphs repositioning the heterogeneous surface and exhibiting the agency of matter (Bolt, 2007).

Directional mapping of the links-links material forces increased the researchers understanding of the knitted surface activity. The programmed materiality of the knitted surfaces "is intrinsically a performative act, which involves instructions and described behaviours" (Scott, 2015, p. 24), between the coded stitch and the selected merino yarn. The links-links structures generate a dichotomy of visible and invisible, seen and unseen collisional material forces. Embodied knowledge acquired through interaction with digital and physical making imparted a deeper understanding of the limitations and potentiality of the technologies, techniques and materials (Philpott, 2011).

Intarsia inlay or partial placements of inlay patterns introduced multi-directional encounters with the links-links material forces. The trialling of additional subtractive design methods with linear and block sectional deletions of inlay further increased surface movements.

> Try to grasp the pattern. It defies you. Try to hold it, finger its details and you are denied. Try to let it 'unfold' itself towards you, perhaps as a musical sequence, then as your eyes flirt and flit around the motifs, listen attentively to its quiet rhythms. (Jefferies, 2012, p. 128)

Inclusion of subtractive design methods resulted in complex inlay pattern fragmentation where the links-links folds revealed and concealed the repetitive layout. The surface folding resulted in a visual aesthetic where the eye attempts to fill the blank spaces and recreate the missing pattern.


Figures 4 and 5. Pattern subtractions generate long inlay yarn floats

Horizontal and vertical linear removal of the inlay coding increased the material activity, enhancing the knitted surface disruption and pattern fragmentation.

The placement, layout and quantity of inlay patterning alter the material behaviour offering additional scope for disruption of the knitted terrain. Inlay pattern subtractions altered the material performance of individual design components. Additionally, pattern subtractions resulted in long yarn floats between the remaining sections of inlay (Figures 4 and 5). Prototyping explored generative methods to create minimal and multiple, curved and linear traces. These floating strands of inlay are usually perceived as programming errors however in this research they are identified as surface-building which offer alternative surface aesthetics. Traces of the maker are evident in the physical knitting, “its rhythms are mine. Its irregularities and imperfections are mine” (Lawrence, 2018, p. 135). Coded stitch structures become material concretisations revealing technical and design knowledge in physical format.

Figure 6. Surface-building blocks

Initial links-links and inlay material knowledge resulted in a pattern library of physical samples. Additional prototyping examined material options, programming inlay traces and approaches to the photographic divisions. These practice-led investigations developed into the surface-building block design components (Figure 6). The surface-building blocks provide pick-and-mix options which consider design elements affecting knitted surface material agency. Investigation of multiple design elements resulted in lists of options increasing design potentiality.

To design with the programmable material forces, a physical-digital-physical mode of making emerged with the surface-building blocks “technically constitutive elements” (Arantes, 2020b, p. 196) in the knitted surface generative process.

Phase 2. A Mode of Making

Initial research practice identified design components communicated as surface-building blocks. Applying the surface-building blocks supports a simplified creative process allowing designers to build complex knitted surfaces through a pick-and-mix approach to design. Phase 2 of this research investigated an approach to building knitted surfaces with numerous material force collisions. Photographs of Coromandel, New Zealand landscapes inspired multiple interconnected sections for filling with links-links structures and inlay pattern repeats. This mode of making involved working from physical landscape to photograph to virtual coding to physical prototype.

Selecting design elements from the surface-building blocks allowed physical links-links samples with differing geometric layouts and scales to position collectively, aiding the practitioner-designers' translation of virtual codes to actual surface activity. Links-links patterns placements optimised multi-directional material forces. Consideration of compressional and divergent aesthetics increased surface encounters. The assemblage of alternative surface haptics is essential as the links-links surface movements reduce the visible knitted surface through vertical or horizontal compression. Combining stitch structures with similar material forces generates fewer oppositional collisions and narrow elongated or wide compacted knitted surfaces. This practice applied a form of material consciousness (Sennett, 2008), letting the material's interaction with the technique and technology guide the design.

A colour-blocking system was established, which generated sections from photographs to fill with solid colours. Physical links-links patterns were selected from the surface-building block library to represent each colour. This colour-blocking allowed a paint-by-numbers method to fill sections with multiple links-links stitches efficiently (Figure 7). According to academic Catherine Dormor (2020, p. 21) textile practice is “a form of thinking that is about the dynamic exchange between practitioner, tools and language that become drawn up into each other. In this way the notion of thinking or thought as a kinetic, temporal and dynamic dimension is key.” Intuitive making and tacit knowledge established an ability to facilitate the translation of two-dimensional codes and proportionally evaluate three-dimensional surface factors.

