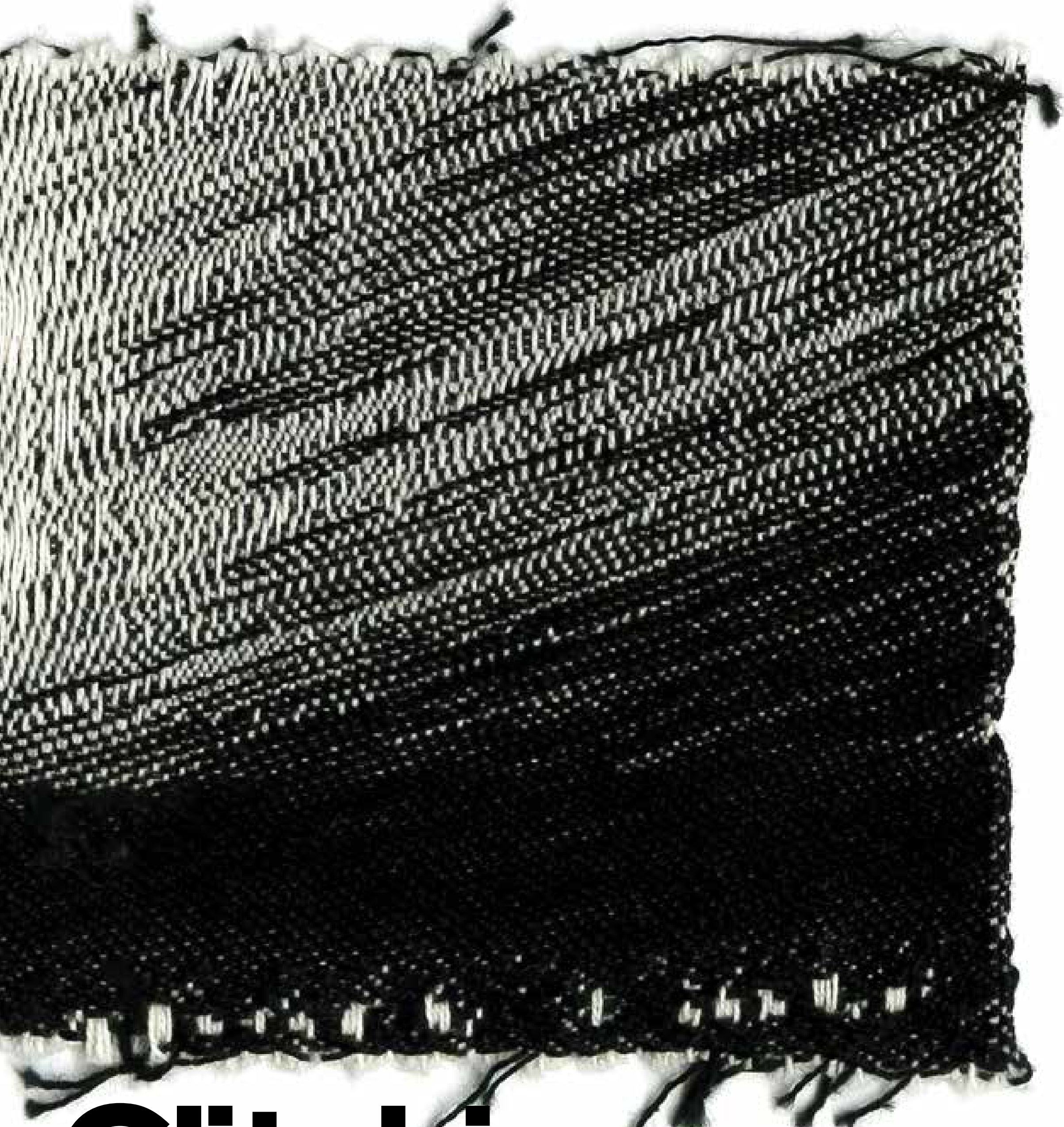

Glitching the Fabric

STRATEGIES OF NEW MEDIA ART APPLIED TO THE CODES OF KNITTING AND WEAVING

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Abstract

Title: Glitching the Fabric: Strategies of New Media Art Applied to the Codes of Knitting and Weaving

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The purpose of the research has been to explore the creative possibilities in applying strategies derived from the domain of digital media and glitch art to a range of processes in the domain of textiles—specifically weaving, knitting, bobbin lace—with particular attention to the role of notations and coding in both domains.

The enquiry presented in this dissertation is based upon the proposition that there are creative possibilities that arise when approaches and strategies from new media and glitch art are transferred to some textile processes, and that this is possible because objects of new media and textile objects share features not limited to the grid.

The research focuses on strategies from digital media and glitch art in the domain of computing and applies these strategies directly to the code and structures in the domain of textiles. The textile objects share some features of new media objects: formal representations (making them subject to algorithmic manipulation), a separation of content and interface, objects can be easily scaled, and they are open for hacking, which is a repurposing of the code.

Strategies employed in this research include developing algorithms to generate structures and behaviour, deliberately inserting error into autonomous systems and exploring the aesthetic spaces generated by the error systems, exploring the manipulation of coded objects, and understanding aesthetic spaces generated by algorithms as navigable spaces.

In this research, these transfers have been tested and conducted through an applied process, creating artefacts of the artistic process, such as artworks, tools for creating artworks, and trial pieces to test techniques and strategies. These artefacts have been produced within the digital domain and the textile domain.

The practical works realised in this way demonstrate the viability and the generative potentials for artistic and design practice that this transfer of strategies between domains yields. The work presented in this dissertation is thus an initial set of experiments laying the groundwork for future explorations employing this transfer of strategies, based on innovative cross-relations and exchange between the domain of computing and the domain of textile production.

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Through the process of doing this work I have managed to tick off all of the things that are supposed to prevent you from completing your PhD: having a child (two), getting married, moving to another city, changing primary supervisors, changing institutions. This work would never have been completed if it had not been for the support of many people. So, thank you.

To my primary supervisors, Karin Wagner and Sven Andersson, for trusting me from the beginning. To Birgitta Nordström, for making me a weaver, and for being my family away from home. To Mick Wilson, for getting me over the finish line.

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To Dory Kornfeld, for thinking it was a good idea to knit a game of Go.

To my parents for absolutely everything. To my wife, Angella Mackey, for the seemingly endless support. And to my boys, Lo and Auden, for forcing me to learn proper time management.

To all I've missed, I'm sorry; it's been a long road and I couldn't have done it without you.

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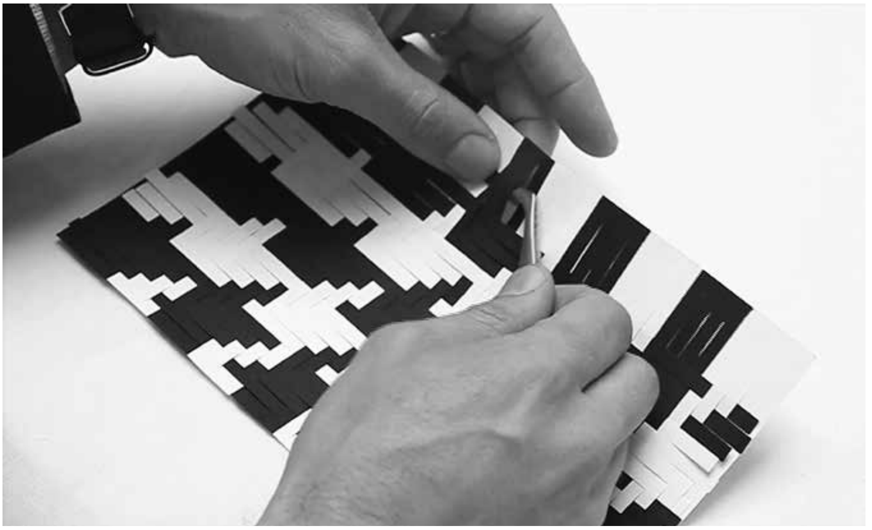
0. Framing the work



5-2-1, and other media accompanying this dissertation

This work is situated within an artistic practice. Practice generated the questions for the enquiry, practice generated the techniques, practice situated the actions and results, and the work is evaluated through practice. Throughout my time in the PhD it became clear that research so rooted had the opportunity to use artistic practice in its factual dissemination.

Accompanying this dissertation are several works, sketches, or documentations of work. They are all available at the Gothenburg University Publications Electronic Archive (GUPEA) at the link:

http://hdl.handle.net/2077/57324

This is intended to be a permanent online record of the dissertation text and the accompanying media.

I recommend that you begin this dissertation by following the link and watching the video entitled 5-2-1. The video is a documentation of a performance lecture created during the PhD process to disseminate the work, and takes advantage of the qualities of narrative and live performance. It provides a good overview of the research project.

0.1 Introduction

This research project applies approaches from new media art and glitch art to the codes of several textile techniques and structures. This is undertaken as a means of exploring and generating creative possibilities and strategies from this transfer of approach from one domain to another. The work presents several successful strategies for this transfer, as well as observations about unsuccessful strategies.

The final deliverables of this research project exist in several forms. Broadly, the content is presented as this dissertation text, and art objects, either physical, digital, printed, or performed. The objects have been presented throughout the research process in various seminars and exhibitions. Many of them are documented in some form in this text: as video or still-image documentation, two-dimensional works included in this text that have been derived from the strategies presented in this text, or links to digital works employing the same strategies.

This text is divided into two sections. This first section is a positioning chapter that frames the research's theory and practice. The second section is comprised of four chapters that present the strategies explored and employed in the research. The positioning chapter introduces the origins of this research project. It defines the terms and concepts required to understand the artistic experiments. It explains and situates previous practises, and approaches. This section provides the theoretical and practical context for the work undertaken in this research project. The positioning section introduces the techniques of knitting and weaving, and new media art and its practises. Given that this work explores a transfer between two domains, it is important to understand what the domains are, what their practises are, and what their values are. Glitch art is introduced as a subset of new media art that specifically explores error and autonomous systems. Lev Manovich outlined features of what he called "new media" objects, and these features are key characteristics that are often exploited by new media artists. The formal representation of an object allows for it to be manipulated by algorithm, and to be "hacked"[1] and repurposed. These qualities in an object of study are of interest to new media artists, and the ability to manipulate them through algorithms and hacking are also of interest. The positioning chapter concludes with a contextualisation of the research by providing an overview of previous work in the field, serving to indicate the novelty of the work presented in this thesis.

The final four chapters each present a specific new media strategy, and its application to various textile techniques. The first strategy chapter explores the use of the grid in digital encoding, and as an organising structure in knitting. Specifically, the intersections of the board in the strategy board game Go are translated to knitted stitches, used to "play" a game of Go in knitted swatches. The second strategy chapter focusses on the structures and patterns of weaving and bobbin lace. One artwork enlarges the structure of woven satin to interrogate the structure, a second artwork augments an industrial bobbin-lace machine with electronics so as to accentuate the physical path of the bobbins as they construct the lace. The third strategy chapter applies glitch strategies to woven satin structures by constructing algorithms to generate a satin structure, and deliberately modifying the algorithms—inserting "error"—to deviate from the traditional satin structure. This produces both distorted satin patterns, as well as distorted satin cloth. The fourth strategy chapter applies the strategy of performance to woven-pattern-generating algorithms. An algorithm is created to generate the traditional woven pattern of houndstooth, and its parameters are then mapped to performance interfaces to create an opportunity for live manipulation of the satin pattern. This results in possible "performance" of the algorithm through video, as well as the generation of woven patterns that can be woven either by hand or by an automated loom.

1 Hacking here, in the sense of: "To apply an unorthodox strategy or expedient solution to adapt (something) to suit one's particular needs or preferences." ("Hack, V[1]. 15e", *OED Online* (Oxford University Press), accessed January 23, 2018.)

0.1.1 The origin of the enquiry

The positioning section presents the origins of this enquiry coming from practice. This enquiry emerges out of the practice of an artist who works across new media, situated within textile techniques. The research and artistic practise of this research project did not progress in a linear fashion, but involved many stops and starts, as well as exercises that complemented the larger research actions. One of these strategies was the notebook, ever-present through the research process, and daily diary-writing in the notebook, on the computer, and with a typewriter. Some excerpts from the notebook and the diary-writing are included in this text as a means of disclosing the practical research practise, as a proposal that they may enrich the sense of how experimentation in practice unfolds and enables new insights, and as an admission of the affective forces that may have influenced the research. These excerpts are formatted so:

> *I remember my mother, endlessly knitting baggy sweaters, rows and rows of crazy colour combinations, but all in scratchy, naturally-dyed local yarn, stacks of Kaffe Fassett books, a sweater bearing the image that I drew obsessively as a child: a tree by a pond. Apparently she was sick then, knitting to occupy herself, but I don't remember that. She taught us to knit. My younger brother knitted a tiny shirt and trousers for his hamster. The hamster shredded it and turned it into bedding. I practiced, catch the yarn, pull it through, catch the yarn, pull it through. Then I stopped.*
>
> *In my twenties. too. much. computer. Wrist pain. Nothing to show for anything. Could you teach me? Catch the yarn, pull it through, out comes a scarf, a toque, mittens. Tension, always too tight.*

IMAGE 0.1 **Chuck's Cabled Socks, knitted by the author.**

This enquiry arose through practice. It was through knitting that I realised the possible opportunities of representing the thinking of knitting in structures similar to those in software, and later this thinking was extended to weaving. When a knitter engages with a pattern, they encounter a kind of arcane pseudo code that tells them, stitch by stitch, row by row, how to construct the garment. As an example, here is an excerpt from the instructions for a pair of socks (pictured above):

> Row 1: Using CC only, k3, ssk, k1. Turn.
> Row 2: Sl1, p6, p2tog, p1. Turn.[2]

Knowledge of knitting is required to understand and execute this code, from the understandings of how to perform each command, to grasping its role within the knitted structure. A translation of this code into plain English might look like this:

> Initial conditions: the piece is being knitted with two yarns, one in a background colour and one in a contrasting colour.
> For the first row, use the contrasting colour; knit three stitches; decrease by one stitch, slanting to the left, by slipping two stitches onto the right needle and then knitting them together; knit one stitch; turn the work over.

2 Euny Jang, *Chuck's Cabled Socks*, 2006, www.eunnyjang.com/knit.

> For the second row, slip one stitch to the right needle without knitting; purl six stitches; decrease one stitch, slanting to the right, by purling two stitches together; purl one stitch; turn the work over.

This translation also requires a basic technical knowledge. Words like *purl*, and instructions like "turn the work over" have no obvious meaning without a basic understanding of the craft.

Knitting notation can also use the grid: the instructions are notated graphically rather than expressed through written language. Here is another example from the same sock pattern, showing a cable pattern, the kind of pattern comprised of long and intertwined horizontal and vertical "cable" features often seen in "fisherman's sweaters", as seen in Image 0.2:

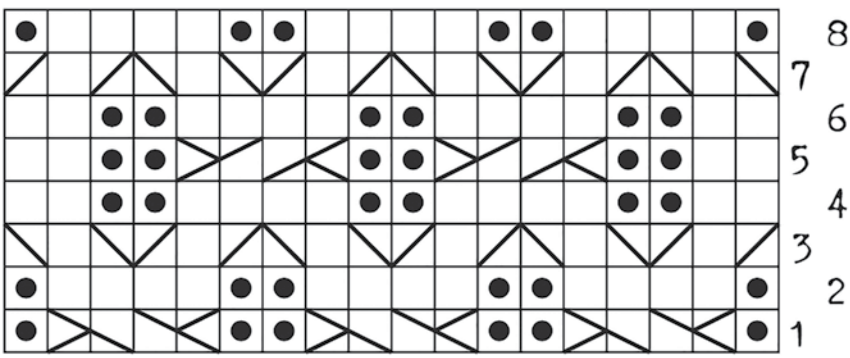


IMAGE 0.2 **The grid notation for a portion of the cables in Chuck's Cabled Socks.**

The grid calls to mind images on computer screens, divided into pixels. There may be a direct connection, or it may simply be that the grid has been a useful tool for humans when organising information in various domains, as explored by Hannah Higgins in *The Grid Book*.[3]

When knitting, I found myself engaging in a process of abstraction and reduction of the original knitting pattern. I have spoken informally to other knitters who have noted that they do similar things. When examining the written or graphical pattern, I began by faithfully reproducing the material as it was notated. The colour of the yarn is represented by the presence or absence of a dot. I would progress horizontally across each row, each row of the grid would be repeated until the end of the garment

3 Hannah B Higgins, *The Grid Book* (Cambridge: The MIT Press, 2009).

is reached, the chart has a height of eight rows that are repeated. Stitch by stitch, square by square. But after several repetitions, I would refer to the chart less and less. I wouldn't memorise the chart, necessarily. Memorising a sequence of 144 actions is possible but requires an enormous effort. I would reduced the pattern to a kind of underlying logic that would construct the pattern. The logic would contain details such as:

- repeat each row of the chart until the end of the knitted row is reached
- repeat the entire chart when its end is reached
- the cables shift on odd-numbered rows
- the cable shifting follows a pattern: cross right over left, diverge from each other, cross left over right, diverge from each other, repeat
- the colour of each stitch in even-numbered rows is the same as that of the stitch directly below it
- cables are separated by two stitches knitted in the background colour
- the cables are created by knit stitches, the background by purl stitches

What was surprising was this way of compressing sequences of action into conditional structures involving concepts such as repetition until a condition is met, certain actions are the same as previous conditions, and certain actions are taken only when certain conditions are met.

The reduction of the cable pattern employs the same formal actions that are the foundation of modern programming languages. The instructions are broken down into formal primitives—the actions of the knitter—similar to commands or functions in programming languages.[4] The knitting primitives in the cable reduction are actions such as knit, purl, cross the cable. Programming primitives would be instructions such as *print* (display text on the screen), mathematical operators (such as + and -), and actions unique to the specific programming language or context. For example, Processing, a language designed for artists and designers, has the command *rect*()[5] for drawing rectangles.

4 Nick Montfort et al., *10 PRINT CHR$(205.5+RND(1)); : GOTO 10* (Cambridge, Mass.: MIT Press, 2013), 10.

5 "Rect()," processing.org, February 10, 2016, https://processing.org/reference/rect_.html.

The cable reduction contains several loops, repetition of instructions, something whose existence in textiles has already been likened to software.[6] Programming languages contain either bounded or unbounded loops,[7] repetitions that either eventually end, or go on for ever. The cable reduction requires each row of the cable to be repeated until the knitter reaches the end of the knitted row. The knitter must also repeat the entire cable pattern once it has been completed. This continues until the section of the garment has been reached, satisfying the criteria to create that garment section, at which point the looping of the cable pattern stops.

Bounded loops contain within them the important concept of conditional statements and conditional branching.[8] That is, to perform an action provided that something is or is not true. In this case, my construction of the statements for determining yarn colour and cable crossing require conditions to be met, which the knitter will be evaluating as they knit. Is the stitch part of the cable? Then it is a knit stitch in the foreground colour, otherwise it is a purl stitch in the background colour.

These processes provide a compression through abstraction, rather than listing each action, they describe behaviours that will generate the list of actions, which can be a more efficient way of memorising or communicating the actions. This is why it was more efficient to internalise the knitting patterns in this way, because it requires less effort to understand the logic of the pattern than to memorise each action required to create it.

The process of abstraction that I engaged in demonstrated the ability of these existing knitting structures to be constructed using similar primitives that are used to construct software. But it also suggests that the knitting patterns can be deconstructed and broken apart in the same way that software can be broken apart. If certain primitives are arranged in a specific algorithm that produces a specific pattern, then it suggests that the primitives could be rearranged, that conditions of the algorithm could be altered, that the basic knitting pattern could be hacked to produce derivatives and variations of the original pattern. This approach of constructing algorithms to produce textile patters, and textiles, forms the basis of the work conducted later in this enquiry.

The work of this PhD takes its starting point not from the grid, but from this procedural abstraction latent in the knitting, that there is a

6 Montfort et al., *10 PRINT CHR$(205.5+RND(1));*, 75.

7 Montfort et al., 95.

8 Montfort et al., 92.

possible kinship in the thinking behind the process of a knitter and a software programmer. Textile patterns and notation become a subject of interrogation using strategies from new media art, investigating whether textiles can be a system of interest for new media practitioners, and as a result, what kinds of creations are possible when strategies from new media art are applied to textile patterns and notation.

The research project emerged from an action of practice, and the practice is an active component of the project. The practice is crucial as a method of enquiry, to produce insight as to what kinds of gestures might be possible when working with textile patterns. The culture of artistic practice also provides a context for the relevance of the results. The successful application of a new-media approach to the structures of some textile techniques will present possible strategies that can be applied in an artistic practice.

0.1.2 Practice as method

This section discusses the methods and actions of enquiry employed in this research project. The focus of the enquiry is to investigate the application of a new media art approach to several textile techniques, their structures and their notations, with the intent to determine if these applications can be applied in ways that are generative and can be employed in an art-making context. If successful, the application of a new media art approach should demonstrate not strategies that produce fixed products, but that the application of this approach provides a new space of strategies and techniques to be explored and employed in the creation of artworks. Given that the desired outcome is an application in an artistic practice, the enquiry employs a practical approach through the production of works of art, technical pieces, and studies (small experiments of technique that may be employed in more fully developed artworks). This section will provide an explanation of how the hands-on approach was designed and developed, how its use directed the research, and how it was considered with respect to other ways of working.

