TEXTILE TERRAINS

A TECHNIQUE-LED DESIGN METHODOLOGY FOR KNITTED SURFACE

Rachelle Moore

School of Art and Design, Auckland University of Technology
A thesis submitted to Auckland University of Technology in fulfilment
of the requirements for the degree of Doctor of Philosophy (PhD), 2022

Abstract

This practice-led research focuses on developing a method of building knitted surface topographies using links-links stitch structures and the knitting technique of inlay. The knitted surface topography builds on the dynamic and fluid nature of knitting, where materials, making and maker absorb and translate properties from surrounding environments and interactions. A knitted surface is an entity constructed through a series of singular movements; stitch by stitch, the knit and the inlay pattern assemble in tandem, resulting in a hybrid surface. A single point builds the multiple to inform a collective surface reliant on neighbouring linkages. Layers interconnect during the making, and dominant material forces alter the knitted surface plane. Weave and knit are embedded digitally and physically in an inlay surface. The assembled material performances inherited from the hybrid textile technique are visible in the folded fragmentation of the knitted surfaces. Material agency folds and unfolds to reveal hidden inlay patterning, as intersecting material forces collide. These oppositional conditions increase the tactility of a knitted surface, providing opportunities for haptic navigation of the fractured textile terrain, allowing the hand to read what the eye omits.

This research follows a digital-craft creative process embracing textile design methods of repetition, traditional weave patterns and digital machine knit tacit knowledge. An alliance forms during the making between designer, materials and technology. A mode of making develops, resulting in a temporal practice approach, designing with rather than against the heterogeneous knitted surface dynamics; the programmed materiality results in linear distortion through inlay pattern subtraction and link-links ground interactions. The compositional inlay placements further disrupt the knitted surface, exposing pattern traces that map material forces. This research journey asks the question: How can the hybrid knit-weave technique, inlay, be used as an ontological investigative medium into built, knitted surface topographies through the assemblage of heterogeneous material forces? The significance of knitted surface is examined, as alternative approaches to making encounter visible and invisible material dynamics that inform topographical terrains.

Table of Contents

Abstract I

List of Figures V

Attestation of Authorship XIII

Acknowledgements XIV

Chapter One: Introducing the Journey 1
- 1.1 Introduction 1
- 1.2 Positioning the Researcher 4
- 1.3 Aims and Objectives 4
- 1.4 Methodological Overview 5
- 1.5 Outline of Thesis 7
- 1.6 Conclusion 8

Chapter Two: Traversing the Scope 9
- 2.1 Introduction 9
- 2.2 What is Inlay Knitting? 9
- 2.3 What is Links-Links Knitting? 14
- 2.4 Inlay as a Hybrid 16
- 2.5 The Importance of Surface 17
- 2.6 Origins of Inlay Knitting 18
- 2.7 Material-based Forces 24
- 2.8 Craft Influences 28
- 2.9 Contemporary Inlay Practice 30
- 2.10 Building a Language 33
- 2.11 Conclusion 35

Chapter Three: Crafting a Knit Framework 36
- 3.1 Introduction 36
- 3.2 Designer's Tacit Intuition 37

3.3 Making in a Hybrid Environment 38
3.4 Interlinked Research Phases 39
3.5 Role of Reflective Practice 40
3.6 The Act of Making 42
3.6.1 Inlay Investigations 42
3.6.2 Digital-crafting 44
3.6.3 Materials and Materiality 47
3.7 Building Material Forces 49
3.7.1 Generating the Knitted Ground 49
3.7.2 Reading Material Forces 51
3.7.3 Approach to Subtractive Design 54
3.8 Emergent Design Strategies 56
3.8.1 Establishing Surface-building Blocks 56
3.8.2 Generating a Mode of Making 58
3.9 Assembled Topographies 63
3.10 Conclusion 66

Chapter Four: Planes of Technique 67
4.1 Introduction 67
4.2 Phase One: Initial Knowledge Acquisition 68
4.2.1 Technique and Technology 68
4.3 Phase Two: Understanding Knitted Material Forces 71
4.3.1 Building Surface Movement 71
4.3.2 Material States 74
4.3.3 Additive and Subtractive Design 78
4.3.4 Visible Surface Traces 80
4.4 Phase Three: Developing a New Design Strategy 81
4.4.1 Language Influences 81
4.4.2 Building a Single Bed Topography 84
4.4.3 Building a Rib Topography 90
4.4.4 Building a Double Bed Topography 96
4.5 Conclusion 102

Chapter Five: Emergent Terrains 104
5.1 Introduction 104
5.2 Phase Four: Synthesis of Practice 105
5.2.1 Surface-building Block Selection 105
5.2.2 Layer One - The Collective Ground 105
5.2.3 Layer Two - The Collective Inlay Pattern 109
5.2.4 Individual Surface Points 111
5.2.5 Assemblage of Single Surface 113
5.2.6 Assemblage of Multiple Surfaces 117

5.3 The Technical Design Fulcrum 119
5.4 Exhibiting the Metamophic Series 121
5.5 Conclusion 126

Chapter Six: Unfolded Findings 127
6.1 Introduction 127
6.2 Making with Materiality 127
6.3 The Edge of Technicality 129
6.4 Personal Reflections 129
6.5 Significance of the Study 130
6.6 Future Directions 131

References 133

Glossary of Terms 144

Appendices
Appendix A. Geomorphic Knitted Surface Terminology 146

Appendix B. How to Build an All-over Inlay Knitted Surface 149

Appendix C. Inlay Pattern Surface-building Block Library 156

Appendix D. Links-Links Pattern Surface-building Block Library 162

Appendix E. How to Build an Intarsia Inlay Knitted Surface Topography 177

Appendix F. How to Build a Rib Intarsia Inlay Knitted Surface Topography 184

Appendix G. How to Build a Double Bed Inlay Knitted Surface Topography 191

Appendix H. How to Build an Intarsia Inlay Knitted Surface Topography Series 202

List of Figures

Figure 1. R. Moore, 2020. The touchstone intarsia inlay knitted surface topography.

Figure 2. R. Moore, 2021. Weft knitted textile construct.

Figure 3. R. Moore, 2021. Woven textile construct.

Figure 4. R. Moore, 2021. Knitted inlay textile lineage.

Figure 5. R. Moore, 2021. Tubular jacquard technical front.

Figure 6. R. Moore, 2021. Single bed all-over inlay.

Figure 7. R. Moore, 2021. Single bed intarsia inlay.

Figure 8. R. Moore, 2019. Intarsia inlay single bed surface.

Figure 9. R. Moore, 2019. All-over inlay single bed surface.

Figure 10. R. Moore, 2020. Double bed inlay technical front.

Figure 11. R. Moore, 2020. Double bed inlay illustrating yarn inserted internally.

Figure 12. R. Moore, 2020. Double bed inlay surface and detail revealing the captured inlaid yarn.

Figure 13. R. Moore, 2021. Link-links code and virtual simulation of knitted textile.

Figure 14. Heterogeneous hybrid material properties of inlay knitting. Adapted from "Knit and weave properties information," in *Textiles for modern living* (p.175), by E. P. G. Gohl and L. D. Vilensky, 1978, Longman Cheshire.

Figure 15. Woven hand knitting. Adapted from *The illustrated dictionary of knitting* (p. 266), by R. Compton, 1989, Interweave Press.

Figure 16. Weave laid-in yarn in hand knitting. Adapted from *The illustrated dictionary of knitting* (p. 267), by R. Compton, 1989, Interweave Press.

Figure 17. Inlay knitting sample with punch-card programmed pattern repeat. From *Brother punch card pattern* (Volume 4) (p. 216), n.d., Brother.

Figure 18. Inlay knitting sample with manual set-up instructions for pattern repeat. *Note.* From *Brother punch card pattern* (Volume 4) (p. 210), n.d., Brother.

Figure 19. Shima Seiki Mfg. Ltd. Inlay Knitting Machine SRY123LP. Photo courtesy of SHIMA SEIKI MFG. LTD. From Shima Seiki Mfg. Ltd., 2020. (https://www.shimaseiki.com/product/knit/nsry/).

Figure 20. Loop presser bed. Photo courtesy of SHIMA SEIKI MFG. LTD. From Shima Seiki Mfg. Ltd., 2020. (https://www.shimaseiki.com/product/knit/feature/#u2).

Figure 21. Parallel needle beds. Photo courtesy of SHIMA SEIKI MFG. LTD. From Shima Seiki Mfg. Ltd., 2020. (https://www.shimaseiki.com/product/knit/feature/#u2).

Figure 22. R. Moore, 2021. Single screen in SDS-One Apex3 old-format software.

Figure 23. R. Moore, 2021. Multiple screens in SDS-One Apex3 automatic software.

Figure 24. Inlaid tube in half Milano knitted stitch structure. From "Development of laid-in knitted fabric for buoyant swimwear," by N. W. Li, C. P. Ho, K. L. Yick, and J. Y. Zhou, 2020, *Journal of Industrial Textiles*, p. 6.

Figure 25. Inlay knitting of pleated circle. From *The Space in between: Exploring weave knitted textiles by constructing surface patterns on three-dimensional shapes*, by V. Hohenstein, 2017, Student Thesis, University of Borås, Faculty of Textiles, Engineering and Business, p. 3.

Figure 26. R. Moore, 2019. Inlay-knitted shoe by Shima Seiki Mfg. Ltd., exhibited at Pitti Filati, Florence, 2019.

Figure 27. R. Moore, 2019. Weave-in knitted bag by H. Stoll GmbH & Co. KG., exhibited at Pitti Filati, Florence, 2019.

Figure 28. Kitty Pennybacker knit-weaving with large floats, knitted on a domestic knitting machine. From Etsy, 2021 (https://www.etsy.com/uk/listing/940289527/pink-blue-scarf?ref=shop_home_active_18&frs=1).

Figure 29. Three types of tectonic force. From *Physical geography,* (p. 389), by J. F. Peterson, D. Slack, & R .E. Gabler, 2017, Cengage Learning.

Figure 30. Geomorphic folds formed by tectonic forces. From *Physical geography* (p. 395), by J. F. Peterson, D. Slack, and R .E. Gabler, 2017, Cengage Learning.

Figure 31. R. Moore, 2022. Research phases of the practice.

Figure 32. R. Moore, 2019. The practice-review process.

Figure 33. R. Moore, 2019. All-over inlay knitting with float variations.

Figure 34. R. Moore, 2019. All-over inlay knitting with striped racked stitch structure.

Figure 35. R. Moore, 2019. All-over inlay knitting single bed with lace stitch structures.

Figure 36. R. Moore, 2020. Mapping the lineage of inlay technique initial practice.

Figure 37. R. Moore, 2019. Two colour inlay with one colour ground.

Figure 38. R. Moore, 2019. Two colour inlay with one colour ground.

Figure 39. R. Moore, 2019. One colour inlay with two colour grounds.

Figure 40. R. Moore, 2019. Traditional twill-weave patterns interpreted as digital all-over inlay knitting.

Figure 41. Woven dornick twill pattern grid. From *Mastering weave structures: Transforming ideas into great cloth* (p. 35), by S. Alderman, 2004, Interweave Press.

Figure 42. R. Moore, 2020. SDS-One Apex3 all-over inlay dornick twill pattern translation.

Figure 43. R. Moore, 2020. Woven dornick twill fabric. From *The dornick project*, by A. Stratton, 2011, Tangles and Webs (http://tanglesandwebs.blogspot.com/2011/12/dornick-project.html).

Figure 44. R. Moore, 2020. All-over inlay knitted dornick twill.

Figure 45. R. Moore, 2020. All-over inlay knitted dornick twill detail of texture.

Figure 46. R. Moore, 2020. Traditional weave patterns as all-over inlay in two scales.

Figure 47. R. Moore, 2020. Regular twill all-over inlay with inverse patterning.

Figure 48. R. Moore, 2019. Single bed intarsia inlay testing different ground yarns.

Figure 49. R. Moore, 2019. Tubular jacquard merino and Pemotex yarn.

Figure 50. R. Moore, 2019. Dimensional form produced during material experimentation with reactive yarns.

Figure 51. R. Moore, 2021. Textile-design print repeating-pattern techniques.

Figure 52. R. Moore, 2021. SDS-One Apex3 repeat patterns for links-links square.

Figure 53. R. Moore, 2019. Scaled knitted-ground links-links patterns.

Figure 54. R. Moore, 2019. Photographic record of physical link-links grounds.

Figure 55. R. Moore, 2019. Personal interpretation of grid illustrating knit, weave and inlay technique connections.

Figure 56. R. Moore, 2019. Analysing convergent and divergent force between knit and Crystal Twill intarsia inlay.

Figure 57. R. Moore, 2019. Holes in Crystal Twill intarsia inlay.

Figure 58. R. Moore, 2019. Reading assembled material forces in intarsia inlay knitted surface topography.

Figure 59. R. Moore, 2020. Large area of intarsia inlay patterning in proportion to knitted links-links ground.

Figure 60. R. Moore, 2020. Knitted surface topography with increased inlay pattern fragmentation.

Figure 61. R. Moore, 2020. Trace pathways of the intarsia inlay yarn.

Figure 62. R. Moore, 2021. Surface-building blocks for knitted surface topography.

Figure 63. R. Moore, 2020. Thumbnails of Coromandel land and rock terrains.

Figure 64. R. Moore, 2020. Creative process of collaging sectional links-links ground.

Figure 65. R. Moore, 2020. On-screen composite view showing layered structure and inlay page codes.

Figure 66. R. Moore, 2020. Visual results of actual to digital image-sectioning methods.

Figure 67. R. Moore, 2020. The creative design process steps for rib intarsia inlay in automatic software.

Figure 68. R. Moore 2021. Proportional sectioning for colour-blocking in series of longer knitted surface topographies.

Figure 69. R. Moore, 2021. Repeating pattern methods trialled for intersecting ground sections.

Figure 70. R. Moore, 2021. Image adjustments trialled for placement of inlay patterning.

Figure 71. R. Moore, 2019. Single bed all-over inlay knitted surfaces.

Figure 72. R. Moore, 2020. Double bed inlay knitted surfaces.

Figure 73. R. Moore, 2020. All-over inlay diamond twill pattern, original scale and 200% scale.

Figure 74. R. Moore, 2020. Knit issue on edge of intarsia inlay due to carrier type.

Figure 75. R. Moore, 2020. Interplay of material forces in brick vertical rectangle, scale 100% to 500%.

Figure 76. R. Moore, 2020. Interplay of material forces in half-drop vertical rectangle, scale 100% to 500%.

Figure 77. R. Moore, 2020. Mapping relationships of multiaxial material forces.

Figure 78. R. Moore, 2020. Transformative material forces resulting in peaks and troughs.

Figure 79. R. Moore, 2020. Mapping the material forces between knitted ground and intarsia inlay.

Figure 80. R. Moore, 2020. Double bed inlay with heat-reactive surface deformation.

Figure 81. R. Moore, 2020. Double bed inlay with sections of solid-ground colour-blocking.

Figure 82. R. Moore, 2021. Knitted surface topography released from machine constraints.

Figure 83. R. Moore, 2020. Programmed vertical, horizontal and block subtraction of intarsia inlay.

Figure 84. R. Moore, 2020. Intarsia inlay pattern subtraction with knitted ground dynamics.

Figure 85. R. Moore, 2020. Minimal intarsia inlay pattern with links-links dominating the surface.

Figure 86. R. Moore, 2021. Intarsia inlay negotiating links-links material forces.

Figure 87. R. Moore, 2020. Rib ground with curved intarsia inlay illustrating multiple traces.

Figure 88. R. Moore, 2020. Single jersey ground with linear intarsia inlay illustrating minimal traces.

Figure 89. R. Moore, 2019. Sand texture from Te Kouma, Coromandel, New Zealand.

Figure 90. R. Moore, 2020. Material forces in the knitted surface emulating nature's fluidity.

Figure 91. Progression of the links-links patterning complexity single to multiple ground collisions.

Figure 92. R. Moore, 2021. Surface-building blocks for single bed intarsia inlay Block Twill knitted surface topography.

Figure 93. R. Moore, 2021. Block Twill intarsia inlay with weave-dominant characteristics.

Figure 94. R. Moore, 2021. Block Twill intarsia inlay with multiaxial material forces.

Figure 95. R. Moore, 2021. Fragmentation of links-links ground and inlay pattern in Block Twill intarsia inlay.

Figure 96. R. Moore, 2021. Interpretation of photograph of land, sea and sky across two knitted surface topographies.

Figure 97. R. Moore, 2021. Diminished surface pattern disruption in the larger knitted surface topography.

Figure 98. R. Moore, 2021. Two-by-two rib with diamond twill intarsia inlay, illustrating the displacement of linear rib.

Figure 99. R. Moore, 2021. Surface-building blocks for rib intarsia inlay Strata V1 and V2 knitted surface topography.

Figure 100. R. Moore, 2021. Strata V1 knitted surface topography with squared inlay edges.

Figure 101. R. Moore, 2021. Strata V2 knitted surface topography with curved surface sections.

Figure 102. R. Moore, 2021. Surface-building blocks for rib intarsia inlay Strata V3 knitted surface topography.

Figure 103. R. Moore, 2020. Converting colour-blocking to rib and links-links grounds.

Figure 104. R. Moore, 2020. Layered relationships of inlay colour and structure pages viewed as a composite page.

Figure 105. R. Moore, 2020. Strata V3 knitted surface topography.

Figure 106. R. Moore, 2021. Double bed inlay demonstrating merino combined with Pemotex yarn.

Figure 107. R. Moore, 2020. Programming of separate inlay pattern and ground layers on a single screen in old-format software.

Figure 108. R. Moore, 2020. Cropped Coromandel landscape photograph for links-links ground sections.

Figure 109. R. Moore, 2021. Surface-building blocks for double bed inlay Lace Twill V5 knitted surface topography.

Figure 110. R. Moore, 2021. Double bed inlay colour coded packages using old-format programming.

Figure 111. R. Moore, 2021. Diamond twill pattern coding conversion for double bed inlay Lace Twill V5.

Figure 112. R. Moore, 2021. Comparison of single bed intarsia inlay and double bed inlay knitted surface topography.

Figure 113. R. Moore, 2021. Double bed inlay, closed and open side-edge knitting options.

Figure 114. R. Moore, 2021. Surface-building block selection for the Metamorphic Series of knitted surface topographies.

Figure 115. R. Moore, 2021. Vertical and horizontal lines dividing the photograph for multiple panel design.

Figure 116. R. Moore, 2021. Colour blocking paint-by-numbers process, filling with links-links ground structures.

Figure 117. R. Moore, 2021. Foliage in the photograph of the landscape converted to blocks of inlay.

Figure 118. R. Moore, 2021. Collective placement of areas of inlay patterning across the multiple panels.

Figure 119. R. Moore, 2021. Inlay pattern vertical, horizontal and block subtraction areas.

Figure 120. R. Moore, 2021. Modification of Metamorphic Series inlay patterning across the linked panel boundaries.

Figure 121. R. Moore, 2021. Composite view allows adjustment of the stitch structure under the inlay pattern edges.

Figure 122. R. Moore, 2021. Inlay pattern following the recumbent folding waves of the links-links ground.

Figure 123. R. Moore, 2021. Knitted surface topography with S-shaped folded ridges fracturing the inlay pattern.

Figure 124. R. Moore, 2021. Vertical convergent material forces.

Figure 125. R. Moore, 2021. Horizontal convergent material forces.

Figure 126. R. Moore, 2021. Metamorphic Series, first prototype, with intermittent inlay patterning.

Figure 127. R. Moore, 2021. Perspectives of the inlay knitted surface topography.

Figure 128. R. Moore, 2021. Metamorphic Series, panel one prototype emerging from the knitting machine.

Figure 129. R. Moore, 2021. Metamorphic Series panels one and two display ground and inlay pattern navigating the multiple.

Figure 130. R. Moore, 2021. Exploring spacing of the inlay pattern in Metamorphic Series panels one and two.

Figure 131. R. Moore, 2021. Rectifying incorrect colour codes on stitch structure page during programming.

Figure 132. R. Moore, 2021. Software errors due to programming complexity of the Metamorphic Series panels.

Figure 133. R. Moore, 2022. Reading across the Metamorphic Series panels.

Figure 134. R. Moore, 2022. Multiaxial patterning collisions across Metamorphic Series panels.

Figure 135. R. Moore, 2022. Technical back view of Metamorphic Series panels.

Figure 136. R. Moore, 2022. Suspended vertical folds.

Figure 137. R. Moore, 2022. On the gallery floor multiaxial folds.

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.

Signed: 

Date: 25.06.2022

Acknowledgements

This time spent immersed in creation has been a journey of self-discovery. Firstly, I would like to whole-heartedly thank my incredibly inspiring supervisors, Dr Amanda Smith and Dr Susan Hedges, for their patience and generous sharing of extensive knowledge that has helped me find the poetics of knitted surface. I am immensely grateful to you both for the constant support and belief in me and the research trajectory. I will always remember the enthusiastic haptic engagement with the knitted surfaces and your encouraging words.

I would like to acknowledge the staff at the Auckland University of Technology, Textile Design Lab, for sharing their knit knowledge, time and the essential inlay knitting technologies. Many thanks especially to Jyoti Kalyanji for her patience and help with technical issues that arose during the unconventional use of the knitting machine.

Thank you to my father, Bob Moore, for his generous gift of time during the many walks around the Coromandel Peninsula to photograph inspirational landscapes. Many thanks also to my mother, Sandra Moore, for embedding a love of knit and yarn in me since childhood, although I remain unable to hand-knit she inspires me with her incredible ability to create and mend. A special thank you to my nephew, Zak Karouso, who so kindly helped with diagrams and final proof reading. Lastly a sincere thank you to all my loved ones for listening to the rollercoaster journey and providing the supportive unwavering belief that I could complete.

Chapter 1: Introducing the Journey

> Inherent to a thread is the possibility to be transformed into myriad textures and shapes. A thread is pure potential, a kind of possibility space for bringing any kind of (knitted) surface about – within the limits of the thread's textile qualities. In knitting we are thus working with a continually reconfigurable creativity. (Arantes, 2020a, p. 161)

1.1 Introduction

Part of the mystery and beauty of knitting is the unpredictability of the medium. As a digital knit designer, I seek to harness this unstructured physical characteristic through structured coding. This design practice aims to embrace the temporality of surface (Bruno, 2020) through encounters with the material dynamics of knitting. The knitted surface is unique, an emergent construction viewed in this research as active matter encountered through the links-links and inlay knitting techniques. Anthropologist Tim Ingold (2018) asks, "what if surfaces are the real sites for the generation of meaning?" (p. 137). This perspective of the knitted ground as a site of critical knowledge relates to an intended interpretation of these surfaces. The textile terrains become materialisations of knitted surface knowledge used as investigative vehicles to answer the research question: How can the hybrid knit-weave technique, inlay, be used as an ontological investigative medium into built, knitted surface topographies through the assemblage of heterogeneous material forces?

This technique-led research is a tactile surface exploration informed by intuitive design responses rather than presented as a scientific or mathematical thesis. Frameworks central to this practice-led research include: the links-links and inlay knitting techniques, materiality, a craft to digital aspect, the singular to the multiple and knitted assemblage of material forces. This practice operates at the edges of the design capabilities of inlay knitting technologies; a location where the technical influences design, and the design extends technical applications (Power, 2007). The surfaces generated are intended to add to knowledge in the field of digital knitting, specifically instigating conversation around alternative modes of thinking about, and making for knitted surfaces. Multiple textile design approaches are incorporated to generate a hybrid crafting (Golsteijn et al., 2014) process. Hybrid crafting blends digital and physical design methods to explore the surface effects of size, scale and repeating patterns on the assembled material agency.

Inlay knitting involves the insertion of an additional yarn, laid horizontally across knitted loops. In 2015 the Japanese company Shima Seiki Manufacturing Limited developed a specifically designed weft-insertion knitting machine; the N.SRYLP. Although inlay as a textile technique has historical roots, digital technologies have only recently embraced this as an industrialised construction method. An inlay knitted surface inherits characteristics from both textile methods, the knit and the weave, exhibiting emergent hybrid material properties. This research considers a design approach utilising the assemblage of heterogenous factors that transform each other. A surface through layered, disruptive material forces such as the oppositional forces that occur inherently between a knitted stitch and inserted inlay yarn. Additional material forces come into play with the inclusion of yarn varieties such as merino, cotton and heat-reactive Pemotex yarn, selected for their inherent physical attributes that collaboratively unfold through surface positioning.

This research aims to design complex knitted surfaces which manipulate material forces occurrent between links-links and inlay knitting techniques. The practice considers the positioning of layered singular and multiple design elements, studying the effect of material forces on the agency of the knitted surface. "Surface especially matters as a site in which different forms of mediation, transfer and transformation can take place" (Bruno, 2020, p. xiv). The surface fragmentations are constructed stitch-loop by stitch-loop, layered with inlay picks and floats. These programmed interactions realign single components, forming alliances with neighbouring points (Arantes, 2020a). This practice endeavours to operate in a making environment that encourages the stitch structure behaviours and yarns to speak for themselves (Albers, 1957). Multiple sections of interactivity generate tangible and intangible design elements programmed to explore dichotomies of visible and invisible material forces (Lee, 2020).

Interpretations of landscapes from the Coromandel Peninsula, in New Zealand inspired the study of foundational material forces between a built knitted stitch and inlay pick. A landscape consists of elevated, lowered and level landforms which exist due to processes and materials that originate in the Earth's interior and surface (Peterson et al., 2017, p. 385). Landscape imagery sourced from my grandmother's farm located in Te Kouma, Coromandel facilitates exploration of surface alliances using a layered design process integrating digital and physical making environments. In the knitting process, a built terrain enfolds into the artefact; traces of the act of making (Ingold, 2016) inform patterned pathways, concealed and revealed as knitted surface disruptions unfold. Academic Catherine Dormor (2020) notes, "it is in the encounter with the other within the space of the fold that an expression of that other is created. As one element folds onto its other self, its multiplicity and capacity become revealed" (pp. 12–13). Intricate design details influenced by traditional weave patterning are used to reveal programmed behaviours, emergent as material performers in the act of making.



Figure 1. The touchstone inlay knitted surface topography.

These knitted surfaces allow viewers to engage haptically as fingers read the knitted tactility. The term haptics is derived from the Greek haptikos, meaning able to touch. The physical qualities of a surface perceived through touch are significantly different to those attained through other senses (Prytherch & McLundie, 2002). Throughout this research journey, one particular inlay prototype became my touchstone knitted surface (Figure 1) providing a tactile focus as I followed the tributaries of my practice. "Our experience of textiles is sensory, felt and lived as much as conceptualised" (Philpott, 2011, p. 101). This prototypes tactility epitomised the fragmented movements and encoded material alliances I sought to enfold into my knitted surface topographies. The surface tactility of this sample acted as a reminder of the importance of haptics within my creative practice (Treadaway, 2007). "It is the combination of kinaesthetic and tactile information supplied from hand to brain, blended with sensory information from the visual system that enables imaginative thought to occur" (Prytherch & McLundie, 2002, p. 37). Utilising a sense of touch to include haptics as a relational mode encouraged navigation of the knitting through reciprocal surface contact (Bruno, 2020). Although I will exhibit my final surfaces, Metamorphic Series, as proof of practice (refer to Chapter Five, *Emergent Terrains*), these knitted surface topographies are perceived not as art; instead, they exist as a personification of personal knowledge and an expression of knitted surface poetics present in a haptic interface.

1.2 Positioning the Researcher

This practice builds on apparel-based knowledge from the perspective of a knitwear designer and lecturer in fashion and textiles disciplines. Before becoming a university lecturer, I worked as a knitwear designer and production manager in the New Zealand fashion industry. Authors Christopher Crouch and Jane Pearce (2012) suggest that "our research position knowingly or unknowingly, underpins all our research" (p. 57). This research is reflective of career experiences, personality and previous textile knowledge. Before undertaking this research, my Shima Seiki Apex-3 software programming skills focused on stitch structures, jacquards, and shaping. Former research investigated seamlessly knitted oversized silhouettes and miniature forms. Although I had previous programming experience, none engaged with the inlay knitting technique or constructed large scale knitted outputs. Taking on a technical role when running the inlay knitting machine often generated challenges due to limited input by industry trained technicians. Personal methods of engagement with knitting's two-dimensional and three-dimensional environments altered the research trajectory, unfolding as a knowledge building and personal development experience.

1.3 Aims and Objectives

This research aims to shift the focus for knitted textiles from three-dimensional form to the designed surface environment through the generation of knitted surface topographies. The usual focus of knitted outputs is the ability to cover the body as a shaped form. However, the emphasis of this project shifted to the built surfaces, as they provided a larger expanse through which to showcase the interactions of link-links ground and inlay knitting techniques. These surfaces are engineered to reveal the complex material agency between the inlay knitting, links-links stitch structures, materials and technology during the design process. This research is a practice-led investigation of knitting techniques intended to extend design opportunities beyond the recognisable all-over single bed inlay application. Multiple inlay surface possibilities are considered through a series of knitted surface topographies to assess intrinsic knitted material forces and act as a means of corralling the boundaries of the investigation.

These knitted surface topographies introduce an alternative design space for creative interaction with inlay knitting through the development of a mode of making that harnesses the structured and unstructured aspects of knitted stitch structures. Through prototyping, the objective is to develop an approach to a knitting technique that embraces the material agency of links-links and inlay during surface construction. These prototypes are methods to answer questions such as: how can these surface movements be manipulated and controlled through

considered design to harness the nature of the knitted surface's material forces, and how does the scale of the knitted ground and inlay patterning affect the interactions of the material forces? Manipulation of material agency (Bolt, 2007) is proposed as an alternative approach to knitted surface generation demonstrating how the assemblage and scale of links-links stitch structures and inlay patterning can construct active topographies with multiple differences. Numerous variables within the knitting process allow the materials and technology to independently influence the knitted surface outputs.

Through this research, it is proposed that designers who profoundly understand technical programming of digital knitting can extend their creative practice through collaborative design with the technology. Academics Amy Cheatle and Steven Jackson (2014) note:

> Rather than suggesting that technology is serving the needs of the artist, we can argue that artists and their digital fabrication tools are engaged in creative entanglements of flow where technology and human making expand and inform one another. (p. 967)

An essential aim of this practice is to identify and understand the technical-design fulcrum. Digital to physical realms are extended through a series of practice-led experimentations to discover potential technological constraints on the knitting design process. This research aims to operate at the edges of this uncovered cusp, incorporating the limits of the inlay knitting technology into surface designs.

The purpose of this research is to investigate an alternative making approach, and through that foster a making space that encourages less traditional perspectives of knitted surface, the results of which could appeal to a broader range of designers. This research knowledge is intended to be used by makers situated outside of the direct field of digital knit. Knit specific terminology is generally used in the knitwear industry to convey technical information for production. Geomorphological terminology is included in this research to interpret and analyse the knitted surface activity, offering a more descriptive discourse to encapsulate the knitted surface movements.

1.4 Methodological Overview

Textile designers bring a range of practical skills and tacit knowledge to research that are unique to their discipline, a specific blend of experience amassed from the fields of design, art, craft and technology (Igoe, 2010). This research uses a plethora of textile approaches to afford manipulation of techniques and "materials

in unfamiliar ways or within new contexts" (Marr & Hoyes, 2016, p. 8). Theorist Michael Polanyi, in *The tacit dimension* (1967), describes this tacit knowing as "we can know more than we can tell" (p. 4). Hybrid textile making methods fostered dynamic exploration and multi-disciplinary perspectives during the evolution of the knitted surface designs and acquisition of new knowledge in this research.

In Chapters Two and Three, a hybrid digital-crafting methodology is discussed. However, deeper discussions on methods utilised are located throughout Chapters Four and Five, while discussing making aspects which respond to the evolving practice. This research journey followed a practice-led pathway allowing the knit practice to unfold rather than be dictated by preconceived ideas (Philpott, 2011). Retrospective analysis of the making established robust connections between the evolving theoretical concepts and practice. In this respect, the research project morphed, enriched by a layering of knowledge. Questions central to the practice revealed and concealed themselves. Relationships between ideas formed, informed and re-formed, as a hybrid approach blending digital and analogue making processes evolved. Using hybrid making methods "does not simply tolerate difference but cultivates it as a spark to researcher creativity" (Kincheloe, 2001, p. 687). This practice combines digital methods of making from textile and fashion design disciplines to generate new knowledge and understanding, integrating inlay knitting techniques and knitted material forces.

This research involves reframing the dichotomy between craft and technology, or analogue and digital (Adamson, 2018). The creative process followed a cyclic approach, with and against the technology, with and against the design. Each of these factors altered how the other evolved and resolved as I sought the outer capability limits of the inlay knitting technologies. In my creative process, the ability to see the curve, to interpret scale and codes as knitted stitches were essential factors contributing to a seamless shift of perspectives from virtual to physical. This approach embraced tacit knowledge (Polanyi, 1967; Schön, 1983), where through intuitive interaction, the technology became an extension of myself and co-creator. As the research evolved, I emerged as an informed practitioner-researcher, following a process of reflection-in-action and reflection-on-action (Schön, 1983).

Through technique-led prototyping, a hybrid making method incorporating multiple digital and physical design aspects was established. Manipulation of surface material forces was explored through interpretations of traditional weave designs, repeating stitch structures, scaled patterns and sectional subtractive techniques. The assembled interactions of these design factors informed the development of a surface-block building system, resulting in a layered mode of making for knitted surface topographies. The knitted surfaces interpreted the Coromandel landscapes as abstracted representations of the original layered terrains. Understanding of positioned active material forces emerged as physical

knitted terrains, building the knitted surface topography stitch by stitch, resulting in crafted disruptions.

1.5 Outline of Thesis

Chapter Two, *Traversing the Scope* reviews the inlay knitting technique from historical, industry usage, design and technological perspectives. The research examines surface, knitting, traditional weave patterns, materiality and material forces through a literature review. This chapter also considers how theoretical discourse regarding assemblage, singular and multiple have influenced the research context.

Chapter Three, *Crafting a Knit Framework*, outlines the methodological process and methods that developed in connection to geomorphological terminology during this technique-led practice. Textile design methods for knitted surface generation are used to assess the effect of scale, size and repeating patterns on the interrelated material forces. Surface-building blocks and the mode of making that transpired during the research journey are discussed. The researcher's positioning addresses the notion of tacit know-how and the impact of interdisciplinary knowledge on the design practice.

Chapter Four, *Planes of Technique*, discusses emergent theoretical and practice-led strands of this research. This chapter looks at digital-to-physical engagement with links-links stitch structures and inlay knitting technique, and assemblage of material forces resulting in the emergence of the surface-building blocks. Knitted surfaces are generated from photographic imagery using textile print design techniques. Through prototyping, analysis and reflection of material forces, surface-building blocks are devised to construct the knitted surface topography.

Chapter Five, *Emergent Terrains*, applies and expands the acquired knowledge from the initial inlay surface practice. The mode of making for knitted surface topographies is developed further and tested using a photographic image to generate a series of knitted terrains. Technical constraints of the inlay knitting machine are identified as the size of the surfaces push the technology to uncover further design potentiality. This research practice culminates in the exhibition of the Metamorphic Series, a five-panel collective landscape demonstrating application of the mode of making on a larger scale.

Chapter Six, *Unfolded Findings*, reflects on the accumulated key research outcomes and contribution of this practice to the field of digital knitting from a design and technical perspective. This chapter concludes the thesis with a discussion of potential uses for the developed mode of making, future research directions and industry applications for inlay knitted surfaces.

1.6 Conclusion

The *Introduction* chapter has outlined the basic concepts and understandings behind this research, and key research questions, aims and applications. This research is a journey of hybridity, blending knit-weave, digital-craft and digital-physical design aspects into dynamic knitted surface topographies. Each element touched on in this chapter will be explored further, and the entwined connections unfolded during practice discussions throughout the exegesis.

Chapter Two: Traversing the Scope

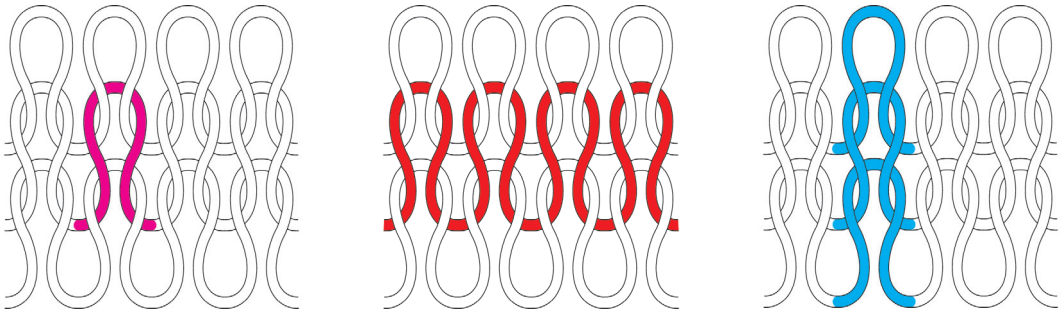
> Instead of thinking of material as static or inanimate, textiles propose a new thinking of multiscale performances relying on the inherent softness, flexibility, and bending of the material. (Thompson, 2014, p. 60)

2.1 Introduction

This chapter provides a framework for this study, connecting technical aspects with design aspects and practice with theory. Foremost, this research engages with two interconnected areas of focus; the inlay and links-links knitting techniques and the emergent knitted surface. This technique-led practice applies the inlay technique through a surface medium to investigate designing with material forces which links-link stitch structures generate. An understanding of knitting technologies is essential to comprehending generated inlay knitted surfaces. This contextual review navigates inlay knitting from a historical and contemporary viewpoint, a digital-craft perspective, and explains relevant technical-design aspects of the inlay knitting technologies used in this study. In conjunction with these factors, surface materiality and material forces are discussed to position the significance of material agency within this creative practice. This research positions itself within the field of knitted textiles in the sub-classification of digital inlay knitting. A literature review examines academic research conducted into this specialised textile technique to assess any potential knowledge gaps that this thesis could begin to fill. The assemblage of contextual elements outlined in this chapter unfolded further during knitted surface topographical builds discussed in Chapters Four and Five.

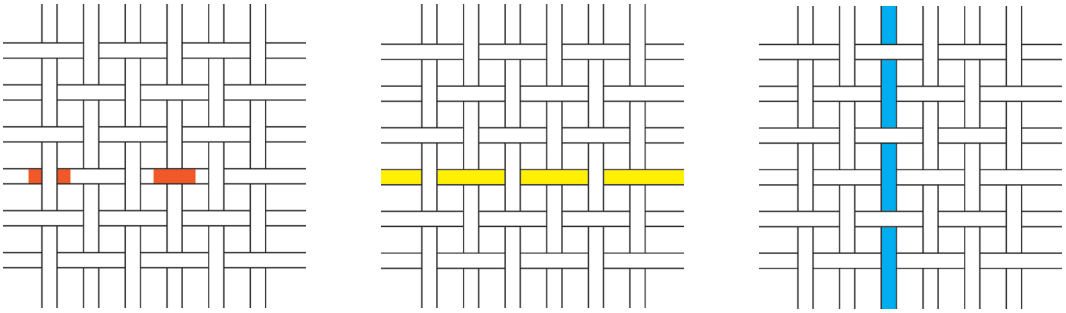
2.2 What is Inlay Knitting?

Textiles are surfaces created from fibres, filaments and yarns. Manufactured textiles are predominantly categorised according to three main production methods: knit, weave and non-woven. According to author Kathryn Hatch (1993), in *Textile science*, knitting is constructed from intermeshing loops formed by one continuous yarn, whereas a weave contains many separate strands of thread and is defined as "fabric in which two or more sets of yarns are interlaced at right angle to each other" (Hatch, 1993, p. 317). The third primary production method is non-woven,



Single knitted stitch loop. Course (horizontal loops). Wale (vertical loops).

Figure 2. Weft knitted textile construct.



Single pick. Pick (horizontal threads). Warp (vertical threads.)

Figure 3. Woven textile construct.

which consists of textiles created through various bonding processes. However, this research employs a hybrid method of making, sometimes referred to as 'inlay'. Inlay knitting is an amalgamation of weft knitted loops and the horizontal insertion of the weft aspect of weave. As a knitted textile making method, the term inlay is also referred to as weave in, inlaid, weave-knit or weft insertion (Spencer, 2001). Throughout this thesis, this method of knitted textile making will be referred to as 'inlay'.

In knitting, there are two types of classification: warp knit and weft knit. This research study investigates weft-knitted inlay textiles constructed on digital knitting technologies. Knit fabric is built from a singular point or stitch loop (Figure 2). Knitted surface stitch structures and patterns use a continuous strand of yarn that interlinks individual loops. The appearance of a knitted surface develops from structural combinations of knit loop movements: front bed (knit), back bed (purl), rib (knit and purl) and transfer stitches. The knitting process interconnects a series of loops utilising a horizontal and vertical grid system. Knitted loops are arranged in horizontal rows, or courses, and vertical wales. The individual knitted stitch relies on all neighbouring loops to fully inform itself; the tension, shape or structural variation of any stitch alters all associative relationships (Arantes 2020a).

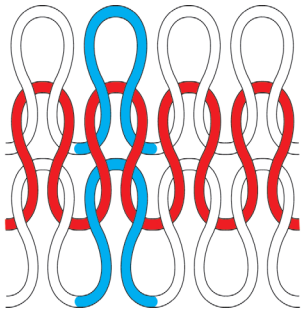
In contrast to knit, woven textiles (Figure 3) are constructed from multiple vertical warps or ends where the ensuing tensions between intersecting horizontal weft threads build the material (Persson, 2017). "Weft yarns, weft, picks or filling are alternative terms for the set of weaving yarns which 'picks' its way across the warp to 'fill' the cloth" (Gohl & Vilensky, 1993, p. 246). The point of intersection between the weft and warp is considered a single pick. Warp ends and weft pick threads are set in a regulated grid-like system; therefore, weave is essentially a structured mathematical process of programmed co-ordinates (Albers, 1965). The quintessential weaving process occurs on a loom, manual or mechanised, where a horizontal weft thread passes between tensioned, raised and lowered vertical warps in designed combinations (Albers, 1965).

The three structural setups central to constructing woven surfaces are plain weave, twill weave and satin weave. The designed points of warp-weft insertion and frequency or manner of intersections alter the woven fabric's appearance and traits (Albers et al., 2000). As renowned weaver Anni Albers (1965) suggests, the appearance of weave is imposed principally by materials and design of the weave directly influencing the properties of the woven outputs. Albers (1965) writes:

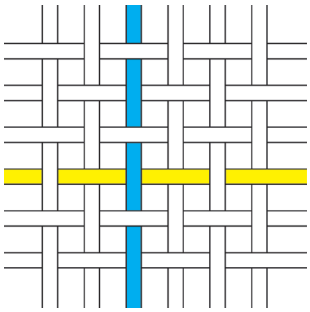
> The structure of a fabric or its weave - that is, the fastening of its elements of threads to each other - is as much a determining factor in its function as is the choice of raw material. In fact the interrelation of the two, the subtle play between them in supporting, impeding, or modifying each other's characteristics, is the essence of weaving. (p. 23)

The formation of an inlay knitted surface occurs when the weft component of a weave combines synchronously with elongated knitted loops (Figure 4). The inlay inserted yarn never forms inside the loop (Spencer, 2001), unlike a jacquard knit (Figure 5) where colouration occurs when additional yarns are knitted on the needles to become stitches. Instead, the inlay yarn positions as a single pick or float of variable length visible in front of or hidden behind the knitted stitch. As inlay yarn does not pass through the knitting needles, this technique provides design options that include insertion of extremely thick or textured yarns across the knitted surface (Black, 2005).

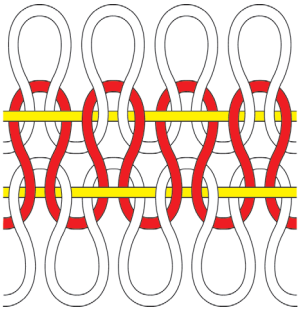
The inlay technique, where the weft weave aspect embeds into the knitted textile, is only achievable due to the continuous loops formed in knitting, which create a conducive environment allowing yarn placement across selected needles. The inlaid yarn can be positioned as an all-over design (Figure 6) or in sections as an intarsia inlay (Figure 7), partially positioned across the width of a textile (Black, 2005). Designs suitable for intarsia or tapestry are often appropriate for intarsia inlay where an isolated area of weft yarn insertion occurs (Guagliumi, 1996).



Parent technique: Weft knit.



Parent technique: Weave.



Inlay knitting.

Figure 4. Knitted inlay textile lineage.

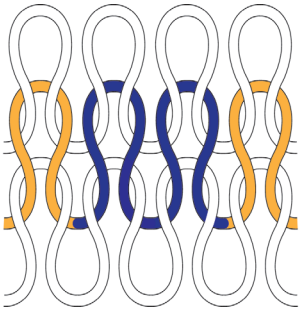


Figure 5. Tubular jacquard technical front.

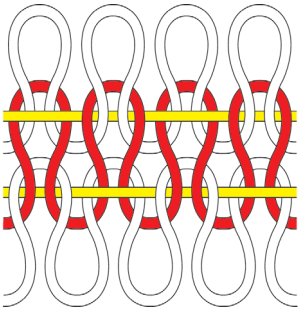


Figure 6. Single bed all-over inlay.

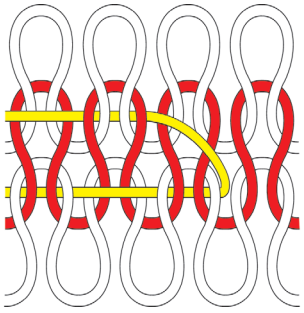


Figure 7. Single bed intarsia inlay.



Figure 8. Intarsia inlay single bed surface.

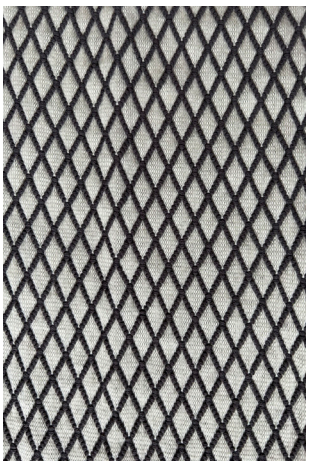


Figure 9. All-over inlay single bed surface.

Intarsia inlay is positioned sectionally as fragments of a repeating pattern (Figure 8) rather than all-over covering of an entire surface (Figure 9). This reductive method of pattern assemblage is a design equation of addition and subtraction, a balance of the pattern remaining and what is removed from the surface. Mathematician Ian Stewart (1998) states:

> Pattern is both a noun and a verb but as a verb it is an active way of seeing the world, a process by which to take in and make coherent the random and often chaotic information the world has to offer. (p. 11)

Intarsia inlay is embedded in the knitted ground, creating the patterned divisions of surface. Interconnected relationships shift between the inlay and knitted ground. Pattern subtraction is a variation that generates different surface behaviours (Philpott, 2011), resulting in altered knit-weave compositional relationships thereby opening up design possibilities for surface activity.

In addition to single bed inlay knits, this research utilises double bed inlay techniques. Double bed inlay knitting (Figure 10) is a variant with an inlay yarn situated between two ground layers of tubular jacquard (Figure 11). Author and academic Lydia Arantes (2020a) notes:

> Knitted surfaces are material concretisations grown out of tiny repeated movements. They do not hide, cover up or conceal; much to the contrary: they reveal. They reveal technical knowledge, skill and dexterity, they reveal an empathetic understanding of materials and patterns. (p. 157)

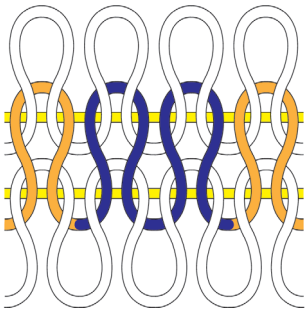


Figure 10. Double bed inlay tubular jacquard technical front.



Figure 11. Double bed inlay illustrates yarn inserted internally.

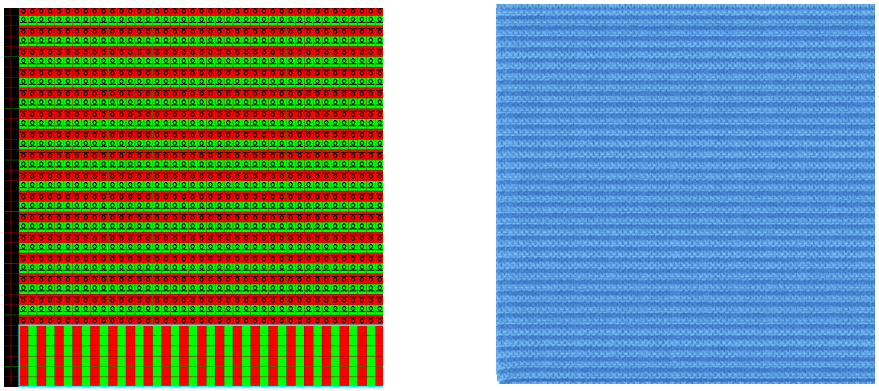


Figure 12. Double bed inlay surface and detail revealing the captured inlaid yarn.

Double bed inlay surfaces are vehicles articulating complex knit coding generated by programming a series of exposed floats rather than embedded picks. Reveal of the inlaid yarn occurs through knitted points of ground removal. Exposure occurs when the ground shifts uncovering the inlay yarn; the stitch transfers from back bed to front bed, revealing the captured internal yarn (Figure 12).

2.3 What is Links-Links Knitting?

Links-links is knitting terminology for a knitted fabric built from combinations of front bed single jersey (knit) and back bed single jersey (purl) stitch structures. Introducing a links-links knitted stitch structure produces an innate folding of knit surfaces. Positioned link-links stitches inform compressional surface movements and have been used to produce self-folding textiles (Glazzard, 2014; Knittel et al., 2015; Scott, 2015; Pavko-Čuden & Rant, 2017). This inherent property of links-links knitting is pivotal in Martha Glazzard's (2014) doctoral research *Re-addressing the role of knitted textile design knowledge: Auxetic textiles from a practice-led, designer-maker perspective.* Glazzard investigated stitch structures to generate self-folding auxetic textiles, which alter when stretched to become more expansive than the original relaxed state. Programming links-links stitch structures on an SDS-One Apex3 screen uses red and green colour codes (Figure 13) which can be processed to



 Red code = Front bed single jersey knit = knit stitch.

 Green code = Back bed single jersey knit = purl stitch.

Figure 13. Links-links code and virtual simulation of knitted textile.

produce a virtual fabric however, it is difficult to digitally convey folding qualities. Glazzard's research demonstrates applied material forces in knit, although the forces generated are not prominent in discussions as a design element; instead, Glazzard emphasises the auxetic traits of links-links.

A links-links surface movement is "based on the structural disequilibrium of face and reverse loops, which cause the fabric to form a three-dimensional structure" (Rant et al., 2014, p. 349). Academics Darja Rant, Ramona Ciobanu, Mirela Blaga and Alenka Pavko-Čuden (2014) explored scaled links-links zig-zag patterning as a potential packaging protection material from a textile-engineering technical perspective. Further research by Pavko-Čuden and Rant (2017) discusses the relationship of links-links three-dimensional material behaviours to sound reduction and anti-bacterial packaging. Academic Jane Scott's (2015) research informed by biomimicry explores links-links stitch structures as part of her responsive knit design system. According to Scott (2015) "shape change is controlled by yarns and knit structure, and the fabric itself determines the final geometries as it transforms from 2D to 3D" (p. 17). Scott applies scale from "the level of the individual stitch and the knitted form" (p. 11) generating knitted textiles which respond to environmental stimuli. Scale in my practice is approached first from a single point on the on-screen grid to multiple neighbouring alliances informing the knitted surface movements.

In a similar woven context, author Anne Fields (2010) discusses collapse weave, a weaving method in which contrasting properties of fibres and different weave structures emphasise surface folding. Released from the linearity of the loom, the rigidity of tensioned threads alters to emerge as "a cloth that bends, distorts and deviates from the usual linear movements of most cloths" (Fields, 2010, p. 6). This release from a tensioned position is similar to the matter movement as the knitted surface topographies are liberated from the needle bed, forming multiaxial folds as the surface settles.

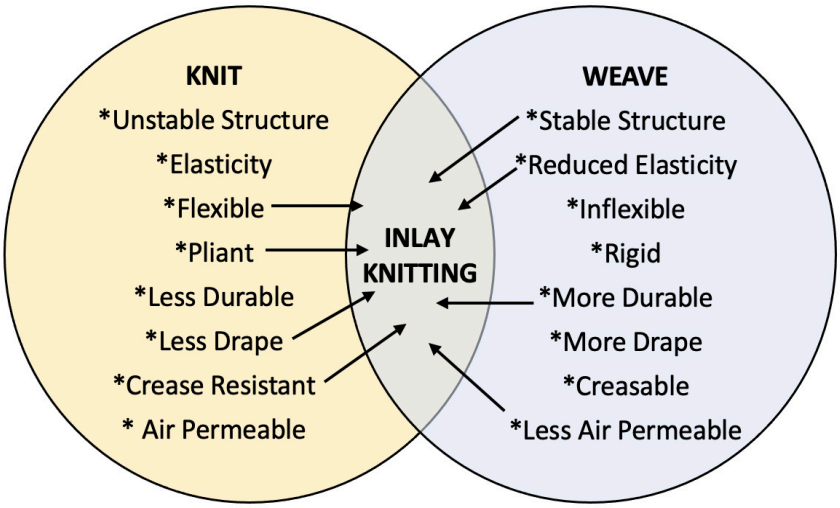


Figure 14. Heterogeneous hybrid material properties of inlay knitting.
Note. Adapted from "Knit and weave properties information," in *Textiles for modern living* (p.175), by E. P. G Gohl and L. D. Vilensky, 1993, Longman Cheshire.

2.4 Inlay as a Hybrid

The surfaces generated in this research practice manipulate the hybrid heterogeneous components of links-links knitted stitch structures and inlay pattern, layering disruptive material properties. Inlay knitting is neither solely a knit nor a complete weave set-up; instead, an inlay surface utilises components from both techniques, forming a heterogeneous hybrid offspring. The parent textile constructs, knit and weave, exhibit opposing behavioural characteristics (Figure 14). The knit offers fluidity and multiaxial directional pliability, whereas the weave provides an element of less elasticity and stability to the textile surfaces (Black, 2005). The inlay yarn alters the material performance of the single jersey ground by "destroying the lateral stretch" (Kinder,1987, p. 11) causing the knitted surface to exhibit behaviours closer to a woven textile.

Academic Malcolm McCullough (1998) suggests that "an artefact is a phenomenon in itself and not just an exact representation of an abstract vision. Its expressiveness is shaped by the very properties of the medium" (p. 203). These derivative hybrid material behaviours offer alternative inlay design opportunities for pliable stable knitted textiles. This research views the hybridity of inlay as an essential element of design utilising variant material characteristics imbued in a combinatory surface environment. This research investigates the amalgamation of two knitting techniques, links-links and inlay, that have quite different material and behavioural qualities. An opportunity exists to explore, understand, control and manipulate the resultant material forces fostering unpredictable surface interactions.

2.5 The Importance of Surface

Surfaces are all around us, everywhere, and as author Joseph Amato (2013) states, "surfaces evade easy definition" (p. 1). Textile yarns and knitted stitches in surfaces have not received the academic consideration warranted by the unique and complex constructive methods of making, which differ so radically from other surface formations (Ingold, 2007; Arantes 2020a). Knitted surface is unique, in that knitting is a built surface rather than a manipulation of surface (Arantes, 2020a). According to Albers (2017), "we will make of our surfaces textile surfaces" (p. 64). A knitted textile has a technical front and technical back face, referencing which surface is outward or inward-facing as the knitting exits the machine. Therefore, a knit can operate as a double-sided surface. Links-links patterns appear on the back face as the inverse of the front face knit (Riechman, 1966). If the links-links pattern is unbalanced, the two sides afford differing surface aesthetics. The technical back of inlay is always the inverse of the technical front. When a float is visible on the front, the back displays the ground and vice versa. Digital two-dimensional knitting code hides the materiality and behavioural quality of the physical three-dimensional knitted surface. Authors Douglas Burbank and Robert Anderson (2012) note it is "tectonic processes that tend to build topography" (p. 22). This research explores how manipulation of the material forces between links-links stitch structures and inlay patterns can inform knitted surface aesthetics.

This research aims not to dress a surface through embellishment, but instead to address the importance of the knitted surface as an embodiment of two embedded textile techniques. This perspective of the importance of knitted surface in this study connects with academic Linnea Nilsson's (2015) discourse on textile influences. Nilsson (2015) discusses three approaches to textile design: textiles are designed for a purpose; or a purpose is found after the textile is designed; or textiles are designed solely for creative practice. Surfaces generated in this research practice are designed to be viewed as dynamic knitted surfaces rather than designed for a particular application. Hybrid knitted surface becomes the vehicle used to creatively navigate combined knitting techniques and tacit knit knowledge.

Surface has been discussed by academics from a range of fields such as social anthropology (Ingold, 2018), physical geography (Peterson et al., 2017), hand-knitting (Arantes, 2020a, 2020b), architecture (Semper, 2004), and materiality (Bruno, 2014). This research aligns with the outlook of author Giuliana Bruno (2014) in *Surface: Matters of aesthetics, materiality, and media*, which places surface at the forefront of the created artefact's essence. "No longer an ephemeral or marginal part of the work, the surface is pushed to the limits of its potentiality to become the actual core and structure of the work" (Bruno, 2014, p. 101). Although Bruno focuses on architecture, film and body surfaces, this book offers an eloquent entrance through which to encounter articulated surfaces as a transformative research environment for knitted terrains.

> Skimming the surface, we not only can weave together the filaments of visual existence, exposing their traces in layers of experience but also trace patterns of transformation. Surface especially matters as a site in which different forms of mediation, transfer, and transformation can take part. (Bruno, 2014, xiv)

In inlay knitting, textile lines of weave skim the surface, embedding and threading into the knitted ground at connective points, this knitted surface disruption and mapping of points will be discussed further in Chapters Four and Five of this thesis. Ingold (2016) refers to traces as "one or the other of two kinds: additive and reductive" (p. 60). In this practice, the inlay lines are tracked across knitted textiles, enabling the viewer to trace the path of fragmented connections and material properties across surface sites. The inlay yarn pathway illustrates the horizontal motion of the knitting machine as knitting needles build the surface. This research study applies additive and subtractive methods to manipulate knitted surface aesthetics, altering inlay traces and interconnected surface relationships.

As highlighted in *Surfaces: Transformations of body, materials and earth* by anthropologist Lydia Arantes (2020a), "knitted things do not have a surface, they are a surface" (p. 163). Hence, surface has a value in knitting, inseparable from the act of making. Arantes (2020a, 2020b) discusses knitted surfaces from a hand-knit perspective, highlighting discussion points around form and surface. Although discussing hand-knits, the concept that knitted surfaces "have to be brought into the final shape from the very beginning" (Arantes, 2020a, p. 162) is just as valid for a digitally knitted surface, in which coding of the surface is the beginning.

Knitted surface builds from multiple individual loops, each stitch communicating its material nature to the neighbouring points. Arantes (2020b) outlines how parameters such as materials, tools, patterns and yarns form a dynamic relationship or web of relations. Alteration of design elements within knitting affects all connective points and, therefore, sections within the entire built surface. Shifting knit parameters adds another layer of influence that underpins the surface, enabling multiple levels of matter activity to occur. Approached from a hand-knit perspective, research by Arantes (2020a) adds validation to the conversation around the importance of knitted surface as a site of information, where surfaces record material transformations, knowledge and layers of activity.

2.6 Origins of Inlay Knitting

The method of weaving yarn into a knit, or inlay knitting, is not a new idea; designers have previously explored this technique through hand knitting and domestic knitting machines. According to author Kathleen Kinder (1987) this knitting method first appeared in the 1770's producing "twilled, brocaded effects

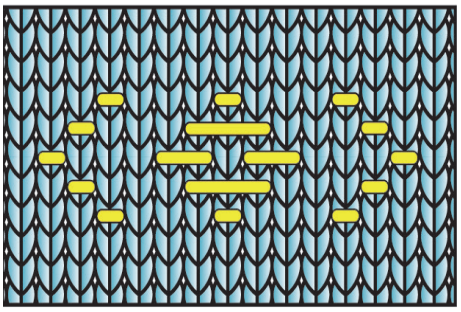


Figure 15. Woven hand knitting.
Note. Adapted from *The illustrated dictionary of knitting* (p. 266), by R. Compton, 1989, Interweave Press.

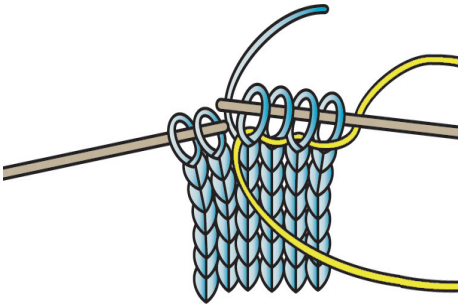


Figure 16. Weave laid-in yarn in hand knitting.
Note. Adapted from *The illustrated dictionary of knitting* (p. 267), by R. Compton, 1989, Interweave Press.

with silk as the inlay yarn" (p. 11). This research looks to the past as a foundation for building knitted textile practices (Kinder, 1987; Turney, 2009). As author Joanne Turney (2009) states in *The culture of knitting*:

> 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. (p. 61)

There is limited literature about digitally knitted inlay surfaces, unlike many other knitting topics, such as: Wholegarment® knitting (Choi & Powell, 2005; Smith, 2013; Taylor, 2015), knitted dimensional forms (Underwood, 2009; Landahl, 2013), form building (McKnelly, 2015; Kaylanji, 2020) or the history of knitting (Spencer, 2001; Power, 2007; Matković, 2010). In 1938 Mary Thomas published illustrations of machine knit weaving describing knitweave as positioned above or below the stitch loop (Kinder, 1987). Kinder (1987), in *Machine knitting: The technique of knitweave* writes a comprehensive history of the knitting technique from a domestic knitting machine perspective, including references to applications of the technique in the fashion industry. This book was written in the late 1980's however, current literature referencing the inlay technique is still often from a domestic or hand knitters viewpoint (Spurling, 2018; Haffenden, 2021). The majority of references to inlay knitting techniques overlook significant recent digital technological advances or design opportunities.

The hand-knitted version of inlay knitting (Figure 15), also referred to as woven knitting (Compton, 1988), is produced on two elongated knitting needles or pins (Gohl & Vilensky, 1993). This hand-created method involves placing a secondary yarn laid across knitted stitches as individual loops form. The hand-guided additional yarn remains detached, floating across and behind stitch loops, rather than fixed within the knitted textile (Compton, 1988). Patterns are crafted through calculated insertion and positioning of a horizontal laid-in yarn to build woven designs in a knitted surface (Figure 16). This hand-woven knitting technique was popular in the nineteenth century, using two or more yarns (Kinder, 1987).

In hand knitter June Hiat's book *The principles of knitting* (2012), several versions of handcrafted inlay are outlined, including purl knit and intarsia inlay techniques. According to Hiatt (2012), the technique is "most often done on a plain stockinette fabric because the added material is intended to be the primary focus and draw the eye" (p. 344). Plain stockinette fabric is a single jersey front bed knit and is commonly used as the ground for inlay knits produced by hand-knit and mechanised machines. Usage of domestic knitting machines peaked during the 1970s, when craft and hand-constructed methods were used to embrace the ambience of the handmade (Fogg, 2010). Domestic knitting machines are available as electronic and hand-operated equipment, capable of complex stitch patterning and colour design work. In the decade 1970 to 1980, many handcraft techniques were re-invented into mechanised versions (Fogg, 2010), with the inlay knitting technique one of these.

The domestic knitting machine version of inlay is referred to as weaving-in (Fogg, 2010), knit-weaving (Guagliumi, 1996) and knitweave (Kinder, 1987; Haffenden, 2018; Spurling, 2021). In the early to mid 1960's the Japanese released a single bed push-button knitting machines capable of producing knitweave (Kinder, 1987). These knitting machines use wheel brushes to direct the additional inlay yarn towards the needles, with the yarn manually placed into a yarn guide (Black, 2005). Author Susan Guagliumi (1966) suggests that, "knitting machine manuals tend to present knit-weaving as an all over, selvedge to selvedge technique that produces a fabric with limited horizontal stretch" (p. 100).

Machine needle selection occurs either through insertion of a punch card (Figure 17), electronic machine programming, or via the designer's labour intensive hand selection of needles (Black, 2005). Manual instructions for setting up the machine occur in a table or grid-like layout (Figure 18), with knit settings for repeat designs. This manual design set-up affords a hand–eye connection to the design, allowing designers to exchange inlay colours within the same knitted course (Black, 2005). Although knitted textiles are generated on a machine, the making process retains an element of handcraft evidenced in the output. These knitted textiles have reduced lateral stretch, permitting sideways usage or cut-and-sew applications similar to woven fabrics (Haffenden, 2018).

Digital inlay knitting technology, the focus of this research practice, is a reinterpretation of inlay mechanisms from hand and domestic machine knitting, a form of digital-craft. As Nilsson (2015) iterates in regards to the influences of technology developments on design:

> Thus as textile materials, techniques, and industries change, it is important to focus not only on developing new products but also on re-examining and developing design practice so as to fully realise – rather than waste – the potential of both traditional and new textiles. (p. 9)

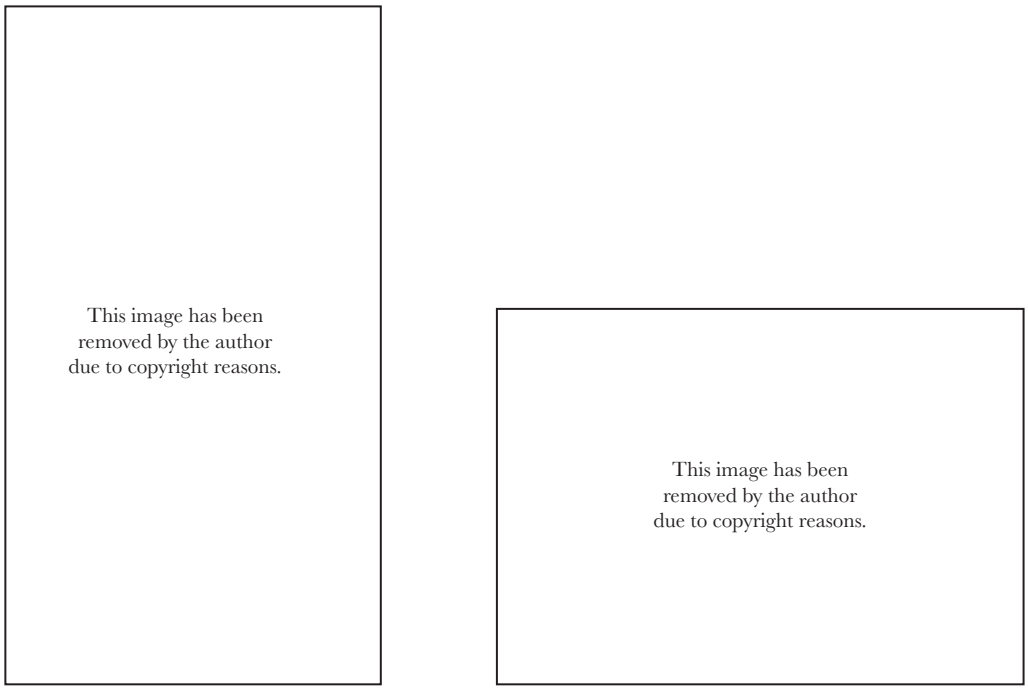


Figure 17. Inlay knitting sample with punch-card programmed pattern repeat.

Note. From *Brother punch card pattern* (Volume 4) (p. 216), n.d., Brother.

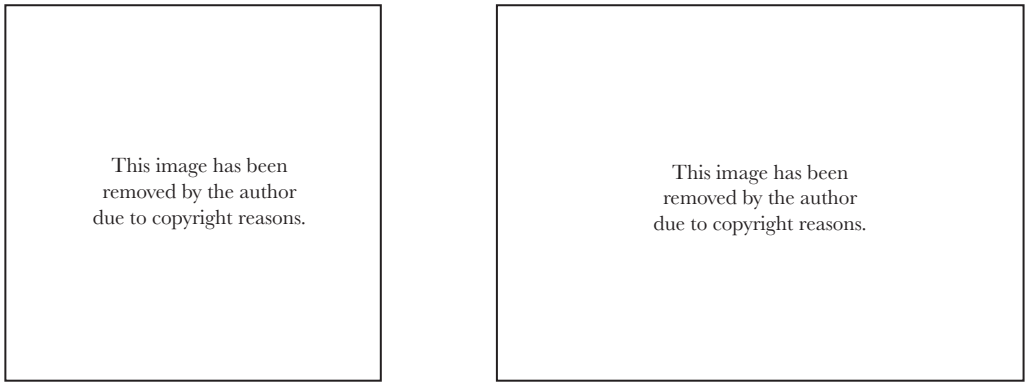


Figure 18. Inlay knitting sample with manual set-up instructions for pattern repeat.

Note. From *Brother punch card pattern* (Volume 4) (p. 210), n.d., Brother.

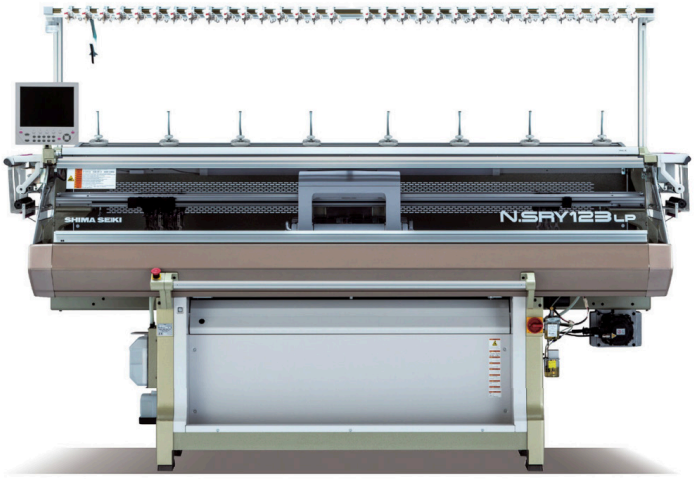


Figure 19. Shima Seiki Mfg. Ltd. inlay knitting machine N.SRY123LP. Photo courtesy of SHIMA SEIKI MFG. LTD.
Note. From Shima Seiki Mfg. Ltd., 2020 (https://www.shimaseiki.com/product/knit/nsry/).

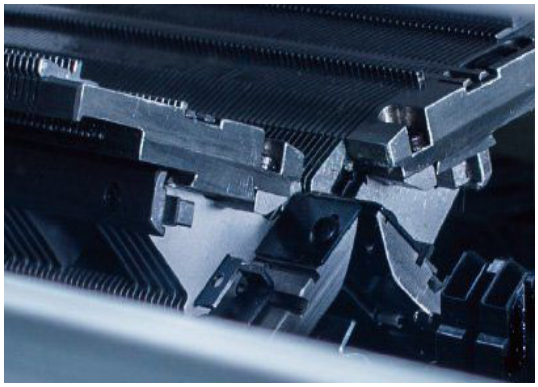


Figure 20. Loop presser bed.
Photo courtesy of SHIMA SEIKI MFG. LTD.
Note. From Shima Seiki Mfg. Ltd., 2020 (https://www.shimaseiki.com/product/knit/feature/#u2).



Figure 21. Two parallel needle beds.
Photo courtesy of SHIMA SEIKI MFG. LTD.
Note. From Shima Seiki Mfg. Ltd., 2020 (https://www.shimaseiki.com/product/knit/feature/#u2).

Although inlay as a textile technique has historical craft roots in hand and domestic machine knitting, it is only recently that digital knitting machines have embraced this method of construction. Past hand and domestic usage of the inlay knitting technique offers new possibilities for digital-craft translations (Haffenden, 2018). Although challenging to knit on digital knitting machines, the inlay technique was possible to achieve before the development of inlay-specific technology (T. Takahashi, personal communication, January 11, 2020). The Japanese company Shima Seiki Mfg. Ltd. released two versions of weft-insertion digital knitting machines in 2014: N.SRY123LP (Figure 19) and N.SRY183LP (Knitting Industry, 2014). In response to this technological development in 2015, competitor German knitting manufacturer H. Stoll GmbH & Co. KG. released a version called the Stoll Weave-In® (Knitting Industry, 2015).

The original Shima Seiki Mfg. Ltd. inlay machines were technique-driven rather than end-use-driven, resulting in shaping and design limitations due to the specialised knitting mechanisms. This research practice utilises the inlay design environment and technical attributes of the Shima Seiki Mfg. Ltd. SDS-One Apex3 software and N.SRY123LP knitting machine available at the Auckland University of Technology Textile Design Laboratory. This model is an original version of the inlay machines, with two loop presser beds (Figure 20) positioned above the parallel needle beds (Figure 21), and therefore more technologically limited than newer versions of inlay machines.

> Inlay fabric is produced by inserting yarn into existing knit fabric in a weave fashion, yielding unique fabrics that are neither typically knit nor woven. Inlay also suppresses typical stretch characteristics of knitwear, and since new yarns and materials can be used for inlay structures, new applications in addition to fashion apparel such as sports and medical as well as other industrial applications can be anticipated. (Shima Seiki Mfg. Ltd., 2020, para. 5).

According to a statement by Masaki Karasuno from Shima Seiki Total Design Centre, at the time of the original inlay knitting machine release, "New fabrics with woven effects offer great opportunities in expanding into other markets. Speciality yarns such as metallic and monofilament yarns can be knit as well, opening new doors to areas other than fashion" (Knitting Industry, June 27, 2014, para. 4). The development of inlay knitting technologies responded directly to the athletic sector's requirements for strategically placed support through yarns and stitch structures (Knitting Industry, 2014), as evidenced in the Nike Flyknit shoe series. The inlay knitting technique allows "for the production of hybrid fabrics that feature both knit and weave characteristics, suited to shoe upper applications that require formfitting function, comfort, flexibility, breathability as well as strength and stiffness" (Knitting Industry, October 30, 2019, para. 4). These unique hybrid traits offer alternative material properties, making the inlay technique ideal for

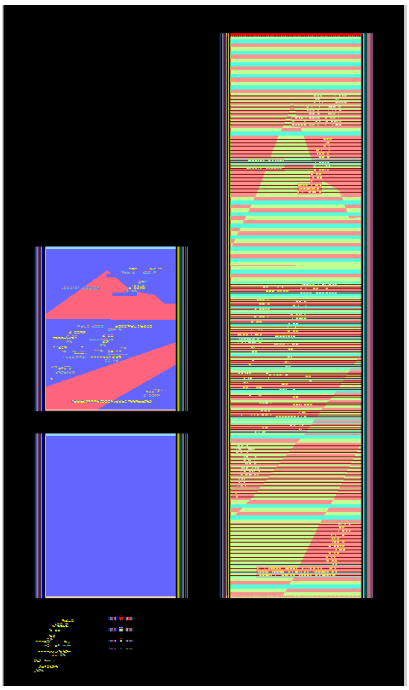


Figure 22. Screen in SDS-One Apex3 KnitPaint old-format software.

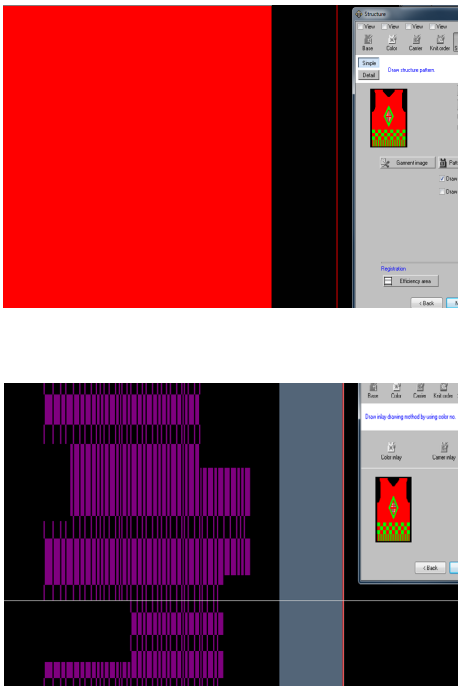


Figure 23. Multiple screens in SDS-One Apex3 KnitPaint automatic software.

applications outside knitted apparel, such as upholstery, interiors, sportswear and technical textiles.

The SDS-One Apex3 technical program, KnitPaint, creates the inlay design using either old-format or automatic software. Old-format software is a blank screen that allows specialised coding to be positioned on the page to build each knitted stitch (Figure 22). Designs generated in old format require manual processing of the encoded screen through a series of complex development steps. In contrast, designs produced using the automatic software (Figure 23) encompass arrangements of pre-set coded information. This pre-programmed set-up determines knitting size, stitch structures and finished edges, and incorporates an automatic development process. Although the automatic software offers a less complex digital environment, design limitations that necessitate programming in old-format software are often encountered. An extended discussion on the technical design role of the SDS-One Apex3 KnitPaint software concerning built inlay knitted surface behaviours is available in Chapters Four and Five.

2.7 Material-based Forces

Greek in origin, 'tectonics' originates from the word 'tekton' meaning carpenter or builder. This word has since expanded in an architectural framework to communicate the science or art of building (Semper, 2004), the structural and constructional relationship of architecture (Sekler, 1965) and the poetics of

construction (Frampton, 1995). Tectonics is a seminal concept used in architecture to define relationships between design, structure and materials (Oxman, 2012).