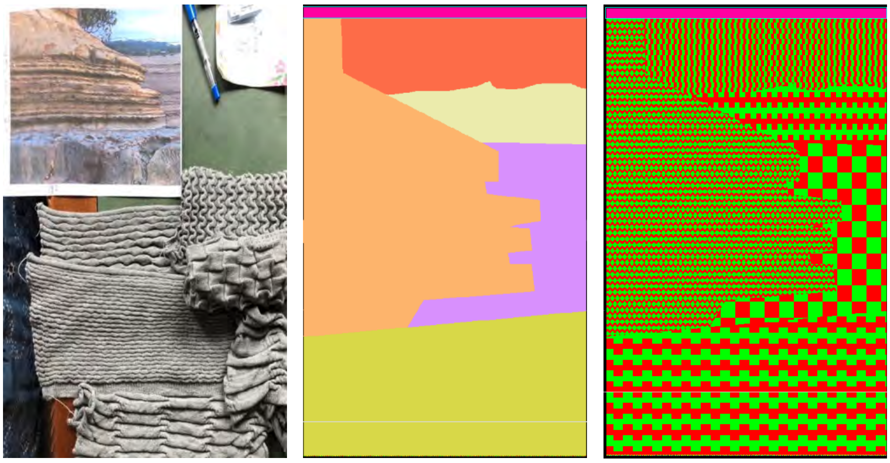

Figure 7. The colour-blocking system for links-links positioning

To establish the placement of the inlay patterning the layout of foliage within the landscape photograph was considered. Adobe Photoshop manipulations highlighted areas of foliage providing a guide for inlay patterning. Traditional twill weave patterns afforded a recognisable woven aesthetic to the inlay layouts. Initially the inlay patterning was arranged with large areas of inlay, altering the mechanical knit behaviours which caused the underlying links-links material forces to disperse. To increase matter agency, other inlay placements trialled subtractive design methods reducing the weave-like surface stability and encouraging inherent stitch movements. Subtraction resulted in areas with minimal courses of inlay pattern appearing as trails, tracing the knitting machines' horizontal movements across the surface. “Following the material traces with fingertips, the point to-point connections between inlay pattern are disclosed and understood” (Moore, 2022, p. 81). These remnants of inlay pattern follow non-linear surface movements imposed by the links-links material force beneath (Figure 8). The material activity folds to disrupt and displace the repeating inlay pattern generating surfaces read as textural knitted terrains.

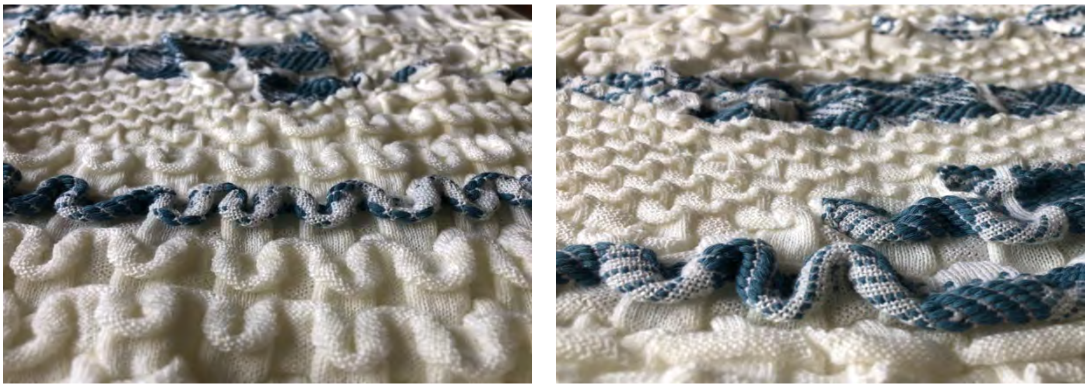

Figure 8. Remnants inlay patterning follow the links-links material force

Phase 3. Building Multiple Terrains

To extend the mode of making and discover design-technical constraints, extremely long panels were set up. Investigations undertaken in Phase 3 built the Metamorphic Series, an installation of knitted surfaces consisting of five panels, each knitted at full needle-bed width and as nine-metre lengths. Scaling up to this extreme length was problematic as proportions altered in the balance of design, material forces interacted differently, and technical programming issues arose. A gridded system was employed to aid in the translation of sectioning from photograph to screen across the multiple panels (Figure 9) as on-screen conversion was difficult to perceive.