To understand why a way of working was chosen, we must be clear as to what the objective of the research is. The objective of this enquiry has been to investigate the application of approaches from one domain to another with the intent to generate techniques and strategies for art practice. Digital media objects are stored and transmitted as codes, such as the encoding of an image as a grid of pixel colour values, or the encoding of a sound as a sequence of air-pressure values. New media art, as will be discussed later, often involves making these codes the objects of study. This approach is also applied to the constituent components of things: in the way that an image may be constructed of pixel colour information that can be treated with various strategies, so can the textual content of a story or web site also be treated, for example, or the collection of images in a database, as will be shown in the section discussion Lev Manovich's Principles of New Media. Textile techniques also use codes to both document or transmit the knowledge of their objects. Codes for transmitting, for example, a sweater, exist as "patterns" that can be followed by knitters to produce a sweater, which is the object described by the pattern. The codes may also have been created to document existing textile objects, rather than transmit the object. Consider, for example, *qipus*, knotted record-keeping objects created by the Incas before the Spanish conquest of Peru.[9] The content of the quipus are as yet unknown, but researchers have created a coding system that records aspects of the quipu structure, such as cord placement and ply spin direction; and information about the kinds, amount, and placement of knots. This coding system allows others to both recreate a specific quipu, and to perform statistical analysis on individual quipus or a group of quipus from the database.[10] The encoding recorded in this database is an example of a code created to document a textile object.

Can techniques for treating codes from one domain be applied to the codes of another domain in ways that can be employed in an artistic practice? The emphasis in the research is on artistic practice, in that the products of the research are intended to be of use in an artistic practice. What is of use for practice? What are the ways in which this could be explored?

This project employed approaches of practice, but could the work have been conducted without using practice as a way of pursuing the enquiry?

As stated in the introduction, the work arose from an observation made through practice, and this process of observations made through practice is a tool that was employed throughout the research. Practice was employed throughout this enquiry in three ways. The first, that the

9 "What Is a Khipu," Khipu Database Project, accessed November 8, 2016, http://khipukamayuq.fas.harvard.edu/WhatIsAKhipu.html.

10 "Khipu Database Project," accessed February 16, 2018, http://khipukamayuq.fas.harvard.edu/.

enquiry arose from observations through practice. The second is that practice was employed directly as a way of examining the transfers of approach between new media art and textile production, and observations made through this practice directed the enquiry. The third is that the experiments and results were anchored in practice. The experiments were conducted in practice, to examine actions taken within that practice, in the hopes of generating strategies to be further used in a practice.

The enquiry was conducted through practice, but practice is not simply a careless process of unreflective doing; it is a balance of practical and theoretical considerations. It would have been possible to have conducted a similar enquiry leaning more heavily on the non-applied than the applied, though the results would have been different and would not have served the enquiry's objectives in the same way.

Though several textiles techniques and structures will be presented in this enquiry, it would also have been possible to instead conduct a survey of many textile techniques, producing a list of textile techniques that appear to be good candidates for the strategy transfers. This would have allowed for a larger list of crafts than those explored in this enquiry, and would have perhaps provided more suggestions for directions of future enquiry. Though a formal survey was not conducted, the crafts chosen for this enquiry were considered, not chosen at random. Knitting was pursued because the enquiry arose from knitting, so it was natural to continue that line of enquiry to investigate the original observations. Weaving was chosen because it has an old relationship with computers, for reasons other than those that were explored in this enquiry; such connections are, for example, the perceived hardware–software division and punchcards of automated looms, though this enquiry was interested in the ways that the codes of weaving were accessible to techniques from new media art. The third textile technique in this enquiry is bobbin lace, which was an opportunity that presented itself during the research. I was presented with access to old, industrial bobbin-lace machinery, which seemed a rare opportunity, and at least tangentially relevant to the enquiry, and so I decided to pursue it.

As stated, a survey of textile techniques may have presented a larger group of eligible techniques for future enquiry, but as will be shown throughout this enquiry, more textile techniques were not needed. The two techniques, plus the minor foray into bobbin lace, provided adequate material to explore. The objective of the research was not to provide as many textile techniques as possible, but to explore transfers of approach and strategy that would be of use in an artistic practice.

If the applications of the work are to be practical, then it is important to test and evaluate the approach through practice. If the enquiry was limited to only a survey, or to exclude practical work entirely, the approach of learning through practice would have been lost. Because the observations made through practice were able to uncover and confirm positive transfers of strategy, practical work was a necessary component of this enquiry.

While notation is a codification for practitioners that assumes existing knowledge on the part of the practitioner, it does not fully encompass a craft. The letters of the alphabet assume the reader's knowledge of pronunciation and the ability to reconstruct words from the assemblage of letters, and notated music assumes the interpreter's ability to translate the notes to the physical actions of an instrument, as well as the stylistic application of dynamics and phrasing that are not explicitly notated. Engaging with the practice directly allowed access to aspects of the craft that are not explicit in the notation. This allows for a fuller understanding of the notation and its function, and allows the enquiry to identify avenues that would not be apparent if the enquiry were to only meet the notation from the perspective of an outsider who did not understand the textile practice. Engaging with the craft, doing it, opens up for a broad range of possible *how*s, as the practitioner encounters and considers each decision, each quality that provides the slightest bit of resistance. This path allows for an opening up of the subject as a result of the practise.

The work was also conducted by me, but other practitioners could have been employed to conduct the work. This would have required finding someone who is both an adept digital practitioner or practicing new media artist, as well as someone with some basic textile skills and affinity. It may have been possible to employ someone else, and they would likely have had other observations through the enquiry, but it is not clear that their observations would have been better or worse suited to the goals of the enquiry. In this case, there is no obvious reason to employ someone. However, observations made by another practitioner are likely to be of interest. The Weaving Codes – Coding Weaves project, discussed in the related-contemporary work section, the closest related work to this enquiry, shows the value that a diversity of practitioners can bring to this enquiry. Their particular sets of skills led them to very different strategic solutions that are also relevant to this enquiry. It would have been possible to incorporate many practitioners in the enquiry, but increasing the numbers of practitioners would have had the effect of dramatically increasing the amount of data, effectively turning the enquiry into one of data management rather than exploration. The goal is not to produce as many techniques as possible, or to identify trends in techniques, but to explore, uncover, and test possible strategies and techniques. Because this enquiry is a beginning, it demonstrates the viability of such transfers of approach and strategy, and opens up for the future incorporation of other practitioners, leading to a potential broadening of the enquiry. McLean and Griffiths also placed themselves in the same position of having to learn a craft as a beginner—such as tablet weaving, for example—and they placed emphasis on learning by hand, rather than only studying the code and theory of the craft. I learned to weave in this enquiry, though an experienced weaver could have been employed. McLean and Griffiths identified the ability of novices to notice aspects of a craft that may be overlooked by experts, and these aspects may be avenues of enquiry relevant to the research.[11]

I observed this same perspective when interviewing new media artist Darsha Hewitt for a magazine article.[12] Hewitt and collaborator Stephanie Brodeur created *Personal Soundtrack Emitters,*[13] a device that allowed a wearer to reinterpret their sonic surroundings as mediated by a simple sound system, a microphone and amplifying circuit in a small wooden box connected to headphones. Hewitt confided to me that the reaction of many musicians and DJs to the artwork had been disdain, surprised that anyone would create an artwork out of something so obvious—obvious to them, at least. Hewitt and Brodeur's positions as visual artists allowed them a privileged, naïve view of sound and its tools, allowing them to create a sophisticated work highlighting the mediation of audio systems, something taken for granted by professionals but usually unnoticed by the layperson. Alvin Lucier's *I am Sitting in a Room* from 1969 highlighted the role of audio systems in manipulating and colouring sound. Lucier's piece plays a short audio recording into a room, records the playback, and afterwards plays that recording back into the room, recording this again, and then playing it back into the room over and over again. At each iteration the content of the sound recording is modified by everything involved in the playing and recording. The sound is shaped by the frequency response

11 David Griffiths and Alex McLean, "Textility of Code: A Catalogue of Errors," *TEXTILE* 15, no. 2 (April 3, 2017): 198–214, https://doi.org/10.1080/14759756.2017.1298308.

12 David McCallum, "Darsha Hewitt," *Musicworks* 107 (2010).

13 Darsha Hewitt and Stephanie Brodeur, *Personal Soundtrack Emitters*, 2006, http://www.darsha.org/?cat=11.

of the amplifier, of the speakers, of the room in which the sound is played, of the microphone, of the recording medium. At each iteration certain frequencies are dampened out of existence, and others are strengthened until they are all that exist. The original recording of speech becomes shimmering frequencies with no discernible content. Brodeur and Hewitt were rediscovering aspects of *I am Sitting in a Room* and setting it into a contemporary context, of ubiquitous mobile music players.

It is not obvious that the observations of novices, of practitioners from other disciplines, will be of more or less value for this enquiry than the observations of an expert, but my inexperience presented itself as an opportunity to conduct the enquiry in a manner that will generate observations that an expert may have overlooked. As stated previously, a continuation of this enquiry would likely also benefit from the active explorations of a textile expert. It must also be noted that the work was not conducted in total isolation of textile expertise. Throughout the enquiry I was in constant dialogue with my secondary supervisor, Birgitta Nordström, an experienced hand weaver and textile artist; Marianne Davidsson, the textile technician at the School of Crafts and Design in Gothenburg; and later portions of the research were conducted in consultation with weaving technicians at the Swedish School of Textiles, mostly when investigating the practicalities of production of the weaving patterns generated in the enquiry on large industrial weaving machines. Nordström and the technicians were able to provide insight as to the relevance and novelty of my discoveries and experiments to the fields of textile art and weaving, as well as suggest possible avenues of enquiry.

This access to expertise was different for the experiments employing knitting and bobbin lace. I am an experienced knitter with knowledge of a broad range of knitting techniques, but no external expert was consulted in the enquiry, except for museum technicians who understood the operation of the machines; and no bobbin lace expert was consulted. This will, of course, have had implications on the results of the experiments. The access to weaving expertise may explain in fact why more work in this enquiry was conducted using weaving rather than knitting and bobbin lace; I will have relied on the expertise and machinery at hand rather than conduct more experiments with no experts to consult. The results from the knitting and bobbin lace experiments may benefit from the scrutiny and consideration of external experts. This is an avenue that should be pursued in a future enquiry.

0.1.3 Terms

This research project draws from several cultures of practice, each with their own terminology to describe aspects of the practice, from the technical construction of objects, be they woven structures, drafting patterns for weaving, or digital images. The uses of terms such as “technique”, “method”, “strategy”, “approach”, “process” are lacking specificity across disciplines, and even within disciplines and individual documents. As such, I shall endeavour to be strict with the use of these terms in this dissertation, in the hopes of providing some clarity to the reader. In a survey of both dictionaries and various resources collected through the process of this research, it became clear that a precise and agreed-upon meaning of any of these terms is impossible. This section will state my use of terms and their intended meanings in this document.

A *technique* shall mean a technical way of doing something, or a way of manipulating elements to achieve a specific final output (as used by Emery[14]). For example: weaving is a technique of arranging multiple orthogonal fibres to achieve a woven fabric, knitting is a technique that knots a single yarn into itself to produce a plane of knitted fabric, data mapping is a technique that interprets data from one medium as though it were a different medium, such as interpreting audio data as image data. It should be noted that even the definitions as provided are imprecise, and themselves encompass many different techniques and what may be termed *styles*. “Knitting” may mean hand knitting, or machine knitting, both of which produce knitted fabrics through distinctly different manipulations. Hand knitting may be performed using a “continental” or “English” style, denoting which hand holds the free yarn and how the yarn is wrapped. The hand knitting may be “Eastern”, “Western” or “combination”, denoting the orientation of the stitches on the resting needle and operation of the active needle. The process of interpreting audio data as image data requires many decisions by the programmer, which may be described as the programmer’s “style”, that the specifics of the technique may vary wildly, though the technique achieves fundamentally the same conceptual output. Despite the variation encompassed in my application of the term *technique*, each of these sub-techniques and styles

14 Irene Emery, *The Primary Structures of Fabrics* (Washington: Textile Museum, 1966), 60.

manipulate the same kinds of elements, in manners that are sufficiently similar, to produce results that are often indistinguishable, regardless of the style used.

An *approach* has a looser meaning, which I interpret to mean the spirit of a culture of practice, though Ada Dietz' description of "algebraic weaving" used the term more in line with what I will call *strategy*.[15] It may be helpful to acknowledge the metaphorical origins of these terms, where *approach* means "The act of coming nearer (relatively), or of drawing near (absolutely), in space."[16] The approach of new media art pays particular attention to the tools used to create media, and glitch art pays particular attention to the ways in which tools fail. The approach of the hand knitter is to use knitting needles and continuous yarn to create a knitted fabric, the specific techniques, styles or strategies employed are not necessarily implied in the approach. *Approach* relates to the term *strategy*, which I interpret to mean more deliberate steps taken within an approach. It may imply specific techniques employed to produce a specific outcome, or conduct a specific enquiry. When considering the term *process*, there is an implication in the doing of something. The execution of a strategy follows a process, the knitting of a garment follows a process. Emery employed the term "construction process"[17] where I would use "technique", though "construction process" is strikingly precise in its application, and embodies this active sense of *process* that I am employing. The term *method* is primarily used within the traditional academic context as a way of conducting research, but it may be used when none of the other above-mentioned terms feel appropriate. However, I find that when reaching for *method* I am likely to use the more ambiguous *way*—as in "a way of doing"—which is useful when emphasising the spirit of actions rather than attempt to be specific in their description.

To reiterate: a *technique* is the manipulation of elements to achieve a specific final output, which may be characterised by various kinds of related sub-techniques or styles; an *approach* is the spirit of operating of a specific culture of practice; a *strategy* is specific actions chosen within a practice; and the *process* emphasises the act of doing.

15 Ada K. Dietz, *Algebraic Expressions in Handwoven Textiles* (Louisville: Little Loomhouse, 1949), 3,6,7.

16 "Approach, N.," *OED Online* (Oxford University Press), accessed January 23, 2018, http://www.oed.com/view/Entry/9837.

17 Emery, *The Primary Structures of Fabrics*, 41.

0.2 Relevant practices and contexts

0.2.1 New media art

The work of this research is conducted specifically in the frame of new media art and negotiates the transfer of approach from new media art to textile techniques. The Principles of New Media established in Lev Manovich's *The Language of New Media* are used as a way of understanding the general concerns and ways of operating within this field, and Domenico Quaranta's *Beyond New Media Art* is used to provide a historic context to the art practice generally known as "new media art".

Domenico Quaranta argued that around the turn of the 1950s and 1960s "the implicit perspective in the most generic interpretation of the expression New Media Art became a mass strategy, common to all the avant- garde art of the period."[18] Quaranta also used the term "new media art" throughout a discussion of the history of the genre, even while identifying different genre terms used throughout the 20th century. It may have been called something else at the time, but he calls it "New Media art". Various labels have been applied throughout the 20th century to describe the work. "Computer art" was used used by A. Michael Noll at Bell Labs in 1962.[19] The 1968 exhibition Cybernetic Serendipity used the term "cybernetic art".[20] Robert Rauschenberg and Billy Klüver founded the performance-art group, Experiments in Art and Technology in 1966.[21] The Ars Electronica festival was founded in 1979,[22] employing the term "electronic art", used elsewhere in, for example, the Dutch Electronic Art Festival in Rotterdam. The 1986 Venice Biennale had a section called "Technology and Computing" section.[23]

18 Domenico Quaranta, *Beyond New Media Art* (Link Editions, 2013), 48.

19 Quaranta, 48.

20 Quaranta, 50.

21 Quaranta, 53.

22 Quaranta, 64.

23 Quaranta, 63.

In 2001, Lev Manovich published *The Language of New Media*, presenting a theory of digital media. In it, he attempted to describe what qualified a media object as "new", and what the implications were of these "new" media objects. How are these objects formally different from an old media object, and what are the implications of these differences? Manovich established what he listed as a set of "Principles of New Media".[24] They are, with some elaboration on their implications:

1. **Numerical representation**

   - A new media object can be described formally—that is, mathematically.
   - A new media object is subject to algorithmic manipulation.

2. **Modularity**

   - New media objects exist within a meta structure of objects. New media objects are collections of samples of the environment, such as pixels over a two-dimensional space for image or air-pressure samples over a duration of time for audio. The objects themselves can be organised into collections, that can themselves be further organised, and so forth.

3. **Automation**

   - The presence of numerical representation, algorithmic manipulation, and modularity allow for automation in media creation, manipulation, and access.

4. **Variability**

   - A media object is not fixed. Rather, its existence as a code rather than a physical *thing* allows it to be infinitely modified.

24 Lev Manovich, *The Language of New Media*, Leonardo Book Series (Cambridge: MIT Press, 2001), 29.

5. Transcoding

- The code of a new media object shares more with the codes of other data objects than with any particular kind of media, and as such is able to have its content shifted to and represented as other media. The media object also exists as both a computer object (the code) and a cultural object (the image, sound, moving picture, etc.)—this dual existence will allow for the disruption of the cultural layer by aspects of the computer layer.

In effect, the single most important feature of new media objects is Manovich's first principle, that of numerical representation. Numerical representation is not a new concept. Numerical and formal representation has existed in many forms of coding, such as written language, music notation, and weaving patterns. What gives rise to the new media is the presence of computation combined with the numerical coding of media objects. The rest of Manovich's principles are consequences of this combination, and, for Manovich, defined the landscape of expression created by new media objects.

Throughout the book, Manovich used various new media art projects as examples of the principles, and their qualities and implications. Because new media art is a catch-all term to describe a broad range of practises, it is difficult to provide a concise definition. But it would not be incorrect to say that the principles of new media objects as outlined by Manovich appear often in new media artworks as a subject or method of interrogation. These features of new media objects, and the manipulations made possible by them, are of interest to new media artists.

Examples of new media artworks that represent Manovich's principles:

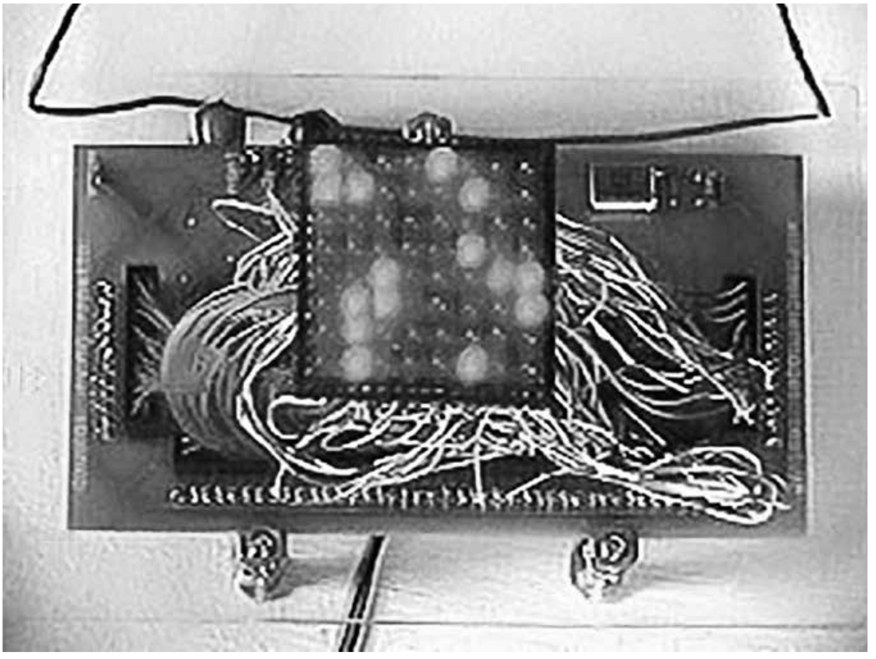


IMAGE 0.3 ***allPossibleImages*, Douglas Reppetto. 1998.**

1. Numerical representation

Douglas Irving Repetto's *allPossibleImages*.[25] An 8x8 grid of LEDs can represent any image of 64 pixels. The actual state of the image, and the binary grid, is stored as a binary string of ones and zeroes. The work cycles through every possible binary number, thereby generating every possible image within this structure. The work also demonstrates Manovich's principle of variability, that the location and form of the work may be a constant, but its image is always changing.

25 Douglas Irving Repetto, *allPossibleImages*, 1998, custom circuitry, LEDs, plexiglass, http://music.columbia.edu/~douglas/portfolio/allpossibleimages/.

IMAGE 0.4 **Promotional image of *Riding Through Walls*, Megan Smith. 2015-2018.**

2. Modularity

Databases. *Riding Through Walls* by Megan Smith.[26] Bicycling across Canada through Google streetview, an assemblage of images intended for viewing places on the street, repurposed and reassembled as a virtual tour. The two-dimensional images used in Google's Street View reside in a database, assembled by the software to construct the virtual experience of being being at a site. This enables other kinds of of interaction with the database, such as the use of a bicycle as a control to navigate the database.

26 Megan Smith, *Riding Through Walls*, 2015, http://ridingthroughwalls.megansmith.ca/.

IMAGE 0.5 **An image from *9eyes*, Jon Rafman.**

3. Automation

9 Eyes by Jon Rafman.[27] The acquisition and processing of images for Google's Street View is an automated process. The *9 Eyes* project documents unusual, almost photojournalistic, scenes captured through the automated process of the Google photographing the streets of the world.

The Radical Software Group created a network sniffing interface in 2001 called the Carnivore Client.[28] This tool also displays qualities of transcoding. It allowed for easy parsing and transcoding of network activity and data to other forms. One example of this is *PoliceState*, by Jonah Brucker-Cohen.[29] The work scans the local network for activity found to mention domestic terrorism, this is then automatically converted to instructions to move 20 remote-controlled toy police cars.

