Piecing Generative Patterns Into Contemporary Quilts

Jon McCormack and **Monika Schwarz**
SensiLab
Monash University
Melbourne, Australia
jon.mccormack@monash.edu
monika.schwarz@monash.edu

Abstract

This paper describes a practical example of human-machine co-creativity: the design and production of two computer-fabricated, bespoke quilts. To create the design we used custom generative software that generates and distorts line geometry, outputting the results as a series of vectors. We then converted this vector line art to a series of stitch patterns that were machine-embroidered using a computer-controlled embroidery machine. Each quilt used twenty different designs that were combined to create the final quilt.

Introduction

Quilting is a traditional craft and creative practice that dates back centuries. Often simultaneously serving aesthetic, narrative and practical goals, the design and production of quilts has traditionally been a manual task, predominantly undertaken by women in domestic settings. But with the rise of digital technology and a renewal of interest in handicrafts and making, new possibilities for quilt-making have emerged. A side effect of our cultural saturation with screen-based technology and virtual representations has been a (re)turn to materiality, grounded in real bodies and social sites (Foster 1996). The technological manifestation of this turn includes areas such as "smart" textiles, mathematical crochet, and computer designed embroidery (Smith 2017).

In this short paper we present the design, development and realisation of two unique contemporary quilts, each fabricated using machine-stitched embroideries created with generative software. The project is a collaboration between the two authors of this paper – a generative artist/creative coder and an embroiderer/quilt maker. Using generative software written by the first author, we first created and then disrupted the geometric form of a spiral to achieve interesting and aesthetically pleasing variations. With the software continuously distorting the spiral into new variations, design selection then became a co-creative process between the second author and the creative software. After this we machine-embroidered twenty designs for each of the two quilts, where their assembly into one object celebrates the variety of possible distortions, offering a narrative of generative exploration in an abstract design space. Within the dialectic of aesthetics, craft and tradition, we see the act of generative quilt making as a contemporary expression of the digital disruption of gender roles and domestic tradition, and an enquiry into the materiality of digital embroidery.

Our embroideries are designed using bespoke generative software built on mathematical, generative design principles. While we found that machine embroidery lends itself beautifully to express the generative algorithms created by the software, it has so far not been explored deeply in either the Fine Arts (Vannier 2019) or in a scientific context (Huron et al. 2022).

An important part of our process was to understand how patterns expressed algorithmically as high-precision vectors can be effectively realised as materially embodied stitch patterns in fabric and thread. This process is more complex than it first appears, tied to the nuances and physical possibilities of stitching patterns – previously in the domain of "sewing lore" – here developed as a means of translation between precise computer representations and material possibility.

We present this research as a narrative told by both authors, with the hope that others may find it useful in related applications. Beyond the technical and methodological contributions, we briefly discuss the work from the perspective of gender stereotypes in a time of renewed interest in the digitisation of traditional crafts. In a modest way, we see this project as an act that challenges the traditional stereotyping of mathematics and domestic craft as separate and role-normalised.

In the following sections we cover the motivations for our approach, and briefly review background and related work. Then we describe the quilt design process in detail and finally we reflect on the process and its outcome, situating the work in relation to mainstream narratives of gender roles, attempting to invert the dominant tech narrative of bringing more women into science and technology disciplines.

Motivation

The world of algorithms and computer science is usually completely separated from the one of embroidery and quilting. At the same time, the first is often perceived as male-dominated, while the second firmly belongs in "a woman's sphere" (see next section). This dichotomy certainly tallies with the real-life experience of the second author, who grew up learning cross-stitching, crocheting and knitting from her mother, who would never have considered teaching these

Figure 1: The quilts featuring embroidered generative patterns in an exhibition setting.

skills to her son. What started in the home was further enforced at school. Between years 5-6 the girls at her German high school had crafts classes, where she picked up sewing. During the same time slots, boys of a similar age could participate in physical education (but not in the craft classes). Today the second author works in data analysis, an area where continuous efforts to bring more women into *STEM* (Science, Technology, Engineering and Mathematics) still have not yet lead to a more balanced gender ratio. The generative quilts presented in this paper are the physical expression of a desire to break through this perceived difference between the two spheres and bring together these two defining aspects in the second author's life.