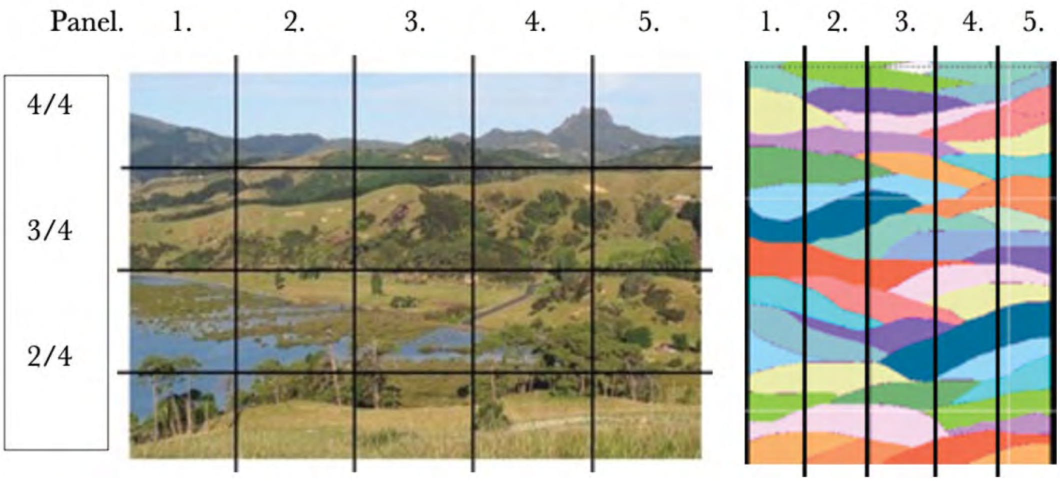

Figure 9. Gridded sectioning for multiple panels

In the creative process for the Metamorphic Series, individual stitch structures interactions influence neighbouring panels. Virtual programming involved designing the collective links-links ground and inlay patterning before copying and layering these as individual panels. The initial creation of the five panels as a collective landscape occurred in the old-format software. Old-format software operates similarly to a blank page used to sketch out the knitted surface designs. Sectioning from the photograph transferred onto five aligned panels, with lines horizontally traversing edge conditions. To achieve the required length in an efficient manner the panel sectioning needed to be copied and mirror flipped. The colour-blocking system positioned the link-links structures as one collective surface (Figure 10). Material forces and ground patterning are read across multiple terrains to inform surface fragmentations. Each panel is a symphony of texture and pattern, a composition constructed from the surface-building block options. Collisions of multi-directional compressional material forces arise from varying the scales and repeating units, shifting neighbouring knitted stitch relationships.

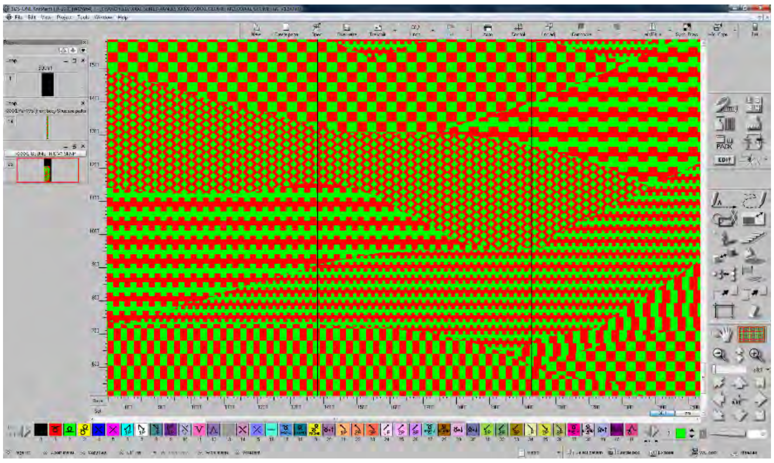

Figure 10. Old-format software set-up of links-links across a collective surface

With the links-links ground established, the multiple panels were set-up again to generate the inlay collective landscape. To position the inlay, foliage from the photographic landscape was transferred to screen as rectangular blocks of a single colour. These colour blocks were filled with inlay patterning before further fragmentation of the repeating design occurred (Figure 11). Using subtractive design methods sections of inlay were erased horizontally and vertically. The fragmentation of the linear coding on screen increases programmed physical disruptions between the inlay and links-links knitting techniques.