27 Jon Rafman, 9-Eyes, 2009-ongoing, http://9-eyes.com/?og=1

28 RSG, "Carnivore," ongoing 2001, http://r-s-g.org/carnivore/.

29 Jonah Brucker-Cohen, *PoliceState*, 2003, http://www.coin-operated.com/2010/05/03/policestate-2003/.

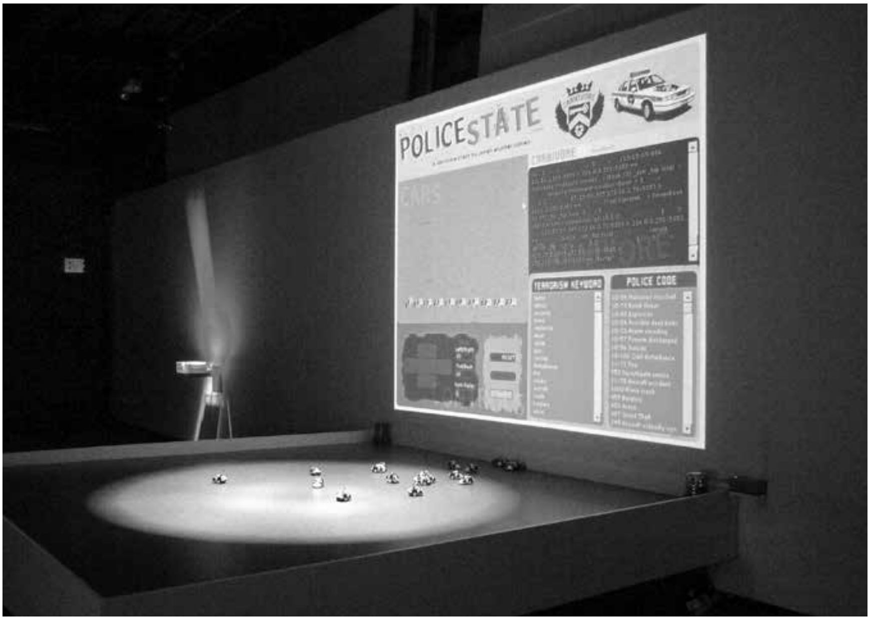


IMAGE 0.6 *Policestate* by Jonah Brucker-Cohen, 2001. Pictured installed at the Sourcecode exhibition at Eyebeam, New York City, 2007.

4. Variability

Variability is commonly exhibited in dynamic web sites. Though www.facebook.com is always considered Facebook, the social-networking site's content is dynamically created and always changing, though it still retains its identity as Facebook.

Dutch net artists Jodi have resided at Jodi.org since 1993, and the face of the site has existed as a dynamic artwork, whose content is constantly shifting. When I check Jodi.org it appears as a mess of garbled text and graphics with links leading to what appears to be a rabbit's warren of similar pages. At the time of writing this text (July 2017), Jodi.org redirects to tatatataa.be with a blank, grey screen, and a deep movie-announcer voice reading what sounds like the menu items of Microsoft Word in a suspenseful tone.

Natalie Jeremijenko's *Onetrees* follows the development of cloned 1000 trees, genetically identical although they develop differently because of the environments in which they grow. This may actually look at variability backwards: how can *different* things have the same code?

IMAGE 0.7 **Jonah Brucker-Cohen. *Alerting Infrastructure!* (2003).**

5. Transcoding

Bob Sturm, *Pacific Pulse* (2003).[30] Bob Sturm collected data from ocean buoys of the Coastal Data Information Project that monitor ocean conditions, including wave height, period and direction; air and water temperature; and wind velocity. Sturm sonified the buoy data to create a multi-channel musical performance.[31]

Jonah Brucker-Cohen's *Alerting Infrastructure!* (2003) is a physical manifestation of a website hit counter, a tally of the number of visitors to a website. The project converts the website hit data to pulses of a drill, suspended with the drill bit against a wall, so that each time a visitor accesses the website they do physical damage to the wall.

30 Bob Sturm, *Pacific Pulse*, 2003, http://www.mat.ucsb.edu/~b.sturm/music/PacificPulse.htm

31 Bob L. Sturm, "Pulse of an Ocean: Sonification of Ocean Buoy Data," *Leonardo* 38, no. 2 (2005): 143–49.

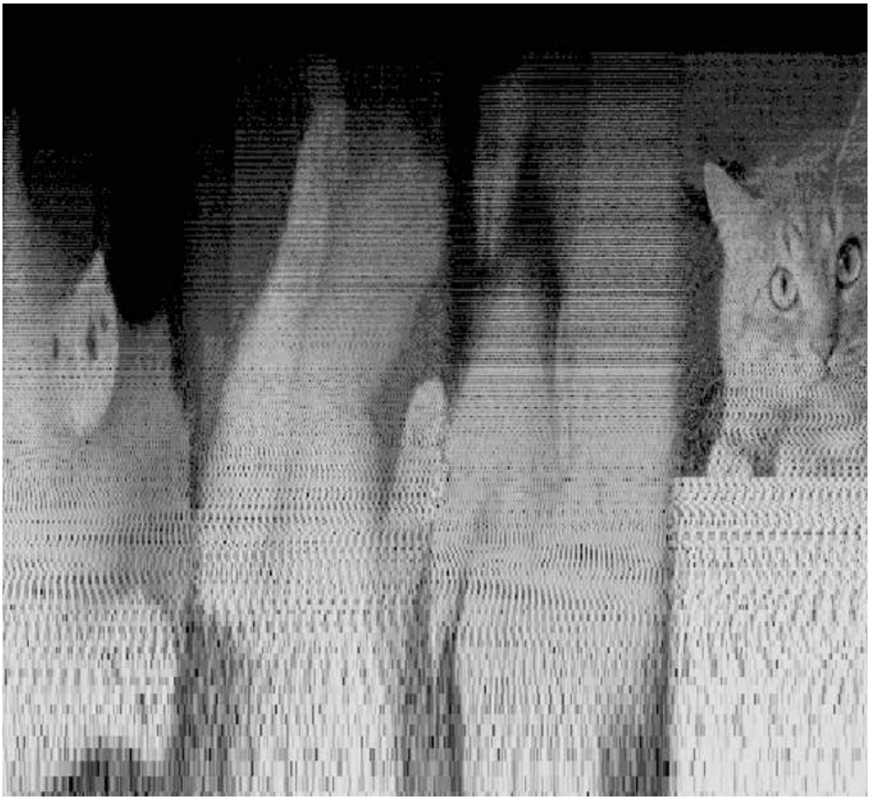


IMAGE 0.8 **Spectrogram of "Look" from *Songs About My Cats* (2001) by Venetian Snares, displaying the source images of cats.**

In the 2001 album *Songs About My Cats* by electronic musician Venetian Snares, images of cats, were converted to pitches by software. The resulting audio can also be reverse coded back to some version of the original images by analysing the audio with a spectrogram, displaying a graph of the frequency intensities of the audio.[32]

Warbike (2005), my own project, transcoded wifi network qualities and activity to music and musical-sounding noise. Data such as network discovery, packet detection, and the encryption status of the network were mapped to parameters such as musical tones, sample playback, and a distortion effect.

32 "Songs About My Cats," *Wikipedia*, January 5, 2016, https://en.wikipedia.org/w/index.php?title=Songs_About_My_Cats&oldid=698296755.

IMAGE 0.9 ***Warbike*** **(2005) by David NG McCallum.**

Each of the works presented above was chosen because each strongly demonstrates and exploits the implications of a specific principle, but it is important to observe that new media objects rarely inhabit only one of the principles. The new media object as identified by Manovich, and its qualities, cause it to often exhibit several of the new media principles, depending on how it is treated.

Of particular importance to this research project is the numerical representation of an object, and its algorithmic manipulation. Algorithmic manipulation of older media objects — such as text or music notation — has already been a strategy in art and research. Chatbots, computer programmes that simulate written human communication, do so by algorithmically analysing a corpus of written text and generating a statistical "map" of the relationships of words and their frequencies. An early example of this was Joseph Weizenbaum's ELIZA from the mid 1960s, a programme that was designed to interact with a user as though it were a psychotherapist. A more recent example is Microsoft's Tay from 2016, a chatbot that used the Twitter social-media platform. Tay is an interesting example of an intersection of Manovich's principles of automation and algorithms and their unforeseen consequences, as often exploited by glitch artists. All messages and questions sent to Tay were added to its corpus, and thus became part of the material from which Tay could draw to create conversation. This was intended to allow Tay to, in effect, learn more about speech by conversing with others, but the result was a hacking of the system by agitators who fed the bot with arguably inappropriate content, causing Tay to tweet racist and otherwise unsavoury messages. The bot was quickly taken offline. I employed a chatbot engine for *Dear Diary* (2005), a net-art piece that used three years of my personal diary as a corpus that could be asked questions. The result was a garbled voyeurism, where the user could never be sure if what they were reading were my private thoughts verbatim, or something I had never written, composed by the bot.

This research project recognises the same potential of algorithmic manipulation of traditional formal representations, but of several textile structures. In this, the project proposes that these textile structures and their manipulation may be of use to new media practitioners—in the same way that other formal structures have been of interest, such as sound and image encoding, databases, and written language. The formal notation of some textile techniques and structures, such as the knitting instructions from earlier in this chapter, and the weaving notation that will be discussed later in this text, are a new body of codes to explore, using similar kinds of exploration that practitioners are already engaging in, such as those mentioned above, and those that will be described when discussing glitch art.

The Language of New Media used cinema as a tool for examining new media. Manovich sought parallels between cinema history and the history of new media, and as such focused his study primarily on the moving image, with mention also of the static image. As a result, other forms of media, such as sound and installation, were largely ignored. This does not mean that Manovich's ideas do not apply to other forms of media, and indeed his principle of transcoding means that, in a sense, the principles and qualities of new media are media-independent. As long as the media object is represented in a code that is accessible to a computer, it will manifest some of Manovich's principles and qualities of new media when processed by a computer. The research of this dissertation explores how the encoding of textile objects can manifest the qualities of new media objects when treated using techniques from new media art.

Manovich's analysis does not adequately address the negative implications of this new world of media. Though new media is not presented as a utopian unlocking of the potential for storytelling and human expression, the book is written in a tone that marvels at the new media landscape, and possibilities unlocked by shifting media paradigms. For example, Manovich proposed that we should think of the "information density of our own workspaces as a new aesthetic challenge"[33]— the term "challenge" here has a distinctly positive tone, that it is a creative opportunity, rather than a burden or problem to be overcome. A decade and a half after the book was published, it may be wise to consider a more nuanced approach, where opportunity is balanced with the challenge of the new media landscape. There has since been considerable debate about the slipperiness of the new electronic and online spaces that people inhabit,[34] and the effects this might work on individual, social, and cultural wellbeing, and of the effects on the development of children who increasingly spend more time inhabiting these spaces.

A sequel of sorts was later published in 2013, *Software Takes Command*, where Manovich refined his previous proposal to focus on the software creating and mediating the media, rather than the encoded media objects themselves. Manovich proposed that the media code is essentially inert without software. It is software that creates, software that processes, and software that presents the media objects. As such, Manovich proposed that the character and behaviour of media objects is determined far more by software paradigms than by the media encoding itself. This is echoed around the same time by James Bridle's "new aesthetic", a proposal that software tools have radically altered how humanity perceives the world, and expresses itself, whether or not a given action has anything to do with new media objects, or the digital. Bridle proposed, for example, that one could determine which CAD software was used to design a given building, simply by looking at it.[35]

The work presented in this dissertation bears some relevance to Manovich's new discussion, in that for the latter part of the research it is the creation of software tools that have allowed for the manipulation and navigation of traditional textile code in new ways. It is not clear whether or not this matters in the discussion presented in this research. This research does not depend on radical, new understandings of software, but of the proposal that textile codes can be interpreted in ways similar to new media objects, and as such can be subject to similar treatments as

33 Manovich, *The Language of New Media*, 330.

34 Sherry Turkle, *Alone Together: Why We Expect More from Technology and Less from Each Other* (New York: Basic Books, 2011).

35 *"The Motive of the Algorithm Is Still Unclear"–Talk by James Bridle*, 2013, 8:00, https://www.youtube.com/watch?v=dQUxJgVLP4o&feature=youtube_gdata_player.

new media objects, leading to new ways of expressing and creating textile patterns and objects. The software presented in this research does not employ techniques where the software has agency, such as genetic algorithms or deep learning techniques such as neural networks. Those would be interesting avenues to pursue in future research, but this work focuses on this new media framing of textile codes, employing simple software to tease out some implications of this reframing.

The research project presented in this dissertation also does not engage with the social dimension of textiles or code. At most, it uses the pervasiveness of houndstooth and satin as a reason for choosing which textiles structures may be good candidates to explore, but does not explore or propose possible ramifications of the disruption of classic patterns. Such explorations may be possible in the future, where the approach and specific techniques developed in this project may be implemented by textile and garment designers.

This project does not explore the philosophical aspect of software as a mediating force of textile patterns. If anything, it takes software paradigms for granted, and considers them as novel strategies for disrupting and exploring textile patterns that have not previously received such a treatment. The project rarely makes use of off-the-shelf software packages. Rather, new programmes are developed to explore disruptions in the patterns.

0.2.2 Glitch art

As stated, this research project explores transfers of approach and strategies from one domain—new media art—to another domain, that of several textile techniques. Though new media art is an umbrella term for a broad range of practices, this enquiry borrows approaches, strategies and techniques from the sub-genre *glitch art*. Glitch art is a practice whose focus is the failure of systems. In one of the earliest written pieces identifying the creative movement that has come to be known as "glitch", Kim Cascone identified the practise as "deconstructive audio and visual techniques that allow artists to work beneath the previously impenetrable veil of digital media."[36] Cascone focused on glitch within music, specifically movements

36 Kim Cascone, "The Aesthetics of Failure: 'Post-Digital' Tendencies in Contemporary Computer Music," *Computer Music Journal* 24, no. 4 (December 1, 2000): 12, https://doi.org/10.2307/3681551.

IMAGE 0.10 **Accidental datamoshing during video conferencing.**

that he identified as having gained momentum in the 1990s, though he makes mention of similar approaches employed in the visual arts, which was also making use of access to newly affordable personal computers for creating and processing media. Though the term "glitch" has its origins in a musical genre of the 1990s, it cannot be said that exploring and exploiting error and failure in the arts began there. As the near-perfect and near-immediate visual reproduction created by the invention of the camera afforded painters the freedom to essentially "break" the expected traditional aesthetics. Carolyn Kane drew parallels between the actions of these painters and the actions of contemporary glitch artists, that "Painting's broad and varied responses to photography in the late nineteenth and early twentieth centuries constituted a set of glitches relative to classical aesthetics and then-dominant conventions of visual representation."[37] Kane's proposition was that pursuing and exploiting error is not new in artistic practices. But as will be elaborated upon further, the subjects and techniques of contemporary "glitch" art are situated within Manovich's principles of new media specifically.

37 Carolyn L. Kane, "Compression Aesthetics: Glitch From the Avant-Garde to Kanye West," *InVisible Culture*, no. 21 (Fall 2014), http://search.proquest.com.ezproxy.ub.gu.se/docview/1771515644/abstract/2DF40F61B0A64053PQ/1.

Cascone's paper was written in the year 2000, when greater access to the internet and communications technologies contributed to a technological determinism that viewed these new technologies as emancipatory. But since then, glitch art has had some time to settle and reorient itself. Four years later, for a bachelor's thesis that appears to be one of the few first documents to analyse glitch art, Iman Moradi analysed the spectrum of expression in glitch art, and attempted to characterise the kinds of glitch-art products. What is a "glitch" exactly, and when is it not a glitch? To address this aspect of purity, Moradi created two categories of glitches, *pure glitch* and *glitch-alike*.[38] Pure glitches are genuine errors that arise from autonomous systems. "Glitch-alike" occurs when a system is deliberately created to produce something that would otherwise be interpreted as an error. An example of this would be a technique such as *datamoshing*, when video keyframes are deleted, causing the video software to "misinterpret" its instructions, interpolating between unrelated images, and causing portions of the video image to smear across the screen. This can often be seen as a pure glitch in conversations over video chat such as Skype when there is a problem with the connection, leading to situations when the subject's eye might appear stuck to the wrong part of her face.

A decade after Cascone formally identified glitch art, Dutch artist Rosa Menkman provided a more impassioned take on the qualities identified by Cascone in her *Glitch Studies Manifesto*.[39] Menkman's manifesto was distinctly political, speaking of the "naive victims of a persistent upgrade culture", describing computers as layers of obfuscated protocols, created political hierarchies and ideologies, and using glitch art to end "the search for the holy grail called the perfect technology". Even though the manifesto is distinctly political and activist in tone, it is evident in the language of the document, and in her work, that Menkman finds a beauty in the artefacts of error and digital decay. "I find catharsis in disintegration, ruptures and cracks," she wrote. And describes the glitch as "a new and ephemeral, personal experience."

Both the technological opportunities identified by Cascone and the political and aesthetic opportunities identified by Menkman show something about those who work with technology, but is crucial to glitch art, and that there is an underlying distrust of new technologies. Though

38 Iman Moradi, "Glitch Aesthetics" Bachelor's diss., University of Huddersfield, 2004, 11.

39 Rosa Menkman, *Glitch Studies Manifesto*, 2010, http://rosa-menkman.blogspot.nl/2010/02/glitch-studies-manifesto.html.

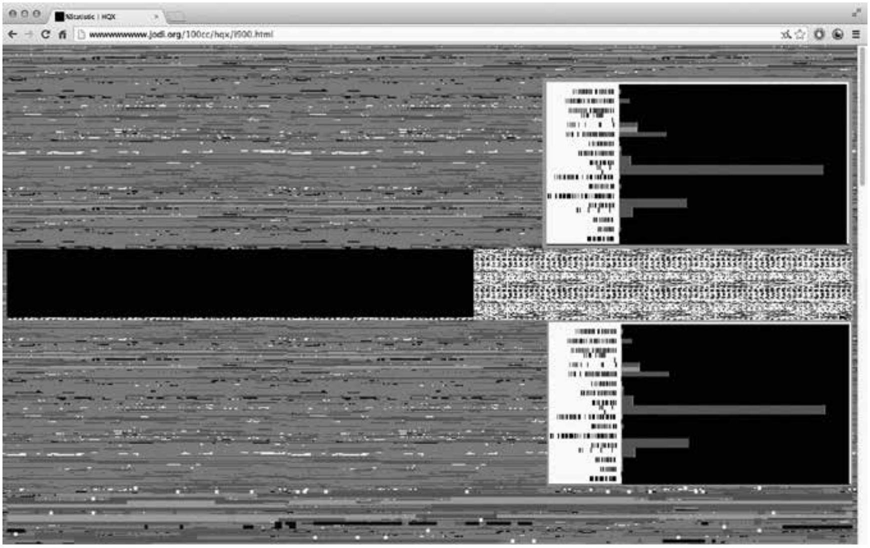


IMAGE 0.11 **Early glitch net art, Jodi's wwwwwwwww.jodi.org (1993).**

now computing technology really is everywhere, and the most striking thing is how banal it is: it has gone from machines of wonder to being simply appliances—no longer "indistinguishable from magic", as Arthur C. Clarke once dreamed.[40] As such, the general relationship to technology has changed. No longer does it feel perilous to take technology for granted, and so artists are now free to be irreverent.

The aesthetics of error have become an aesthetic form of their own, sometimes unconnected to any pure glitch or glitch-alike source, as seen in the works and general communication of artists such as Rosa Menkman, Jon Cates, and also pioneering Dutch glitch web artists, Jodi (see Image 0.11).

Persistent in glitch art are the questions, "What does it mean *that* it goes wrong?" What does "going wrong" mean? What are the implications of something that can go wrong? Are we aware that we were dealing with things that can go wrong? Often we do not know that we are at the mercy of a tool or system until something goes wrong.

In asking these questions, glitch art has pursued and invented strategies to interrogate its subjects, and to present the subjects in their

40 Arthur C. Clarke, "Hazards of Prophecy," in *The Futurists.*, ed. Alvin Toffler (New York: Random House Inc, 1972), 133–50.

works. These strategies have often shared much with Manovich's principles of new media, either openly stated, or in spirit. The basic principles are those of formal representation and automation, as at its core glitch requires autonomous systems to fail or perform counter to their intended purposes. The numerical and formal representation of media objects, their software, and their organising environments—such as databases, or the Web—has allowed the objects and their environments to be manipulated and disrupted. The approach of the glitch artist is often to either capture the effects of systems failing, or to subject the numerical representations to algorithmic manipulation, creating artefacts and behaviours that transgress the usual and expected outcomes of the objects and their environments.

0.2.3 Textiles, origins and choices

This section presents an understanding of "textiles" to set the boundaries for techniques that could have been considered in the research, and presents the reasons for choosing the textile techniques employed in the research. Some of these decisions were made at the beginning of the research, and others were made through observations gathered during practice. Specifically, the project made use of hand knitting; a bobbin-lace machine; and weaving using a floor loom, a digital loom, and a fully-automated industrial loom. The woven patterns employed were satin and houndstooth.

The research originated from observations made while knitting by hand, a handicraft technique by which a single element (a yarn), is knotted into itself by means of two needle points,[41] to make a textile. From the initial observation, a goal was formulated to explore transference of techniques and strategies from new media art to knitting and to other possible textile techniques. Though knitting implies a space of textile production limited to handicraft textiles, the actual space of textile techniques is much broader than that. The concept of textiles encompasses a range of related practices and techniques. Consider definitions of "textile" and related words from the Oxford English Dictionary:

41 An argument could be made that other knitting techniques exist that may be characterised as not "two needles", such as using circular or double-pointed needles, though even with these techniques the knot-making is still constructed by using two needlepoints.