> When a structural concept has found its implementation through construction the visual result will affect it through certain expressive qualities which clearly have something to do with the play of forces and corresponding arrangement of parts in the building yet cannot be described in terms of construction and structure alone. For these qualities which are expressive of a relation of form to force, the term tectonic should be reserved. (Seker, 1965, p. 126)

Physical geographers James Peterson, Dorothy Slack and Robert Gaber (2017) describe tectonics as forces that "originate in the planet's interior, yet they contribute significantly to the nature of the Earth's exterior topology, affecting composition, shape, size and appearance of the surface terrain" (p. 386). This research study applies tectonics as crafted material forces that become surface builders, deforming and reforming the knitted surface. Making becomes an enquiry into a selected materials potential (Harris, 2005). In my knitted surface topographies, material forces are influenced by the fibre composition, yarn weight, knitting quality and stitch structure combinations. The material forces emerge as individual knitted stitch behaviours altering neighbouring alliances. This research practice maps the surface movements, viewing the material forces as an integral factor of the knitted surface topography design process.

Adapting the behaviour of the individual stitch modulates the multitude to inform a larger knitted surface area. Academic Rachel Philpott (2011) notes, "by managing the form, material and behaviour of the single unit, one is able to control the complexity of a larger structure" (p. 29). Manipulations of disruptions across knitted surfaces occur on singular or multiple scales. Ingold (2013) discusses the process of growth with the maker as a participant amongst the active materials. The designer works with the material forces during the making processes, "bringing them together or splitting them apart, synthesising and distilling" (Ingold, 2013, p. 21), generating an emergent outcome through manipulation of the relational knitted network. Academics Mike Anusas and Cristián Simonetti (2020) also embraced this concept of growth, viewing knit as an organism growing from the propagation of individual stitches. Inlay textiles react differently to solely knitted textiles due to additional variant material forces imposed by the hybrid construction methods and material properties. The knitted surface topographies in this study emerge from the interconnected layers of making, folding onto and into themselves, materialising as a surface synthesis of knitting and weave. Each time the physical knitting settles, it is a new version of itself as interconnected material forces restructure the knitted surface topography.

As Albers (2017) iterates, "sometimes material surface together with material structure are the main components of a work; in textile works, for instance, specifically in weavings or, on another scale, in works of architecture" (p. 45). Materials are an essential agent in the making of the textile, with materials playing a fundamental part in the assembly and transformation of knitted surfaces (Arantes, 2020b). "Materials generally denote substances that will be further processed, it points to the forces of production at the time" (Lange-Berndt, 2015, p. 15). The term 'material' depicts elements subject to alteration through interaction with handling, their surroundings or physical properties (Lange-Berndt, 2015). Programmed manipulation of the material performance through stitch combinations is key to the built knitted surface topographies developed in this research study. All materials bring individual traits to design amalgamations during knit production. However, inlay has an additional layer of interaction generated by the hybridity of the two-parent technique. Building a knitted textile is dependent on the combinatory choices of materials and construction techniques. The surface reacts to the density of materials, the tactility, and the space and voids generated (Persson, 2017).

Material can also be immaterial; an instance of this is digital coding (Wagner, 2001). Digital material holds no physical existence but contributes to the physical output when generating digital knitting. It is through two-dimensional virtual coding that the three-dimensional physical emerges. The "dynamic matter and digital data become materials for a generative design process where matter is decoded and recoded as new knit structures are explored" (Stephens, 2016, p. 13). The flow of material properties in a knitted textile is visible as the surface grows, revealing itself course upon course and building stitch by stitch. Arantes (2020b) follows the flow of materials (Ingold, 2007), and advocates the value of following the flow of material properties. This research expands on Arantes' (2020b) perspective, following the flow of material properties with arising material forces seminal to the built knitted surface topographies. The material properties have a voice that shifts as material alliances, and the knitting machine technical environments change. In knit, unlike most textile production processes, surface and structure are constructed in one process, and the material is an active participant from the beginning. Individual controlled loops exhibit properties from their yarn and stitch structure lineage, directly affecting local and global knitted surface topography and the mechanical result (Markande et al., 2019). Digitally knitted surfaces are material concretisations grown from precise programmed movements that illustrate technical knowledge and an in-depth understanding of materials (Arantes, 2020a).

Ingold (2020) suggests that form [or surface] is generated "through the gradual unfolding of that field of forces set up through the active and sensuous engagement of practitioner and material" (p. 342). The process of making transpires as a conversation between maker and material (Ingold, 2013). These entangled

relationships between materials and maker are not always conducive to perfect or harmonious outputs. Often frictional issues arise from a myriad of negotiated relationships between material design factors and technology (Arantes, 2020b). These oppositional aspects of crafted design escalate material forces in knitting, intensifying disruptions within the surface plane. Knitted surfaces become sites of narration, recording the interaction between material, maker and technology. Philosopher Manuel DeLanda (2004) discusses material-form relationships:

> We may now be in a position to think about the origin of form and structure not as something imposed from the outside on an inert matter, not as a hierarchical command from above as in an assembly line, but as something that may come from within the materials, a form that we tease out of those materials as we allow them to have their say in the structures we create. (p. 21)

In knitted textiles, an element of material speech is present within the surface itself. The conversations between the knitting machine, technological knowledge, designer and materials merge into the knitted surface. To build on this concept of material speech, Professor of Architecture Juhani Pallasmaa (2000) states, "Materials and surfaces have a language of their own. Stone speaks of its distant geological origins, its durability and inherent symbolism of permanence; brick makes one think of earth and fire, gravity and the ageless traditions of construction" (p. 4). What knitted surfaces can articulate hinges on the characteristics of material or yarn selected. Natural fibres retain memory of their origins; woollen yarn remembers the crimping of sheep fleece as elasticity, and silk fabric derived from finely spun fibres preserves an element of weightlessness.

Vibrant matter (Bennett, 2010) or active matter (Delanda, 2004; Ingold, 2013; Küchler, 2020), are materials and processes that dynamically participate in the assemblage of transformative knitted surface topographies. This creative practice considers the "possibility that materials possess a vitality and agency independent of, and yet entangled with, humans" (Preston, 2019, p. 32). This research draws on these notions of materiality, where materials actively contribute to the designer's practice. Knits emergent "matter-energy" (DeLanda, 2004, p. 19) is evident when the knit-weave aspect of links-links and inlay trigger dynamic surface interactions. Control of material forces through informed knowledge of material performance and the "systematic behaviour of its assembly" (Kolarevic & Klinger, 2013, p. 7) shifts resultant knitted surface topographies.

Anthropologist Susanne Küchler (2020) discusses the linkage between neighbourhood points, the inside and outside of surfaces hidden amongst folds and a manifestation of surface geometries. Surfaces reveal and conceal. The knitted surfaces in this project result from a multiplicity of colliding points, a "mapping of temporal processes" (Küchler, 2020, p. 187) or a tracing of active material forces in

motion. A knitted surface is not passive; it morphs, realigning as a different version of itself each time it resettles. Discussion concerning active matter is often from a stimuli-reactive, material or interactive, electronic, programmable perspective that contributes to the creative process (Bergstrom et al., 2010; Stephens, 2016). Viewing textiles as interactive materials, Küchler's paper 'Technological materiality: Beyond the dualist paradigm' (2008) provides a focused outlook on textiles with reactivity generated by an additional electronic stimulus. Knitted surface topographies in this practice rely on inherent material characteristics and heat-reactive properties of selected fibres combined with stitch structures to realise surface transformations.

This research aligns with the role of materials and technology being collaborating agents (Cooper, 2014) that provide a level of autonomy to the surface design process. The maker and active material work together as participants rather than imposing their will upon the output (Delanda, 2004; Lange-Berndt, 2015). Following the properties of the materials (Arantes, 2020b) promotes conversations between assembled heterogeneous material performers (refer to Figure 14, page 16). Materials have agency. They move and act as if with a life of their own (Lange-Berndt, 2015), reacting to material forces transforming the knitted surface. In digital inlay knitting, active matter emerges through the material flux and digital coding as material forces disrupt surface equilibriums.

2.8 Craft Influences

Assemblage of the dynamic material forces occurs through methods of hybrid crafting (Golsteijn et al., 2014). Hybrid crafting refers to making where "both crafting process and result will include both physical and digital elements" (Golsteijn et al., 2014 p. 594). Crafting in this sense is not handmade; instead, it references original textile-making techniques that are reinterpreted and assembled as digital data. This research is positioned at the juncture intersecting craft-based textile knowledge and digital textile technologies. "Digital fabrication methods are opening up new [hybrid] possibilities for craft, art and design" (Zoran & Buechley, 2013, p. 5). The application of craft knowledge and ethos to technology and production offers opportunities to produce "continuous innovation and repeated uniqueness" (Woolley, 2011, p. 20) in mass production environments (Niedder, 2009). As academic Jenny Underwood (2009) states:

> The role of textiles is changing...What we are seeing is perhaps a return to the designer as a material innovator. Innovations and advances in textile fibres and tech are influencing how textiles are being used. Traditional techniques and technology, the ornamental and structural, and the micro and macro are blurring. Textile techniques, once associated with being hand-crafted are being transformed into high tech automated processors using sophisticated and complex technology and machinery. (p. 156)

In this research, craft, crafting and craftmanship are applied expert knowledge and mastery of a technique or material (Dormer, 1997). Author Peter Dormer (1997) notes, "it is craft not as 'handcraft' that defines contemporary craftsmanship, it is craft as knowledge that empowers a maker to take charge of technology" (p. 140). Craft applications expand through the inclusion of technologies: "a driving factor of digital craft is its combination of new technology with physical hands-on experience" (Nitsche et al., 2014, p. 720). The digital knitting technologies employed in this research are seen as materials to empower the maker-researcher when combined with designerly knowledge informing digital outputs (Cross, 1997; Nitsche et al., 2014). Academic David Pye (1968) discusses craftsmanship offering a meaning applicable to contemporary digital making:

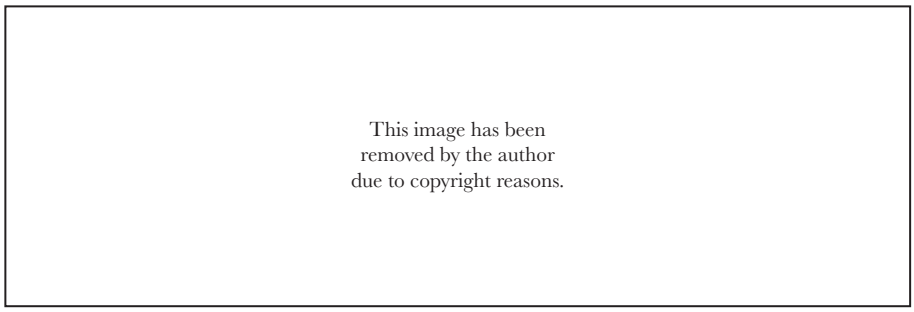
> Craftmanship…means simply workmanship using any kind of technique or apparatus, in which the quality of the result is not predetermined, but depends on judgement, dexterity and care which the maker exercises as he works. The essential idea is that the quality of the result is continually at risk during the process of making. (p. 20)

McCullough (1998) states, "we build up digital artefacts one step at a time, one piece on top of another, with what is already there affecting what is to come" (p. 155). This idea of built artefacts relates to inlay knitting, where layering the connective material forces of singular points affects the neighbouring surface dynamics. This controlled building of componentry to craft the whole begins at programming stage, with assemblage of coded information required to produce the knitted surfaces. The knitted surface being virtual before being made physical, the intangible code builds tangible outputs.

Hybrid digital-crafting is not new, it is now over 20 years old as a concept; however, as digital tools have become more accessible the debate around craft and computing practice has grown (Harris, 2012). In relation to digital-craft practice, academic Jane Harris (2012) notes:

> Progressing beyond the technical range of digital media, the craft sector is arguably just beginning to demonstrate how computing output may benefit from an ethos of making that incorporates poetic and aesthetic concepts akin to more conventionally crafted forms. It could also be argued that through experimental engagement with digital media, computing is to some extent indirectly repositioning, perhaps even reinvigorating, craft practices, highlighting strengths. (p. 109)

In many textile industries, the application of digital technologies such as computer numerical control (CNC) machinery and digital textile print have refined a connection between virtual and actual making. However, digital knitting has



The technical front view. The technical back view.
Figure 24. Inlaid tube in half milano knitted stitch structure.
Note. From "Development of laid-in knitted fabric for buoyant swimwear," by N. W. Li, C. P. Ho, K. L. Yick, and J. Y. Zhou, 2020, *Journal of Industrial Textiles,* p. 6.

always struggled with the virtual-to-physical translation due to the complex computer interface and the inherent physical material properties of knit. Many makers struggle with designing on-screen, citing a disconnect caused by a lack of haptic stimuli digital-crafting offers (Prytherch & McLundie, 2002; Harris, 2005). "Inherent in such practitioners is the compulsion to interrogate materials and tools, defining new languages of construction and process" (Harris, 2012, p. 92). I discovered that my making operated in a fluid virtual-physical space, where my digital skills became more intuitive, contributing to a broader range of potential material practice (Harris, 2005).

Digital creative methods are more often associated with mass manufacturing than the craft-making environment (Harris, 2012); however, this research aims to increase awareness of the potential of inlay knitting technologies to produce hand-like aesthetics, triggering conversations around future usage by craftspeople. The personal skill and in-depth knowledge of knit programming I possess is a unique opportunity to contribute to the digital knit environment from design and technical perspectives.

2.9 Contemporary Inlay Practice

There is limited research about inlay digital knitting techniques and technologies, with the main focuses in this area found to stem from architectural, engineering and medical applications. These functional inlay applications have directed research into areas such as textile reinforcement for concrete structures (Balea et al., 2014; Lee et al., 2020), compressional medical garments for therapeutic and sports applications (Bera et al., 2016; Xiong & Tao, 2018) and buoyancy fabrics (Li et al., 2018, 2020). One of the functional applications for the inlay technique is research investigating low-density, high-buoyancy fabrics for swimwear (Figure 24) conducted by engineers Li et al. (2018, 2020). The production of the buoyant knitted textiles uses inlay knitting technology to insert hollow tubes inside stitched

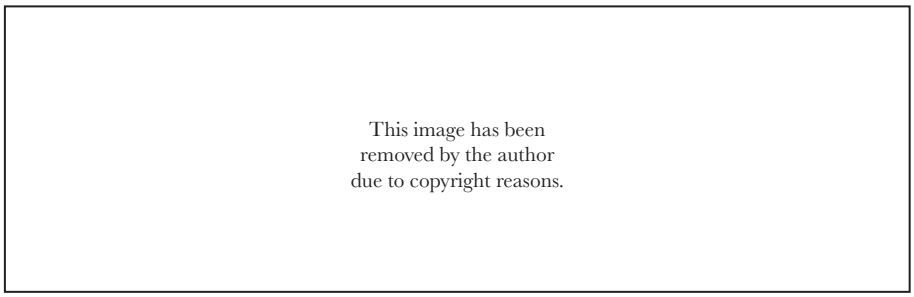


Figure 25. Inlay knitting of pleated circle.
Note. From *The space in between: Exploring weave knitted textiles by constructing surface patterns on three-dimensional shapes*, by V. Hohenstein, 2017, Student Thesis, University of Borås, Faculty of Textiles, Engineering and Business, p. 3.

layers. Li et al. work with a half milano knitted stitch structure. Half milano knit is constructed from two courses of double jersey and one course of single jersey knitting. The stitch structures result in interior space between front and back knitted layers, allowing placement of a tube inside the stitches. This research follows a formulaic, regimented process of testing the floatation efficiency of the textiles. Although this is a functional approach to inlay applications, insertion of yarn inside knitted textiles is relevant to the double bed developments with interiorly placed yarns discussed in Chapter Four.

Master's student Viviana Hohenstein (2017) includes a design approach to inlay knitting in her thesis *The Space in between: Exploring weave knitted textiles by constructing surface patterns on three-dimensional shapes*. This research was conducted at the University of Borås, Sweden, and used the H. Stoll GmbH & Co. KG. Weave-In® technology in a technical facility similar to the Auckland University of Technology's Textile Design Laboratory. Hohenstein created shaped pieces and stitched the separate panels to generate three-dimensional silhouettes. The inlay technique in Hohenstein's research explores colour, yarn and shape (Figure 25). However, the inlay designs only apply the technique across the textile from edge to edge, as all-over inlay with a front bed knitted ground. This approach to inlay design imitates the application techniques demonstrated by the knitting machine manufacturer, with a similar aesthetic to domestic machine swatches. Therefore, I believe the positioning of the inlay knitting technique constrains the research outputs achieved by Hohenstein. This constraint highlights opportunities for an alternative design practice utilising inlay knitting technologies to extend inlay techniques into more unique directions through weave replication, placement, scale and compositions of variant ground stitch structures.

As with Wholegarment® technology, where the knitting industry was slow to embrace technological potential (Hunter, 2004; Black, 2005; Power, 2007; Smith, 2013), I believe inlay knitting technology is technically more advanced than the designs released by Shima Seiki Total Design Centre and used by industry designers. Academic Jess Power (2007) states in her review of knitting technologies



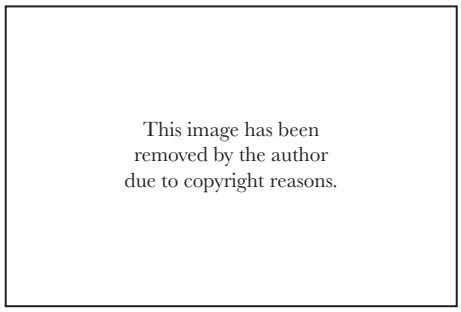
Figure 26. Inlay-knitted shoe by Shima Seiki Mfg. Ltd., exhibited at Pitti Filati, Florence, 2019.



Figure 27. Weave-in knitted bag by H. Stoll GmbH & Co. KG., exhibited at Pitti Filati, Florence, 2019.

through the ages, "throughout history there appear to be periods of innovation where technology leads design, followed by periods of development where design exploits the technological capability and then the cycle repeats" (p. 10). Many knitted sample swatches distributed to companies primarily portray all-over inlay knitting with jacquard-like repeating patterns. These selvedge to selvedge inlay swatches remain primarily within a jacquard aesthetic similar to examples of all-over inlay knitting found in domestic machine knitting books (Guagliumi, 1996). This jacquard-based design aesthetic was reinforced in the inlay training I received in January 2020 at the Shima Seiki Mfg. Ltd. facility in Wakayama, Japan. Samples generated in training sessions followed a strict formula that referenced jacquard designs previously created by the technical tutor. In the main, this inlay knitting technology has been used for replication, rather than for creative design generation.

More creative and advanced inlay knitted developments are emerging, usually from Shima Seiki Mfg. Ltd. (Figure 26) and H. Stoll GmbH & Co. KG. (Figure 27) technical research and design departments. These designs extend technical boundaries of inlay application, shifting into design areas such as woven-lookalike apparel, footwear and products. Knitted designs viewed at the Shima Seiki Total Design Centre in January 2020 showcased complex shaping and knitting techniques blended with inlaid yarns. However, designers who undertake the official Shima Seiki Mfg. Ltd. training are encouraged to use pre-programmed patterns from the SDS-One Apex3 design-software pattern library. These pre-set inlay designs are similar to the stitch structure library available for pre-programming knitted surfaces. Although initially helpful in expanding knit knowledge, these pre-programmed patterns can prevent creative leaps (Archer, 1964) and limit design innovation. This method of creating with pre-set designs is a recognised design issue, as witnessed in the programming of Wholegarment® knitting, where pre-set shapes have significantly reduced creative design developments (Black, 2005; Smith, 2013; Kalyanji, 2020).



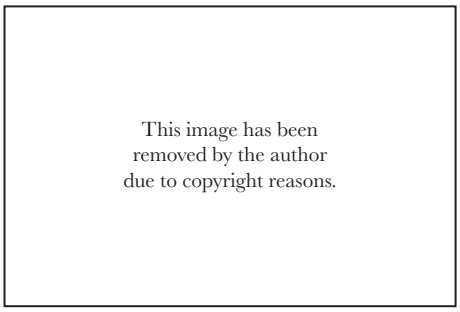


Figure 28. Kitty Pennybacker knitweaving with large floats, knitted on a domestic knitting machine. *Note.* From Etsy, 2021 (https://www.etsy.com/uk/listing/940289527/pink-blue-scarf?ref=shop_home_active_18&frs=1).

Contemporary designer Kitty Pennybacker's creative practice blends textile skills of knitting, weaving, cording and felting. The predominantly interior focused outputs are created on domestic knitting machines using the knit-weave technique (Figure 28). The knitted textiles primarily consist of 100% wool and employ an intarsia approach. The designed sections of inlaid yarns positioned into the knitted ground explore texture and colour (Pennybacker, 2021), forming large intarsia inlay pattern repeats. An old cording machine has developed a unique process which generates thick cording from wool (Pennybacker, 2021). The cord is manipulated into designs with large floats, unlike the practice in this research, which adapts traditional weave patterns using small picks and floats. Although Pennybaacker uses mechanised domestic knitting machinery, the making process is labour intensive, "a scarf can take two days to make, a throw a week and cushion covers a couple of days" (Scott, 2019). These handmade textiles are an example of where digital inlay knitting could mimic analogue knit aesthetics, providing time-saving production opportunities for bespoke knits.

2.10 Building a Language

Knit language in academia tends to communicate in knit specific technical terminology based on the mechanics of production used by technicians and designers in an industry situation. The issue of communication of knit information amongst knit designers and technicians (Eckert, 1997; Underwood, 2009; Yang, 2010) and between knitters and other disciplines (Glazzard, 2014) is widely acknowledged. Glazzard (2014) discusses the influence language had on participants in her doctoral research focus groups, with engineers, scientists, and textile and product designers reacting differently to commonly used industry knit terminology. This issue of understanding highlights discipline demarcations in thinking and the need to access a less field-specific language for interdisciplinary discussions around knit design extension and practice. Underwood (2009) and Kalyanji (2020) both refer to architectural terminology to contextualise the built components of their shape-focused research.

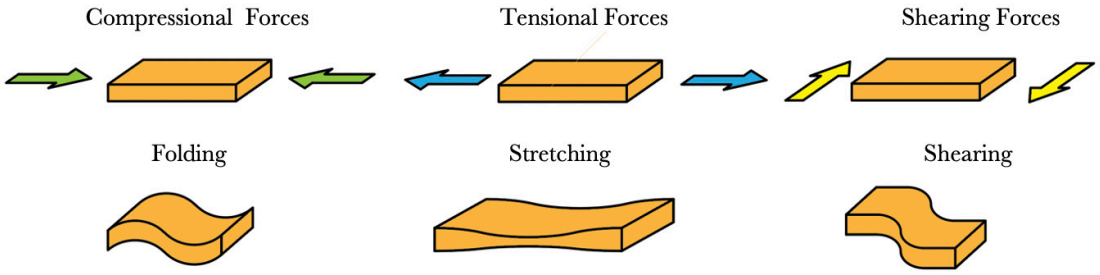


Figure 29. Three types of surface forces.
Note. Adapted from *Physical geography,* (p. 389), by J. F. Peterson, D. Slack, & R .E. Gabler, 2017, Cengage Learning.

This research draws on geomorphology, the study of "Earth's landforms and its surfaces processes" (Rosenburg, 2019) for language to analyse the knitted surface movements and navigate this design practice. Geomorphology, a sub-field of physical geography and geology, shares terminology with multiple Earth sciences disciplines (Rosenberg, 2019). Discourse in this thesis refers to three principal types of tectonic forces. Compressional forces push together, tensional forces pull apart in opposing directions, and shearing forces slide past each other (Figure 29). These Earth based tectonics are also known as convergent, divergent, and transformational forces (Plummer et al., 2018). Compressional forces create symmetrical and asymmetrical folds (Peterson et al., 2017). In this research, knitted material forces observe similar surface movements affected by the positioning and scale of links-links stitch structures.

Folding transforms surface depth, width, length and volume and divides the surface, blurring edge boundaries (Philpott, 2011). Geomorphology offers an expanded vocabulary to traverse the deformative knitted surface. Tight folds occur when the space between links-links stitch structures is small and broad folds when wider spacing is evident between links-links stitch structures (Figure 30). Examples of language similarities between disciplines are 'ground', referencing the Earth and knitted surface and 'fault' used to describe an area of rupture caused by stresses (Burbank & Anderson, 2012). The built surface movements in this practice exhibit textural qualities similar to the Earth's topographical characteristics. Topography is "the arrangement of high and low elevations in a landscape" (Peterson et al., 2016, p. 631). The Earth's exterior topography is changed by the composition, shape, size and appearance of the surface (Peterson et al., 2016). The word topography is used in this research to identify knitted surfaces which result from the collision of tensions, stresses and material forces transferred within a knitted pliable plane. Peterson et al. (2016) suggest that "primary geomorphic mechanisms increase the topographic irregularities on Earth's surface" (p. 386). A hybrid vocabulary derived from the glossary of terms (refer to page 144), and geomorphic terminology (refer to Appendix A) assists navigation of the knitted surface practice in Chapters Four and Five.

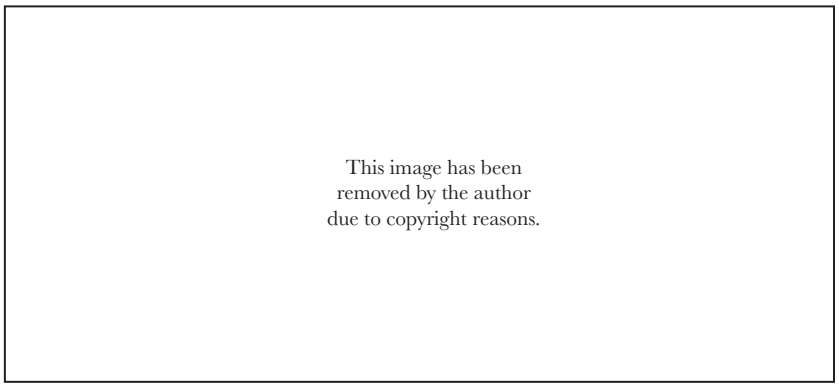


Figure 30. Geomorphic folds formed by tectonic forces

Note. Folded rock structures become increasingly complex as the applied compressional forces become more unequal from the two directions. From *Physical geography* (p. 395), by J. F. Peterson, D. Slack, and R .E. Gabler, 2017, Cengage Learning.

2.11 Conclusion

This chapter, *Traversing the Scope*, positions links-links and inlay knitting techniques and highlights the significance of knitted surface, valued for its surface factor rather than its textile application or form. An examination of relevant literature established a contextual background for this research. These theoretical strands embed further into this study as the practice developments unfold, revealed and concealed through the built knitted surface topographies. In addition, a descriptive language emerged, blending knit and geomorphologic terminology to articulate crafted material forces and resultant surface aesthetics. The research generated through this technique-led journey amalgamates practice-led knowledge which builds on the research milieu outlined in this chapter.

Chapter Three: Crafting a Knit Framework

> The identification of an analytical method allows us to suppose that the artistic object no longer appeared to the eyes of logic painters as something fatally and mystically all-encompassing, homogeneous, and unanalysable, but rather it established itself as a producible and analysable entity, in its heterogeneous factors, in relation to a model of construction and decoding. (Celant, 2009, p. 13)

3.1 Introduction

This chapter outlines broader methodological framing of the research before addressing the design methods and processes that underpin key phases of the practice. This study is primarily a technique-led investigation through the generation of crafted knitted surface topographies. As highlighted in Chapter One, the fundamental aim of this research was to investigate the links-links and inlay knitting techniques and their potential to build knitted surface topographies through the assemblage of material forces. The overarching framework in this research aligns with action research (Schön, 1983; Frayling, 1993; Swann, 2002), particularly the subcategory known as practice-led research (Gray & Malins, 2004). The subjective nature of practice-led research means that using several research approaches is typical, but inevitably the practice develops its own distinct blended methodological identity (Gray & Malins, 2004). Constant reflection-in-action and reflection-on-action (Schön, 1983) occurred in this practice-led research to build technique and technological know-how through digital-physical making. A hybrid methodological approach was applied utilising tacit knowledge (Merleau-Ponty, 1965; Dormer, 1997) and influenced by traditional craft contexts and my unique textile-design and knit background.

Although literature written specifically on knitting methodologies in a design-research context is limited (Bye, 2010; Glazzard, 2014), the very act of knitting requires physical practice and therefore becomes a method, used to generate new knowledge. According to academics Jon McCormack, Alan Dorin and Troy Innocent (2004), "generative systems offer a methodology and philosophy that views the world in terms of dynamic processes and their outcomes" (p. 1). Rather than approaching the question of surface transformation from a calculable perspective, this research manipulates layered elements to build material forces in dynamic knitted surfaces. This practice was influenced by my textile design background and the introduction of a geomorphic language base, resulting in

a new approach to knit design. The knitted surface becomes an articulation of knowledge (Seago & Dunne, 1999; Mäkelä, 2007; Finn, 2014), as noted by fashion academic Angela Finn (2014):

> The design aesthetic, methods of construction – both textiles and garment – and the quality of materials form part of the knowledge encapsulated in garment objects. Decoding this knowledge requires the researcher to draw on their expert knowledge to place objects within a market or make deductions about its quality. (p. 141)

Designed artefacts collect and preserve information. However, objects are mute and need ways to tell their story to become actual research. As enlarged upon in this chapter, this research study uses materials and technologies to record the making process, with knitted surfaces seen as articulations of the accumulated knowledge. Arantes (2020a) adds to the discourse around knitted surfaces as valid sites of experience that record material transformations and activity. The hybrid knitted surface and the creative process, in turn, become signifiers, places of discovery and vehicles of knowledge (Mäkelä, 2007; Nimkulrat, 2013).

3.2 Designer's Tacit Intuition

This practice-led research operates from the point of accumulated tacit knowledge (Merleau-Ponty, 1965) within the field of digital knitting. "Tacit knowledge is personal know-how, and it exists in people" (Dormer, 1997, p. 147). Tacit knowledge is intuitively applied in this 'making' and amassed from years of personal knit experience and engagement with physical textiles. Independent of our minds, our bodies are a means "through which we come to know the world and articulate our sense of self" (Negrin, 2015, p. 115). My accumulated experiential learning across multiple textile disciplines has created a knowledge nexus that forms a research bridge between craft-making skills and technological knitting abilities.

In textile design, haptic connections form between the maker and the materials (Igoe, 2010). "Haptic sensibilities, by their very nature defy reductionist methods of investigation, yet are demonstrably highly significant in the perception of our reality." (Prytherch & McLundie, 2002, p. 38). For me, part of knowing and understanding knit qualities is acquired through repetitive haptic stimulation (Prytherch & McLundie, 2002). Interpretation of on-screen codes requires physical prototyping to understand the actual knitted surface. Direct interaction and bodily engagement with materials, craft techniques, tactile surfaces and textile technologies leads to innate tacit knowledge or experiential knowledge (Albers, 1965; Igoe, 2010). Tacit knowledge is acquired physically and intellectually as a "result of

using both intellectual and material tools" (Crouch & Pearce, 2012, p. 38). This form of knowing is difficult to quantify, as it is subjective. Still, academics Kristina Niedderer and Catherine Townsend (2010) suggest documentation and visual evidence recording the experience can support intangible facets of tacit knowledge in research.

Academic Elaine Igoe (2010) "warns of the dangers of reliance on tacit knowledge and the importance to question the tacit", endorsing "the ability to begin to objectify, articulate and challenge assumptions" (p. 2). Although tacit knowledge embeds in my practice, it can also be a design constraint. Knit programming is taught in a structured and controlled manner that can limit experimentation of alternative approaches to the technology. Hence, design freedom arose from a lack of formal training or prior knowledge of inlay knitting technologies at the beginning of the research, just a basic conceptual understanding of the technique. The experiences gained through self-instruction were pure technology, material and designer versus outcomes obtained by following the structured programming notes found in the SDS-One Apex3 KnitPaint help menu. The learning acquired during this design autonomy or freedom has remained visible in the knitted surfaces produced. However, the technical knowledge obtained during the Shima Seiki Mfg. Ltd. structured training in January 2020 has also significantly influenced the practice-led research outputs.

3.3 Making in a Hybrid Environment

This research applies a hybrid crafting (Golsteijn et al., 2014) approach to qualitative research similar to bricolage (Kincheloe, 2001; Lincoln, 2001), through interdisciplinary practice. Practice-led research focuses primarily on the act of making and the generation of new outputs (Scrivener, 2000). Knitting is a practical craft with physical, tactile outputs. The digital knitting environment lends itself to practice-led research due to the extreme difference between two-dimensional and three-dimensional surfaces. In addition, design variables such as materials, stitch structure, machine gauge and knitting tension influence the physical knitted surface. Constant reflection-in-action and reflection-on-action (Schön, 1983) occurred in this practice as a methodology of building know-how through digital and physical making to generate complex knitted surfaces emerged. Donald Schön, in *The reflective practitioner* (1983), proposes the idea of reflective research activity as a practice-based epistemology with the reflective practitioner central to the research. This practice-led accumulative approach fostered a greater understanding of the physically connected material behaviours that occurred in this study between positioned material forces.

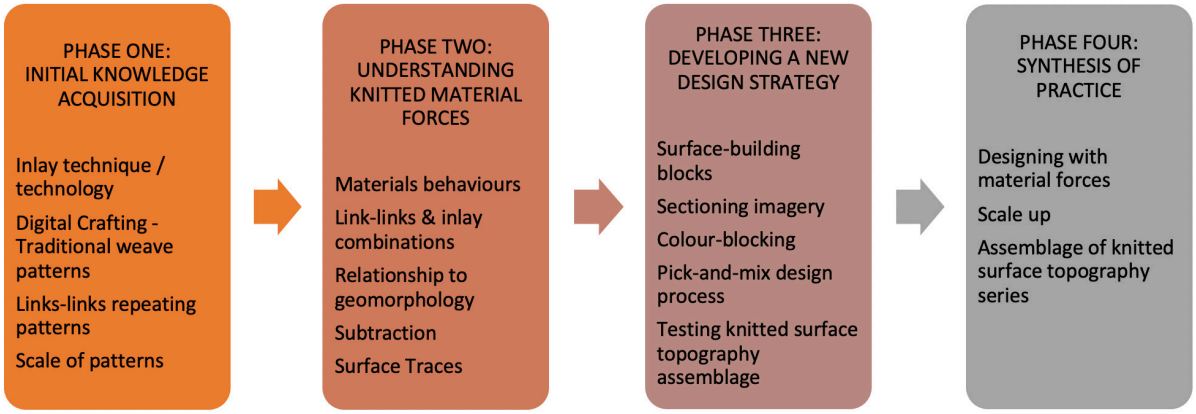


Figure 31. Research phases of the practice.

3.4 Interlinked Research Phases

This hybrid practice evolved through intersecting research phases into a knit surface-building methodology. Although mapping the research into phases (Figure 31) enables the practice to be structured, the actual pathway followed was less linear and contained cross-over points as ideas interlinked and knowledge increased. Phase One, *Initial Knowledge Acquisition*, focused on initial learning of the inlay technique and technology through stitch structures, materials, repeating patterns, traditional weaves and scale investigations. Phase Two, *Understanding Material Forces*, used geomorphic language to analyse knitted material forces and articulate surface deformations that occurred during layering of knitting techniques and material behaviours. Phase Three, *Developing a New Design Strategy,* informed the generation of the surface-building blocks and a pick-and-mix design process. Phase Four, *Synthesis of Practice,* explored the application of material forces and surface-building blocks to assemble larger complex knitted surface topographies. This technique-led approach to the research fostered a greater understanding of the digital-physical material behaviours that occurred in this study between positioned material forces and the knitting techniques; links-links and inlay.

In this research study, reflective analysis of the knitted surfaces and encountered material forces provided a critical focal point to the research methodology. Author Nigel Cross (2006) describes "the study of form and configuration of artefacts" as "design phenomenology" (p. 101). Cross (2006) implies that understanding the output is "where design knowledge resides in products themselves: in the forms and materials and finishes which embody design attributes" (p. 101). This research builds on this concept of understanding beyond the object to include a material force assemblage process that combines multiple methods of creation. Although the research pathway was at times indistinct, as I ventured into the role of a designer-researcher these linkages between methods and practice strengthened. As Philpott (2011) notes, "it is essential that these documentation methods be systematically integrated with reflective practices in order to evolve the practice in a meaningful

way" (p. 33). Multiple mind maps throughout the research journey revealed and modified relationships between the making and theoretical concepts, consolidating the practice pathway.

3.5 Role of Reflective Practice

Retrospective connectivity through reflection-on-action (Schön, 1983) permitted an element of the creative leap (Archer, 1964) or intuitive shifts of perception to manifest as altered viewpoints in the research process. Cross (1997, 2006) writes about design thinking and views moments of illumination as a 'creative bridge' building connections between creative designs. These inspirational instances occurred during exploration of inlay techniques, between ideas and the actual, the digital screen and physical textile, the active materiality of the knitted surfaces. Recording processes acted as a structural boundary to ensure practice-led rigour through the creative practice as an evolving 'reflection-in-action' and 'reflection-on-action' cycle (Schön1983; Scrivener, 2000). Academic Maarit Mäkelä (2016) writes:

> When documenting their creative processes, they consciously reflect on their current experiences during the process (reflection-in-action) and on the documented experiences once the entire process has been completed (reflection-on-action). In this way, documentation can assist in capturing the experiential knowledge in the creative process so that what the practitioner learns from within her practice becomes explicit, accessible and communicable. (p. 2)

Reflective practice occurred throughout the creative process, with reflection-in-action during the making and reflection-on-action (*Schön, 1983),* capturing my analytical process through journals and mind mapping. In *Doing research in design*, authors Christopher Crouch and Jane Pearce (2012) suggest that "practice is a combination of tacit and explicit knowledge, and it is the researchers job to try and unravel the two" (p. 38). When first programming my process followed a series of consciously created designs to understand the inlay technology. However, as my knowledge increased, programming became more intuitive. An element of unconscious creativity emerged enhanced by an ability to read the two-dimensional screen as a three-dimensional knit. Operating the knitting machine provided additional opportunities to acquire tacit knowledge from immediate interaction with stitch quality, tactility, knit handle and material behaviours. This design approach encouraged creativity as prototypes were emergent and evolved through generative feedback loops between maker and technology (Stephens, 2016).

Additionally, practice-review sessions occurred during several research phases, highlighting interrelated key findings and the significance of particular knitted



Figure 32. The practice-review process.

surface techniques for further experimentation. The practice was positioned in non-hierarchal groupings on tables and frames (Figure 32) for viewing by other designers. This practice-review process engaged with multiple perspectives and allowed an additional level of objectivity to enter this development process. Inclusion of progress critiques in the research approach was immensely beneficial, as often my perception was too intertwined with the knitted technical factors to see significant design aspects. The inclusion of alternative voices reinforced the importance of the digitally knitted surfaces and aided in building robust conceptual connections between the practice, theory and design. This review process enabled me to structure the research, establishing fundamental linkages within the practice while also reordering my design thinking.

Christopher Frayling's (1933) discussion on research methods in design questioned, "How can I tell what I think until I see what I make or do?" (p. 7). I would rephrase the question to include the need to touch what I create: How can I tell what I think until I see *and touch* what I make and do? The tactility and the physical touch of the knitted surface provided additional information and more profound understanding (Harris, 2005). Albers (1965) discusses tactility, stating that material surface and structure are the main components of textile work. The physical, pliable handle and ability to fold, unfold, and refold as alternative knitted surfaces is conveyed through the fingers, a physicality perceived not solely by the eye. One of my methods of reflective practice is to touch, my fingertips absorb information (Igoe, 2010); therefore, the physical engagement with the knitted surface topography is integral to knowledge acquisition in this research (Harris, 2005).



Figure 33. All-over inlay knitting with float variations.



Figure 34. All-over inlay knitting with striped racked stitch structure.



Figure 35. All-over inlay knitting with lace stitch structures.

3.6 The Act of Making

3.6.1 Inlay Investigations

A personal ability to navigate the virtual and physical environments of digital knitting knowledgeably was critical to fostering a stronger design position (Philpott, 2012). Developing this understanding of new technologies was seen as an opportunity to craft and extend known knitting techniques beyond the expected (Niedderer, 2009). Exploration of the inlay technique started with all-over inlay designs using the SDS-One Apex-3 automatic software to understand inlay programming and possible visual aesthetics. The prototypes investigated the length of floats (Figure 33) and placement of different combinations of inlay pick and float. Initial prototypes naively mixed knitted stitch structures, purl, rib, lace transfer and needle racking with inlay knitting (Figure 34, 35). These deviations from the typical single stitch structure generally used for inlay designs were considered peculiar by experienced knit technicians at the Shima Seiki Mfg. Ltd training facility in January 2020. However, a deeper understanding of inlay techniques' potentiality and knitting machine knowledge evolved through programming these all-over inlay prototypes. (The technical steps for programming a single bed all-over inlay knitted surface are available in Appendix B.)

Initial practice mapped the inlay knitting applications and built connections between techniques, informing a lineage chart (Figure 36). Initial inlay prototyping provided an overview of single-bed, double-bed and rib knitted grounds with various inlay surface aesthetics. These inlay knitted surfaces embody hybrid material properties from the parent textile techniques: knit and weave. The knitted surfaces manifest variable material characteristics (refer to Figure 14, page 15), depending on the placement and inlay pattern selected. Control of the design process from an idea into a two-dimensional code to a three-dimensional prototype

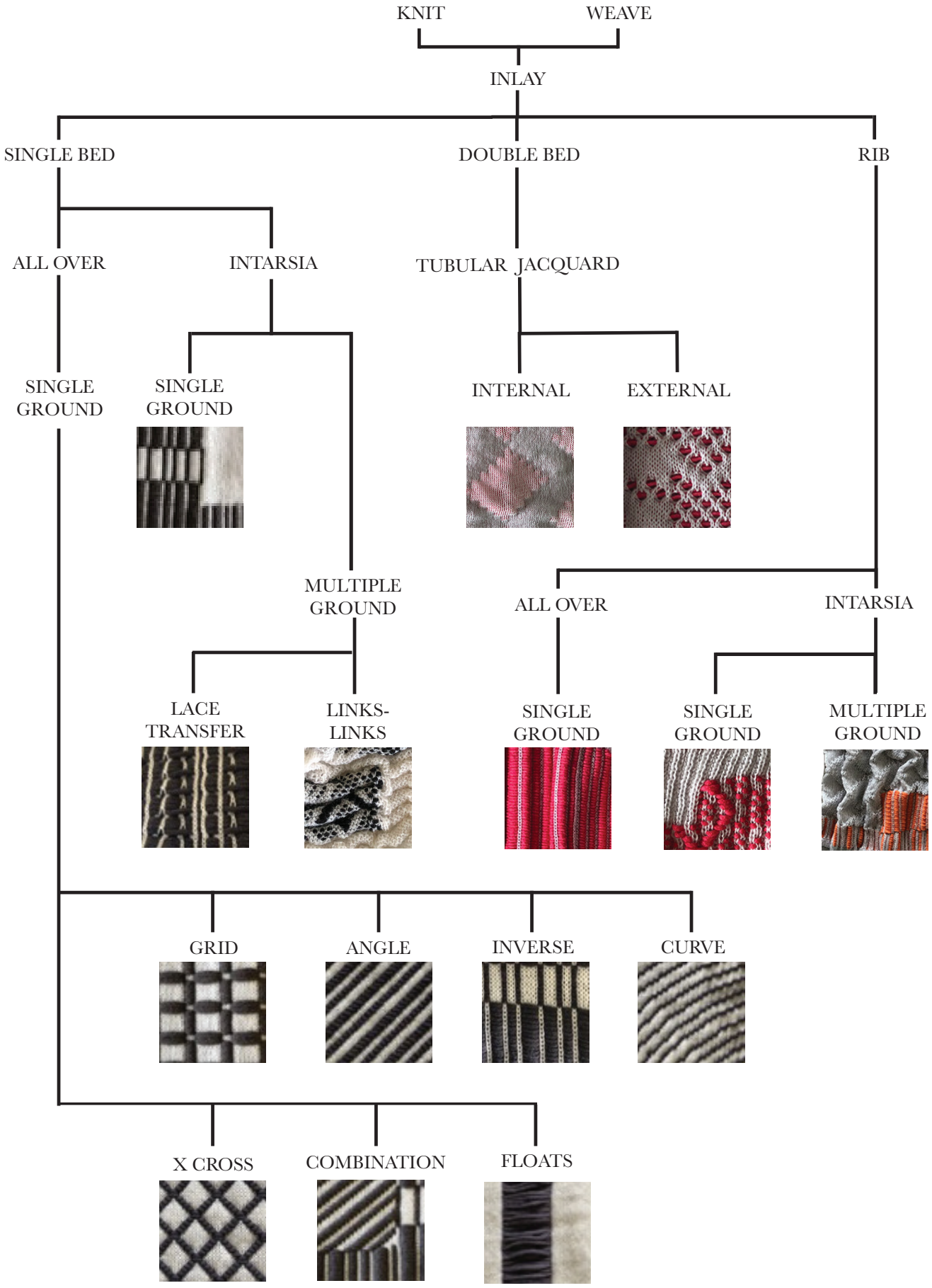


Figure 36. Mapping the lineage of inlay technique initial practice.

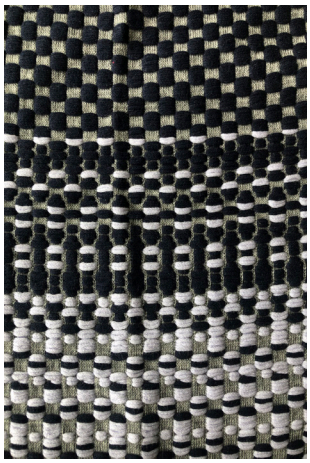


Figure 37. Two colour all-over inlay with one colour ground.



Figure 38. Two colour intarsia inlay with one colour ground.



Figure 39. One colour all-over inlay with two colour grounds.

provided bodily knowledge through haptic analysis (Harris, 2005) of the knit handle. Initial practice evaluated colour opportunities, materials, scale, and trialled knitting with half gauge and full gauge on the 14 gauge N.SRY123LP knitting machine to produce multiple knitted surface adaptations.

Prototypes used neutral shades of grey, with the inlay yarn ranging from muted hues to pops of bright colour. High contrast colours increased the visibility of pattern traces across the disrupted knitted ground with inlay appearing to float on top of the knitted surface. In comparison, monochromatic prototypes provided subtle versions where ground and inlay blended, creating an effect of weave embedded in the knitted surface. These prototypes looked at potential applications of multiple inlay colours (Figures 37, 38), or two ground colours on a single surface (Figure 39). However, although colour entered the design equation, it was "only as a by-product - since of course nothing is colourless - not as a focal point. Any colour effect is, for the moment, incidental, not intentional" (Albers, 2017, p. 46). Colour was applied to demonstrate the technique and extend knowledge rather than a critical design factor. This research journey's colour pathway has scope for future research expanding on this initial experimentation.

3.6.2 Digital-crafting

The act of making requires decisions around the artefact's structure and appearance and a strategy for its creation (Dormer, 1997). Inlay knitting technique trials used traditional plain and twill weave patterns (Figure 40). These patterns were selected in response to self-imposed design questions: Could identifiable analogue woven patterns be translated into digitally knitted versions that maintained a hand aesthetic? Could these weave patterns afford the effect of a weave embedded into the knitted surface?

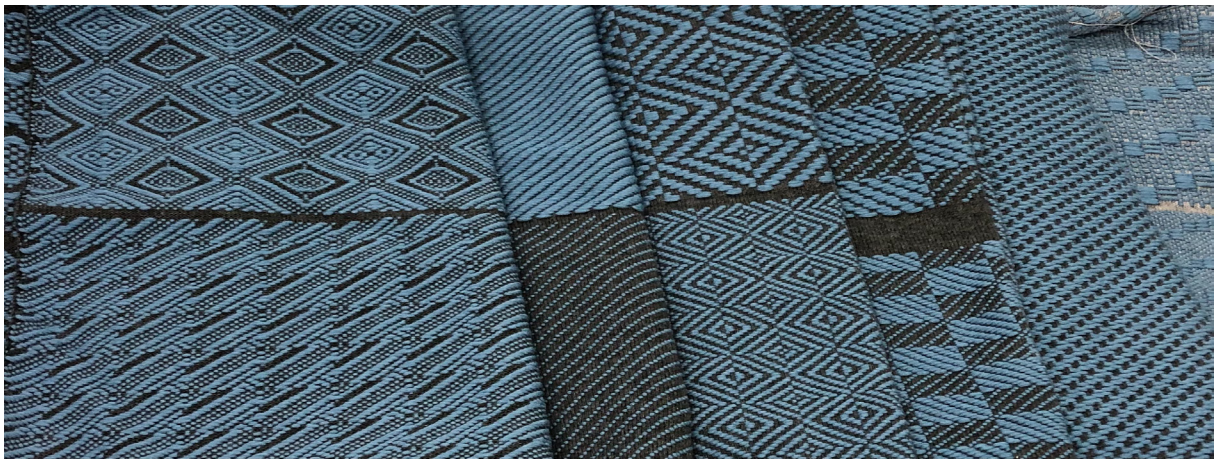


Figure 40. Traditional twill weave patterns interpreted as digital all-over inlay knitting.

To explore the juxtaposing idea of woven fabric in a knitted surface, I applied a digital-craft approach utilising weave patterning from Sharon Alderman's *Mastering weave structures: Transforming ideas into great cloth* (2004). Sharon Alderman is a handweaver, artist and author whose grid layout of fundamental to intricate weave patterns provided a comprehensive woven-design process. These woven instructions were guidelines for inlay pick and float coded arrangements transferred to the technical SDS-One Apex3 environment. Purple and white squares representing picks and floats translated as inlay points in the digital grid, forming a coded pattern (Figures 41, 42). This process involved implementing traditional plain and twill weave layouts such as the dornick twill illustrated in Figure 43 as a woven fabrication and Figure 44 and 45 as an inlay knitted construct. As physical inlay knitted surfaces, the selected patterns offer a close aesthetic representation of original woven textiles. Small picks and floats appear more embedded in the knitted ground than longer surface floats. These all-over inlay prototypes informed the inlay pattern component of the surface-building blocks (refer to Appendix C).

The inlay technique and technology prototyping incorporated scaled designs with varying float lengths on front bed knitted grounds to initially determine the effect of inlay on material behaviours and surface aesthetics. The inlay pattern was scaled up using the SDS-One Apex3 scale function, which allowed X and Y axis controlled scaling (Figure 46). The colour exchange function enabled efficient prototyping of inverse inlay patterns (Figure 47), which aided visualisation of inlay colour balance from two-dimensional screen to three-dimensional knitted surface. A shift towards making and crafting with digital materials is becoming more recognised as a constructive method in which making becomes as significant as the made artefact (Turney, 2009).

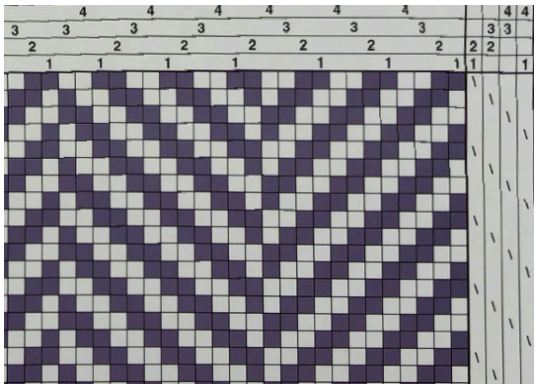


Figure 41. Woven dornick twill pattern grid. *Note.* From *Mastering weave structures: Transforming ideas into great cloth* (p. 35), by S. Alderman, 2004, Interweave Press.

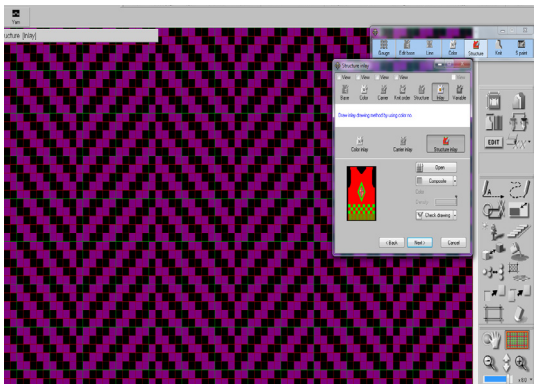


Figure 42. SDS-One Apex3 all-over inlay dornick twill pattern translation.



Figure 43. Woven dornick twill fabric. *Note.* From *The dornick project*, by A. Stratton, 2011, Tangles and Webs (http://tanglesandwebs.blogspot.com/2011/12/dornick-project.html).

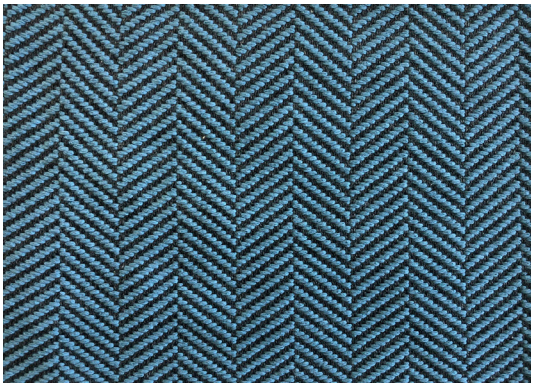


Figure 44. All-over inlay knitted dornick twill

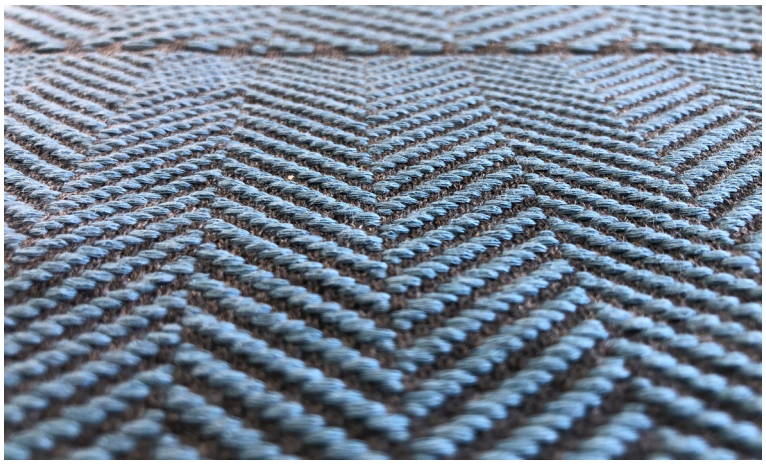


Figure 45. All-over inlay knitted dornick twill detail of texture.

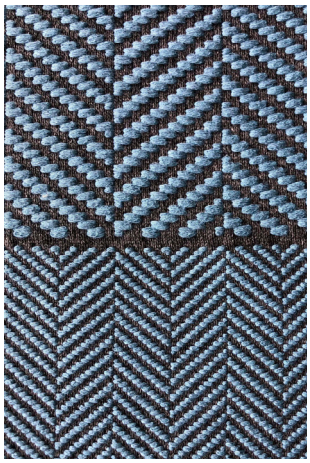


Figure 46. Traditional weave patterns as all-over inlay in two scales.



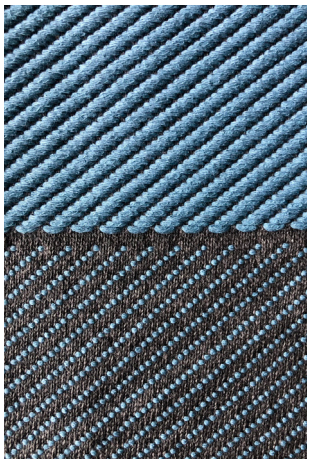


Figure 47. Regular twill all-over inlay with inverse patterning.

3.6.3 Materials and Materiality

This research is a quest for knowledge unique to digital knitting, which is crucial to advancing a discipline (Bye, 2010). Professor Bruce Archer (1979) argues that "there exists a designerly way of thinking and communicating that is both different from scientific and scholarly ways … and as powerful as scientific and scholarly methods of enquiry when applied to its own kinds of problems" (p. 17). Textile design research draws on an understanding of materials from an experiential and technical perspective (Mori, 2012). Architect Toshiko Mori (2012) notes:

> By exploring the tectonics [material forces] of textiles, one not only appreciates an impressive multiplicity of its methods and applications, but also recognises the potential embedded in a seemingly primitive technique and its emergence as a major material technique of the 21st century. (p. 76)

Two-dimensional and three-dimensional making environments combine during all phases of this research practice. It is through exploration, play and making, either through the abstract (virtual) or final output (physical), that material behaviours begin to be understood (Armitage, 2011). The act of knitting and the resultant outputs were informed by the intrinsic characteristics of the fibre and yarns selected. New material knowledge was generated through a hands-on approach to material manipulation and a deep understanding of the design practice (Marr & Hoyes, 2016). Understanding material agency (Lange-Berndt, 2015) required physical engagement with multiple knitted surface transformations.

A knitted swatch replication and analysis method produced comparable samples knitting the same prototype multiple times, exchanging yarn compositions (Figure 48). Merino, acrylic, cotton, wool blends and Pemotex (polyester) yarns were



Cotton ground.



Merino ground.



Acrylic ground.

Figure 48. Single bed intarsia inlay testing different ground yarns.



After applied heat.



After applied heat.

Figure 49. Tubular jacquard merino and Pemotex yarn.

investigated for ground knitting, with nylon-core cotton for the inlay patterning. Merino retains properties inherited from the crimped fleece; memory held in the yarn and consequently evidenced as an elastic quality in knitted samples. The Pemotex yarn requires heat activation to artificially trigger convergent forces in the knitted plane through applied sectional shrinkage (Figure 49). Tubular jacquard prototypes included Pemotex yarn, resulting in deformation of the double bed knitted surface, similar to links-links surface aesthetics. The material testing procedure confirmed yarn choices by observing agency levels that different materials offered the knitted surface movements. Each material speaks (Pallasmaa, 2000) a different language: the interactive dynamics of material agency (Bolt, 2007) encourage emergent transformational surfaces.

This process of material testing was not a measurable analysis of material behaviours. Instead, it was subjective, based on the fibre's visual effect on the knitted surface and its tactility. These factors relied on amalgamation of co-emergent yarn properties to produce requisite surface movements. Academic Barbara Bolt (2007) discusses the notion of 'acting ensemble', exploring emergent material practice by applying co-emergent properties set by the designer, materials and tools. Thereby informing a situation where the outcome is unknown in advance but instead characterised by interactive play between the agency of matter (Bolt, 2007). In knit practice, to understand the programmed digital you need the



Figure 50. Rigid dimensional form produced during material experimentation with reactive yarns.

corresponding physical prototype. The coded to decoded, generates emergent material practices that foster a dynamic environment set by the designer and technology.

Materials experimentation trialled reactive yarns, producing rigid dimensional forms (Figure 50). Although the knitted surfaces were considered too inflexible at this practice stage, this experimentation supported materials selection discussed in Chapter Four. Artefacts perceived as significant to the extension of my practice emerged from this entangled environment. These directional leaps necessitated the cyclic blending of phases in the research. This practice triggered the inclusion of material forces and reactive yarns as essential design elements in double bed knitted surface topographies.

3.7 Building Material Forces

3.7.1 Generating the Knitted Ground

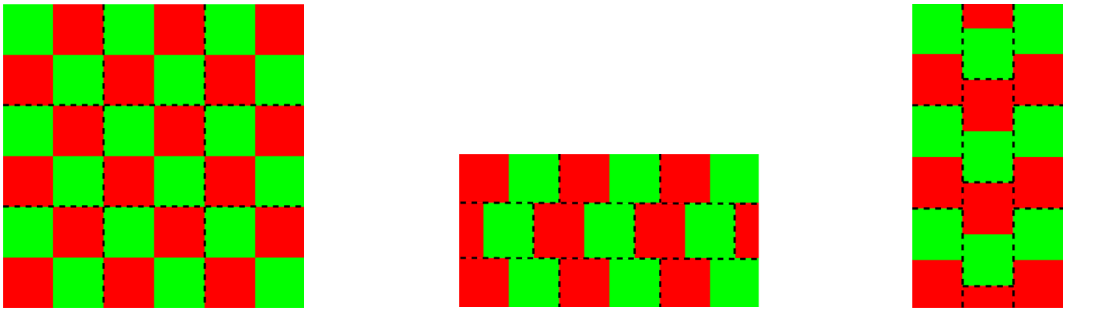
In Phase Two of the research, *Understanding Knitted Material Forces* the research investigated potential surface movements generated by self-folding links-links stitch structures. This practice builds on prior knowledge of textile practices encapsulated in a folded or assembled form (Philpott, 2011; McKnelly, 2015), and auxetic knitted textiles (Glazzard, 2014). Textile design repeating pattern formats foster material and stitch behavioural knowledge. The development of pattern repeats offered this practice an ordered and replicable design process for constructing the knitted grounds.

In knitting, the potential of an infinite repeat is constrained by the width of the knitting machine's needle bed. Initially, various shapes were trialled in repeat



Block repeat. Brick repeat. Half-drop repeat.

Figure 51. Textile design print repeating pattern techniques.



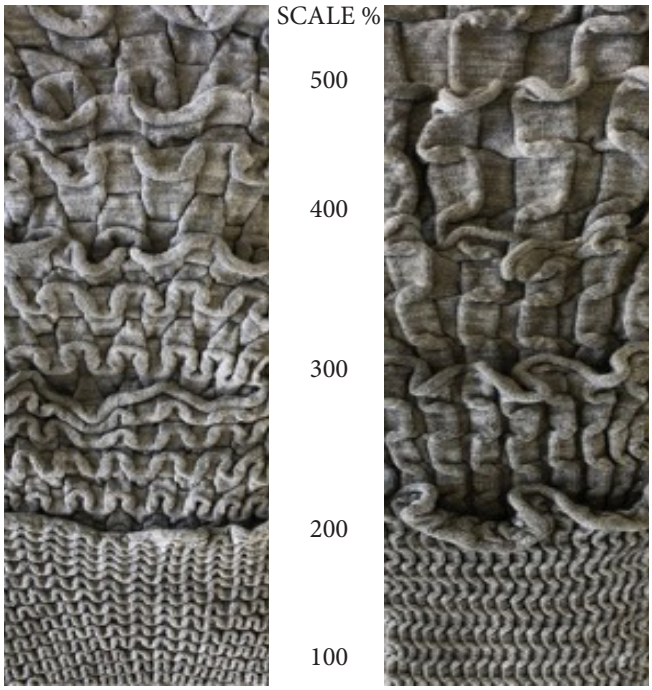
Block repeat. Brick repeat. Half-drop repeat.

Figure 52. SDS-One Apex3 knit repeating patterns for links-links square.

however, regular geometric shapes were most suitable for repetition on-screen as the gridded design environment makes curves challenging to achieve. Construction of links-links repeating patterns used digital print unit-repeat arrangements: block, half drop and brick (Figures 51, 52). Coded red and green areas represent front and back bed single jersey, respectively. Unlike print, whose motifs are often separated by background colour, there is no background in the knitted versions. As evidenced in Figure 52, this causes the square shapes in the half-drop and brick repeat to merge at points of intersection. This merging creates a visual effect in which the individual links-links unit is no longer a set geometric shape. Red and green colour codes represent stitch structures that are not static as they physically translate into surfaces, generating knitting with vertical or horizontal dominant compressional material forces.

In a discussion on knitted textiles, academics Shashank Markande, Michael Dimitriyev and Elisabetta Matsumoto (2019) note:

> Not only can stitch pattern control the local and global geometry of a textile, but the creation process encodes mechanical properties within the material itself. Unlike standard additive manufacturing techniques, the innate properties of the yarn and the stitch microstructure has a direct effect on the global geometric and mechanical outcome of knitted fabrics. (p. 1)



Vertical rectangle half-drop. (vertical compression)

Vertical rectangle brick. (horizontal compression)

Figure 53. Scaled knitted links-links ground patterns.

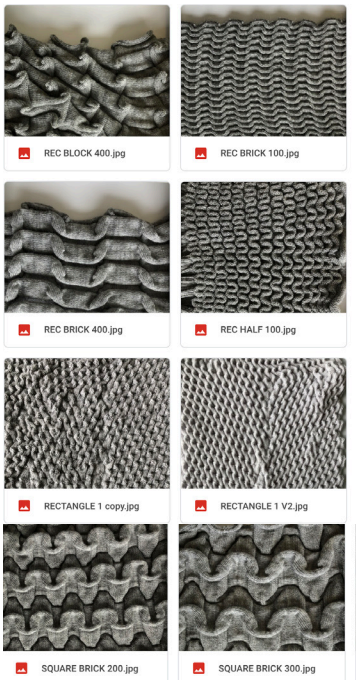


Figure 54. Photographic record of physical links-links grounds.

Integration of links-links behavioural knit knowledge entwined with scale investigations during exploration of the base repeat unit at 100% pattern size through to 500% pattern size (Figure 53). Initial photographic records (Figure 54) instigated the generation of a digital library representative of the physical prototypes. These links-links prototypes informed the geometric pattern component of the surface-building blocks applied in Phase Four to test material forces and inlay pattern relationships. The links-links knitted practice provided a visual library of knitted material forces, translating coded screen combinations into physical surface disruptions (refer to Appendix D). The links-links layouts additionally formed a geometric pattern reference for designing double bed inlay tubular jacquard grounds.

3.7.2 Reading Materials Forces

The knitted surface practice progressed through layering the links-links and inlay knitting techniques. Textile design is underpinned by mathematics as physical textiles manifest grids and calculations between pattern and technique. In knit, programmed patterns are multiple combinations of individual stitch loops that sequentially construct a surface. To visualise the interconnected knit and weave points of patterning, I initially mapped the two techniques together in a grid format (Figure 55). The automatic software's stitch structure codes and the inlay pattern are programmed on two separate screen pages with the information combined in

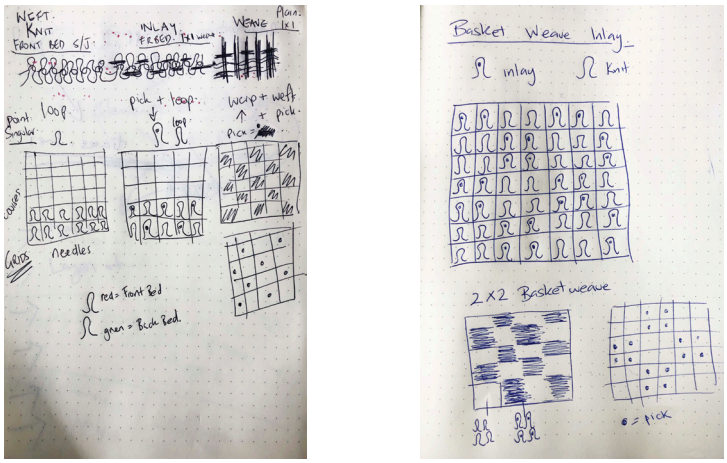
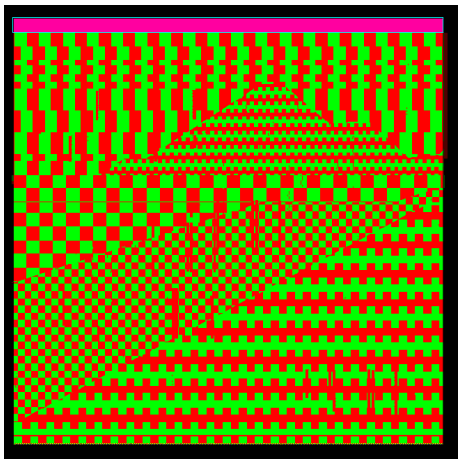


Figure 55. Personal interpretation of grid illustrating knit, weave and inlay technique connections.

the development process. Figure 56 illustrates the on-screen structure and inlay colour pages and corresponding physical knitted surface for a version of Crystal Twill inlay. These link-links with intarsia inlay prototypes tested deformative relationships between pattern designs, positioning, and scale within the knitted surface. (The technical steps for programming a single bed intarsia inlay knitted surface topography are available in Appendix E.)

The knitted surface topography the Crystal Twill inlay pattern contains short floats and is recognizable as a traditional woven fabric design. The twill setup and amount of inlay used in this prototype allowed the stitch structure beneath to shift in places with the material forces but the static nature of this inlay changed these forces. Reduced folding resulted in a weave-dominant effect with increased stability of the knit surface. The inclusion of horizontal and vertical linear subtractions of inlay facilitated shared material forces generated by the links-links ground. Single courses of inlay follow the recumbent folds, along the ridges and into the folded peaks and dips. Initial prototypes contained holes due to programming an uneven number of courses between the subtracted inlay and knitting with a tight stitch quality (Figure 57).

The links-links sections collide as juxtaposing forces arise between the heterogenous pliable stitch and stabilising inlay surface characteristics. During analysis of the complex surface folds, commonalities between inspirational landscape imagery and knitted surface movements emerged. Similar surface aesthetics between folded land and the knitted surface formed visual connections to geomorphology (refer to Appendix A). Knit compressional material forces occur horizontally, vertically or angled with multiaxial used to encapsulate multi-directional surface movements. Through the use of photographs, material forces can be seen beyond that which the natural eye captures. In the photographs, surface disruptions are static, allowing examination of material alliances between individual stitch structures and points of inlay knitting. Analysis of these images increased understanding and awareness



Stitch structure coded layer.



Inlay pattern coded layer.



Figure 56. Analysing convergent and divergent force between knit and Crystal Twill intarsia inlay.



Figure 57. Holes in Crystal Twill intarsia inlay

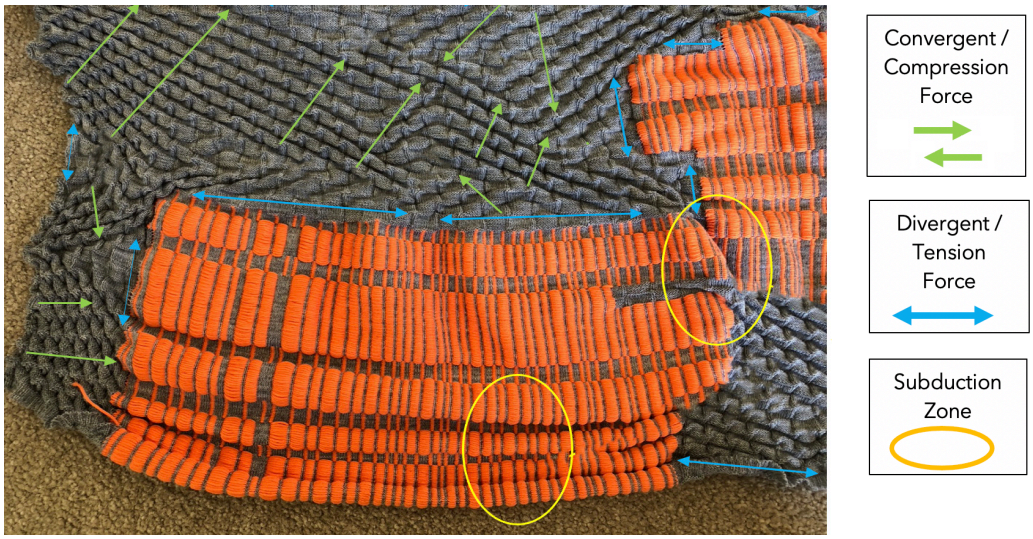


Figure 58. Reading assembled material forces in intarsia inlay knitted surface topography.

of material forces which became a key design component of the knitted surface topographies. The knitted surfaces were mapped with arrows to highlight changing material force activity (Figure 58). These visual records of the experiments and the analysis yielded a pattern-synthesis method (Cross, 1997), a process of active engagement with the puzzle pieces that I had to connect or disconnect.

> Designing is a process of pattern synthesis, rather than pattern recognition. The solution is not simply lying there among the data, like the dog among the spots in the well-known perceptual puzzle; it has to be actively constructed by the designer's own efforts. (Cross, 2006, p. 24)

During this process of pattern synthesis, I discovered an internal paradox. This enigma arose from being the subjective designer so fully immersed in the making and the objective researcher observing and delineating tacit and explicit knowledge findings. Reflection allowed time to step back and observe the results dispassionately yet remain connected to the theoretical underpinning and subsequent design shifts.

3.7.3 Approach to Subtractive Design

Initial experimentation investigating the effect of inlay patterns and knit structures on material forces generated prototypes of varying success. Trials explored large areas of intarsia inlay in proportion to solely knitted ground (Figure 59). These original material force explorations applied linearly arranged patterns of intarsia inlay with a single stitch structure beneath with combinations of links-links grounds constructed the surrounding knitted surface. These prototypes resulted in a weave-dominant aesthetic, displaying properties of surface stability rather than surface

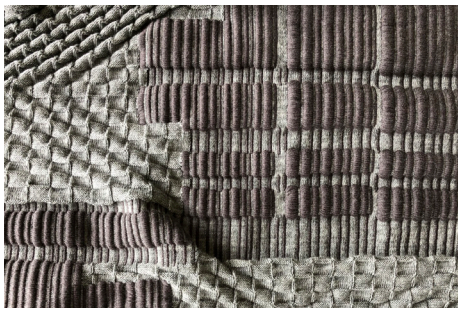


Figure 59. Large area of intarsia inlay patterning in proportion to links-links ground.



Figure 60. Knitted surface topography with increased inlay pattern fragmentation.

deformation. Introduction of subtractive design methods and reduction of inlay to knitted ground ratios countered this flattened surface effect.

Horizontal and vertical subtractive methods used the SDS-One Apex3 KnitPaint clear function to delete inlay patterning fostering folded corrugations and pattern fragmentations across the knitted surface (Figure 60). The first subtraction prototypes occurred due to the inaccurate positioning of inlay patterning. I realised this opened up opportunities for increased fragmentation of the inlay pattern, and designs shifted to include a systematic deletion approach. Subtractive design instigated a systematic approach engaging with layered links-links and inlay on a stitch-by-stitch basis. Float length and the amount of inlay pattern fragmentation required influenced vertical subtractions. Carrier direction and the number of courses between inlay sections influenced horizontal subtractions. What began as a programming design oversight became a surface-building block in the pick-and-mix mode of making.

Digital making in knitting often involves missteps and miscalculations. Textile design academics Anne Marr and Rebecca Hoyes (2016) "identify risk-taking and 'unlearning' as essential strategies to invite valuable setbacks as well as happy accidents" (p. 5). The value of being the programmer and seeing the results of programming errors that arise from not knowing added to design possibilities in this research. An example of this occurred during the subtraction of inlay process when I initially left behind random courses of inlay as I did not zoom in on the area. Once knitted these pattern remanets added a trace of the maker and making method to the knitted surface. These mistakes would be viewed as flaws by a traditional technician and are often removed without sharing. According to McCullough (1998):

> Experimentation is especially useful for becoming familiar with constraints: we learn from our mistakes. We must accept that beginning work in a new medium will be full of setbacks. There will also be fortuitous discoveries, however, particularly of affordances. Design is not only invention, but also a sensitivity to a medium. (p. 225)



Figure 61. Trace pathways of the intarsia inlay yarn.

Design connections between initial practice and material forces were partially intuitive and included creative leaps bridging understanding (Archer, 1964). One creative leap resulted in lines of connection, illustrating the journey of the inlay yarn. These lines are the result of pattern subtractions which cause long inlay floats between the remaining inlay pattern. Trials investigated linear and curved, horizontal and vertical subtractions to generate minimal or multiple inlay traces (Figure 61). The traces became a design element adding to my surface-building block options. These would never have happened if I had entered the research as a technically proficient programmer of the inlay knitting technique. Inlay long yarn trails are usually perceived as a programming mistake or machine malfunction and removed by technicians. This self-taught faction of the research shifted the knitted outputs in an unexpected and unique direction. As a reflective practitioner, I assessed the design value of the inadvertent surface traces of the inlay yarn that emerged. A lack of know-how can work as a catalyst for greater understanding; understanding how and why the issue occurred means adding or subtracting these yarn pathways within the inlay surface designs.

3.8 Emergent Design Strategies

3.8.1 Establishing Surface-building Blocks

Phase Three of the research process, *Developing a New Design Strategy*, was influenced by material forces, knitting techniques and geomorphic language. Built knitted surface aesthetics were informed by photographed landscapes, geometric repeating grounds, surface movements and inlay patterning. The positioning of crafted design components became a key factor in the layering of material behaviours, letting materials speak (Lange-Berndt, 2015) and fracturing pliable knitted planes. The initial links-links knitted surface prototypes and inlay weave-like patterns generated a reference library of material forces, scale and pattern knowledge with digitally programmed counterparts for future applications (refer to Appendix C and D). The two-dimensional screen contains a static representation of the fluid dimensional knit in digital knitting. The stitch codes reference physical knitted surface constructs which generated the links-links ground and inlay surface-building blocks (Figure 62).