Related Work

Generative art – which adopts a process-oriented approach to the generation of creative artefacts (McCormack and Dorin 2001) – pre-dates modern technology (McCormack et al. 2014), but is widely used today and often undertaken using computers (Boden and Edmonds 2009). As the tools and technology for physically fabricating digital information have become more accessible, software generative processes can be used to fabricate physical things. The idea for our project and its realisation was influenced by the shifting of traditional gender roles in contemporary society. This world was formed by previous generations, and in the next section we summarise the effects they had on the art of quilting. We are also certainly not alone in exploring this exciting cross-section between algorithms and crafts, which we also discuss below.

The Historical Connection of Quilting to "a Woman's Sphere"

Quilting as a technique was born out of the necessity for warm bed covers, but also gave an opportunity to embellish your surroundings. While it was first developed in England (Prichard 2010), today's quilting methods are dominated by American quilting techniques (Rolfe 1998).

Throughout history, quilting and embroidery was strongly perceived as a domestic task, performed by women. They both belonged to "a woman's sphere", one in which "women were expected to operate only within a domestic sphere and women's work was deemed of low value" (MacDowell et al. 2016). A cultural association enforced from an early age, it was treated as a natural disposition of women to quietly sit and sew (Parker 2010). As such, embroidery formed part of the (limited) curriculum in Victorian boarding schools for girls. Techniques were also handed down from mother to daughter, for examples in the form of stitch samplers.

Binding the quilt into the domestic sphere went along with a firm differentiation of embroidery as a craft rather than an art. But today this distinction is less clear, with an entire generation of still mostly female artists employing embroidery in their art, often with the intention to challenge its cultural association with femininity (Vannier 2019). Quilting specifically made its way into the Fine Arts as a distinct form, known as "Contemporary quilt art" (Lenkowsky 2008). As historian Elaine Hedges puts it, quilts transitioned from "expressions of women's private lives, testaments to their domestic allegiances" to "acts that helped women to expand their world and thus to negotiate their transition into modern times" (quoted in MacDowell et al. (2016), p.5).

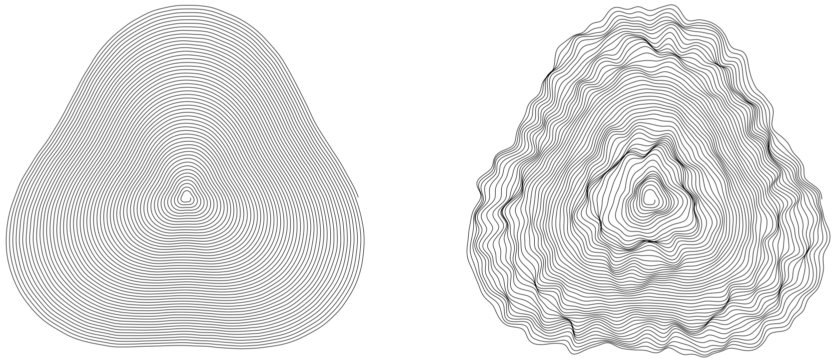

Figure 2: A spiral shape generated by the Structure Generator (left), then deformed by the Noise Deformer (right)

Crafts with Algorithms

We are not the only ones to bridge the gap between algorithms and crafts, and with it the divide between both sectors. It is an ongoing topic in Margaret Wertheim's work to communicate STEM subjects to women. In the "Crochet Coral Reef" project she brings together "a unique mix of mathematics, environmental science, community practice and feminism"[1]. Recreating the shapes of corals, the crochet patterns used in the project are based on hyperbolic geometry. Similarly, Bergamo and Silva (2020) used a Cellular Automata algorithm to create crochet patterns for digital doilies to explore computational creativity.

Focusing more on machine embroidery and quilting, the techniques we are using here, we also find parallels in a few works presented at recent Bridges conferences, held by the Bridges Organisation[2] in order to foster connections between mathematics and arts. Among these projects are those of Dunham and Shier (2019), who realised a fish pattern based on a Pointcaré circle model in machine embroidery. In two other works mathematical principles are used to design blocks for quilts – while Ellison (2019) created blocks from the sum of odd integers Bento, Ferreira, and Hall (2018) used Voronoi diagrams. And Carlson, Paley, and Gray (2015) have used a step process to create fills for quilts based on geometric distributions of points on a plane.