> **Textile:** B.noun.1.a. A woven fabric; any kind of cloth. Also, a synthetic material suitable for weaving; any of various materials, as a bonded fabric, which do not require weaving. (Usually in pl.) 4. A manufactured material; now only a 'textile fabric', a woven stuff.[42]
>
> **Fabric:** 3. a. 'Any body formed by the conjunction of dissimilar parts' (Johnson); a frame, structure.[43]
>
> **Cloth:** I.1.a. A piece of pliable woven or felted stuff, suitable for wrapping or winding round, spreading or folding over, drying, wiping, or other purpose; a swaddling or winding cloth, wrap, covering, veil, curtain, handkerchief, towel, etc.[44]
>
> **Weave:** 1. a. trans. To form or fabricate (a stuff or material) by interlacing yarns or other filaments of a particular substance in a continuous web; to manufacture in a loom by crossing the threads or yarns called respectively the warp and the weft. Also with obj. the web itself, a garment made up of such a stuff or material. [45]
>
> **Knit:** 2. trans. b. To form (a close texture) by the interlooping of successive series of loops of yarn or thread.[46]

In a general sense, these definitions present a *textile* as a (generally, two-dimensional or flat) material made of pieces of animal, plant, or synthetic materials. These can be made out of individual fibres or pieces of the original material (such as single fibres, sinews, or branches), or as yarns that have been made by spinning fibres, which is often the case with most fabrics found in daily life, such as clothing and household fabrics. These textile materials can be then divided into two groups, so called

42 "Textile, Adj. and N.," *OED Online* (Oxford University Press, June 2017), http://www.oed.com/view/Entry/200011.

43 "Fabric, N.," *OED Online* (Oxford University Press, June 2017), http://www.oed.com/view/Entry/67394.

44 "Cloth, N.," *OED Online* (Oxford University Press, June 2017), http://www.oed.com/view/Entry/34649.

45 "Weave, v.1," *OED Online* (Oxford University Press, June 2017), http://www.oed.com.ezproxy.ub.gu.se/view/Entry/226680.

46 "Knit, V.," *OED Online* (Oxford University Press, June 2017), http://www.oed.com.ezproxy.ub.gu.se/view/Entry/104056#eid40001441.

"non-woven" materials such as felt, and materials created by the knotting or weaving of single or multiple elements.

Emery categorised knitting within textile techniques that used a single element, within *interlooping* techniques, which are formed by creating loops of the yarn drawn through loops already created in the yarn.[47] Crochet is also included in this categorisation. And, whereas crochet is *lateral* interlooping, where the loops are drawn through loops made on the same row, knitting is *vertical* interlooping, where the loops are drawn through loops made below the current loop, on a previous row. This interlooping is what allows garments such as sweaters to be unraveled, where the undoing of the knots gradually releases the single thread used to make the knitted piece.

Materials made from multiple elements employ techniques such as weaving or braiding: techniques whose aim is to combine multiple elements to construct a textile. This does not include techniques such as yarn spinning—whose aim is to bind discrete fibres together to create a yarn—or rope making, whose aim is to twine threads together to create rope. The research presented in this project investigates three textile-making techniques. Most of the work is done using weaving, either by hand, by hand with a floor loom, by hand with a digital loom, or with a fully-automated industrial loom. The work also employed knitting, and to a much lesser extent, bobbin lace (a multi-element technique related to braiding). The only technique whose choice was considered beforehand was weaving, and the others arose from practice.

The research concept arose from casual knitting. I had taken up hand knitting as a hobby as an attempt to reengage with physical practices. I had perceived an active algorithmic process in my manner for dealing with knitting patterns, and wanted to explore those further. Because the project arose from knitting, knitting was chosen to be examined further, to investigate possible transfers of strategy from new media art. Many small experiments were conducted in the early stages of research, such as converting knitting patterns to pseudo code, and examining KnitML, a markup language created to attempt to create machine-readable and machine-modifiable knitting patterns. These experiments are not included in this dissertation. What is included is the project presented in the first project chapter, which presents an effort to combine an element of computation (as a representative from new media art) with hand knitting.

47 Emery, *The Primary Structures of Fabrics*, 39.

The second strategy chapter presents a small project that employed an industrial bobbin-lace machine. Bobbin lace is a multi-element technique that creates a two-dimensional fabric by twisting pairs of yarns. This technique was not chosen deliberately. Rather, it was an opportunity that presented itself while teaching a course for the School of Design and Crafts (now called the Academy of Design and Crafts, *Högskolan för design och konsthantverk*) at a local textile museum, *Remfabriken*. The students and teachers had access to the machines of the museum, and I was struck by the expressive qualities of the industrial bobbin-lace machines on site. The artwork presented in the second project chapter is the result of a one-month process exploring the movements and functioning of the bobbin-lace machine within the goals of this research project.

The bulk of the project work presented in this dissertation uses several forms of weaving. The engagement with weaving arose from weaving's oft-mentioned relationship to computers and the history of computing. Comparisons between weaving and computation have been made for many reasons. Charles Babbage's designed-but-never-produced Analytical Engine is largely seen as a precursor to modern computers, and Babbage had a reverence for the Jacquard loom because of its apparent programmable nature.[48] The system of punched cards of the Jacquard loom was adapted to programme computers. Both weaving and computer displays have used grids to display images. The connections between the Jacquard loom and modern computation have been made by Sadie Plant and others, often relying on metaphors employed by Ada Lovelace when describing Babbage's machines. Even though the connection between the Jacquard loom and computation as made by Plant has been convincingly disputed by Davis and Davis,[49] certain aspects of weaving and computation still share much in common: such as formal notation structures, an apparent "hardware" and "software" division of the machine and the weaving pattern, the shared use of punch cards. As such, it is worth exploring weaving as a possible candidate for the procedures explored in this PhD project.

As was earlier explained in the discussion of researching through practice, it was decided that I should learn to weave by hand as a strategy to gain an understanding of the technique and its structures. This strategy was employed by McLean and Griffiths, explained later in this text,

48 Sadie Plant, *Zeros + Ones: Digital Women + the New Technoculture* (London: Fourth Estate, 1997), 18.

49 Martin Davis and Virginia Davis, "Mistaken Ancestry: The Jacquard and the Computer," *Textile: The Journal of Cloth & Culture* 3, no. 1 (Spring 2005): 76–87.

as a way to gain insights that might be invisible to an expert. Within this process of learning the technique, two woven expressions were chosen for further exploration. These expressions are *satin*, and *houndstooth*. The word "expression" is used here, because, technically, satin is a woven structure with specific expressive characteristics, while houndstooth is a visual phenomenon that arises from a specific woven structure employing a specific thread colouration pattern. However, both produce unique, identifiable expressions, visually and to the touch. The decision to pursue these specific expressions was strongly influenced by their pervasiveness. Satin is one of the three basic patterns in weaving (alongside *twill* and *tabby*), and so its foundational position has caused it to be used extensively in woven textile production. Houndstooth has been found in garments dated from the first-century BC,[50] and in contemporary dress as a staple in garments such as outerwear and accessories. Both of these pervasive expressions are the product of a strict coding in the yarn orientation and colouring, which makes them ideal candidates for exploring in this research project. Learning to create and control expressions that are so culturally pervasive was a powerful feeling, as expressed by my research diary entries of the time. It was eye-opening to learn that such pervasive patterns were the result of encoding that could be easily altered. This provided an initial incentive to consider these techniques.

Diary: Satin, the lover

Satin invented luxury.

It has a full history as one of the three basic weaves, the patterns on which all other weaving techniques are based. It provides the basis for decorative techniques like damask, using the difference in shine of warp- and weft-faced satin to dazzling visual effect.

Its physical structure of a loose web of binding points causes it to drape elegantly over anything it is placed against and on top of. Silk satin wouldn't be suitable for trousers—it isn't strong enough. But it is perfect for delicate things. It hugs curves, making it ideal to hint at the body underneath the dress. Its loose binding points cause long lengths of thread to be exposed, reflecting the light better than any other kind of weave. For this, glitters and shines. It scintillates and gleams. It shimmers like water, as though you

50 "Gerumsmanteln," *Vävmagasinet* 2/06 (2006).

were wearing a sparkling brook.

Satin and silk were practically made for each other. The silkworm's proteins gives us a fibre that is light, shiny, airy and perfect for enhancing the qualities of satin, and for satin to show off the qualities of the silk.

Because of all this, satin has an allure.

Satin occupies this space in our cultural consciousness. It fills a niche that we like filled, to feel beautiful, to feel luxurious, to feel pampered. Satin occupies many other uses, but we don't think of these. We think of how satin hugs our bodies in gowns and supports the ring in the ring box. Satin makes us feel good.

Diary: houndstooth

"Oh, houndstooth". My mother's reaction to the toy boxer that I had brought home bearing the wrestler Hulk Hogan's face and a bizarre houndstooth smock. Not, "wow, a boxing doll!" or "wow, Hulk Hogan!" But, "oh, houndstooth."

I remember being confused, looking at the cloth and thinking that maybe the little jagged shapes looked kind of like dogs' teeth. But forever cemented in my head from that comment was the knowledge that houndstooth is A Thing, something that people notice and causes them to remark "oh, houndstooth."

Houndstooth hadn't entered my consciousness much since then, until I began weaving. Now I can't stop seeing it everywhere, because it is everywhere. It comes in and out of fashion, but it is one of those enduring patterns that lives in wardrobes and on the streets even when it isn't in fashion. The pop celebrity Lady Gaga has been seen in a getup with houndstooth dress, purse, shoes, hat, and even sunglasses, performing at a houndstooth piano, bench and microphone—also in a "Who wore it better?" celebrity fashion comparison pitted against tautological celebrity Kim Kardashian, also wearing the same houndstooth dress, gasp!

Ultimately the creation of this dress and the choice of these ladies to wear it happened for a reason. The most obvious explanation is that houndstooth makes a statement. It is loud, which aligns with Lady Gaga's attempts to be shocking. The social power of houndstooth was encapsulated in a recent fashion column, stating that "… the effect of a woman in houndstooth … is a fierce one, signifying power *over and above prettiness…"*[51] *It hints at the human tradition to create pattern, ornamentation and visual presentation that inspires awe.*[52]

The Gerum cloak had 32 holes in the fabric, believed to have been caused by a sharp weapon, also suspected to having caused the death of the owner. Although it cannot be supported, there is a sneaking suspicion that the loud houndstooth pattern might have made it difficult for the wearer to conceal themselves. Houndstooth cannot be ignored.

The houndstooth. Start with a black square and climb the ramp up, two threads at a time until you reach the next black landing point. Cross it, climb down the black steps, creating an identical white negative space between your black reference points.

The houndstooth. Canines biting into canines, interlocking. No force, no tension, equally supporting each other in a net of teeth on teeth on teeth. A surface of jaws.

Step back and it melts into a shimmering grey. Not black, not white, not really grey, but a scintillating more alluring than any LCD screen. Waiting for the subway, the ad flickers across the screen and suddenly the edge of your vision is exploded by a tiny point that grows to become a woman's jacket. Big, chunky houndstooth. It isn't printed, it is the real deal in unbelievably thick yarn that can't help but form the grid that tricks your eyes.

In German, hahnentritt. Hen's kick, path, scratch, step. A grid of wet paint, black and white segments streaked by the hen on a mission. Its four-taloned toes dragging their mark across the universe of fabric.

Houndstooth is lo-fi psychedelia. It plays on the biology of the eye. Our built-in physiological edge-detection doesn't quite know what to do with the interlocked pattern. Instead of the comforting regularity of a check or plaid, it is the high-contrast counterchange of caressing positive and negative space. An edge should be made sharper by our visual apparatus, but instead the pattern shimmers in our vision. It doesn't stay still.

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51 Susannah Frankel, "Ready to Wear: Houndstooth Is Fierce, and Signifies Power over and above Prettiness," The Independent, November 2, 2009, http://www.independent.co.uk/life-style/fashion/features/ready-to-wear-houndstooth-is-fierce-and-signifies-power-over-and-above-prettiness-1813062.html.

52 T.A. Heslop, "How Strange the Change from Major to Minor: Hierarchies and Medieval Art," in *The Culture of Craft*, ed. Peter Dormer (Manchester University Press, 1997), 53–66.

> *The pattern is so commonplace that we forget what it does to us when we see it. Our senses are so overloaded by the other things in the world that move and shimmer in millions of colours. We forget that if we stop, for a second, this two-tone texture jams our brains' perception and provides a beauty that refuses to be understood and can't be grasped.*

Both provided very clear "ideal" expressions—the expressions that are pervasive, of shiny, draped satin, and bold houndstooth—where deviation from the ideal caused by the transferred strategies was evident. Though the motivation to explore these expressions was affective, the results of the research presented in this dissertation will prove to validate these choices.

Weaving is generally comprised of three foundational structures. *tabby*, *satin*, and *twill*. tabby is the most basic structure, where every weft thread proceeds as lying over one warp thread, under the subsequent thread, and continuing in this manner. The warp threads also lie over and under the weft threads in the same manner, creating a kind of checkerboard pattern. Of the three foundational structures, tabby is the strongest and most rigid.

Twill is a structure whose qualities lie somewhere in between satin and tabby. Unlike the over-under pattern in tabby, twill weft threads will lie over and under several warp threads. The pattern of each weft thread is shifted slightly with respect to its neighbours, creating diagonal *wales* in the pattern. A standard twill pattern would have each weft thread lying over two warp threads, then under two warps threads, with each weft thread shifted with respect to its neighbour by one warp thread. Twill produces a textile that is more pliable than tabby, yet still is more durable than satin. Twill is most commonly found in denim, and is used extensively for trousers.

Satin has binding points arranged in a regular, sparse structure. This creates a fabric that drapes well (because of the binding points), shines (because the structure produces long, exposed threads that reflect the light), but is weak and so unsuited to garments that require strength (such as trousers, for example). Satin is thus used for garments that contour the body (such as dresses and undergarments), and situations where a shine is a desirable effect (such as again in dresses, scarves, or display textiles such as in a ring box). Satin is also used to great effect in damask weaving. Warp-faced and weft-faced satin structures are so called because the structures produces long, exposed warp fibres or weft fibres, respectively. This dramatically affects the viewing angle at which the woven material reflects light. Damask weaving exploits this by constructing patterned motifs out of contrasting warp-faced and weft-faced satin sections of the textile. This can produce dazzling patterns, often using a single colour of yarn.

All of the foundational weaving structures provide regular, predictable structures that could easily be treated with techniques from new media, such as creating an algorithm that generates the structures (as will be shown later in this dissertation). Satin, with its strong expressions of shine, drape, and a smooth surface, provides an opportunity to investigate disruptions and modifications of these expressions through treatment of the pattern with techniques from new media.

The houndstooth pattern is likely pervasive because of its bold visual effect. It is, in effect, a simple check pattern, with disruptions of the check's squares. A check pattern already generates visual artefacts because of the high contrast relationship between the black and white areas, and the disruptions of the squares in houndstooth may further contribute to this. Modifications in the structures that create houndstooth (either in its yarn colouration or in the woven pattern) will also modify the pattern's expressions, and this relationship was explored in this research project, and will be presented in the final project chapter.

0.3 Directly related contemporary work

This subsection presents contemporary work that is addressing similar concerns, or employing similar approaches, to those explored in this research project. These works will provide a relational context to the work conducted in this dissertation, to demonstrate how this work is related, but also how it differs from previous work that has been conducted.

0.3.1 Glitch textiles

This enquiry is based on transferring approaches and strategies from new media and glitch art to codes in textiles, noting several glitch artists have already been deliberately combining the two domains. Often, the strategy in these works is to use the grid in textiles to act as a display of glitched digital content. The approach and ethos of glitch art has been

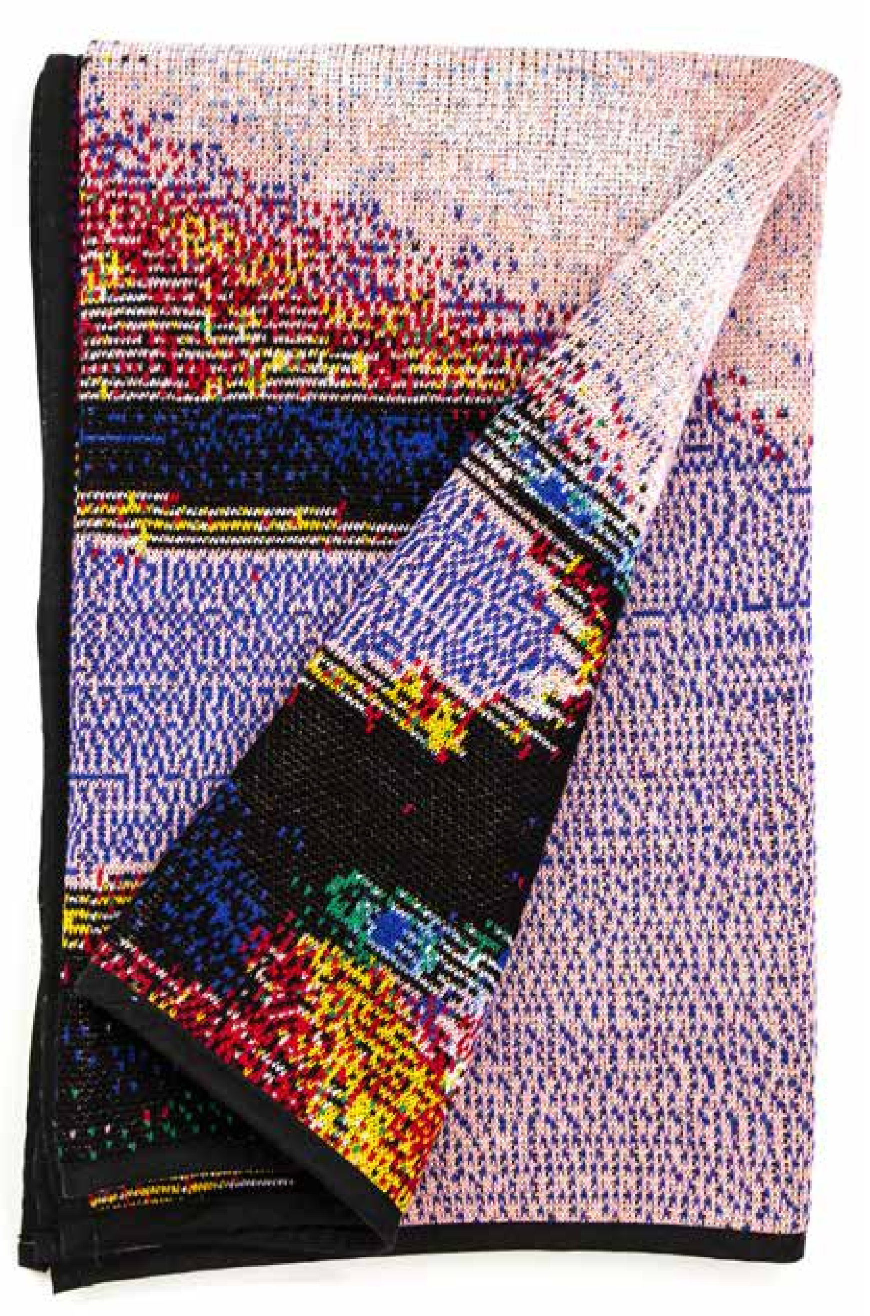


IMAGE 0.12 **Philip Stearns' blankets created from faulty displays of point-and-shoot digital cameras.**

IMAGE 0.13 **Jeff Donaldson's *Notendo*, knitted scarves based on images from a glitched Nintendo game console.**

PHOTO BY JOHN DE CRISTOFARO

IMAGE 0.14 **A woven tapestry from Jeff Donaldson's *adaptedNES* series, 2017.**

PHOTO BY STEF MIERO

IMAGE 0.15 **A woven tapestry from Jeff Donaldson's *Light Scans* series, 2017.**

IMAGE 0.16 **Melissa Barron's weaving of the classic Activision game loading screen from the 1980s**

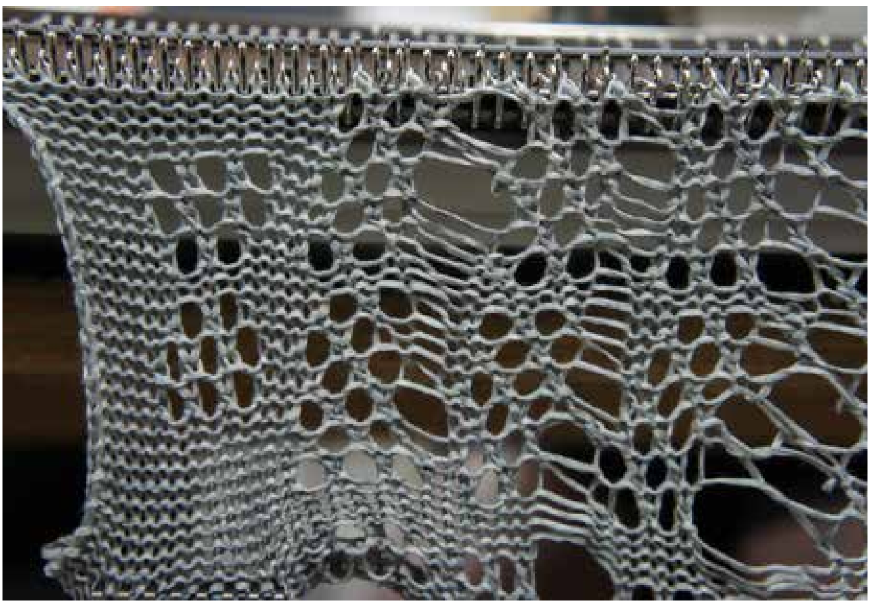


IMAGE 0.17 **Nukeme's Glitchknit knitted lace, from a modified knitting machine.**

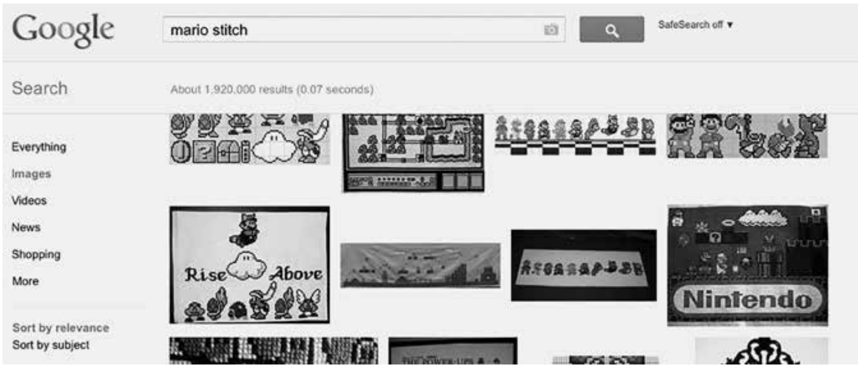


IMAGE 0.18 **The results of a Google search for "mario stitch". Note the textile results numbering in the millions.**

transferred to textiles under the term "glitch textiles", used by several artists to describe their work. Philip David Stearns has taken images from broken digital camera displays and has them woven as blankets, seen in Image 0.12. Stearns gained notoriety through a crowdfunding campaign to commission the TextielLab in Tilburg, Netherlands to produce them.[53] Melissa Barron has taken or caused glitches in classic computer systems and woven them with a jacquard loom, seen in Image 0.16. Some of her pieces have long floats, a kind of textile error, though it is unclear if this is because of the way the loom functions with her patterns, or whether she chose to have that in the pattern. These long floats contribute to the sense of something breaking. Jeff Donaldson has also been taking glitch images as inspiration for a collection of scarves, taking glitched digital images from a Nintendo console and weaving them on a computer-controlled knitting machine, on a weaving machine, and also using ambient light read by a flat-bed scanner as a source for a tapestry, as seen in Images 0.13-0.15. There is something shared by the approach of all these artists, and that is the use of the cloth grid as medium for expressing digital images. The shared grid of cloth and pixel representation makes this a natural progression. In many ways this is no different than the millions of Marios knitted, woven and cross-stitched by avid crafters around the world, see the results of a simple Google search for "mario stitch" in Image 0.18. There is a kinship and a systematic similarity that allows practices to intersect.