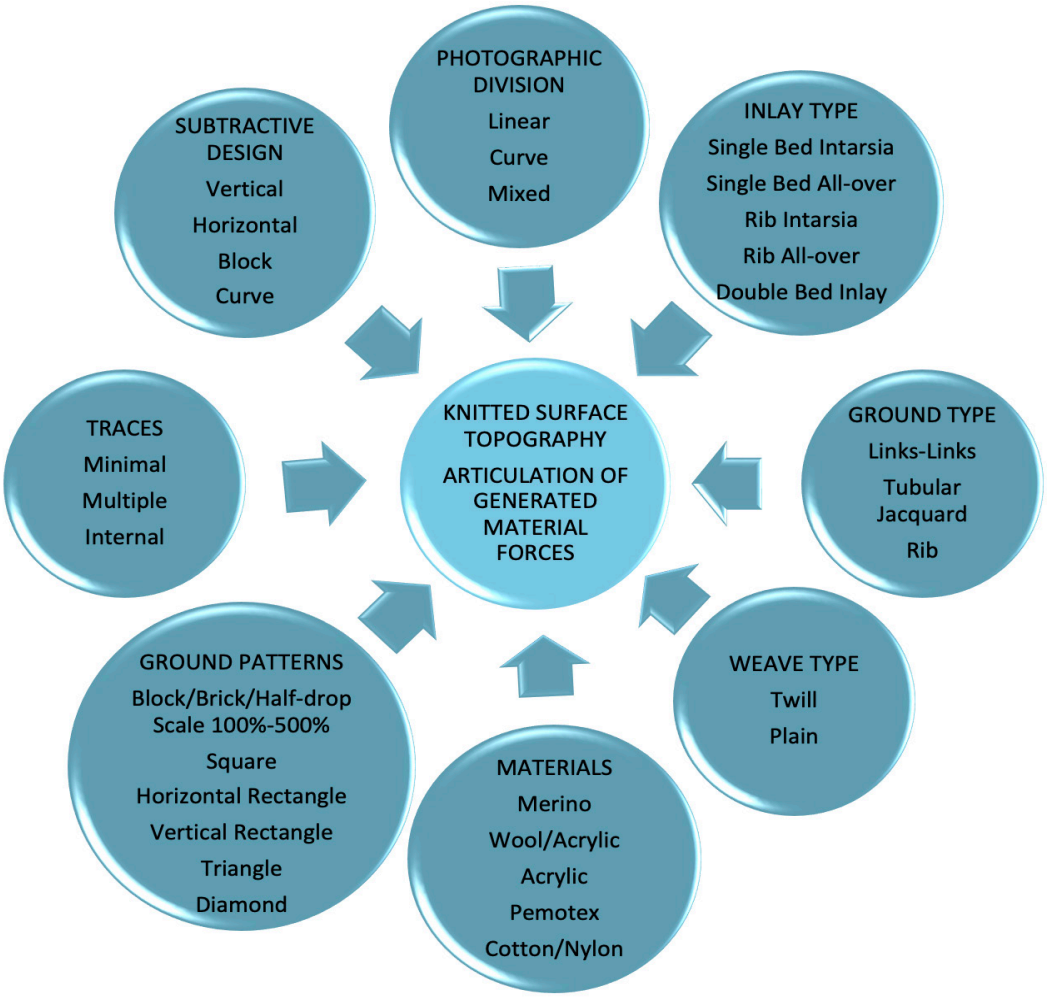


Figure 62. Surface-building blocks for building a knitted surface topography.



Figure 63. Thumbnails of Coromandel terrains.

Application of the surface-building blocks as a pick-and-mix method of creative practice emerged as the complexity of the knitted surfaces increased. The knitted surface topography constructs layer surface-building block components selected from; materials, inlay type, ground type, ground pattern repeat and scale, traces, subtractive design, weave type, and photographic division. Surface-building blocks and the mode of making derive from all phases of the research. The assemblage process focuses on layered relationships of the design components and their effectual performance in the assembled environment (Beaubois et al., 2015). Due to heterogeneous relationships between layered surface-building blocks, the single bed and double bed inlays' assemblage requires divergent design approaches. These advanced assemblage methods are discussed in detail in Chapters Four and Five.

3.8.2 Generating a Mode of Making

A method of building knitted surface topographies emerged significantly influenced by the prototypes' aesthetics, in which links-links surface movements fractured inlay patterning. The land and seascapes of the Coromandel (Figure 63) connect to my life in New Zealand with imagery illustrating the natural layering of physical factors. Throughout this research, the landscape photographs translate from digital to physical, back to digital, and then back to physical formats. Through a series of generative processes, natural geomorphic landscapes informed the knitted surface topographies.

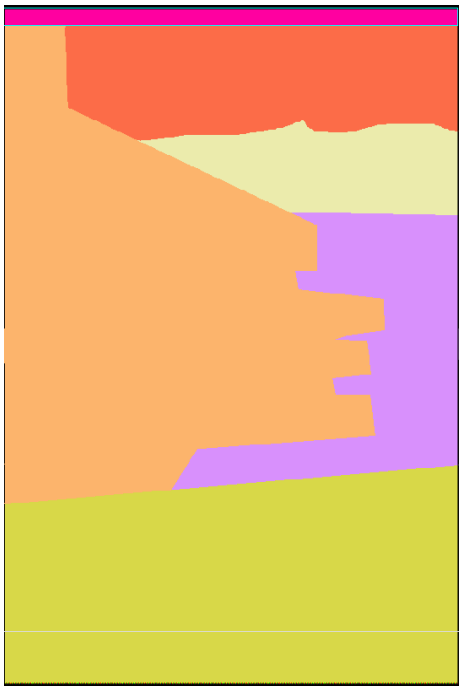
In this research, photography was integral to the design process: as a method of inspiration, and as a system for designing the knitted surface topographies and mapping material forces (Figure 64). Landscape images informed sectioning templates for placement of the knitted ground. The actual photographed landscape shifts to the virtual coded screen in a hybrid-making process emergent as physical knitted surfaces. Different design approaches to combine multiple links-links



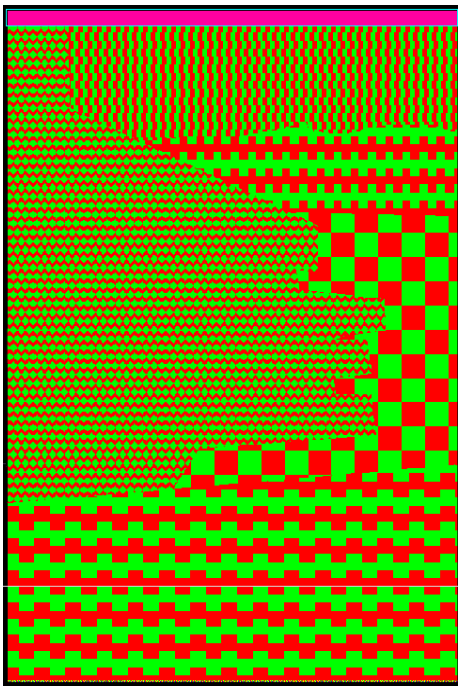
Physical swatch collaging.



Hand-drawn sectioning of photograph.



Colour-blocking sections .



Fill with links-links patterns.

Figure 64. Creative process of collaging sectional links-links ground.

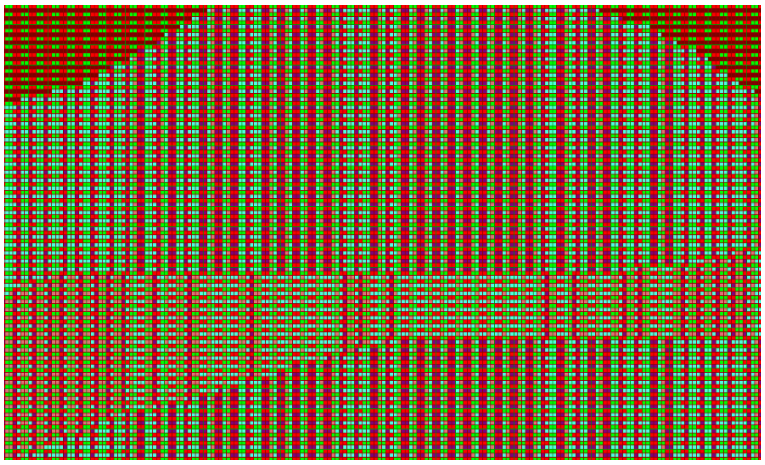


Figure 65. On-screen composite view showing layered structure and inlay page codes.

grounds trialled collaging methods in which photographs, abstracted lines, sectional coding and tactile samples blended to produce knitted surface movements. The physical and digital formats of the links-links grounds and inlay patterns are valuable resources to share with other designers, to enable codes to be read as knitted surfaces. The collaging method references digital and physical design elements informing knitted surface selections. Initial applications of the geometric pattern surface-building blocks collaged physical links-links options considering the tactility, aesthetics and material forces.

Practice-led action research is "distinct from other forms of reflective research in being deliberately planned and systematic, with a distinct purpose and deliberate strategies for moving from reflection to research" (Crouch & Pearce, 2012, p. 114). My structured nature disseminated the reflective practice and emergent approach to knitted surface design into step-by-step procedures. Steps for building a single bed, rib and double bed inlay knitting contain similar approaches to the surface design; however, each inlay type contains several design-technical variances (refer to Appendix B, E, F and G). This approach to digital making applies a pick-and-mix method selecting design components from the surface-building blocks. Both automatic and old-format software require the inlay and the stitch structure to be generated as separate layers. Automatic software retains these separations, whereas the old-format software merges the layers to enable the programmed codes to process.

Layering emerged as a method of creation at multiple prototyping stages; layering of knitting techniques, aesthetics, and material forces. Codified placement of the inlay technique on the layered digital screens generates surfaces where knitting rules distort. Programming operated in a multi-tiered realm, with individual pages holding design information for stitch structure, inlay and colour. The overlapped syntax of coded pages is visible on-screen in composite view (Figure 65), allowing designer-programmer input and activation between specific knit and inlay points,



Original Photograph.



SDS-One Apex3 direct on-screen.



SDS-One Apex3 digital knit design.

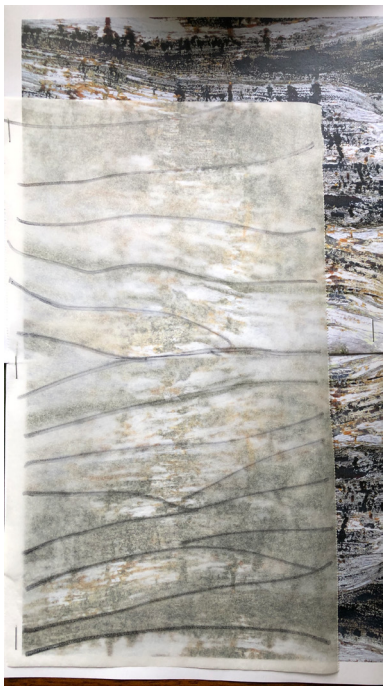
Figure 66. Visual results of actual to digital image-sectioning methods.

manipulating singular points of material force. Through alternative combinations of these surface-building blocks, the agency of the surface is manipulated (Lange-Berndt, 2015), resulting in knitted surface topographies when virtual coding becomes actual.

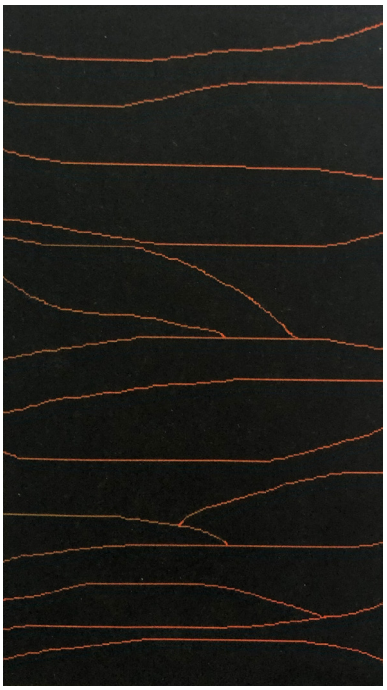
Photographs informed interconnected sectional divisions through either linear or curved lines. This initial transference of sections from physical imagery to digital explored several creation methods: direct hand-to-screen delineation, importation of the image into the knit-design program, creating index image colours in Photoshop and drawing lines using the SDS-One Apex3 tablet. I experienced a sense that, as the number of computerised steps increased, the digital dictated the generated aesthetic, resulting in an artificial look. To prevent this, I preferred to proceed with a more direct hand-to-screen interpretation of my designed sections. Printing the photograph and hand drawing the sectional divisions in preparation for transference to the structure or colour page on screen maintained the handmade aspect and instilled an intuitive design presence. This approach allowed proportional adjustments to occur with opportunities to merge sections. As evidenced in Figure 66, direct hand-to-screen surface drawing facilitated greater retention of the original image layers than the knit software generative method.

These hand-drawn sections are filled with solid colours in a colour-blocking method that allows systematic pattern filling during knitted surface creation. The colour blocks offer opportunities to gauge the placement of intersecting lines and patterning relationships to neighbouring sections. Multiple colours allowed testing of alternative pattern options, each knitted surface encountering a different set of material behaviours. Using the colour-blocking method facilitates an ability to pattern the entire panel, rapidly filling sections, similar to a paint-by-numbers approach. The SDS-One Apex3 KnitPaint base pattern repeat function allows efficient sectional patterning once a single pattern-unit repeat is identified.

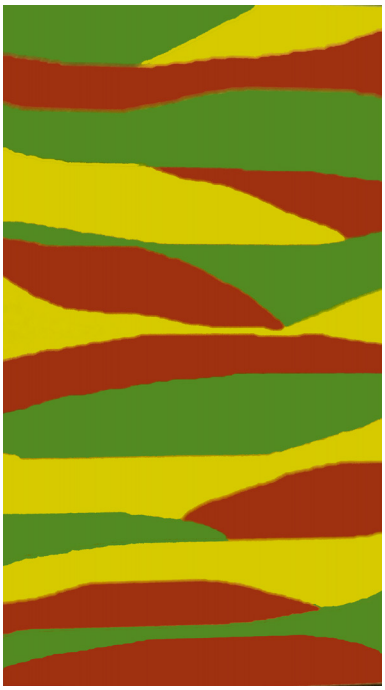
Figure 67 illustrates physical-digital-physical steps used to create a rib intarsia inlay in automatic software using the surface-building blocks. In this prototype curved sectioning derived from the photograph was hand-drawn on-screen. Colour-



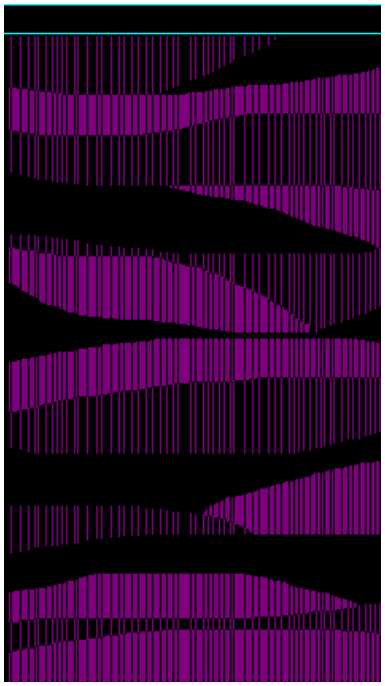
Step 1.
Photograph with sectioning lines.



Step 2.
Hand-drawn on-screen sectioning.



Step 3.
Colour blocking.



Step 4.
Fill inlay pattern page with pattern.



Step 5.
Fill structure page with rib structure.



Step 6.
Physical knitted prototype.

Figure 67. The creative design process steps for rib intarsia inlay in automatic software.

blocking of these sections occurs on the inlay pattern page before each colour is exchanged for an inlay pattern or colour zero representing no inlay. (The technical steps for programming a rib intarsia inlay knitted surface topography are available in Appendix F.) The application of these outlined steps is dependent on the inlay type selected from the surface-building blocks. Single bed and rib inlays use variations of colour-blocking and fill techniques in automatic software. Double bed inlays apply similar steps, although are built-in old-format software which requires additional coded knit information. (The technical steps for programming a double bed inlay knitted surface topography are available in Appendix G.)

Affiliation with the digital environment and abilities fosters crafting with knit codes. The screen and programmed codes have become my materials, and technology is a tool used to draw knitted surfaces. The act of making generates a "material consciousness" (Sennett, 2008, p. 123), assimilated over time into tacit knowledge. Technical aspects of creation are embedded in the knitted surfaces as visual references of knowledge and intuition. Tacit knowledge guides programmed performance and interactions of material forces and knitted surface topographies; this application of material knowledge is a form of the thought unknown (Bollas, 1987). My design process occurs as a direct transference from hand to the digital screen, similar to sketching on paper. These digital lines form traces of either additive or reductive layers (Ingold, 2016) embedded into my knitted surface. As this practice progressed, the number of intersecting colours and patterns increased in complexity. This approach provided a sense of digital-physical engagement through direct involvement in the programming and engaged an intuitive design approach. The practice and design strategies evolved in response to encountered design-technical aspects which are expanded on in Chapters Four and Five.

3.9 Assembled Topographies

Phase Four of the research, *Synthesis of Practice*, encompasses assemblage methods to create increasingly complex knitted surface topographies. Application of the surface-building blocks into considerably larger prototypes facilitated practice which tested the scope of the mode of making. I intended to extend the Shima Seiki Mfg. Ltd. knitting technology into designs that required advanced programming and technological learning. Compositional surfaces demonstrate material forces "modulated in a single surface" (Kolarevic & Klinger, 2013, p. 8). Composition infers the assembly of elements either according to rules or by chance (Smith, 2013). The repeating patterns, scale, materials and stitch structures were assembled with layered manipulation, affording known and unknown surface movements. Programming influences knit and weave creation rules; this applied effect increases material activity, disrupting the knitted surface. Intangible factors of knitted textiles are difficult to calculate or quantify, yet these characteristics directly impact the design aesthetic: pattern, texture, and the surface's tactility. Knitting becomes a

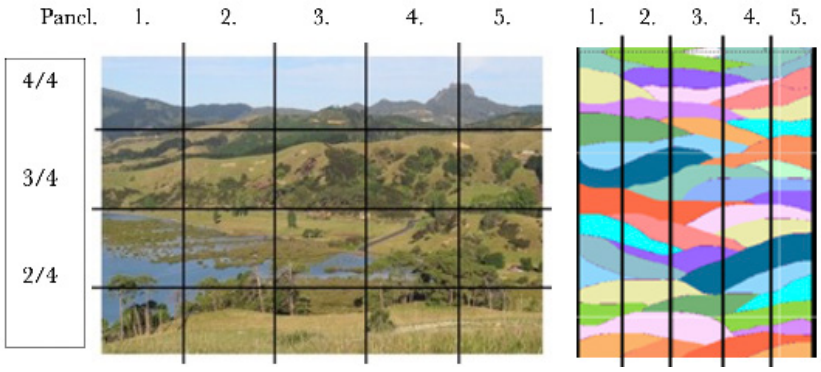
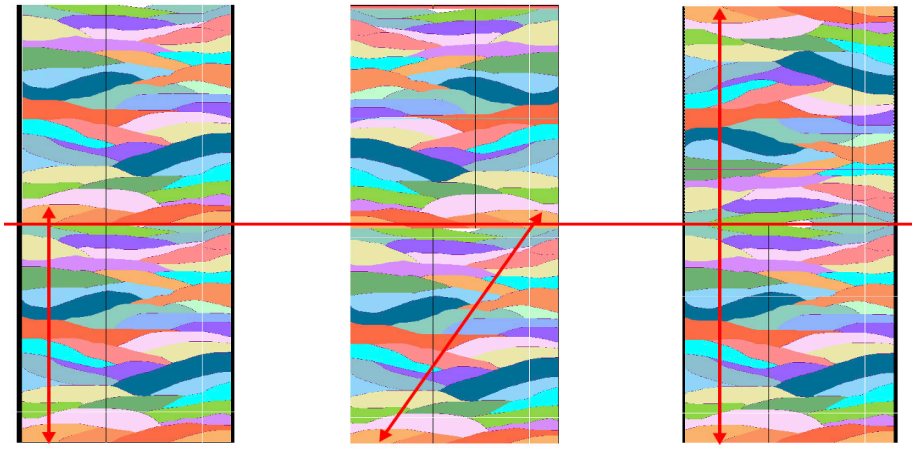


Figure 68. Proportional sectioning for colour-blocking in series of longer knitted surface topographies.



Block repeat. Mirror repeat. Chevron repeat.

Figure 69. Repeating pattern methods trialled for intersecting ground sections.

way of thinking through material engagement with these intangible elements and understanding the technical environment.

To extend the technology and the practice, extremely long panels were set up at the full needle-bed width. Prototypes investigated different patterns, scales, and tactility assemblages across interconnected knitted surfaces. The larger knitted surface topographies presented technical and programming challenges not encountered in smaller samples. A collective knitted surface design built across five panels informed a method encompassing both old-format and automatic software. Each panel in the series is an individual informing neighbouring pattern alliances. The relative size of the screen hindered the ability to translate on-screen to an actual knitted surface. A divisional method of drawing five vertical lines to represent the five panels and dividing the image horizontally into quarters (Figure 68) countered the issue of proportion. This provided half the length of my long panels which could then be doubled to generate the full length. Individual panels set up in old-format form the interconnected knitted surface series. Links-links and inlay designs are built separately in old-format across multiple panels before being layered in the



Figure 70. Image adjustments trialled for placement of inlay patterning.

automatic software as single panels for additional tweaking. (The technical steps for programming a single-multiple knitted surface topography are available in Appendix H.)

Textile print techniques were applied to complete the full length colour-blocked sectioning for the elongated surfaces (Figure 69). The long panels allow multiple interactions between oppositional material forces and variant dynamics space to disrupt the knitted surface topography. To test design variations block, mirror and chevron repeating pattern techniques were applied generating full panel lengths, before selecting mirror repeat. The mirrored repeat of half the panel allows a flipped and mirrored duplication of the coloured sections within the knitted surface, thereby creating the length desired. Using these replication methods reduced the programming time while ensuring no visible repeat in every panel. This prepared the patterns for the paint-by-numbers approach filling colour-blocked with links-links or inlay patterns.

A method was developed to generate the placement of the inlay patterning. A range of digital manipulations using Adobe Photoshop focused on foreground features of the photograph (Figure 70). These design approaches investigated a blend of level adjustment functions to accentuate the foliage in the photograph. The posterise image adjustment setting was selected as it provided clear areas to translate into inlay patterning. Dark areas became blocks of inlay transferred into the digital milieu. On-screen designing relied on intuitive design choices to aid the compositional balance of inlay patterning and to work with technological boundaries. Research methods and practice evolved, responding to design and technical issues encountered. The assemblage methods employed to build knitted surface topographies across multiple panels are discussed further in Chapter Five, *Emergent Terrains*.

3.10 Conclusion

When situating this research, I continually re-evaluated my role, shifting from a technical perspective to a design-focused lens. Traditionally in the knitting industry, these roles have held different skills and knowledge; however, I am a blend of technician and designer, not entirely one or the other. As a knit programmer and technically capable of running the digital knitting machine, this was my initial default research position. However, the more I engaged with the practice-led research approach, the more the lines between technical and technique blurred, and I acknowledged my designer viewpoint. This shift in thinking led to a conceptual expansion of the research practice trajectory. There was an unfolding of additional theoretical layering in the work as perspectives shifted into the reflective-practitioner realm (Schön, 1983).

As a knit methodology and methods emerged, I began to recognise the unique situation I was in to generate and impart new knowledge in the field of digital inlay knitting as a designer-practitioner-researcher. The hybrid methodologies used enhanced this research, encouraging an interweaving of interdisciplinary practice through digital crafting. My textile design background and prior knitting experience have substantially influenced the research process and outputs. Textile design methods provided a base knowledge to develop the links-links grounds and weave patterns into a library of knitted surface-building blocks. During the project, acknowledging existing and new tacit knowledge generated questions about personal contribution to the construction of inlay knitting techniques and surfaces: How do I affect the inlay knitted surfaces that evolved in this research? How does knit tacit knowledge manifest as surface knowledge? Constructing compositional knitted surfaces with the designed units allowed a homogenous input to transform into a heterogeneous output. The outlined mode of making discussed in this chapter is evolutionary, as each application of the surface-building blocks encountered new design-technical constraints to create with. The methodological approach, methods and design strategy outlined above are articulated in more depth through Chapters Four and Five as the practice extended.

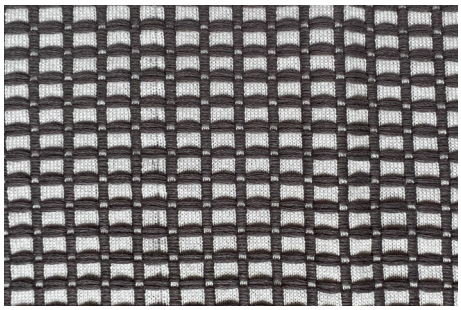
Chapter Four: Planes of Technique

> Surface quality of material, that is, matière, being mainly a quality of appearance, is an aesthetic quality and therefore a medium of the artist; while quality of inner structure is, above all, a matter of function and therefore the concern of the scientist and the engineer. Sometimes material surface together with material structure are the main components of a work. (Albers, 2017 p. 45)

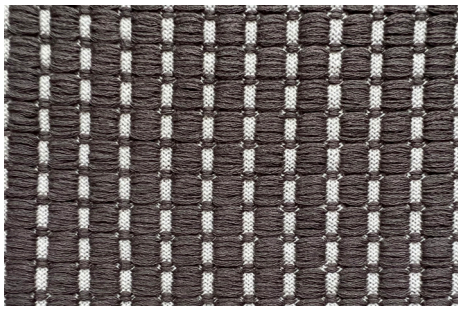
4.1 Introduction

This chapter discusses new applications of traditional textile practices that transpired as my creative process evolved. The inlay knitted surfaces apply blended textile and craft practice fostering a dynamic design dialogue. Material forces are generated and assembled through a series of layered interactions. The knitted surface topographies articulate a process and output, accentuating tacit knowledge enfolded and embedded into the physical artefact (Nimkulrat, 2009). Dormor (2020) notes, "the term unfolding reveals the complexity of events and hints at a more processual situation within which elements become uncovered, hidden and recovered by parts, not necessarily in any chronological or logical order" (p. 11). This chapter is not a chronologically ordered discussion of practice; instead, the chapter addresses three interlinked research phases; *Initial Acquisition of Knowledge, Understanding Knitted Material Forces and Developing a New Design Strategy* (refer to Figure 31, page 39). Dialogue regarding the technique-led practice occurs in conjunction with parallel conceptual strands that emerged during the research journey. The reflective technique-led practice doubles back on itself in a labyrinth of thoughts and design connections materialise from the echoes of thinking through making (Dormor, 2020).

The artistic freedom obtained through this haphazard mode of making was often difficult for my ordered personality to embrace. At times I felt lost and unsure of the relevance of some aspects of the testing process, struggling with design autonomy after years of design restrictions imposed by industry and academia. However, practice developments helped consolidate the core surface focuses; material forces, textured knitted surface topographies and materiality. These focused on extending inlay knitting techniques through the subsequent phases of design and increased technological understanding. Although the research has been structured into phases, the practice overlapped and blended cyclically, linking backwards and forwards between phases as knowledge increased.



Technical front.



Technical back.

Figure 71. Single bed all-over inlay knitted surface.





Figure 72. Double bed inlay knitted surfaces.

4.2 Phase One: Initial Knowledge Acquisition

4.2.1 Technique and Technology

A greater understanding of design components leads to greater awareness of the design conditions that make textile surfaces (Albers, 1965). Technological interaction is central to this research practice. Programming of digital inlay knitting occurs in two ways: via automatic software or the old-format programming interface. These methods require specialist knowledge of knitting and the technology, which was achieved through iterative cycles of experimentation and assimilated knowledge from knit experts in this research. Initial experimentation stemmed from self-taught prototyping focusing solely on the automatic software. To extend design potentiality beyond all-over single bed inlay knitting (Figure 71), I undertook two weeks' tuition at the Shima Seiki Mfg. Ltd. Training facility in Wakayama, Japan. This instruction significantly expanded prior programming knowledge and provided an insight into the inlay technique's usage. Coding acumen resulting from prototypes developed in Japan provided a foundation for alternative knitted design techniques and surface outputs. The understanding and inclusion of complex double bed inlay knitting (Figure 72) shifted the research potentialities beyond encountered automatic software constraints. Old-format software facilitates programming on a blank page using advanced knit coding knowledge. The inclusion of old-format methods of making knitted surfaces introduced double bed inlay design opportunities into this practice.

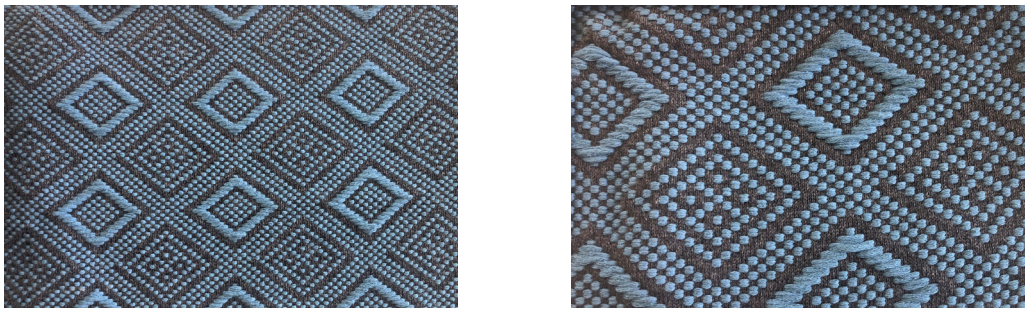


Figure 73. All-over inlay diamond twill pattern, original scale and 200% scale.

As a technical knowledge base of inlay technique was established through initial knit practice (refer to Figure 36, page 43), the research focus shifted to the designed surface aesthetic. Several digital-craft based making methods were folded into the creative process investigating inlay surface aesthetics, providing new possibilities for design outputs (Niedderer, 2009). Knitted and woven textiles are historically craft-based techniques. Architecture academic Mette Thomsen (2014) notes:

> The term digital crafting suggests the intersection between digital design tools and the capacity for precision, variation, and control within the craft tradition. Designing for digital fabrication necessitates an embedded understanding of the craft tradition. (p. 61)

This research blended digital repeating patterns and woven-craft approaches to making, looking to the past as a catalyst to reinvent a shift into the future (Kinder, 1987; Turney, 2009). Academics Connie Golsteijn, Elise van den Hoven, David Frohlich and Abigail Sellen (2014) observe that although crafting was historically centred around functionality, there is also a recreational aspect that is more about the reflective journey of creation rather than the end function.

In the knitted surface, inlay traverses multiaxial material forces that fracture the knitted plane, viewed as configurations patterning the surface. The viewer's eye navigates the intricate weave designs, recognising the organisation and balance of multiple pattern units perceived as an "embodiment of order" (Jefferies, 2012, p. 126). Some of my most successful weave replications were visual articulations of intricate twill patterns. In particular, the diamond twill where the inlay floats and picks embedded in the knitted ground, often as single points of intersection. This point-by-point layering of inlay pick and stitch loop preserved a rigorous weave aesthetic. The knitted diamond inlay is emergent as a defined portrayal of the original woven version. The small floats in the initial all-over inlay prototype maintain the weave aesthetic better than in the increased scale version (Figure 73). Woven textiles generally consist of a series of short rather than long floats, so although these inlay versions are still identifiable patterns, they transgress through scaled digital translation from their point of origin.



Swing Carrier. Non-Swing Carrier.

Figure 74. Knit issue on edge of intarsia inlay due to carrier type.

Weave-based prototypes sought a balanced relationship between the inlay and knitted ground and displayed visually organised patterns. According to Albers (1965), in these patterns, the viewer can see "the essence of designing, a visually comprehensive, simplified organisation of forms that is distinct from nature's secretive and complex workings" (p. 71). The recognisable weave factor remained, acting as a signifier to the viewer, the eye interpreting and reading the known even when parts of the pattern were deleted or fragmented. The inlay knitted surfaces display variable inherited properties implemented by float lengths, pick placements and materials affording a higher degree of elasticity than a woven textile. As this research journey progressed, these foundational digital interpretations of the craft-based technique informed decisions through an implicit understanding of materials (Adamson, 2018) and technology to generate desired knit aesthetics. During the initial inlay technique exploration, I discovered the visual effect of varying the stitch structures underneath the inlay pattern. Stitches such as lace transfers, rib or links-links can be programmed to disrupt the inlay pattern, re-positioning singular points within the knitted surface. In particular, the intarsia inlay prototypes allowed surrounding areas of knitted ground to retain links-links material behaviours. Knitted surfaces built combining intarsia inlay and links-links stitch structures triggered memories of the Earth's tectonics. This connection, combined with the need to articulate surface movements provided a geomorphic focus for the designed knitted surface topography aesthetics.

Although this research follows a technique-led design perspective rather than a technical lens, some prototypes were impossible to knit without in-depth knowledge of the knitting machine obtained through the initial practice. One such technical fault materialised during preliminary investigations of the intarsia inlay causing knitting issues on the pattern edges (Figure 74). The N.SRY123LP knitting machine has swing carriers, which cause knit issues for intarsia inlay due to additional carrier movement between the knitted stitch and inlay float. This carrier side swinging motion is responsible for tearing on the inlay pattern edges. During Shima Seiki Mfg. Ltd. sessions, my trainer resolved this problem by introducing yarn feeder fixed blocks. These are moulded metal pieces that screw onto the carriers

preventing the mechanical swing action and converting the swing carriers to non-swing carriers. The latest inlay knitting machines all contain non-swing carriers. This carrier adaptation was a major technological breakthrough for intarsia inlay surfaces on the N.SRY123LP knitting machine, significantly reducing knitting issues. The inclusion of blockers was also a turning point in my perspective of the design-technical balance, each aspect feeding the other in a collaborative making environment.

4.3 Phase Two: Understanding Knitted Material Forces

4.3.1 Building Surface Movement

In this practice, a single stitch informs a collective knitted surface through neighbouring networked connections. "A module never works alone but as an aggregation of a multitude of instances. Thus, the whole emerges out of the interaction of a series of individual objects" (Tessmann, 2009, p. 52). The prototypes aimed to capture compositional occurrences of assembled material forces on singular and multiple levels. Individual knitted loops are dependent on networked relationships to transform from linear stable points into heterogeneous stitch sequences. Heterogeneous knitted surface behaviours resulted from the exploitation of positioned material mechanics built from links-links textile print-based repeats: block, half drop and brick. An alternatively positioned square offset repeat tested less structured repeats, resulting in indeterminate material forces inconducive to controlling knitted surface movements. Each straight-sided geometry was tested as multiple scaled versions ranging from 100% to 500% to explore resultant effects on material forces. The repeating links-links patterns additionally informed the double bed inlay grounds. Applying a direct transference of links-links patterns into the tubular jacquard knitted ground resulted in overly complicated visual compositions due to the initial scale and colour combinations prototyped. Further sampling of the double bed inlay technique applied increased scales of the original links-links pattern repeats, resulting in less-overcrowded surface patterning.

Emergent compressional and tensional material forces informed the geometric shapes and scales of links-links in variant repeating unit arrangements. For example, the links-links rectangle replicated in a brick repeat exhibits horizontal convergent material forces (Figure 75), decreasing the surface width. The scaled variants offer a range of surface behaviours ranging from tight to broad elongated folds with twisted torsions. The same rectangle in a half-drop repeating pattern (Figure 76) produces vertical surface compressions. These convergent forces create vertical recumbent folds in waves that extend the surface width. Links-links knitting with balanced amounts of knit and purl such as square produce the same



Figure 75. Interplay of material forces in brick vertical rectangle, scale 100% to 500%.



Figure 76. Interplay of material forces in half-drop vertical rectangle, scale 100% to 500%.

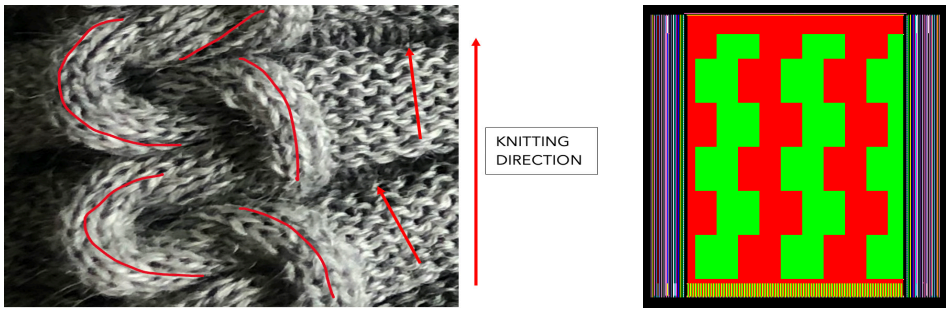


Figure 77. Mapping relationships of multiaxial material forces.



Figure 78. Transformative material forces resulting in peaks and troughs.

appearance on the technical front and back surfaces. Triangle and the diamond links-links designs are unbalanced, and the technical front and back knitting afford different surface effects. The material forces reduce as the pattern ratio of knit to purl stitch structure increases. Textures for single bed inlay prototypes were selected to accentuate material force collisions and tactility in the larger knitted surfaces.

Reflective analysis of knitted surface deformations revealed convergent and divergent folded material forces. "Nonlinear behaviour needs non equilibrium conditions to become manifest" (DeLanda, 2004, p. 17). The material forces result in imbalanced surface conditions generating asymmetrical folding that shift the stitch loops from the programmed two-dimensional grid. The resultant fractious material behaviours were generated not through my will imposed upon the surface; the knitted surface deformations arose as a collaboration between material behaviours, technique and designer during production (DeLanda, 2004). Transforming the flat plane towards a site of active matter highlighted the importance of understanding the material forces through the mapping of knitted stitch configurations and movements (Figure 77). Folding and unfolding knitted surfaces established a map of temporal events (Küchler, 2020) containing traces of the maker's material interaction. Material forces resulted in subduction zones generating peaks and troughs where the line curves and the grid distorts as the knitted surface folds over itself (Figure 78).

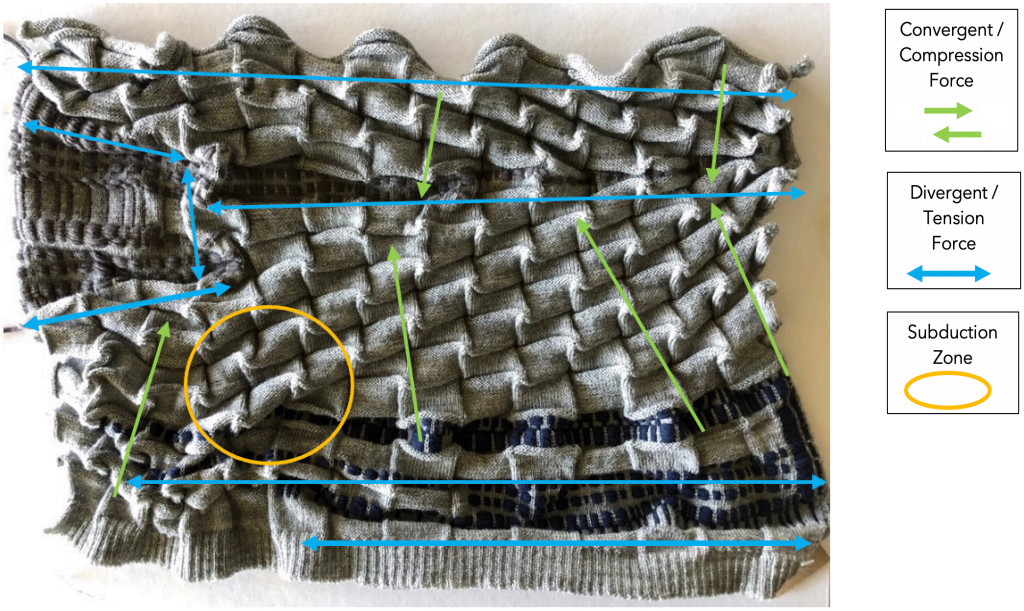


Figure 79. Mapping the material forces between knitted ground and intarsia inlay.

The surface becomes "a site where complex forces meet" (Adamson & Kelley, 2013, p. 1). Asymmetrical folds react to convergent forces generated by the placement of the links-links repeat. In contrast to this compression, the inlay creates divergent forces that extend and stabilise the surface. Interconnected to these material forces are collisional subduction zones where torsions are evident in the knitted surface. Photographic mapping of the interplay between knit and inlay material forces highlights the material convergence (green), divergence (blue) and subduction (yellow) surface movements (Figure 79). Dimensional knitted surface topographies encapsulate multiaxial and unbalanced convergent, divergent and transformational forces.

4.3.2 Material States

Material fibres were selected based on behavioural properties, in which the materials emphasised the knitted surface 'texturology' (Bruno, 2014). After testing various fibres, I selected merino and a wool-acrylic blend for the ground knits, due to their properties of matter emergent agency. These fibres embrace the surface deformations that the links-links stitch structures influence. The surface folds achieved by cotton were less distinct and prone to unfolding (refer to Figure 48, page 48). In contrast the merino knitted ground maintained its knitted surface topography even when the overall surface scale increased and suspension of the textile occurred. Experimentation with materials resulted in informed design decisions based on the "material performance and the systematic behaviour of its assembly" (Kolarevic & Klinger, 2013, p. 7). Inlay textiles react differently to solely knitted textiles, due to the variant material properties of the opposing construction





Before heat is applied to Pemotex yarn. After heat is applied to Pemotex yarn.

Figure 78. Double bed inlay with heat-reactive surface deformation.

methods. Inlay knits are assembled in the digital grid as interconnected layers of making, folding onto and into themselves, encountered as a disrupted surface. According to researcher Claire Pajaczkowska (2005), the grid becomes "a matrix of intersecting verticals and horizontals, as systematic as graph paper, and yet it is soft, curved and can drape itself into the three-dimensional fold" (p. 233). The digital coding emerges from the knitting machine as a pliable knitted textile with surface conditions acquiescent to the material stresses and forces present.

This practice folded and enfolded material thinking through crafted programming of the material forces to generate knitted surface shifts. According to Dormor (2020), textile practice occurs at, on and within the folding surface, recognising the fluidity and layering that this approach requires. The materials, the knitted loop and the inlay are always in a behavioural relationship (Jefferies, 2008). The balance of this liaison relies on the ensuing material forces. The materials in my surfaces are not static or inanimate but connected by vibrant material forces. Understanding the dynamic material behaviours provides opportunities for innovative structural thinking and extension of potential designs (Thomsen, 2014). This practice relies on understanding the interactions between the knitting technology, techniques and material forces that result in knitted surface topographical folding. Knowing how a reaction occurs means a reaction can be replicated, altered and manipulated during the act of making.

Tactility emerged as a critical design factor. The double bed grounds generated minimal surface movements. A heat-reactive polyester yarn, Pemotex, was introduced to the knitted grounds to increase surface deformation in double bed inlays (Figure 80). In my practice, the reactive yarn formed a linkage between initial knitted surface prototypes and the double bed inlay surface designs, evidence of this research's cyclic journey. Initial prototyping with Pemotex yarn trialled all-over steam, resulting in rigid solidified parts of the knitted surface. Zonal heat application fostered a process affording multiple surface options in the active knitted matter from a single design. While double bed inlay surfaces with Pemotex yarn visually navigate similar multiaxial material forces, they are less predictable than the single bed links-links grounds.





Technical front. Technical back.

Figure 81. Double bed inlay prototype with sections of solid colour blocking.

An alternative double bed inlay design aesthetic originated from solid colour-blocking investigations (Figure 81). Knitting issues occurred when exposing the inlaid yarn in the tubular jacquard ground during the colour exchange. Although this surface aesthetic was considered effectual, it was viewed as a significant shift from the intersecting ground sections employed in the single bed knitted surface topographies. These solid blocks of colour offered fewer opportunities for tubular pocket formation and possessed an element of disconnect with the photographic landscapes. The surfaces retained a high level of structured pattern organisation, rather than the fracturing and folding required to situate within my crafted knitted surface topographies. Heat-reactive fibres countered these flatter surface conditions. The performative characteristics of the reactive material enhanced the programmed matter activity, allowing folds and fragmentation to enter the double bed inlay surface equation through external influences.

Bolt (2007) challenges the idea that materials and a designers tools are simply a means to an end. Creative practice is portrayed "as a performance in which linkages are constantly being made and remade. Whilst each actor has the same praxiological status, each has its own character and contribution to make as part of the work of art" (Bolt, 2007, p. 3). In this sense, the materials selected became active participants in the creative process, with characteristics and quirks that enter the design equation. Knit, weave, yarn, and technology are all performers enlisted in the generation of knitted surface topographies. Knitted surface topographies are articulations and sculptural interpretations of the manipulated materials embedded in their making.

Digital knitting is programmed in a virtual structured grid system however, the linear structure morphs as the static two-dimensional screen informs the dynamic three-dimensional matter agency that exits the knitting machine. The coded material becomes uncodified in the shift from virtual to physical presence. At what



Figure 82. Knitted surface topography released from machine constraints.

point does this change occur? Is the matter agency activated as the knitted surface falls from the needles, free from constraints as a dimensional surface (Figure 82), constrained by knitted edges but not held within a frame? According to Pavko-Čuden and Rant (2017), "in flat knitting, some link-links structures exhibit self-folding after exiting the take-down zone. The folded state represents the relaxed, that is, the passive state" (p. 60). However, I view this emergent knitted surface as active as it morphs as the programmed combinatory material stresses and forces come into effect.

Similar to DeLanda's (2004) perspective, the knitted surfaces become active material forming an evolutionary collaboration with, or sometimes in opposition to, the design and designer. This perspective is evidenced in the knitted surfaces: the digital screen illustrates an ordered coded design; however, the introduction of physical factors such as the knitted loop, inlay pick and materials create an interplay of forces that inject their own will into the design equation. As Bolt (2007) suggests;

> Our relation to technical things is inevitably characterized by a play between the understandings that we bring to the situation and the intelligence of our tools and materials. This relation is not a relation of mastery but one of co-emergence. (p. 3)

The virtual simulation of the inlay knitted surface does not display the fluidity of knitting, where the technique is an active participant in the creation of surface folding. I become a director of the material forces while the tactile output is dependent on the performance and interaction of many factors such as the machine gauge, yarn and stitch quality. An argument begins, a battle between the constructed affordances and the appearance of shifting allegiances between subsequent material forces. The hierarchy of techniques generates dynamic interactions. In combination with design decisions related to stitch structures,

weave floats and positioning, the surface morphs into multiple options. The knitted surfaces are articulations and sculptural interpretations of the manipulated materials incorporated in their making. The complex surface illustrates the assemblage revealed. The individual knitted stitches collectively entwine to build a multitude or entire terrain.

During the making process, layers occur consecutively, "multiple and mutable layers enfold meaning within and between modes of practice" (Dormor, 2020, p. 20). One of the procedural questions that arose during this research concerned these interrelated material relationships: Are these layer relationships affected by a layering of command? Is there a hierarchy of activity with invisible rules applied? Do the materials shift first with the knitted stitch structure before the weave counters with stability? Which component of the technique has more influence, the knitted loop or the inlay pick? When the inlay pattern has a longer float, the knitted loop can afford more movement, but the inlay holds more stability when applied en masse, overriding surface shifts. Understanding and influencing these interconnected relationships is key to designing with the knitted material forces. The dominance of knitted ground or inlay pattern became evident as the prototypes moved into territories of material force exploration.

4.3.3 Additive and Subtractive Design

The research examines this idea of a hierarchy or dominance through the assemblage of intarsia and double bed inlays, where the inlay yarn partially breaks the surface plane. Material behavioural manipulation correlates directly to the inlay placement, pattern, and quantity achieved through additive and subtractive design. To allow material forces to enter the inlay and encourage zonal or partial subservient interaction with the knitted ground, I experimented with reductive derivatives of the intarsia inlay pattern. Ingold (2016) notes, "lines that are scratched, scored or etched into a surface are reductive since in this case they are formed by removal of material from the surface itself" (p. 44). Fragmentation across the knitted surface topography transpires when the compressional, tensional and shearing forces collide. Reading of material forces occurs across the vertical and horizontal axes. Reciprocal relationships emerge between oppositional material forces generated by the positioning of knit and weave-like textile structures.

Programmed horizontal and vertical subtractions (Figure 83) fracture the inlay patterning, allowing the ground material activity to dominate the knitted surface folds. Larger blocks of subtracted inlay patterning shifted the inherent stability of inlay, encouraging the ground deformation. The composite screen-view of both inlay and stitch structure layers allowed informed design decisions when positioning material force alliances. Knitted loops push and pull the neighbouring stitches,



Figure 83. Programmed vertical, horizontal and block subtraction of intarsia inlay.



Figure 84. Intarsia inlay pattern subtraction with links-links knitted ground dynamics.



Figure 85. Minimal intarsia inlay pattern with links-links dominating the surface.



Figure 86. Intarsia inlay negotiating links-links material forces.

and the interlocked singular inlay picks enmesh to inform the surface dynamics (Figure 84). This pattern-modification method is critical to vertical and horizontal surface fragmentations, allowing dominance of weave or knit characteristics for each programmed point, informing a component of the surface-building blocks. The ability to position a weave-like structure in designated areas offers designers the opportunity to alter the knitting's material behaviour, and extends future pattern, surface and application opportunities.

The removal of considerable amounts of the inlay pattern results in the knit becoming dominant in the overall aesthetic (Figure 85). In these combinatory prototypes, the reduced inlay pattern provides too little design for the eye to navigate towards the immaterial completion of the pattern layout. Understanding the ratio of inlay to knit and the layered relationship is essential to generating the desired material forces and a balanced aesthetic. This "designerly way of knowing" (Cross, 2006, p. 5) is partially tacit learning acquired innately. My practice shifted between digital and physical realms, increasing my understanding and ability to envision two-dimensional codes as three-dimensional knitted surfaces.

Aspects of the designs disrupted and warped the vertical and horizontal elements of the digital-programming grid. A successful grid disturbance method was created by introducing horizontal trails of points of inlay across the knitted surface (Figure 86). Inlay dashes or dots that remain negotiate the knitted surface peaks



Figure 87. Rib ground with curved intarsia inlay illustrating multiple knit linkages.



Figure 88. Single bed knitted ground with linear intarsia inlay illustrating minimal knit linkages.

and troughs, revealing and concealing the ends of intarsia inlay. These subtracted individual points serve as remnants of the inlay knitting, traces of patterns with the ability to blur the linear edges and follow the material properties (Arantes, 2020b). The barely visible inlay picks effectively connect the inlay knitting across the entire width of the needle bed, affording pathways from one side to the corresponding edge. When these traces are layered over horizontal courses of purl stitch structures the inlay follows the knitted surface ridge. The variations of subtraction added to the surface-building block design options.

4.3.4 Visible Surface Traces

My initial interaction with the inlay technique was self-taught, resulting in unexpected findings, such as the yarn visibly tracing connective inlay pathways. As author Richard Sennett (2008) notes, "machines break down when they lose control, whereas people make discoveries" (p. 113). Trace connections between elements initiated a shared choreography and co-authorship of a mapped surface trajectory. These yarn float pathways resulted from my subtractive design approach to inlay patterning. "In our terms the trace is any enduring mark left in or on a solid surface by a continuous movement" (Ingold, 2016, p. 43). In my prototypes, trails of connection are visible as continuous strands on the knitted surface's technical back-face, revealing the inlay yarn's migration. The two-by-two rib ground with curved inlay areas illustrated in Figure 87 demonstrates the concertina effect of a ribbed ground on multiple traces of inlay yarn. The length of the inlay yarn stretches across the knitting needles; however, once released from the machine's constraints, these strands relax, forming longer, curved linkages.

These traces can be eliminated, minimised or multiplied depending on the programming and positioning of the intarsia pattern. Linear inlay designs with straight edges can be programmed to produce minimal inlay linkages (Figure 88). These trails are a residue of the making process, relying on the knitted inlay

design's directional location on an odd or even course. The locational relationship between each intarsia inlay section to the neighbouring pattern is critical to revealing or concealing yarn pathways. The number of traces generated is controllable, with curved inlay divisions generating more inlay points of connection between trough and crest bands than linear territories. Inlay linkages appeared as uncontrolled maps in the initial surfaces, occurring due to limited inlay-programming knowledge. However, as my technical inlay programming knowledge progressed, this creative mistake allowed a unique element to enter the surface-building blocks and mode of making.

Inlay yarn draws the pathway between intarsia areas, remaining inside the edges of the knitted surface. This trajectory is invisible on-screen, becoming visible when making the virtual into physical. "Whilst vision gives a detailed description of the surface features of our environment, a superficial mapping of the landscape, touch provides insight as to how these elements are interrelated" (Philpott, 2012b, p. 55). Following the material traces with fingertips, the point-to-point connections between inlay patterns are disclosed and understood. Academics Roland Johansson and Randell Flanagan (2009) note;

> When humans manipulate objects, the brain uses tactile afferent information related to the time course, magnitude, direction and spatial distribution of contact forces, the shapes of contacted surfaces, and the friction between contacted surfaces and the digits. The inside of the human hand is equipped with four functionally distinct types of tactile afferents. (p. 345)

Knowledge attained through haptic interaction with the concealed surface is required to understand different facets of the knitted surface; the topography is tactile. The patterns and materials are understood as active participants imbued with complex behaviours offering new design potential (Thomsen, 2014). Experience and reflection fold into the twists and torsions as material forces collide. The knitted surface topographies rely on programmed replication, alteration and know-how to assemble the inter-relational material forces.

4.4 Phase Three: Developing a New Design Strategy

4.4.1 Language Influences

The material forces that occurred through links-links repeats and scale testing evoked visual connectivity to land movements. The geomorphic language selected to articulate the material forces and encapsulate surface aesthetics informed this



Figure 89. Sand textures from Te Kouma, Coromandel, New Zealand.



Figure 90. Material forces in the knitted surface emulating nature's fluidity.

design practice. "Our planet's surface topography, the distribution of landscape highs and lows, is complex and intriguing" (Peterson et al., 2017, p. 385). Translation of landscape photographs inspired knitted surface topographies which explore complex surface relationships on a micro and macro level, building an innate understanding of surface movements. Applying material forces as an integral part of knitted surface design generates a new perspective on links-links and inlay interactions with knitted surface processes. Figure 89 is a textural snapshot taken at Te Kouma, Coromandel, capturing the sand caught in time yet fluid in its ability to shift with the next tide. "After it is built, structure is still not a fixed entity. It moves and changes, depending on how it is used" (Grosz 2001, p. 7). Knitted surfaces shift and morph with each positioning. The knitted surfaces in this study retain the ability to manifest as active sites constantly emergent due to the structural flexibility of knitting, emulating the fluidity of nature (Figure 90).

A fluid design approach was applied to intuitive knowledge during the digital creative process, directly responding to technical and material design issues. The research was a journey of material thinking through practice. Theoretical context evolved through reflective practice, parallel with the material thinking behind the creative process and the connective relationships that emerged. Subtracted fragments of the inlay pattern in the knitted surface topographies cause the human eye to attempt to complete pattern configurations and build regularity from the irregular. The fragments consist "of elements that can be dislocated, manipulated, cloned and endlessly mutated" (Hedges, 2012, p. 57). My pattern design method



Figure 91. Progression of the links-links patterning complexity single to multiple ground collisions.

disrupted the knitted surface. The assembled units increased the potential for novel design solutions (Philpott, 2011), as heterogeneous knitted terrains. In the knitted surfaces, design compositions followed repeating patterns. These patterns are not merely ornamental but intrinsic to building a knitted surface topography.

> The repetition of working units, whether understood as repeat or not, generates the textile object. Consequently, all textile techniques are based on the idea of patterning: an isolated unit (repeat) is repeated with potential infinity. So, we can state patterns are not accidental but substantive to textiles. (Kraft, 2004, p. 281)

Material forces imbued in the links-links ground are built with the inlay pattern positioned as separate yet interrelated to the knitted loops' behavioural properties. These patterns can be infinitely variable and like encoded language, the textiles arbitrarily converse (Barber, 1994) with the designer in an open-ended exchange. Consideration of the inlay positioning and proportion occur synchronously with the development of ground patterning in these knitted surfaces. A knitted inlay is a hybrid textile constructed from intersections that build one point from two autonomous factors, tracking paths that react to different material rules and forces; the subsequent surface embodies coerced disruptions. "Landforms represent the interplay of one set of processes that elevate, depress, or disrupt the Earth's surface creating topographic inequalities" (Peterson et al., 2017, p. 386). The programmed links-links grounds and scales afford intersectional collisions influenced by surface movements contained in natural environments.

Initial hybrid surfaces investigated programmed material behaviours positioning intarsia inlay into a single links-links ground. These investigations provided a base understanding of inlay edge technical knitting issues but lacked a design emphasis. Single motif repeating grounds promptly progressed to complex divisional placement of multiple links-links grounds (Figure 91), increasing knitted surface

disruption. Multiaxial material forces from a single links-links ground resulted in more fabric drop from the weight than multiple intersecting patterned surfaces. The vertical drop of the knitted surface is an encounter between multiple elements with interconnective relationships, a dynamism of assembled alliances. The surface manifests "as both action and artefact, process and product, becoming and being" (Carlin, 2018, p. 11). The heterogeneous knitted surface topography conditions exhibit multiple matter configurations.

4.4.2 Building a Single Bed Topography

The organic patterns of natural landscapes have informed my practice, offering an alternative interpretation of pattern and placement for knitted surface. Classification of surface movements draws from geomorphological terminology relating to directional material forces, navigating complex folding over the knitted surface topographies. The building of the single bed inlay surface designs utilised structured digital processes to create unstructured physical outputs (refer to Appendix E). The design approach layers linear-digital grids to produce surface transformations during the conversion to physical knitted surfaces. This method of making relies on intuition in a way I struggle to articulate, as it is a connection between myself and the technology. This unarticulated tacit knowledge (Polyani, 1967) has become personal knowledge acquired through intense engagement with the links-links and inlay knitting techniques.

During this topographical investigative practice stage, several links-links ground scales and intarsia inlay designs were built using the layered automatic software method. These prototypes taught reflective approaches to construct single bed knitted surface fragmentation through material force manipulation. Design componentry selection for the construction of knitted surface topography occurred in a formulaic pick-and-mix approach from the identified surface-building block components; for example, the design components selected for the Block Twill knitted surface topography (Figure 92).

The library of links-links prototypes reinforced design decisions based on tactility, force direction, and surface aesthetics. These links-links grounds were collaged directly onto the screen into the sections inspired by the layered photographs. Initial selection of the ground structures was based on the screen aesthetic and proportion, without consideration of the disruptions multiaxial forces could cause. With a growing understanding of the sectional surface interactions, opposing directional material forces generated surface deformations that maximised the collision of designed horizontal and vertical stresses. The Block Twill prototype contains a distinctive weave origin built from inverse and standard coded inlay in alternating rectangular blocks. Solid areas of inlay patterning establish weave-

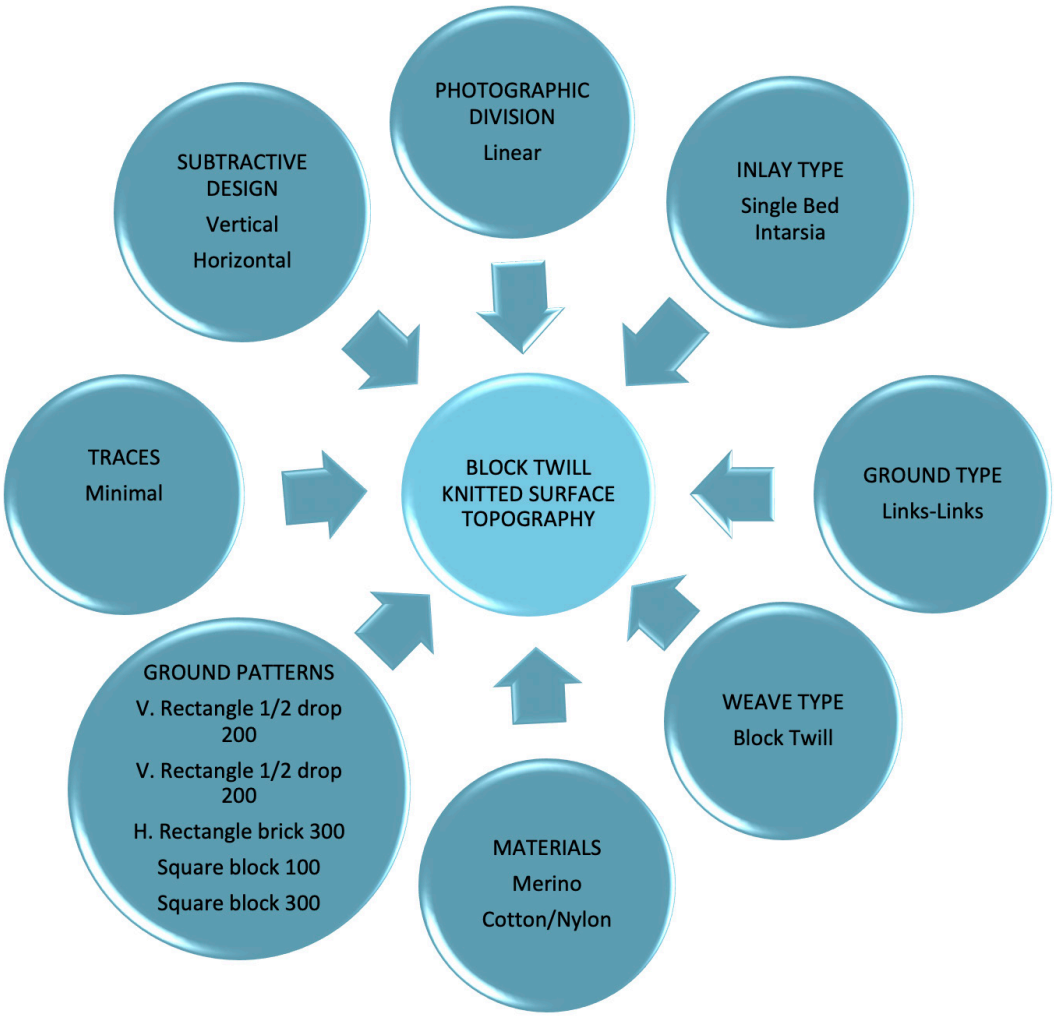


Figure 92. Surface-building blocks for single bed intarsia inlay Block Twill knitted surface topography.



Figure 93. Block Twill intarsia inlay with weave-dominant material forces.



Figure 94. Block Twill single bed intarsia inlay with multiaxial material forces.



Figure 95. Fragmentation of links-links ground and inlay pattern in Block Twill intarsia inlay.

dominant characteristics that influence the stability of the knitted surface (Figure 93). Programmed collisions rapidly exchange link-links grounds over short distances instigating multiaxial active boundaries (Figure 94). These fractured areas demonstrate evidence of the dominant properties of merino yarn in the resultant dynamic knitted surface activity.

Layering of material forces transpired to reveal and conceal surface patterns in which horizontal and vertical linear deletions of the inlay allow oppositional convergent and divergent material forces to materialise as active folds. These linear deletions follow the folding tract of the links-links ground, allowing disruption of the linear grid through biaxial compressions. Crafted two-dimensional knit codes built an environment conducive to the transference of vibrant matter (Bennet, 2010) into complex three-dimensional surface disruptions (Figure 95).

Fragmentation of material forces and patterning deform the entire surface, where the fragment, according to Barnett (1999),

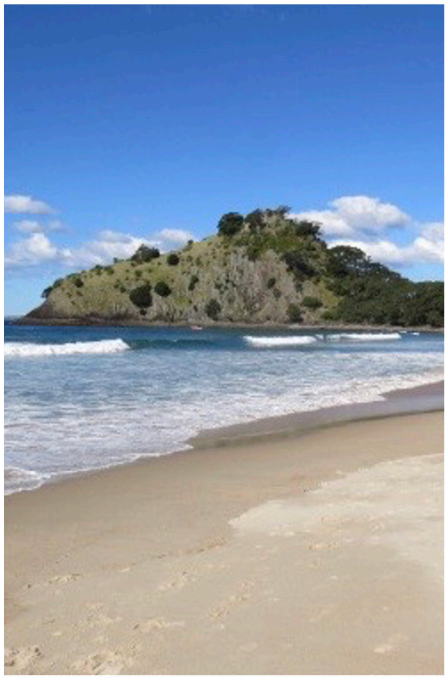
> bears witness to a broken whole; yet it is also a site of uncertainty from which to start over; it is where the mind extends beyond the fragile boundaries, beyond frayed and indeterminate edges, expanding in the fluidity of the smooth. (p. 188)

The fragmentation of the inlay pattern breaks the programmed surface affording an element of ambiguity in my design process as an unstructured knitted surface emerges. The compressional or tensional edge conditions increase or reduce the width of the knitted textile. These active boundary conditions are responses to the componentry decisions formulated during assemblage, generating non-linear surface movements.

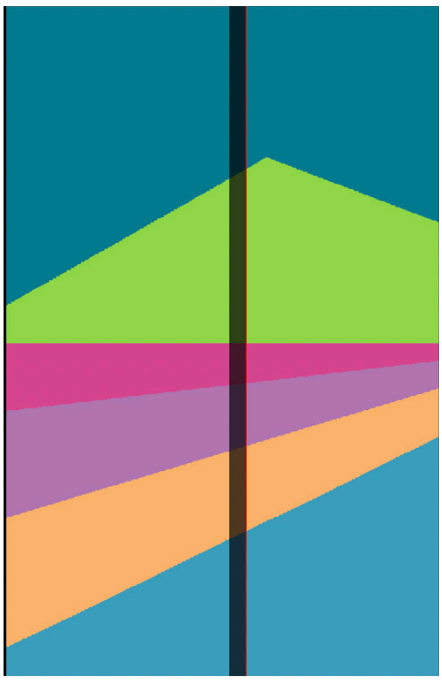
This practice observed surface folds and fractures generated as a response to the merino's material performance; similar to how surface relief is informed by the Earth's behaviour when subjected to forces and stresses. "Folding, which is a bending or crumpling of rock layers, occurs when compressional forces are applied to rocks that are ductile (bendable) rather than brittle" (Peterson et al., 2017, p. 389). The knitted loop formation is conducive to a malleable material where the resultant matter demonstrates dynamic fluid traits within the knitted surface. The knitted loop is coerced in multiaxial directions in response to the inlay and the push and pull of neighbouring links-links loops. The key to knitting a single bed intarsia inlay topography is the technical clearing of the edges. Areas of back bed stitch structure and inlay overlaps require alteration to front knit to remove knitting issues at these technique edges. This blend of technical and design knowledge is essential to the development of this research practice. Without this deeper technical understanding of inlay and material force assemblage, digital knitting design remains limited. In discourse relating to hand knitting, Arantes (2020a) writes:

> Not just due to the fractal character of knitted surfaces but also due to the various ways of building them up through using different types of stitches and patterns, knitted things are far from being flat, two-dimensional phenomena, even if the term surface – particularly in an elementary mathematical sense – might imply such a geometric state. Knitted surface textures present us with a whole textile landscape in and of themselves. (p. 163)

My designed surfaces illustrate and support the acquisition of material forces knowledge through a physical vehicle (Mäkelä, 2007; Nimkulrat, 2009). These constructions of material forces inform topographies that encourage navigation by touch across the entire surface. The hand embraces surface disruptions as Dormor



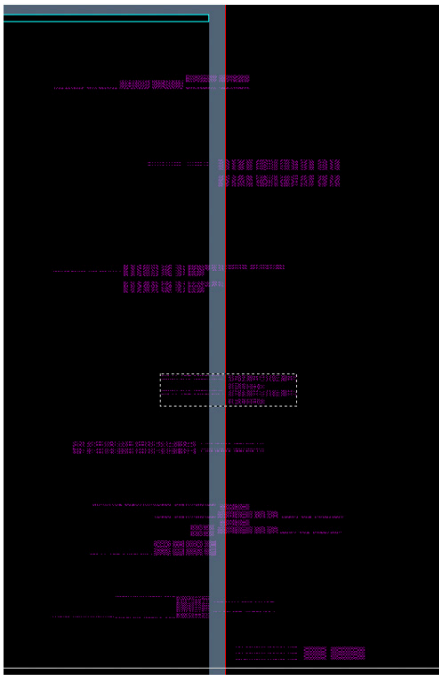
Landscape photograph.



Sectional colour-blocking.



Fill layer with links-links pattern.



Fill layer with inlay pattern.

Figure 96. Interpretation of photograph of land, sea and sky across two knitted surface topographies.

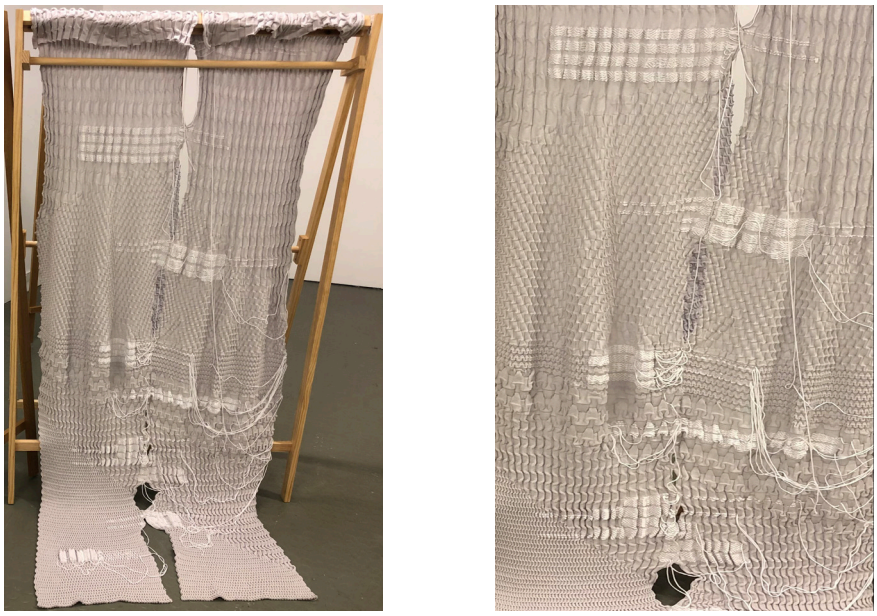


Figure 97. Diminished surface pattern disruption in the larger knitted surface topography.

(2020) notes, "the caress is a seeking to know" (p. 104). Physical encounters explore the notion that haptics offer multiple information exchanges for the maker during the crafting process (Harris, 2005). I absorb information through touch, responding to the tactility and understanding more than vision alone comprehends (Prytherch & McLundie, 2002). As Philpott (2011) suggests, "our intimate and ubiquitous daily bodily contact with textiles fosters a particularly close relationship between textile designers and the materiality of their discipline" (p. 101). The virtual coding decodes as physical form, the material forces between knitted stitch and inlay are navigated as fingertips unfold the hidden surface.

Although the original photographic images are horizontal, my knitted panels tend to be vertical layouts due to needle bed constraints of width whilst the length is limitless. Digital manipulation of the photographs occurred through processes that cropped, transformed and divided the images. The interrelated sectioning interpreted the photographic divisions evidenced in nature's layers of land, sea and sky across two knitted panels (Figure 96). Colour-blocking of these sections allowed a paint-by-numbers approach and efficient filling of the digital surface with numerous links-links grounds. The realisation of zonal proportion on-screen was critical; sometimes, the size of the divided sections increased or lines shifted to improve the overall aesthetic balance. These design adjustments relied on an ability to convert on-screen codes into the physical knit. The increased panel size encountered diminished surface disruption when smaller-scaled grounds positioned in larger knitted surfaces (Figure 97). Increasing the surface size required some links-links grounds to be scaled up to maintain an overall design equilibrium, as achieved in smaller prototypes.



Technical front.



Technical back.

Figure 98. Two-by-two rib with diamond twill intarsia inlay, illustrating the displacement of linear rib.

The inlay pattern and the ground structures provided border design crossover of pictorial scenes over multiple panels, yet each textile's edge conditions reacted independently. This design extension across multiples encouraged a collapse of the framed boundaries through the embedded surface's specifically positioned conditions. Crafting the knitted surface across borders uses "the idea of connectedness in terms of paths between points" (Messer & Staffin, 2018, p. 209). To design an effective transference of the inlay patterning across interconnected panels, it was necessary to preserve the aesthetic of the inlay beyond the knitted panel edges. If the pattern subtraction method removed significant amounts of the identifiable weave appearance, the eye dissipated the inlay design, rather than tracing pathways and connecting across knitted surfaces. At this length, the multiple interconnected knitted surfaces were programmed directly into the automatic software.

4.4.3 Building a Rib Topography

During the additional exploration of the inlay technique using the automatic software, I discovered the potential to shift the grid's programmed vertical linearity by introducing rib as a knitted ground (refer to Appendix F). The rib inlay offers design opportunities for subtle surface fragmentation as individual stitch loops warp, deforming neighbourhood stitches and mapping a distortion of the vertical linear. Initial rib-based prototypes applied a two-by-two rib structure, covering the entire ground with twill and plain intarsia inlay patterns. These inlay patterns maintained the weave aesthetic even when the rib emitted the illusion of partial concealment of design. Obscuring the intarsia inlay pattern occurred due to the tight folds of consistent convergent forces informing the rib's regular vertical ridges (Figure 98). These tight folds informed pattern effects, with specific points mapping back on themselves (Messer & Staffin, 2018). The intarsia inlay positioning imparted surface disruption, imposing a displacement of the rib's movement to a positioning outside the virtual programmed site. Through an increased

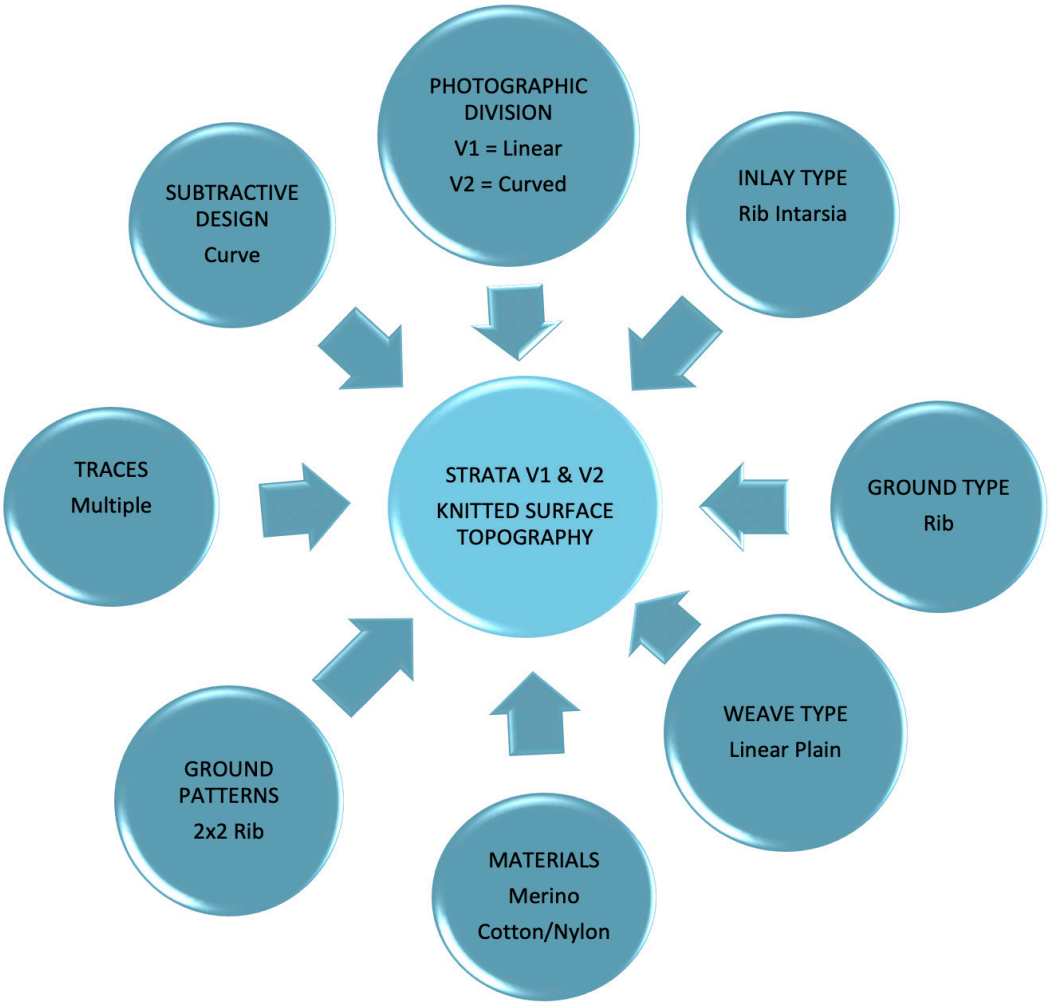


Figure 99. Surface-building blocks for rib intarsia inlay Strata V1 and V2 knitted surface topography.



Figure 100. Strata V1 knitted surface topography with squared inlay edges.

understanding of the heterogeneous behaviours of the knitted loop and inlay, I could code the knit's compositional performance, informing the active surface matter. The material forces of the intarsia inlay produced the visual conveyance of linear rib to the left or right in response to the inlay application. Twill inlay is very tactile, exhibiting an embroidery-like appearance, and feels similar to reading the surface as braille. The resultant visual effect holds a QR-code-matrix quality as the eye attempts to decode the inlay pattern.