Our work differs in that it uses custom generative algorithms, originally designed for automated drawing, which we have re-purposed specifically for this application. The designer is given extensive control to explore the aesthetics of an abstract, generative design space, something that other common algorithms (such as Voronoi partitioning) or mathematical models (summing integers) tend to make difficult, with the algorithm itself being aesthetically dominant. This can result in the algorithm's aesthetic defining the design, leading to what has been termed "algorithmic genericism" (McCormack 2017).

[1]https://www.margaretwertheim.com/science-women

[2]https://www.bridgesmathart.org

Quilt Design and Making Process

We will now describe the design process of creating the quilts in more detail. We emphasise our co-creative approach of a "human in the [algorithmic] loop", where important design decisions were made based on interaction between the generative software and the conversion of vector lines to material stitch patterns by the artist/designer creating the quilt. The artist/designer exercised their creative and technical understanding of the process to build a narrative in the quilt's overall design, one that went beyond random selection or purely algorithmic decision making.

Generative Software

Our generative software system is based on concepts of "controlled chaos" or "purposeful randomness" (Koestler 1967). It combines geometric order with controllable noise to generate patterns that have structure with variation, inspired by the shapes and forms of natural objects, such as ocean waves, spiral sea shells and plant phyllotaxis (Thompson 1961; Prusinkiewicz and Lindenmayer 1990; Jean 1994; Meinhardt, Prusinkiewicz, and Fowler 1995).

The software consists of two components, a *Structure Generator*, $S :\to \mathbb{R}^2$, and a *Noise Deformer*, $N : \mathbb{R}^3 \to \mathbb{R}^2$. The Structure Generator generates geometric shapes as a series of connected vectors, including lines, grids, circles and spirals. Vector representation permits the generation of shapes of arbitrary size and precision (as opposed to a pixel-based representation). The geometric shapes generated by S are fed into N, which deforms the geometry according to a series of different noise functions, all of which have a temporal component. The deformer takes a geometric vector, $\mathbf{g} \in \mathbb{R}^2$ and a scalar, $t \in \mathbb{R}$, which represents the time, returning a new two-dimensional vector, $\mathbf{g}' \in \mathbb{R}$, representing the deformed input vector, e.g. $\mathbf{g}' = N(\mathbf{g}, t)$. Figure 2 shows a sample output of S (left) and the same output after N has been applied (right). The time parameter, t, causes the noise patterns to animate and change while still retaining other features such as frequency and amplitude, giving the designer variation on the basic deformation.

In the current implementation, there are six different noise

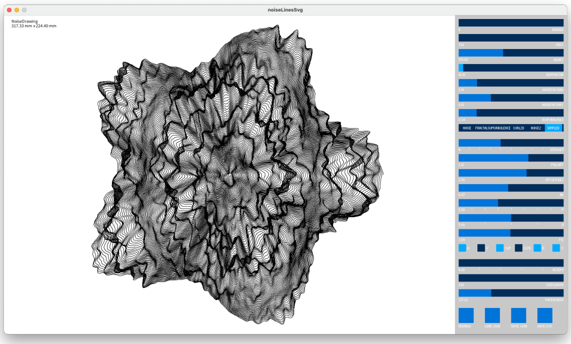

Figure 3: User interface for the generative software. The sliders on the right control different aspects of structure and noise generation.

functions that the designer may choose from:

- **Perlin Noise** An implementation of Ken Perlin's classic *Noise* function (Perlin 1985) in 3D;
- **Fractal Sum** A noise function obtained by summing octaves of Noise at different scales (Ebert et al. 2003);
- **Turbulence** An alternative summing function with absolute Noise values summing at each octave;
- **Curl Noise** A 2D implementation of Bridson, Houriham and Nordenstam's *Curl Noise* for procedural simulation of fluid flow (Bridson, Houriham, and Nordenstam 2007);
- **DNoise** A 2D Vector created by sampling the gradient of Noise around the sample point;
- **Simplex Noise** A version of simplex noise (Perlin's improved Noise function (Perlin 2002))

Each category of noise has a variety of parameters that affect the overall deformations and distinct features, including spatial scale, temporal scale and falloff. Access to these parameters is via an interactive user interface (Figure 3).