53 Phillip David Stearns, "Glitch Textiles," Kickstarter, 2012, https://www.kickstarter.com/projects/phillipstearns/glitch-textiles.

Glitch has been described as an aesthetics of error,[54] which allows for a broad range of techniques and approaches to be included under the umbrella of glitch, though the techniques may themselves dramatically differ in their relationship to error. This range of approaches and techniques also creates a range of ways in which glitch textiles can relate to textiles themselves, and the works presented under the name "glitch textiles" appear to have a different relationship to textiles than those presented in this dissertation.

This research project differs from the work of the four above-mentioned glitch-textile artists. The key points of difference is the subject of the glitch, and the role of the textile technique. All the presented works satisfy a kind of pure glitch, where the images originate in pure glitches, but the use of the textile is not as a glitched medium. The works use the one-to-one, pixel-to-stitch relationship of digital images and cloth, to use the cloth as a display medium for their digital glitch images. The glitch happens before the textile, and though there is this tight kinship between the cloth and the digital image through the pixel and stitch, the cloth is being used as a display like a printer or screen to display *digital image* content. But to call these "glitch textiles" would be like calling the glitched images printed in this dissertation, "glitch paper".

Their ability to do this translation speaks to a kinship between textiles and computers. But the aesthetics that they are using are that of the source medium, not the presentation medium. Most of the textile artefacts presented are without error. No dropped stitches, no long floats, no incorrect stitches. They do not want the textiles glitched; they want perfect blankets and scarves.

Barron's work comes closest to possessing a knowledge of the textile glitch. Her long floats strung between either side of the pieces show either a mechanical error in the weaving process, or a deliberate choice to create something that was "wrong", according to tradition. The work of Nukeme (Image 0.17) most resembles the modification of the textile pattern, by actively modifying images of textile patterns in software and changing them at a pixel level. His haphazard lace directly challenges the form that lace is supposed to follow.

Where does the glitch happen? This is an important question when trying to decide what the word "glitch" means when we start moving

54 Tim Barker, "Aesthetics of the Error: Media Art, The Machine, the Unforeseen, and the Errant," in *Error: Glitch, Noise, and Jam in New Media Cultures*, ed. Mark Nunes (London: Continuum, 2010).

it outside of its traditional hard, cold technological milieus. In a sense, visual glitch also involves a translation from code to image. It is the code within the machine that is breaking, the screen is faithfully displaying what it is given. The use of textiles by Stearns represents a kinship between computer and textile, but that relationship is that of the grid and binary representation. The glitch textile works presented here represent a discovery of textiles, materiality, and the computer-like beyond the computer.

As with all glitch, the glitch action is subverting the intention of the user and creator and not that of the system, because the system has no intention in itself, it has no agency (but it is still autonomous). The approach of this enquiry is rather a transfer of strategies used in digital glitch and usually applied to digital code, applied to the codes of textiles, specifically weaving patterns.

0.3.2 Feijs and Toeters: Fractal houndstooth

Concurrent with the research project of this dissertation, Mathematician Loe Feijs and fashion designer Marina Toeters explored mathematical possibilities in the houndstooth pattern. Feijs constructed a piece of software that could render patterns related to houndstooth.[55] Feijs' software used a pre-set matrix to determine the weaving pattern, which could be manually filled in with any trivial weaving, but for the sake of the research was filled with various twill variations. The software bears a striking resemblance to the houndstooth software that will be presented in this dissertation's final project chapter. By contrast, the software presented in this dissertation uses an algorithm to create the twill. While Feijs' software produced singular houndstooth images, the software of this dissertation incorporates an interface—either the mouse or an external controller—that allows for a navigation of the possible pattern space. These differences will be more apparent when the software is presented in the fourth strategy chapter.

Feijs' continued exploration of houndstooth departed from the weaveable, to explore the houndstooth basic shape as a motif for fractals. Houndstooth appears to have a basic unit that forms its tessellation. From a weave construction perspective, this unit is not the basis for the

55 Loe MG Feijs, "Geometry and Computation of Houndstooth (Pied-de-Poule)," in *Proceedings of Bridges 2012*, 2012, 299–306, http://bridgesmathart.org/2012/cdrom/proceedings/05/paper_5.pdf.

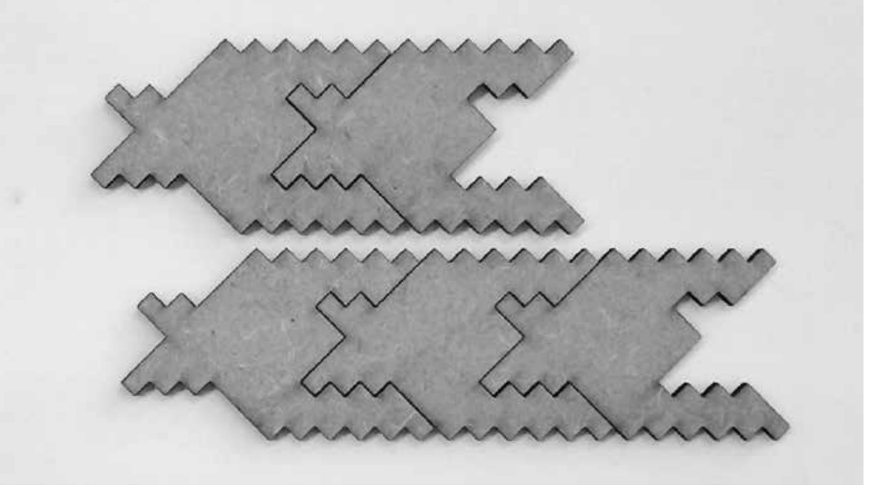


IMAGE 0.19 **Lasercut houndstooth tiles by Feijs.**

houndstooth repetition, but is the form that arises from the repeating 2/2 twill pattern—which has the dimensions of 4 × 4 threads—and the repeating warp and weft colouring, which has the dimensions of 8 × 8 threads. Nonetheless, the eye perceives this "tooth" shape from the structure, and Feijs and Toeters used it as a basic unit of tessellation. This allowed Feijs to explore alternate colourings of the houndstooth tessellation and to laser-cut wooden puzzle pieces of this basic pattern that could be assembled and arranged in new patterns (Image 0.19[56]).

Part of Feijs' exploration was to construct a pattern in the Logo programming language that could trace a basic houndstooth pattern, which could be scaled to provide different resolutions of the houndstooth pattern. By scaling the variables in the code down to their lowest possible values, Feijs proposed a "true" minimal houndstooth shape. This was compared to "puppytooth", a pattern generally understood as the lowest resolution houndstooth. While puppytooth is woven with alternating *pairs* of black and white warp and weft threads in a 3/1 twill, it is unclear whether Feijs' proposed shape is weavable using any basic weaving structures. Feijs' minimal houndstooth appears to be the most basic houndstooth "shape", but not the most basic houndstooth weave (which appears to be, in fact, houndstooth proper with its 2/2 twill).

56 Feijs.

IMAGE 0.20 **Exploring the houndstooth shape with embroidery, by Feijs and Toeters.**

In a later paper,[57] Feijs and Toeters considered the basic houndstooth shape as a possible fractal pattern, using the basic houndstooth shape as units that could be arranged into a larger houndstooth shape, envisioning the fractal iterations increasing and decreasing infinitely. The patterns were laser-cut into fabric that was used to produce garments. Feijs and Toeters, in their conclusion, considered whether their fractal houndstooth pattern could be woven using a traditional loom. The complexity of the pattern makes this highly unlikely. Though, applying their fractal approach to weaving variables such as twill patterns, loom configuration (such as heddle and pedal tie-up, and pedalling pattern), and thread colouring may produce interesting, and certainly weavable, results. A very similar approach was used by Ada Dietz, to be discussed on page 67.

57 Loe MG Feijs and Marina Toeters, "Constructing and Applying the Fractal Pied de Poule (Houndstooth)," in *Proceedings of Bridges 2013: Mathematics, Music, Art, Architecture, Culture* (Tessellations Publishing, 2013), 429–432, http://archive.bridgesmathart.org/2013/bridges2013-429.pdf.

Feijs and Toeters later explored another fractal variation of houndstooth, by packing the houndstooth shape with zig-zags, and exploring fractal iterations of this structure.[58] The manufacturing of this by machine-controlled embroidery or laser cutting was explored, and then once again put into practice as motifs on garments (Image 0.20[59]).

The work of Feijs and Toeters represents a fascination with houndstooth, and an attempt to deconstruct and reconstruct it using fractal techniques. It uses the weaving pattern as a point of departure—to which they have not yet returned—to explore the aesthetic, mathematical and manufacturing possibilities of the perceived unit in houndstooth.

0.3.3 Weaving Codes – Coding Weaves

Also concurrent with this PhD work was the multi-institutional research project Weaving Codes – Coding Weaves, led by Alex McLean at the University of Leeds. The project's progress was catalogued in a blog,[60] and a summary was also provided through a published paper.[61] The project shared much in terms of spirit and approach with the work of this PhD project. As a grounding for the work, the project's web site stated the view of considering ancient looms "as early digital art machines that prefigured concepts of dyadic arithmetic and logic."[62] The project's research questions were stated as:

- What are the historical and theoretical points at which the practice of weaving and computer programming connect?
- What insights can be gained if we bring these activities together, through live-shared experience?
- How do digital technologies influence our ways of making?

58 Loe M. G. Feijs and Marina Toeters, "A Novel Line Fractal Pied de Poule (Houndstooth)" (Proceedings of Bridges 2015: Mathematics, Music, Art, Architecture, Culture, Tessellations Publishing, 2015), 223–30, http://archive.bridgesmathart.org/2015/bridges2015-223.html.

59 Feijs and Toeters.

60 "Weaving Codes – Coding Weaves," accessed February 16, 2018, http://kairotic.org/.

61 Griffiths and McLean, "Textility of Code."

62 "About," Weaving codes—coding weaves, April 28, 2014, http://kairotic.org/about/.

The project listed as its strategies:

- investigating patterns from the perspectives of weaving and music
- developing a computer language and code for describing the construction of weaves … and using it to drive computer-controlled looms.
- grounding live coding research in craft and in new social and pedagogic contexts,

Central to the group's work was an emphasis on learning a craft by hand, and even constructing the tools of the craft, to understand how it works, and modelling the craft in software to be able to provide a way of analysing the craft. This was done with warp-weighted weaving looms, backstrap weaving looms, tablet weaving looms. McLean described the process as allowing them to "learn from failure"[63]. Through the process he also observed an ability to transfer knowledge from a previous craft, in this case it was from knitting to warping a warp-weighted loom.[64] McLean used this process of learning the craft to help develop a notational language to describe the weave structures of the loom.[65]

When working in the opposite direction, when constructing a simulation of a 4-shaft loom, and then comparing it to the reality of weaving, collaborator Dave Griffiths observed, "There is a lot of reasoning required in response to issues of structure that cannot be defined ahead of time. You need to respond to the interactions of the materials and the loom itself…"[66] The software represented an ideal, but the material provides resistance in practise. Griffiths described the process of writing the software simulation as a way of understanding the patterns and technique.[67] Creating the simulation is also a strategy to learn by actively engaging with the subject,

63 Alex McLean, "Making a Warp Weighted Loom," Weaving codes—coding weaves, February 13, 2015, http://kairotic.org/making-a-warp-weighted-loom/.

64 McLean.

65 McLean.

66 Dave Griffiths, "Coding with Threads: Frame Loom," Weaving codes—coding weaves, December 22, 2014, http://kairotic.org/coding-with-threads-frame-loom/.

67 Dave Griffiths, "Dyadic Device: A 4 Shaft Loom Simulation.," Weaving codes—coding weaves, December 14, 2014, http://kairotic.org/dyadic-device-a-4-shaft-loom-simulation/.

but in this case it is an explicit engagement with the patterns and notation of the craft, not the physical act of the craft itself. One interesting result of Griffiths' was that creating visually "interesting" patterns in his 4-shaft loom simulator's notation also led to "interesting" weaving patterns.

The project created software to model different kinds of textile structures. Software was created to model woven structures created out of a single thread, where the warp and weft are made from the same thread, in order to aid in modelling an ancient Greek form of weaving that is effectively a combination of warp weaving and tablet weaving.[68] A software language was constructed to model tablet weaving that notated the manipulation of the "cards".[69] This allowed for a simulation of a weaver's actions.

Software was created to render images of *quipu* (or *khipu*), an Incan record-keeping system of knots tied on threads, from the Harvard Khipu Database Project, a database of all known quipus, with their structures encoded.[70] This allowed them to attempt to apply Claude Shannon's concept of "data entropy" to analyse the quipus for trends and deviations in the data structures. It also allowed them to sonify the quipus, again listening for trends and changes in the data.

Griffiths understood woven objects as encoding actions in time,[71] which allows for woven objects to be "read", or reverse engineered.[72] This led to an experiment where the instructions for weaving a piece of fabric were encoded in the weaving of the fabric itself, based on a language constructed of rotations of the cards in the tablet weaving. Griffiths wrote, "One of the potentials of weaving I'm most interested in is being able to demonstrate fundamentals of software in threads..."

The Weaving Codes – Coding Weaves project demonstrates researchers applying several strategies involving textile techniques and software,

68 Dave Griffiths, "Procedural Weave Rendering," Weaving codes—coding weaves, November 9, 2015, http://kairotic.org/procedural-weave-rendering/.

69 Dave Griffiths, "A Language for Tablet Weaving," Weaving codes—coding weaves, January 2, 2015, http://kairotic.org/a-language-for-tablet-weaving/.

70 Dave Griffiths, "Pixel Quipu," Weaving codes—coding weaves, December 2, 2015, http://kairotic.org/pixel-quipu/.

71 Dave Griffiths, "A Cryptoweaving Experiment," Weaving codes—coding weaves, December 1, 2015, http://kairotic.org/a-cryptoweaving-experiment/.

72 Dave Griffiths, "Learning to Read, Notate and Compute Textiles in Aarhus," Weaving codes—coding weaves, October 15, 2014, http://kairotic.org/learning-to-read-notate-and-compute-textiles-in-aarhus/.

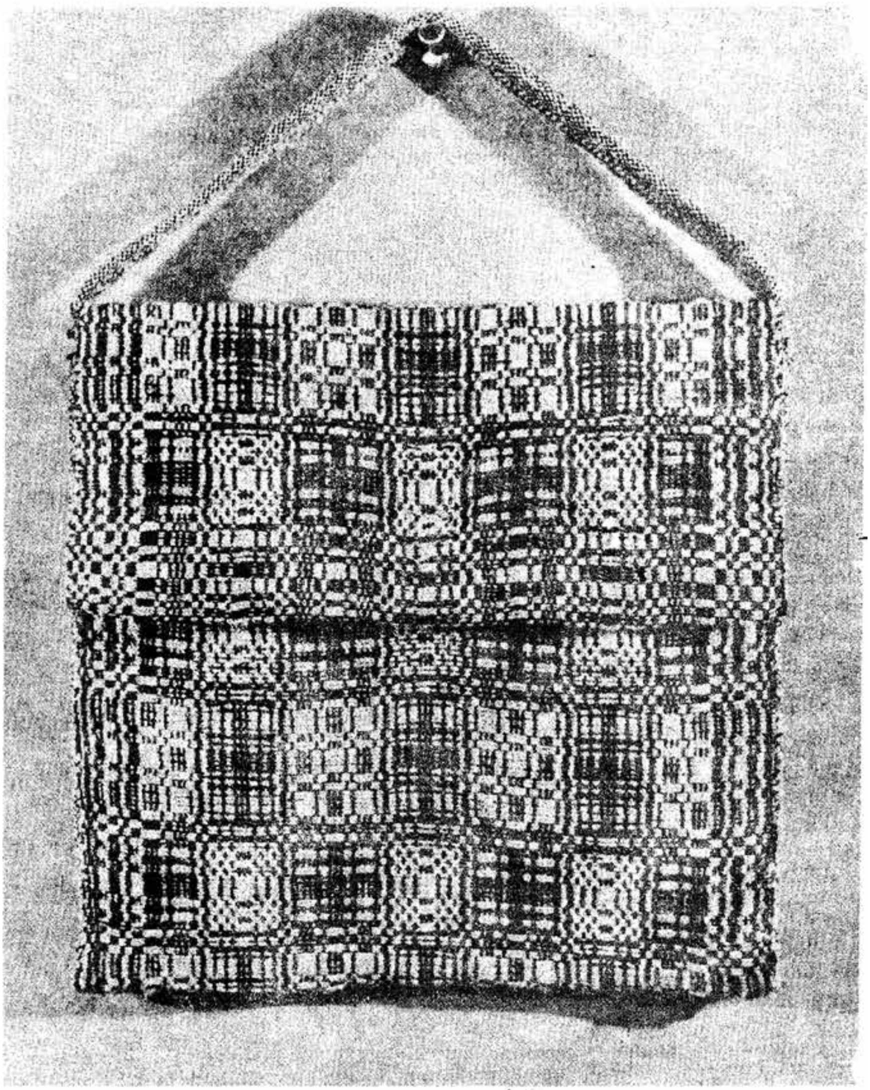
specifically strategies that were also employed in the research presented in this dissertation. The researchers engaged in learning the crafts by hand in order to understand their structures and functions. The project also created software to model what existed in these weaves, but also as a means to understand how the information of the weave was structured, and to allow for innovation in the craft. The software was used as a lens and tool for working with the existing woven material. The work presented in this dissertation differs from Weaving Codes – Coding Weaves in several ways. The first is simply the subjects interrogated. Weaving Codes did not interrogate satin or houndstooth. This dissertation also introduces glitch and glitch art into this process of interrogation of the textiles, which Weaving Codes did not.

0.3.4 Ada Dietz: Algebraic Weaving

Though not contemporary, this work shares so much in common that it could very well be a contemporary project. In the mid 1940s, American weaver Ada Deitz began experimenting with using polynomial equations to construct woven patterns. The algebraic constants such as x and y came to represent features of the setup of the loom, such as the tie-up of the harnesses in the loom. The work was presented in the 1949 leaflet *Algebraic Expressions in Handwoven Textiles*.[73] Dietz' technique allowed for the creation of a range of possible patterned expressions. The work of Dietz represents an early relative to the work presented in this dissertation. Dietz established an algorithmic relationship between components of the weaving process, and explored the results of modifying the components and their relationships. The work presented in the strategy chapters of error and houndstooth use a similar strategy. I discovered Dietz' work late in the dissertation-writing process, and was amazed by Dietz' application of similar techniques to the configuration of the loom, which I had already identified as a possible extension of the work of this dissertation, where the performance of the houndstooth or the glitching of parameters could be applied not just to the woven pattern, but directly to the loom's configuration.

73 Dietz, *Algebraic Expressions in Handwoven Textiles*.

ALGEBRAIC EXPRESSIONS
AKD-3-Z-0-1A



This photograph show the square of a trinomial $(x+y+z-)^2$ woven in the overshot weave. The warp and tabby weft is rust colored cotton. The pattern weft is gray ratine in a wool and rayon mixture. 23

IMAGE 0.21 An excerpt from Ada Dietz' *Algebraic Expressions in Handwoven Textiles* (p. 23)

0.4 Subjects not addressed in this text

There are bodies of discourse pertaining to the subjects of this dissertation that are not problematised. However, the work presented in this dissertation might be useful to these discussions.

I am writing this work in a western, 21st-century context, and it is difficult in this context to discuss either textiles or technology (and specifically textiles *and* technology) and avoid issues of gender. While both realms are viewed as heavily gendered, there is significant work showing that the divisions are neither clear-cut nor obvious.