Assemblages explored multiple overlapping intersections to intensify collision between knitted material forces. A series of strata-inspired prototypes utilised the pick-and-mix technique to select components from the surface-building blocks: plain weave inlay with inverse pattern and sections of purely knitted two-by-two rib (Figure 99). As Dormor (2020) proposes, woven surfaces are "a space for thinking through the interplay of textile structure and its behaviour" (p. 65). Ribbed ground prototypes allowed me to recognise the importance of balance between the inlay pattern and plain rib areas of relief. Prototype Strata V1 did not contain enough inlay patterning to significantly disrupt the knitted surface, due to an over-merging of the divisional sections on-screen. The inclusion of inverse inlay in the design increased the pattern contrast and aided in defining zonal separations. The prototype Strata V1 contains several inlay sections that incorporate a partial subtraction comprised of deleted linear blocks, producing squared edges (Figure 100).

Behavioural relationships in the ribbed surface increased by multiplying the number of interconnected layers sketched on-screen. Pattern impacts the way we interact with, see and negotiate our environment (Jefferies, 2012). The structured squaring of the intarsia inlay edges, as evidenced in Strata V1, was not effective at maintaining the layered sectional contours of the original photograph. According



Figure 101. Strata V2 knitted surface topography with curved surface sections.

to DeLanda (2015), "nonlinear patterns represent a variety of possibilities of which the linear case is but a limiting one" (p. 17). The nonlinear design approach to surface division used in Strata V2 produced multiple traces of the inlay yarn pathways and maintained a stronger connection to the inspirational source (Figure 101). The two-by-two rib creates the illusion of longer floats, bringing the foreground knitted surface closer together through the tight vertical folds.

This practice progressed to incorporate knowledge of material forces gained from previous prototypes. The juxtaposition of the tightly regulated rib folds with active matter generated through the links-links grounds created an environment of contrasting material forces. The horizontal rib compressions sit beside the multiaxial forces of the links-links grounds, increasing the knitted surface deformation and altering the edge conditions. Dormor (2020) notes "as a structure and an action, folding resists occupying a singular space, preferring a space that has the capacity to stretch, fold and inflect" (p. 11). The layering of components from the surface-building blocks generated the knitted surface topography of Strata V3 (Figure 102). Using colour-blocking and pattern fill the compound ground was built on the structure page through intuitive positioning of the two-by-two rib and the dynamic links-links ground repeats (Figure 103). The inlay pattern was then aligned to the mixed ground and viewed as a composite screen to check the designed behavioural interactions (Figure 104).

The emergent surface reveals the intersectional reactions of knit and inlay, demonstrating relational material forces that generate symmetrical and asymmetrical folds. "In their unfolding, the pleats reveal their formation, in their formation their unfolding is created. This is the temporal field of the fold. It holds within itself an unfolding event: folds within folds" (Dormor, 2020, p. 12). The links-links ground increases the distortion of the edge conditions, and convergent

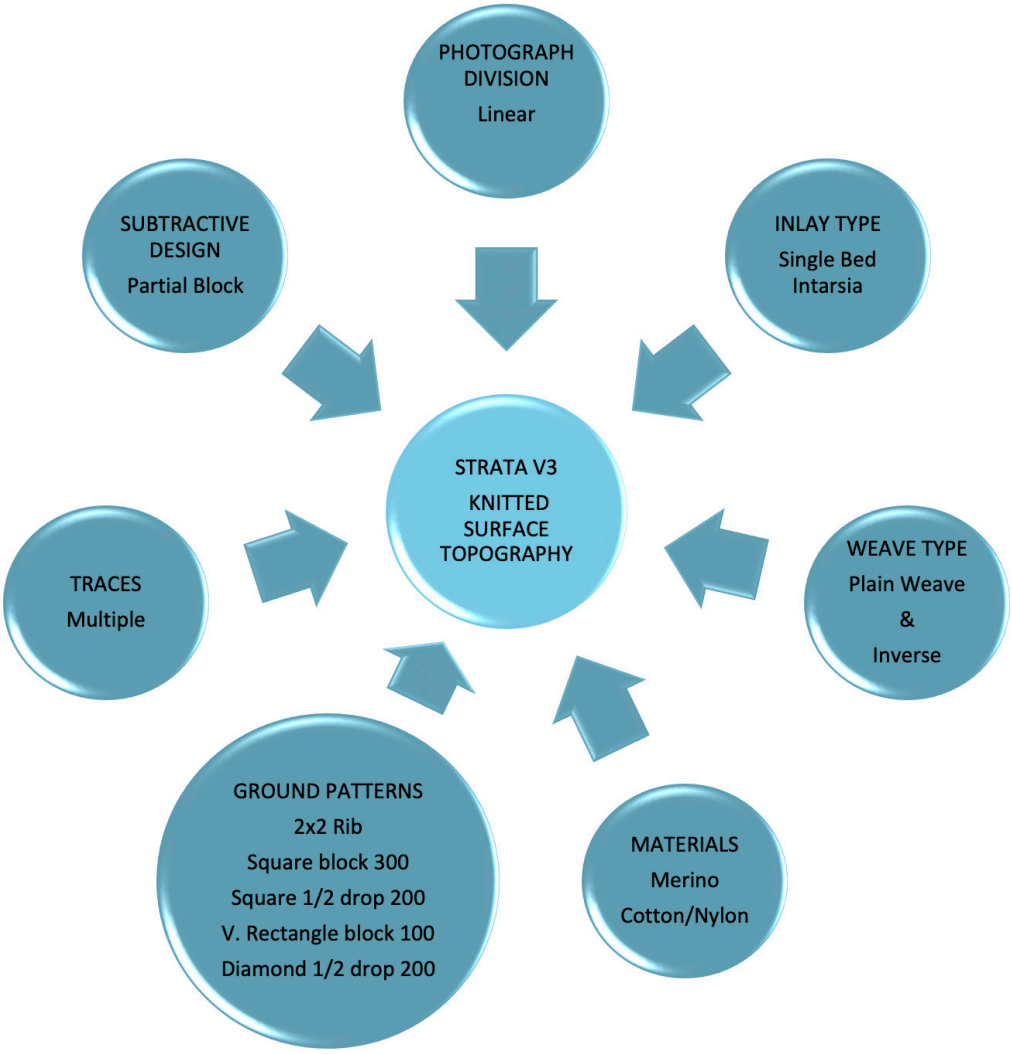


Figure 102. Surface-building blocks for Strata V3 rib intarsia inlay knitted surface topography.

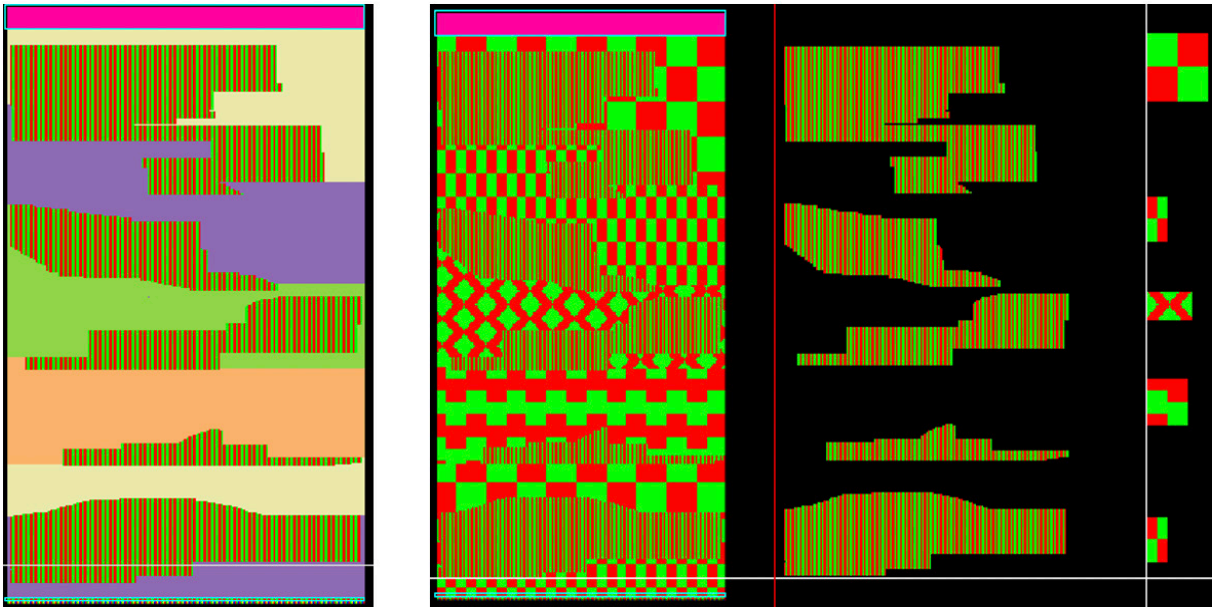


Figure 103. Converting colour-blocking to rib and links-links grounds.

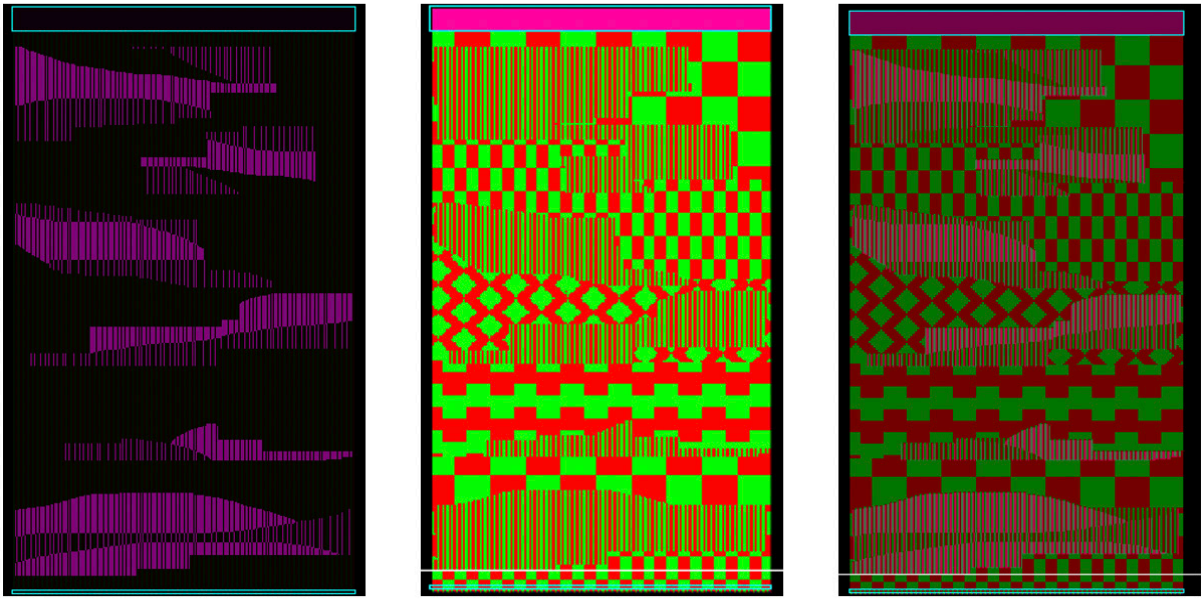


Figure 104. Layered relationships of inlay colour and structure viewed as a composite page.





Technical front. Technical back.

Figure 105. Strata V3 knitted surface topography.

and divergent forces become evident. The rib areas behind the inlay pattern provide consistency within the ground while allowing a subtle distortion of the pattern (Figure 105). The technical surface back illustrates the pathway of inlay yarn as traces are drawn over the surface (Ingold, 2016). The rib's accordion-like surface affects the pathway curves as the trace is longer than the folded ground it lies behind. The built knitted surface navigates the yarn and stitch agency, generating active boundaries that settle and resettle, concealing and revealing the nuances of embedded material forces.

4.4.4 Building a Double Bed Topography

Inlay knitting technology is used in double bed surface prototypes to position strands of yarn inside two grounds rather than embedding them within a single ground. The construction of double bed grounds consists of tubular jacquard knitting techniques that allow two surfaces with varied appearances to be created. Complex old-format programming applies packages that dictate the inserted yarn's visible points in the double bed knitted surfaces (refer to Appendix G). The double bed inlay designs are modulated interpretations of weave patterns, due to technical coding issues involving the number of needles and courses required for an individual juncture of reveal. Single bed inlay patterns require a sole code to form an inlay point, whereas double bed inlay entails a group of four codes to generate one point of surface exposure. These double bed inlays remain level planes with limited visible disruption of material forces until reactive yarns such as Pemotex enter the surface assemblage process.



Before heat is applied.



After heat is applied.

Figure 106. Double bed inlay demonstrating merino combined with Pemotex yarn.

These double bed knits require external activation to generate dormant material forces contained in the reactive yarn. As noted by DeLanda (2015), "morphogenesis can only take place if an external agency acts on inert matter" (p. 21). In this research, heat is the catalyst used to activate the deformative behaviour of the Pemotex yarn, triggering other material states (DeLanda, 2015). The thermal reactive properties of the prototypes were stimulated through a heat source, allowing an increased level of control in the crafted material forces. As observed in the double bed inlay prototype, combining a ground yarn with Pemotex yarn allows yarn activation with variant colour opportunities (Figure 106). The tubular pockets combine with the convergent material forces of the Pemotex yarn, informing asymmetrical folds and troughs.

Academic Jane Scott (2015) states in response to programmable reactivity in knit:

> Shape change is controlled by yarns and knit structure, and the fabric itself determines the final geometries as it transforms from 2D to 3D. The careful application of all aspects of the textile: fibres, yarns, fabric, and form, means that rather than applying additional technology to a knitted substrate [surface], my work embodies the nature of knit itself as a responsive form. (Scott, 2015, p. 17)

Like author Anne Fields' (2010) collapse weave technique, the double bed inlay surfaces use the dynamic behaviour of the fibres to distort the linear making process, following the material's properties (Arantes, 2020b). The surface stability emerges from the positioning and activation of compressional yarn characteristics rather than the knit or weave surface aspects. The inclusion of Pemotex yarn in the ground knitting creates a surface awaiting activation, a "site where complex forces meet" (Adamson & Kelley, 2013, p. 1). The activated Pemotex yarn captures the material forces and individual stitch movements as a singular preserved state of matter flux. Once heat activated, the knitted surface becomes a permanent representation of the material's dynamic affordances.

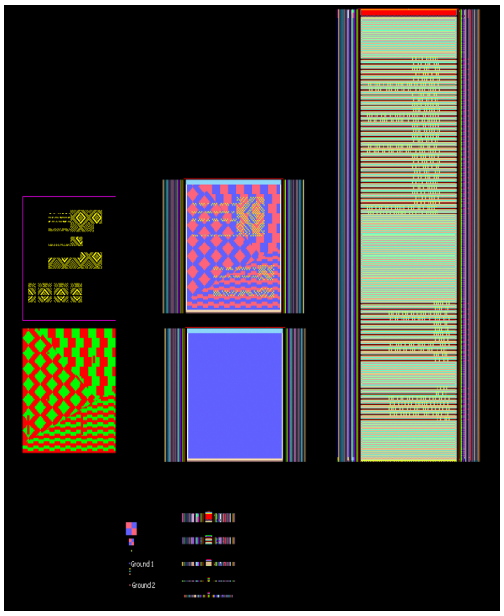


Figure 107. Programming of separate inlay pattern and ground layers on a single screen in old-format software.

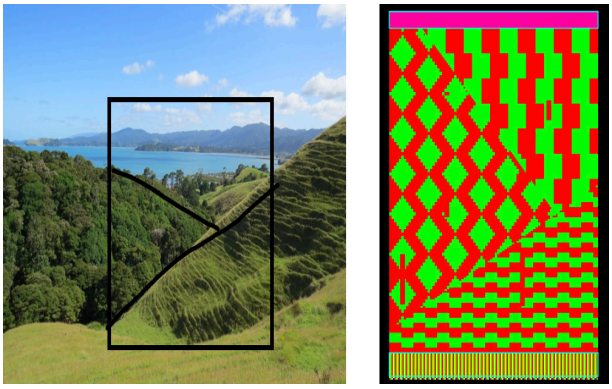


Figure 108. Cropped Coromandel landscape photograph for ground sections.

Double bed inlay techniques apply a layered assemblage of designed components within old-format software on a single screen (Figure 107). The terrain layout for the preliminary tubular jacquard grounds used cropped and merged sections from a photographic landscape (Figure 108). These partitional lines were altered on the digital screen, shifting the balance between interconnected surface conditions. Philpott (2011) writes that "attention to details of surface texture in the design process establishes the material, tactile object as central, rather than the image of the object" (p. 120). This tacit response to the screen emerged through knowledge and the ability to interpret the coded digital as the built physical surface's tactility. Academic Peta Carlin (2018) refers to building a relationship between surface and place, noting that "the resultant web can be read as a structure, surface or pattern, or often a combination of these, for the concept like a fabric is pliable and is given shape via deft manipulations" (pp. 10-11). Although Carlin references weave, this applies to the encountered relational layers between the surface linearity of the knit and inlay components entwined with the material behaviours, maker and technology.

Shima Seiki SDS-One Apex3 software packages hold essential knitting machine information in a coded format required to develop knit designs. These double bed inlay surfaces cannot be generated via automatic software due to the complex knitting information required. Surface-building blocks selected for the initial double bed inlay prototypes (Figure 109) were adaptive derivatives of a prior single bed prototype. The previously used inlay and links-links ground patterns were copied to an old-format programming page. The coded colours of the ground were

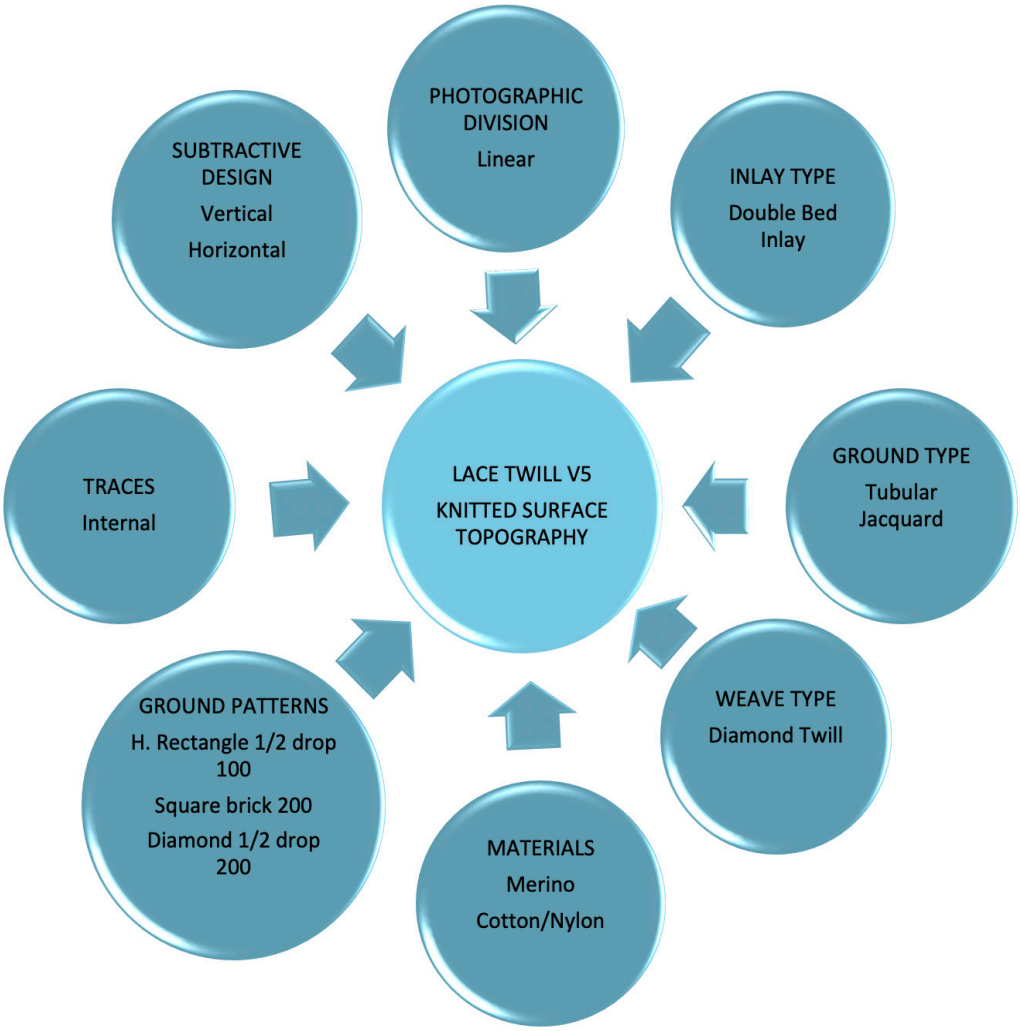


Figure 109. Surface-building blocks for double bed inlay Lace Twill V5 knitted surface topography.

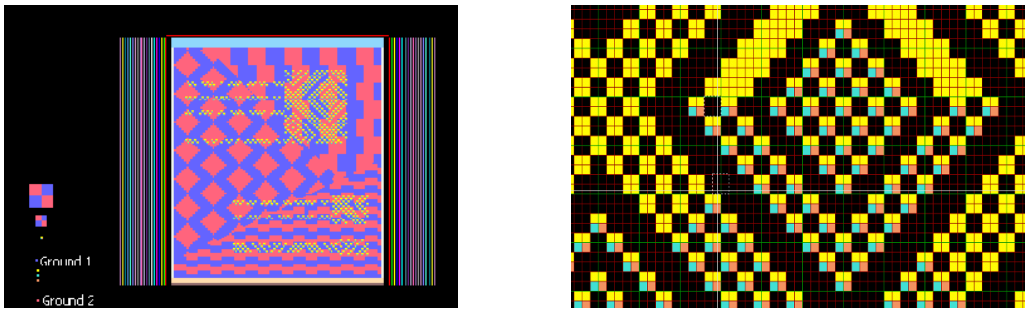


Figure 111. Diamond twill pattern coding conversion for double bed inlay Lace Twill V5.

exchanged with tubular jacquard package colours, altering the single bed to double bed knitting (Figure 110).

Replicating the diamond twill pattern in the Lace Twill V5 double bed inlay surface required an increase in the original pattern scale (Figure 111) and the placement of programmed packages for the lace holes. The weave-inspired pattern is disclosed across the exterior of the surfaces, detailed but inert in larger sections unless horizontal or vertical fragmentation allows the material forces to enter the surface equation. This crafted manipulation of material forces informs the textural manifestation of design intent. The double bed inlay technique required too many needles and courses per package to knit an exact representation of the complex diagonal twill pattern shifts.

The separately crafted ground and the inlay pattern components were positioned layer upon layer, merging design and technical knowledge. The double bed inlay pattern's interrelated arrangement in relation to the jacquard ground can be on an even or odd course, as the inserted yarn is positioned internally across the entire surface. During double bed inlay trials, it was discovered that the visible points of the positioned yarn must remain within the knitting area of a single carrier, as multiple carriers interchanging inside the inlay pattern caused technical knitting issues. Subtraction of inlay patterning entailed deletion of entire package groups, horizontally and vertically. In this respect, the technical disclosed design possibilities, with packages positioned in response to technological and tacit knowledge. This practice transpired not as the search for an optimal solution; instead, the technique-led design was exploratory (Philpott, 2011). The knitted surfaces marked the passage of my knowledge-building journey.

The design assemblage process for the double bed inlay technique tested assemblage variations of inlay patterning. These double bed inlay prototypes trialled singular and multiple points of yarn exposure, generating surface knowledge through variant additive and reductive exploration. According to Albers (1944), free material experimentation provides a space for material performance



Figure 112. Comparison of a single bed intarsia inlay and double bed inlay knitted surface topography.

which "can result in art, or it can result in the satisfaction of invention in some more technical way" (p. 52). The material behaviour of Pemotex yarn is necessary for transformative surface shifts. Material forces become physical manifestations of coding placements, in which the surface transforms "as the digital manifests itself as a material surface" (Rauch, 2020, p. 59).

The scales of the geometric ground patterns are critical in the double bed practice, as assemblages using small scale repeats produced predominantly inflexible surface deformations. Scaling up the geometric pattern surface-building blocks increased the volume of material in tubular pockets, encouraging a more flexible folding behaviour comparable to the multiaxial links-links surface disruptions (Figure 112). This design replication process utilising surface-building blocks generated for single bed grounds provided a comparative environment between knitting techniques, regarding the successful inclusion of material forces and resultant surface topographies. The thermally activated Pemotex folds are semi-controlled, partially directed by the maker assisting the unpredictable heat activation processes that dictate surface disruptions. The activated surface shifts are emergent within the design process rather than a pre-existing condition.

The double bed inlay packages result in enclosed yarn mapping beneath knitted surfaces, selvedge to selvedge, emerging through crafted lace holes to reveal encoded patterns. Ingold (2016) discusses traces drawn over a surface; however, my double bed techniques conceal inlay traces between surfaces, appearing, disappearing and reappearing. The inlaid yarn establishes pathways built from regular knitting machine movements forming irregular layering between grounds. Double bed inlay edges can be closed with the inlay yarn visible as a series of taut vertical loops, fully closed edges using tubular jacquard colour exchanges or open tubular edges revealing longer traces of the internal yarn (Figure 113). The emergent edge conditions are "zones of interactivity" (Halliwell, 2020, p. 63), becoming either structured planes or unstructured biaxial compressions disrupting visibility of the inlay yarn's path.



Closed side edges.



Closed side edges.



Open side edges.

Figure 113. Double bed inlay, closed and open side edge knitting options.

4.5 Conclusion

This research has developed to combine theoretical and material practices inspired by geomorphological surfaces. This knitted surface practice is underpinned by in-depth knowledge of designed material forces and inlay knitting techniques. The assemblage of material forces discussed in this chapter offers an alternative to stable planes, transforming surface aesthetics by visibly warping linearity through individual stitch deformations. My practice was fluid, with reflections folding into an intuitive experience through a series of creative leaps, drawing on new technical and tacit know-how. The manifestation of knowledge has become a personal, contextual journey, occurring over time and through direct engagement with the technology and knitted surfaces.

This research journey highlighted an internal conflict involving the precipice between technical and design knowledge. Does the technical lead the design, or does the design lead the technical? (Power, 2007). In this research practice, the technical initially guided the design; however, this shifted when the technical learning responded to the designed inlay knitted surfaces. The knowledge balance has altered, allowing the design to occur outside the known technical locale. Rather than programming being an impediment to potential creations, resolution of design issues occurred during this process as designer and technology co-created. This investigative development process looped back to the beginning, enfolding the knowledge gained from preliminary prototypes into the advanced knitting techniques learnt along this research journey. The research route followed a series of cyclic iterations, with interconnective points of design discovery along practice pathways. The theoretical context of this practice evolved through the analysis of making, in parallel with the thinking behind emergent interconnective process relationships.

Using the surface-building blocks to design the knitted surface topography established a creative process utilising the interrelated responsive behaviours of the components to generate multiaxial surface activity. The material forces of knitted surfaces fracture the surface as tactile representations of photographic landscapes. The design components form a "web of relations that, on closer inspection, turns out to be a web of relations of relations" (Arantes, 2020b, p. 196), in which multiple dynamic relationships arise between yarn, knitted stitch structure, inlay, technology, materials and designer. The knitted surface topographies enfold the knowledge and showcase the links-links and inlay knitting techniques becoming sites of technical-design know-how (Nimkulrat, 2013). The next phase of this practice was an informed practice synthesis to extend surface assemblage testing with the surface-building blocks.

Chapter Five: Emergent Terrains

> Knitted surfaces are material concretisations grown out of tiny repeated movements. They do not hide, cover up or conceal; much to the contrary: they reveal. They reveal technical knowledge, skill and dexterity, they reveal an empathetic understanding of materials and patterns. (Arantes, 2020a, p. 157)

5.1 Introduction

This chapter encapsulates the design methods and technical knowledge discussed previously in Chapter Four by investigating the effect of size and scale on knitted surface topographies. The synthesis of my practice utilised extreme elongation of the surface lengths to discover the intersecting point of balance between the technical and technological design boundaries. This research is positioned at this pivotal junction of knowledge, embracing uncovered technological constraints interwoven with the assemblage of the hybrid inlay technique.

A series of prototype panels investigate the generational process of a collective landscape in which material activity negotiates multiple surfaces. "The play between the physical and the digital is recursive, experimental, and interpretative; each informs the other while never truly resulting in the same output" (McKnelly, 2015, p. 3). Each panel is an individual persona interconnected to neighbouring surface conditions through the links-links ground and inlay pattern positioning.

The task of interpreting a physical landscape, via a photograph taken of my grandmother's Coromandel farm, into a knitted surface topography transpired. The intent of this translation of physical to digital to knitted surface was an extensive exploration of the programming and processing abilities of the Shima Seiki Mfg. Ltd. inlay knitting technology. During programming, a collaborative relationship emerged between the inlay knitting technology, design and material properties. The knitted panels are embodiments of individual points of disrupted materiality modulated in a single surface (Kolarevic & Klinger, 2013), becoming sites of textile knowledge (Mäkelä, 2007). The landscape is programmed to be read across the multiple terrains, navigating the interconnected material behaviours. The exhibited Metamorphic Series become terrains informed by intangible and tangible design components as technology and designer work in partnership.

5.2 Phase Four: Synthesis of Practice

5.2.1 Surface-building Block Selection

The elongated surfaces illustrate my ability to construct inlay designs at the edge of the capability of inlay knitting technologies, utilising disruptive positioning of the agency of matter (Bolt, 2007). The single bed knitted inlay intarsia technique was selected as the most effective surface to demonstrate this juncture of technology and design components. The programming incorporates the notion of following the flow of material properties (Arantes, 2020b), activating divergent performances of the hybrid textile technique, inlay knitting. The Metamorphic Series uses scaled link-links grounds and a traditional diamond twill weave pattern (refer to Appendix G). By applying the surface-building block process (Figure 114) the collective surface assemblage of links-links repeating patterns facilitates a mixture of vertical and horizontal compressions, demonstrating a range of textural qualities. Collaging multiaxial material forces counteracts a significant reduction of knitted surface length or width.

Designing the single and multiple panels required an on-screen process of pattern synthesis (Cross, 2006). Variable scales prevent the monotony of similar textures when viewed next to each other. Composition of the tactility sometimes meant modifying the colour-blocking to increase collisional material behaviours. The intricate pick and float configuration of Diamond Twill inlay facilitates the appearance of a woven textile embedded into a knitted surface. The length of the Metamorphic Series afforded room for additional active boundary collisions between link-links grounds and inlay patterning. These programmed surface deformations and pattern fragmentations built on surface movements suggested by smaller samples and advanced personal material force knowledge.

5.2.2 Layer One - The Collective Ground

Landscapes from my grandmother's farm on the Coromandel Peninsula, New Zealand, inform the multiple knitted surface topographies in the Metamorphic Series. The selected photograph was divided vertically into five equal sections, translating into five sequentially knitted panels. The sectional division of the imagery operated as a temporal mapping (Küchler, 2020). Layers were used to decode the landscape and to separate contoured ground and embedded networks of foliage. These components informed the links-links stitch structures and the inlay pattern placements. The extreme length of the programmed panels in the series necessitated the formulation of visual coping mechanisms. These methods included vertical and horizontal lines to provide a computational gauge for my eye and mind. Breaking the surface into hand-drawn sections provided a relational guide

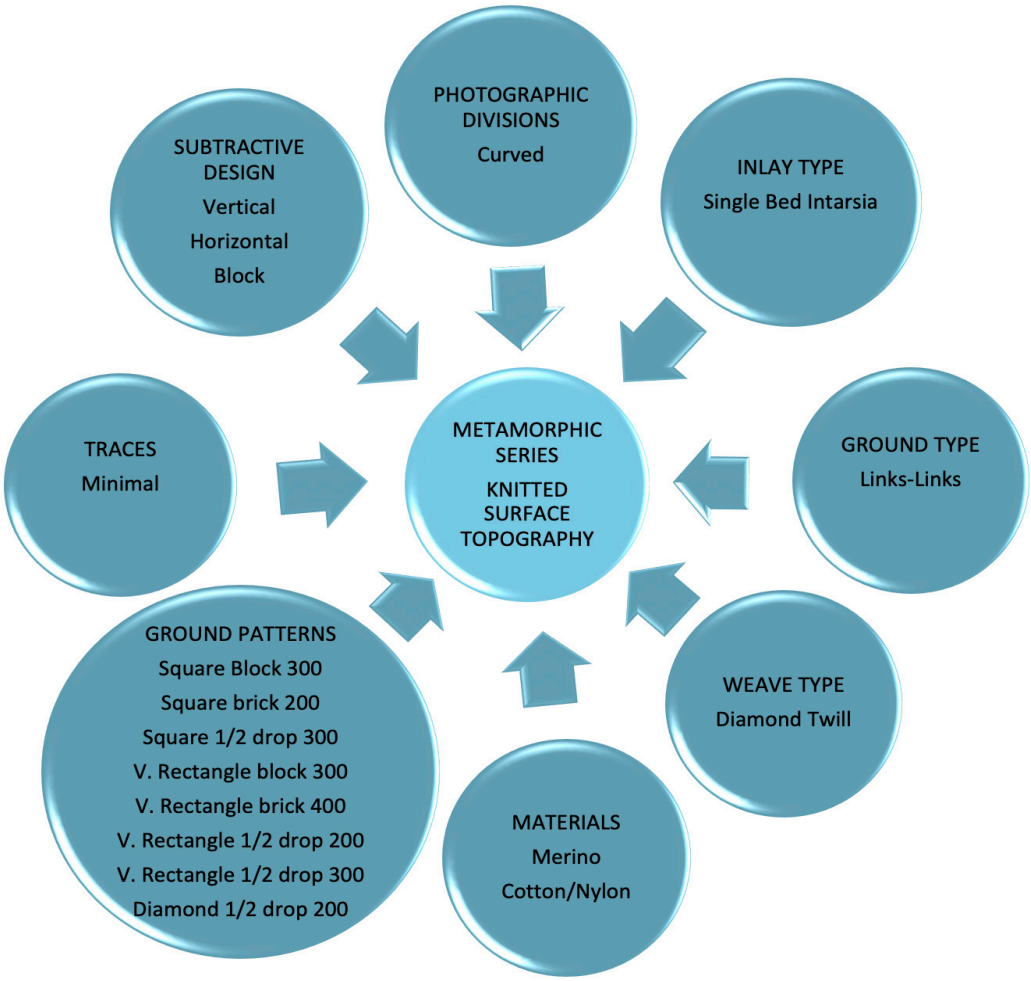


Figure 114. Surface-building blocks for the Metamorphic Series knitted surface topographies.

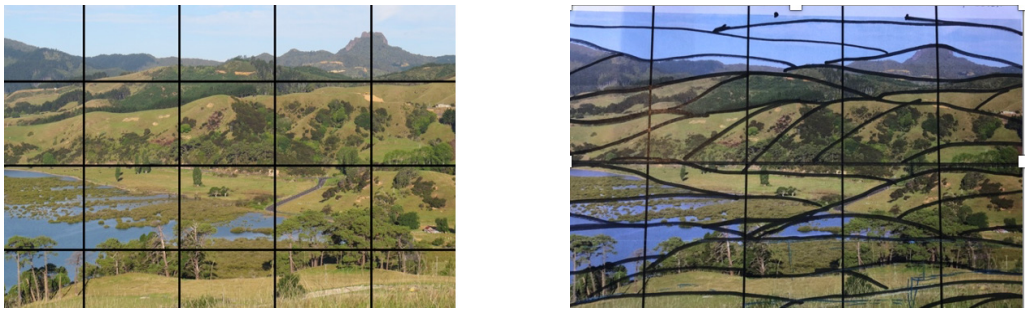


Figure 115. Vertical and horizontal lines dividing the photograph for multiple panel design.

to the actual length and width of the panels as separates and as one collective. A divisional grid system similar to techniques used for proportional drawing divided the image for this multiple-surface application (Figure 115).

The individual panels in the Metamorphic Series are a collective assemblage built in the old-format software. Old-format programming has the advantage of performing as a blank page, without the interference of the software automatically reading the colours as coded information. The panels were set up at full needle-bed width and the maximum length programmable in the automatic software. Five vertical lines separated the individual panels on-screen, and eight horizontal divisions enabled navigation of the extreme length. This proportional division aided physical scaling during the transference of continuous curved contours across multiple surfaces. The sections informed multiple terrains built from singular parts, where "its reality is defined by the structure formed by differential elements and distributions of singularities" (DeLanda, 2015, p.17). These linear divisions were then recurved, eliminated and reformed, building stitch loop alliances while maintaining connectivity to the layered landscape.

The balance of ground colour-blocking harnesses intuition during the virtual placement of the variant links-links patterns. The stitch structure arrangements foster multiaxial material forces. These entwined material forces travel internally to knitted surface boundaries. The selected, scaled links-links patterns exhibit juxtaposing behavioural characteristics, forming heterogeneous alliances that generate surface fragmentations. Author Anne Smelik (2016) notes that "becoming is about creating alliances or encounters" (p. 167). The transformative knitted surfaces become through built agency, enabling emergent activity between neighbouring knitted loops. The frequent interchanging of ground patterns increased virtual surface disruptions in a "stabilizing and destabilizing process of iterative intra-activity" (Barad, 2003, p. 822).

Physical swatches were collaged to select the links-links grounds from the previously developed geometric pattern surface-building blocks (refer to Chapter Four). This method ensured a medley of contrasting scales and patterns, providing a range

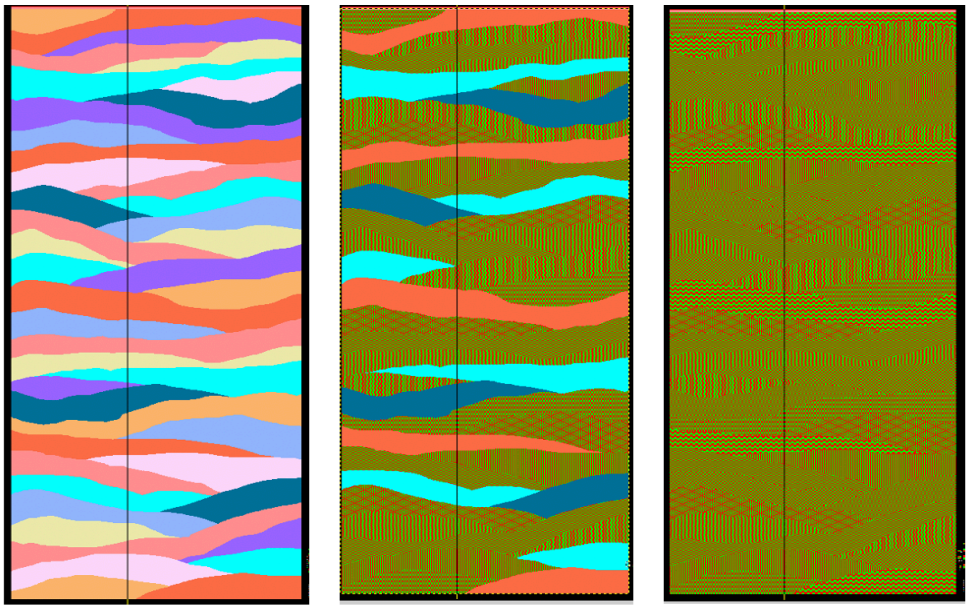


Figure 116. Colour-blocking paint-by-numbers process, filling with links-links stitch structures.

of tactility and material interactions. Once applied to the digital environment, active boundaries were evaluated in terms of visual discordance between border patterning. Developing the knitted surface aesthetic is a subjective design approach in which my "visual system is working to match its input with…prior knowledge to arrive at the best guess of what is being seen" (Pepperwell, 2019, p. 117). The digital knit coding is decoded into an approximation of the resultant physical knitted surface topography, applying tacit knowledge and experience to reveal the hidden material activity.

Crafted geometric units exploit the intrinsic properties of materials and links-links stitch structures, activating surface; the interaction is "an enfolding and unfolding relationship, between materiality, material and the processes of their construction" (Dormor, 2020, p. 18). The colour-blocking for the links-links ground was designed as half the panel length before applying a mirror block repeat to establish sectioning for the full length (refer to Chapter Three). The colour-blocked sections were filled with eight links-links grounds using the devised paint-by-numbers method (Figure 116) prototyped in previous practice. The complex pattern arrangement considered the directions of material forces and the textures of neighbouring patterns. Assembled ground structures traversed multiple panels to facilitating oppositional material forces, maximising surface fracturing. The Metamorphic Series colour-blocked image was saved as a separate file before the ground patterns were applied. Saving at the colour-blocked stage facilitates a proficient exchange of the links-links grounds to test alternative aesthetics for the topography from a single image. Substitution of the performative surface behaviours (Scott, 2015) activates the process of becoming other (Smelik, 2016).



Figure 117. Foliage in the photograph of the landscape converted to blocks of inlay.

This programming reinforced my understanding of material forces through combinatory displacements of vertical and horizontal asymmetrical material forces over a longer length of programmed data. Too many horizontal compressional forces positioned together significantly reduced the length of the panels and increased their width. In contrast, too many concurrent vertical convergent forces reduced the width of the panels while increasing their length. Using ground structures of a similar scale resulted in similar visual effects of low contrast between surface sections. In this Metamorphic Series, the topographies of the landscape manifest following the flow of materials (Ingold, 2013), enfolded in fragmented surface dynamics. Each programmed surface navigates a distinct assemblage of acquired knowledge, communicated through vibrant matter (Bennett, 2010) and generated surface movements.

5.2.3 Layer Two - The Collective Inlay Pattern

The collective knitted inlay placement over multiple surfaces used the old-format software and the same proportion division set-up as the collective ground. Initial designs considered knitted inlay as curved divisions; however, these generated numerous technical knitting issues due to the horizontal linearity of the inlay knitting technique. Instead, block portioning was used, with the original positioning following the foliage layout over the landscape, traversing across multiple panels (Figure 117). The base pattern repeat function filled all colour-blocked areas with the selected inlay pattern. After the collective additive and subtractive stages, the knitted inlay pattern fill occurred to maintain a constant pattern across the panels. The diamond twill inlay used the traditional woven scale initially tested, to maintain the recognisable woven aesthetic embedded into the knitted ground.

Due to the extreme surface elongation, the intarsia inlay positioning occurred across half the length of the panels before a vertical block repeat was applied to the designed layout to generate the second half of the design. This design approach proved a time-efficient method for covering each panel length with pattern variations without entailing the drawing of every knitted inlay section. Although

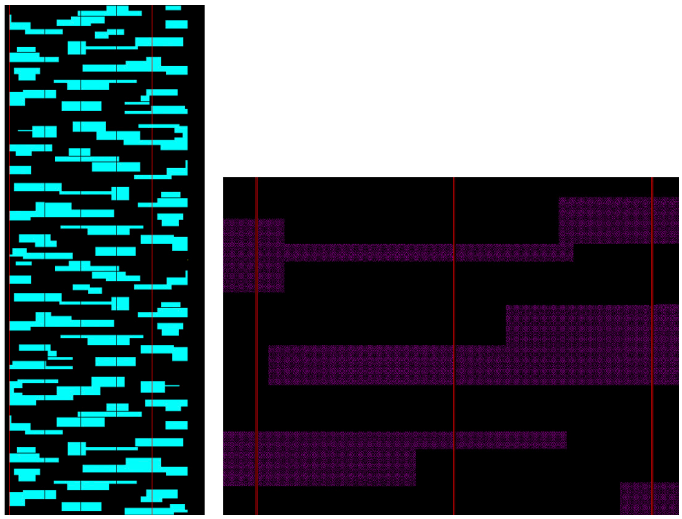


Figure 118. Collective placement of areas of inlay patterning across the multiple panels.

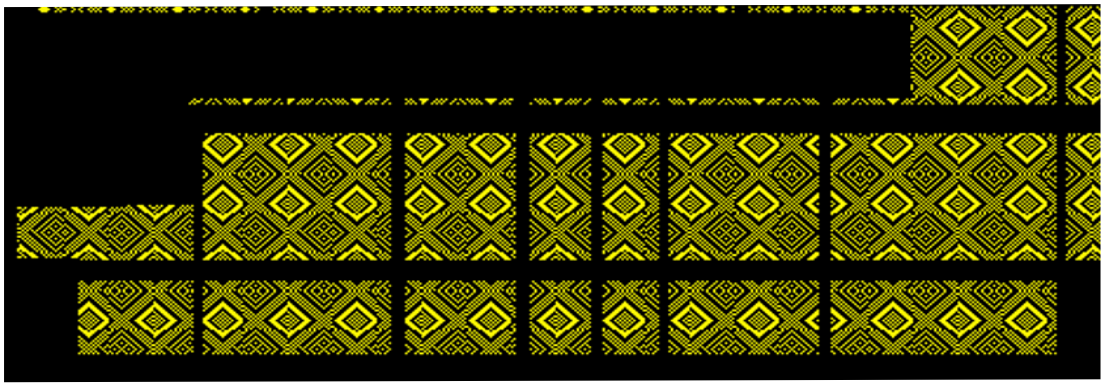
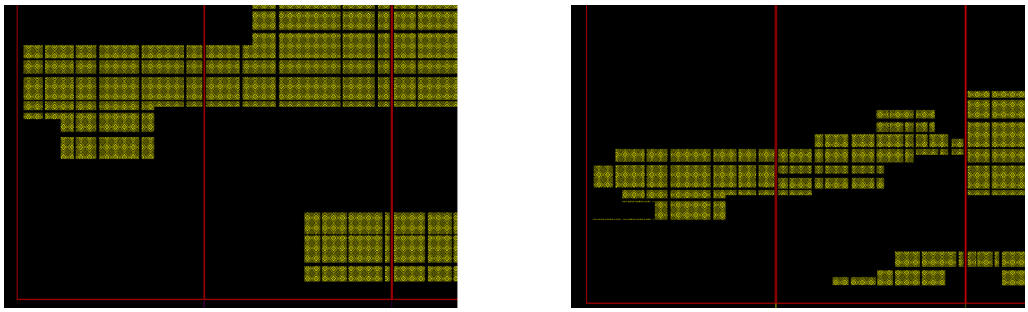


Figure 119. Inlay vertical, horizontal and block subtraction areas.

a block repeat creates a double-up of the inlay positioning in the panel length, layered interactions vary due to the knitted grounds beneath and the subtraction process. The edge conditions link directly to the patterning of the neighbouring edge, and the cumulative knitted surface of the entire series becomes more than the sum of the individual panels (Kolarevic & Klinger, 2013).

Additive and subtractive methods were applied at the collective stage in the old-format programming allowing inlay edge pattern and surface conditions to align across the multiple panels (Figure 118). Inlay can be drawn in any colour however I replaced the initial purple colour with vivid yellow to increase on-screen visibility and minimise random points of inlay pattern that sometimes remained after the subtraction process. The generalised inlay placement rules included situating the first pattern on an odd-numbered course, and an even-number of courses between all inlay patterned areas. Due to the design complexity, these rules were often manipulated to suit the individual inlay subtractions and arising relationships between neighbouring patterns (Figure 119). The trails of knitted inlay used minimal courses of the diamond twill pattern to trace entry and exit pathways



Initial inlay linkage. Adjusted inlay linkage.

Figure 120. Modification of Metamorphic Series inlay patterning across the linked panel boundaries.

across the ground within individual panels. The final carrier directions were only visible on-screen after automatic processing. However, it was possible to reduce issues and refine the positioning during the individual assemblage stage by using even courses of patterning.

The pattern was dispersed and gathered (Stenner, 2012), creating a transformative environment for multiple surface encounters. The design process consisted of several cyclic phases, with adjustments emerging during the layering construct of singular panels. The design components were examined individually and together, ensuring crafted material activity transpired between overlapping points of knitted inlay and ground. The Metamorphic Series panels embrace the notion of the individual and the multiple being interconnected. Academic Paul Stenner (2012) notes that "by playing with the difference between gathering and dispersal, pattern can add a little order to chaos and a little chaos to order" (p. 137). The patterning was positioned, folding the structured programmed surface into the unstructured physical surface. These revised patterns followed a cyclical process, copied back into the collective design, permitting the modification of boundary linkages (Figure 120). The assemblage process was fluid, utilising programmed materiality (Scott, 2015) to harness singular and multiple components' characteristics (Philpott, 2011).

5.2.4 Individual Surface Points

This knitted surface topography generation method considered the collective and the individual, analysing individual componentry layering, collective inlay and links-links interactions aligned within multiple knit panels. The relationship between the singular stitch loop and the corresponding inlay point was examined on-screen in a grid. The composite viewing function aided the clearance of structures layered beneath the edges of the inlay pattern. The stitch structures positioned on the edges of the knitted inlay pattern were changed to front bed knitting. The coded amendment on the edges countered knitting issues that occurred as the inlay carrier changed direction course after course. The Metamorphic Series practice unfolded

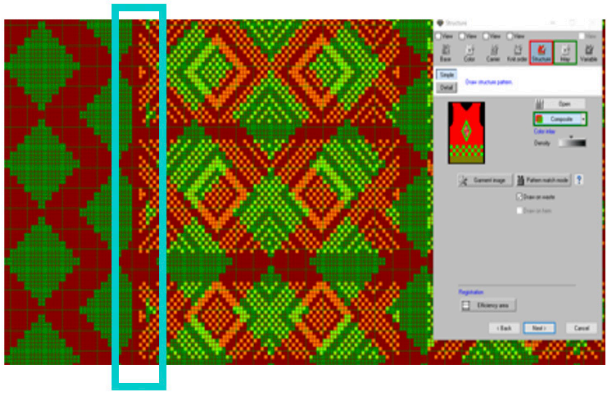


Figure 121. Composite view allows adjustment of the stitch structure under the inlay pattern edges.



Figure 122. Inlay pattern following the recumbent folding waves of the links-links ground.



Figure 123. Knitted surface topography with S-shaped folded ridges fracturing the inlay pattern.

over time, informing a cyclic practice that shifted backwards and forwards between the collective and the individual. As "'becoming' is a practice of change" (Smelik, 2016, p. 167), this surface practice morphed in response to knowledge acquired at all development stages and was constantly in flux. Over time, these surfaces have unfolded (Ingold, 2013), recording the agency of matter (Bolt, 2007) and a personal accumulation of research knowledge.

Using the composite layering function allowed subtle alterations to the patterning, informing the behaviour of the layered individual points (Figure 121). This stimulus of the knitted ground or inlay pattern performance shifted the exertion of neighbouring forces (Arantes, 2020b) on the X and Y axes, altering surface stresses and tensions. During the Metamorphic Series design process, the material force of the knitted ground interacting with the knitted inlay pattern was visible as a traceable line. This trace disrupted the horizontal line, resulting in recumbent folding waves (Figure 122) in which the inlay followed the agency of materials revealed along the convergent crest. The removal of neighbouring inlay points exposed the material forces of the horizontal and vertical ground that fostered dynamic, unbalanced knitted surface folding. The subtraction of vertical inlay sections and the selected scale of the links-links ground allowed the S-shaped

vertical ridges to fracture the linear inlay patterning layout (Figure 123). The horizontal compressional forces generated an environment conducive to tight, overturned folds informed by heterogeneous surface behaviours. Singular loops and inlay picks formed alliances that altered the neighbouring encounters with material forces. The single edified the single, generating multiaxial matter activity within the entirety of the surface. These surfaces propose a shift in the way we think about knitted textiles, from static to dynamic, inanimate to animate. The knitted surfaces evidenced in the Metamorphic Series panels utilise the fundamental ability of knit to perform, flex and unflex, fold and unfold (Thomsen, 2014) in response to material forces seen and unseen.

5.2.5 Assemblage of Single Surface

As Lee (2020) recognises that surfaces "materialise the technologies that have created them" (p. 51), the Metamorphic Series surfaces portray the knowledge and the constraints of the technology as physical interfaces. The knitted surface topographies showcase a technologically designed layering system of applied material forces to instigate design conversations that encourage "a new way of seeing" (Celant, 2009, p. 214). The inlay embedded in the knitted ground is most successful when the design detail contains numerous single inlay picks and short-length floats. The intricate arrangement of patterns has the ability to "destabilize an internal ordering of surface structure" (Jefferies, 2012, p. 131). My practice requires sizeable sections of uninterrupted surface patterning for the mind to inform the eye and retain glimpses of the removed design. As Professor of Visual Arts Janis Jefferies (2012) denotes:

> 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. (p. 128)

Minimal traces of inlay patterning across the knitted surface follow the flow of the materials, breaking the linearity of the virtual grid. These trails of inlay demonstrate the ability to share the material forces of the stitch structures underneath, revealed as a visible surface trace. In the synthesis of my practice, every construct navigates new understanding, with each surface unfolding as a site of knowledge (Mäkelä, 2007; Nimkulrat, 2013), exhibiting fluctuating material behaviours' that record matter's agency (Barad, 2003).

The static, weave-like nature of the knitted inlay alters the dynamics of the folding links-links ground. In the Metamorphic Series panels, unfragmented sections of inlay affect the knitted surface material forces, informing stable planes within the

transformative ground. This dominance relates to the horizontal and vertical subtractions of the inlay pattern and the placement relationship to the scaled ground structures. Vertical disruptions are maximised with horizontal convergent material forces (Figure 124), and horizontal breaks create more fracturing when coupled with vertical convergence (Figure 125). Dormor (2020) states:

> The temporary bend in the cloth relies on its opening out, its movement, to reveal itself and that which has been caught up in the fold. In many ways, it is unfolding that announces the presence of folding. (p. 11)

The first prototype for the Metamorphic Series illustrated intermittent collisional boundaries, arising from an insufficient amount of inlay patterning (Figure 126). The small amount of inlay pattern significantly reduced the embedded weave in the knitted surface effect and generated a knit-dominant surface. The series used the diamond twill inlay as a weave signifier, positioned to conceal and reveal the pattern in response to the identified programming constraints. The overall visual aesthetic of the solid sections of the twill inlay is that of a traditional woven fabric inserted into the knitted surface. The surface presents as an illusion, disrupting the viewer's visual interpretation, and questioning the conundrum: How can a weave be contained internally in a knitted surface? The hybridity of my fractured inlay knitted surface forces the viewer to attempt a pattern interpretation, visualising to some extent the unseen yet perceived pattern (Pepperell, 2019). Areas of unbroken inlay patterning produced the most significant effect of weave embedded in a knitted surface, allows viewers to focus on the woven aspect as a textile in its own right. The Metamorphic Series programming applied an unbalanced twill pattern; therefore, the knitted surface technical front and technical back afford alternative amounts of inlay exposure (Figure 127).

These built inlay terrains are dynamic and dependent on programmed surface encounters (Grosz, 2001). The physical deformations of the knitted ground subverted my programmed intent. In physical form the virtual angling of the ground contours reduced due to the unstructured interplay of material forces creating a horizontal linear partitioning effect. The angled block contouring was exaggerated on screen for the second prototype, to accentuate the delineation between active boundaries. The scale of the links-links ground also modified the intensity of the surface folds and torsions. The larger-scaled patterns contained more stable front and back bed areas, neutralising the deformative material forces. Digression from simple inlay designs into complex interactions of the ground and inlay in the larger panels caused a programming glitch. The automatic software generated incorrect carrier directional movements. Instead of a standard left to right followed by a right to left carrier movement, the software intermittently added two courses in the same direction directly after each other. Adjusting the programming shifted the issue rather than eliminating it. Technical support at the

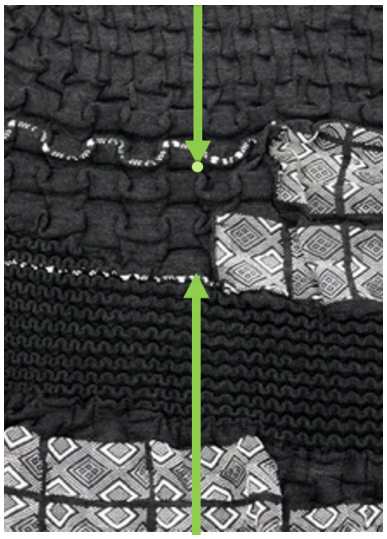


Figure 124. Vertical convergent material forces. .



Figure 125. Horizontal convergent material forces.

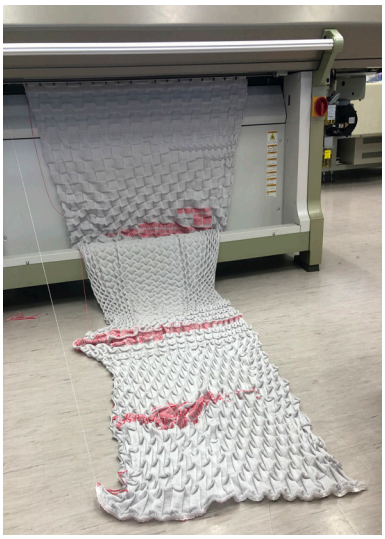


Figure 126. Metamorphic Series, first prototype, with intermittent patterning.



Technical front.



Technical back.

Figure 127. Perspectives of the knitted surface inlay exposure.



Figure 128. Metamorphic Series, panel one prototype emerging from the knitting machine.

Shima Seiki Mfg. Ltd. training facility suggested not breaking the inlay placement rules of even courses and always aligning the inlay blocks starts and ends. However, my assemblages did not always fit this rule, so the extra directional courses became part of the traces across the knitted surfaces.

As the development of the Metamorphic Series progressed, multiple links-links ground sectioning fostered knitted surface displacement and fissures of internal stresses, in which the "surface is volumised, creating multiple temporalities and spatialities" (Halliwell, 2020, p. 69). When the Metamorphic series panel one emerges from the knitting machine, the surface dynamics become visible once the horizontal tension of the needle bed is released (Figure 128). The knitting machine deciphers the codes, knitted stitch by stitch, inlay pick by pick, building behavioural relationships through the assemblage of these hybrid layers. The fluctuating landscape shifts, the matter has agency (Bolt, 2007) as the material forces influence the fragmented surface. The materials and inlay knitting technique engage in becoming with the capacity to transform (DeLanda, 2004; Kidd & Smitheram, 2014). The released knitting deforms as the surface materialises, offering "an invitation to leap inside the hollow of the fold, to see what happens. And to think inside the continuity of the fold is to think in a continuous present" (Barnett, 1999, p. 32). Each elongated panel is a novel persona representing an embodiment of knowledge through addition-subtraction of the inlay pattern and neighbouring knitted stitch properties (Arantes, 2020a). Shifting and morphing, the knitted surface inhabits alternative disruptions of a linear plane. The knitted surfaces become transmitters of knowledge, and contain personal connections as well as the making process employed.

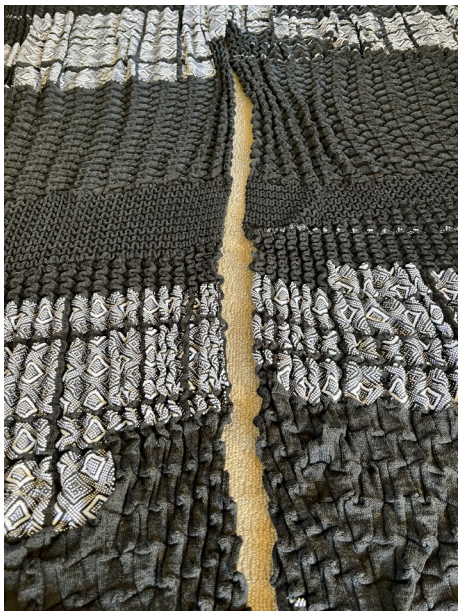


Figure 129. Metamorphic Series panels one and two display ground and inlay pattern navigating the multiple.

5.2.6 Assemblage of Multiple Surfaces

The multiple surfaces encapsulate the heterogeneous material forces within and between each panel, communicating knowledge as physical variances of "material consciousness" (Sennet, 2008, p. 123). Drawing across the panels, the inlay pattern is applied as a form of mark making upon the knitted ground, where it traces my working process (Halliwell, 2020). Authors Cara McCarty and Matilda McQuaid (1998) note that "when cloth surfaces are sculptured, highly articulated, individual landscapes are formed by manipulating, and revealing the inner beauty of the yarns" (p. 25). The Metamorphic Series used merino for the ground yarn, in varying shades of grey, in a recollection of sketching with graphite. High contrast inlay colours were applied during prototyping to increase the visibility of the inlay patterning amid the fragmented ground. This colouration enables the eye to trace the single points of inlay pattern across a multitude of interactions

The links-links ground and inlay pattern navigate the multiple as interconnected topographical terrains across panels (Figure 129). Each designed surface identifies as an individual, with space between the panel edges permitting the formation of a distinct collective landscape. The singular panels in the series are adaptations of each other. Each surface embodies knowledge variations, with inherited characteristics exhibiting a different persona in the surface series. Susanne Küchler (2020), Professor of Anthropology and Material Culture at University College London, describes "attending to surfaces when surfaces are thresholds between the visible and the invisible" (p. 188). My surfaces navigate visible and invisible influences, shifting seamlessly between the virtual and actual, with each surface a knowledge contributor that informs the collective.

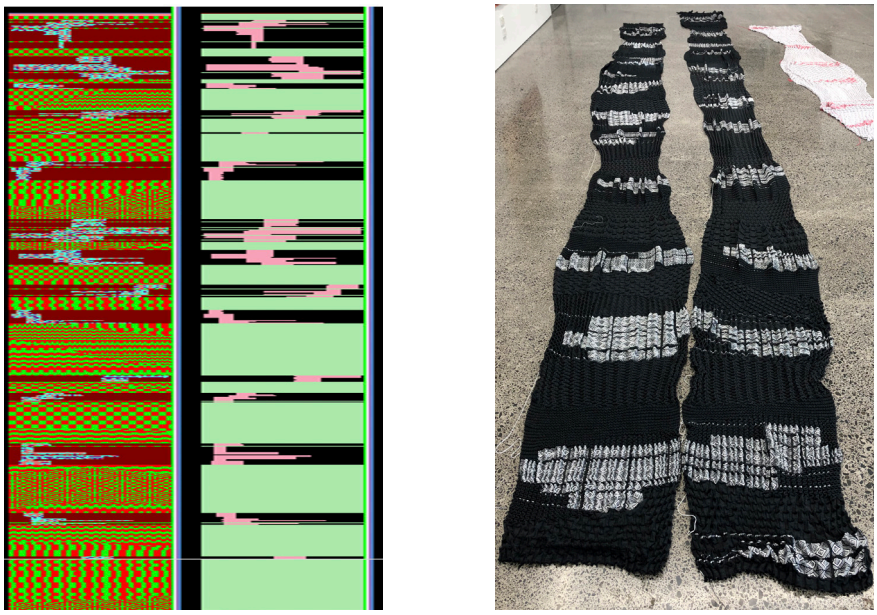


Figure 130. Exploring spacing of the inlay pattern in Metamorphic Series panels one and two.

The compositional relationship between the inlay and ground across multiples can only be accurately comprehended in the physical knitted surface. When programming the Metamorphic Series panels on-screen positionings were deliberately unbalanced, yet tangible ground material forces unpredictably equalise the sectional spacing in prototype panels (Figure 130). The multiaxial visible and invisible material forces alter the dichotomies of surface encounters. The knitted surface is a pliable plane, the ground repositions and shifts. To counter this on-screen adjustments observed the compressional direction of material forces, encouraging a more organic inlay placement. An alternate landscape materialises as the agency of matter (Bolt, 2007) settles, revealing and concealing the knitted surface topologies in response to the environment. For the final exhibition of the Metamorphic Series, knowledge gained through the prototype panels informed the arbitrary inlay positioning that unfolds along the ground axis built from my landscape photographs.

The virtual flat programmed grid is incapable of simulating the disruptive material properties. Physical knitted surfaces contain a level of unpredictability that emerges from the structured design process. The knitted surface embraces unaligned stresses and material forces, which converge at the panel edges, generating biaxial compressional conditions. The interrelated edge conditions react differently due to individual points of programmed materiality (Scott, 2015). Networks of multiple intersections allow activation of connected dynamic boundaries. Combinatory convergent and divergent material forces activate folded sites through the placement of stitch structures. Complex asymmetrical folds emerge from the symmetrically repeated codes.

Sections of inlay that connect across the panel edges illustrate similar material forces under variant conditions, as each panel displays different links-links ground layouts. The visual effect is continuous, but the interplay of material forces is unique. Positional amendments of the knitted inlay up or down the panel alter the active boundaries and the ensuing surface deformations. All the collective knitted surface design panels were affected when the inlay patterns shifted on the X or Y grid axis in response to compositional balance. This generative design process involved singular and collective revisions. Virtual to physical, and back to virtual, modifications occurred as I refined placement of the integrated material forces within the Metamorphic Series elongated knitted surface topographies

The built knitted surface topographies include visual relief of surface in two ways. One method used links-links ground deformation without inlay interruption, and the other larger stabilised inlay areas. Both provide a visual reprieve from the other, allowing the viewer to focus on the signifying aspects of the knitted hybrid surface. Depending on the pattern and amount of inlay positioned in the surface, the knitted ground layer forces predominantly disrupt the landscape. However, the static nature of the twill inlay can be programmed to change these forces, reducing the complex folds as solid inlay sections increase surface stability. Unfractured sections of knitted inlay counterbalance the underlying knitted ground material forces. The level planes of inlay amid the ground deformations facilitate the mapping of weave-dominant areas of unfractured pattern.

5.3 The Technical Design Fulcrum

The length of the panels in the Metamorphic Series increased from previous samples, significantly expanding the size of the knitted surface. The scale of the knitted links-links grounds and inlay patterns applied to the surface-building blocks built in previous practice and discussed in earlier chapters. Each component was permanently placed on a single layer when designing with old-format methods, making design modifications difficult. Therefore, the singular assemblage of each panel in the Metamorphic Series transpired in the automatic software environment, allowing separate layering of each designed component. The links-links and inlay designs were copied from the collective set-up and positioned on the relevant automatic software pages. The length of the panel on-screen remained an impediment to seeing the entirety of the surface within the digital grid. Continuous use of the zoom function affected my ability to read the patterns as unbroken surfaces, impeding the visualisation of the physical outputs. This impediment continued until physical prototypes emerged, and points of reference developed through experience that fostered internal rendering of the knitted surface topographies of the Metamorphic Series. This developing ability to translate knit codes on-screen with the proportional physical knitted surface aided design decisions.

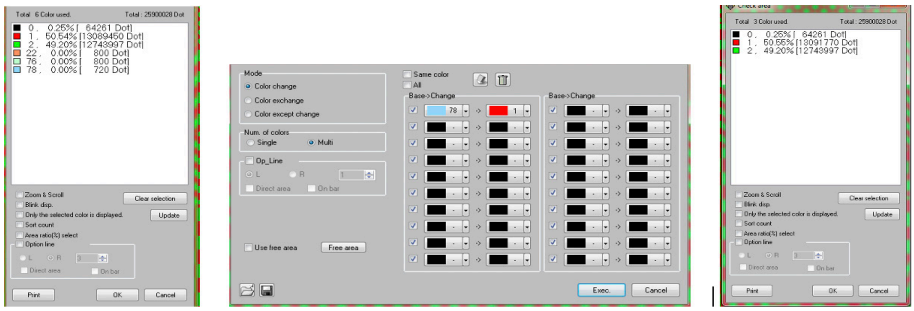


Figure 131. Rectifying incorrect colour codes on stitch structure page during programming.

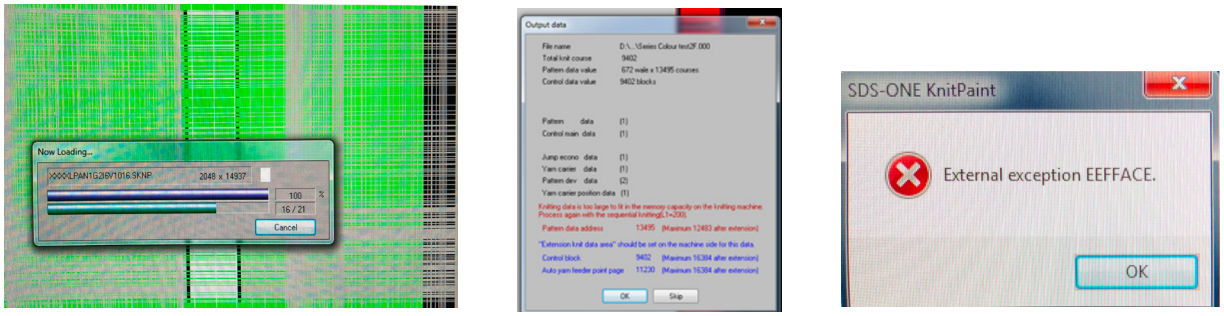


Figure 132. Software errors due to the programming complexity of the Metamorphic Series panels.

The composite pages function in the automatic software allowed simultaneous viewing of the structure and inlay colour layers. In response to the underlying stitch loops, the assembled subtraction of individual inlay points encouraged multiaxial zones of interactivity (Halliwell, 2020). On the structure page, programmed knit codes changed to clear the horizontal perimeters of the intarsia inlay. This amendment ensured that only front bed loops were situated on the edges, reducing knitting complications at these unstable turning points. At this stage, I checked the structure page for random colour codes (Figure 131) that sometimes remained from the colour-blocking development step. If incorrect codes were present, the colour change function reallocated front or back single jersey knit structures to rectify the incorrect automatic programming.

Designs generated in old-format software can contain any amount of inlay desired, similar to drawing on a page; however, numerous errors transpire during the technical processing stage due to the amount of programmed data (Figure 132). This practice experienced errors that had not previously been encountered by Shima Seiki technical experts, highlighting the technical design cusp of this surface practice. One error involved the automatic software function, knitting assist, which highlighted knit error for technicians and was unable to operate due to the file size. The intended use of the Shima Seiki knitting technology is by industry, for garments and blanket-sized pieces; therefore, the complexity and size of the Metamorphic Series surface designs destabilised the design system, producing a series of system errors. Being creative is not so much the desire to do something

with the materials but sometimes listening to what wants to be dictated by the materials (Albers, 1944). In working with the inlay knitting machine, my technical capabilities led the design until personal knowledge developed enough to program on the edge of possibility. For example, the on-screen page has a limited number of courses available to hold the coding. Therefore the length of the final knitted panel is determined by the vertical expansion of the digital knitting codes.

Finding the balance between designed output and technical constraints was critical to processing the knitting data, allowing the program to be transferred to the knitting machine. Initial prototype designs contained considerable inlay, prompting numerous software errors at the processing stages. These errors necessitated reduced inlay patterning in the knitted surface topography overall length. Digital technology has changed the maker's role, enabling continuous reprogramming during making to test designs (Zoran, 2013). A trial-and-error approach to my practice led to an in-depth understanding of the amount of knitted inlay possible within the individual surfaces when extended to these extreme lengths. During these subtractive inlay patterning trials, I discovered that the vertical inlay needed to reduce due to the vertical on-screen expansion that occurs when developing the codes for knitting.

In addition, a sequential knitting process was employed, which divided the long panel into parts, allowing these to be loaded and knitted continuously. This sequential knitting process reduced the file size while maintaining the integrity of the overall design aesthetic. Sequential knitting used single dots of code 200 in the L1 option line, allowing the KnitPaint software to divide the long panel into a sequence of smaller interconnected parts. The knitting machine read the parts as separate .000 files but knitted a single consecutively linked surface. These surface designs involved programming with rather than against the discovered technological constraints. Each long panel contained twelve sequentially knitted sections and required nine hours of knitting. The knitting machine ran slower to prevent knitted loops from dropping off the needles during the links-links and inlay transfers. The knitted surface deformation practice was teased out of the materials and techniques, facilitating a process of technological discovery.

5.4 Exhibiting the Metamorphic Series

The exhibited knitted surface topographies are textiles which let the yarns articulate knitted surfaces with no purpose other than their own orchestration, combining technique, technology and knowledge. The final exhibition of the Metamorphic Series showcased the five collective panels suspended from the ceiling and draped along the ground (Figure 133). The designed patterning built from landscape imagery can be read singularly and across multiple panels. The panels allowed a symphony of colliding texture and pattern, which articulated the potentiality of

the inlay technology, knitting techniques and knowledge acquired (Figure 134). Burbank and Anderson (2012) note, "in order to build topography, work must be done against gravity" (p. 26). The weight of the Metamorphic Series has altered the surface textuality. To counter the gravitational pull, I would in the future, increase the number of directional material force exchanges in suspended sections.

The addition of an open-ended tubular finish to each panel allowed the insertion of an aluminium rod to display the surfaces in a state of partial suspension. The suspension permits surface perspectives of both the technical front and the technical back (Figure 135). Viewers experienced the double-faced knitted surfaces through visual and haptic interactions, allowing observation of the inverse effect of inlay. This inverse patterning evoked a transposed colour balance while also illustrating the traced pathway on the technical back through the knitted surface plane of activity. The selection of a neutral ground and chromatic inlay colour increased the effect of inlay embedded in the knitted surface rather than visually floating on top. Several viewers referenced nature when engaging with the knitted surface topographies, seeing landscapes and textural convergence of water tributaries.

The more significant areas of links-links ground in the Metamorphic Series topographies facilitated recognition of link-links in this research, expanding my knitted surface viewpoint beyond the initial inlay focus. As in Bruno's notion of the surface "as a form of contact that enables intimacy" (2014, p. 231), the viewer is encouraged to wander amidst the suspended knitted surface topographies, personally connecting with the active 'surfaceness' (Halliwell, 2020). The programmed horizontal and vertical material forces perform differently suspended (Figure 136) versus the relaxed folded state inhabiting the floor (Figure 137) demonstrating multiaxial surface fragmentations. The suspended knitted surface topographies are elongated with horizontal folds outstretched while vertical ones remain. Viewers interacted with the vertical and horizontal knitted surface topographies differently. The two-dimensional coded digital becomes a dynamic physical knitted surface that invites textural encounters. Fingertips explored the ground textures, whereas the suspended accordion folds were expanded and released, activating material behaviours. Academic Barbara Rauch (2020) describes:

> Surface qualities that 'erupt' as the digital manifests itself as a material surface. The tactility of the new surfaces offers a critical insight into how we understand a material object and the technology that made it come to life. (p. 59)

When hands interact with a surface, information relays about the physical attributes of that surface (Johansson & Flanagan, 2009). By physically connecting with the knitted surface topographies, the viewer reads the programmed effects, fingers



Figure 133. Reading across the Metamorphic Series.



Figure 134. Multiaxial patterning collisions across Metamorphic Series panels.



Figure 135. Technical back view of Metamorphic Series panels.



Figure 136. Suspended vertical folds.



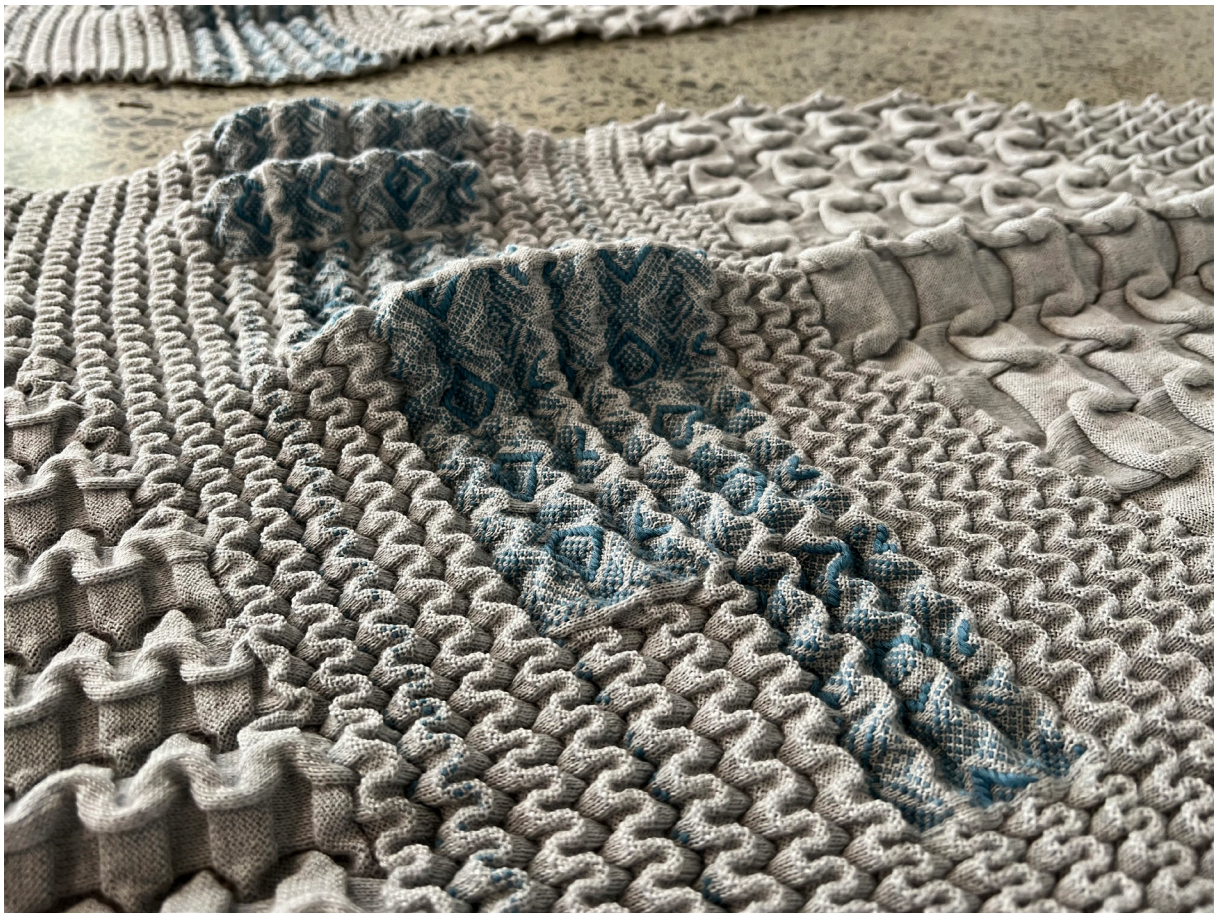


Figure 137. On the gallery floor multiaxial surface fragmentations.

traverse folds, engaging with the material forces. Touch relies on intuition to guide it rather than being a conscious action (Philpott, 2011). The caress is an unintentional forage, seeking the concealed while feeling the revealed knitted material forces. The Metamorphic Series of knitted surface topographies are the manifestation of tactile matter, offering critical insight into my understanding of the inlay knitting technology and material performances (Rauch, 2020).