Being a fully parametric system, searching the design space can be automated using techniques such as evolutionary search. Specifically, we have experimented with Quality-Diversity (QD) algorithms (Pugh, Soros, and Stanley 2016) which attempt to optimise both the aesthetic quality *and* the diversity of possible designs (see Figure 4). In contrast with more traditional evolutionary approaches, which favour finding only the fittest individual, QD algorithms try to find the widest range of high-fitness individuals within the design space of a generative system.

The system was initially designed to generate vector plots using a computer-controlled drawing machine (an Axidraw plotter), with the designs realised materially using ink and pen on fine art paper (Figure 4). Upon encountering these drawings, created by the first author, the second author decided to try and turn them into stitch patterns suitable for machine embroidery. This required significant knowledge and experimental exploration, discussed next.

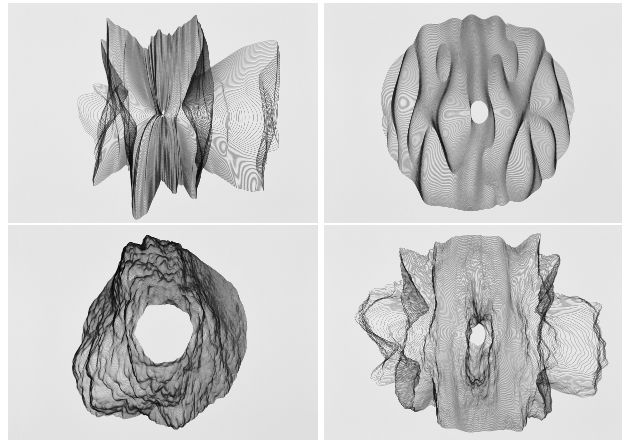

Figure 4: Example forms created with the generative system plotted on fine art paper.

From Vector to Stitch

One limitation that had to be taken into account is the difference between embroidery and a drawing in general. While there are no limitations on a line drawn with ink onto paper (Figure 5a), a stitched line is created by punching holes through the fabric in steps. In the case of a curved line, which we use for the embroidered quilt panels, the stitch length determines how smooth that line will look.

Also, to machine-stitch an embroidery it needs to be in a specific format compatible with the intended machine. Vector images can be converted into so-called "stitch plans" and exported into such formats using specialist embroidery software. Since the generative software created by the first author can export vector graphics, a conversion into simple running stitches could be quickly achieved. This enabled the second author to dedicate time to experiment with the generative software interactively and select a variety of designs. The patterns were chosen by focusing on aesthetically pleasing designs and to showcase the diversity of possible distortion effects over a single geometric shape. In this way, the second author became a "human in the [algorithmic] loop".

The innovation in machine embroidery, and machine sewing generally, lies in their speed and stitch uniformity. This innovation was gained by a simple change. Hand embroidery is done by looping a single strand of thread through fabric (Figure 5b). Instead, in machine sewing, two threads are looped through each other resulting in a stitched line. Figure 5c demonstrates the process: the top thread runs through the needle while the bottom thread is wound onto the bobbin in the bobbin case (1). When the needle moves downwards through the fabric the hook in the bobbin case catches the top thread (2). While the needle moves upwards the bobbin case rotates anticlockwise so the top thread gets looped around the bottom thread (3). As the bobbin case rotates further the top thread slips of the hook (4) and the upwards movement of the needle fixes the loop into place (5).

The last step in the process, the actual stitching of the designs, used a Husqvarna Viking Epic 2.0 embroidery ma-