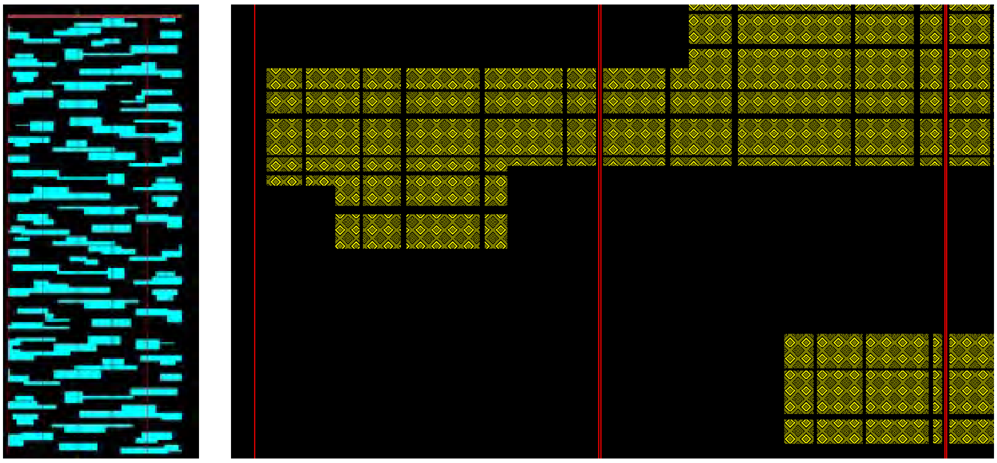

Figure 11. Old-format software set-up of inlay multiple panels

Construction of the individual knitted terrain involved copying the links-links and inlay panel layouts from old-format software into the corresponding automatic software pages. Layering of the two knitting techniques allowed modification of manipulated material forces. Altering coding in a single panel signified changes across the interconnected multiple panels. Adjusted links-links or inlay patterning required transference back onto the old-format pages to retain correct programmed linkages. Design modifications occurred during a composite view which permitted separate layers to be viewed together. This composite perspective allowed layered stitch interactions to be understood and refined prior to knitting off.

The amount of inlay patterning a design contains additionally affected the potential surface design.

Technical constraints arose if too much inlay patterning was positioned vertically due to issues when the coded knit information processed for knitting. Furthermore, the extreme length and complexity of the knitted surfaces generated technical issues as the automatic software struggled to process the quantity of programmed information. A sequential knit setting applied before processing was essential to overcome this programming constraint. Sequential knitting divided each panel horizontally while still resulting in a single seamless surface exiting the knitting machine. Individual panels used up to 12 sequential knit separations and required nine hours knit time due to the knit complexity.

The surfaces generated during this research phase exhibit the inlay knitting technique in an applied mode of making. The surfaces showcase inlay, in a technologically designed layering system combined with links-links material forces. The complex designs are intended to instigate conversations encouraging new ways of seeing knitted surfaces. The final installation of the Metamorphic Series exhibited the five panels suspended and traversing the gallery floor (Figure 12). This manner of exhibition encouraged viewers to haptically engage with the two-sided surface of the knit and to visually navigate the terrains as a single landscape. Haptic encounters caused material agency of the knitted surface to shift in response to physical encounters. Fingers read the visible and hidden surface, negotiating a tactile conversation between the viewer and knit. Haptic engagement increases textile understanding (Philpott, 2011). Viewers encounter different tactile facets generated by multiple material collisions in the knitted surface. The knitting techniques, patterns and materials are perceived as active participants introducing material behaviours and providing new design possibilities for knitted surface.

Figure 12. The Metamorphic Series

Conclusion

This practice adds to current knit research through investigations of links-links and inlay knitting techniques. As the inlay knitting technique is a relative newcomer to digital knitting, there is a gap in the textile research environment that this design research occupies. Drawing on traditional textile techniques, hybrid crafting methods and tacit knowledge, this practice investigated the technical-design cusp of the Shima Seiki Mfg. Ltd knitting technologies. Physical feeds into digital before returning to physical in a generative feedback loop. The programmed material forces and inherent material performances manipulate surface disruptions and pattern fragmentation. Control of material encounters through the positioning of virtual coding generates knitted surfaces which illustrate design-technical knowledge. The knitted surfaces become vehicles of knowing and know-how. The knitting techniques navigate an assemblage of acquired material force knowledge, communicated through the recorded agency of matter (Bolt, 2007), to be read visually and haptically.

This practice-led research offers an alternative approach to generating complex knitted surfaces. Through a design process, programmed material forces disrupt knitted surfaces and patterning. The surface-building blocks provide a base library of knit design components affording a structured approach to digital programming while contributing to unstructured surface movements. Although this practice focussed on the layering of links-links and inlay knitting techniques in the future extension of the mode of making could combine other knitting techniques. By utilising the repeating pattern and scale approaches to design, the pick-and-mix approach could expand to offer additional surface-building block options. Increased accessibility to complex digital knitting technologies for interdisciplinary designers offers new design opportunities for knitted surfaces.

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