5.5 Conclusion

The programming of the Metamorphic Series panels occurred from three interrelated design perspectives: firstly, the design of the five knitted panels as a single entity through interconnected links-links stitch structures and inlay patterned sections; secondly, the considered positioning of relational material forces between each inlay pattern once overlaid into the ensuant links-links stitch structures; and thirdly the assemblage of constructed material forces at the singular level within the grid; the interaction of the inlay pick with the neighbouring knitted loop informing the knitted surface topography.

This research encompasses an alternative approach to building knitted surfaces. The theoretical context of practice evolved in tandem with the analysis of making to understand the processes and assessment behind the emergent surface relationships. This chapter, *Emergent Terrains*, highlights boundaries between design and technology, fostering a design space in which the designer negotiates with the constraints of the technology (Rauch, 2020). This practice naturally journeyed to this cusp as tacit creativity became positioned at this intersection of knit technology and design. The exhibition of the Metamorphic Series navigated this practice space, illustrating knit knowledge and the developed mode of making in a synthesis of practice.

The technological constraints encountered disrupted the design practice, informing the making process. “Making is not just a combination of skills and hard work, it is an enquiry into the potential of a chosen media” (Harris, 2005, p. 25). A synergetic environment emerged that transcended programming frustrations to a point where the design and technical spoke to each other influencing design decisions. The discovered technical framework necessitated adjustments of the surface designs that embraced the unfolding technical constraints. As Albers (1944) states, “no limitations other than the fiat of the material itself are set. More than an active process, it is a listening for the dictation of the material and a taking in of the laws of harmony” (p. 54). This statement aptly describes the connection formed throughout this material practice. The research builds on a deeper understanding of the technological constraints and design possibilities explored through connections to geomorphic language and a devised mode of making.

Chapter 6: Unfolded Findings

> [W]hat is really at stake, is a new kind of surface ontology which replaces the opposition of inside and outside, invisible and visible, immaterial and material, with a complementary relation that thrives on transformation rather than distinction. (Küchler, 2008, p. 116)

6.1 Introduction

In nature, tectonic forces draw upon the earth's terrain. Every landscape holds a story of landform creation; with traces of the people and place carved into the contours, shifting surfaces capture time in layered deposits. Similarly, I sketch upon the dynamic knitted surface, patterning with knowledge and tacitly embedding self and the inspirational landscape into the design. This research investigated how the hybrid knit-weave technique of inlay could be used as an ontological investigative medium to build knitted surface topographies through the assemblage of heterogeneous material forces. The surface becomes an interrelation of relationships, where the assemblage process fractures patterns through ground disruptions. The emergent mode of making combining links-links material forces with inlay embraces systematic surface behaviours and layered material forces in collaboration with technological constraints. Although built as an assemblage of elements, each knitted surface topography retains an ambiguity in the design equation. This unstructured design component arises from the intersections of material forces informing this temporal mapping process (Küchler, 2020).

6.2 Making with Materiality

The synergetic approach to design using the surface-building blocks integrates surface, technique, technology and materials forces. This practice contributes to the digital knitting research environment by increasing awareness of the potentialities of links-links and inlay knitting techniques. Research in this thesis re-imagines craft-based textile techniques through blended interdisciplinary making with fields outside textile design such as fashion, product, spatial or interior design. The research primarily focused on approaches that follow the material properties (Arantes, 2020a), building knitted surface topographies that reference terrain characteristics of the Coromandel Peninsula landscape. The surface topography of knitting allows for the continuous deformation of zones, with arranged stitches

generating structural material forces that fracture the surface plane. The hybridity of the inlay technique allows singular surface points where the inlaid yarn is captured and controlled by the knitted loop, influencing neighbouring points and altering surface dynamics. By utilising programmed materiality (Scott, 2015), the inlay knitting mimics the ground movements with the pattern distorted by underlying material forces.

The layering of surface-building blocks utilises material forces to activate knitted surface interactions between singular points of the collective. The inlay surfaces foster the performances of matter, releasing emergent material properties and capacities (DeLanda, 2015). The materials have agency, moving and reacting to their own dynamic rhythm as they transform the surface (Lange-Berndt, 2015). Manipulation of this material agency allows crafting with material affordances (McCullough, 1996) through the assemblage of heterogeneous material forces. Utilising bodily knowledge (Merleau-Ponty, 1965), surface sections are constructed as stabilised or destabilised planes through vertical and horizontal subtraction of inlay patterning. The inlay yarn traverses the knitted surface, programmed to minimise or accentuate traces between interconnecting intarsia inlay patterns. The patterning breaks the linear grid as the eye seeks to reconstruct disrupted repeating inlay sections.

This investigation developed surfaces that apply single and double bed inlay methods to demonstrate a range of applications of the inlay knitting technique. This scope of the capabilities of inlay knitting technology opens up creative opportunities and encourages design shifts away from all-over single jersey patterning. Intarsia inlay and the exposure of inlay in the double bed surfaces change the inherent knit properties in specific sections. Knit or weave behavioural characteristics dominate the surface. Sectional positioning of the inlay knitting permits variable surface properties that depend on the combinatory design choices of ground stitch structures, inlay patterns and materials. In this practice, material performances were layered to stabilise or destabilise the knitted surface conditions during the act of becoming other.

My knitted surface topographies use three yarns selected for their material performances and inter-reactive states. New materials continuously emerge; future yarns offer opportunities to alter surface material characteristics. The selected materials "not only enable and constrain action, they also unfold through collaborations with people, workspaces, and even each other" (Rosner, 2012, p. 1155). Pemotex yarn permits engineered convergent material contractions that result in solidified surface sections. The surfaces showcase the links-links, inlay knitting techniques, and interconnected material affordances (McCullough, 1998), instigating new ways of building temporal knitted surfaces. Our bodies are a means to navigate the unarticulated aspects of the world. This tacit knowing relies on engagement and interaction with the making and the made.

6.3 The Edge of Technicality

During the design of the multiple-panel series, approaches evolved that aided comprehension of the virtual, allowing conversion of scale from photograph to screen to surface. The practice investigated repeating motifs, and variations of panel size and pattern scale, to examine effects on the knitted surface. Prototyping the series of extra-long panels resulted in new approaches to digital programming using divisional grids to aid the interpretation of proportion. The scale of the repeating patterns increased my understanding of the intersecting material alliances. Due to less effective collisional material forces, a links-links ground with a too-large pattern resulted in a flat plane. Exploring extremely long panels instigated a design space at the edge of the capabilities of the Shima Seiki Mfg. Ltd. inlay knitting technologies. This previously unexplored intersection is where technology and design impose constraints upon each other, forming a co-alliance with the designer and materials.

Designers often view the constraints of digital knitting technology as a barrier to design rather than as a tool. Personal knowledge, perspective and positioning have significantly influenced my trajectory in this project as a knit designer with extensive technical programming knowledge. This allowed the practice to extend beyond all-over inlay surfaces by including old-format programming. This programming knowledge fostered an environment in which inlay techniques outside of automatic software constraints were developed. Double bed inlay knits are only achievable by coding complex package programming in old-format software. Personal in-depth technical knit understanding also provided an alternative approach to designing multiple panels, combining attributes from the automatic and old-format software.

6.4 Personal Reflections

This research was a technique-led journey, a meandering of tributaries of technical-design knowledge and self, rather than a practice purely focused on producing artistic artefacts. Technique-led experimentations contributed to surface outcomes, utilising aspects of the practice and context. The interconnecting theoretical strands have influenced the practice. At times I struggled to balance my inclination to remain entrenched in the technical environment with an innate desire to design creatively. However, this crossroad in practice is my recognised environment, with my structured nature significantly influencing the designed knitted surface outputs. As Ingold (2013) notes, making becomes a “correspondence between maker and material” (p. xi). Interactive and intuitive collaborations formed between materials, technology and designer. This research practice involved a series of exploratory exercises that at times travelled into unknown territory before my need to avoid confusion reigned the practice back to a structured environment.

Hopefully, others reading my thesis will be able to respond to these glimpses and pick up these pathways into the unknown, extending the research potentiality.

Tacit knowledge acquired from digital and physical environments manifested as knitted surfaces. McCullough (1998) states, "human beings, like things, have become interfaces in a technological world" (pp. 233–234). Tacit intuition embraced layers of bodily knowledge acquired through reflective practice and engagement with the technique and knitted surfaces. The knitted surfaces unfolded over time, exhibiting visible traces of the technique's material forces, technological constraints and gestures of bodily knowledge. This research practice operates within discovered technological constraints to allow the design to unfold while following the material and stitch structure behaviours. Although the research was technique-led design, this flipped at times to practice led because of technical aspects encountered at the edge of the technology's abilities. The digital-physical making process has become so embedded in my practice that it is a way of thinking design in which "the distinction between the digital and the non-digital is no longer useful" (Rauch, 2020, p. 51).

6.5 Significance of the Study

The findings of this practice are significant to textile design research and practice community and beneficial to designers outside of the textile field. The methodology outlined in this thesis offers an alternative approach to knitting technologies for various disciplines such as fashion, interior and product design. The mode of making developed from a structured investigation of repeating pattern, scale, materials, links-links and inlay knitting techniques exploring surface behaviours. The methodology and methods framework could be replicated or adapted for other knitting techniques such as rib or tuck stitch, affording future creative practice. The generated surface-building blocks provide a visual and haptic resource enabling the maker to become a participant working with the material performances (Ingold, 2013). The layering of design elements specifically activates intersecting material forces on singular and multiple levels, building alliances between the knitting techniques and material behaviours (Oxman, 2012). The materials are no longer mute as they navigate the convergent material forces. These surfaces exist as knitted surfaces significant for their assembled material behaviours. Instead of artefacts for an exhibition, the surfaces become critical sites of material practice, illustrating technique, technical exploration and designer knowledge.

This research draws on geomorphic language to analyse links-links and inlay knitted surface movements and inform the design practice. Geomorphic terminology was applied to understand material forces and design a knitted surface, offering an original contribution to the knit research environment. The geomorphic

language and emergent methodology explore the design potential of the inlay knitting technology. Digital two-dimensional codes conceal the physical knitted surface's three-dimensional materiality and behavioural properties. This research provides a resource for designers by understanding how two knitting techniques interact and adopting geomorphic language to support the mapping of resultant material forces and textural surface qualities.

This thesis adds to current research on inlay and links-links knitting techniques. As the inlay knitting technique is a relative newcomer to digital knitting, there is a gap in the digital knit research environment that this research occupies. Recent shifts to a more technological workspace caused by the global pandemic have highlighted research opportunities that support designers' understanding of two-dimensional versus three-dimensional environments. Practice discussed in this thesis bridges the complexities of the digital-physical knit environment, providing a vehicle for engagement with a knitted surface by multiple disciplines. This research presents the complex knitting technologies as step-by-step creative practice using surface-building blocks to inform decision making. The ability to assemble material forces and relational alliances in targeted placements is significant to future design opportunities. The targeted stabilising or destabilising of areas allows the knitted surface to exhibit paradoxical attributes such as sections of reinforcement combined with areas of flexibility, which are two desired attributes for many product design objects.

6.6 Future Directions

While this is the conclusion of the thesis, this is also a beginning point, a position from which to build other pathways of practice that extend on the knowledge acquired and documented here. There is scope for developing a deeper design connection to the geomorphic language in relation to the knitted surface analysis and design with knitted surfaces created to mimic the geomorphological movements of landforms. Questions begin to emerge in this thesis about connections between language and knitted surfaces which can be expanded upon in future research. How much can land surface structures and language parallel knitted surfaces? Can the relationship between geomorphic language be translated into a collaboration with scientists from Earth science disciplines to investigate knitting topographic data? The terminology in this thesis is a starting point to continue to build upon increasing designer articulation and understanding of knitted surface movements.

This practice builds on existing knit research to provide an alternative design methodology while adding to discourse in digital-crafting digital-craft practice exploring the relationship between two-dimensional and three-dimensional design environments. There remains significant potential to expand on design factors

touched on during prototyping that sat outside the scope of this study. These under-utilised developments relate to inlay knitting with multiple colours, variations of ground stitch structures and knitted dimensional forms. The inclusion of additional carriers for multiple alternative yarns and colours, the insertion of e-textiles and shaping options offer opportunities to expand this area of research. Opportunities also exist to extend this research through alternative materials, variations of the stitch structures, and inlay patterning applied.

The textile hybridity of the inlay knitting technique allows singular surface points where the inlaid yarn is captured and controlled by the knitted loop to influence neighbouring points, altering the surface dynamics. The intarsia inlay allows specific placements of additional yarn. Therefore, the material properties can be manipulated, generating stabilised targeted areas. The mode of making developed in this research can be applied to knitted garment form-building or other knitting techniques using the surface-building block approach to design. Designed links-links with inlay knitted surfaces could also be employed to create interior products with the haptic used in therapeutic sensory products, reconnecting people to the physical world and promoting wellbeing. In addition, the craft-based aspect of this practice could appeal to bespoke makers who often create specific surface designs using personalised patterning to define their origin. The inlay techniques discussed in this thesis mimic traditional woven-look patterning through a digital design and production process. This manufacturing process fosters the bespoke individualisation of craftsmanship but proposes a more time-efficient customised making process through digital-crafting.

Further to these outlined potentials, the findings contain a creative approach to knitted surface design replicable in an educational setting. Teaching practice could expand on the step-by-step technical knitting instructions provided in the Appendices, allowing multiple disciplines creative access to the knit technologies. This thesis offers a starting point for future interdisciplinary developments rather than an end. The knitted surface topographies materialise the agency of matter, making tangible the intangible, programmed material forces as surfaces become transmitters of knowledge. Each sample from the Shima Seiki Mfg. Ltd. N.SRY123LP inlay knitting machine is a new persona, fostering the temporal nature of knit and signifying endless opportunities for knitted surface design.

References

Adamson, G. (2018). *Thinking through craft*. Bloomsbury Publishing.

Adamson, G., & Kelley, V. (2013). *Surface tensions: Surface, finish and the meaning of objects*. Manchester University Press.

Albers, A. (1944). Work with material (2nd ed.). *College Art Journal*, *3*(2), 51–54. https://www.jstor.org/stable/772462

Albers, A. (1957). The pliable plane; Textiles in architecture. *Perspecta*, 36–41. https://doi.org/10.2307/1566855

Albers, A. (1965) *On weaving.* Studio Vista Limited.

Albers, A. (2017). Tactile sensibility. In A. Albers, N. F. Weber & M. Cirauqui (Eds.), *On weaving* (pp. 44–47). Princeton University Press.

Albers, A., Danilowitz, B., & Weber, N. F. (2000). *Anni Albers: Selected writings on design*. University Press of New England.

Alderman, S. D. (2004). *Mastering weave structures: Transforming ideas into great cloth*. Interweave Press.

Amato, J. A. (2013). *Surfaces: A history*. University of California Press.

Anusas, M., & Ingold, T. (2013). Designing environmental relations: From opacity to textility. *Design Issues*, *29*(4), 58–69. http://www.jstor.org/stable/24266966

Anusas, M., & Simonetti, C. (Eds.). (2020). *Surfaces: Transformations of body, materials and earth*. Routledge.

Arantes, L. M. (2020a). Knitted surface in the making. In M. Anusas & C. Simonetti (Eds.), *Surfaces: Transformations of body, materials and earth* (pp. 151–166). Routledge.

Arantes, L. M. (2020b). Unraveling knitting: Form creation, relationality, and the temporality of materials. *The Journal of American Folklore*, *133*(528), 193–204. https://doi.org/10.5406/jamerfolk.133.528.0193

Archer, L. B. (1964). Systematic method for designers. *Design*, 56–59.

Archer, B. (1979). Design as a discipline. *Design studies*, *1*(1), 17-20.

Armitage, T. (2011). Technology as a Material. Infovore. http://infovore.org/archives/2011/08/22/technology-as-a-material/.

Balea, L., Dusserre, G., & Bernhart, G. (2014). Mechanical behaviour of plain-knit reinforced injected composites: Effect of inlay yarns and fibre type. *Composites Part B: Engineering*, *56*, 20–29. https://doi.org/10.1016/j.compositesb.2013.07.028

Barad, K. (2003). Post humanist performativity: Toward an understanding of how matter comes to matter. *Signs: Journal of Women in Culture and Society*, *28*(3), 801–831. https://www.jstor.org/stable/10.1086/345321

Barnett, P. (1999). Folds, fragments and surfaces: Towards a poetic cloth. In *Textures of memory: The poetics of cloth* (pp. 25–34). Angel Row Gallery.

Beaubois, V., Marenko, B., & Brassett, J. (2015). Design, assemblage and functionality. In B. Marenko & J. Brassett (Eds.), *Deleuze and design* (pp. 173–190). Edinburgh University Press.

Bera, M., Chattopadhyay, R., & Gupta, D. (2016). Influence of linear density of elastic inlay yarn on pressure generation on human body. *Journal of Industrial Textiles*, *46*(4), 1053–1066. https://doi.org/10.1177/1528083715612233

Bennett, J. (2010). *Vibrant matter: A political ecology of things*. Duke University Press.

Bergström, J., Clark, B., Frigo, A., Mazé, R., Redström, J., & Vallgårda, A. (2010). Becoming materials: Material forms and forms of practice. *Digital Creativity*, *21*(3), 155–172. https://doi.org/10.1080/14626268.2010.502235

Black, S. (2005). *The art of knitting: Inspirational stitches, textures and surfaces*. Thames & Hudson.

Bollas, C. (1987). *The shadow of the object: Psychoanalysis of the unthought known*. Free Association Books.

Bolt, B. (2007). Material thinking and the agency of matter. *Studies in Material Thinking*, *1*(1), 1–4. https://www.materialthinking.org/papers/37
Brother. (n.d.). *Brother punch card pattern* (Volume 4).

Bruno, G. (2014). *Surface: Matters of aesthetics, materiality, and media*. University of Chicago Press.

Bruno, G. (2020). Prologue. Surface matters. In Y. Lee (Ed.), *Surface and apparition: The immateriality of modern surface* (pp. xii-xviii). Bloomsbury Publishing.

Burbank, W.L. & Anderson, R.S. (2012). *Tectonic geomorphology, 2nd Ed.* Wiley Blackwell Ltd.

Bye, E. (2010). A direction for clothing and textile design research. *Clothing and Textiles Research Journal*, *28*(3), 205–217. https:doi.org//10.1177/0887302X10371505

Carlin, P. (2018). *On surface and place: Between architecture, textiles and photography*. Taylor & Francis.

Celant, G. (Ed.). (2009). *Piero Manzoni*. Electa.

Cheatle, A., & Jackson, S. J. (2015, February). Digital entanglements: Craft, computation and collaboration in fine art furniture production. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing*, 958-968. http://www.amycheatle.net/wp-content/uploads/2014/10/paper685_cscwcheatle.pdf

Choi, W., & Powell, N. B. (2005). Three dimensional seamless garment knitting on V-bed flat knitting machines. *Journal of Textile and Apparel, Technology and Management*, *4*(3), 1–33. https://www.researchgate.net/publication/237482349_Three_dimensional_seamless_garment_knitting_on_V-bed_flat_knitting_machines

Compton, R. (1988). *The illustrated dictionary of knitting*. Batsford.

Connor, S. (2004). Michel Serres' five senses. In D. Howes (Ed.), *Empire of the senses: The sensual culture reader* (pp. 318–334). Berg Publishers.

Coole, D., & Frost, S. (2010). Introducing the new materialisms. In D. Coole & S. Frost (Eds.), *New materialisms: Ontology, agency, and politics* (pp. 1–44). Duke University Press. https://doi.org/10.1515/9780822392996-002

Cooper, E. (2014). Reassessing the challenge of the digital. In M. van Eechourd (Ed.), *The work of authorship* (pp. 175–214). Amsterdam University Press.

Crouch, C., & Pearce, J. (2012). *Doing design research*. Bloomsbury Publishing.

Cross, N. (1997). Creativity in design: Analyzing and modeling the creative leap. *Leonardo*, *30*(4), 311–317. https://www.jstor.org/stable/1576478

Cross, N. (2006). *Designerly ways of knowing*. Springer.

DeLanda, M. (2004). Material complexity. In N. Leach, D. Turnbull & C. Williams (Eds.), *Digital tectonics* (pp.14–21). Wiley.

DeLanda, M. (2006). Deleuzian social ontology and assemblage theory. In M. Fuglsang & B. Sørensen (Eds.), *Deleuze and the social* (pp. 250–266). Edinburgh University Press.

DeLanda, M. (2015). The new materiality. *Architectural Design*, *85*(5), 16–21. https://doi.org/10.1002/ad.1948

Dormor, C. (2020). *A philosophy of textile: Between practice and theory*. Bloomsbury Publishing.

Dormer, P. (Ed.). (1997). *The culture of craft*. Manchester University Press.

Eckert, C. (1997). *Intelligent support for knitwear design* [Doctoral dissertation, The Open University]. https://www.cse.dmu.ac.uk/~mstacey/pubs/claudia-thesis/Thesisfin.pdf

Etsy. (2021). *Pink blue scarf*. https://www.etsy.com/uk/listing/940289527/pink-blue-scarf?ref=shop_home_active_18&frs=1

Fields, A. (2010). *Collapse weave: Creating three dimensional cloth.* Everbest Printing Company.

Finn, A. L. (2014). *Designing fashion: An exploration of practitioner research within the university environment* [Doctoral dissertation, Queensland University of Technology]. QUT ePrints. https://eprints.qut.edu.au/77850/

Frampton, K. (1995). *Studies in tectonic culture*. MIT Press.

Frayling, C. (1993). *Research in art and design*. Royal College of Art.

Fogg, M. (2010). *Vintage fashion knitwear: Collecting and wearing designer classics*. Cameron House.

Glazzard, M. (2014). *Re-addressing the role of knitted textile design knowledge: Auxetic textiles from a practice-led, designer-maker perspective* [Doctoral dissertation, Nottingham Trent University]. Nottingham Trent University, IRep. http://irep.ntu.ac.uk/id/eprint/308/

Gohl, E. P. G., & Vilensky, L. D. (1993). *Textiles for modern living*. Longman Cheshire.

Golsteijn, C., Van Den Hoven, E., Frohlich, D., & Sellen, A. (2014). Hybrid crafting: Towards an integrated practice of crafting with physical and digital components. *Personal and Ubiquitous Computing*, *18*(3), 593–611. https://doi.org/10.1007/s00779-013-0684-9

Gray, C., & Malins, J. (2004). *Visualizing research: A guide to the research process in art and design*. Routledge.

Grosz, E. (2001). *Architecture from the outside: Essays on virtual and real space*. MIT Press.

Guagliumi, S., (1996), *Hand Manipulated Stitches for Machine Knitters, 4th Ed*. The Taunton Press.

Haffenden, V. (2018). *Translating between hand and machine knitting*. The Crowood Press.

Halliwell, L. (2020). The depth of surface. In Y. Lee (Ed.), *Surface and apparition: The immateriality of modern surface* (pp. 63–76). Bloomsbury Visual Arts.

Harris, J. (2012). Digital practice in material hands: How craft and computing practices are advancing digital aesthetic and conceptual methods. *Craft Research*, *3*(1), 91–112. https://doi.org/10.1386/crre.3.1.91_1

Hatch, K. L. (1993). *Textile science.* West Group.

Hedges, S. (2012). *On Frascari's Notion of Construal* [Doctoral dissertation, University of Auckland]. http://hdl.handle.net/2292/19484

Hiatt, J. (2012). *The principles of knitting*. Simon and Schuster.

Hohenstein, V. (2017). *The space in between: Exploring weave knitted textiles by constructing surface patterns on three-dimensional shapes* [Student thesis, University of Borås, Faculty of Textiles, Engineering and Business]. Digitala Vetenskapliga Arkivet. https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1121385&dswid=-5310

Hunter, B. (2004). Complete garments: Evolution or revolution? (Part 3). *Knitting International*, *111*(1321), 20–2.

Igoe, E. (2010). The tacit-turn: Textile design in design research. *Duck Journal for Research in Textiles and Textile Design*, *1*, 1–11. https://researchportal.port.ac.uk/en/publications/the-tacit-turn-textile-design-in-design-research

Igoe, E. (2021). *Textile design theory in the making*. Bloomsbury Publishing.

Ingold, T. (2010). Bringing things to life: Creative entanglements in a world of materials. *World*, *44*, 1–25. Working Paper: https://eprints.ncrm.ac.uk/id/eprint/1306/1/0510_creative_entanglements.pdf

Ingold, T. (2013). *Making: Anthropology, archaeology, art and architecture*. Routledge.

Ingold, T. (2016). *Lines: A brief history*. Taylor & Francis

Ingold, T. (2018). Surface textures: The ground and the page. *Philological Quarterly*, *97*(2), 137–154. https://abdn.pure.elsevier.com/en/publications/surface-textures-the-ground-and-the-page

Jefferies, J. K. (2008). Contemporary textiles: The art fabric. In N. Monem & J. K. Jefferies (Eds.), *Contemporary textiles: The fabric of fine art* (pp. 34–62). Black Dog Publishing.

Jefferies, J. (2012). Pattern, patterning. In C. Lury & N. Wakeford (Eds.), *Inventive methods: The happening of the social* (pp. 125–135). Routledge.

Kalyanji, J. (2020). *Seamless knit–dimensions unfolding: An investigation of 3-dimensional knitted form-building* [Doctoral dissertation, Auckland University of Technology]. Open Repository, AUT. https://openrepository.aut.ac.nz/handle/10292/13826.

Kidd, A., & Smitheram, J. (2014). Designing for affect through affective matter. *Interstices: Journal of Architecture and Related Arts*, 82–92. https://doi.org/10.24135/ijara.v0i0.479

Kincheloe, J. L. (2001). Describing the bricolage: Conceptualising a new rigor in qualitative research. *Qualitative Inquiry,* 7(6), pp.679–692. https://doi.org/10.1177/107780040100700601

Kinder, K. (1987). *Machine knitting: The technique of knitweave.* B.T. Batsford Ltd.

Knittel, C. E., Nicholas, D. S., Street, R. M., Schauer, C. L., & Dion, G. (2015). Self-folding textiles through manipulation of knit stitch architecture. *Fibers*, *3*(4), 575–587. https://doi.org/10.3390/fib3040575

Knitting Industry. (2014, June 27). *Shima Seiki unveils flat knitting machines for inlay fabrics.* https://www.knittingindustry.com/shima-seiki-unveils-new-flat-knitting-machines-for-inlay-fabrics/

Knitting Industry. (2015, May 26). *Stoll-weave-in technique to be highlighted in latest capsule collection.* https://www.knittingindustry.com/stollweavein-technique-to-be-highlighted-in-latest-capsule-collection/

Knitting Industry. (2019, October 30). *Shima promotes knit to general footwear market.* https://www.knittingindustry.com/shima-promotes-knits-to-general-footwear-market/

Kraft, K. (2004). Textile patterns and their epistemological functions. *Textile*, *2*(3), 274–289.
https://doi.org/10.2752/147597504778052711

Kolarevic, B., & Klinger, K. (Eds.). (2013). *Manufacturing material effects: Rethinking design and making in architecture*. Routledge.

Küchler, S. (2008). Technological materiality: Beyond the dualist paradigm. *Theory, Culture & Society*, *25*(1), 101–120. https://doi.org/10.1177/0263276407085159

Küchler, S. (2020). Epilogue. In M. Anusas & C. Simonetti (Eds.), *Surfaces: Transformations of body, materials and earth* (pp.185–190). Routledge.

Landahl, K. (2013). *On form thinking in knitwear design* [Doctoral dissertation, University of Borås]. http://hdl.handle.net/2320/12587

Lange-Berndt, P. (2015). *Materiality.* Whitechapel Gallery.

Lean, M. (2021). *Taking on textile thinking.* In E. Igoe (Ed.), *Textile design theory in the making* (pp. 99–110). Bloomsbury Publishing.

Lee, M., Mata-Falcón, J., Popescu, M., Block, P., & Kaufmann, W. (2020). Potential approaches for reinforcing complex concrete structures with integrated flexible formwork. In *RILEM International Conference on Concrete and Digital Fabrication* (pp. 669–679). Springer.

Lee, Y. (Ed.). (2020). *Surface and apparition: The immateriality of modern surface*. Bloomsbury Visual Arts.

Li, N. W., Ho, C. P., Yick, K. L., & Zhou, J. Y. (2018, September 3–5). *Novel buoyant fabrics created by integrating inlay knitted structure* [Paper presentation]. 46th Textile Research Symposium, Teijin Academy Fuji, Susono City, Shizuoka Prefecture, Japan. http://hdl.handle.net/10397/80320

Li, N. W., Ho, C. P., Yick, K. L., & Zhou, J. Y. (2020). Development of laid-in knitted fabric for buoyant swimwear. *Journal of Industrial Textiles*. https://doi.org/10.1177/1528083719900932

Lincoln, Y. S. (2001). An emerging new bricoleur: Promises and possibilities – a reaction to Joe Kincheloe's 'Describing the bricoleur'. *Qualitative Inquiry,* 7(6), 693–696. https://doi.org/10.1177/107780040100700602

Mäkelä, M. (2007). Knowing through making: The role of the artefact in practice-led research. *Knowledge, Technology & Policy*, *20*(3), 157–163. https://doi.org/10.1007/s12130-007-9028-2

Mäkelä, M. (2016). Personal exploration: Serendipity and intentionality as altering positions in a creative process. *FormAkademisk-forskningstidsskrift for design og designdidaktikk*, *9*(1), 1-12. http://dx.doi.org/10.7577/formakademisk.1461

Markande, S., Dimitriyev, M., & Matsumoto, E. (2019). Twisted topological tangles: Or the knot theory of knitting. In *APS March Meeting Abstracts*. (Vol. 2019, pp. K63–001).

Marr, A., & Hoyes, R. (2016). Making material knowledge: Process-led textile research as an active source for design innovation. *Journal of Textile Design Research and Practice*, *4*(1), 5–32. https://doi.org/10.1080/20511787.2016.1255447

Matković, V. M. P. (2010). The power of fashion: The influence of knitting design on the development of knitting technology. *Textile*, *8*(2), 122–146. https://doi.org/10.2752/175183510X12791896965493

McCormack, J., Dorin, A., & Innocent, T. (2004). Generative design: A paradigm for design research. In J. Redmond, D. Durling & A. de Bono (Eds.), *Futureground – DRS International Conference 2004,* Melbourne, Australia. https://dl.designresearchsociety.org/drs-conference-papers/drs2004/

McCullough, M. (1998). *Abstracting craft: The practiced digital hand*. MIT Press

McKnelly, C. L. (2015). *Knitting behaviour: A material-centric design process* [Doctoral dissertation, Massachusetts Institute of Technology]. DSpace@MIT. http://hdl.handle.net/1721.1/99249

Merleau-Ponty, M. (1965). *Phenomenology of perception.* Routledge.

Messer, R., & Straffin, P. (2018). *Topology now!* (Vol. 42). American Mathematical Society.

Mori, T. (2012). Weaving: The tectonics of textiles. In T. Schröpfer, J. Carpenter, S. Kennedy, L. Margolis, T. Mori, N. Tehrani & P. Yeadon (Eds.), *Material design* (pp. 76–87). De Gruyter.

Negrin, L. (2015). The corporeal experience of fashion. In A. Rocamora & A.Smelik (Eds.), *Thinking Through Fashion* (pp. 115-131). I.B. Tauris & Co. Ltd.

Niedderer, K. (2009). Relating the production of knowledge and the production of artefacts in research. In N. Nimkulrat & T. O'Liley (Eds.), *Reflections and connections: On the relationship between creative production and academic research* (pp. 59–67). University of Art and Design Helsinki.

Niedderer, K., & Townsend, K. (2010). Craft research: Joining emotion and knowledge. *Design and Emotion 2010 (Proceedings), Chicago, USA, IIT*, 5–7.

Nilsson, L. (2015). *Textile influence: Exploring the relationship between textiles and products in the design process* [Doctoral dissertation, Högskolan, University of Borås]. Digitala Vetenskapliga Arkivet. https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A868073&dswid=-3964

Nimkulrat, N. (2009). Creation of artifacts as a vehicle for design research. *Nordes*, (3). https://archive.nordes.org/index.php/n13/article/view/33

Nimkulrat, N. (2013). Situating creative artifacts in art and design research. *Form Akademisk – Research Journal of Design and Design Education*, *6*(2), 1–16. https://doi.org/10.7577/formakademisk.657

Nimkulrat, N., Seitamaa-Hakkarainen, P., Pantouvaki, S., & de Freitas, N. (2016). Experience/materiality/articulation. *Studies in Material Thinking*, *14*. https://www.nithikul.com/SMT14.html

Nitsche, M., Quitmeyer, A., Farina, K., Zwaan, S., & Nam, H. Y. (2014). Teaching digital craft. In *CHI'14 Extended Abstracts on Human Factors in Computing Systems* (pp. 719–730).

Oxman, R. (2012). Informed tectonics in material-based design. *Design Studies*, *33*(5), 427–455. https://doi.org/10.1016/j.destud.2012.05.005

Pajaczkowska, C. (2005). On stuff and nonsense: The complexity of cloth. *Textile*, *3*(3), 220–249. https://doi.org/10.2752/147597505778052495

Pallasmaa, J. (2000). Hapticity and time. *Architectural Review*, *207*(1), 78–84.

Pavko-Čuden, A., & Rant, D. (2017). Multifunctional foldable knitted structures: Fundamentals, advances and applications. In B. Kumar & S. Thakur (Eds.), *Textiles for advanced applications* (pp. 55–84). Intech. https://www.intechopen.com/chapters/56019

Pepperwell, R. (2019). Problems and paradoxes of painting and perception, *Art & Perception*, *7*(2-3), 109–122. https://doi.org/10.1163/22134913-20191142

Pennybacker, K. (2021, October 10). *Kitty Pennybacker. About.* https://www.kittypennybacker.com/about

Persson, I. (2017). Tactile constructions: Building with textile, sensual mathematics [Master's thesis, University of Arts, Crafts, and Design, Stockholm]. Digitala Vetenskapliga Arkivet. https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1106849&dswid=5743

Peterson, J. F., Slack, D., & Gabler, R. E. (2017). *Physical geography* (11th ed.). Cengage Learning.

Philpott, R. (2011). *Structural textiles: Adaptable form and surface in three dimensions* [Doctoral dissertation, Royal College of Art]. Research Online. https://researchonline.rca.ac.uk/434/1/Philpott_Rachel_PhD_Textiles_Structural_Textiles_Thesis_2011.pdf

Philpott, R. (2012a). Crafting innovation: The intersection of craft and technology in the production of contemporary textiles. C*raft Research*, *3*(1), 53–74. https://dspace.lboro.ac.uk/2134/12956

Philpott, R. (2012b). Entwined approaches: Integrating design, art and science in design research-by-practice. In *Proceedings of the DRS Bangkok conference*. https://repository.lboro.ac.uk/articles/conference_contribution/Entwined_approaches_integrating_design_art_and_science_in_design_research-by-practice/9332708

Plummer, C. C., Carlson, D. H., & Hammersley, L. (2018). *Physical geology* (16th ed.). McGraw-Hill Education.

Polanyi, M. (1967). *The tacit dimension*. Routledge & K. Paul

Power, J. (2007). Functional to fashionable: Knitwear's evolution throughout the last century and into the millennium. *Journal of Textile and Apparel Technology and Management*, *5*(4), 1–16. http://eprints.hud.ac.uk/id/eprint/13848/

Preston, J. (2019). You are embued with tolerance…. *Architecture and Culture*, *7*(1), 31–43. https://doi.org/10.1080/20507828.2018.1551050

Prytherc, D., & McLundie, M. (2002). So what is haptics anyway? *Research Issues in Art, Design and Media, 2,* 29.

Pye, D. (1968). *The nature and art of workmanship*. Cambridge University Press.

Rauch, B. (2020). Surface eruptions: Machine creativity and emotive data objects. In Y. Lee (Ed.), *Surface and apparition: The immateriality of modern surface* (pp. 51–62). Bloomsbury Visual Arts.

Reichman, C. (1966). *Knitting dictionary.* National Knitted Outerwear Association.

Rosenberg, M. (2019, February 26). *What is physical geography?* https://www.thoughtco.com/physical-geography-overview-1435345

Schön, D. (1983). *The reflective practitioner: How professionals think in action.* Routledge.

Scrivener, S. (2000). Reflection in and on action and practice in creative-production doctoral projects in art and design. *Working papers in art and design*, *1*(1).

Scott, J. (2015). Mutate: The evolution of a responsive knit design system. In *Proceedings of the 2nd Biennial Research Through Design Conference, 25*-27. https://eprints.ncl.ac.uk/file_store/production/266155/CCC4322C-3F1A-442C-ACD1-FD05A5F963D9.pdf

Scott, C. (2019, March 18). Meet the Yorkshire designer who makes knitwear for our homes. *The Yorkshire Post*. https://www.yorkshirepost.co.uk/whats-on/arts-and-entertainment/meet-yorkshire-designer-who-makes-knitwear-our-homes-1758136

Seago, A., & Dunne, A. (1999). New methodologies in art and design research: The object as discourse. *Design Issues*, 1*5*(2), 11–18. https://www.jstor.org/stable/1511838

Sekler, E. (1965). Structure, construction, tectonic. In G. Kepes (Ed.), *Structure, in art, in science* (pp. 125–133). G. Braziller.

Semper, G. (2004). *Style in the technical and tectonic arts, or, practical aesthetics*. Getty Publications.

Sennett, R. (2008). *The craftsman*. Penguin Books.

Shima Seiki Mfg. Ltd.. (2020, October 10). https://www.shimaseiki.com/product/knit/feature/#u2

Smelik, A. (2016). Gilles Deleuze. In A. Rocamora & A. Smelik (Eds.), *Thinking through fashion: A guide to key theorists* (pp. 165–183). Bloomsbury Publishing.

Smith, A. E. (2013). *Seamless knitwear: Singularities in design* [Doctoral dissertation, Auckland University of Technology]. Open Repository. http://hdl.handle.net/10292/5761

Smitheram, M. (2016). *The hand of the cloth: An ontological and aesthetic unfolding through digital and virtual materiality* [Doctoral dissertation, Auckland University of Technology]. Open Repository. http://hdl.handle.net/10292/10621

Spencer, D. J. (2001). *Knitting technology: A comprehensive handbook and practical guide*. Woodhead Publishing.

Spurling. F. (2021) *Designing knitted textiles: Machine knitting for fashion.* Laurence King Publishing.

Stenner, P. (2012). Pattern. In C. Lury & N. Wakeford (Eds.), *Inventive methods: The happening of the social* (pp. 150–160). Routledge.

Stephens. C. (2016). *Digital dynamics: An interactive design process for generating knitted textiles* [Master's exegesis, Auckland University of Technology]. Open Repository. http://hdl.handle.net/10292/10129

Stewart, I. (1998). *Nature's numbers: Discovering order and pattern in the universe.* Weidenfeld & Nicolson.

Swann, C. (2002). Action research and the practice of design. *Design Issues*, *18*(1), 49–61. https://www.jstor.org/stable/1512029

Taylor, J. (2015). *The technical designer: A new craft approach for creating seamless knitwear* [Doctoral dissertation, Nottingham Trent University]. IRep. http://irep.ntu.ac.uk/id/eprint/28318/

Tessmann, O. (2009). Processes for performative geometry. In A. Agkathidis (Ed.), *Modular structures in design and architecture* (pp. 51–54). BIS Publishers.

Thomsen, M. R. (2014). Digital crafting and the challenge to material practices. In S. Yelavich & B. Adams (Eds.), *Design as future-making* (pp. 58–65). Bloomsbury Publishing.

Treadaway, C. (2007). Digital crafting and crafting the digital. *The Design Journal*, *10*(2), 35–48. https://doi.org/10.2752/146069207789272668

Turney, J. (2009). *The culture of knitting*. Berg.

Underwood, J. (2009). *The design of 3D shape knitted preforms* [Doctoral theis, RMIT University]. Research Repository. https://researchrepository.rmit.edu.au/esploro/outputs/doctoral/The-design-of-3D-shape-knitted-preforms/9921861597201341#file-0

Woolley, M. (2011). Beyond control: Rethinking industry and craft dynamics. *Craft Research*, *2*(1), 11–36. https://doi.org/10.1386/crre.2.11_1

Xiong, Y., & Tao, X. (2018). Compression garments for medical therapy and sports. *Polymers*, *10*(6), 663.

Yang, S. (2010). *A creative journey developing an integrated high-fashion knitwear development process using computerized seamless v-bed knitting systems* [Doctoral dissertation, Curtin University]. eSpace. http://hdl.handle.net/20.500.11937/1253

Zoran, A., & Buechley, L. (2013). Hybrid reassemblage: An exploration of craft, digital fabrication and artifact uniqueness. *Leonardo*, *46*(1), 4–10. https://doi.org/10.1162/LEON_a_00477

Zoran, A. S. (2013). *Hybrid re Assemblage: Bridging traditional craft and digital design* [Doctoral dissertation, Massachusetts Institute of Technology]. DSpace@MIT. http://dspace.mit.edu/handle/1721.1/7582

Glossary

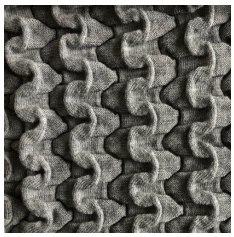
Automatic software	Shima Seiki Mfg. Ltd. design system that expands programmed knit designs using a series of predetermined development instructions.
Carriage	Mechanism that selects needles for knitting and transports yarn carriers across the needle bed
Convergent forces	Generating colliding compressional surface movement towards each other
Course	Horizontal row of interconnected looped stitches
Compressed pattern	Shima Seiki Mfg. Ltd. term – a computerised image of the knit design as registered coloured packages
Developed pattern	Shima Seiki Mfg. Ltd. term – a computerised image of the knit design as expanded knitting information applying the compressed patterns registered coded colours
Divergent forces	Generating surface movement away from each other
Double bed knitting	A knitting technique that knits on two needle beds to create a knitted textile
End	Weaving term for a single warp thread
Float	Length of thread or yarn that lies across the front or back of a knitted or woven surface
Gauge	Knitting term used to calculate per inch the number of knitting needles on a needle bed

Ground	A knitted base built from stitch structures
Inlay knitting	Inlaid yarn lies horizontally across the needle bed, it is not knitted into the stitch.
Intarsia	A sectional knitting technique used to incorporate blocked areas of contrasting colour or pattern
Knit Stitch	Front face of single jersey knitting
KnitPaint programme	Shima Seiki Mfg. Ltd. term - the technical design system for programming for the Shima Seiki Mfg. Ltd. knitting technology
Knitting	Textile technique that creates a fabric or garment through the interlocking of connected loops formed on needles using a continuous yarn
Loop	Single knitted stitch formed by a continuous yarn
Material forces	Surface movements arising from interactive influences generated by fibre properties and behaviours. Also referred to as tectonic forces
Old-format	Shima Seiki Mfg. Ltd. term - the technical programming page set-up for generating complex knit designs using coded packages to develop for knitting.
Option lines	Shima Seiki Mfg. Ltd. term - used to store the technical knitting information for controlling each knitted course
Package	Shima Seiki Mfg. Ltd. term – a programmed component comprised of sequenced knitting instructions used to colour code compressed patterns
Pick	Weaving term for a single point of a weft thread
Purl stitch	Reverse face of single jersey knitting
SDS-One Apex3	Shima Seiki Mfg. Ltd. knitting software for programming digitally knitted textiles and garments

Single bed knitting	Knitting technique that knits on one needle bed to create a fabric
Single jersey	Knitting technique that creates a front faced knitted fabric
Stitch code	Programming registered colour that contains knitting information
Stitch structures	Knitted stitches used to create surface texture or pattern
Thermo-reactive yarn	Activated fibres that contract with applied heat
Transfer stitch	Method of moving a stitch from the original needle position to an adjacent needle
Transformative forces	Generating surface movement up and down
Tubular jacquard	Knitting technique that knits on the front and back bed forming a pocket between two surfaces
Wales	Vertical rows of interconnected looped stitches

APPENDIX A.
GEOMORPHIC KNITTED SURFACE TERMINOLOGY

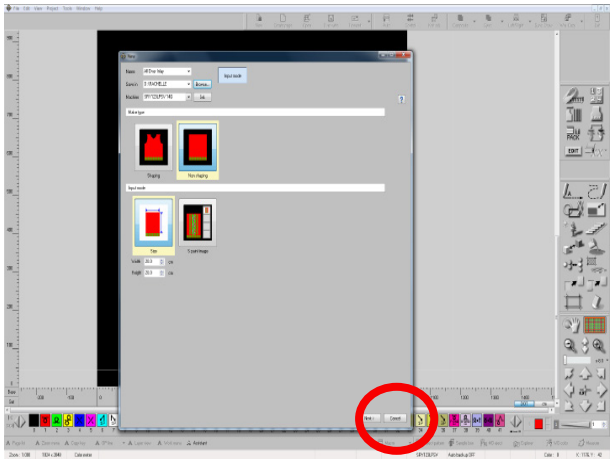
TERM	DEFINITION	FORCES	KNITTED SURFACE EXAMPLE
CONVERGENT	Forces pushing towards or moving together	COMPRESSION	Vertical Convergent  Horizontal Convergent 
DIVERGENT	Forces pulling outward or moving apart	TENSION	
TRANSFORM	Forces sliding areas past each other up and down direction or twisting / torsions	SHEARING	
CREST or PEAK	The highest point of the fold, the upfolded arch	COMPRESSION	
TROUGH or DIP	The lowest point of the fold, the downfold arch	COMPRESSION	
SUBDUCTION ZONE	One area is pushed under the other	COMPRESSION	

FOLD	Bending or crumpling of surface caused by compressional tectonic forces	COMPRESSION	
RECUMBENT FOLD	Bending or wrinkling or flexures that occurs on a horizontal axis plane	COMPRESSION	
SYMMETRICAL (SIMPLE) FOLD	Balanced fold that has even pressure from all directions	COMPRESSION	
ASYMMETRICAL FOLD	Unbalanced fold that has more pressure from one or more directions	COMPRESSION	
TIGHT FOLDS	Folds that are close together	COMPRESSION	
BROAD FOLDS	Folds that are a distance apart	COMPRESSION	

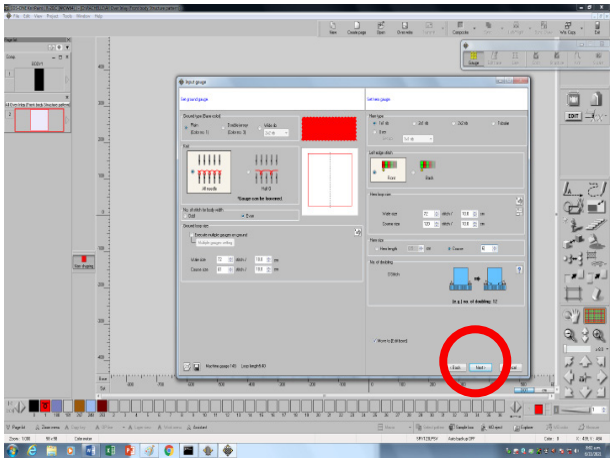
COMPLEX FOLDS	Applied compressional forces that become more unequal from two or more directions	COMPRESSION	
ACTIVE BOUNDARIES	Intersections of forces	ALL SURFACE FORCES	
FAULT	A breakage zone	ALL SURFACE FORCES	

Adapted from terminology in *Physical geography*, by J. F. Peterson, D. Slack, and R .E. Gabler, 2017, Cengage Learning.

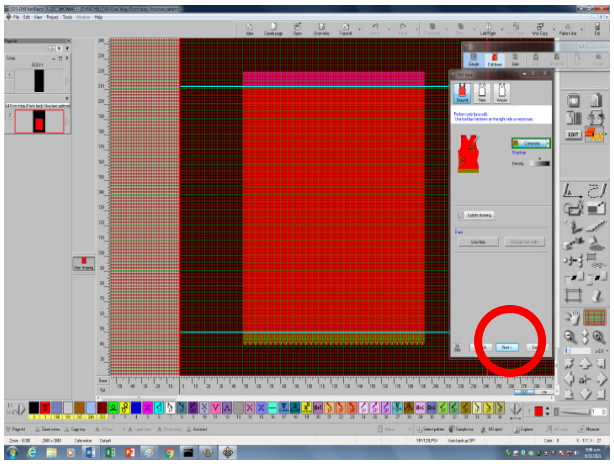
APPENDIX B.
How to Build an All-over Inlay Knitted Surface



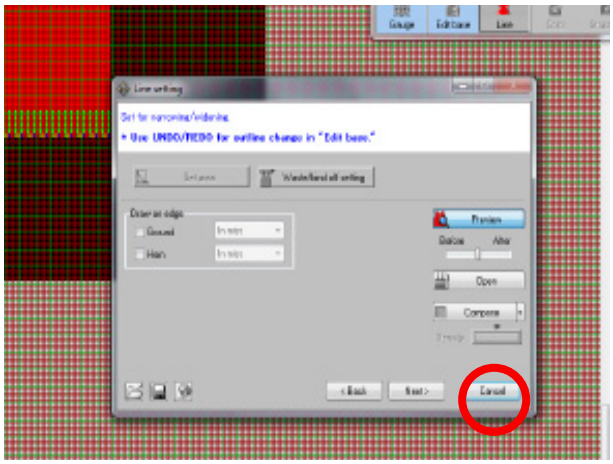
- STEP 1. Set Up New Swatch in Automatic Software
- File > New
- Set up f le name
- Browse to f nd correct folder
- Set Machine: N.SRY123LPSV 14
- Size of panel: width and height
- Click > OK



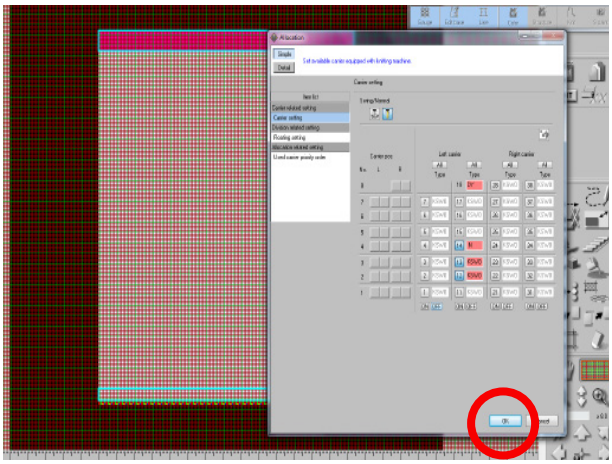
- STEP 2. Set Up New Swatch in Automatic Software
- Input Gauge & Select all needle
- Input Ground loop size (if known from swatch or use default)
- Select hem type
- Input hem loop size (if known from swatch or use default)
- Set hem size (cm or number of courses)
- Click > Next



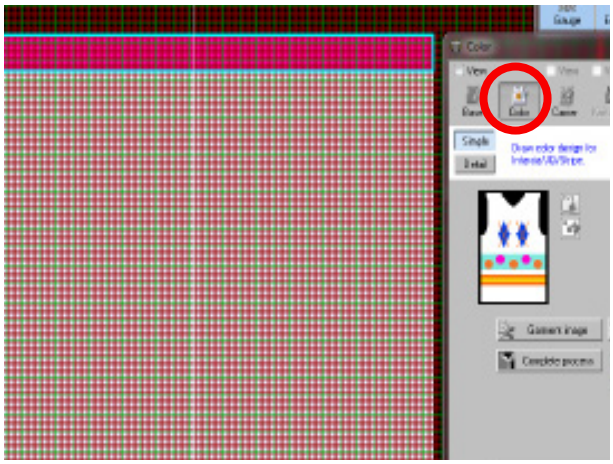
- STEP 3. Set Up New Swatch in Automatic Software
- Edit Base
- Options to change the hem type and the waste type
- Click > Next



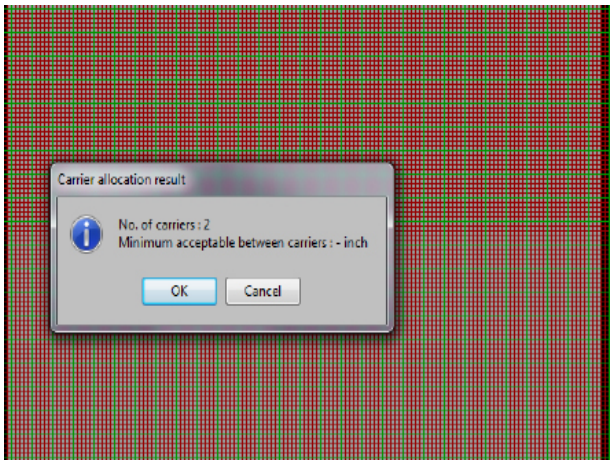
- STEP 4. Set Up New Swatch in Automatic Software
- Line Setting
- Leave as default
- Click > Next



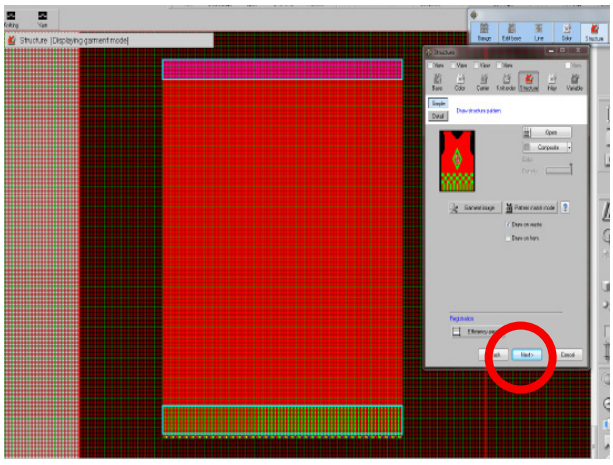
- STEP 5. Set Up New Swatch in Automatic Software
- Allocation
- Select Carrier type = Swing (KSW1) or Non Swing (KSW0)
- Select Carriers to use
- 14 = N (Inlay) 13=KSW0 (Ground) 12 = KSW0 (Waste)
- Click > OK



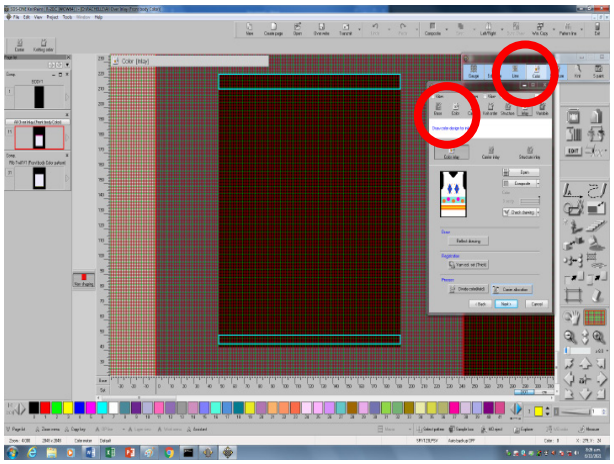
- STEP 6. Set Up New Swatch in Automatic Software
- Colour page
- Leave as default (can adjust later if want more colours added)
- Default is set for one ground colour and one waste colour
- Click > Next



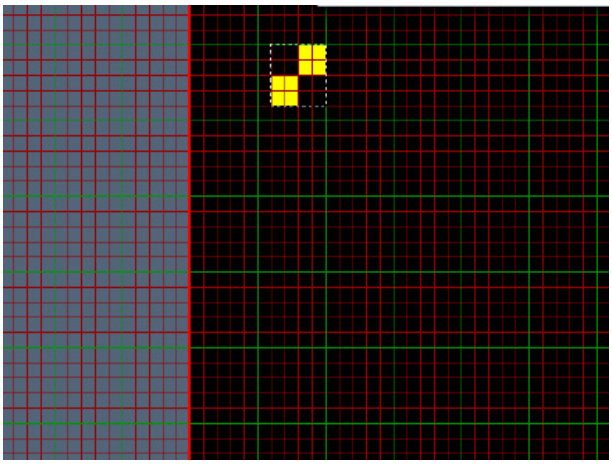
- STEP 7. Set Up New Swatch in Automatic Software
- Carrier Allocation Result
- Click > OK



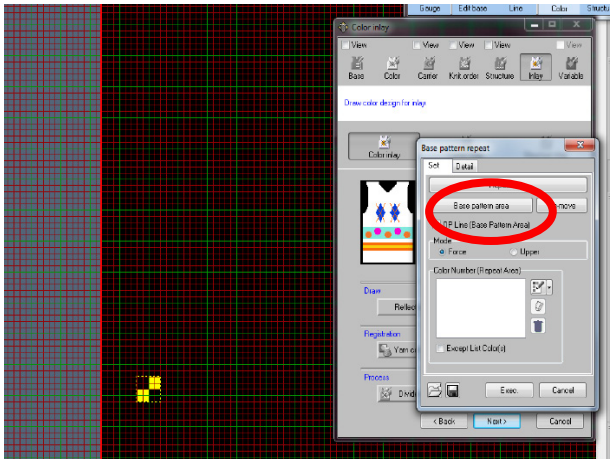
- STEP 8. Set Up New Swatch in Automatic Software
- Structure page
- The default is a red code = front bed single jersey
- Hem is the codes for the hem set up in step 2



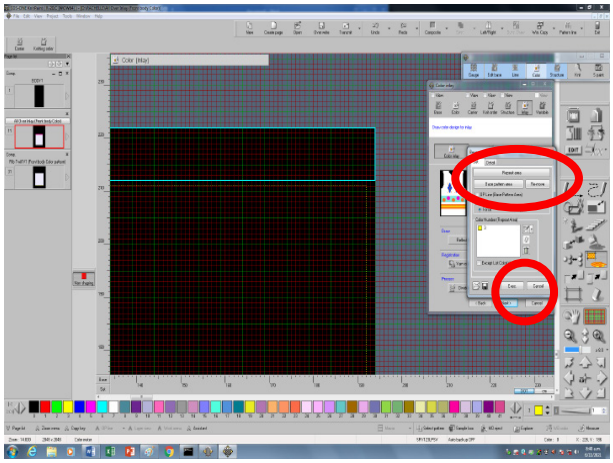
- STEP 9. Create Inlay Pattern
- Inlay Colour Page
- Click > Inlay
- Opens up Inlay Colour page this is used to set up the inlay pattern



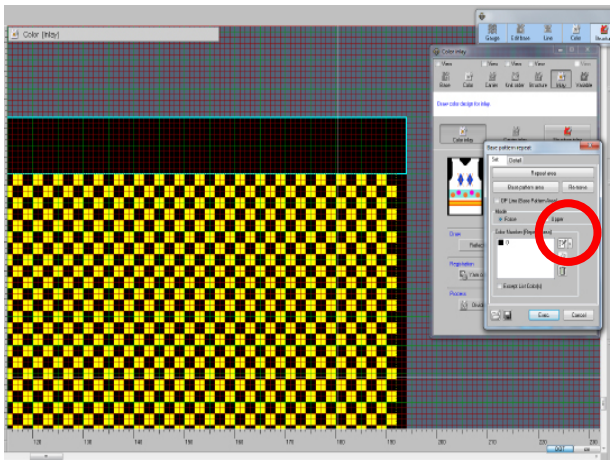
- STEP 10. Create Inlay Pattern
- Develop the inlay base unit for repeating pattern to the right of red line (this is outside the developing area, use it to draw like a blank page)
- Zoom in to see grid & use a bright colour so it is easy to see the design



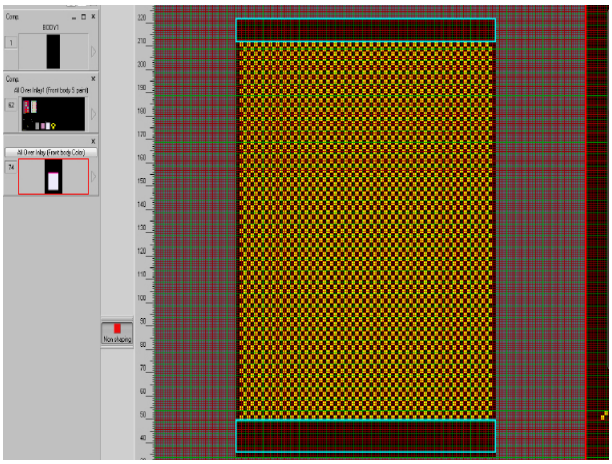
- STEP 11. Create Inlay Pattern
- Click > Base pattern repeat tool
- Click > Base pattern area
- Drag an area box around the unit repeat pattern
- Click > Ok



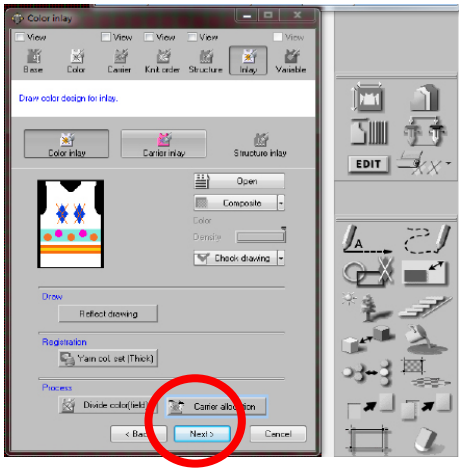
- STEP 12. Create Inlay Pattern
- Click > Repeat Area
- Drag an area box around the unit repeat pattern
- Inlay must start 1 course up from the bottom and finish 1 course from the top of the swatch
- Inlay must sit inside side edges by minimum of two needles
- Click >OK



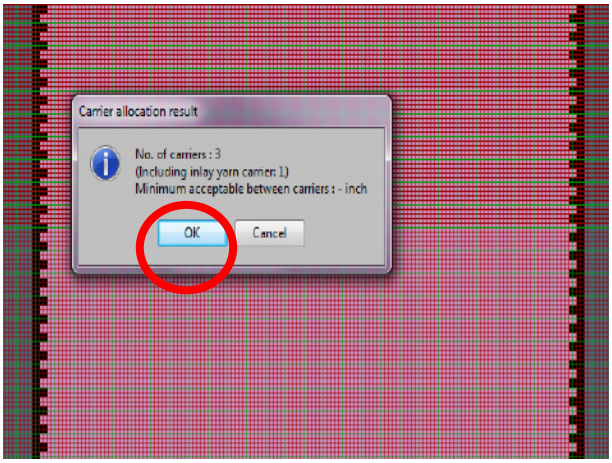
- STEP 13. Create Inlay Pattern
- Select colour to repeat over with pull down tab on Add icon
- Select black ground colour
- If there are other colours in the list remove them (click the Delete All icon)



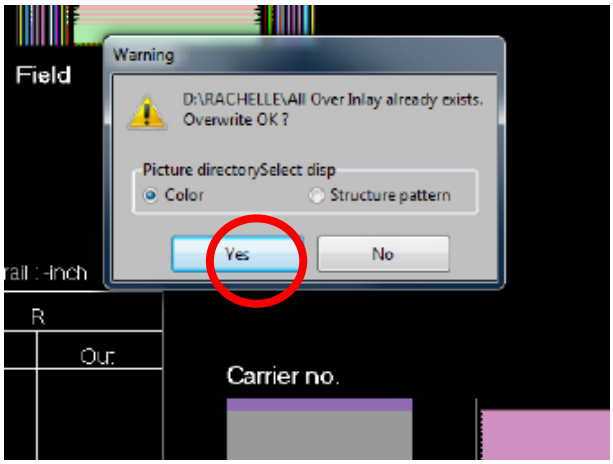
- STEP 14. Create Inlay Pattern
- Click > Exec
- Fills with the repeat of the base unit in the set area
- Click > Cancel



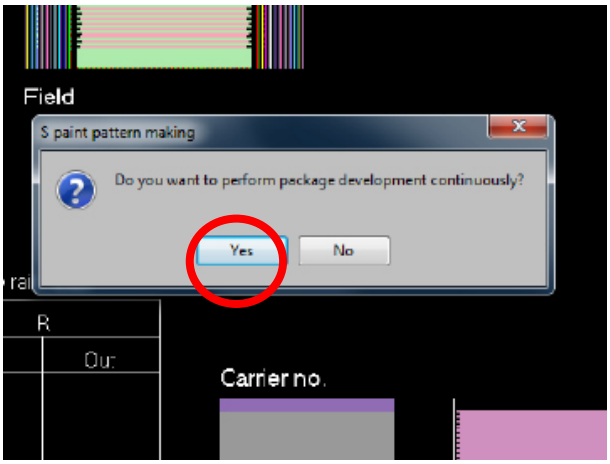
- STEP 15. Automatic Software Development
- Click > Next



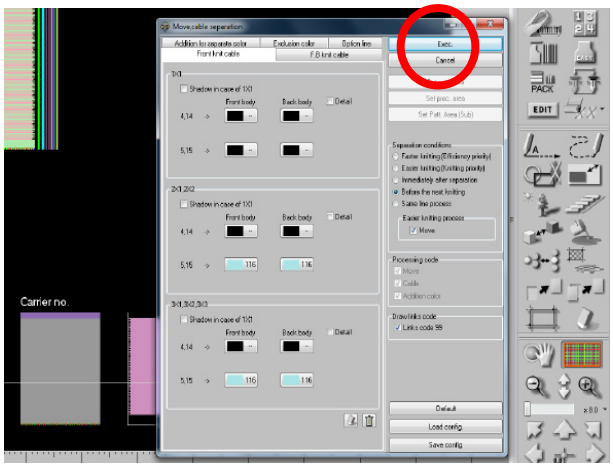
- STEP 16. Automatic Software Development
- Carrier Allocation Result
- Click > OK



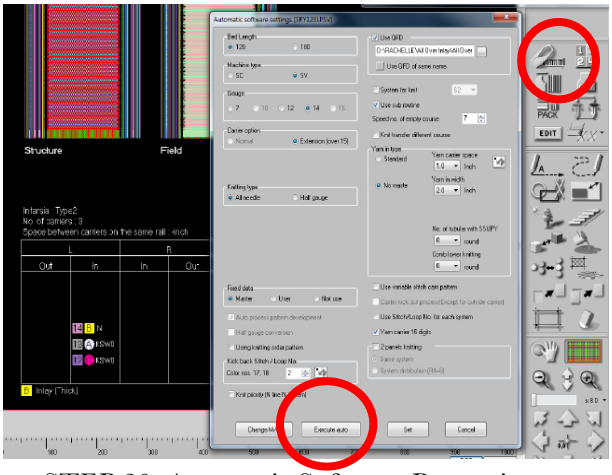
- STEP 17. Automatic Software Development
- Name Overwrite
- Click > Yes



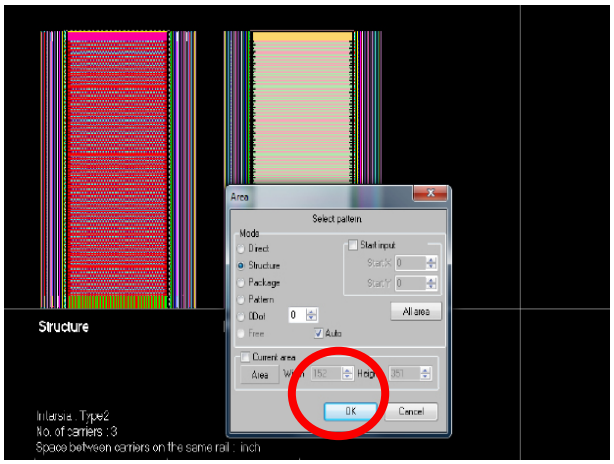
- STEP 18. Automatic Software Development
- S paint pattern making
- Do you want to perform package development continuously?
- Click > Yes



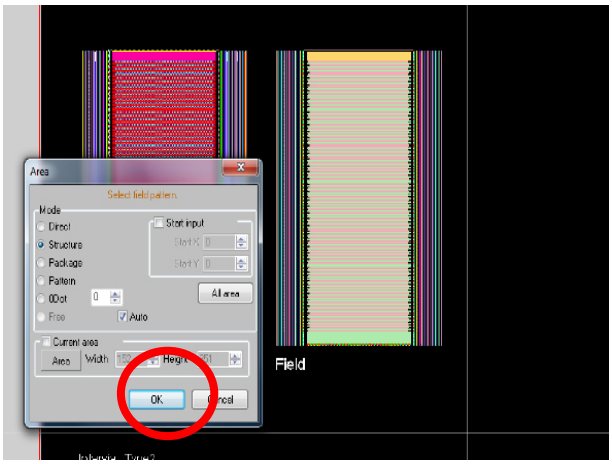
- STEP 19. Automatic Software Development
- Move Cable Separation - Leave all settings as default
- Click > Exec



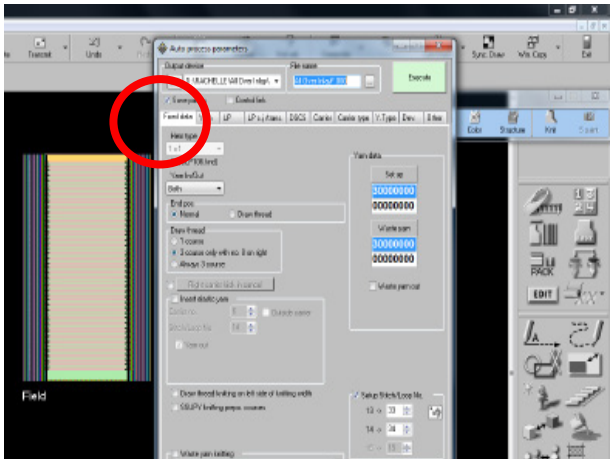
- STEP 20. Automatic Software Processing
- Click > Automatic Processing
- Bed Length = 120
- Machine = SV & Gauge = 14
- Carrier Option = Extension
- Knitting = All Needle
- Click > Execute Auto



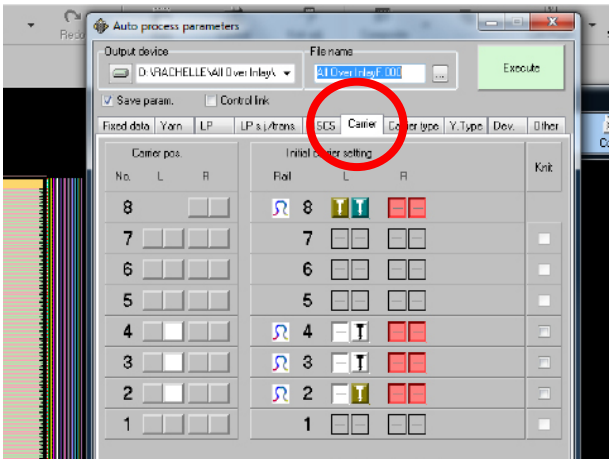
- STEP 21. Automatic Software Processing
- Select Structure Pattern
- Click > Inside the Structure image
- Click > OK



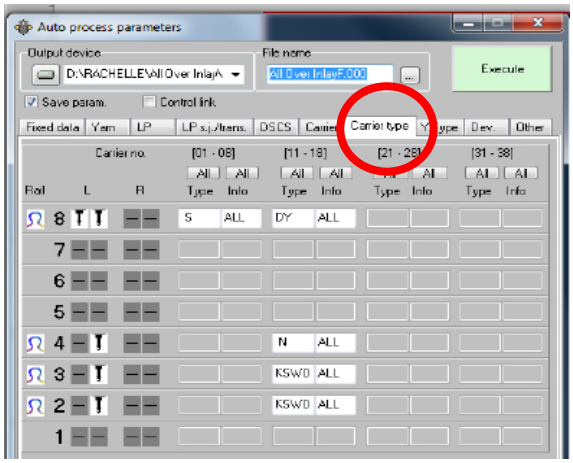
- STEP 22. Automatic Software Processing
- Select Field
- Click > Inside the Field image
- Click > OK



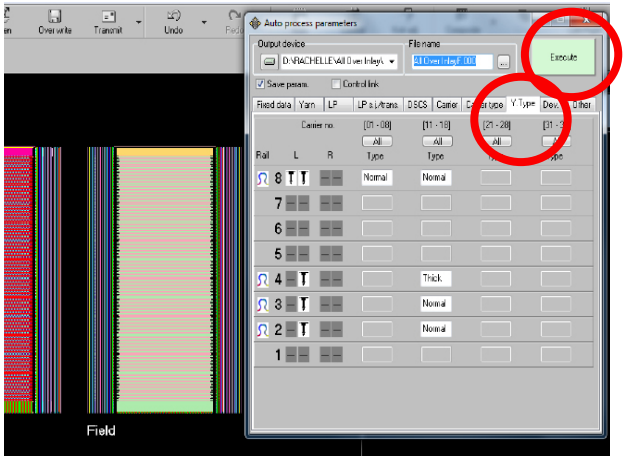
- STEP 23. Automatic Software Processing
- Click > Auto Processing (RHS menu)
- Set Auto Process Parameters
- Fixed Data Tab > Check Set Up and Waste Carriers



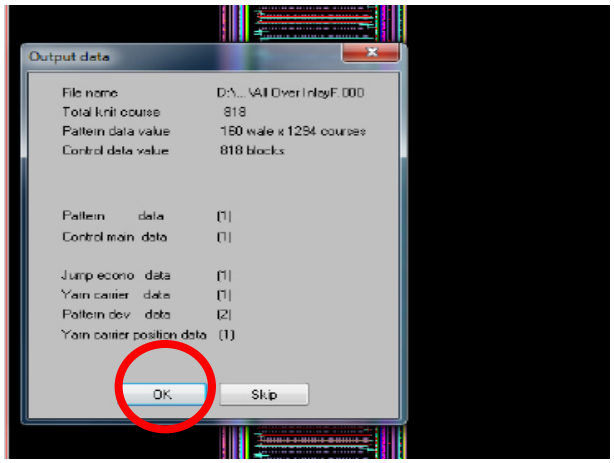
- STEP 24. Automatic Software Processing
- Carrier tab
- Carrier 8 Left and Right (never adjust)
- Carriers 14 & 13 & 12 in use from the left



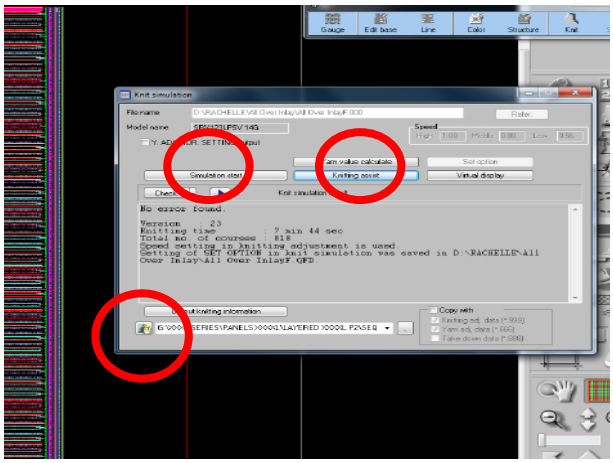
- STEP 25. Automatic Software Processing
- Carrier Type tab
- Carrier 14 = N = Normal = Inlay carrier
- Carrier 13 & 12 = KSW0 = Non swing = Ground & Waste



- STEP 26. Automatic Software Processing
- Yarn Type tab
- Carrier 14 = Thick
- Carrier 13 & 12 = Normal
- Click > Execute



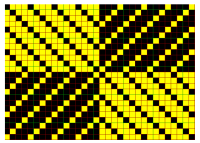
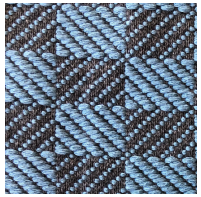
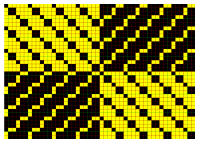
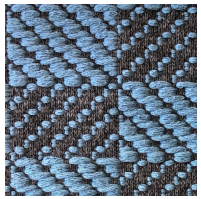
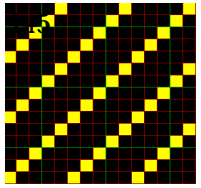
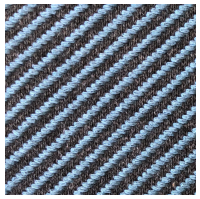
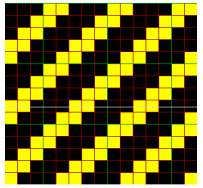
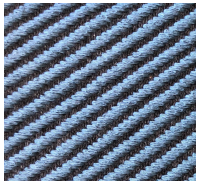
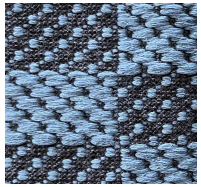
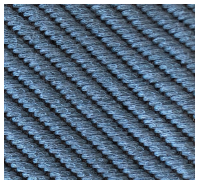
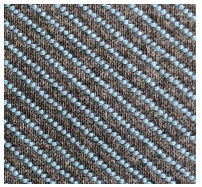
- STEP 27. Automatic Software Processing
- Data Output
- Click > OK



- STEP 28. Automatic Software Processing Completed
- Knit Simulation
- Click > Simulation Start
- Click > Knitting assist
- The file is OK to knit if no issues or fix if issues shown
- Copy .000 file to usb to knit

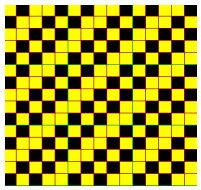
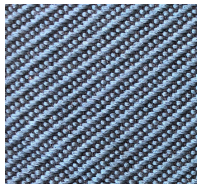
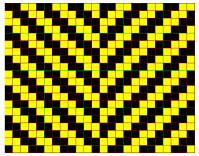
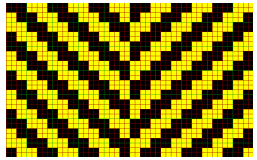
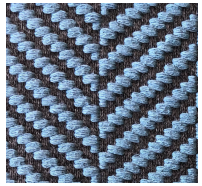
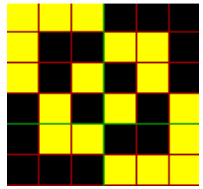
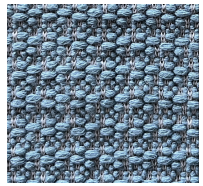
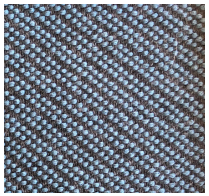
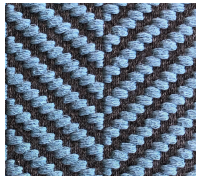
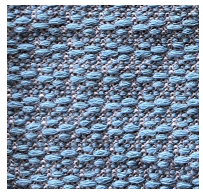
APPENDIX C.
Inlay Pattern Surface-building Block Library

DESCRIPTION	**SINGLE JERSEY KNITTED BASE WITH INLAY**
DATE KNITTED	11.10.19
GROUND YARN	WOOLYARNS
COMPOSITION	WOOL / ACRYLIC
COUNT	2/36
NUMBER OF ENDS	1
CARRIER	13
INLAY YARN	KISS
COMPOSITION	COTTON with NYLON CORE
COUNT	1/16
NUMBER OF ENDS	1
CARRIER	14
MACHINE	SRY123 LPSV 14G
HEAT METHOD	STEAM
ISSUES	NO ISSUES YARN RUNS WELL

BLOCK TWILL100%		**BLOCK TWILL 200%**		**TWILL REGULAR 1**		**TWILL REGULAR 2**	
INLAY CODE REPEAT UNIT	**SWATCH**	**INLAY CODE REPEAT UNIT**	**SWATCH**	**INLAY CODE REPEAT UNIT**	**SWATCH**	**INLAY CODE REPEAT UNIT**	**SWATCH**
	 **TECHNICAL FRONT & BACK**		 **TECHNICAL FRONT & BACK**		 **TECHNICAL FRONT**		 **TECHNICAL FRONT**
	 **TECHNICAL BACK**		 **TECHNICAL BACK**		 **TECHNICAL BACK**		 **TECHNICAL BACK**

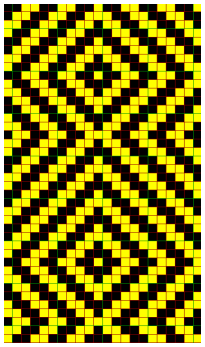
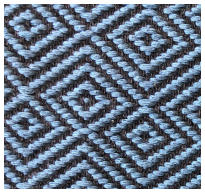
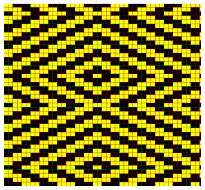
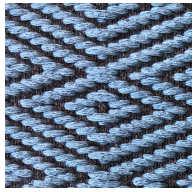
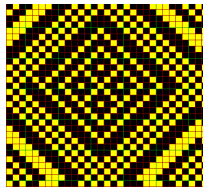
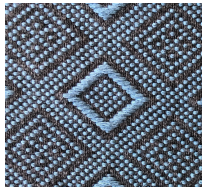
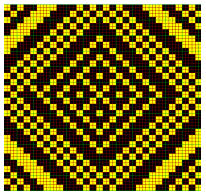
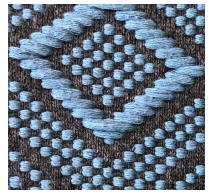
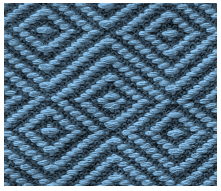
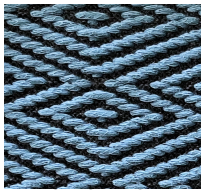
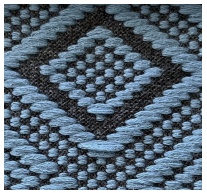
SURFACE MOVEMENT	FLAT SURFACE PLANE. NO FOLDING. NO VISIBLE MOVEMENT THE INLAY IS DOMINANT IN THE KNIT. STABLE WITH REDUCED STRETCH X & Y AXIS. LONGER FLOATS IN 200% ALLOW SLIGHTLY MORE STRETCH. TECHNICAL BACK IS THE PATTERN INVERSE. TECHNICAL BACK OF REGULAR TWILL 1 & 2 MIRROR ON Y AXIS.
FORCES EVIDENT	FORCES ARE BALANCED. SYMMETRICAL SURFACE. THE INLAY IS DOMINANT.