Weaving and knitting are strongly tied to women's handicraft, and as such have been used as tools to examine the value of "women's work", the value of alternate modes of thinking and working, and as important pieces in feminist discourse, such as Roszika Parker's *Subversive Stitch: Embroidery and the Making of the Feminine*,[74] and the work of Lucy Lippard and Judy Chicago. These are but a few names, and the discourse is of course much broader.

I am a man who knits, but I am very aware that it was my mother who taught me and not my father. But when one searches beyond the familiar, beyond handicraft, into other domains, and looks further back in history, or to non-Western contexts, or to industrial production of textiles, it becomes more difficult to make these clear divisions. Counter-examples of textiles as women's work make themselves known: the colourful knitting by the male indigenous inhabitants of Taquile, Peru; men weaving in ancient Egypt as recorded by the ancient-Greek historian Herodotus.[75]

When discussing technology it is difficult not to associate it with "men's work". Women still make up a disproportionately low percentage

74 Rozsika Parker, *The Subversive Stitch: Embroidery and the Making of the Feminine*, Repr. and rev. ed. (London: Women's Press, 1996).

75 Herodotus, *An Account of Egypt*, trans. G. C. Macaulay, 2006, https://www.gutenberg.org/ebooks/2131.

of the workforce in technology fields.[76] But there has been considerable discussion, again within feminist discourse, reevaluating women's contribution to the history of technology and computation, such as Sadie Plant's history of Ada Lovelace and her work on Charles Babbage's Difference Engine and the advent of computer programming in the 19th century.[77]

Women's place in the history of computing cannot be characterised by people like Lovelace who might be seen as outliers. Jane Margolis and Allan Fisher found a relationship between the role of the personal computer as a toy for boys in the home and boys' likelihood to pursue a career with computers, and by extension the unlikelihood that girls would.[78] In fact, the gender balance of many professions in the United States was slowly approaching parity until the mid 1980s, when the percentage of women working in computer science started to plummet while other professions continued to creep in the direction of parity.[79] This shift coincided with the introduction of personal computers in the home, often presented explicitly as toys for boys. It appeared that, up until that point, the United States, and perhaps other western nations, was approaching a point in computer science where women would not be underrepresented. This is of course conjecture, but once again we are shown that the western relationship between computation and gender is not universal.

The creation of the contemporary craft movement through the industrial revolution created several themes of discussion that continue to this day. One is social upheaval through technical development, the division of labour and the plight of the worker, characterised in the writings of Karl Marx, and we are reminded of its importance every time a textile factory collapses in Asia. Another is the role of making and its capacity in self-actualisation, shown in the Arts and Crafts movement in writings by John Ruskin and William Morris, and in similar movements such as *slöjd*

76 Europäische Kommission, Inhalte und Technologien Generaldirektion Kommunikationsnetze, and Iclaves S. L, *Women Active in the ICT Sector Final Report ; a Study* (Luxembourg: Publ. Office of the Europ. Union, 2013), http://dx.doi.org/10.2759/27822.

77 Plant, *Zeros + Ones*.

78 Jane Margolis and Allan Fisher, *Unlocking the Clubhouse: Women in Computing* (Cambridge, Mass: MIT Press, 2002), 24.

79 Steve Henn, "When Women Stopped Coding," NPR.org, accessed February 26, 2016, http://www.npr.org/sections/money/2014/10/21/357629765/when-women-stopped-coding.

in Sweden. This theme reappears in the contemporary DIY culture both characterised as a kind of meditative act of making with one's hands, and also in the re-skilling rhetoric presented by proponents of newer digital fabrication techniques such as 3D printing and computer-controlled milling machines. Yet another theme is a reverence for craft knowledge and the craftsperson, a theme which is present in all of the areas mentioned the paragraph above, and currently manifests itself in places such as Richard Sennet's *The Craftsman*,[80] and internet videos fetishising this or that craftsperson. This actually aligns with my own love of making, which compelled me to learn to knit, weave, programme, and was the seed for this PhD.

Each of the concerns mentioned in this section could provide novel insight into the decisions made throughout this research project. Especially when considering the influence of pervasiveness on the decision to use certain textile techniques and expressions, it may be fruitful to consider questions such as: Why are some patterns pervasive? Are pervasive qualities more or less likely to yield fruitful transfers of strategy? These lines of enquiry will likely yield a better understanding of the results of this enquiry, and perhaps suggest new directions. The research of this dissertation has chosen a different focus, but will benefit in the future from asking the above-mentioned questions.

80 Richard Sennett, *The Craftsman* (London: Allen Lane, 2008).

1. The grid

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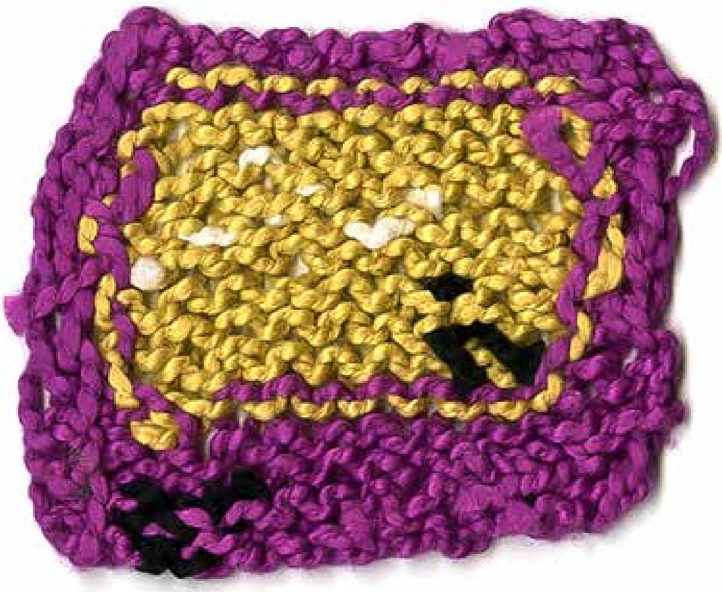

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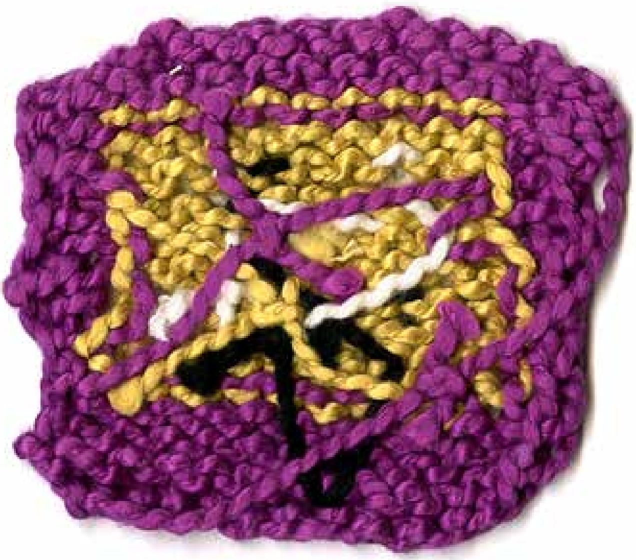

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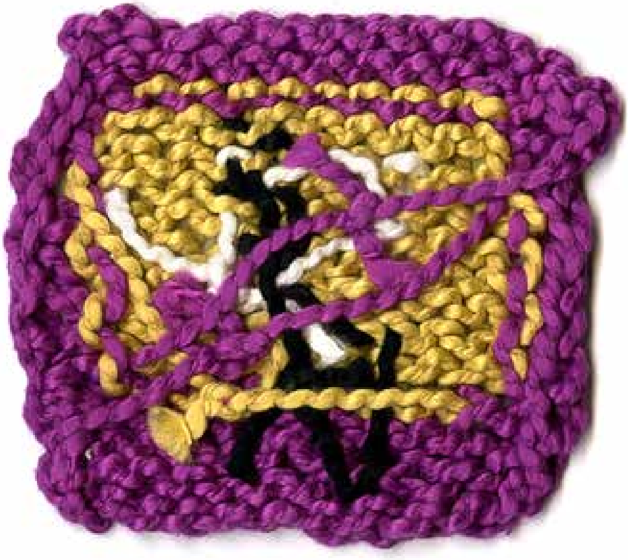

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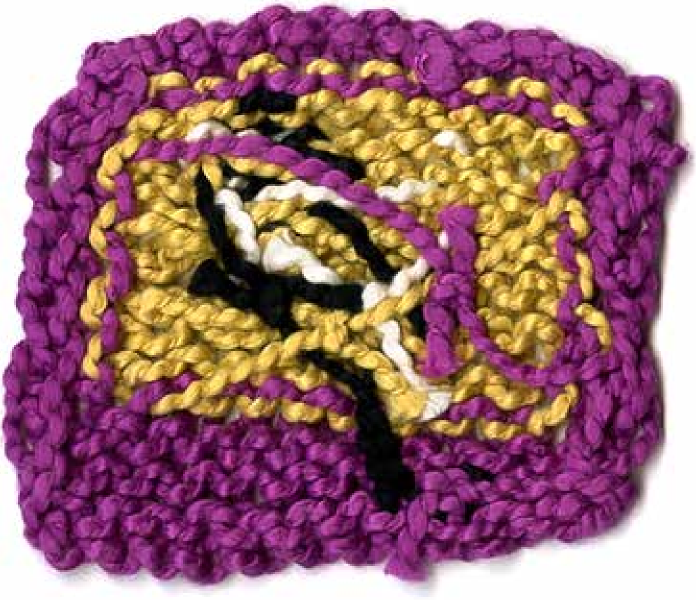

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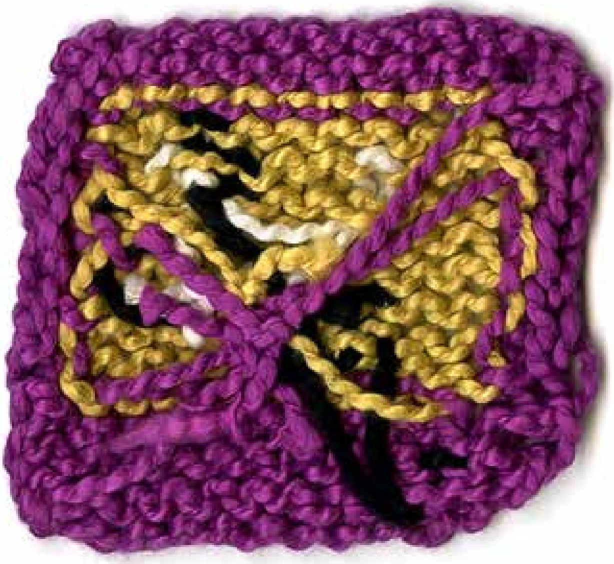

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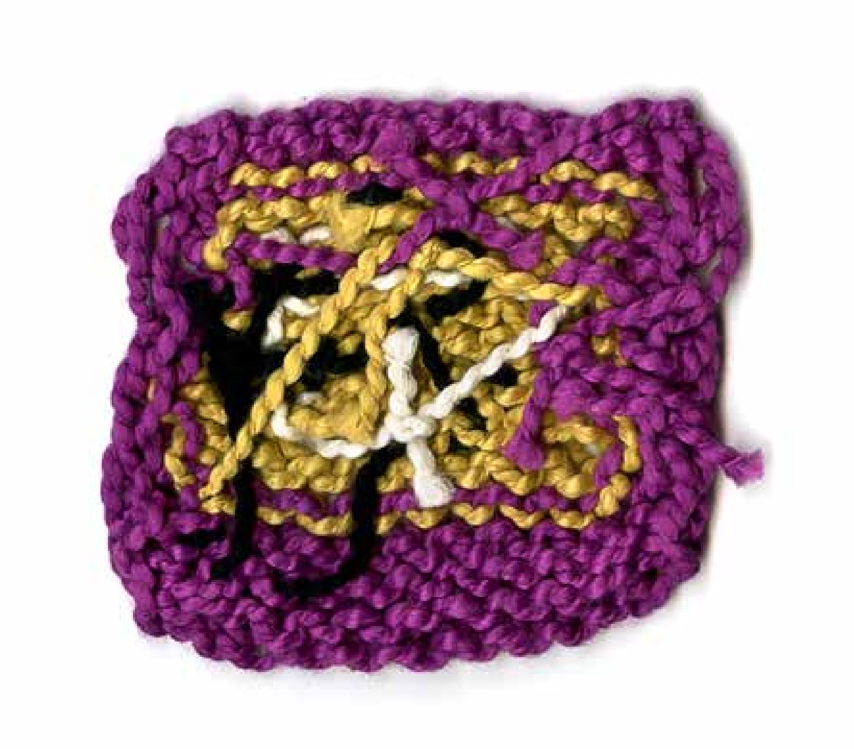

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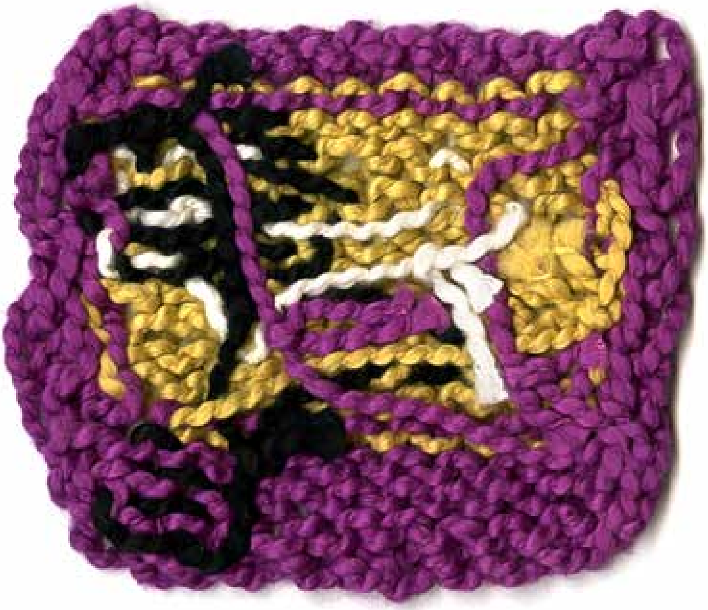

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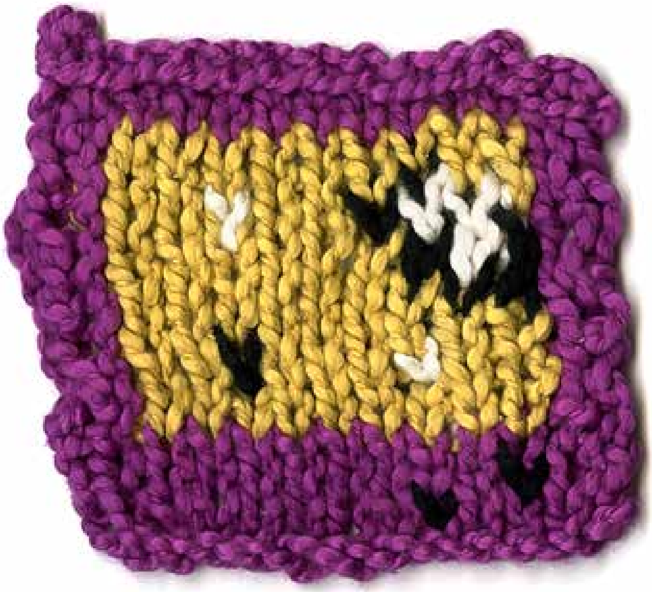

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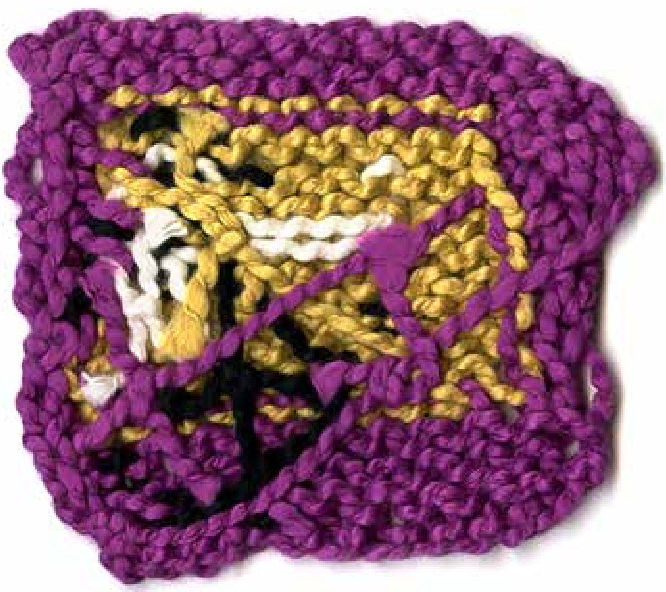

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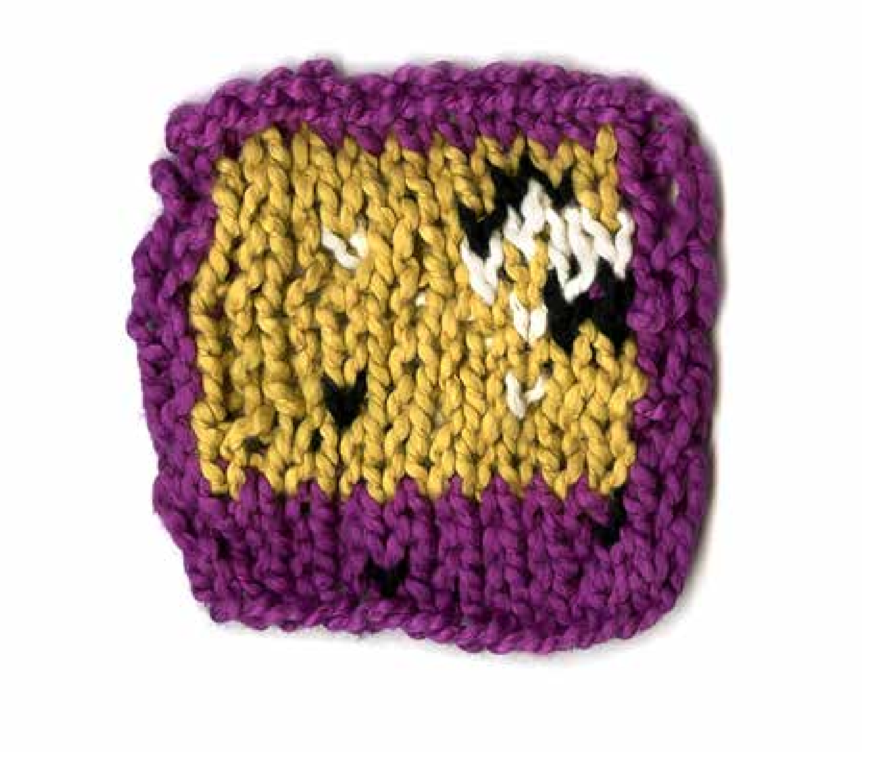

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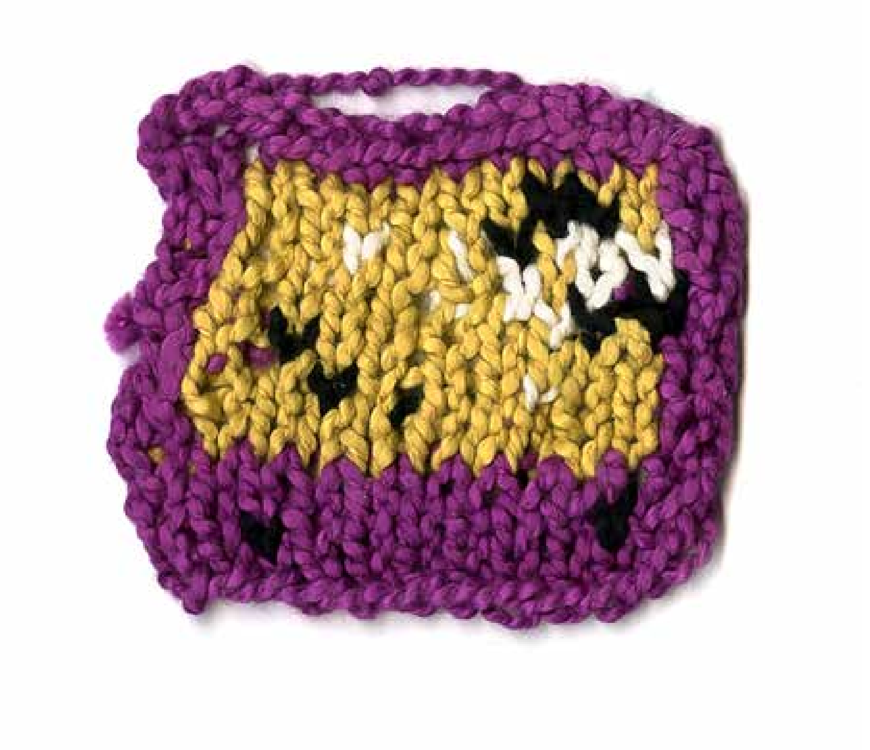

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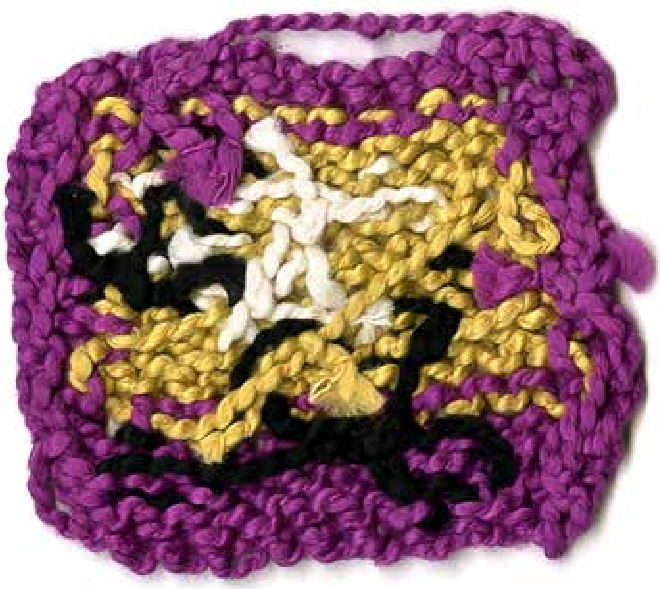

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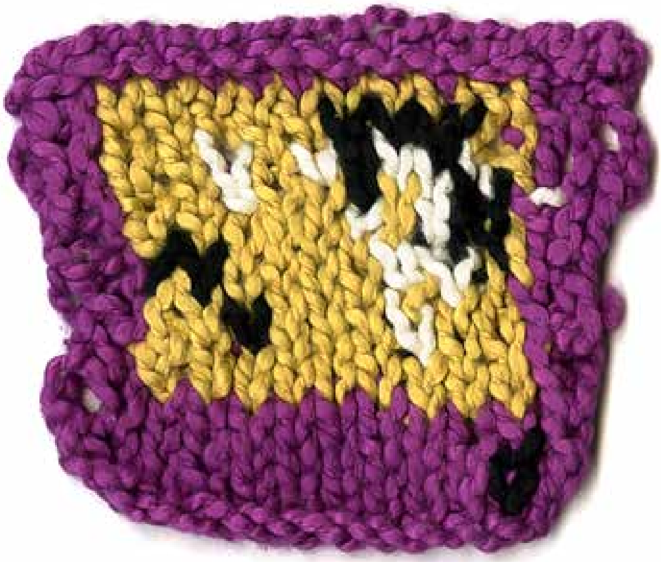

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1.1 Introduction

The goal of the research is to explore the creative possibilities of transfers of approach and strategy from new media art to textiles, and begins with a strategy based upon traditional comparisons of textiles and computers: the use of the grid for representation (of images, of sets of data or information). The experiment engages with the grid to explore possibilities for exploration or development. By engaging in a traditional meeting of the two practises in a considered way, will this work uncover something that had not been previously noticed? Will the work be able to uncover opportunities for transfers of strategy that have not previously been noticed?