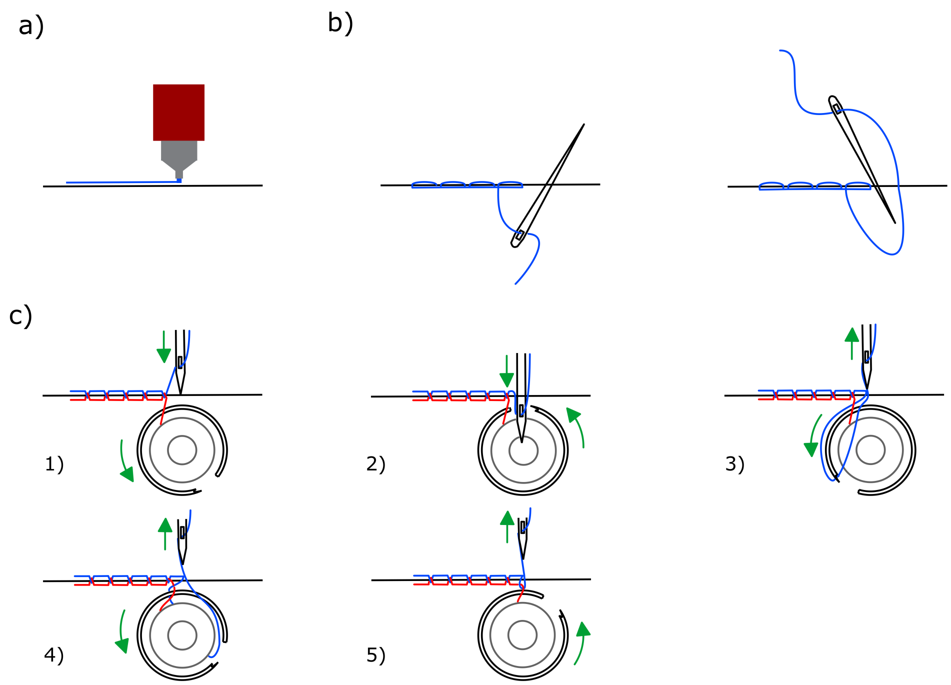

Figure 5: Comparison between the different techniques: a) Drawing a continuous line onto paper; b) Looping a single thread through fabric with an embroidery needle forming a back stitch ; c) Machine-sewing a running stitch with two threads

chine. Machine embroidery requires a certain amount of experimentation to make a design work and involves finding the right combination of fabric, thread, needle and stabilizer (an additional layer hooped underneath the fabric to add stability during the stitching process). As with coding, this is often an iterative process where adjustments to the materials and the designs have to be made after the first attempts.

Quilt Creation and Exhibition

The first quilt was created for an exhibition in November 2022. The quilt (180 x 150 cm) features twenty embroideries in grey thread on black and white cotton panels, separated by grey borders. The top layer was quilted onto a wadding layer and a black backing. The quilt was exhibited again in August 2023 during a second exhibition set in a public library. A second quilt was made as part of that exhibition, allowing regular patrons of the library to witness its creation process over the two weeks.

In both exhibitions the quilts were shown alongside our generative software running on an interactive screen, on which visitors could explore the generative process by creating and distorting shapes themselves. This way, many intuitively made the connection between the geometric forms on the screen and their material realisation on fabric in thread.

Conclusion

While our paper describes a contribution in the application of generative art and generative systems to the craft of quilt making, we also reflect on another aspect of this collaboration, embodied in the process.

In recent years there have been a number of calls for more "women in STEM", addressing a perceived (and actual) gender imbalance in the science and technology sector. Governments, scientific research institutes, universities and tech companies are now often required to address issues of diversity that have been neglected for decades. This has lead to a positive increase in the number of women and other minorities undertaking careers in STEM disciplines and being more inclined to learn the skills necessary for these disciplines, such as programming and mathematics.

However while calls for more diverse participation in tech, for example, are now widespread, rarely do we see similar calls or incentives for men to participate in careers and skills that have traditionally being considered "women's work". This includes traditional "domestic" skills such as sewing, needle-craft, cobbling, and textiles. The reasons for this are undoubtedly numerous and nuanced, but financial reward is one obvious motivating factor – a society in which a programmer can earn far more than a fabrician[3], is one that considers the former a more important skill.

Knowing how to design and work with textiles has always been a valuable skill. But with the incorporation of technology into clothing and textiles, there is a renewed interest in traditional crafts. Hence they may become more widely val-

[3] A fabrican is a less gendered term than *seamstress*.

ued than they have been. In a modest way, we see our collaboration as one that showcases the idea that the two cultures of science/technology and art are not as separate, either by gender or skill, as once imagined (Cordle 1999).

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