DESCRIPTION	**SINGLE JERSEY KNITTED BASE WITH INLAY**
DATE KNITTED	11.10.19
GROUND YARN	WOOLYARNS
COMPOSITION	WOOL / ACRYLIC
COUNT	2/36
NUMBER OF ENDS	1
CARRIER	13
INLAY YARN	KISS
COMPOSITION	COTTON with NYLON CORE
COUNT	1/16
NUMBER OF ENDS	1
CARRIER	14
MACHINE	SRY123 LPSV 14G
HEAT METHOD	STEAM
ISSUES	NO ISSUES YARN RUNS WELL

REGULAR TWILL 3		**DORNICK TWILL 100%**		**DORNICK TWILL 200%**		**PLAIN DICED 1**	
INLAY CODE REPEAT UNIT	**SWATCH**	**INLAY CODE REPEAT UNIT**	**SWATCH**	**INLAY CODE REPEAT UNIT**	**SWATCH**	**INLAY CODE REPEAT UNIT**	**SWATCH**
	 **TECHNICAL FRONT**		 **TECHNICAL FRONT**		 **TECHNICAL FRONT**		 **TECHNICAL FRONT**
	 **TECHNICAL BACK**						 **TECHNICAL BACK**

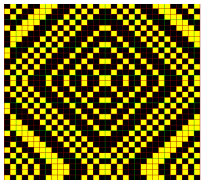
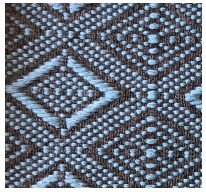
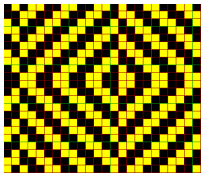
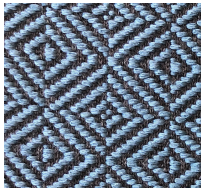
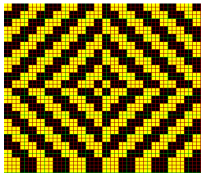
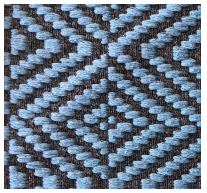
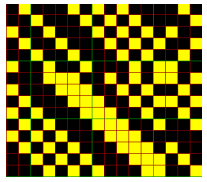
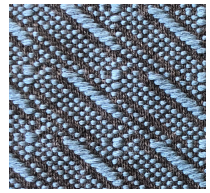
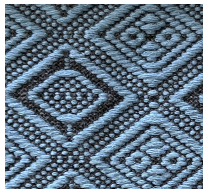
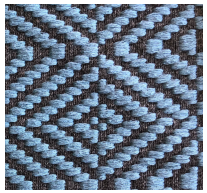
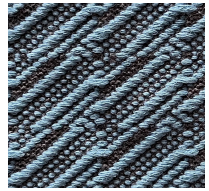
SURFACE MOVEMENT	FLAT SURFACE PLANE. NO FOLDING. NO VISIBLE MOVEMENT THE INLAY IS DOMINANT IN THE KNIT. STABLE WITH REDUCED STRETCH X & Y AXIS. LONGER FLOATS IN 200% ALLOW SLIGHTLY MORE STRETCH. TECHNICAL BACK IS THE PATTERN INVERSE. TWILL IN TECHNICAL BACK OF REGULAR TWILL 3 MIRRORS ON Y AXIS.
FORCES EVIDENT	FORCES ARE BALANCED. SYMMETRICAL SURFACE. THE INLAY IS DOMINANT.

DESCRIPTION	**SINGLE JERSEY KNITTED BASE WITH INLAY**
DATE KNITTED	11.10.19
GROUND YARN	WOOLYARNS
COMPOSITION	WOOL / ACRYLIC
COUNT	2/36
NUMBER OF ENDS	1
CARRIER	13
INLAY YARN	KISS
COMPOSITION	COTTON with NYLON CORE
COUNT	1/16
NUMBER OF ENDS	1
CARRIER	14
MACHINE	SRY123 LPSV 14G
HEAT METHOD	STEAM
ISSUES	NO ISSUES YARN RUNS WELL

DIAMOND TWILL 1		**DIAMOND TWILL 1 200% in X axis only**		**DIAMOND TWILL 2**		**DIAMOND TWILL 2 200%**	
INLAY CODE REPEAT UNIT	**SWATCH**	**INLAY CODE REPEAT UNIT**	**SWATCH**	**INLAY CODE REPEAT UNIT**	**SWATCH**	**INLAY CODE REPEAT UNIT**	**SWATCH**
	 **TECHNICAL FRONT**		 **TECHNICAL FRONT**		 **TECHNICAL FRONT**		 **TECHNICAL FRONT**
	 **TECHNICAL BACK**				 **TECHNICAL BACK**		 **TECHNICAL BACK**

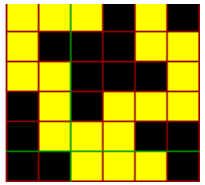
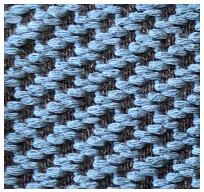
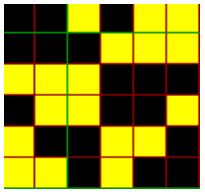
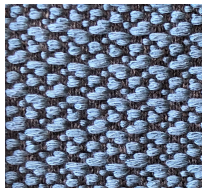
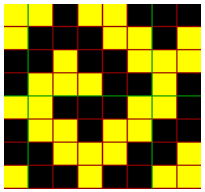
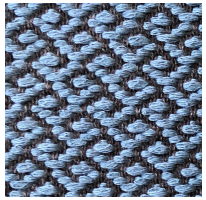
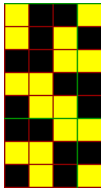
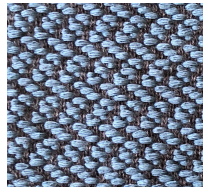
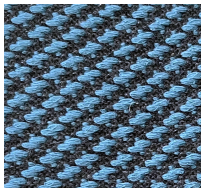
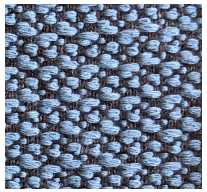
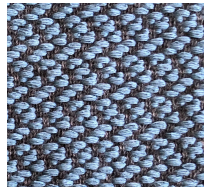
SURFACE MOVEMENT	FLAT SURFACE PLANE. NO FOLDING. NO VISIBLE MOVEMENT THE INLAY IS DOMINANT IN THE KNIT. STABLE WITH REDUCED STRETCH X & Y AXIS. LONGER FLOATS IN 200% ALLOW SLIGHTLY MORE STRETCH. TECHNICAL BACK IS THE PATTERN INVERSE.
FORCES EVIDENT	FORCES ARE BALANCED. SYMMETRICAL SURFACE. THE INLAY IS DOMINANT.

DESCRIPTION	**SINGLE JERSEY KNITTED BASE WITH INLAY**
DATE KNITTED	11.10.19
GROUND YARN	WOOLYARNS
COMPOSITION	WOOL / ACRYLIC
COUNT	2/36
NUMBER OF ENDS	1
CARRIER	13
INLAY YARN	KISS
COMPOSITION	COTTON with NYLON CORE
COUNT	1/16
NUMBER OF ENDS	1
CARRIER	14
MACHINE	SRY123 LPSV 14G
HEAT METHOD	STEAM
ISSUES	NO ISSUES YARN RUNS WELL

DIAMOND TWILL 3		**CRYSTAL TWILL 1**		**CRYSTAL TWILL 1 200%**		**IRREGULAR TWILL 1**	
INLAY CODE REPEAT UNIT	**SWATCH**	**INLAY CODE REPEAT UNIT**	**SWATCH**	**INLAY CODE REPEAT UNIT**	**SWATCH**	**INLAY CODE REPEAT UNIT**	**SWATCH**
							
TECHNICAL FRONT		**TECHNICAL FRONT**		**TECHNICAL FRONT**		**TECHNICAL FRONT**	
							
TECHNICAL BACK		**TECHNICAL BACK**		**TECHNICAL BACK**		**TECHNICAL BACK**	

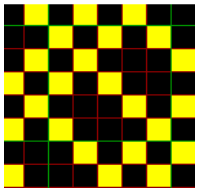
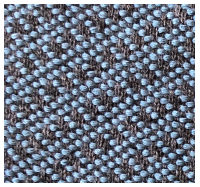
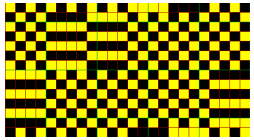
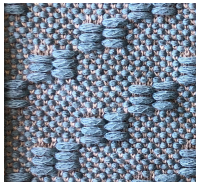
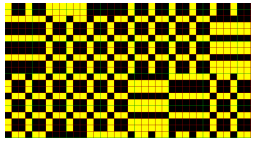
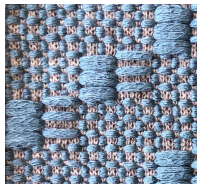
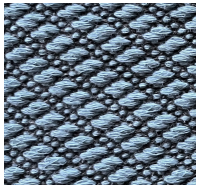
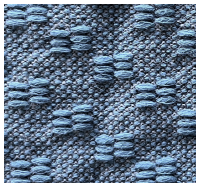
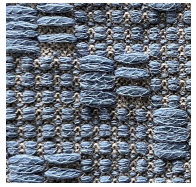
SURFACE MOVEMENT	FLAT SURFACE PLANE. NO FOLDING. NO VISIBLE MOVEMENT THE INLAY IS DOMINANT IN THE KNIT. STABLE WITH REDUCED STRETCH X & Y AXIS. LONGER FLOATS IN 200% ALLOW SLIGHTLY MORE STRETCH. ANGLE OF TWILL IN TECHNICAL BACK OF IIREGULAR TWILL MIRRORS ON Y AXIS.
FORCES EVIDENT	FORCES ARE BALANCED. SYMMETRICAL SURFACE. THE INLAY IS DOMINANT. TECHNICAL BACK IS THE PATTERN INVERSE.

DESCRIPTION	**SINGLE JERSEY KNITTED BASE WITH INLAY**
DATE KNITTED	11.10.19
GROUND YARN	WOOLYARNS
COMPOSITION	WOOL / ACRYLIC
COUNT	2/36
NUMBER OF ENDS	1
CARRIER	13
INLAY YARN	KISS
COMPOSITION	COTTON with NYLON CORE
COUNT	1/16
NUMBER OF ENDS	1
CARRIER	14
MACHINE	SRY123 LPSV 14G
HEAT METHOD	STEAM
ISSUES	NO ISSUES YARN RUNS WELL

PLAIN CREPE 1		**PLAIN CREPE 2**		**PLAIN CREPE 3**		**PLAIN CREPE 4**	
INLAY CODE REPEAT UNIT	**SWATCH**	**INLAY CODE REPEAT UNIT**	**SWATCH**	**INLAY CODE REPEAT UNIT**	**SWATCH**	**INLAY CODE REPEAT UNIT**	**SWATCH**
	 **TECHNICAL FRONT**		 **TECHNICAL FRONT**		 **TECHNICAL FRONT**		 **TECHNICAL FRONT**
	 **TECHNICAL BACK**		 **TECHNICAL BACK**		 **TECHNICAL BACK**		 **TECHNICAL BACK**

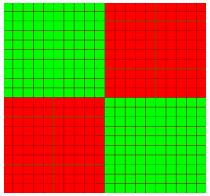
SURFACE MOVEMENT	FLAT SURFACE PLANE. NO FOLDING. NO VISIBLE MOVEMENT THE INLAY IS DOMINANT IN THE KNIT. STABLE WITH REDUCED STRETCH X & Y AXIS. TECHNICAL BACK IS THE PATTERN INVERSE.
FORCES EVIDENT	FORCES ARE BALANCED. SYMMETRICAL SURFACE. THE INLAY IS DOMINANT.

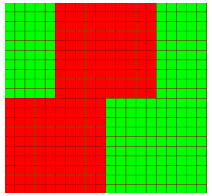
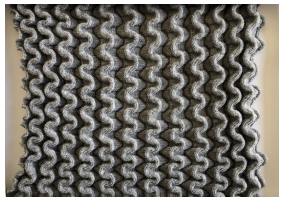
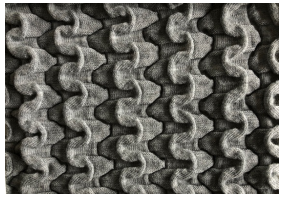
DESCRIPTION	**SINGLE JERSEY KNITTED BASE WITH INLAY**
DATE KNITTED	11.10.19
GROUND YARN	WOOLYARNS
COMPOSITION	WOOL / ACRYLIC
COUNT	2/36
NUMBER OF ENDS	1
CARRIER	13
INLAY YARN	KISS
COMPOSITION	COTTON with NYLON CORE
COUNT	1/16
NUMBER OF ENDS	1
CARRIER	14
MACHINE	SRY123 LPSV 14G
HEAT METHOD	STEAM
ISSUES	NO ISSUES YARN RUNS WELL

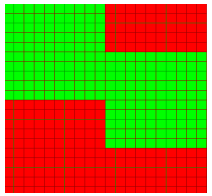
PLAIN CREPE 5		**PLAIN GRID 1**		**PLAIN GRID 2**			
INLAY CODE REPEAT UNIT	**SWATCH**	**INLAY CODE REPEAT UNIT**	**SWATCH**	**INLAY CODE REPEAT UNIT**	**SWATCH**	**INLAY CODE REPEAT UNIT**	**SWATCH**
	 **TECHNICAL FRONT**		 **TECHNICAL FRONT**		 **TECHNICAL FRONT**		**TECHNICAL FRONT**
	 **TECHNICAL BACK**		 **TECHNICAL BACK**		 **TECHNICAL BACK**		**TECHNICAL BACK**

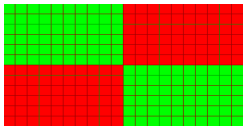
SURFACE MOVEMENT	FLAT SURFACE PLANE. NO FOLDING. NO VISIBLE MOVEMENT THE INLAY IS DOMINANT IN THE KNIT. STABLE WITH REDUCED STRETCH X & Y AXIS. LONGER FLOATS IN 200% ALLOW SLIGHTLY MORE STRETCH. ALL TWILL ANGLES ARE MIRRORED IN Y AXIS. PLAIN CREPE 5 IS THE ONLY TECHNICAL BACK WITH SIGNIFICANT CHANGE DUE TO LONG FLOATS BETWWEN ANGLED SINGLE POINTS OF INLAY. TECHNICAL BACK IS THE PATTERN INVERSE.
FORCES EVIDENT	FORCES ARE BALANCED. SYMMETRICAL SURFACE. THE INLAY IS DOMINANT.

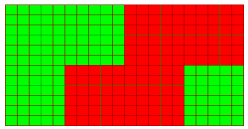
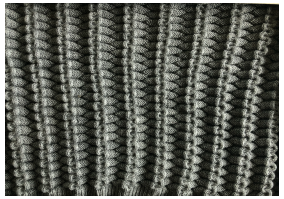
APPENDIX D.
Links-Links Pattern Surface-building Block Library

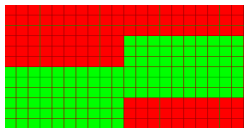
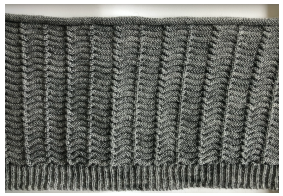
DESCRIPTION	**SQUARE BLOCK REPEAT**				
DATE KNITTED	21.9.19				
YARN COMPANY	WOOLYARNS				
COMPOSITION	WOOL / ACRYLIC				
COUNT	2/36				
NUMBER OF ENDS	1				
CARRIER	13				
NEEDLES x COURSES	252 x 282				
MACHINE	SRY123 LPSV 14G				
HEAT METHOD	STEAMED				
REASON FOR KNITTING	TO EXPLORE THE COMBINATION OF KNIT & PURL IN A SQUARE ARRANGEMENT WITH A BLOCK REPEATING PATTERN TO SEE HOW THE KNIT REACTS / FOLDS.				
ANALYSIS OF HANDLE / STITCH QUALITY	SLIGHTLY LOOSE KNITTING NEED TO TIGHTEN UP STITCH QUALITY. STEAM THEREFORE RELAXATION OF YARN, LOSES SOME DEFINITION OF SURFACE TACTILITY				
ISSUES	NO ISSUES YARN RUNS WELL				
CODE REPEAT UNIT 100% SCALE	**SQUARE BLOCK 100%**	**SQUARE BLOCK 200%**	**SQUARE BLOCK 300%**	**SQUARE BLOCK 400%**	**SQUARE BLOCK 500%**
	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK
SURFACE MOVEMENT	SLIGHTLY LOOSE KNITTING NEED TO TIGHTEN UP STITCH QUALITY. SLIGHTLY RAISED SURFACE. MULTI DIRECTIONAL MOVEMENT.				GOOD QUALITY AND HANDLE, LESS SURFACE MOVEMENT DUE TO MORE STABLE AREAS AND FEWER CHANGES OF STITCH STRUCTURE
FORCES EVIDENT	CONVERGENT FORCES IN MULTIPLE DIRECTIONS CAUSING SURFACE MOVEMENTS UP (CRESTS) AND DOWN (TROUGHS). TORSIONS ARE OCCURING ON DIAGONAL SIDES OF THE SQUARES THIS IS FORCING THE FABRIC UP AND DOWN.TOWARDS THE CENTRE OF THE PANEL THE COMPRESSIONAL FORCES FROM THE LEFT AND RIGHT COLLIDE		CONVERGENT FORCES IN MULTIPLE DIRECTIONS HOWEVER LESS MOVEMENT THAN SMALLER SCALES SAMPLES NOT AS INTERESTING VISUALLY DUE TO THE INCREASED STABLE AREAS OF KNITTING THE OPPOSING FORCES HAVE REDUCED AND THE SURFACE IS NOT AS TEXTURAL A		

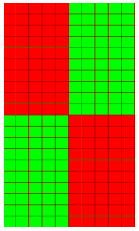
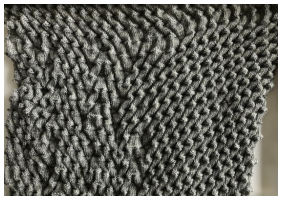
DESCRIPTION	**SQUARE BRICK REPEAT**				
DATE KNITTED	21.9.19				
YARN COMPANY	WOOLYARNS				
COMPOSITION	WOOL / ACRYLIC				
COUNT	2/36				
NUMBER OF ENDS	1				
CARRIER	13				
NEEDLES x COURSES	252 x 282				
MACHINE	SRY123 LPSV 14G				
HEAT METHOD	STEAMED				
REASON FOR KNITTING	TO EXPLORE THE COMBINATION OF KNIT & PURL IN A SQUARE ARRANGEMENT WITH A BRICK REPEATING PATTERN TO SEE HOW THE KNIT REACTS / FOLDS.				
ANALYSIS OF HANDLE / STITCH QUALITY	GOOD STITCH QUALITY AND HANDE. STEAM THEREFORE RELAXATION OF YARN, LOSES SOME DEFINITION OF SURFACE TACTILITY				
ISSUES	NO ISSUES YARN RUNS WELL				
CODE REPEAT UNIT 100% SCALE	**SQUARE BRICK 100%**	**SQUARE BRICK 200%**	**SQUARE BRICK 300%**	**SQUARE BRICK 400%**	**SQUARE BRICK 500%**
	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK
SURFACE MOVEMENT	CLEARLY DEFINED ANTICLINES AND SYNCLINES AND A TIGHT FOLDED VERTICAL WAVE EFFECT.	THE FOLDED CRESTS HAVE MOVED FURTHER APART AND SIT FLATTER, BROADER FOLDS. THERE ARE VARYING LEVELS OF RAISED AREAS CREATED BY THE STAGGERED PURL STRUCTURES BETWEEN THE VERTICAL WAVES OF KNIT STITCHES.			
FORCES EVIDENT	HORIZONTAL CONVERGENT FORCES CREATE 'S" VERTICAL WAVES FROM RAISED PURL STITCHES.				

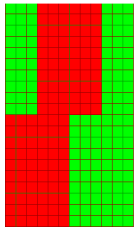
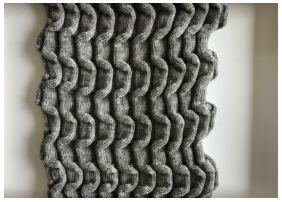
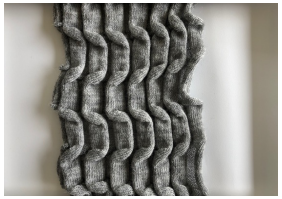
DESCRIPTION	**SQUARE HALF-DROP REPEAT**				
DATE KNITTED	21.9.19				
YARN COMPANY	WOOLYARNS				
COMPOSITION	WOOL / ACRYLIC				
COUNT	2/36				
NUMBER OF ENDS	1				
CARRIER	13				
NEEDLES x COURSES	252 x 282				
MACHINE	SRY123 LPSV 14G				
HEAT METHOD	STEAMED				
REASON FOR KNITTING	TO EXPLORE THE COMBINATION OF KNIT & PURL IN A SQUARE ARRANGEMENT WITH A HALF DROP REPEATING PATTERN TO SEE HOW THE KNIT REACTS / FOLDS.				
ANALYSIS OF HANDLE / STITCH QUALITY	GOOD STITCH QUALITY AND HANDE. STEAM THEREFORE RELAXATION OF YARN, LOSES SOME DEFINITION OF SURFACE TACTILITY				
ISSUES	NO ISSUES YARN RUNS WELL				
CODE REPEAT UNIT 100% SCALE	**SQUARE HALF DROP 100%**	**SQUARE HALF DROP 200%**	**SQUARE HALF DROP 300%**	**SQUARE HALF DROP 400%**	**SQUARE HALF DROP 500%**
	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK
SURFACE MOVEMENT	d	THE FOLDED PURL CRESTS MOVE FURTHER APART AND SIT FLATTER, BROADER FOLDS. STILL SYMMETRICAL APPEARANCE WITH TWISTED EFFECT ON THE HORIZONTAL WAVE SECTIONAL EDGES			
FORCES EVIDENT	VERTICAL CONVERGENT FORCES ARE CAUSING THE FABRIC TO FOLD A HORIZONTAL WAVE OF PURL STITCHES				

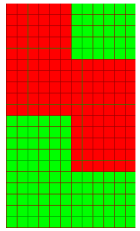
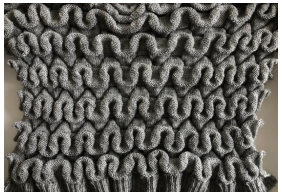
DESCRIPTION	**HORIZONTAL RECTANGLE BLOCK REPEAT**				
DATE KNITTED	30.10.19				
YARN COMPANY	WOOLYARNS				
COMPOSITION	WOOL / ACRYLIC				
COUNT	2/36				
NUMBER OF ENDS	1				
CARRIER	13				
NEEDLES x COURSES	252 x 282				
MACHINE	SRY123 LPSV 14G				
HEAT METHOD	UNSTEAMED				
REASON FOR KNITTING	TO EXPLORE THE COMBINATION OF KNIT & PURL IN A RECTANGLE ARRANGEMENT WITH A BLOCK REPEATING PATTERN TO SEE HOW THE KNIT REACTS / FOLDS.				
ANALYSIS OF HANDLE / STITCH QUALITY	GOOD STITCH QUALITY AND HANDE. HANDLE IS CRISP AND CRUNCHY WITH THE STITCH DEFINITION CLEAR AND SHARP DUE TO NO STEAM THEREFORE NO RELAXATION OF YARN				
ISSUES	NO ISSUES YARN RUNS WELL				
CODE REPEAT UNIT 100% SCALE	**HORIZONTAL REC BLOCK 100%**	**HORIZONTAL REC BLOCK 200%**	**HORIZONTAL REC BLOCK 300%**	**HORIZONTAL REC BLOCK 400%**	**HORIZONTAL REC BLOCK 500%**
	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK
SURFACE MOVEMENT	SLIGHTLY RAISED TEXTURAL SURFACE. TIGHT FOLDS AND SMALL TWISTS. SCALE IS TOO SMALL, VISUALLY 'MESSY'. TECHNICAL BACK IS SAME BUT ANGLE DIRECTION FLIPS.	RAISED TEXTURAL SURFACE GENERATED THROUGH FOLDS AND TWISTS. BROAD FOLDS WITH TORSIONS / TWISTS OCCURING ON DIAGONAL SIDES OF THE RECTANGLES THIS IS FORCING THE FABRIC INTO CRESTS AND TROUGHS. MULTI DIRECTIONAL SURFACE MOVEMENTS. TECHNICAL BACK IS SAME BUT ANGLED DIRECTION FLIPS.			
FORCES EVIDENT	VERTICAL CONVERGENT FORCES CAUSING TIGHT SHORT FOLDS SHIFTING INTO SLIGHTLY BROADER FOLDS AS THE SCALE INCREASES. THE COMPRESSIONAL FORCES ARE UNBALANCED.				

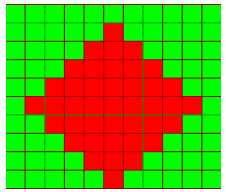
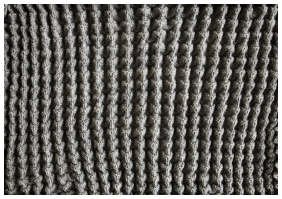
DESCRIPTION	**HORIZONTAL RECTANGLE BRICK REPEAT**				
DATE KNITTED	30.10.19				
YARN COMPANY	WOOLYARNS				
COMPOSITION	WOOL / ACRYLIC				
COUNT	2/36				
NUMBER OF ENDS	1				
CARRIER	13				
NEEDLES x COURSES	252 x 282				
MACHINE	SRY123 LPSV 14G				
HEAT METHOD	UNSTEAMED				
REASON FOR KNITTING	TO EXPLORE THE COMBINATION OF KNIT & PURL IN A RECTANGLE ARRANGEMENT WITH A BRICK REPEATING PATTERN TO SEE HOW THE KNIT REACTS / FOLDS.				
ANALYSIS OF HANDLE / STITCH QUALITY	GOOD STITCH QUALITY AND HANDE. HANDLE IS CRISP AND CRUNCHY WITH THE STITCH DEFINITION CLEAR AND SHARP DUE TO NO STEAM THEREFORE NO RELAXATION OF YARN				
ISSUES	NO ISSUES YARN RUNS WELL				
CODE REPEAT UNIT 100% SCALE	**HORIZONTAL REC BRICK 100%**	**HORIZONTAL REC BRICK 200%**	**HORIZONTAL REC BRICK 300%**	**HORIZONTAL REC BRICK 400%**	**HORIZONTAL REC BRICK 500%**
	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK
SURFACE MOVEMENT	SLIGHTLY RAISED TEXTURAL SURFACE. MULTI DIRECTIONAL MOVEMENT. SCALE IS TOO SMALL, VISUALLY 'MESSY'.	SLIGHTLY RAISED TEXTURAL SURFACE. MULTI DIRECTIONAL MOVEMENT. FABRIC HAS A DEFINITE DISTORTED SLANT ON SURFACE FACE. HEM VISIBLY DISTORTED ASYMMETRICALLY. THE COMPRESSIONAL FORCES ARE UNBALANCED CREATING UNEVEN SURAFCE MOVEMENTS. THE TWISTS GENERATED HAVE AN APPEALING TACTILITY AND THE FOLDS HIDE MORE FABRIC			
FORCES EVIDENT	CONVERGENT FORCES CAUSING TIGHT SHORT FOLDS.	CONVERGENT FORCES. TORSIONS / TWISTS ARE OCCURING ON DIAGONAL SIDES OF THE RECTANGLES THIS IS FORCING THE FABRIC UP AND DOWN IN FOLDS.			

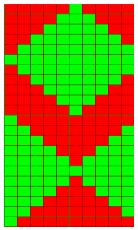
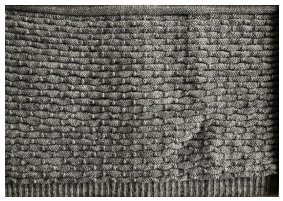
DESCRIPTION	**HORIZONTAL RECTANGLE HALF DROP REPEAT**				
DATE KNITTED	30.10.19				
YARN COMPANY	WOOLYARNS				
COMPOSITION	WOOL / ACRYLIC				
COUNT	2/36				
NUMBER OF ENDS	1				
CARRIER	13				
NEEDLES x COURSES	252 x 282				
MACHINE	SRY123 LPSV 14G				
HEAT METHOD	UNSTEAMED				
REASON FOR KNITTING	TO EXPLORE THE COMBINATION OF KNIT & PURL IN A RECTANGLE ARRANGEMENT WITH A HALF DROP REPEATING PATTERN TO SEE HOW THE KNIT REACTS / FOLDS.				
ANALYSIS OF HANDLE / STITCH QUALITY	GOOD STITCH QUALITY AND HANDE. HANDLE IS CRISP AND CRUNCHY WITH THE STITCH DEFINITION CLEAR AND SHARP DUE TO NO STEAM THEREFORE NO RELAXATION OF YARN				
ISSUES	NO ISSUES YARN RUNS WELL				
CODE REPEAT UNIT 100% SCALE	**HORIZONTAL REC HALF DROP 100%**	**HORIZONTAL REC HALF DROP 200%**	**HORIZONTAL REC HALF DROP 300%**	**HORIZONTAL REC HALF DROP 400%**	**HORIZONTAL REC HALF DROP 500%**
	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK
SURFACE MOVEMENT	SCALE IS TOO SMALL, VERY TIGHT SMALL FOLDS AND TWISTS. THESE TWISTS ARE ALIGNING VERTICALLY. TEXTURALLY FLATTENED SURFACE	SLIGHTLY RAISED TEXTURAL SURFACE. TWISTS ARE ALIGNING VERTICALLY WITH SLIGHT ANGLE.	RAISED TEXTURAL SURFACE. BROADER FOLDS AND LARGER TWISTS. TWISTS ARE LINEAR ALIGNING VERTICALLY WITH SLIGHT ANGLE.		
FORCES EVIDENT	VERTICAL CONVERGENT FORCES ARE INCREASING THE FABRIC WIDTH AND REDUCING THE LENGTH				

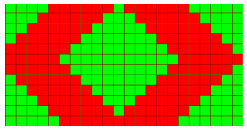
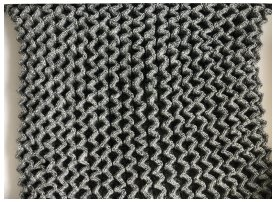
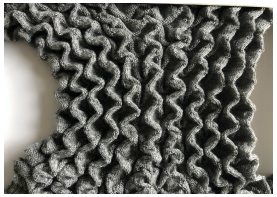
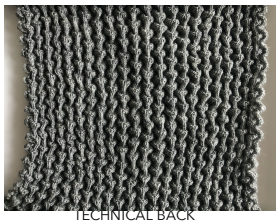
DESCRIPTION	**VERTICAL RECTANGLE BLOCK REPEAT**				
DATE KNITTED	21.10.19				
YARN COMPANY	WOOLYARNS				
COMPOSITION	WOOL / ACRYLIC				
COUNT	2/36				
NUMBER OF ENDS	1				
CARRIER	13				
NEEDLES x COURSES	252 x 282				
MACHINE	SRY123 LPSV 14G				
HEAT METHOD	UNSTEAMED				
REASON FOR KNITTING	TO EXPLORE THE COMBINATION OF KNIT & PURL IN A RECTANGLE ARRANGEMENT WITH A BLOCK REPEATING PATTERN TO SEE HOW THE KNIT REACTS / FOLDS.				
ANALYSIS OF HANDLE / STITCH QUALITY	GOOD STITCH QUALITY AND HANDE. HANDLE IS CRISP AND CRUNCHY WITH THE STITCH DEFINITION CLEAR AND SHARP DUE TO NO STEAM THEREFORE NO RELAXATION OF YARN				
ISSUES	NO ISSUES YARN RUNS WELL				
CODE REPEAT UNIT FOR 100%	**VERTICAL REC BLOCK 100%**	**VERTICAL REC BLOCK 200%**	**VERTICAL REC BLOCK 300%**	**VERTICAL REC BLOCK 400%**	**VERTICAL REC BLOCK 500%**
	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK
SURFACE MOVEMENT	SLIGHTLY RAISED TEXTURAL SURFACE. MULTI DIRECTIONAL MOVEMENT. 100% SCALE IS TOO SMALL, VISUALLY 'MESSY'. SMALL TORSIONS GENERATED BY POINT OF STITCH STRUCTURE CHANGE.		RAISED TEXTURAL SURFACE. TORSIONS GENERATED BY POINT OF STITCH STRUCTURE CHANGE.MULTI DIRECTIONAL MOVEMENT. HEM VISIBLY DISTORTED ASYMMETRICALLY	RAISED TEXTURAL SURFACE. TORSIONS GENERATED BY POINT OF STITCH STRUCTURE CHANGE. MULTI DIRECTIONAL MOVEMENT. FABRIC HAS A DEFINITE SLANT ON SURFACE FACE. TECHNICAL BACK IS SAME BUT ANGLE DIRECTION FLIPS.	
FORCES EVIDENT	CONVERGENT FORCES IN MULTIPLE DIRECTIONS. THE COMPRESSIONAL FORCES ARE UNBALANCED FROM LEFT AND RIGHT SIDES				

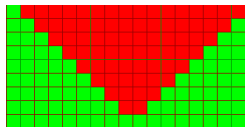
DESCRIPTION	**VERTICAL RECTANGLE BRICK REPEAT**				
DATE KNITTED	21.10.19				
YARN COMPANY	WOOLYARNS				
COMPOSITION	WOOL / ACRYLIC				
COUNT	2/36				
NUMBER OF ENDS	1				
CARRIER	13				
NEEDLES x COURSES	252 x 282				
MACHINE	SRY123 LPSV 14G				
HEAT METHOD	UNSTEAMED				
REASON FOR KNITTING	TO EXPLORE THE COMBINATION OF KNIT & PURL IN A RECTANGLE ARRANGEMENT WITH A BRICK REPEATING PATTERN TO SEE HOW THE KNIT REACTS / FOLDS.				
ANALYSIS OF HANDLE / STITCH QUALITY	GOOD STITCH QUALITY AND HANDE. HANDLE IS CRISP AND CRUNCHY WITH THE STITCH DEFINITION CLEAR AND SHARP DUE TO NO STEAM THEREFORE NO RELAXATION OF YARN				
ISSUES	NO ISSUES YARN RUNS WELL				
CODE REPEAT UNIT 100% SCALE	**VERTICAL REC BRICK 100%**	**VERTICAL REC BRICK 200%**	**VERTICAL REC BRICK 300%**	**VERTICAL REC BRICK 400%**	**VERTICAL REC BRICK 500%**
	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK
SURFACE MOVEMENT	VERY TEXTURAL APPEARANCE. TIGHT FOLDS. FLATTENED SURFACE DUE TO THE CLOSE SET PURL RIDGES. THE SURFACE SECTIONS CONCERTINA TOGETHER.	SLIGHTLY RAISED TEXTURAL SURFACE. MOSTLY BALANCED FOLDED MOVEMENT. FOLDS BECOME BROAD IN 500% SCALE. THE WIDTH OF THE KNIT SIGNIFICANTLY REDUCES AS THE LENGTH ELONGATES. HORIZONTAL CONVERGENT FORCES RESULT IN TIGHTLY FOLDED RIDGES OF PURL TEXTURED SURFACE AND ALTERNATIVELY FLIPPED KNIT SECTIONS. THE SURFACE SECTIONS CONCERTINA TOGETHER. TECHNICAL BACK IS SAME BUT ANGLE DIRECTION OF PURL RIDGE FLIPS.			
FORCES EVIDENT	COMPRESSIONAL MOVEMENT IN THE HORIZONTAL DIRECTION IS CAUSING EVEN VERTICAL LINEAR VISUAL EFFECT.				

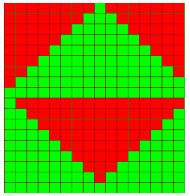
DESCRIPTION	**VERTICAL RECTANGLE HALF DROP REPEAT**				
DATE KNITTED	21.10.19				
YARN COMPANY	WOOLYARNS				
COMPOSITION	WOOL / ACRYLIC				
COUNT	2/36				
NUMBER OF ENDS	1				
CARRIER	13				
NEEDLES x COURSES	252 x 282				
MACHINE	SRY123 LPSV 14G				
HEAT METHOD	UNSTEAMED				
REASON FOR KNITTING	TO EXPLORE THE COMBINATION OF KNIT & PURL IN A RECTANGLE ARRANGEMENT WITH A HALF DROP REPEATING PATTERN TO SEE HOW THE KNIT REACTS / FOLDS.				
ANALYSIS OF HANDLE / STITCH QUALITY	GOOD STITCH QUALITY AND HANDE. HANDLE IS CRISP AND CRUNCHY WITH THE STITCH DEFINITION CLEAR AND SHARP DUE TO NO STEAM THEREFORE NO RELAXATION OF YARN				
ISSUES	NO ISSUES YARN RUNS WELL				
CODE REPEAT UNIT 100% SCALE	**VERTICAL REC HALF DROP 100%**	**VERTICAL REC HALF DROP 200%**	**VERTICAL REC HALF DROP 300%**	**VERTICAL REC HALF DROP 400%**	**VERTICAL REC HALF DROP 500%**
	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK
SURFACE MOVEMENT	CLEARLY DEFINED ANTICLINES AND SYNCLINES AND A TIGHT FOLDED HORIZONTAL PURL WAVE EFFECT. THE FOLDS FLIP FACING DOWN OR UP THE FABRIC DEPENDING ON IF SWITCHING STITCH STRUCTURE FROM KNIT TO PURL OR PURL TO KNIT	ANTICLINES AND SYNCLINES AND A FOLDED WAVE EFFECT. INCREASED SCALE CAUSES THE FOLDED CRESTS TO MOVE APART AND SIT FLATTER, IN BROADER FOLDS. TWISTED EFFECT ON THE WAVE SIDE EDGES. SURFACE IS MORE OPEN DUE TO THE INCREASED KNIT AND PURL STABLE AREAS			
FORCES EVIDENT	VERTICAL CONVERGENT FORCES ARE FORCING THE FABRIC TO FOLD ALONG THE STAGGERED LINES OF KNIT CREATING A HORIZONTAL WAVE OF PURL STITCHES, A 3D CRESTED SURFACE				

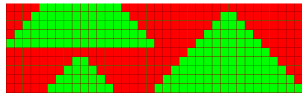
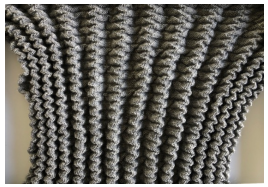
DESCRIPTION	**DIAMOND BLOCK REPEAT**				
DATE KNITTED	21.10.19				
YARN COMPANY	WOOLYARNS				
COMPOSITION	WOOL / ACRYLIC				
COUNT	2/36				
NUMBER OF ENDS	1				
CARRIER	13				
NEEDLES x COURSES	252 x 282				
MACHINE	SRY123 LPSV 14G				
HEAT METHOD	UNSTEAMED				
REASON FOR KNITTING	TO EXPLORE THE COMBINATION OF KNIT & PURL IN A VERTICAL DIAMOND (LONGER LENGTH THAN WIDTH) BLOCK REPEAT ARANGEMENT TO SEE HOW THE KNIT REACTS / FOLDS				
ANALYSIS OF HANDLE / STITCH QUALITY	GOOD STITCH QUALITY AND HANDE. HANDLE IS CRISP AND CRUNCHY WITH THE STITCH DEFINITION CLEAR AND SHARP DUE TO NO STEAM THEREFORE NO RELAXATION OF YARN				
ISSUES	NO ISSUES YARN RUNS WELL				
CODE REPEAT UNIT 100% SCALE	**DIAMOND BLOCK 100%**	**DIAMOND BLOCK 200%**	**DIAMOND BLOCK 300%**	**DIAMOND BLOCK 400%**	**DIAMOND BLOCK 500%**
	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK	 TECHNICAL FRONT & BACK
SURFACE MOVEMENT	A CRIMPED APPEARANCE. MOVEMENT IN THE VERTICAL AND HORIZONTAL DIRECTIONS. SIMILAR TO TRIANGLE BLOCK 100 EXCEPT A BIT LESS COMPRESSED. THIS SAMPLE IS A BIT 'MESSY' VISUALLY.		MORE OPEN STRUCTURAL APPEARANCE. REDUCED SURFACE MOVEMENTTHAT IS IRREGULAR. THIS SAMPLE IS TOO FLAT TO GENERATE THE SURFACE MOVEMENT THE PROJECT REQUIRES		
FORCES EVIDENT	CONVERGENT FORCES IN HORIZONTAL DIRECTION. THE COMPRESSIONAL FORCES ARE REDUCED AND MORE UNBALANCED IN LARGER SCALES				

DESCRIPTION	**DIAMOND BRICK REPEAT**				
DATE KNITTED	21.10.19				
YARN COMPANY	WOOLYARNS				
COMPOSITION	WOOL / ACRYLIC				
COUNT	2/36				
NUMBER OF ENDS	1				
CARRIER	13				
NEEDLES x COURSES	252 x 282				
MACHINE	SRY123 LPSV 14G				
HEAT METHOD	UNSTEAMED				
REASON FOR KNITTING	TO EXPLORE THE COMBINATION OF KNIT & PURL IN A VERTICAL DIAMOND (LONGER LENGTH THAN WIDTH) BRICK REPEAT ARANGEMENT TO SEE HOW THE KNIT REACTS / FOLDS				
ANALYSIS OF HANDLE / STITCH QUALITY	GOOD STITCH QUALITY AND HANDE. HANDLE IS CRISP AND CRUNCHY WITH THE STITCH DEFINITION CLEAR AND SHARP DUE TO NO STEAM THEREFORE NO RELAXATION OF YARN				
ISSUES	NO ISSUES YARN RUNS WELL				
CODE REPEAT UNIT 100% SCALE	**DIAMOND BRICK 100%**	**DIAMOND BRICK 200%**	**DIAMOND BRICK 300%**	**DIAMOND BRICK 400%**	**DIAMOND BRICK 500%**
	 TECHNICAL FRONT	 TECHNICAL FRONT	 TECHNICAL FRONT	 TECHNICAL FRONT	 TECHNICAL FRONT
	 TECHNICAL BACK	 TECHNICAL BACK	 TECHNICAL BACK	 TECHNICAL BACK	 TECHNICAL BACK
SURFACE MOVEMENT	MORE CONVERGENT FORCES THAN DIAMOND BRICK 100 IN VERTICAL DIRECTIONS CAUSING REGULAR SURFACE MOVEMENT WITH GENERATION OF FOLDS ON A HORIZONTAL PLANE. THESE FOLDS ARE A TIGHT CONCERTINA WITH GOOD ELASTICITY, HOLD AND RECOVERY BUT NOT MUCH TACTILITY		THIS SAMPLE IS FAIRLY FLAT SURFACE APPEARANCE WITH PUCKERED MOVEMENT. IT HAS FEWER CONVERGENT FORCES DUE TO THE LARGER AREAS / RATIOS OF THE SAME KNIT STRUCTURE AND THEREFORE REDUCED OPPOSING FORCE AREAS.		
FORCES EVIDENT	CONVERGENT FORCES IN VERTICAL DIRECTION. THE COMPRESSIONAL FORCES ARE REDUCED AND MORE UNBALANCED IN LARGER SCALES				

DESCRIPTION	**DIAMOND HALF-DROP REPEAT**				
DATE KNITTED	21.10.19				
YARN COMPANY	WOOLYARNS				
COMPOSITION	WOOL / ACRYLIC				
COUNT	2/36				
NUMBER OF ENDS	1				
CARRIER	13				
NEEDLES x COURSES	252 x 282				
MACHINE	SRY123 LPSV 14G				
HEAT METHOD	UNSTEAMED				
REASON FOR KNITTING	TO EXPLORE THE COMBINATION OF KNIT & PURL IN A VERTICAL DIAMOND (LONGER LENGTH THAN WIDTH) HALF DROP REPEAT ARANGEMENT TO SEE HOW THE KNIT REACTS / FOLDS				
ANALYSIS OF HANDLE / STITCH QUALITY	GOOD STITCH QUALITY AND HANDE. HANDLE IS CRISP AND CRUNCHY WITH THE STITCH DEFINITION CLEAR AND SHARP DUE TO NO STEAM THEREFORE NO RELAXATION OF YARN				
ISSUES	NO ISSUES YARN RUNS WELL				
CODE REPEAT UNIT 100% SCALE	**DIAMOND HALF DROP 100%**	**DIAMOND HALF DROP 200%**	**DIAMOND HALF DROP 300%**	**DIAMOND HALF DROP 400%**	**DIAMOND HALF DROP 500%**
	 TECHNICAL FRONT	 TECHNICAL FRONT	 TECHNICAL FRONT	 TECHNICAL FRONT	 TECHNICAL FRONT
	 TECHNICAL BACK	 TECHNICAL BACK	 TECHNICAL BACK	 TECHNICAL BACK	 TECHNICAL BACK
SURFACE MOVEMENT	ON THE TECHNICAL FACE A TIGHTLY FOLDED HONEYCOMB OF RAISED SURFACE RIDGES. ZIG ZAGS IN THE VERTICAL DIRECTION. ON THE TECHNICAL BACK THE VERTICAL LINEAR APPEARANCE HAS ARROW HEAD-LIKE APPEARANCE. GOOD DIMENSIONALITY AND RECOVERY.		DISTORTED TEXTURED SURFACE, UNSTRUCTURED LESS DEFINED MOVEMENT. CRUMPLED APPEARANCE WITH LARGER UNPREDICATABLE OVERTURN FOLDS. SHEARING FORCES AS THE UNEQUAL FORCES SLIDE THE MATERIAL IN MULTIAXIS DIRECTIONS AT ANGLES		
FORCES EVIDENT	HORIZONTAL CONVERGENT FORCES FROM THE SIDES. VERTICAL WAVES CREATED. COMPLEX FOLDS. SCALE 100% HAS BALANCED FORCES		UNEVEN OPPOSING CONVERGENT FORCES WITHIN THE SURFACE.		

DESCRIPTION	**TRIANGLE BLOCK REPEAT**				
DATE KNITTED	21.10.19				
YARN COMPANY	WOOLYARNS				
COMPOSITION	WOOL / ACRYLIC				
COUNT	2/36				
NUMBER OF ENDS	1				
CARRIER	13				
NEEDLES x COURSES	252 x 282				
MACHINE	SRY123 LPSV 14G				
HEAT METHOD	UNSTEAMED				
REASON FOR KNITTING	TO EXPLORE THE COMBINATION OF KNIT & PURL IN A TRIANGLE BLOCK REPEAT ARANGEMENT TO SEE HOW THE KNIT REACTS / FOLDS				
ANALYSIS OF HANDLE / STITCH QUALITY	GOOD STITCH QUALITY AND HANDE. HANDLE IS CRISP AND CRUNCHY WITH THE STITCH DEFINITION CLEAR AND SHARP DUE TO NO STEAM THEREFORE NO RELAXATION OF YARN				
ISSUES	NO ISSUES YARN RUNS WELL				
CODE REPEAT UNIT 100% SCALE	**TRIANGLE BLOCK 100%**	**TRIANGLE BLOCK 200%**	**TRIANGLE BLOCK 300%**	**TRIANGLE BLOCK 400%**	**TRIANGLE BLOCK 500%**
	 TECHNICAL FRONT	 TECHNICAL FRONT	 TECHNICAL FRONT	 TECHNICAL FRONT	 TECHNICAL FRONT
TECHNICAL BACK	 TECHNICAL BACK	 TECHNICAL BACK	 TECHNICAL BACK	 TECHNICAL BACK	 TECHNICAL BACK
SURFACE MOVEMENT	A CRIMPED APPEARANCE. MOVEMENT IN THE VERTICAL AND HORIZONTAL DIRECTIONS	THE SURFACE IS FOLDING. DOMINANT PLEATS ARE IN OPPOSITE DIRECTION TO THE BASE, DUE TO TRIANGLE BECOMING WIDER AND SHORTER PROPORTIONALLY	THE SURFACE IS FOLDING LARGER OVERFOLDS, THESE WAVES ARE FORMING FROM SIDE TO SIDE WITH VERTICAL SUBDUCTIONS. HERE ARE TWISTS THAT OCCUR IN THE INTERCHANGE AREAS OR TIPS / POINTS OF THE PURL TRIANGLES. THE SHAPING STEPS ARE MORE VISIBLE ON THE TECHNICAL BACK AS STITCH DETAILS. TECHNICAL BACK THE TRIANGLE FLIPS ON X AXIS		
FORCES EVIDENT	CONVERGENT FORCES IN HORIZONTAL AND VERTICAL DIRECTIONS CAUSING SURFACE MOVEMENTS UP AND DOWN AND GENERATING FOLDS IN A VERTICAL PLANE, THESE ARE TIGHTER FOLDS TOWARDS THE HEM. THIS SAMPLE IS A BIT 'MESSY' VISUALLY.	CONVERGENT FORCES STRONGER IN THE VERTICAL DIRECTIONS CAUSING FOLDS IN A HORIZONTAL PLANE. THE SAMPLE HAS BEEN COMPRESSED DOWN IN LENGTH INCREASING WIDTH. FORCES REDUCE AS SCALE INCREASES			

DESCRIPTION	**TRIANGLE BRICK REPEAT**				
DATE KNITTED	21.10.19				
YARN COMPANY	WOOLYARNS				
COMPOSITION	WOOL / ACRYLIC				
COUNT	2/36				
NUMBER OF ENDS	1				
CARRIER	13				
NEEDLES x COURSES	252 x 282				
MACHINE	SRY123 LPSV 14G				
HEAT METHOD	UNSTEAMED				
REASON FOR KNITTING	TO EXPLORE THE COMBINATION OF KNIT & PURL IN A TRIANGLE BRICK REPEAT ARANGEMENT TO SEE HOW THE KNIT REACTS / FOLDS				
ANALYSIS OF HANDLE / STITCH QUALITY	GOOD STITCH QUALITY AND HANDE. HANDLE IS CRISP AND CRUNCHY WITH THE STITCH DEFINITION CLEAR AND SHARP DUE TO NO STEAM THEREFORE NO RELAXATION OF YARN				
ISSUES	NO ISSUES YARN RUNS WELL				
CODE REPEAT UNIT 100% SCALE	**TRIANGLE BRICK 100%**	**TRIANGLE BRICK 200%**	**TRIANGLE BRICK 300%**	**TRIANGLE BRICK 400%**	**TRIANGLE BRICK 500%**
	 TECHNICAL FRONT	 TECHNICAL FRONT	 TECHNICAL FRONT	 TECHNICAL FRONT	 TECHNICAL FRONT
		 TECHNICAL BACK	 TECHNICAL BACK	 TECHNICAL BACK	 TECHNICAL BACK
SURFACE MOVEMENT	A CRIMPED APPEARANCE. RESULTS IN A TIGHTLY FOLDED PURL TEXTURED SURFACE	MOVEMENT IN THE VERTICAL DIRECTIONS. RESULTS IN A TIGHTLY FOLDED PURL TEXTURED SURFACE WITH A WAVE LIKE APPEARANCE DUE TO SMALL CREST TIPS	MOVEMENT IN THE VERTICAL DIRECTIONS. RESULTS IN A FOLDED PURL TEXTURED SURFACE WITH A WAVE LIKE APPEARANCE DUE TO SMALL CREST TIPS		
FORCES EVIDENT	CONVERGENT FORCES IN VERTICAL DIRECTIONS CAUSING SURFACE MOVEMENTS UP AND DOWN AND GENERATING A TIGHT SERIES OF SMALL FOLDS WHERE THE KNIT IS PUSHED UNDER THE PURL				

DESCRIPTION	**TRIANGLE HALF DROP REPEAT**				
DATE KNITTED	21.10.19				
YARN COMPANY	WOOLYARNS				
COMPOSITION	WOOL / ACRYLIC				
COUNT	2/36				
NUMBER OF ENDS	1				
CARRIER	13				
NEEDLES x COURSES	252 x 282				
MACHINE	SRY123 LPSV 14G				
HEAT METHOD	UNSTEAMED				
REASON FOR KNITTING	TO EXPLORE THE COMBINATION OF KNIT & PURL IN A TRIANGLE HALF DROP REPEAT ARANGEMENT TO SEE HOW THE KNIT REACTS / FOLDS				
ANALYSIS OF HANDLE / STITCH QUALITY	GOOD STITCH QUALITY AND HANDE. HANDLE IS CRISP AND CRUNCHY WITH THE STITCH DEFINITION CLEAR AND SHARP DUE TO NO STEAM THEREFORE NO RELAXATION OF YARN				
ISSUES	NO ISSUES YARN RUNS WELL				
CODE REPEAT UNIT 100% SCALE	**TRIANGLE HALF DROP 100%**	**TRIANGLE HALF DROP 200%**	**TRIANGLE HALF DROP 300%**	**TRIANGLE HALF DROP 400%**	**TRIANGLE HALF DROP 500%**
	 TECHNICAL FRONT	 TECHNICAL FRONT	 TECHNICAL FRONT	 TECHNICAL FRONT	 TECHNICAL FRONT
	 TECHNICAL BACK	 TECHNICAL BACK	 TECHNICAL BACK	 TECHNICAL BACK	 TECHNICAL BACK
SURFACE MOVEMENT	A CRIMPED APPEARANCE. MOVEMENT IN THE VERTICAL DIRECTIONS. RESULTS IN A TIGHTLY FOLDED PURL TEXTURED SURFACE. THE SURFACE SECTIONS CONCERTINA CLOSELY TOGETHER	TECHNICAL FRONT HAS MOVEMENT IN THE VERTICAL & HORIZONTAL DIRECTIONS. RESULTS IN A BROADER STAGGERED FOLDED PURL SURFACE WITH PARALLEL STAGGERED 'S' WAVES DIVIDING THE SURAFCE AREAS OF REPEAT DUE TO THE DROP OF THE KNIT AND PURL OPPOSING FORCES COLLIDINGI N SMALL AREAS. TECHNICAL BACK HAS STAGGERED FOLDS. SHAPING STEPS VISIBLE ON REVERSE			
FORCES EVIDENT	HORIZONTAL CONVERGENT FORCES ACROSS THE FABRIC	VERTICAL CONVERGENT FORCES I			

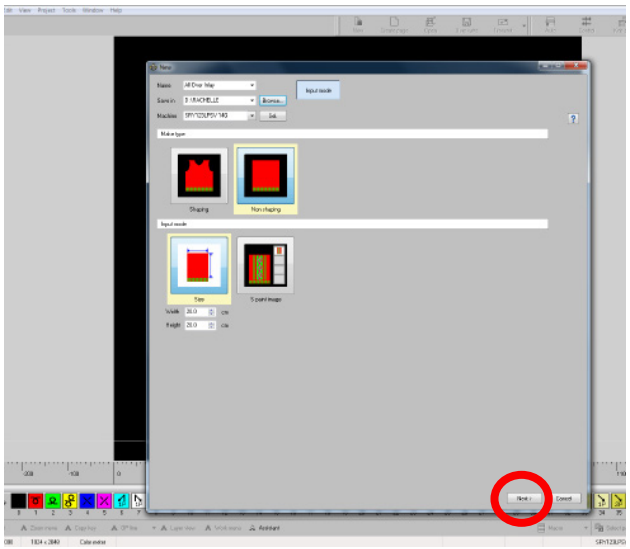
APPENDIX E.
How to Build an Intarsia Inlay Knitted Surface Topography



- STEP 1. Select Photographic Image

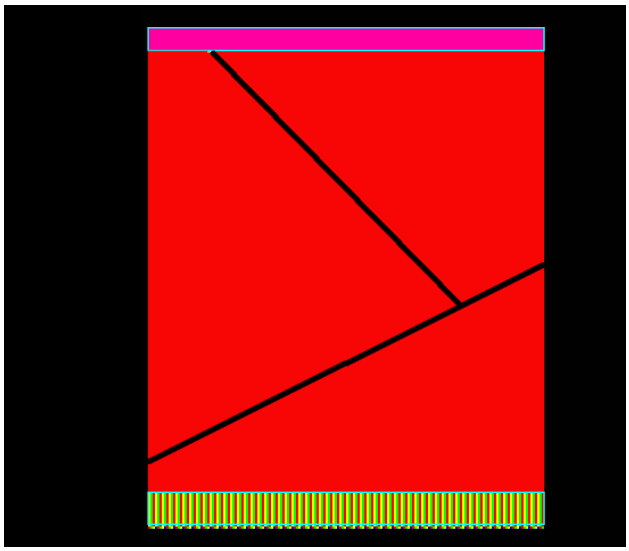


- STEP 2. Divisions of Landscape
- Draw by hand sections for geometrics ground patterns
- If creating a small swatch only use part of the photograph

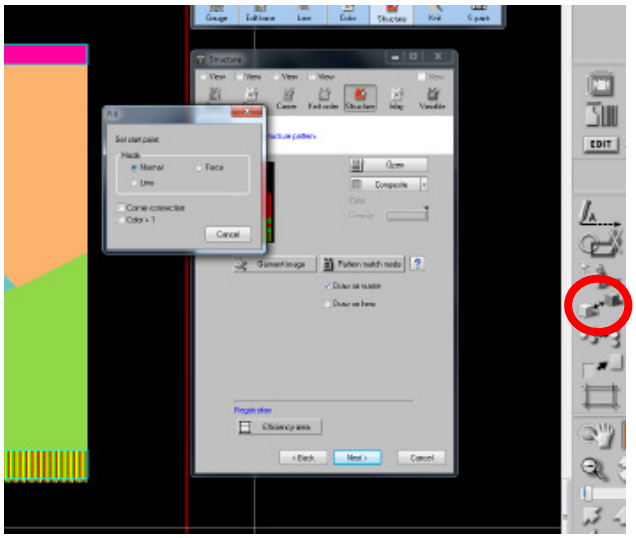


- STEP 3. Set Up a New Swatch in Automatic Software KnitPaint
- File > New
- Set up swatch the length and width required
- See Appendix E. How to Set up an All-Over Inlay Swatch

  Steps 1-8



- STEP 4. Structure Page Sectional Division
- Draw directly on screen the divisions from the photograph
- This example uses linear division (straight lines)

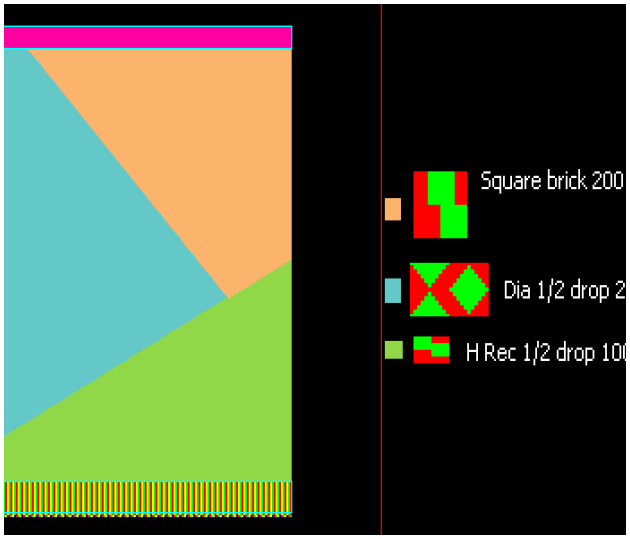


- STEP 5. Colour Block Sections
- Select a different colour for each section (or if using the same geometric ground more than once = use the same colour)
- Use the Fill tool to fill each section with colour
- File > Save File as colour block version

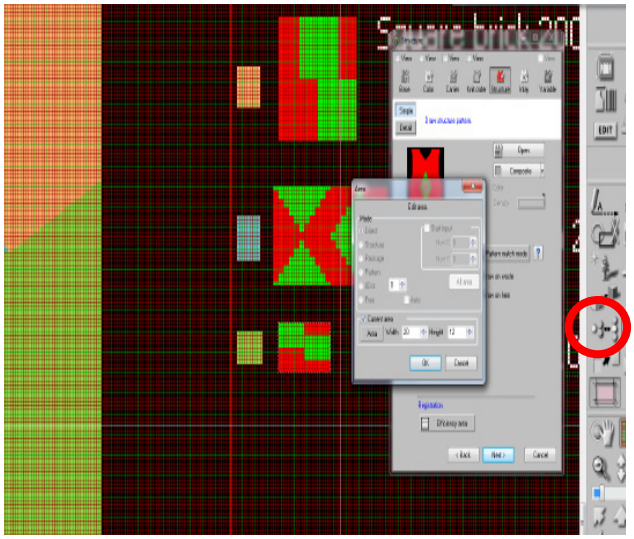
(It is easier to exchange links-links grounds in future iterations if you retain this as a separate file)



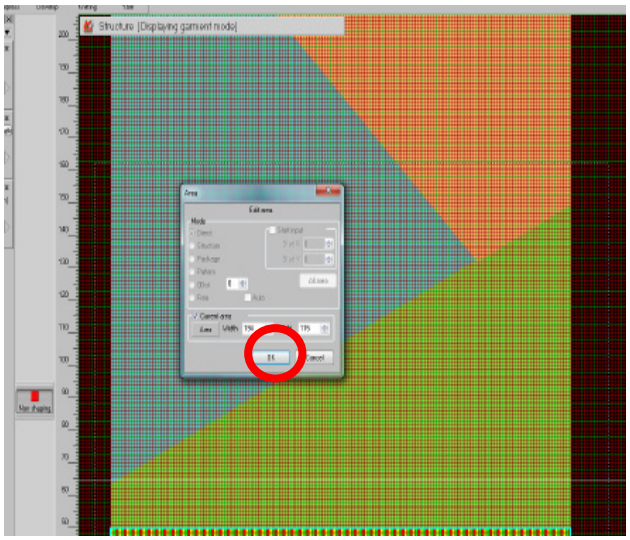
- STEP 6. Fill with Links-Links Ground Patterns
- Select ground patterns and scales from the Links-Links Surface-building Block library (digital imagery or physical swatches)
- Or design pattern repeat unit on-screen to the right of red line



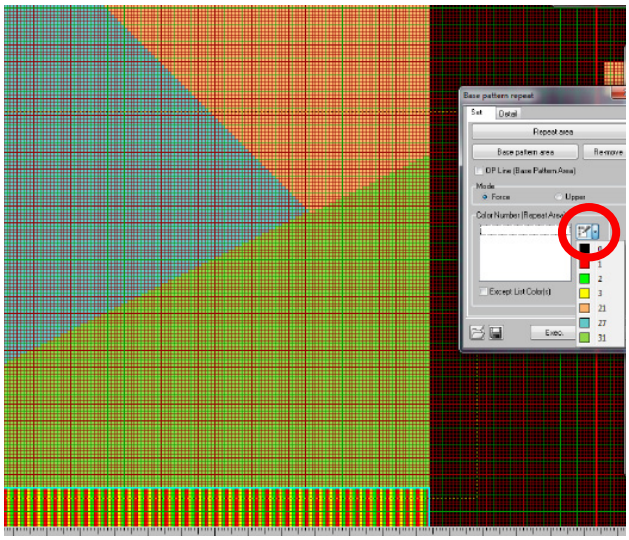
- STEP 7. Links-Links Ground Patterns
- Copy > Point the base unit for repeat from the corresponding KnitPaint digital file
- Place the base units to the right of the red line next to the colour it will fill



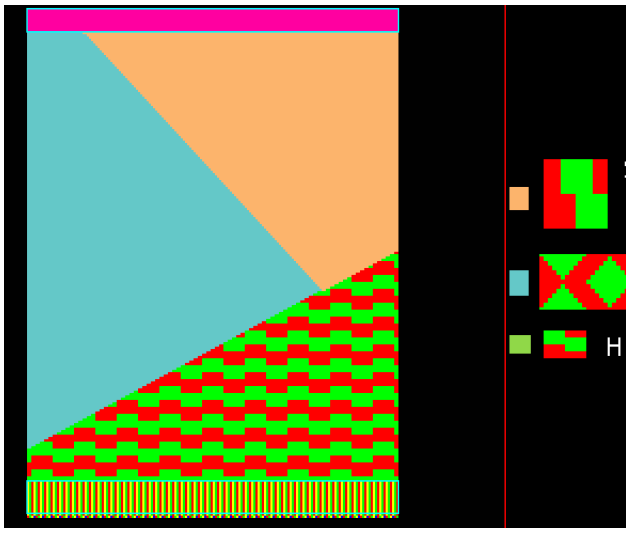
- STEP 8. Links-Links Ground Patterns
- Fill colour blocks with links-links patterns
- Use Base Pattern Repeat tool
- Click > Base pattern area
- Drag an area box around the unit repeat pattern
- Click > Ok



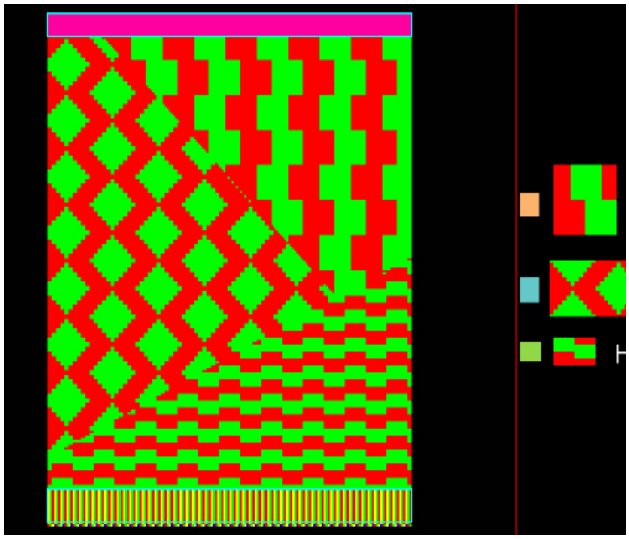
- STEP 9. Links-Links Ground Patterns
- Click > Repeat Area
- Drag an area box around the area to repeat pattern into
- Click >OK



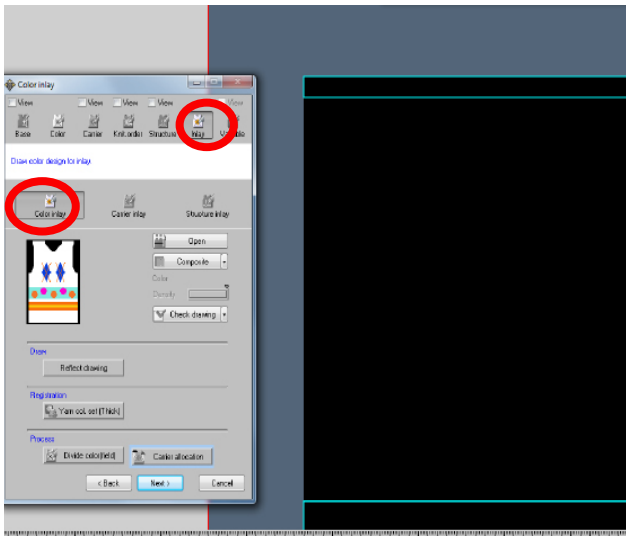
- STEP 10. Links-Links Ground Patterns
- Click >Delete All to clear colours in Repeat Area
- Click > Add > use tab to add the colour to repeat onto
- Select only the colour required



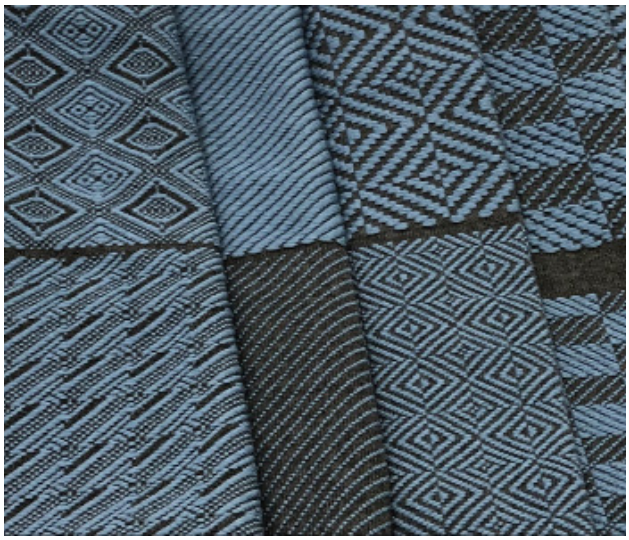
- STEP 11. Links-Links Ground Patterns
- To fill with the inks-links repeat pattern
- Click > Exec



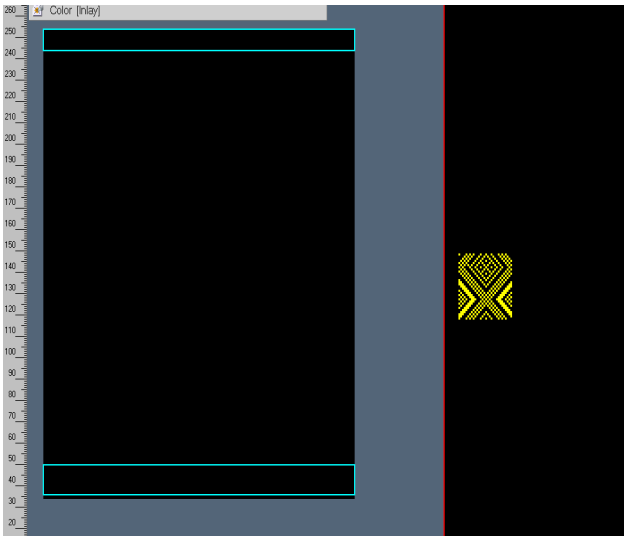
- STEP 12. Links-Links Ground Patterns
- Repeat Steps 8 - 11 to fill all colour blocked areas with pattern
- Click > Cancel when completed



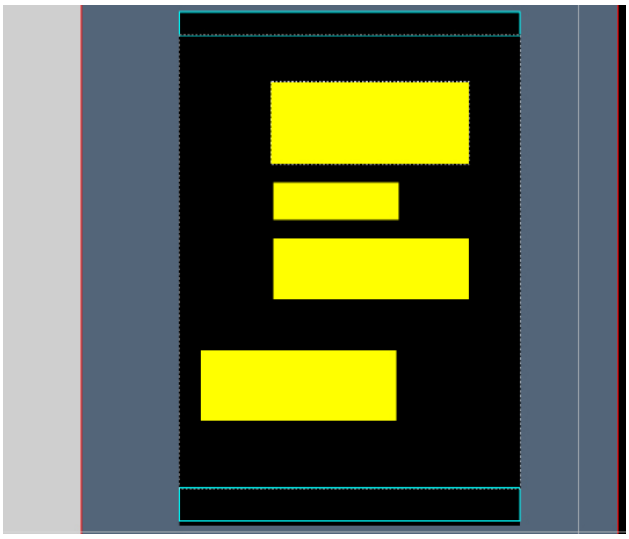
- STEP 13. Set Up Inlay Pattern
- Open Inlay Colour Page



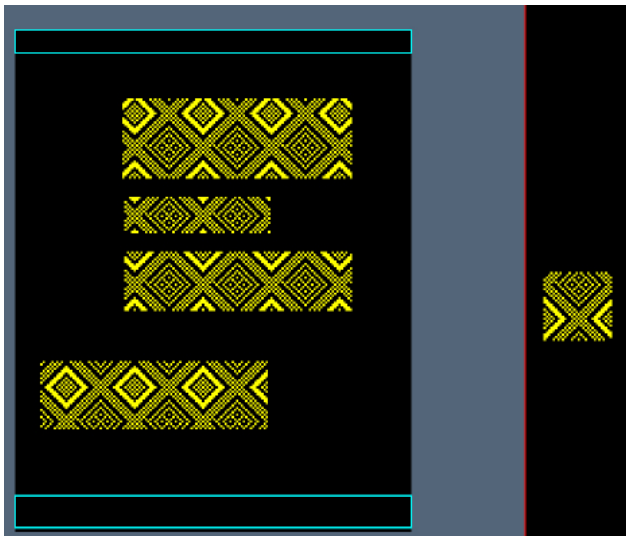
- STEP 14. Set Up Inlay Pattern
- Select inlay pattern from Inlay Pattern Surface-building Block Library (digital imagery or physical swatch)
- Or design pattern repeat unit on-screen to the right of red line