Presented here is the work *Sticks and Stones*. The chapter outlines the choices made in constructing *Sticks and Stones*, from the choice of knitting as a medium, to the choice of Go as a subject that can be explored through knitting. The board game Go was played through knitting, where a knitted structure was used as a the medium for representing the board and the game state; the grid of the knitting represented the grid of the board, and the colour of the stitches represented the state of the corresponding space on the board. This transfer of strategies was operational and required active experimentation and play to be more fully developed from an initial concept to a series of possible strategies. The board game was chosen as a way of engaging with the act of playing through the transfer as a means of feeling out the potential in the transfer, and to suggest future opportunities for transfer.

The work revealed that the grid is but one metaphor for examining knitting, but it does not fully encapsulate all facets of the technique.

Focussing on the grid produced a result that did not fulfil structural or aesthetic expectations of either knitting or Go. Playing Go with knitting, as well as subsequently using knitting structures as a strategy for playing Go, produced results that were less than satisfactory.

This chapter presents a contribution to new knowledge that the use of the grid as a way of joining textiles and computation is insufficient and may lead to unsatisfactory results. The grid is a useful tool, but does not fully encapsulate all aspects of knitting or all aspects of computation. Because its applicability in both domains is limited to certain aspects of those domains, it is too narrow a metaphor for understanding knitting or computation. If the grid is to be applied as a strategy for joining the domains, its use must be carefully applied, or else there will arise unintended consequences. The contemporary craft practice of using cross-stitch to display low-resolution computer graphics is an example of when the grid is useful and functions well, but *Sticks and Stones* is an example of when the grid is an insufficient tool to join the domains.

*Sticks and Stone*s did not reveal creative possibilities of a transfer of strategies from new media art to textiles, but it did reveal limitations and unintended consequences in traditional framing of the relationship between textile techniques and computation. A recognition of these limitations may help to frame future projects, and to better understand their limits. These limitations also provide opportunities for exploitation and development by testing possible creative opportunities created by the limitations and their aesthetic expression.

The work of this chapter does not provide an obvious connection to the next stage of the research. Rather, the lack of obvious or satisfactory results of strategy transfer provided a motivation to look elsewhere. This led to a "back to basics" focus, presented in the following chapter, where the work examines traditional hand weaving, the technique that is most often connected to computation.

1.2 *Sticks and Stones*

This research began with an observation made during traditional knitting. Specifically the observations were made while knitting intricately patterned work that required counting on the part of the knitter. This could involve structures such as cables, as was discussed in the introduction, or knitted surfaces other than stockinette stitch (made of alternating rows of all knit stitches and all purl stitches) or garter stitch (made of all knit stitches), or for example a sweater, that requires counting for increasing and decreasing to follow contours of sleeves and collars. While knitting patterns such as these it was observed that, rather than following the garment pattern stitch-by-stitch, I was reducing the pattern's instructions into an algorithm that would reproduce the desired pattern. This process of creating algorithms has been an important strategy of my new-media art practice, and the research was begun as an attempt to see whether other similar transfers of strategy could be taken from new media art and applied to textile techniques. The first step was to continue the exploration of knitting. *Sticks and Stones* was a performance piece that was conceived as an exploration into possible transfer of strategy.

The application of strategies is an operational concept that needed to be played with in order to be fleshed out. This first experiment begins with the most basic of similarities between the digital and textiles, which is the grid as an organising feature and tool. As such, the first tool to explore a transfer of strategies is the use of a board game, to explore the active transfer through the playing of the game.

The piece *Sticks and Stones* was a fusion of two things based on grids: knitting and Go. Go is a game of strategy played on a board with a grid, and knitting is largely conceived of as a grid. *Sticks and Stones* represented a Go board as a knitted swatch, where each intersection of the board was represented by a stitch: brown for empty, and black or white for intersections containing a piece. We played a game, but there was no board in the game. A new swatch was knitted for each move, resulting in a collection of knitted swatches showing the state of the board at each move. This piece, and this section of the dissertation examining the piece, was an exploration of the meeting of two activities based on the grid, Go and knitting, loosely occupying spaces of computation and craft. These two activities were able to meet because the grid allowed for a transference from one to the other.

*Sticks and St*ones was performed at a performance-art festival[81]in a moderately-trafficked shopping arcade, in a space that was set up to evoke knitting: rocking chairs and a table, yarn and needles. The space also included a traditional Go board and pieces arranged on a nearby table where passers-by were invited to play a short game of Go.

81 At the Mountain Standard Time performance art festival in Calgary, Alberta, Canada with Dory Kornfeld, an avid crafter and Go player. The piece was exhibited in the Craft Off series of performances sharing the theme "craft and competition", curated by Nicole Burisch.

The game was played by knitting a swatch for every move of the game. The first swatch knitted was a square of 9 × 9 stitches in yellow yarn, representing an empty, wooden Go board, surrounded by a boarder knitted in purple yarn. The following swatch, representing the first move of the game, was an almost identical swatch, though one of the yellow stitches was knitted in black, to represent the first move of the game—this is analogous to the first black piece laid on a wooden board to start a game.

1.3 Go

Go has a long history connected to military strategy, poetry, games, and computation. It shares much with the other famous strategy board game, chess, but mostly for their differences than their similarities.

Both are games of military strategy, with a black army battling a white army. Both can be used as metaphors or models for real battles. The objectives of chess and Go differ significantly. Chess is a game of assassination or capture. Go is a game of territorial claim and defence. As a Go proverb states, "Chess is a battle. Go is a war." Much of the traditional Go strategy is written in the form of these simple, short proverbs, often employing a metaphor rather than any direct instruction for how a player should conduct their gameplay.

The vagueness of the proverbs, and the difference in scale with respect to chess, point to another aspect that is important to Go. Chess is a game of precision, pieces move to kill enemy pieces. Surgical moves remove key pieces from the board. A checkmate is constructed through a precise positioning of pieces.

Strategy in Go is less precise and calculated than chess. An accumulation of pieces exerts an influence that controls territory. Power is slowly manifested by clouds of pieces that begin diffuse but eventually define precise boundaries and defences of the territory. No single piece can end the game; it is the combined work of every piece that wins the war.

The Go board begins as a blank canvas, slowly dressed throughout the gameplay. The players take turns placing their pieces on the board where they remain until the end of the game unless they are captured. Go players build a landscape of power relations. Pieces are said to exert influence rather than affect only their position on the board. The movement in the game is not of moving pieces, but of shifting influence in a changing landscape.

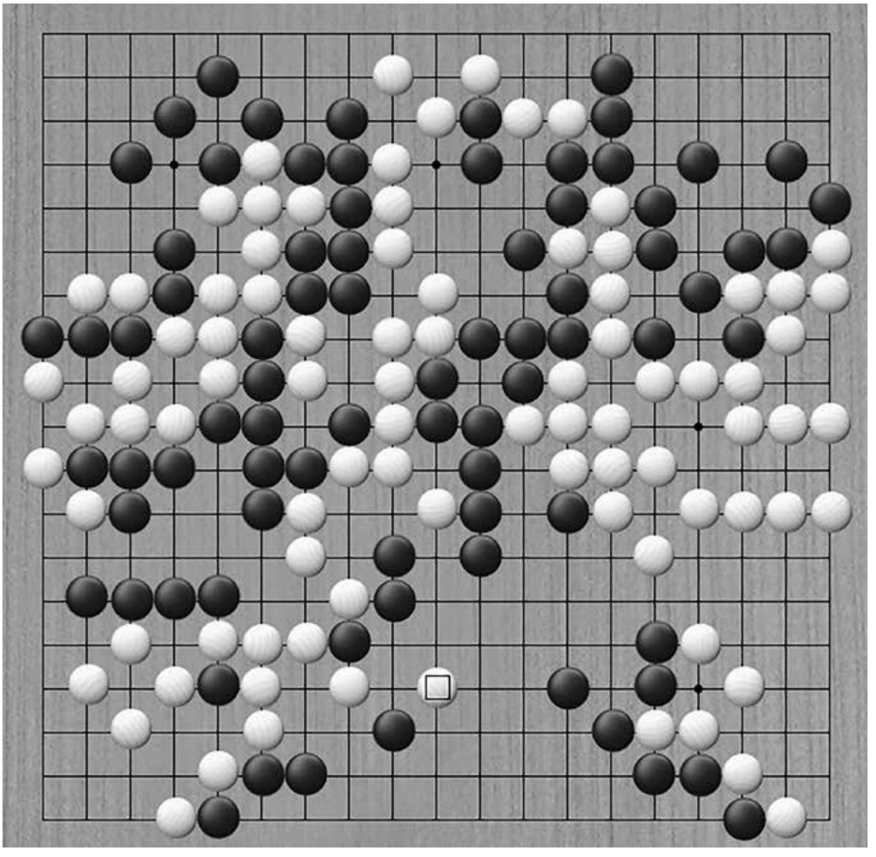


IMAGE 1.1 **An example of a game of Go in process.**

Go has long been a favourite challenge of computer scientists developing artificial intelligence. Go is a difficult game for humans; but for a computer, Go is very difficult.[82] This is not to say that chess has never been difficult for a computer, but the vagueness required to win at Go described makes it more difficult to model, and this is what makes it tough for a smart computer. With respect to traditional techniques of creating an artificial intelligence that can triumph at game-playing, this is simply a matter of scale.

If we compare possible opening moves of chess and Go we are shown the differences in options. Opening chess moves involve moving a pawn either one or two spaces or moving a knight to one of two places. This makes for a possible 20 opening moves. Go, by contrast, allows the first player to place a piece on any of the 361 intersections on the board. If a computer were to plan ahead the first four moves, it would require calculating the advantages of a possible 46,525,680 moves.

Software could not challenge the intuition of a skilled human player until quite recently. AlphaGo,[83] a programme created by Google, defeated Lee Sedol, a Go player with the highest possible professional ranking, in a five-game match. It is worth noting that AlphaGo did not use a strict rule-based system, the kind of techniques that previously made a Go-playing machine quite difficult because of the large scale of the problem. AlphaGo used a set of artificial neural networks, a distributed intelligence model that learns. As a result, AlphaGo was able to play in a manner entirely appropriate to the rules of the game, though unpredictable to humans.[84]

The use of Go in *Sticks and Stones* was not connected to this artificial-intelligence dilemma directly. Go was used because it is played on a grid, as is knitting, and because of this history of Go and computers it has come to be associated with computer intelligence. Despite this strong connection between the game of Go and artificial intelligence, Go is not a good example of the algorithmic thinking that this doctoral work is investigating. It is precisely the inability to reduce the game into any neat algorithms that makes it so difficult for computers and their scientists. Go strategy views

82 David Silver et al., "Mastering the Game of Go with Deep Neural Networks and Tree Search," *Nature* 529, no. 7587 (January 28, 2016): 484–89, https://doi.org/10.1038/nature16961.

83 Silver et al.

84 Cade Metz, "In Two Moves, AlphaGo and Lee Sedol Redefined the Future," WIRED, March 16, 2016, http://www.wired.com/2016/03/two-moves-alphago-lee-sedol-redefined-future/.

each piece as representing not just an occupied space on the board, but as an entity that exerts influence on the space around it, in a sense like energy fields. There is little counting done by the player, although counting does become important in specific decision-making points in the game. Humans rely on received wisdom through Go proverbs and through intuition from experience. Even the latest Go programmes lack the finesse of a finely-tuned algorithm, endlessly stumbling their way through losses until they find themselves in a winning game. Go represents computation only in its inability to be conquered by computation. This is why it has been interesting to computer scientists. Go functioned in *Sticks and Stones* as a symbol of computation.

1.4 The role of shape in Go and knitting

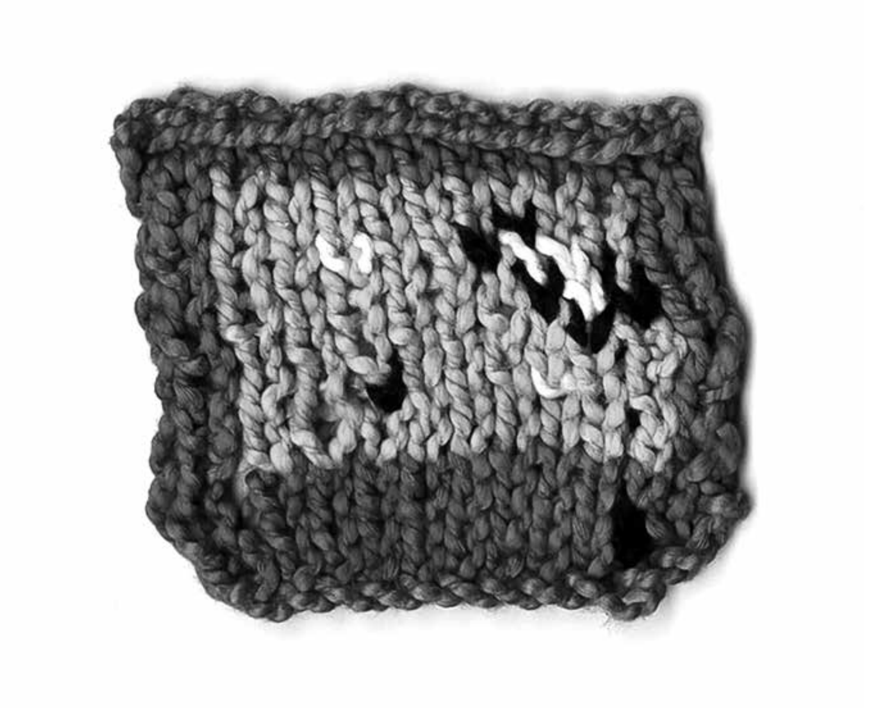
Playing this game using knitting presented both a technical challenge and an experiential navigation of the process, because it was a game that was not meant to be knitted, a technique that was not designed for the game. In order to represent the Go board in knitting it required that the swatches be constructed in a way that allowed for several things that were important to the game and to the presentation of the piece.

The construction of the swatches, both front and back sides, can be seen at the beginning of this section. Each swatch needed a border so that each stitch of the playing surface—the "board"—would be visible and not behave strangely as a selvage stitch, a stitch at the edge of a knitted piece. Doing this required knitting a border of a different colour to allow space for the playing surface to be seen. This required an intarsia technique, a technique in knitting used for constructing a knitted surface out of large areas of different colours. Intarsia requires that each block of colour have its own yarn, so that the more blocks of colour there are the more there was to be handled by our hands. Already, forcing knitting to do something it was not designed to do, and was not very good at, was testing the limits of the knitters' expertise.

The swatches were numbered so that the order of the moves would be decipherable after the game had been played, should any of the swatches be placed out of order. The game also required a way of tallying captured pieces. To accomplish this, the lower portion of the swatch's border was enlarged, allowing space for two other pieces of information. One was a collection of stitches that could be made black or white to show captured pieces. The other was a set of stitches that displayed the move number in a binary encoding: a black stitch for a 1, a purple stitch for a 0. The numbers 0-7 can be represented here in decimal, binary, and our knitted system, with stitches represented by Vs with black as 1 and purple as 0:

Decimal value	Binary value	Knitted representation
0	0000	VVVV
1	0001	VVVV
2	0010	VVVV
3	0011	VVVV
4	0100	VVVV
5	0101	VVVV
6	0110	VVVV
7	0111	VVVV

The initial swatches of *Sticks and Stones* were knitted faster than the latter because there was less to do in creating them. A simple grid of one colour could be knitted very quickly. Knitting the first swatch required manipulating three pieces of yarn, two for the border and one for the board. When more colours were introduced, the mechanics of alternating yarn to create the differently coloured stitches slowed the process down considerably. No longer were there three pieces of yarn, but at least five. The game-board area itself was knitted using a kind of multi-colour *stranded* knitting, and this technique has specific rules. The most common of these stranded techniques is Fair Isle knitting, used to create colourfully patterned sweaters. Stranded knitting almost always uses only two colours at a time, allowing the knitter to control one colour with each hand. Very



rarely are more than two colours used in the same row. Unused yarn is bound behind the visible stitch—known as *wrapping*—but still fixed to the fabric. This is important to prevent loose loops of yarn at the back of the fabric, and also to provide more anchor points for the structural integrity of the textile. The more colours there are to wrap, the less obvious it becomes how and which colours ought to be carried for any given stitch. When the arrangement of colours representing the position of the pieces was not regular, as it would normally be with stranded knitting, the carrying or floating of any excess yarn behind the piece became a moment of decision, slowing down our knitting. When is the next black piece? How many stitches until then?

It became clear early in the game that the regularity of the knitting grid in *Sticks and Stones* was falling apart. It became difficult to read the state of the game from the swatch. Because of differences in stitch tension, some stitches were different sizes than others. Stitches didn't appear to fit neatly into any row or column. Gaps appeared between stitches. It was as though the structural integrity of the fabric was weakened. We thought we were knitting a grid, but the grid was falling apart in our hands.

Historical knitting techniques exist for specific reasons, to create garments that fulfil distinct functions, both aesthetic and functional. The basic principle of knitting is to create a loop in the yarn, draw a piece of the yarn through this loop, thereby creating another loop, and continue. Before this line of crafts there was weaving, a technique for creating fabric from the enmeshing of many different pieces of yarn. Knitting's relatives include crafts such as crochet and *nålbindning*, all of which use different kinds of tools to created a fabric by looping a single yarn through itself, what Emery refers to as "interlooping".[85]

Stranded knitting involves visually repeating patterns, which are beautiful. But when knitting in this technique it becomes apparent that the structural limitations of stranded knitting (such as to not have floats that extend more than five stitches) are what give rise to the beautiful visual repetition. The beautiful repetition exists not only because it is beautiful, but because such repetition is structurally sound. Repetition creates a redundancy in the support of the fabric, and it creates heavier fabric for colder climates. The cultural requirements of the garment must not be ignored either. An ugly garment is rarely a garment worn. Likely these requirements were satisfied simultaneously, and because of this the practical techniques are also beautiful. And there is an understanding of the physical requirements of the fabric built into the aesthetic system.

Like knitting, the game of Go is also dependent on shapes. This is a difficult concept for beginners to understand. Often the beginner will react to opponents' individual moves, but a good Go player responds to shapes. Certain shapes are considered strong, such as the "table". Strong shapes in Go are strong strictly from a view of calculation. They are shapes that are easier to defend from attack, and difficult to attack. That is, if the shape exists on the board it is likely that those pieces will stay there until the end of the game, and the player will maintain their hold on that territory on the board.

But these shapes that are strong in Go are not necessarily strong in knitting, and vice versa. Both Go and knitting must have respective sets of criteria to determine what makes a shape structurally sound, which might be expressed as rules. It was naïve to believe that the technique of knitting could be so simply applied to Go because they both contain a grid. While both activities have systems and techniques that support the presentation of a grid, knitting and Go have idioms that cannot be simply

85 Irene Emery, *The Primary Structures of Fabrics* (Washington: Textile Museum, 1966), 38.

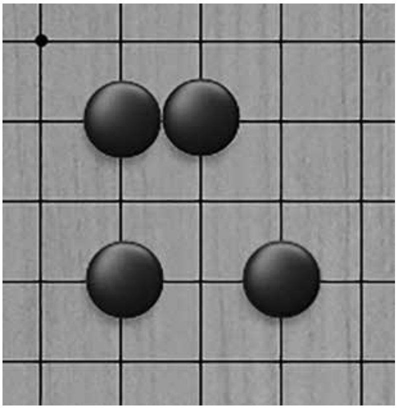


IMAGE 1.2 **The “table”. A strong Go shape.**

translated into each other’s system. There is a reason that two-colour knitting techniques developed in the way that they did, and it was not only for aesthetics. Knitting must create a fabric useful to the culture, but also useful to the body. Go patterns created in knitted stitches are not useful to the body, they do not fit into the established system of strong structures. If the goal of *Sticks and Stones* was to make a sweater, then it would have failed. But the requirements were slightly different from that of traditional knitting: *Sticks and Stones* required a legible, knitted grid, and the knitting of the Go shapes weakened the grid in such a way as to make it both unsuitable for garments, and illegible for game-playing. The technique was not fit, from a knitting perspective, and not from a Go perspective, either.