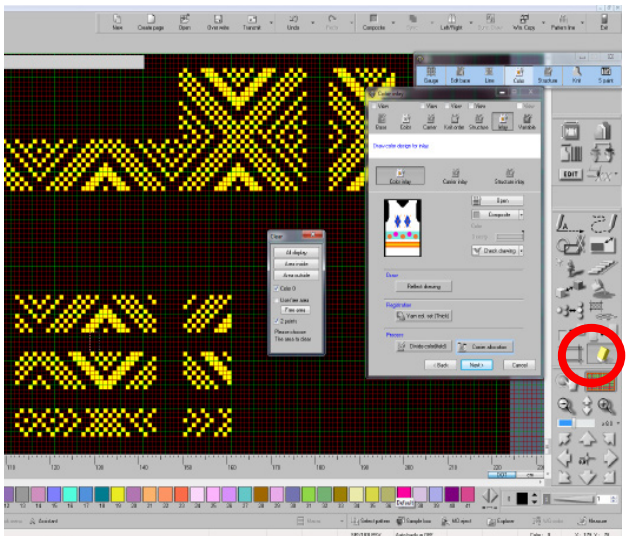
- STEP 15. Set Up Inlay Pattern
- Copy the base unit for repeat from the corresponding KnitPaint digital file
- Place the base unit to the right of the red line



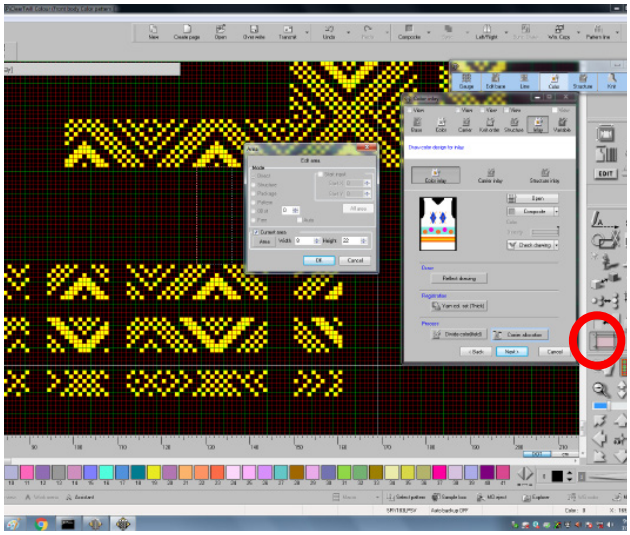
- STEP 16. Set Up Inlay Pattern
- Draw coloured blocks to fill with inlay repeating pattern
- The first block must be positioned on an even numbered course from the bottom of the panel
- There must be even number of courses between the blocks
- All blocks must contain an even number of courses



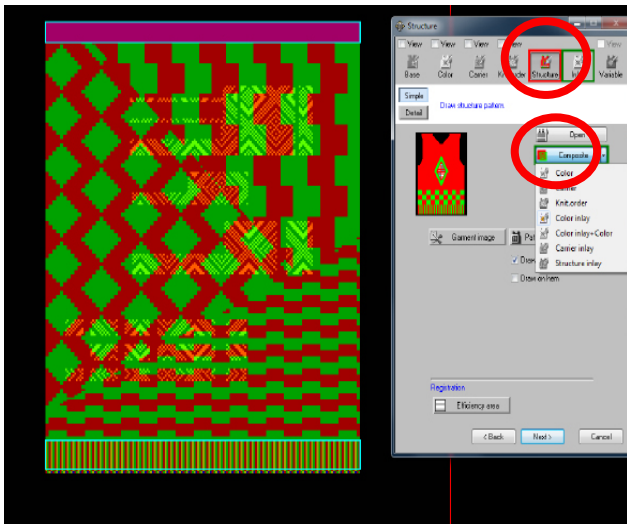
- STEP 17. Set Up Inlay Pattern
- Use Base Pattern Repeat tool to fill with the inlay base unit repeat (see Steps 8-10 with geometric repeat)
- Must set the repeat area for inlay 2 needles in from both side edges
- Click > Exec
- Click > Cancel



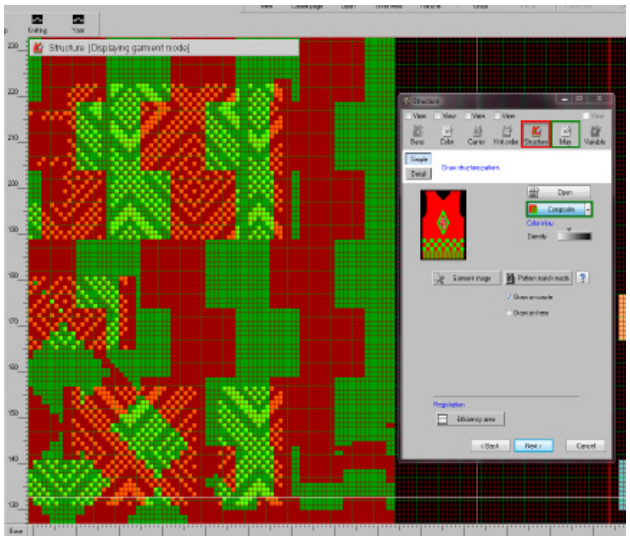
- STEP 18. Set Up Inlay Pattern
- Subtraction of inlay pattern
- Use the Clear tool with colour black
- Vertical subtractions can be any amount but need to consider the floats between areas
- Horizontal subtractions must be even numbered amounts and have even numbered courses between inlay sections



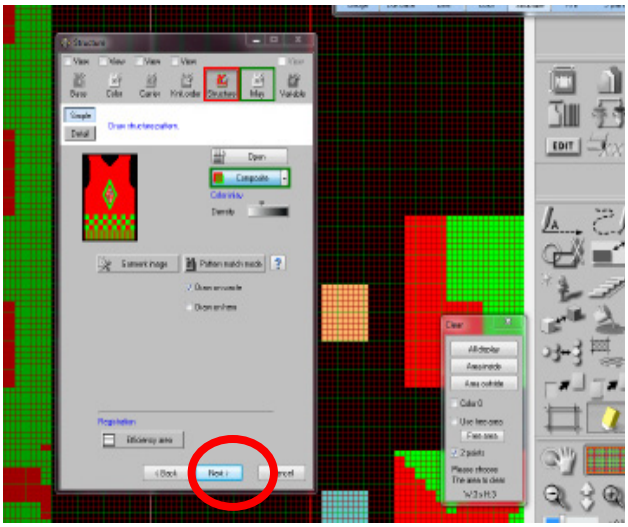
- STEP 19. Check Inlay Positioning
- Use Area tool to check the inlay subtraction is correctly positioned
- Check the number of course between sections and all the horizontal sections in a block



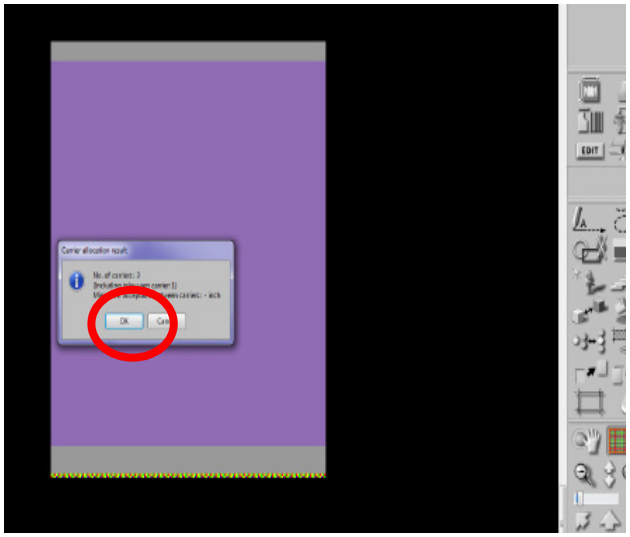
- STEP 20. Adjust Inlay Pattern Edges
- On the Structure page
- Click > Composite > pull down tab and select Colour Inlay page
- Use slider to adjust the opacity



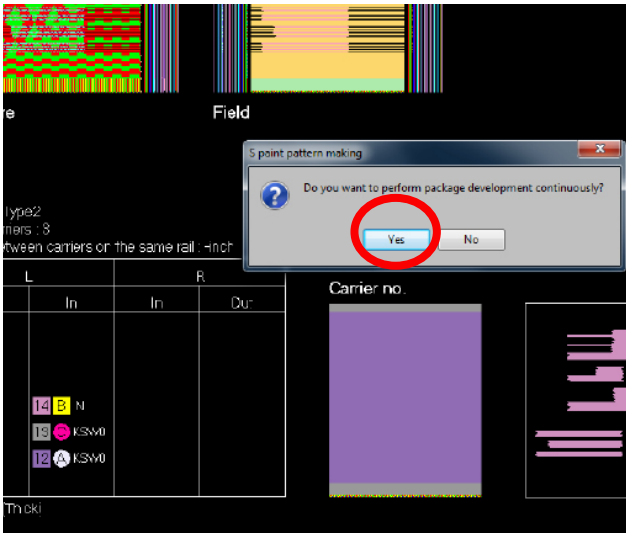
- STEP 21. Clear Stitch Structure on Vertical Inlay Edges
- Change the structure 2 needle inside and outside the inlay pattern to front bed single jersey knit
- Change on edges Code 2 = Green to Code 1 = Red
- This prevents tearing at the intarsia inlay edge in the knitting stage



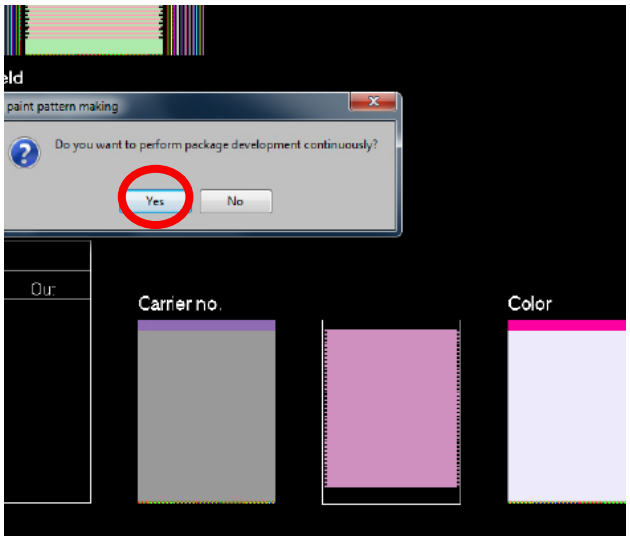
- STEP 22. Automatic Software Development
- Click > Next



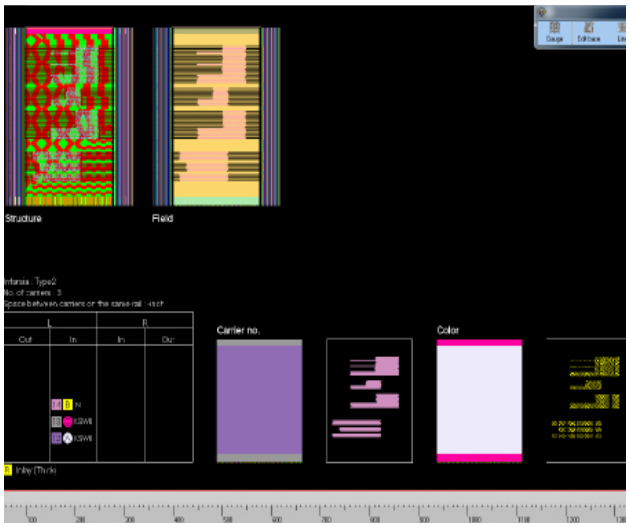
- STEP 23. Automatic Software Development
- Carrier Allocation Result
- Click > OK



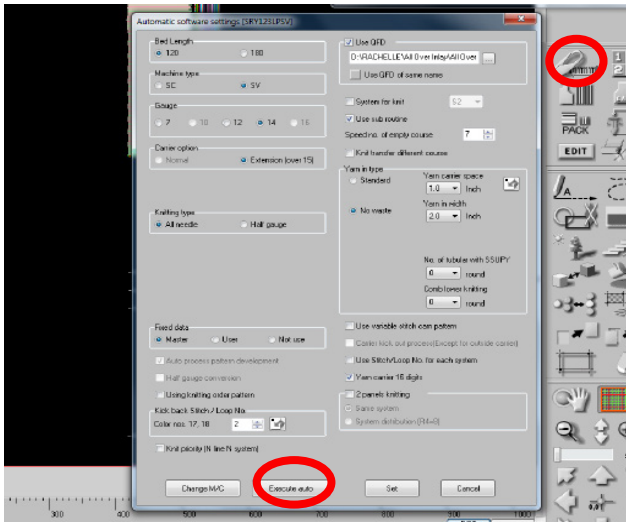
- STEP 24. Automatic Software Development
- Warning Overwrite file
- Click > OK
- S paint pattern making
- Click > Yes



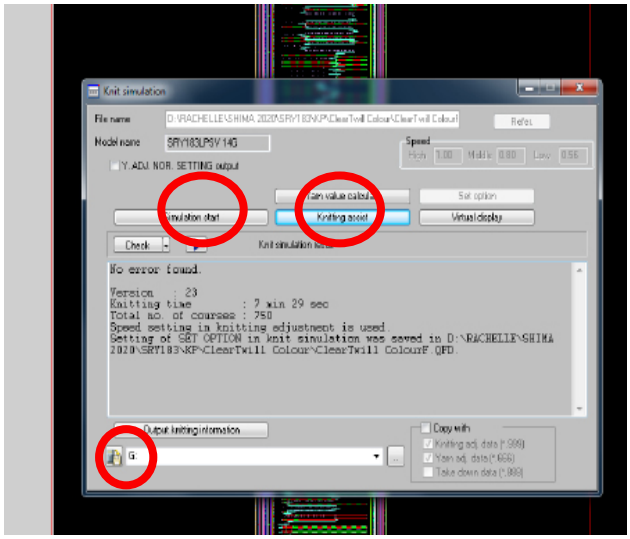
- STEP 25. Automatic Software Development
- S paint pattern making
- Do you want to perform package development continuously?
- Click > Yes



- STEP 26. Automatic Software Development
- This is the Developed page
- This shows all the carrier information and the different pages that make up the programming information for the knit



- STEP 27. Automatic Software Processing
- Click > Automatic Software Process
- For full Automatic Software Processing steps for an automatic software inlay swatch refer to Appendix B. Steps 20 - 28

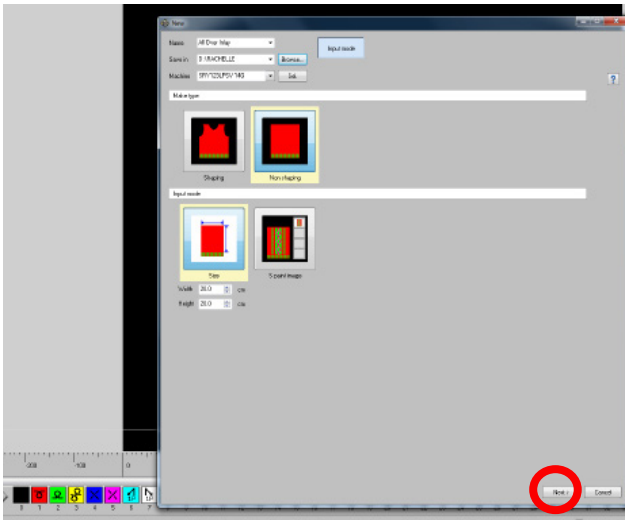


- STEP 28. Automatic Software Processing Completed
- Click > Simulation start
- Click> Knitting assist
- Click > OK
- Copy .000 file to usb for knitting

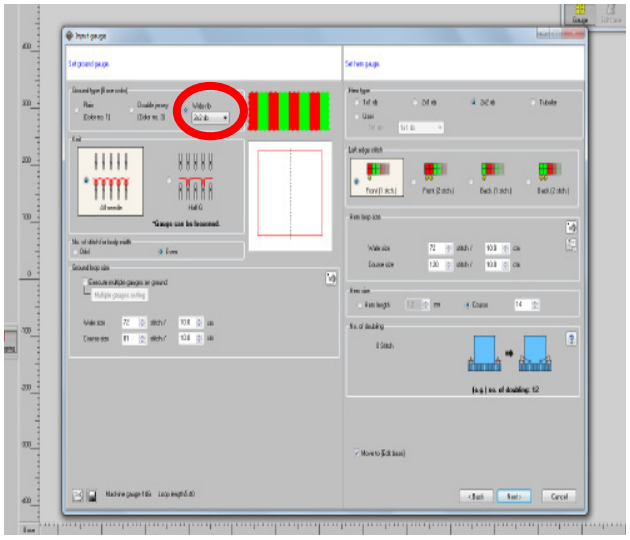
APPENDIX F.
How to Build a Rib Intarsia Inlay Knitted Surface Topography



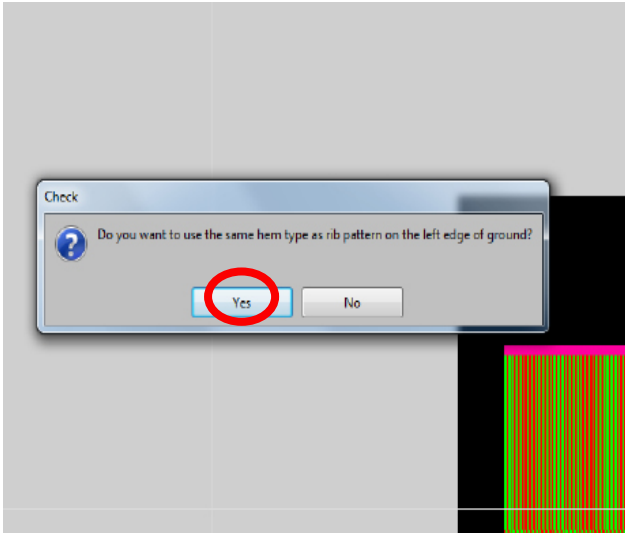
- STEP 1. Select Photographic Image
- Select an image with mutliple intersections
- Draw by hand sectional divisions for inlay patterns
- If creating a small swatch only use part of the photograph



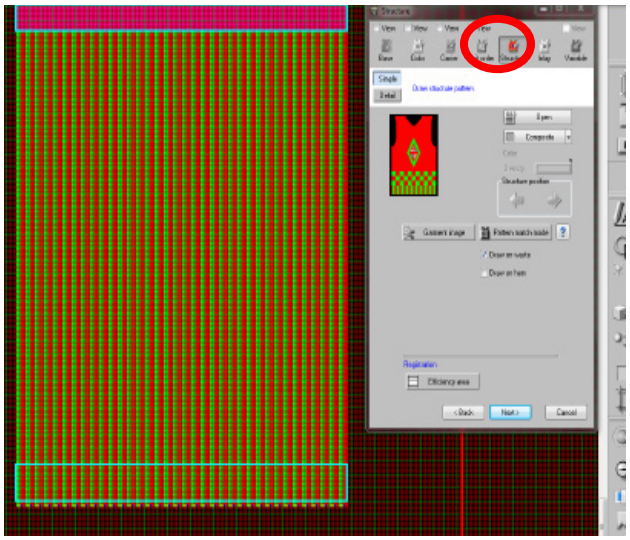
- STEP 2. Set Up a New Swatch in Automatic Software
- File >New
- Set up swatch size
- Click > Next



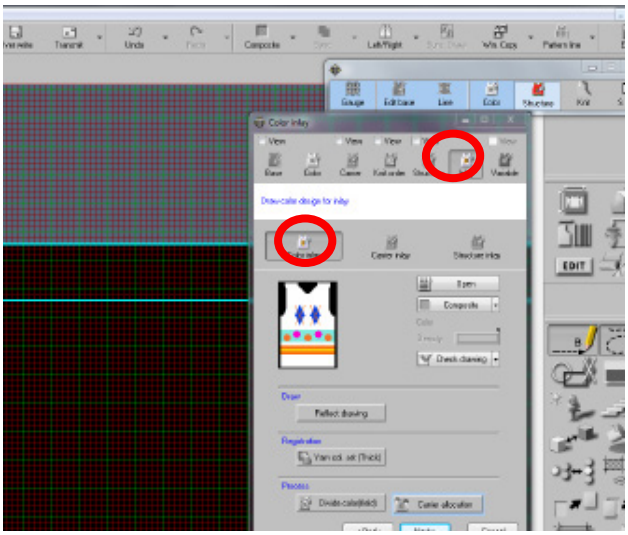
- STEP 3. Set Up Rib Ground
- Select > Ground type > Wide rib
- Set the rib > e.g. 2x2
- Click > Next



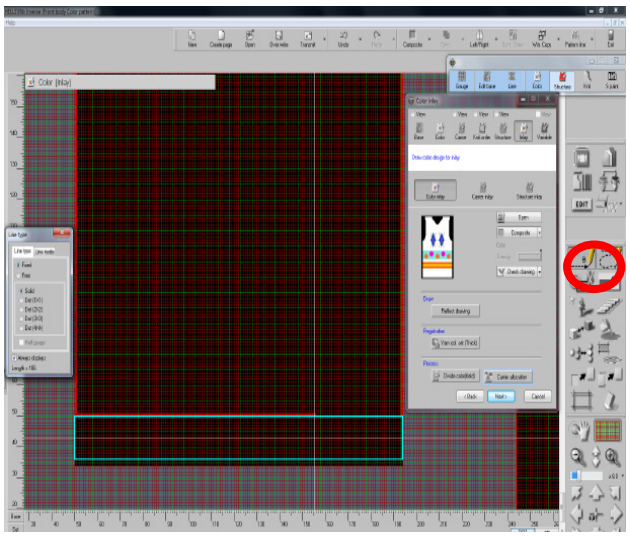
- STEP 4. Set Up Rib Ground
- Do you want to use the same hem type as rib pattern on the left edge of ground?
- Click > Yes
- See Appendix E. Steps 1-8 for completion of set up of new swatch



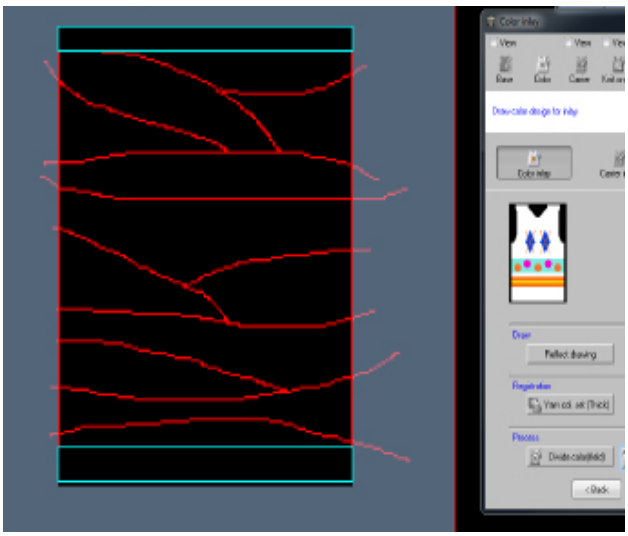
- STEP 5. Structure Page
- Struacture page displays a rib ground stitch structure



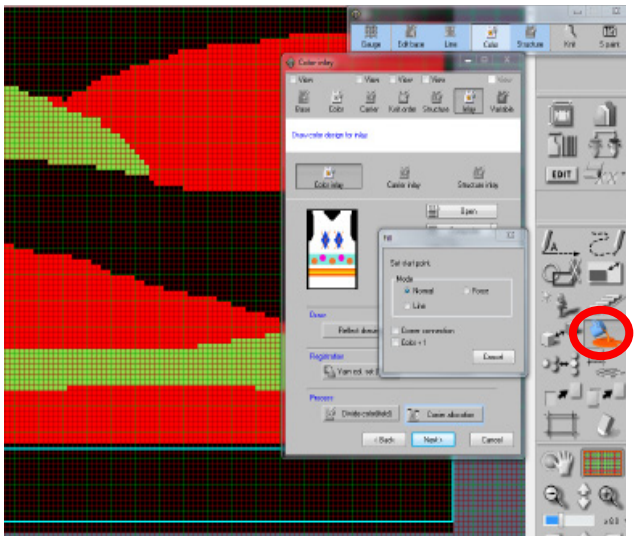
- STEP 6. Set Up Inlay Pattern
- Open Inlay > Inlay Colour page



- STEP 7. Set Up Inlay
- Frame inlay area
- Use Line tool to frame all the inlay edges to contain the colour when using the Fill tool

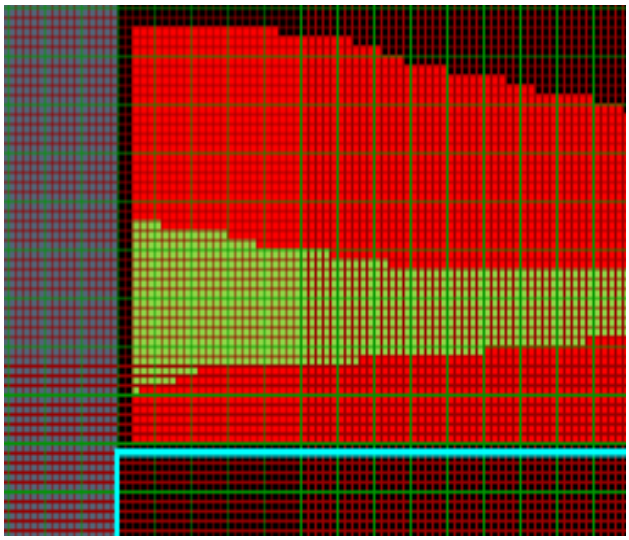


- STEP 8. Set Up Inlay
- Inlay Colour page sectional division
- Draw directly on screen the divisions from the photograph
- This example uses contoured division (curved lines)

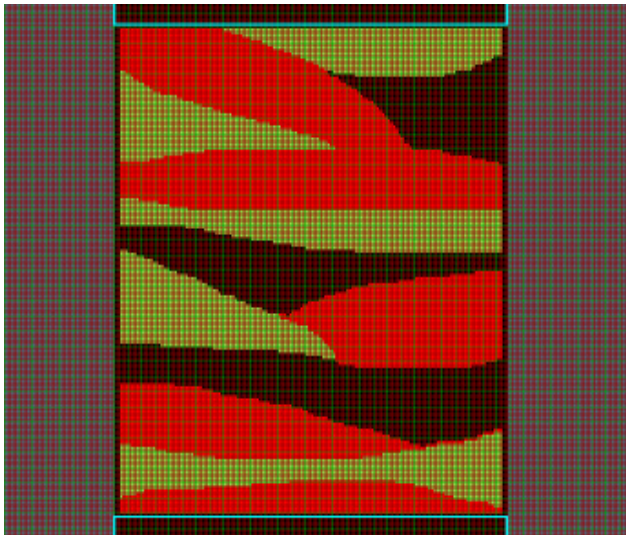


- STEP 9. Set Up Inlay
- Select 2 colours (inlay & inverse inlay areas)
- Leave plain rib area black
- Use Fill tool to colour sections (each area must be enclosed)
- File > Save File as colour block version

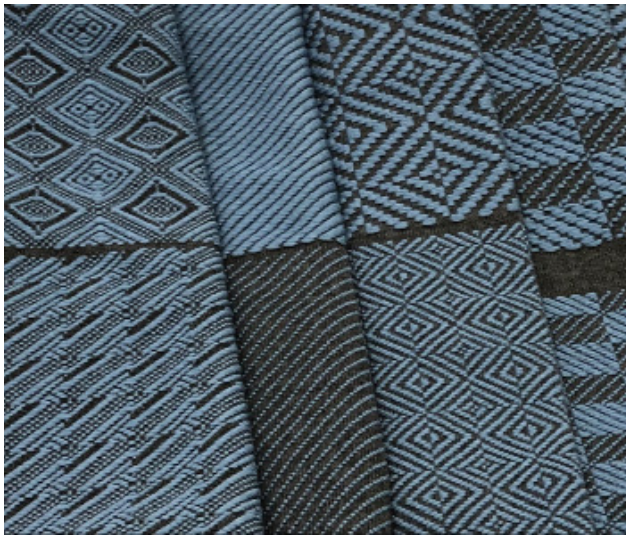
(It is easier to exchange inlay patterns in future iterations if you retain this as a separate file)



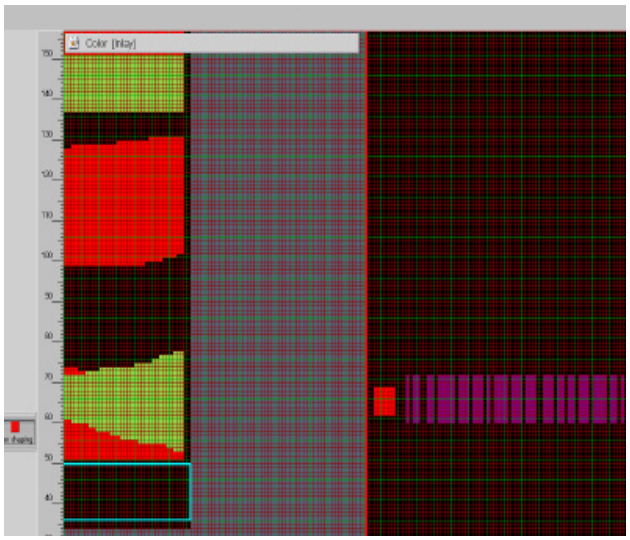
- STEP 10. Set Up Inlay
- Clear the inlay swatch edges
- Inlay must sit inside side edges by minimum of two needles
- Inlay must start 1 course up from the bottom and finish 1 course from the top of the swatch (or start on an even course and finish on an odd course0
- Change edges and any remaining contour lines



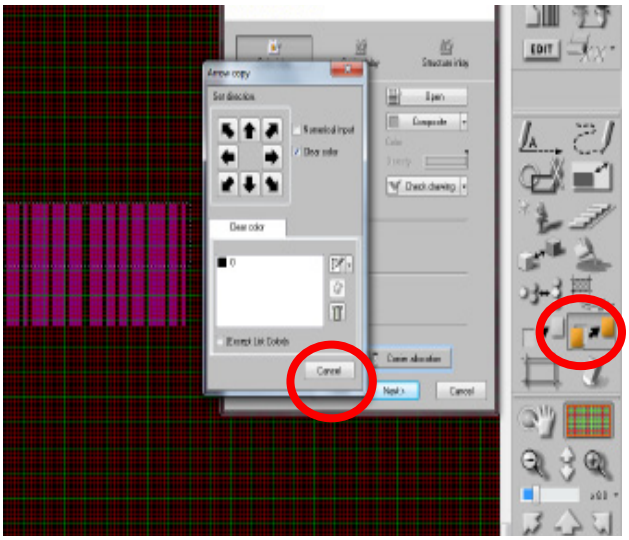
- STEP 11. Set Up Inlay
- Colour Blocked for Inlay Pattern Fill



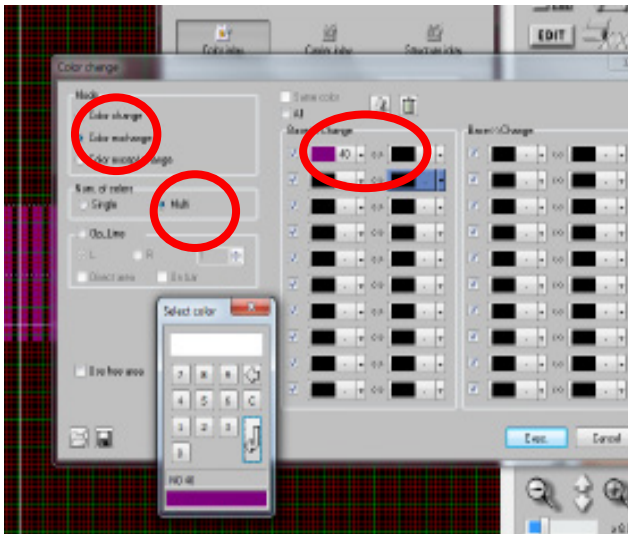
- STEP 12. Select Inlay Pattern
- Select inlay pattern from Inlay Surface-building Block library (digital imagery or physical swatch)



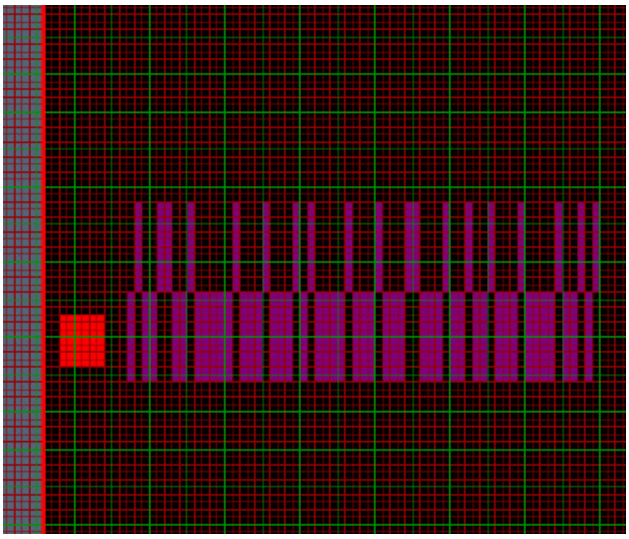
- STEP 13. Set Up Inlay
- Use Copy tool > Point
- Select and copy the base unit for repeat from the corresponding KnitPaint digital file
- Place the base units to the right of the red line next to the colour it will fill



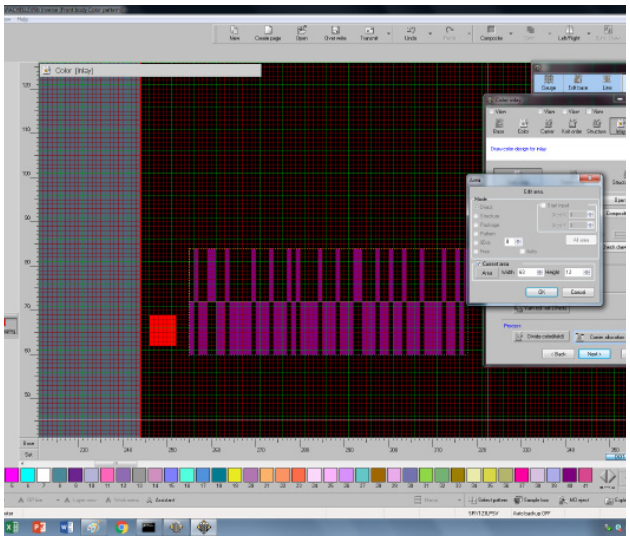
- STEP 14. Set Up Inverse Inlay
- Use Area tool > drag around the inlay repeat unit
- Click > OK
- Use Copy tool > Arrow > Execute > Up > Cancel > Cancel
- This ensures the inlay and inlay inverse will align vertically



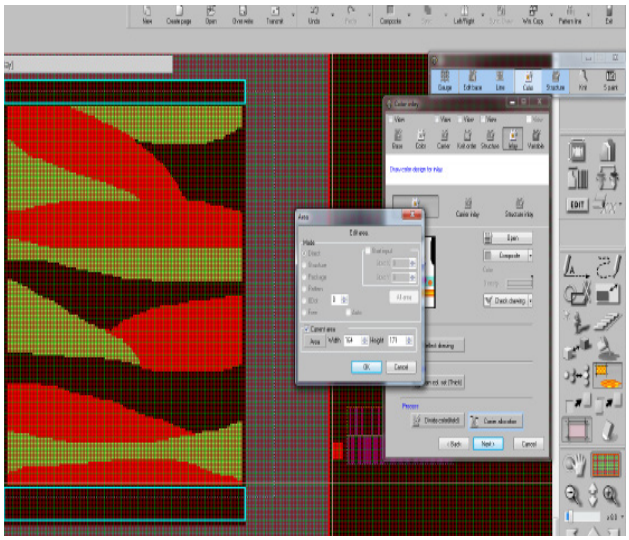
- STEP 15. Set Up Inlay
- Set up inverse inlay pattern
- Select the inlay base unit repeat to be converted to inverse inlay
- Use Area tool > Drag to select > OK
- Use Colour Change tool > Colour Exchange > Multi
- Set the inlay colour to change to black
- Set the black to change to inlay colour
- Click > Exec



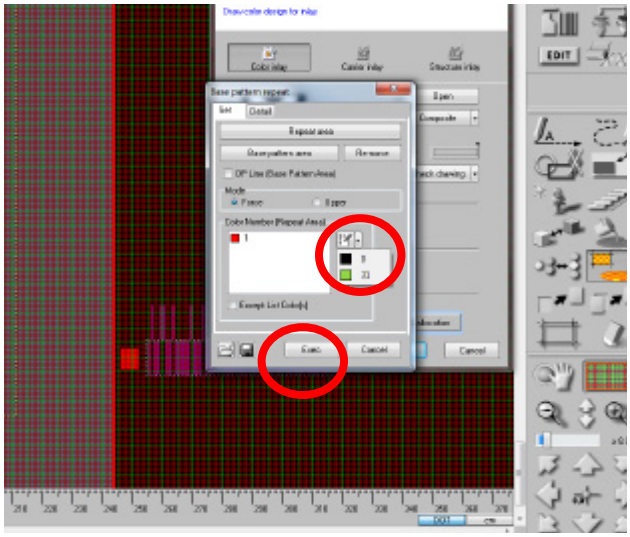
- STEP 16. Set Up Inlay
- Inlay pattern & inverse inlay pattern repeat units



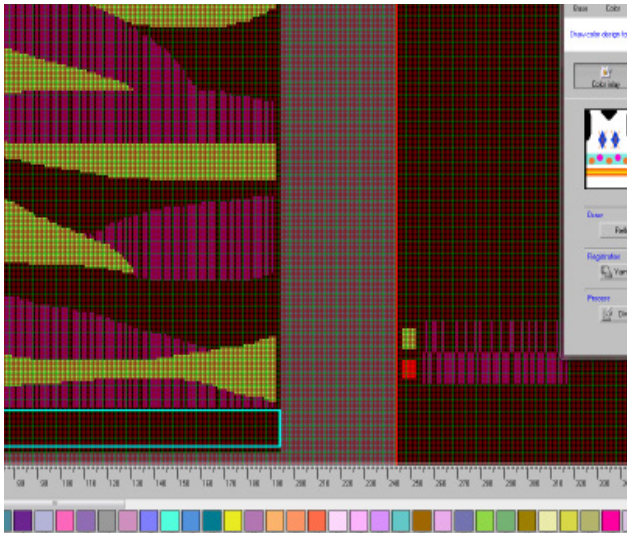
- STEP 17. Set Up Inlay
- Base Pattern Repeat tool
- Set Base Pattern Area > drag over inlay unit repeat only
- Click > OK



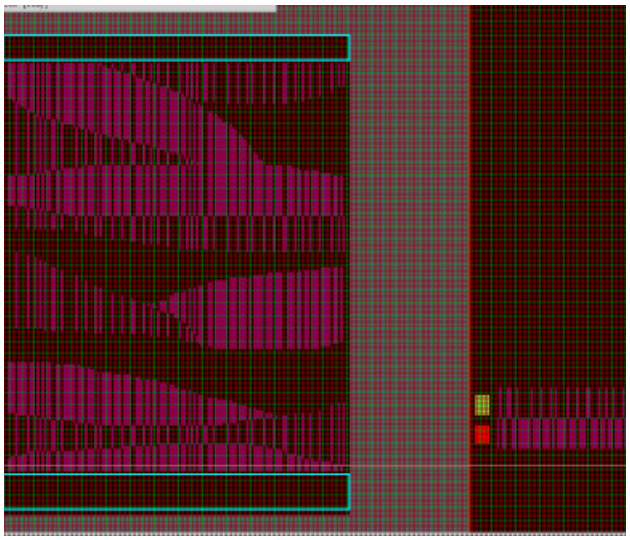
- STEP 18. Set Up Inlay
- Repeat Area > Drag a box over the entire swatch area
- Click > OK



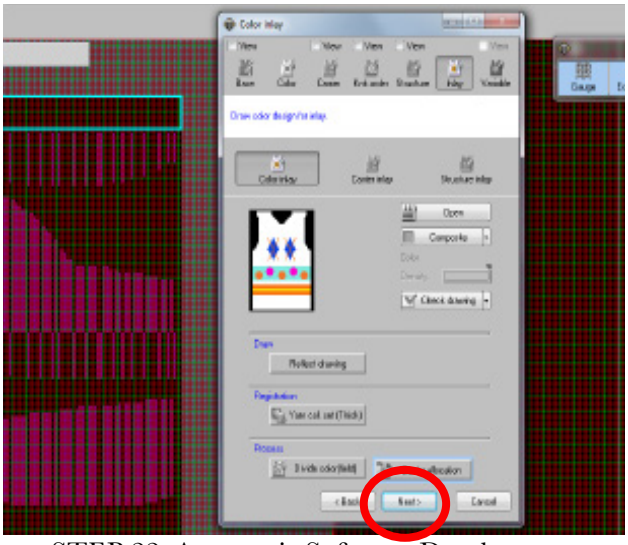
- STEP 19. Set Up Inlay
- Delete All to clear colours in Repeat Area
- Click > Add icon > use tab to add the colour to repeat onto
- Select only the colour required
- Click > Exec



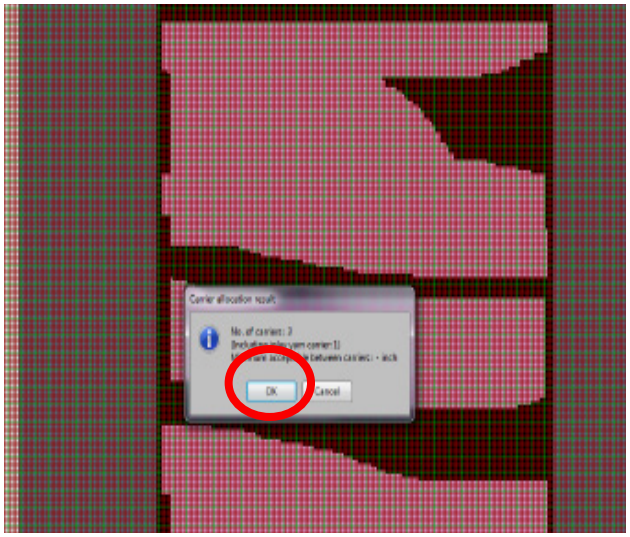
- STEP 20. Set Up Inlay
- Fills all areas of the same colour with the selected pattern



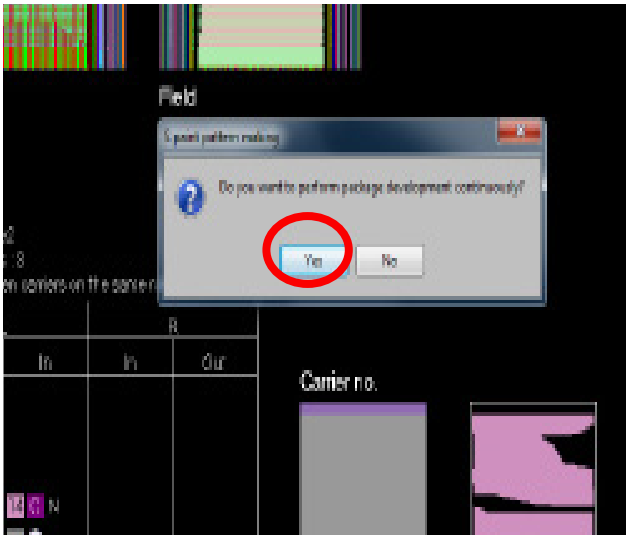
- STEP 21. Set Up Inlay
- Repeat Steps 17-20 to fill with Inverse Inlay pattern



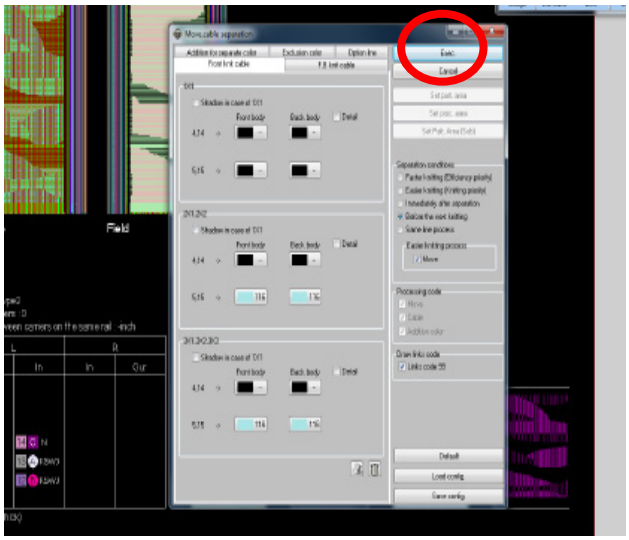
- STEP 22. Automatic Software Development
- Click > Next



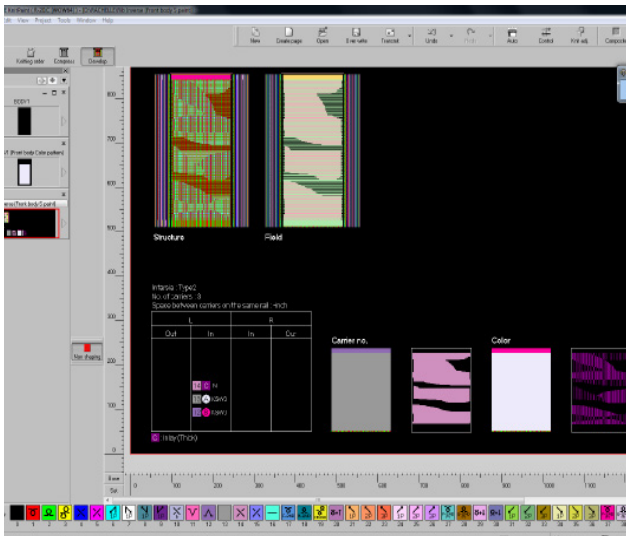
- STEP 23. Automatic Software Development
- Carrier Allocation result > OK



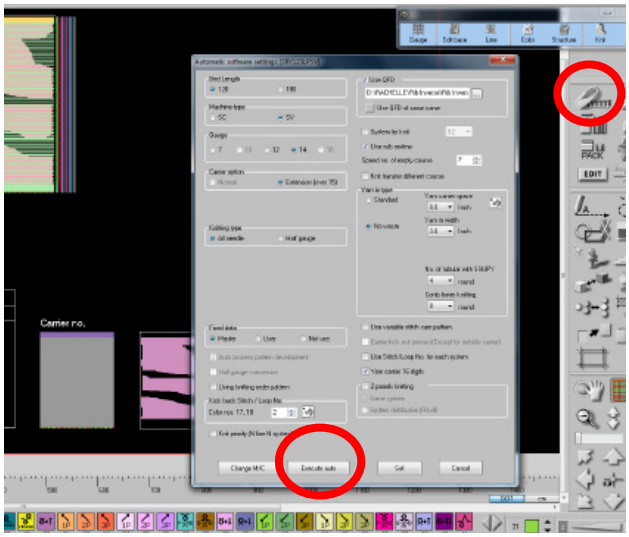
- STEP 24. Automatic Software Development
- Warning Overwrite file
- Click > Yes
- S Paint Pattern Making
- Do you want to perform package development continuously?
- Click > Yes



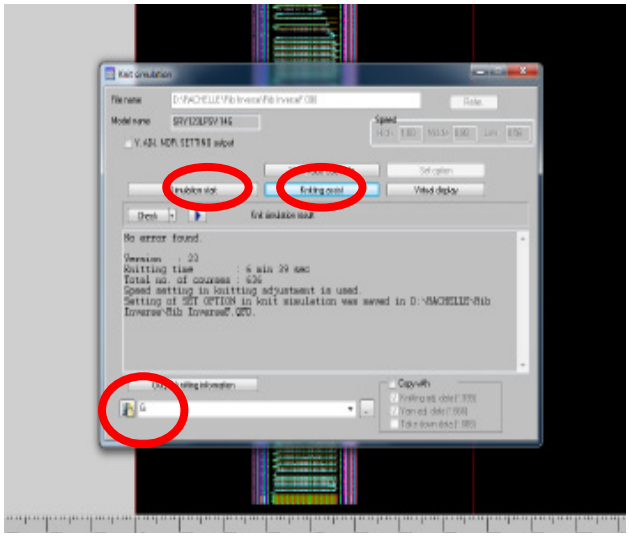
- STEP 25. Automatic Software Development
- Move, Cable Spearation
- Leave as default settings
- Click > Exec



- STEP 26. Automatic Software Development
- This is the Developed page



- STEP 23. Automatic Software Processing
- Click > Automatic Software Setting
- Click > Execute Auto
- For full Automatic Processing settings for an inlay swatch refer to Appendix B. Steps 20 - 28



- STEP 24. Automatic Software Processing Completed
- Click > Simulation start
- Click> Knitting assist
- Click > OK
- Copy .000 file to usb for knitting

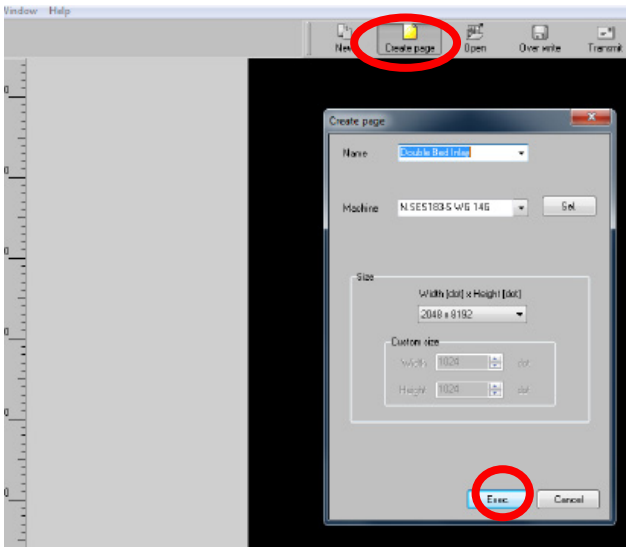
APPENDIX G.
How to Build a Double Bed Inlay Knitted Surface Topography



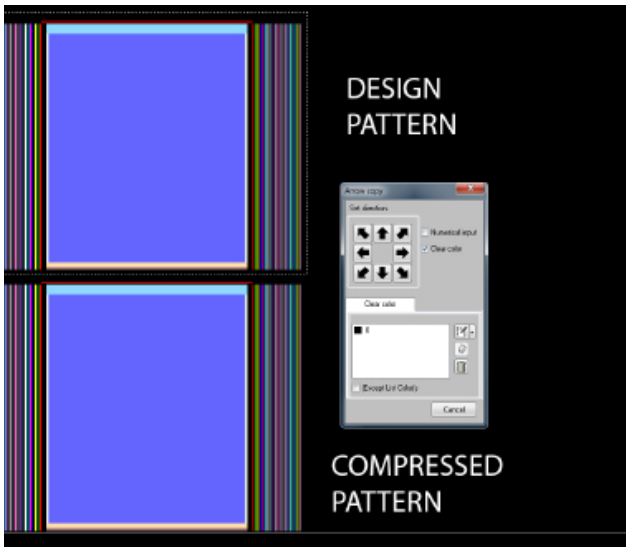
- STEP 1. Select Photographic Image



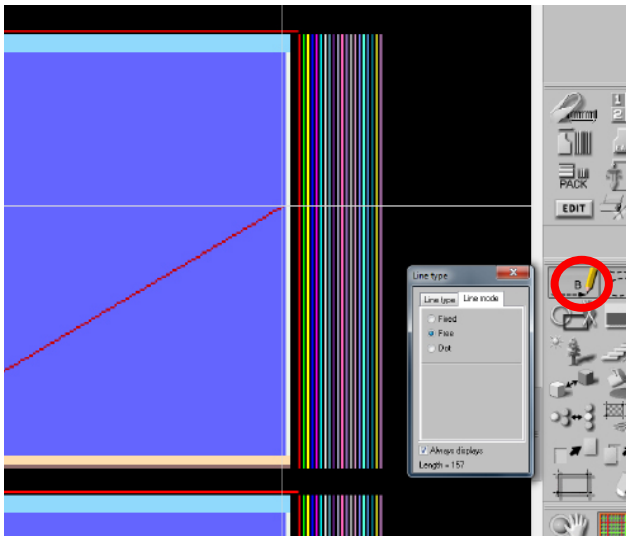
- STEP 2. Divisions of Landscape
- Draw by hand sectional divisions for geometrics ground patterns
- If creating a small swatch only use part of the photograph



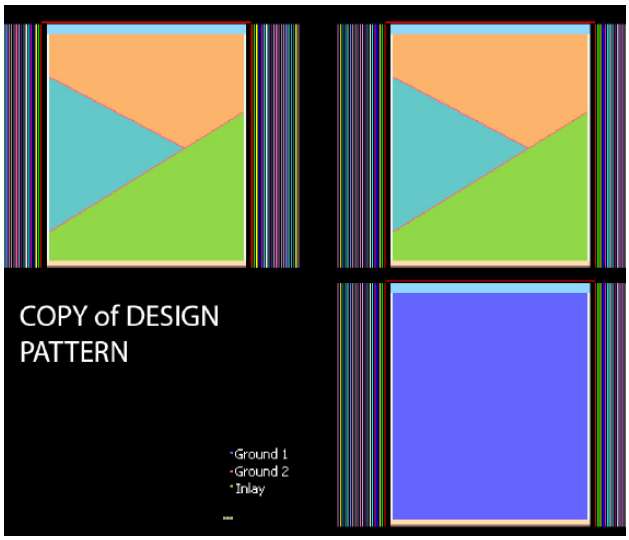
- STEP 3. Set Up an Old-format Page in KnitPaint
- Use Create page > Set up a basic old-format swatch the size required using correct packages then add option lines (information on basic swatch set up is available in the Shima Seiki KnitPaint Help menu)
- This is the Compressed Pattern



- STEP 4. Create the Design Pattern
- Use Copy tool > Drag area over the Compressed Pattern
- Use Arrow Up
- Click > Cancel
- This is the Design Pattern where the ground and inlay codes are assembled



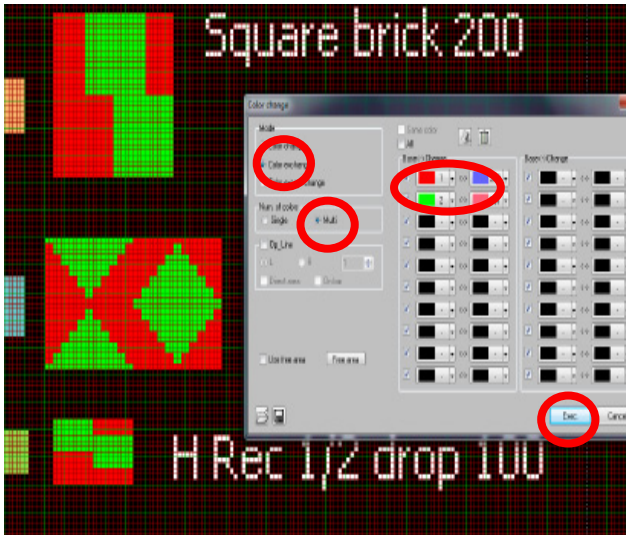
- STEP 5. Draw Divisions from Photograph
- Draw on the Design Pattern the section linear divisions
- Use Line tool > Line mode > Free
- Use colour code 201 (this is the double bed ground PAK code colour) & only draw onto the colour code 200



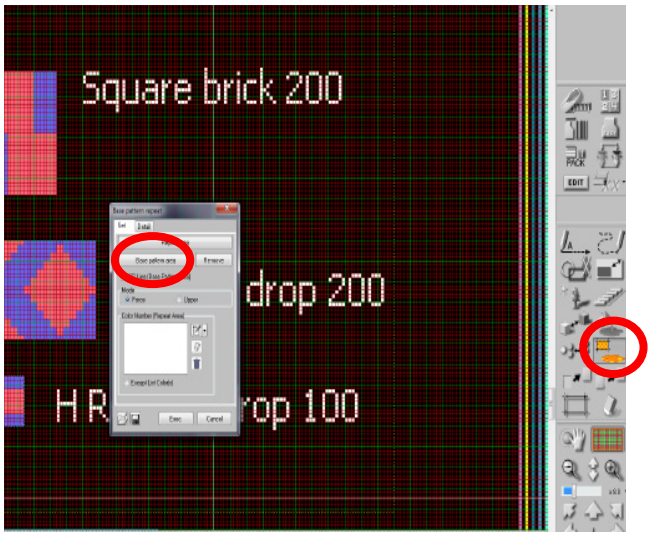
- STEP 6. Colour Block Sections
- Select a different colour for each section (or if using the same geometric ground more than once = use the same colour)
- Use the Fill tool to fill each section with colour
- Use Copy tool > Arrow > Left
- Place the copy of the colour blocked stage to the left of the actual design pattern (It is easier to exchange geometric grounds in future iterations if you retain this as a separate copy)



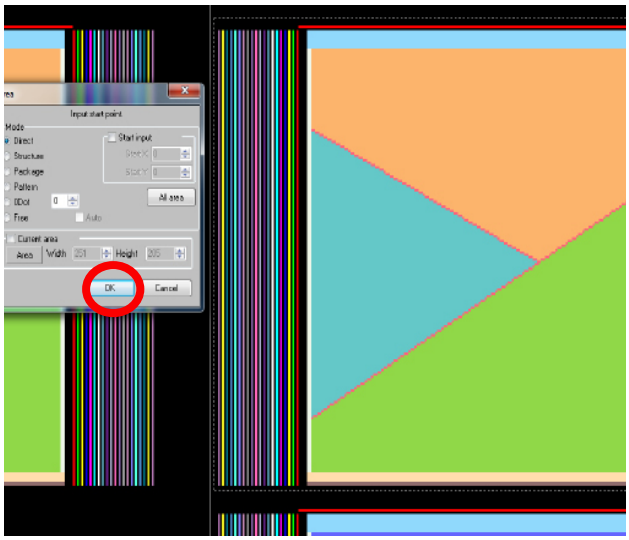
- STEP 7. Select Geometric Ground Patterns
- Select patterns and scales from the Links-Links Surface-building Block library (digital imagery or physical swatches)
- Place the pattern repeat unit on-screen to the left of the compressed pattern and design pattern



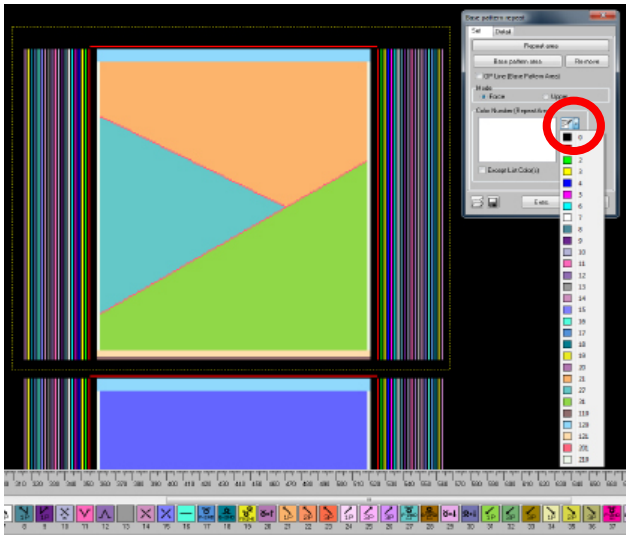
- STEP 8. Change to PAK Colour Codes
- You must change the colour codes of the geometric patterns to 200 & 201 for the double bed knitting PAKs
- Use Colour Change tool > Colour Exchange > Multi
- Exchange colour code 1 = 200 & 2=201
- Click > Exec then Click > Cancel



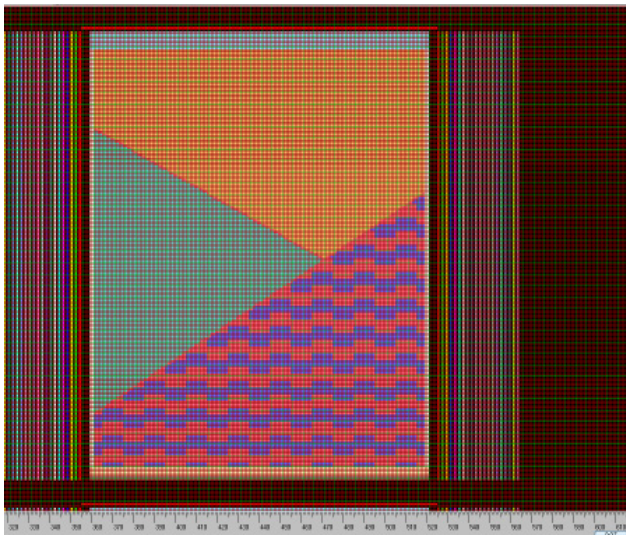
- STEP 9. Fill with Geometric Patterns
- Use > Base Pattern Repeat Tool
- Click > Base pattern area
- Drag an area box around the unit repeat pattern
- Click > OK



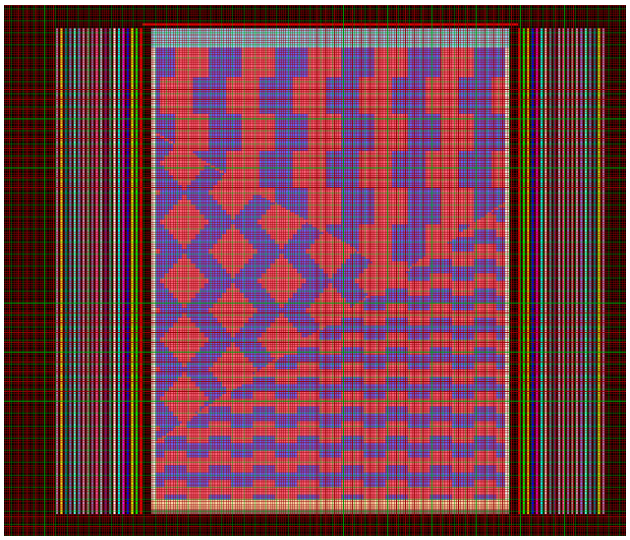
- STEP 10. Fill with Geometric Patterns
- Click > Repeat Area
- Drag an area box around the area to repeat the pattern into on the DesignPpattern
- Click > OK



- STEP 11. Fill with Geometric Patterns
- Click >Delete All to clear colours in Repeat Area
- Click > Add > use tab to add the colour to repeat onto
- Select only the colour required to pattern copy on to



- STEP 12. Fill with Geometric Patterns
- To complete the fill with the geometric pattern
- Click > Exec



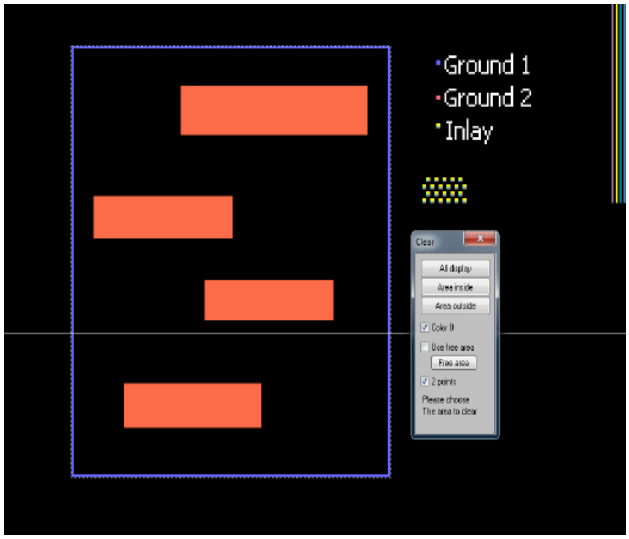
- STEP 13. Fill with Geometric Patterns
- Repeat Steps 9 - 12 to fill all colour blocked areas with pattern
- Click > Cancel when completed



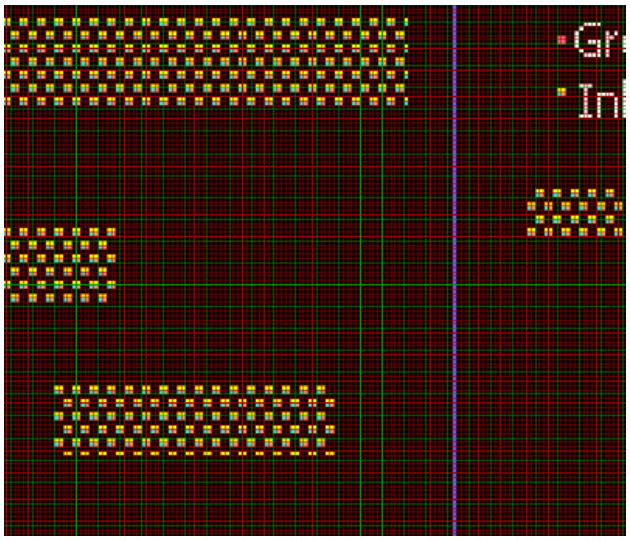
- STEP 14. Set Up Inlay Pattern
- Select inlay pattern from Inlay Surface-building Block library (digital imagery or physical swatch)
- Or design pattern repeat unit on-screen to the left of the Compressed Pattern



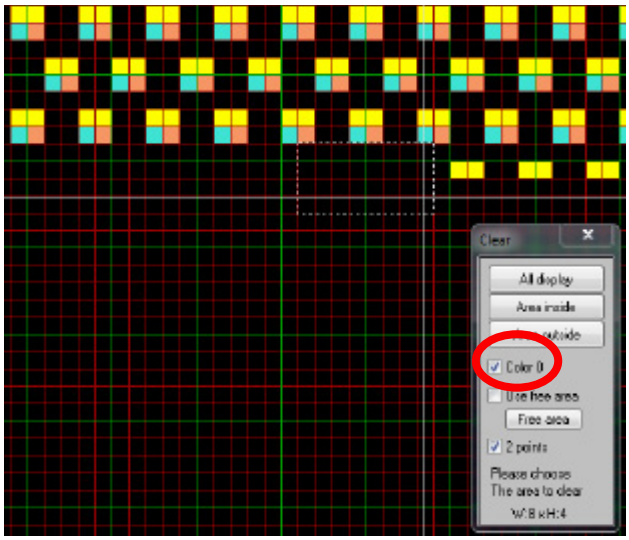
- STEP 15. Creating Inlay Pattern Directly On-screen
- The double bed inlay must use the colour codes from the PAK
- Colour codes for this example are set as 202/ 203 / 3 & 3
- These muse be in the correct order
- Each group of 4 codes = 1 inlay exposed point
- These groups must be surrounded by a minimum of one grid square of colour code 0 on all sides
- Create the base unit repeat



- STEP 16. Set Up Inlay Pattern
- Create the full inlay design to the left of compressed pattern
- Set up a frame the size of the swatch to define the pattern area
- Use Clear tool > Set up inlay blocks to position pattern
- Inlay must be a minimum of 2 needles in from the edges of textile



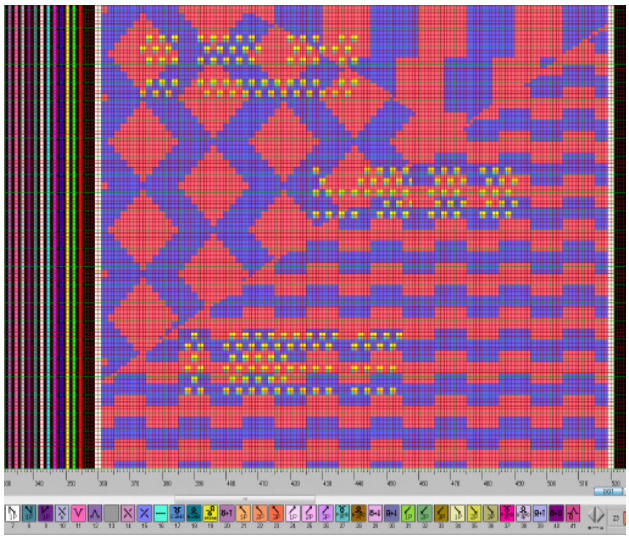
- STEP 17. Set Up Inlay Pattern
- Use Base Pattern Repeat tool to fill with the inlay base unit repeat (see Steps 9-11 with geometric repeat)
- Click > Exec
- Click > Cancel



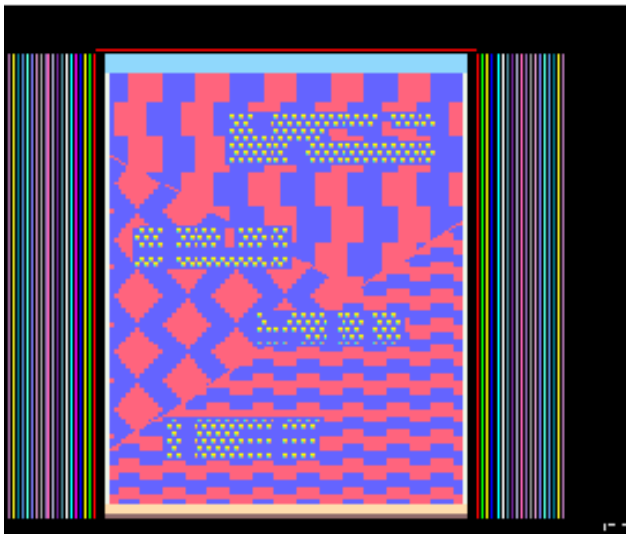
- STEP 18. Set Up Inlay Pattern
- Check all inlay is 4 code groups
- Use the Clear tool to remove partial groups
- Tick Colour 0 = black > to remove any part coded colours



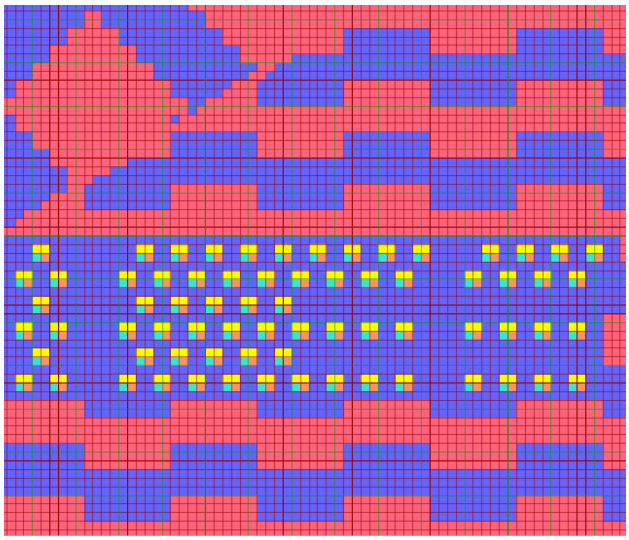
- STEP 19. Set Up Inlay Pattern
- Subtraction of inlay pattern
- Use the Clear tool with colour black
- Vertical subtractions must remove full PAK code groups
- Horizontal subtractions must remove full PAK code groups



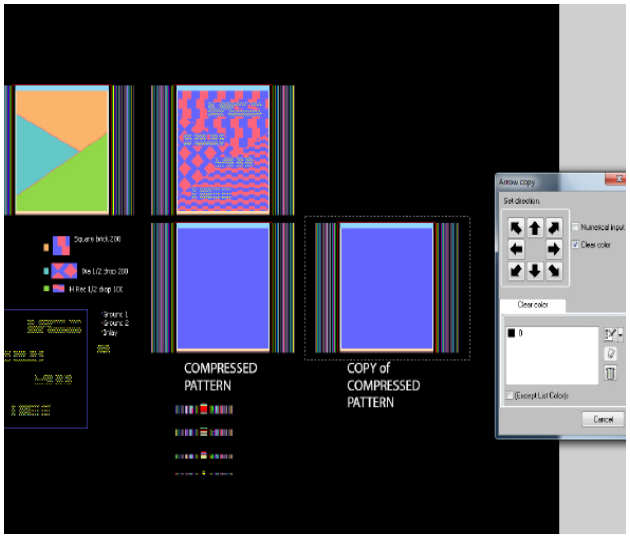
- STEP 20. Set Up Inlay Pattern
- Position inlay on top of ground geometrics in Design Pattern
- Use Area tool > drag a box around the inlay set up > OK
- Use Copy tool > Point Set
- Select Upper > Clear Colour > Colour 0 = black
- Click > Execute



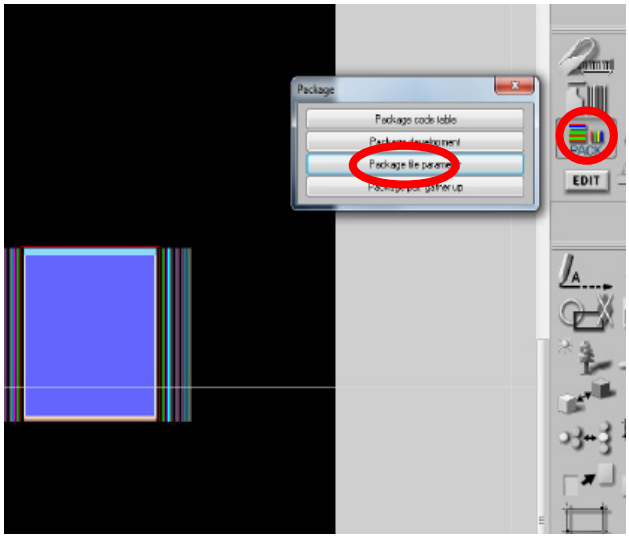
- STEP 21. Set Up Inlay Pattern
- The inlay and ground geometrics are now positioned together on the same layer



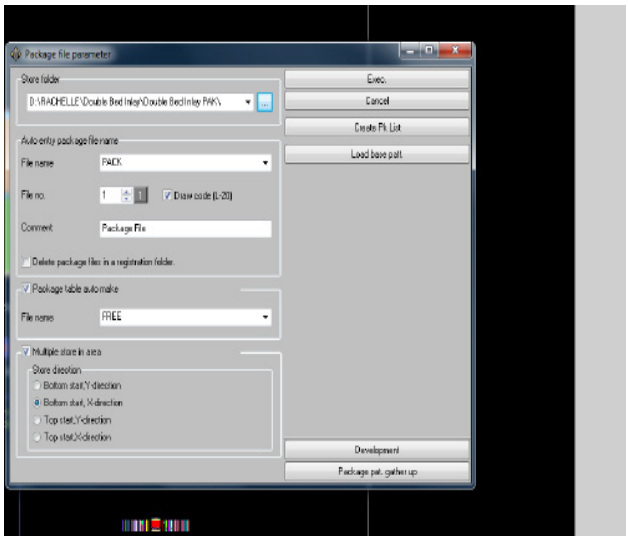
- STEP 22. Set Up Inlay Pattern
- Check all inlay pattern edges
- Clear around the inlay > Change the ground to code 200 anywhere there is are inlay codes
- 1 course above and below
- 2 needles on the side edges
- Use Fill tool & Line tool



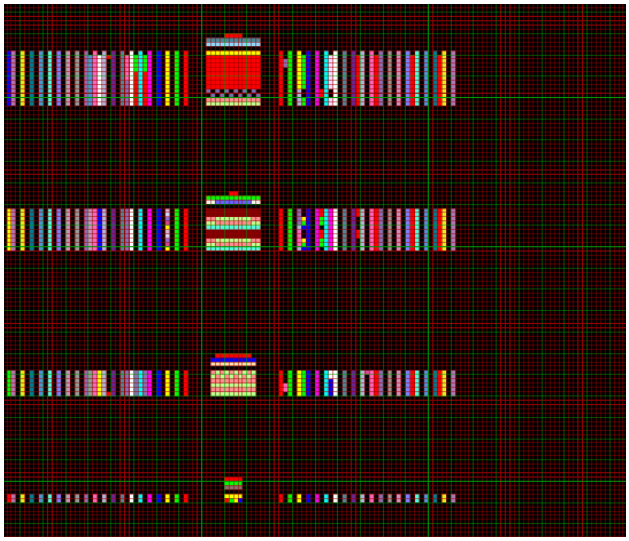
- STEP 23. Pattern Development
- Copy the compressed pattern
- Use Area tool > drag a box over the Compressed Pattern > OK
- Use Copy tool > Arrow > Right
- Click > Cancel



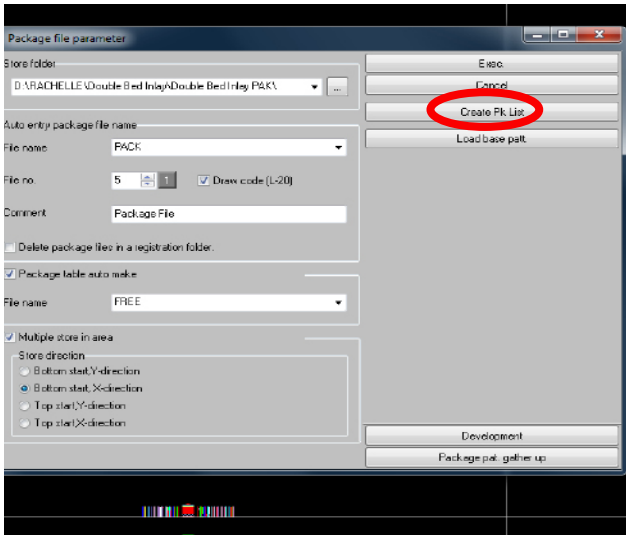
- STEP 24. Pattern Developentt
- Save the Package (PAK) files
- Click PACK > Package File Parameter



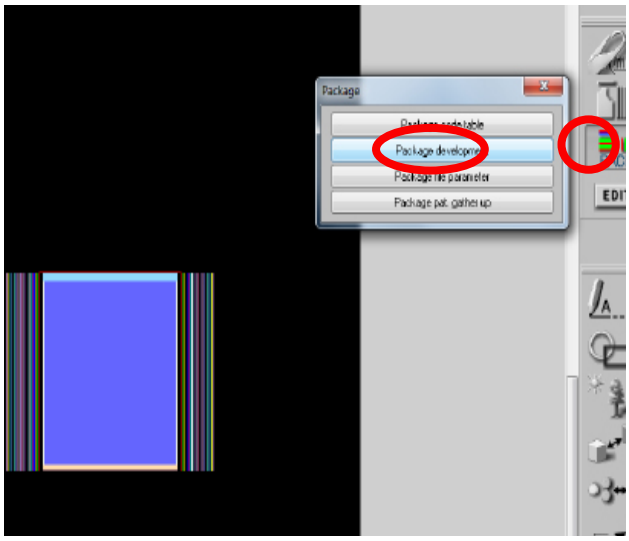
- STEP 25. Pattern Development
- Browse and set up a PAK folder > OK
- File name = PACK
- File No. = 1
- Tick > Draw code
- Tick > Package table auto make
- File name = FREE
- Tick > Multiple storage area
- Tick > Bottom start X-direction



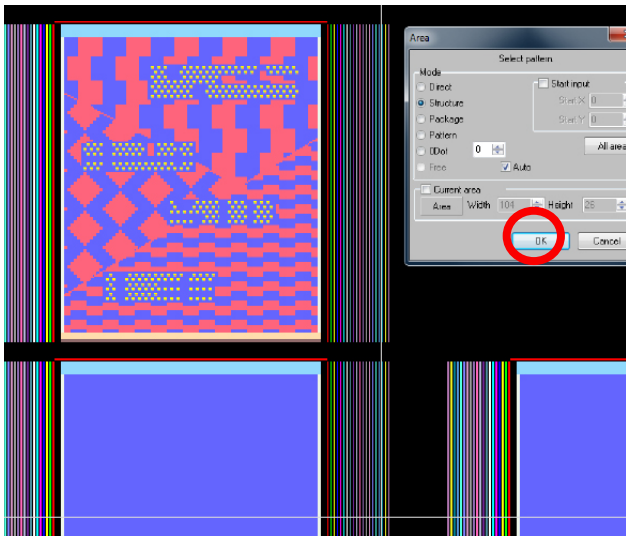
- STEP 26. Pattern Development
- Click > Exec
- Drag an area around the packages
- Click > OK



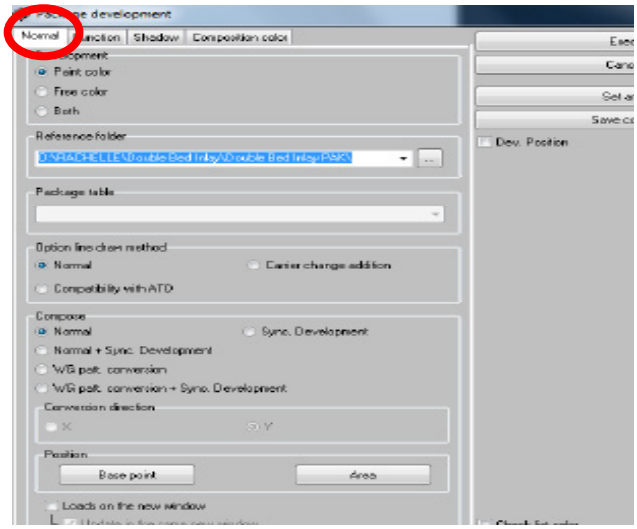
- STEP 27. Pattern Development
- Click > Create Pk. List
- Click > Cancel



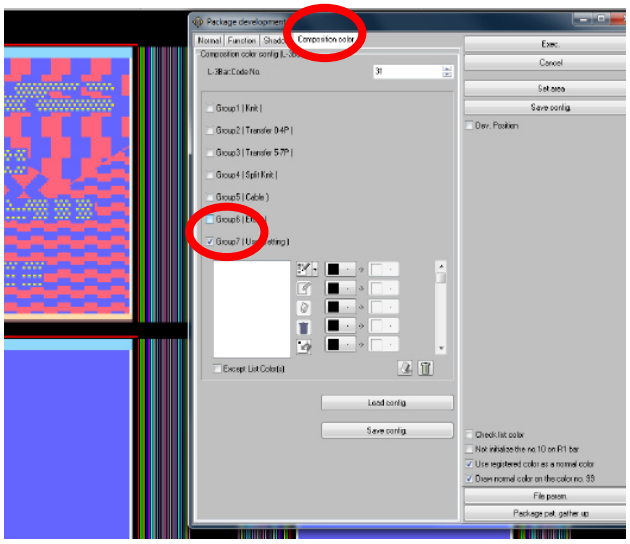
- STEP 28. Pattern Development > Set up L3 Bar
- Click > PACK > Package Development



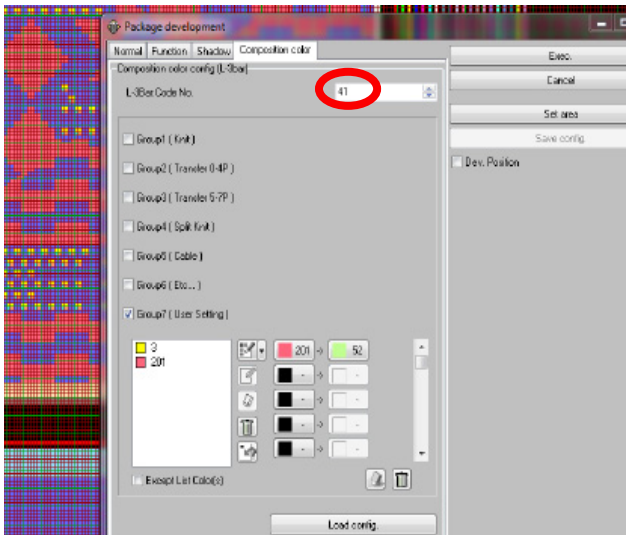
- STEP 29. Pattern Development > Set up L3 Bar
- Area pop up box > Click inside the Design Pattern
- Click > OK



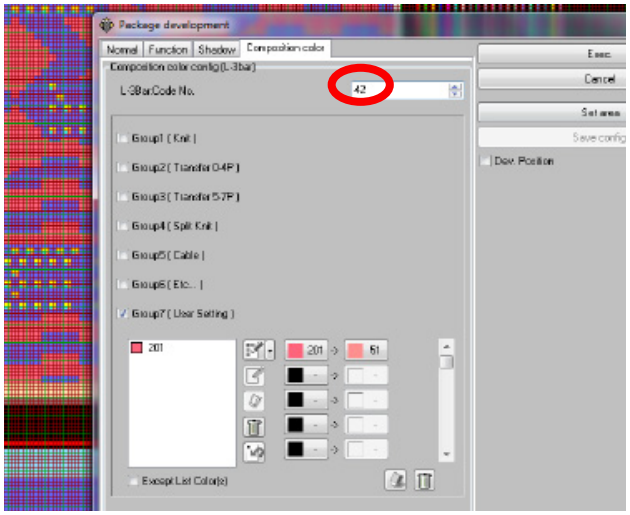
- STEP 30. Pattern Development > Set up L3 Bar
- Normal tab
- Select > Paint Colour
- Option line draw method > Normal
- Compress > Normal
- Select > Loads on same window



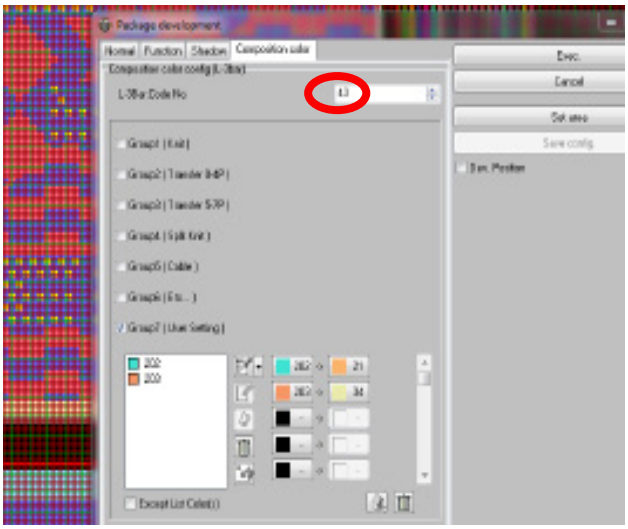
- STEP 31. Pattern Development > Set up L3 Bar
- Colour Composition Tab
- Select > Group 7 (User Setting)



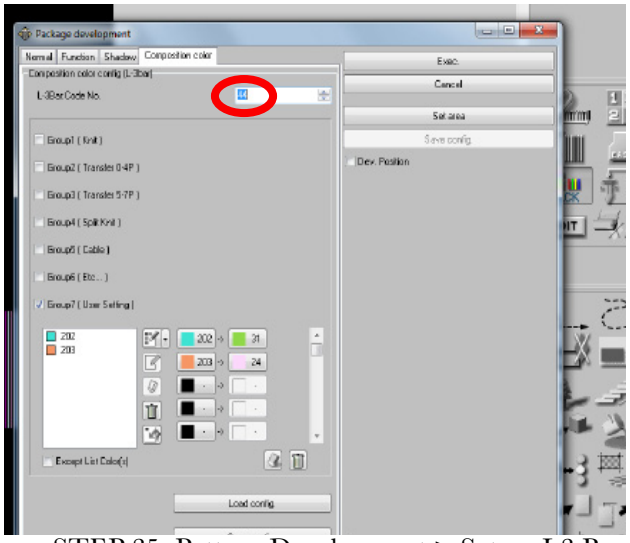
- STEP 32. Pattern Development > Set up L3 Bar
- L3Bar colour code number = 41
- Select > Group 7 (User setting)
- Click > Add > pull down tab
- Set up colour 3 knits as a stitch code 3
- 201 > colour 201 becomes stitch code 52



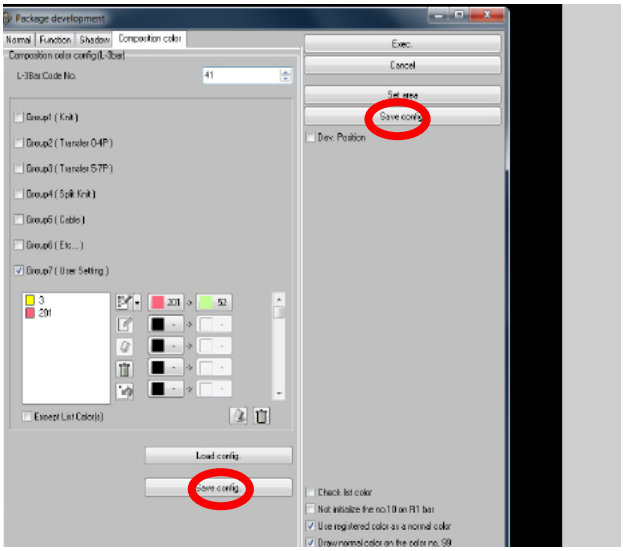
- STEP 33. Pattern Development > Set up L3 Bar
- L3Bar colour code number = 42
- Select > Group 7 (User setting)
- Click > Add > pull down tab
- Set up colour 201 > colour 201 becomes stitch code 51 (front knit



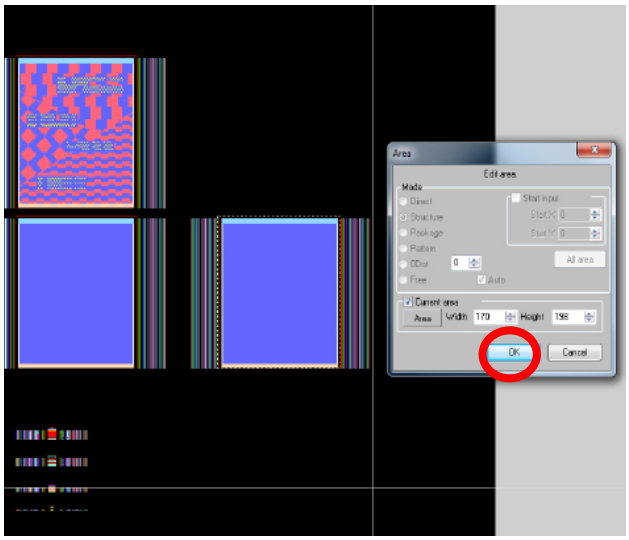
- STEP 34. Pattern Development > Set up L3 Bar
- L3Bar colour code number = 43
- Select > Group 7 (User setting)
- Click > Add > pull down tab
- Set up colour 202 > colour 202 becomes stitch code 21
- Set up colour 203 > colour 203 becomes sticth code 34



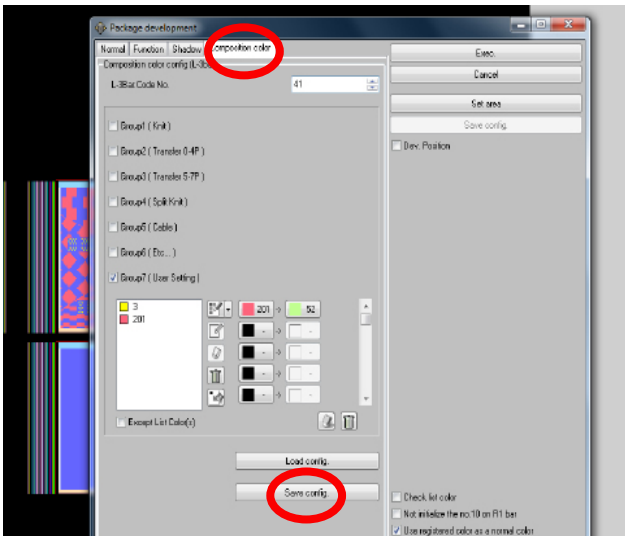
- STEP 35. Pattern Development > Set up L3 Bar
- L3Bar colour code number = 44
- Select > Group 7 (User setting)
- Click > Add > pull down tab
- Set up colour 202 > colour 202 becomes stitch code 31
- Set up colour 203 > colour 203 becomes sticth code 24



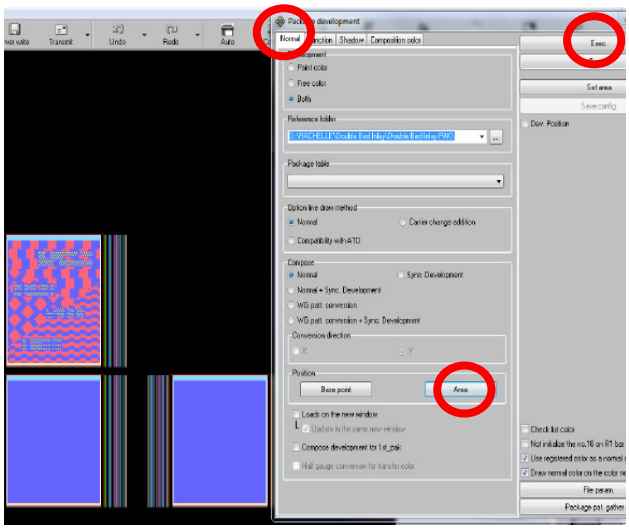
- STEP 36. Pattern Development > Set up L3 Bar
- Click > Save Config (below Load config)
- Browse and find file folder
- Name of file
- Click > Save
- Click > Save Config (below Set Arrea)
- Click > Cancel



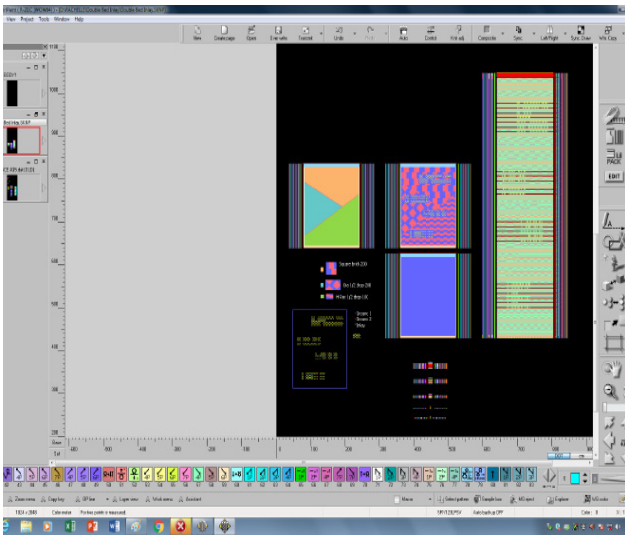
- STEP 37. Package Development
- PACK > Package Development
- Click > Inside Compressed Pattern > OK



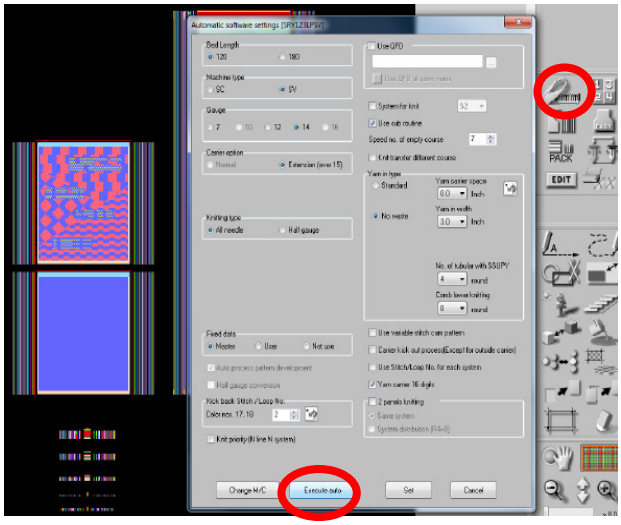
- STEP 38. Package Development
- Composition Colour tab
- Load Cofig
- Find file > Select > Open
- Check correct information is in L3Bar Code No.



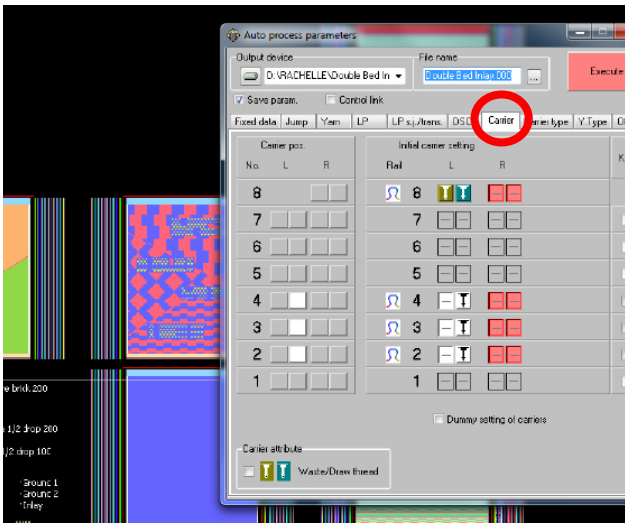
- STEP 39. Package Development
- Normal Tab
- Click > Area
- Click > Inside Design Pattern > OK
- Click > Exec



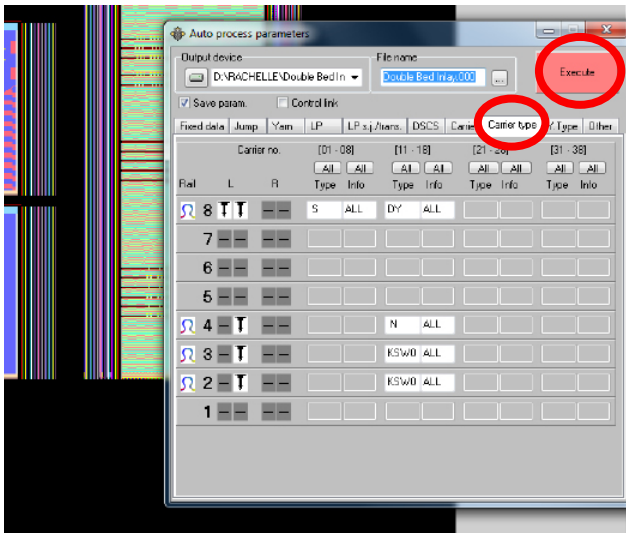
- STEP 40. Package Development
- This creates the Epanded Pattern



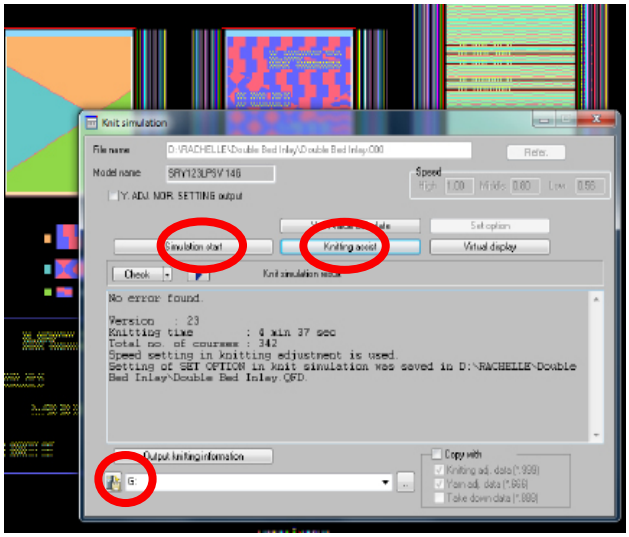
- STEP 41. Automatic Processing
- Click > Automatic Software Process
- Click > Execute auto
- Click > Inside the Expanded Pattern > OK



- STEP 42. Automatic Processing
- Check Carriers Tab
- Need a minimum of 2 carriers for ground
- Need 1 inlay carrier
- Need Carrier 8 & 18 (do not touch set up)
- Click > Execute



- STEP 43. Automatic Processing
- Check Carrier TYpe tab
- Inlay carrier = N
- Ground Carriers = KSW0 (non swing) or KSW1 (swing)
- Click > Execute
- Click > OK



- STEP 44. Automatic Processing Completed
- Click > Simulation start
- Click> Knitting assist
- Click > OK
- Copy .000 file to usb for knitting

- Save old-format > Save (Over write)

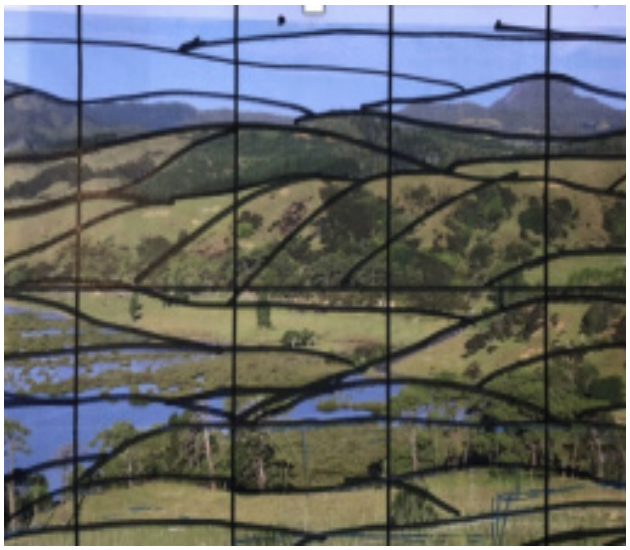
APPENDIX H.
How to Build an Intarsia Inlay Knitted Surface Topography Series



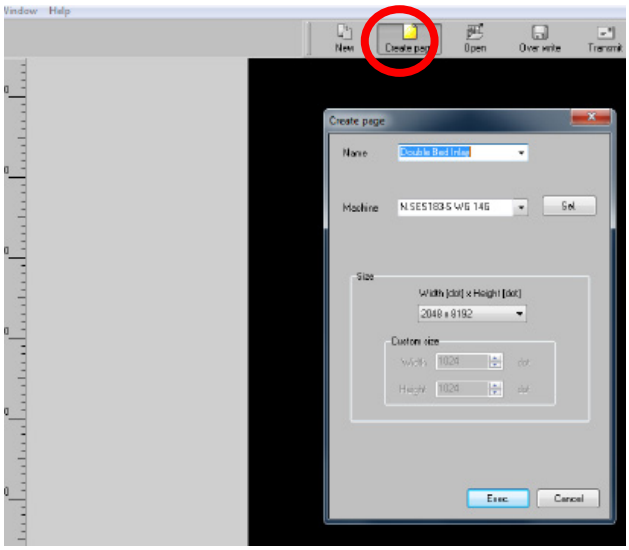
- STEP 1. Select Photographic Image



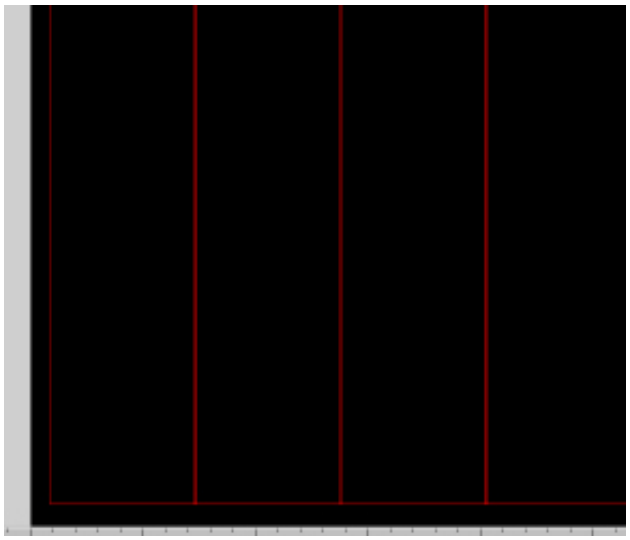
- STEP 2. Divisions of Landscape
- Separate the image into the number of vertical panels in the series
- Separate the image into four horizontal sections to help with on screen proportion



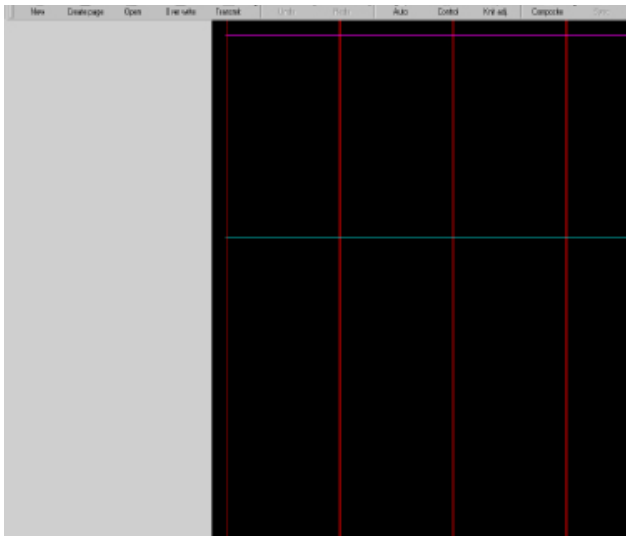
- STEP 3. Divisions of Landscape
- Draw by hand sections for geometrics ground patterns



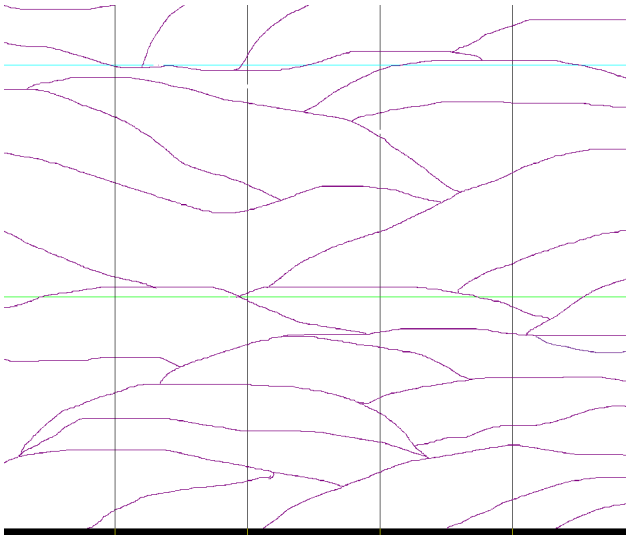
- STEP 3. Set Up Ground in Old-format
- Use Create page
- Set width and height required
- Click > Exec



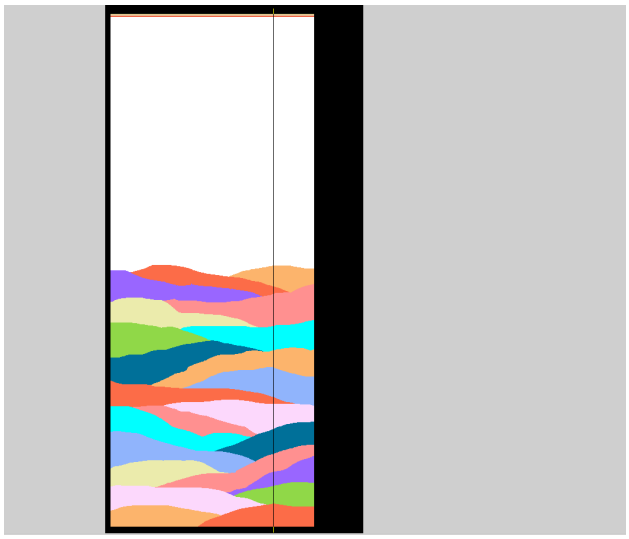
- STEP 5. Set Up Ground in Old-format
- Divide into Vertical Individual Panels
- Use Clear tool > draw rectangle half the length and the full width required for the multiple panels
- Use colour 0 = black > 2 needle width to separate into individual panels



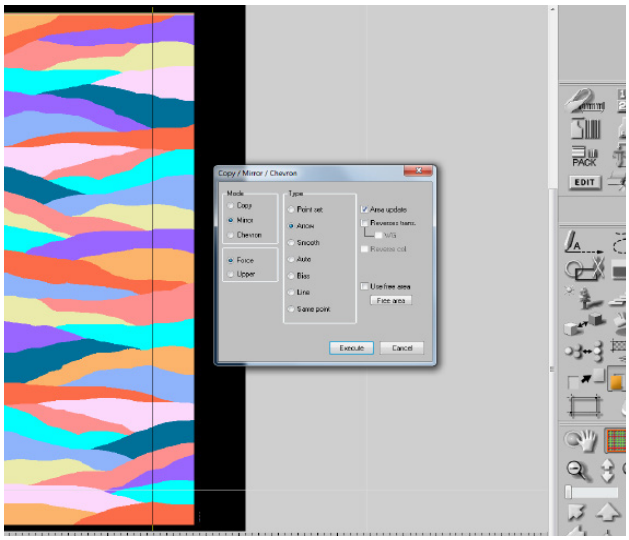
- STEP 6. Set Up Ground in Old-format
- Divide Horizontally into Sections
- Use Line tool > divide horizontally into four even parts
- Save old-format > Save (Over write) Blank Panel Set-Up
- Saving as a separate files during the process will allow you to use for the inlay panel set-up



- STEP 7. Set Up Ground in Old-format
- Draw Sections from Photograph
- Fill panels with a ground colour
- Draw across the mutilple panels the section divisions
- Draw half the panel only
- Use Line tool > Line mode > Free
- Save old-format > Save (Over write) > Geo Sections



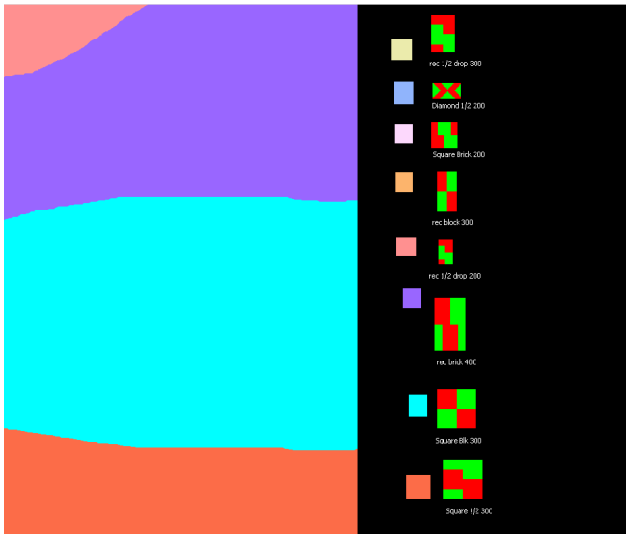
- STEP 8. Set Up Ground in Old-format
- Colour block half the panel only
- Select a different colour for each ground geometric (or if using the same geometric ground more than once = use the same colour multiple times)
- Use the Fill tool to fill each section with colour Select Geometrics



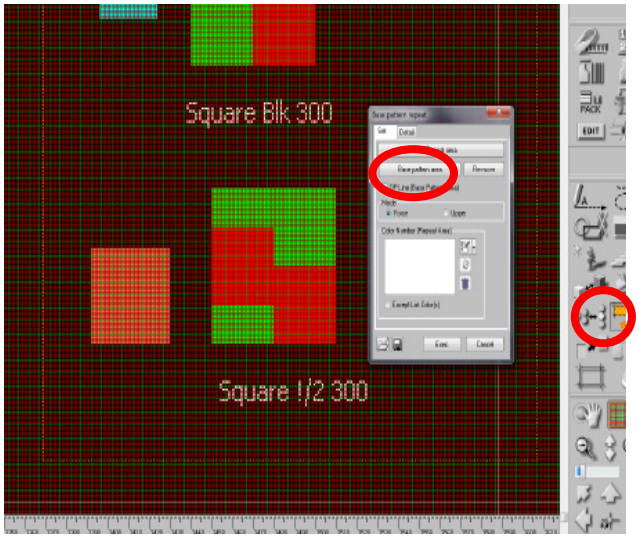
- STEP 10. Set Up Ground in Old-format
- To colour block the full length of the panels
- Use Area tool > select around the colour blocked section
- Click > OK
- Use Copy tool > Mirror > Arrow > Up
- Blend any odd intersections of colour blocking
- Save old-format > Save (Over write) > Colour Block Ground



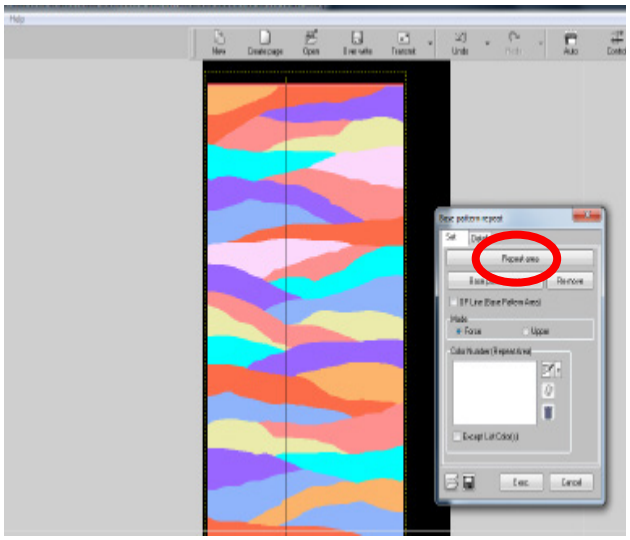
- STEP 11. Set Up Ground in Old-format
- Select ground links-links patterns
- Select patterns and scales from the Links-Links Surface-building Block library (digital imagery or physical swatches)



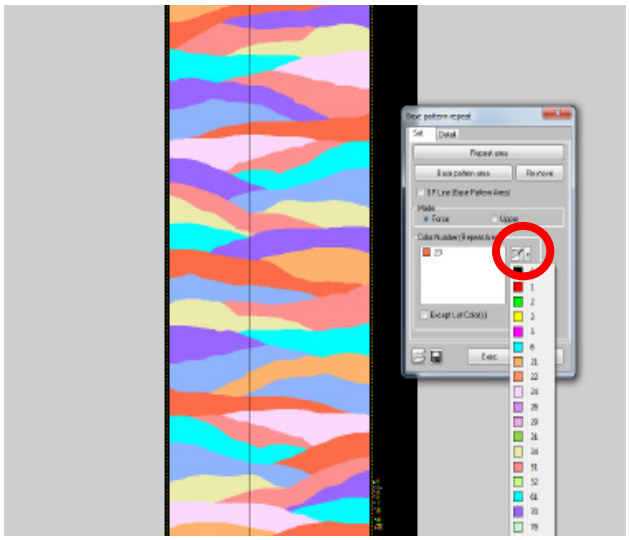
- STEP 11. Set Up Ground in Old-format
- Place the links-links pattern repeat unit on-screen to the right of the multiple panels next to the colour to fill



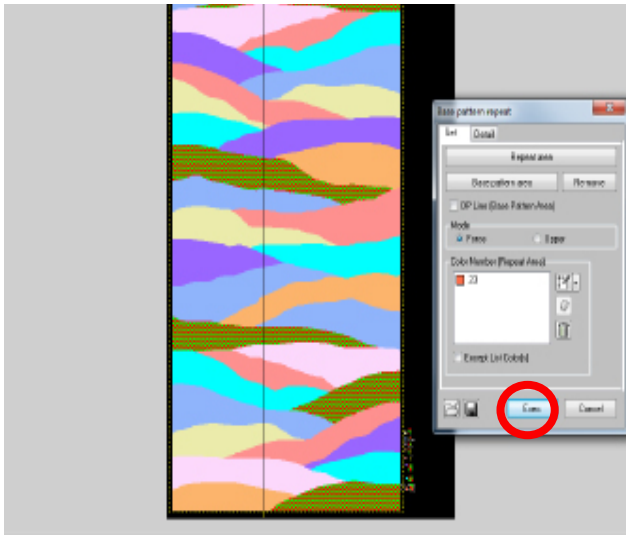
- STEP 12. Set Up Ground in Old-format
- Fill with links-links grounds
- Use Base Pattern Repeat Tool
- Click > Base pattern area
- Drag an area box around the unit repeat pattern
- Click > OK



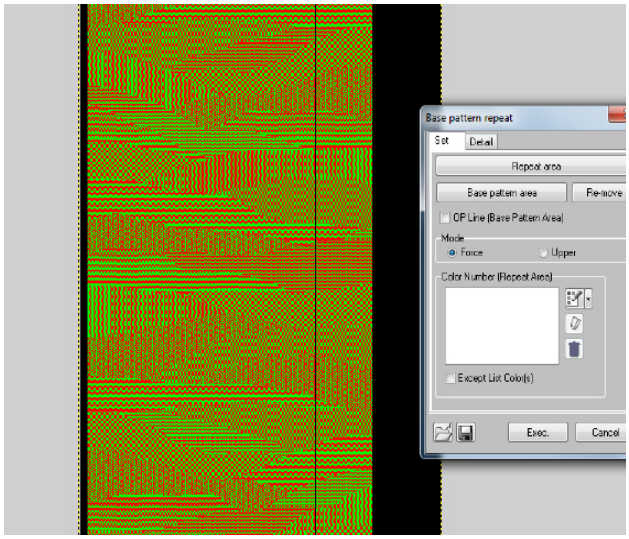
- STEP 13. Set Up Ground in Old-format
- Click > Repeat Area
- Drag an area box around the multiple panels
- Click > OK



- STEP 14. Set Up Ground in Old-format
- Click >Delete All to clear colours in Repeat Area
- Click > Add > use tab to add the colour to repeat onto
- Select only the colour required to pattern copy onto



- STEP 15. Set Up Ground in Old-format
- To complete the fill
- Click > Exec



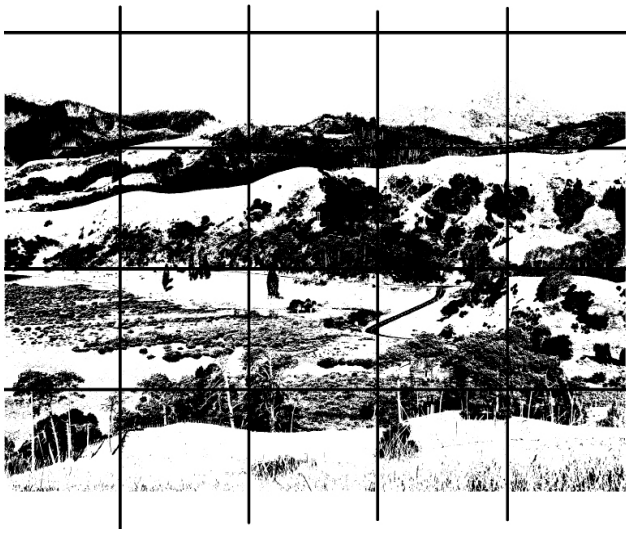
- STEP 16. Set Up Ground in Old-format
- Repeat Steps 12 - 15 to fill all colour blocked areas with geometric pattern
- Click > Cancel when completed
- Save old-format > Save (Over write) > Multiple Panel Grounds



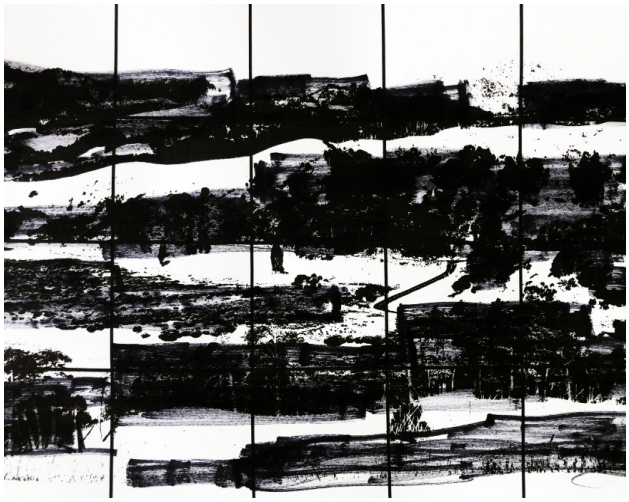
- STEP 17. Generate Inlay Positioning in Photoshop
- Open image in Photoshop
- Separate the image into the number of vertical panels in the series
- Separate the image into four horizontal sections to help with on screen proportion



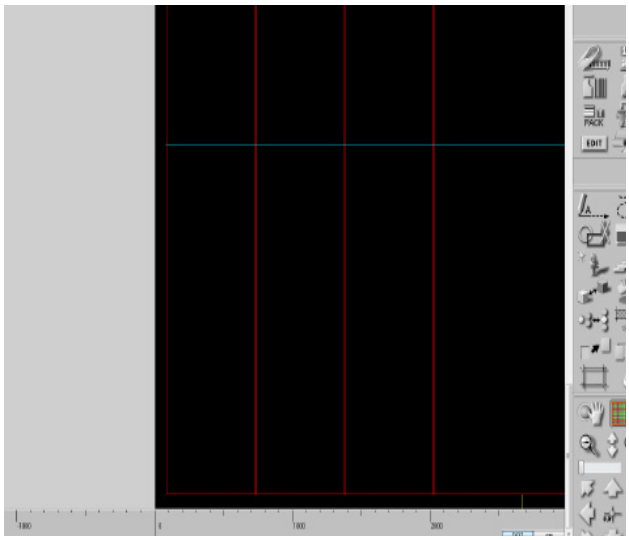
- STEP 18. Generate Inlay Positioning in Photoshop
- Image > Mode > Greyscale
- Discard Colour Information > Discard



- STEP 19. Generate Inlay Positioning in Photoshop
- Use Image > Adjustments > Posterize
- Adjust to suit design



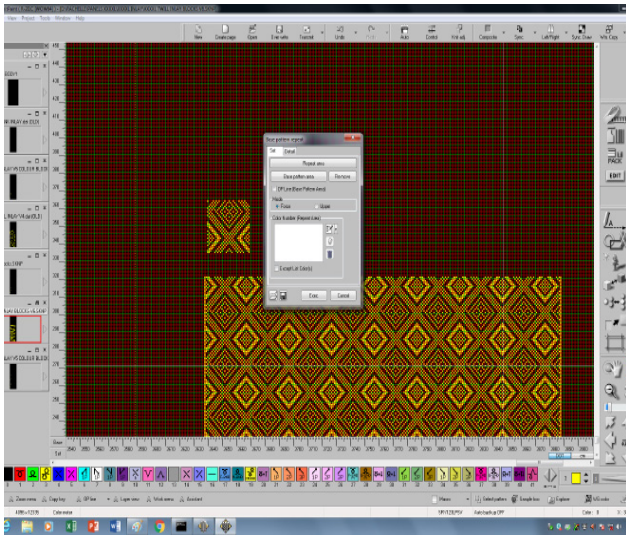
- STEP 20. Generate Inlay Positioning in Photoshop
- Print off the image and hand draw the positioning of the blocks of inlay



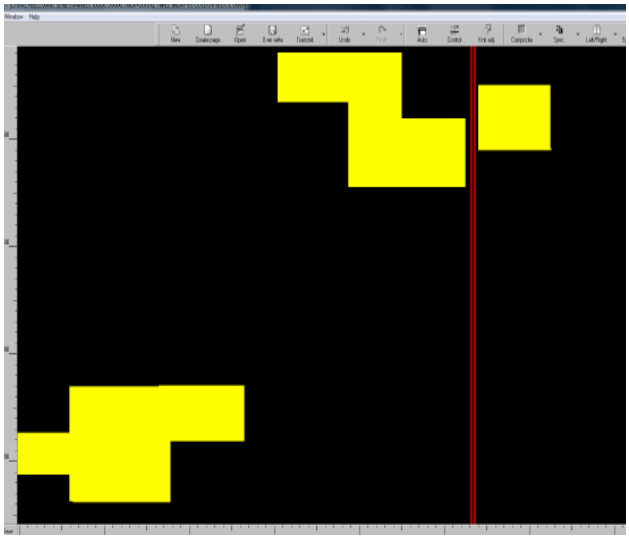
- STEP 21. Multiple Panel Inlay Set-Up in Old-format
- File > Open File > Blank Panel Set Up
- Frame the vertical panels with lines
- Use Line tool > divide horizontally into four even parts



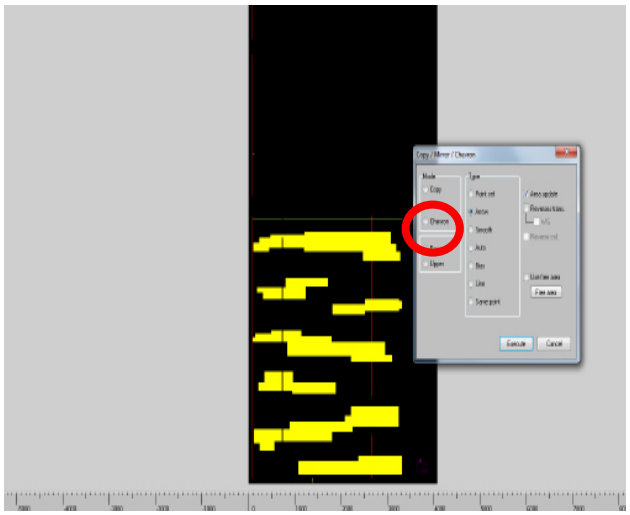
- STEP 22. Multiple Panel Inlay Set-Up in Old-format
- Select inlay pattern from Inlay Surface-building Block library (digital imagery or physical swatch)
- Or design pattern repeat unit on-screen to the right of the multiple panels



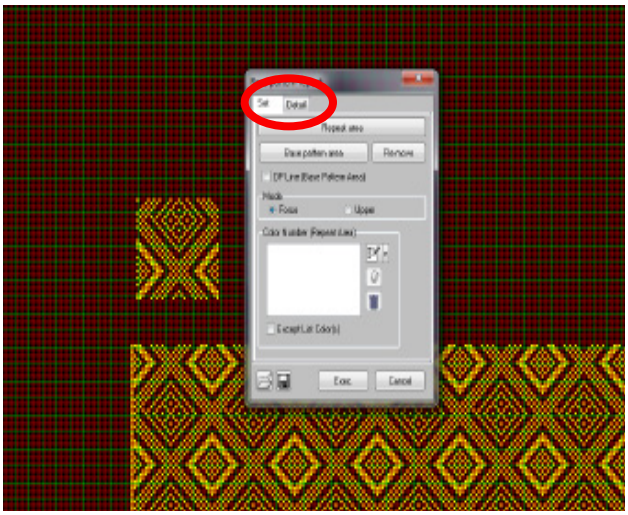
- STEP 23. Multiple Panel Inlay Set-Up in Old-format
- Place the inlay pattern repeat unit on-screen to the right of the multiple panels
- Check the pattern repeat



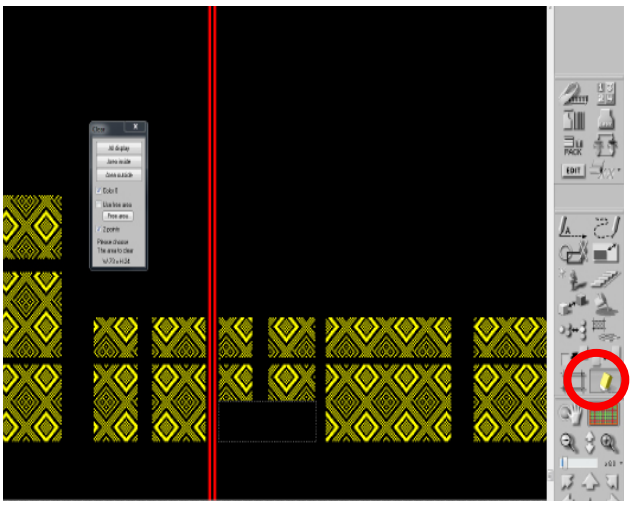
- STEP 24. Multiple Panel Inlay Set-Up in Old-format
- Transfer inlay position from image
- Colour block half the panel only
- The first block must be on an even numbered course from the bottom of the panel with an even number of courses between the blocks
- Clear all the panel side edges a minimum of 2 needles
- All blocks must contain an even number of courses



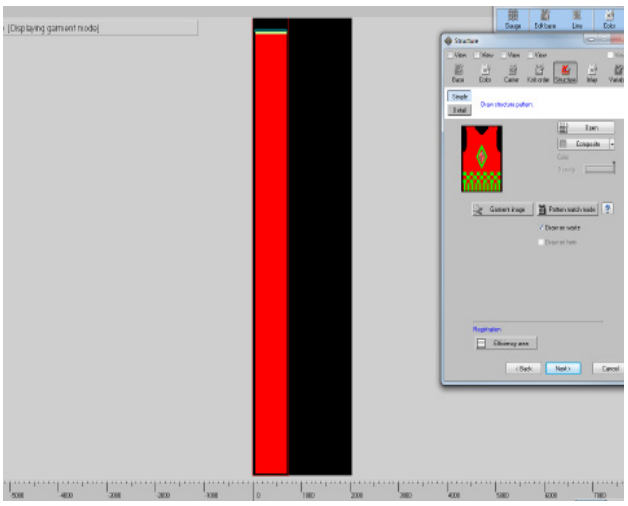
- STEP 25. Multiple Panel Inlay Set-Up in Old Format
- Use Area tool > select colour blocked section > Click > OK
- Use Copy tool > Mirror > Arrow > Up
- Check positioning of the inlay in full length for even courses between blocks
- Save old-format > Save (Over write) > Colour Block Inlay



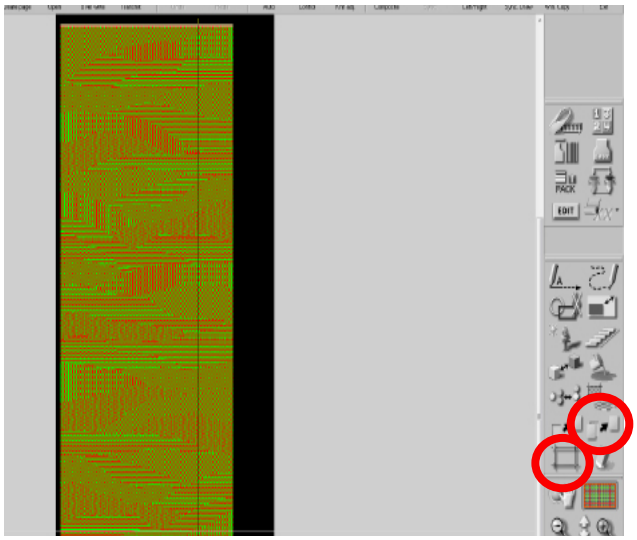
- STEP 26. Multiple Panel Inlay Set-Up in Old Format
- Use Base Pattern Repeat tool to fill with the inlay base unit repeat (see steps 12-16)
- Click > Exec
- Click > Cancel
- Check all panel edges minimum of 2 needles in are clear of inlay



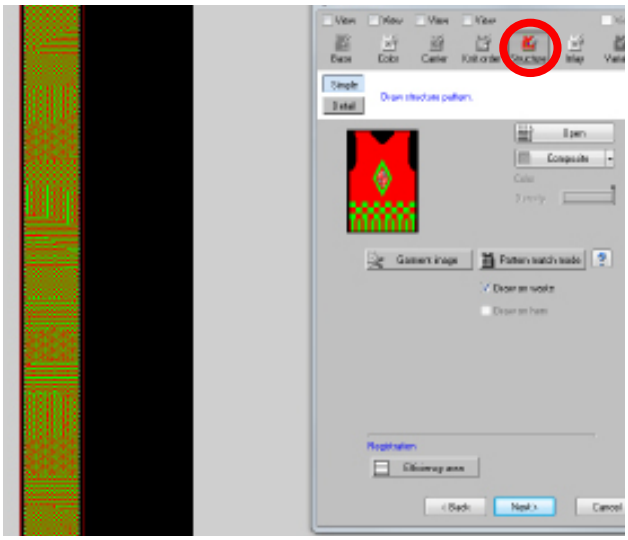
- STEP 27. Multiple Panel Inlay Set-Up in Old Format
- Subtraction of inlay pattern across panels
- Use the Clear tool with Colour 0 = black
- Vertical subtractions can be any amount but need to consider the floats between areas
- Horizontal subtractions must be even numbered amounts and have even numbered courses between inlay sections
- Save old format > Save (Over write) >Multiple Panel Inlay



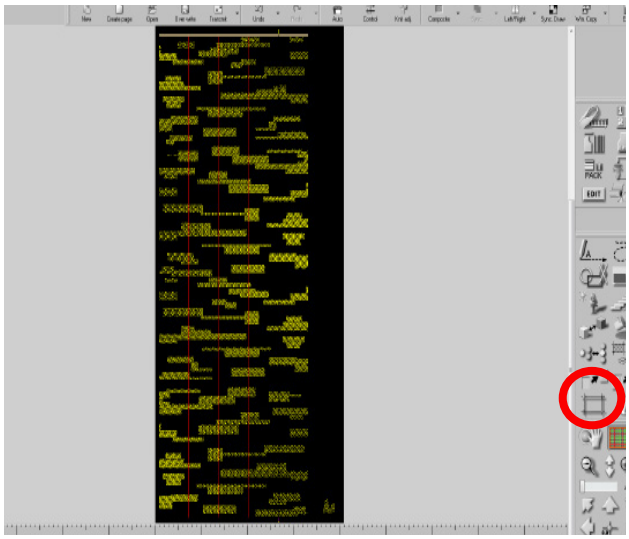
- STEP 28. Surface Assemblage in Automatic Software
- Set Up a New Swatch in Automatic Software KnitPaint
- File > New
- Set up swatch the length and width required for 1 panel
- See Appendix E. How to Set up an All-Over Inlay Swatch Steps 1-8
- This is the Automatic Software Panel file



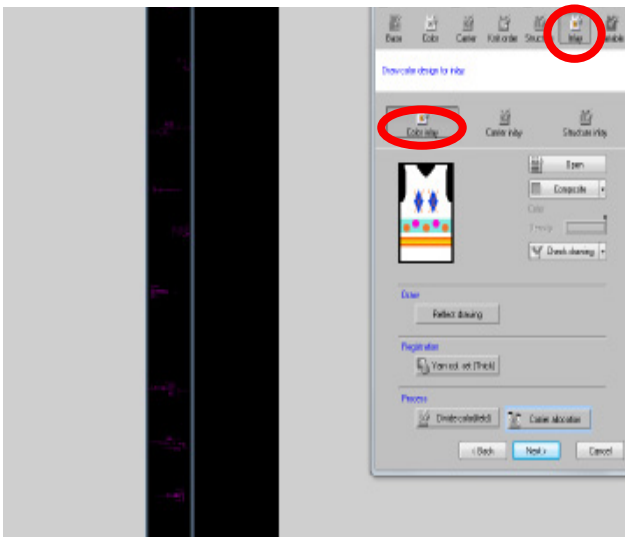
- STEP 29. Surface Assemblage in Automatic Software
- Go to the Multiple Panel Grounds page in old format
- Use Area tool > select 1 panel > OK
- Use Copy tool > Point set > Execute



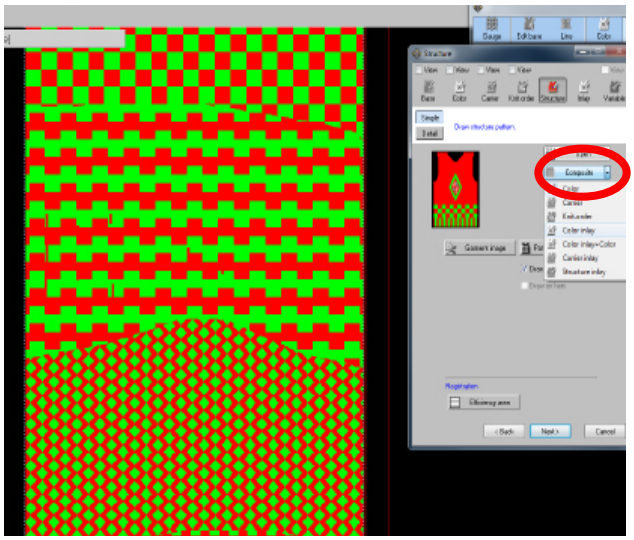
- STEP 30. Surface Assemblage in Automatic Software
- Switch to the Automatic Software Panel file > Structure page
- On the Structure page place the copy of the links-links ground panel



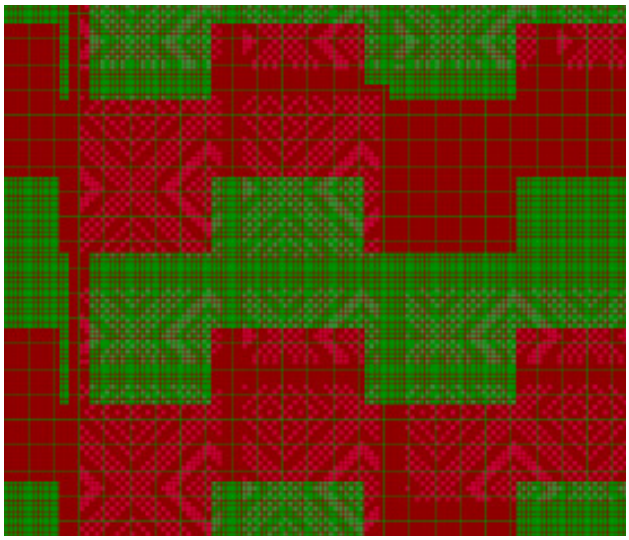
- STEP 31. Surface Assemblage in Automatic Software
- Go to the Multiple Inlay Panel page in old format
- Use Area tool > drag a box to select 1 panel > OK
- Use Copy tool > Point set > Execute



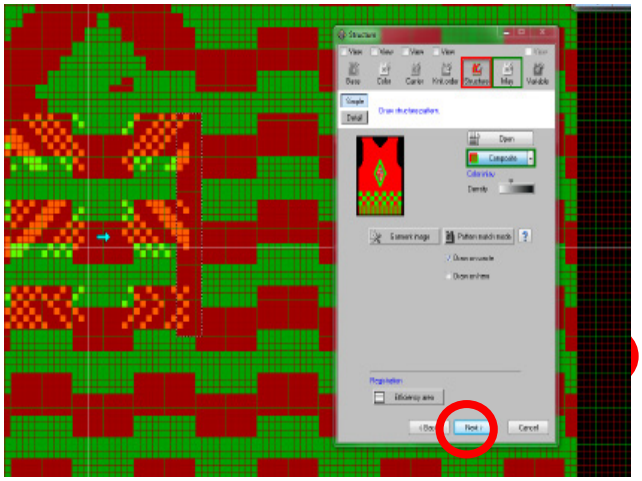
- STEP 32. Surface Assemblage in Automatic Software
- Switch to the Automatic Software Panel file > Inlay Colour page
- On Inlay > Colour Inlay page place the copy of the inlay panel



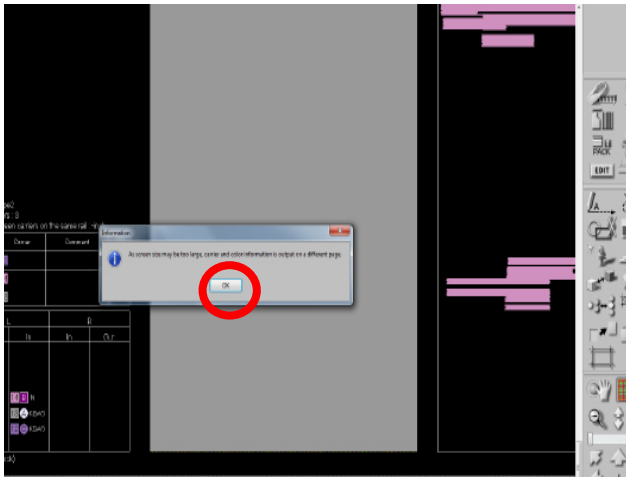
- STEP 33. Surface Assemblage in Automatic Software
- Check inlay pattern edges on the Structure Page
- Click > Composite > pull down tab and select Colour Inlay
- Use the slider to adjust the opacity



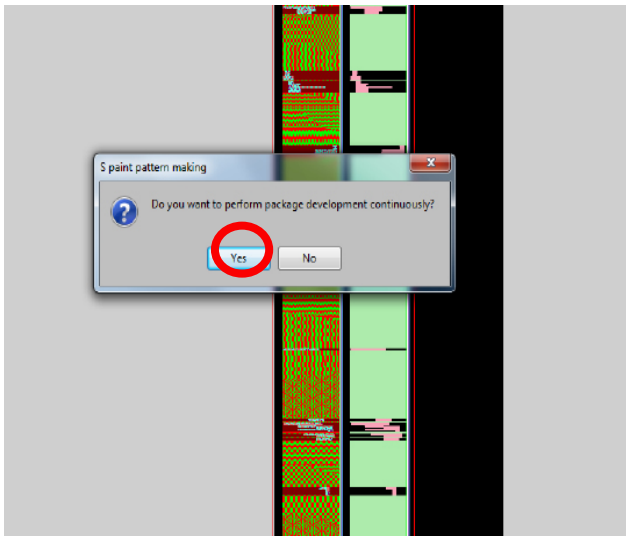
- STEP 34. Surface Assemblage in Automatic Software
- Clear stitch structure on vertical inlay edges
- Change on edges code 2 = green to code 1 = red
- Change the structure 2 needle inside and outside the inlay pattern to front bed single jersey knit
- This prevents tearing at the intarsia inlay edge in the knitting stage



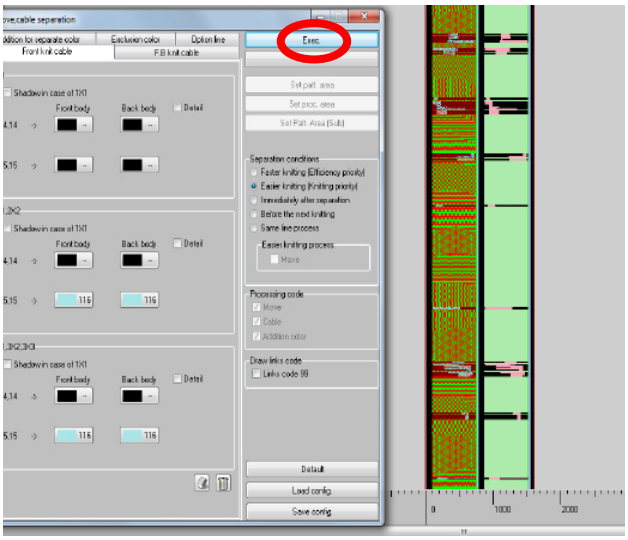
- STEP 35. Atomatic Software Development
- Click > Next to start automatic software development



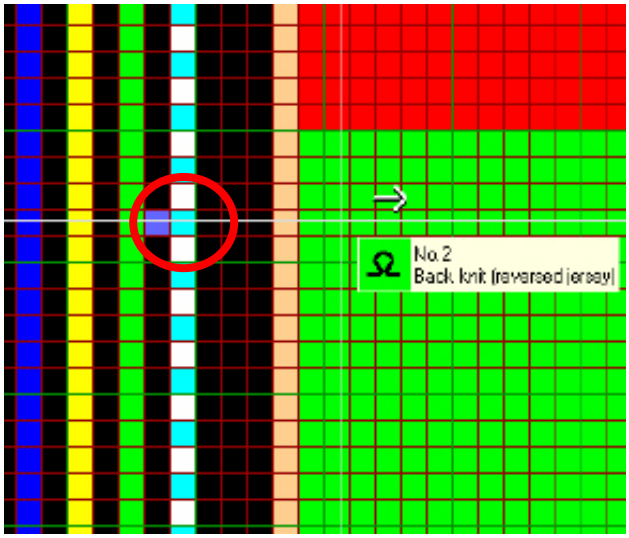
- STEP 36. Atomatic Software Development
- Overwrite warning > OK
- This step takes considerable time as the file is so large please leave the computer to process



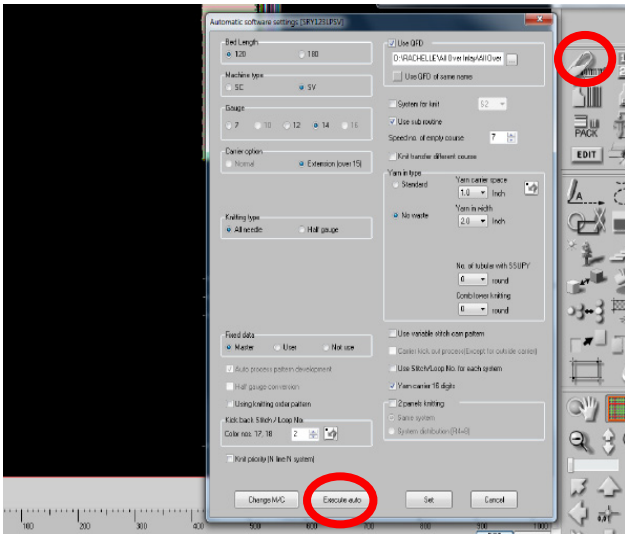
- STEP 37. Atomatic Software Development
- S paint pattern making
- Click > Yes



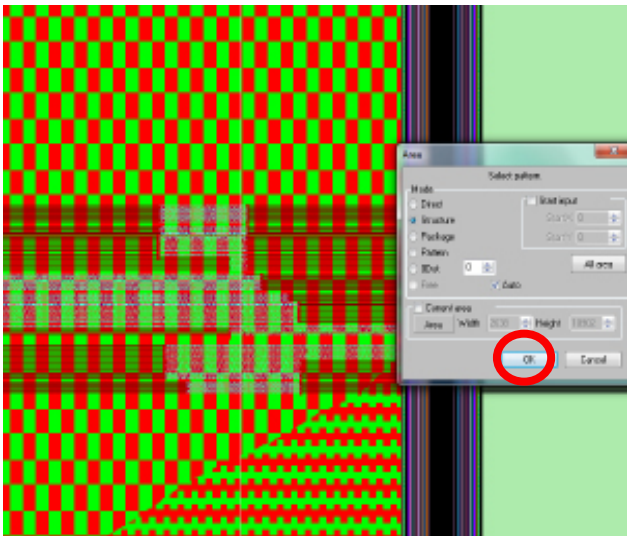
- STEP 38. Atomatic Software Development
- Move Cable Separation - Leave all settings as default
- Click > Exec



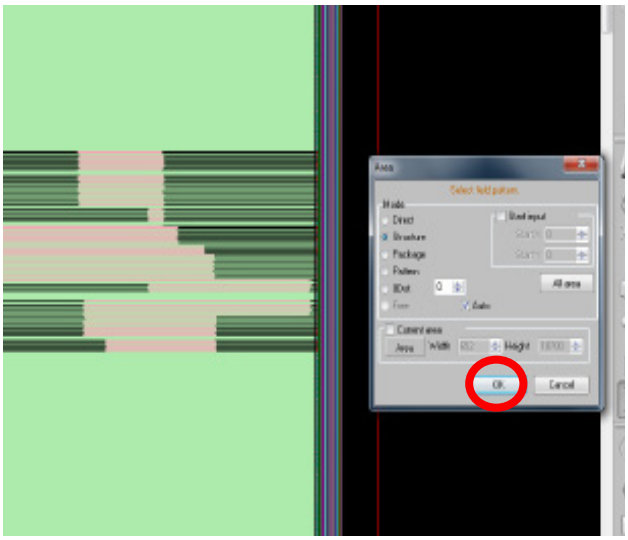
- STEP 39. Sequential Knitting
- On the developed page in R1 add a single 200 code for each segment of sequential knitting
- The code 200 must be on an odd course so the knitting machine is knitting from the left hand side
- Place code 200 on single bed knitting only not inlay areas



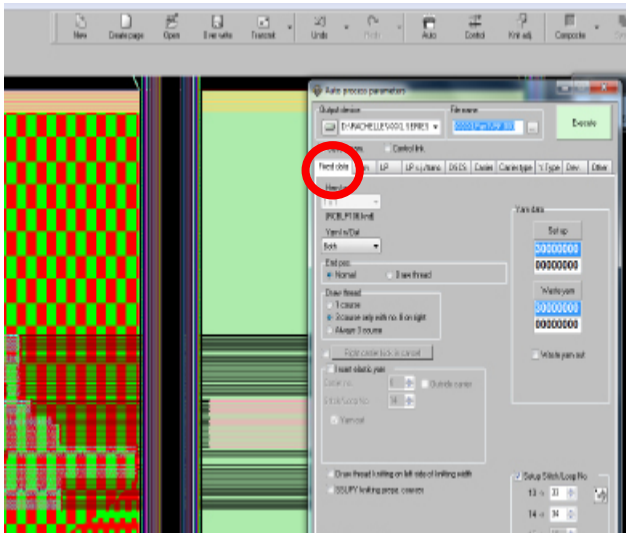
- STEP 40. Automatic Software Processing
- Click > Automatic Software Setting
- Click > Execute Auto



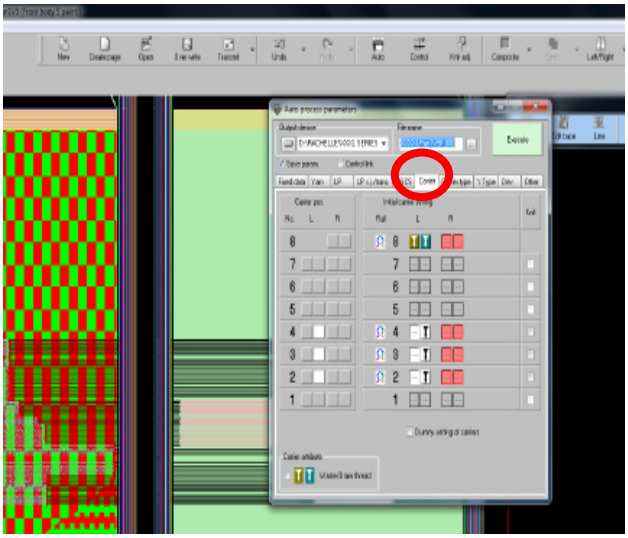
- STEP 41. Automatic Software Processing
- Click > inside Structure pattern > OK



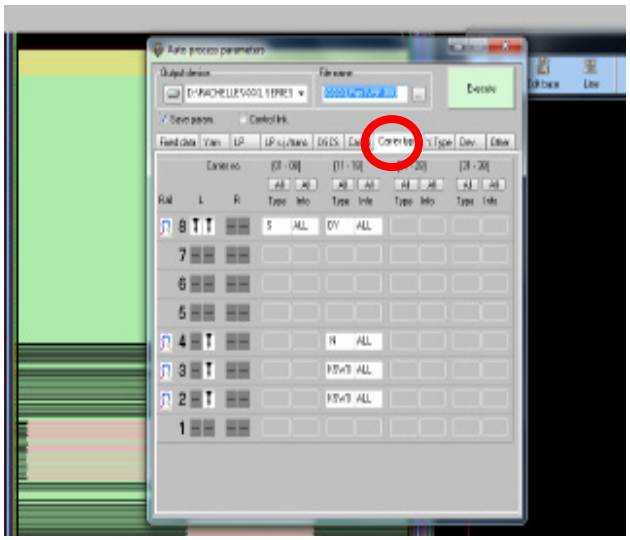
- STEP 42. Automatic Software Processing
- Click > inside Field pattern >OK



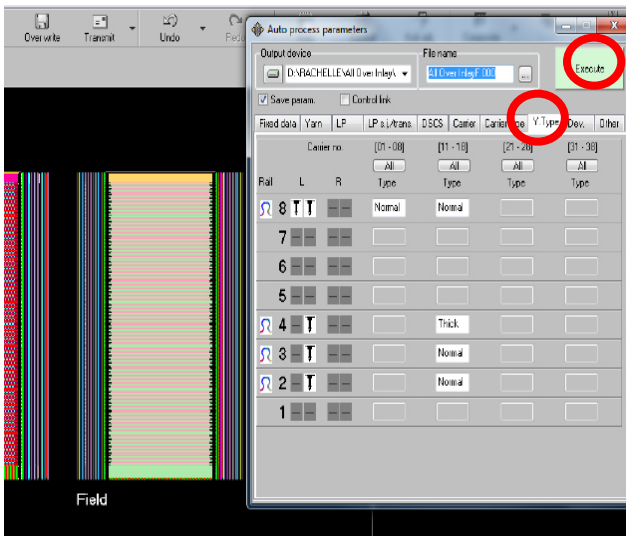
- STEP 43. Automatic Software Processing
- Auto Process parameters
- Check Fixed Data tab > Check Set up & Waste yarn carriers



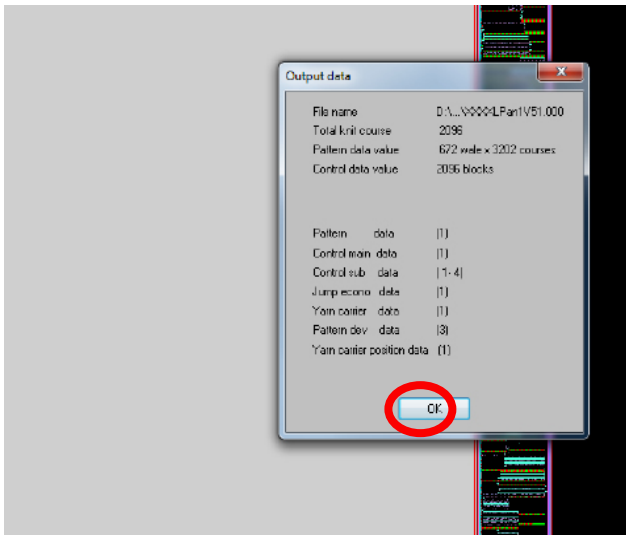
- STEP 44. Automatic Software Processing
- Carrier tab
- Carrier 8 in use from the left and right (never adjust)
- Carriers 14 & 13 & 12 in use from the left



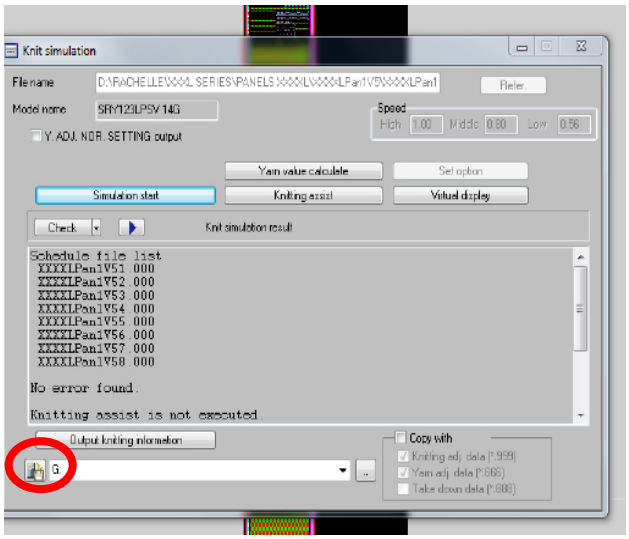
- STEP 45. Automatic Software Processing
- Carrier tab
- Carrier 14 = N = Normal = Inlay carrier
- Carrier 13 & 12 = KSW0 = Non swing = Ground & Waste



- STEP 46. Automatic Software Processing
- Yarn Type tab
- Carrier 14 = Thick
- Carrier 13 & 12 = Normal
- Click > Execute



- STEP 47. Automatic Software Processing
- Output data > OK
- This will pop up for every sequential file >
- Click > OK for each file



- STEP 48. Automatic Software Processing Completed
- Click > Simulation start
- The sequential files are listed
- Do not use Knitting Assist if the file is too large
- Copy .000 file to usb for knitting