1.5 The grid is an incomplete metaphor

Despite *Sticks and Stones* initially appearing to be a failure in its inability to connect knitting and computation in a meaningful way, it has been fruitful in several ways, and in large part these were the assumptions with which the doctoral work began. *Sticks and Stones* is an important project in how it shows us what the connection between software and textile processes is not. The first operating assumption was that computers and textiles both use grids for image representation.

First, let us establish the meanings of the words *grid* and *computer*. We can use the Oxford English Dictionary (OED) as a basis for the words. The OED definition 6.a. for *grid* is "A network of lines, esp. two series of regularly spaced lines crossing one another at right angles..."[86] Though in this case it is not the lines that are important, but the spaces in between the lines that create cells for information, be they sums in a ledger or pixels in an image. An alternate interpretation is that they are not drawn lines, but parallel linear arrays of the object in question: such as lines of pixels arranged above and below each other. The OED definition for 3.a *computer* is "An electronic device (or system of devices) which is used to store, manipulate, and communicate information, perform complex calculations, or control or regulate other devices or machines, and is capable of receiving information (data) and of processing it in accordance with variable procedural instructions (programs or software)..."[87]

Computers are not grids. Even inside the computer, the processor and memory are not grids. Grids are a convenient technique for image representation, and a convenient way to store information. But a computer would still exist without the screen, and many computers are never connected to a screen, such as microcontrollers, modern thermostats and cars. Neither is knitting a grid, as can be seen in the degradation of the Go patterns throughout the game. Knitting is a complex knot-work using a single thread whose units—stitches—can be used to represent patterns and images in a grid.

Computation is often assumed to be binary, that "computers work with ones and zeroes". This understanding arises from the mechanics of modern computers, where information is stored in a binary system, as ones and zeroes. However, computers are not binary. The OED definition did not mention the word "binary", because it is not necessary for computation. Experiments in organic and quantum computing have yet to produce something that could be called a proper computer in the modern sense, but the problem is a mechanical one rather than a conceptual one. This was the same problem faced by Charles Babbage's

86 "Grid, N.," *OED Online* (Oxford University Press), accessed February 12, 2018, http://www.oed.com/view/Entry/81373.

87 "Computer, N.," *OED Online* (Oxford University Press), accessed May 5, 2017, http://www.oed.com.ezproxy.ub.gu.se/view/Entry/37975.

19th-century Differential Engine, only recently completed.[88] And so it is only a matter of time before a functioning quantum computer is produced. These systems do not need to use a binary system. The theoretical quantum computer would provide a functional computer with "bits" of more states than two. Even so, it will be a computer by any modern definition.[89] The use of binary in computation and textiles represents a tool that is at the disposal of humans, but it does not provide a fundamental plank of computation nor of textiles.

Knitting is not a grid. It is notated as a grid, it is conceived as a grid, and its patterns even appear as grids when viewed at a human scale. This grid aspect is only present in the human interactions with knitting: the notation, the thought and the perception of knitting as a series of stitches organised into rows. This grid is how we think of the work, how we conceive of and compose the work, and how we see the knitting. As a beginner, the grid is important after one has internalised the knot-making process that is the foundation for the knitting technique. The knitter is taught the fundamental building block of knitting: the knit stitch. The knitter repeats this action over and over again, drawing the thread through a loop and removing the loop from the left needle, until this movement is embedded into their unconsciousness, into their muscle memory. The knotting of the thread becomes no longer a thing at the level of consciousness, but a function that is called by the higher levels of thought and then executed by the muscles, or by automaticity. "Pull the yarn through the loop" is accomplished by the gentle resistance communicated though the sense of touch and muscle activation and resistance to communicate that the knitter's needles have in fact grasped the yarn and not air.

The knitter repeats this action, slowly etching the action into their consciousness, until a scarf is made, the most basic knitted article. The knitter is then informed that this is how one knits: a knit stitch is repeated back and forth, constructing a grid until a rectangle of fabric has been constructed. Everything else is a variation upon this. The purl stitch is just a reversed knit stitch. Every other kind of stitch is a variation of this. Different shapes are created by knitting more or fewer stitches, or modifying a knit stitch. It is a grid based on this one stitch. But knitting is not accomplished by thinking about the stitch, it is accomplished by thinking

88 Glenn Adamson, ed., *The Craft Reader* (Oxford: Berg, 2010), 48.

89 The Oxford English Dictionary, for example, provides three definitions of "computer", none of which use the word "digital".

about arranging collections of stitches, and this is why one must learn the stitch so deeply that it is no longer thought about.

Bauhaus weaver Anni Albers presented a similar concept when discussing weaving, though it is equally applicable here: “The grid notation gives an accurate construction of the weave, but not a naturalistic representation of it.”[90] Albers was specifically writing about features of weaving, other than its construction, that was important to weavers: density, drape, the feel of the cloth. Though this is not specifically the issue being discussed here, it does speak to the difference between a textile’s notation or pattern, and to the aspects of the textile object that are *not* notated in the grid notation.

What was shown in *Sticks and Stones*, or reinforced, is that knitting is not a grid, or not only a grid. The degradation of the swatches in the game shows that if knitting is perceived only as a grid, and not as its construction as a series of interdependent knots whose arrangement supports the larger form, then the form itself cannot be supported. The grid is useful for aspects of knitting, such as the notation, but it is an incomplete model of knitted fabric and the act of knitting.

1.6 Front end back end

Sticks and Stones provided one novel way of viewing knitting from the perspective of computation that may open itself up to transfers of strategy from new media art. The degradation of the physical swatches, caused by the concentration on the grid metaphor, suggested a possible similarity with the front-end–back-end metaphor of software development.

The most common computer interface is the desktop, which represents “files” and “folders”, that are opened and manipulated and closed. This interface has been constructed by a designer to allow the user to interface with the computation of the computer. When the images of the desktop are presented or activated, they are done so by a piece of software with the purpose of translating between a computational layer and the user. The software has two layers known as the *front end* and the *back end*. The front end is this interface seen by the user, and the back end the layer that performs the functions of the software.

90 Anni Albers, *On Designing* (Middletown: Wesleyan University Press, 1966).

Knitting provides a kind of front and back end. The front end is conceptual, structural. It is the grid, the patterns, the cables and images that make up the knitted garments. But it is dependent on a back end, the underlying complexity of knots. This knot-work is mostly ignored by the knitter because the interaction with the individual stitches and the grid is sufficient to knit a garment. The knot-work is perhaps only considered when a knitter is fixing a problem in the fabric, a dropped or twisted stitch, or darning a hole. In such instances, the path of the thread is carefully navigated and altered to fix a problem.

The front- and back-end construction is really one of software engineering and human–computer interaction, a way of allowing developers to focus either on the human or the code. The human interface to knitting is the grid and its stitches, but it is only a flattening of the complexity of the knot-work underneath.

This front-end–back-end similarity between the two media perhaps opens up for transfers of strategy from new media art, where techniques specific to the front-end or back-end could be borrowed from the art practice and applied to the "front-end" and "back-end" of knitting. It is not clear how this might happen, nor was it pursued in this research. The realisation of this possible similarity did not make itself apparent until much later in the research process, and was thus not feasible to pursue within this project.

1.7 The final knell

A quick experiment was performed to reverse the work that had been done in *Sticks and Stones*, and that was to play Go using shapes from stranded knitting. A game of Go was played against a computer, constructing a stranded-knitting-like structure on the board, as seen in the lower-left quadrant of the board in Image 1.3.

One obvious failing of this strategy was that it was unresponsive. No game can be won by disregarding the actions of the opponent. Knitting must also be responsive, to the concerns of the material and the garment. Everything changes with a stitch, and everything changes with a move.

The Fair Isle structure did turn out to be a strong structure. It was originally assumed that the structure would be weak enough to allow the computer to slowly chip at the edge pieces and eliminate it entirely. That did not happen. It was strong, but it is an expensive structure to produce;

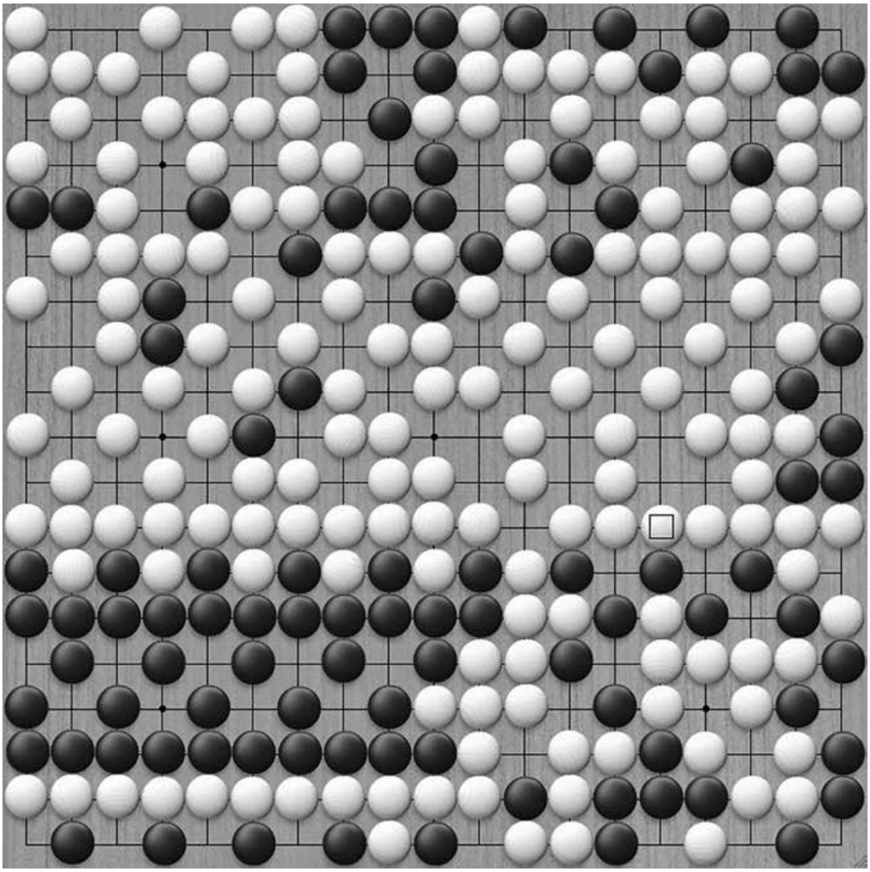


IMAGE 1.3 **A game of Go against the computer using a stranded knitting pattern, seen in the mass of black pieces in the lower-left quadrant of the board.**

it requires many pieces to construct. Go is often a game of tradeoffs. It is won by creating the strongest gestures with the fewest actions. Many well-placed semi-strong structures are better than one strong structure. The Fair Isle structure might have been strong, but it was inefficient and so unsuitable to Go.

The game also failed to address the similarity that I first noticed between knitting and computation. It had no pattern, no algorithm, and no underlying structure. It was already established that Go is not a game of firm pattern and structure but one of a fuzzy aggregation of influence. Neither did the game make use of any of these underlying characteristics of knitting that I found so fascinating.

1.8 Conclusion

This chapter presented an attempt to apply thinking and structures associated with computation, to a knitting. It was hoped that this experiment would yield interesting results for the aim of this research project, which is to investigate the creative possibilities in applying strategies from new media and glitch art to textile techniques. This experiment was knitted because it was an extension of the observations that led to this research, and these observations were made while knitting. The board game Go was chosen as a subject and strategy that represented computation. The combination of these two subjects, Go and knitting, was performed by playing a game of Go through the act of knitting, by using the shared grid of both subjects to transfer structures of Go to structures of knitting. In this case, the intersections of the Go board were represented by the colour of knitted stitches.

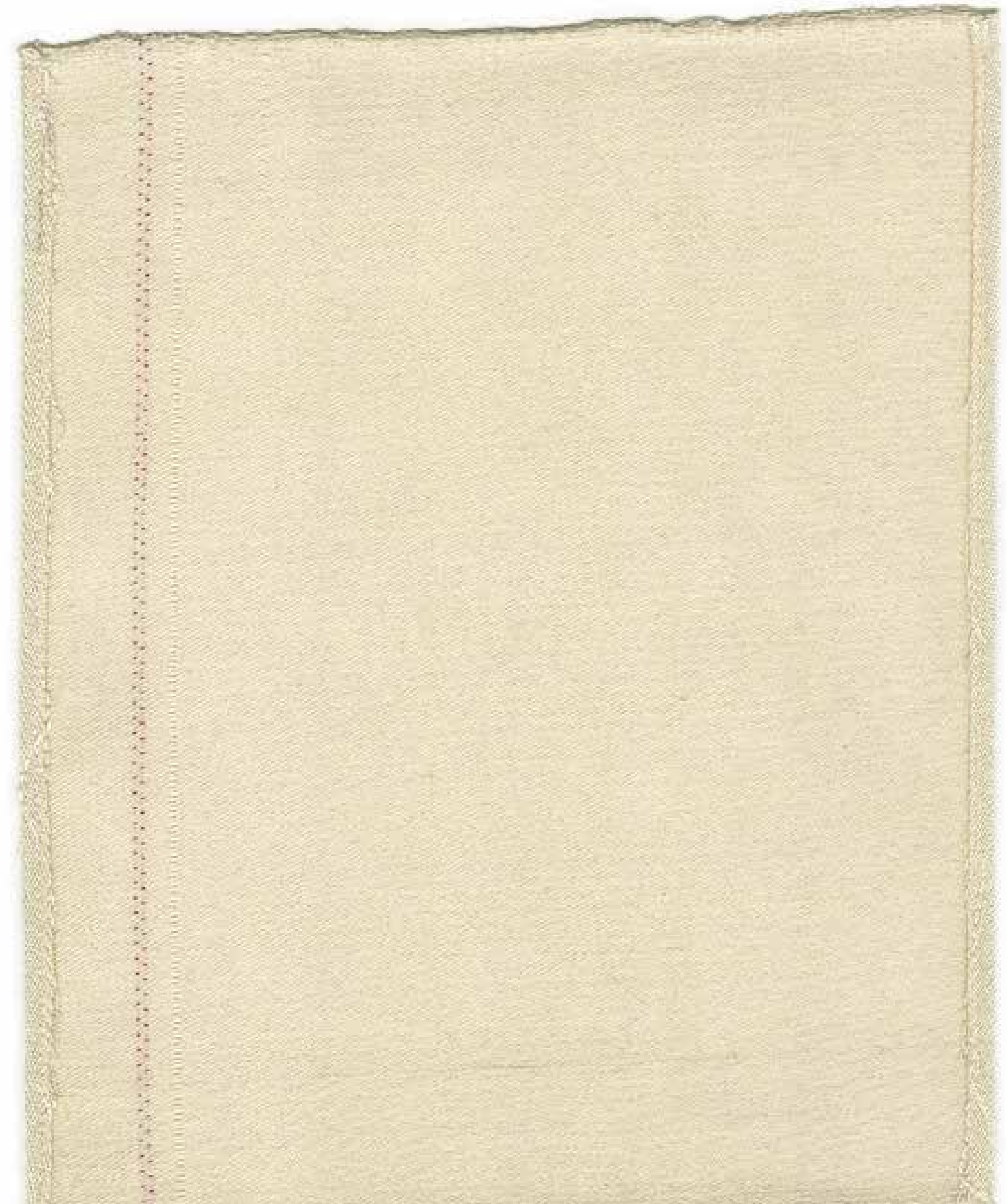
The results of this experiment were unsatisfactory. Producing a textile that was constructed using stranded knitting to represent structures native to Go led to a piece of fabric that did not suit the requirements of knitting, and in doing so made it also difficult to continue playing a game of Go in this manner. Though knitting and Go share a grid, the function of the grid is different in both domain. For Go, the grid is a structure over top of which the game is played. For knitting, the grid is an abstraction of the knitted structure, and a tool for communicating the form and construction of a knitted textile. Both knitting and Go depend on notions of strong shape, and strength constructed by the interrelation of their constituent components—in knitting this is the knitted stitch, and in Go this is the stone, or playing piece. The relationship between knitted stitches that creates strength, is not the same as the relationships between Go pieces that create strength. And so constructing strong structures of one medium in the other medium does not create strength, it creates weakness. This was shown in both the original experiment, where knitting a game of Go created a textile that was essentially falling apart (it did not satisfy criteria essential to knitting, and so made playing Go impossible), and in the followup experiment, where playing Go using a strong knitting shape was a guaranteed losing tactic (it did not satisfy criteria essential to Go).

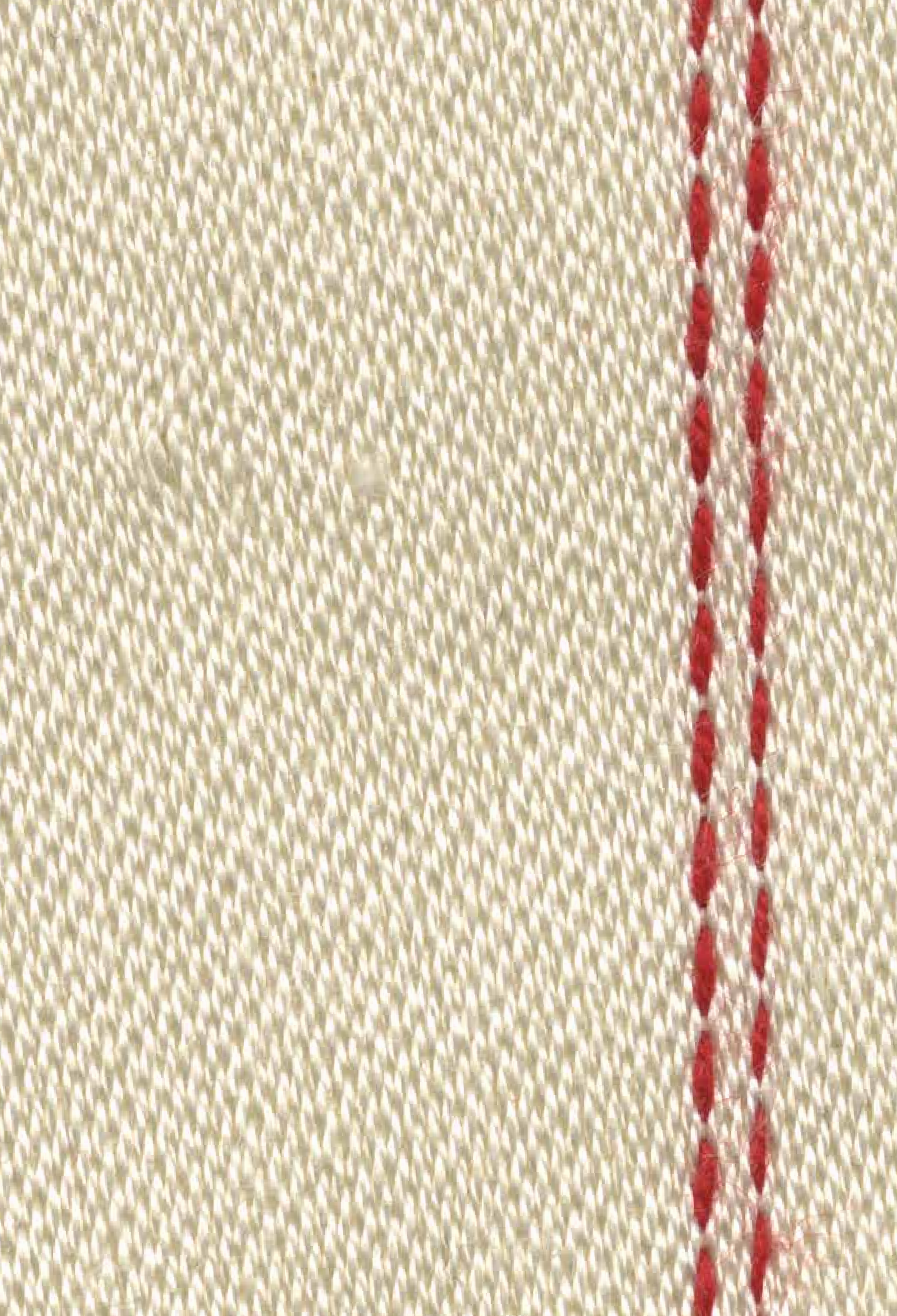
Furthermore, knitting the game of Go did not generate any obvious directions for future artistic engagement. It was not necessarily a dead end, but the result did not suggest actions to continue the experiment using the same subjects and parameters with which it started.

What the experiment did reveal, and the knowledge that this chapter contributes, was the inability of the grid to be a simple shared metaphor that necessarily creates opportunities for transfers of strategy. This is not to say that the grid is not useful, as it has been used many times, for example, to display pixel graphics in cross-stitch. But its success is not a given, and so some transfers of strategy will be successful, and others will not. The function of the grid in the two chosen domains must be carefully considered before it can be used as a tool to join them.

Rather than exploring the spaces of successful and unsuccessful transfers of strategy within the grid and knitting, it was decided to take a step back in the research, and to begin at the root of most comparisons between computation and textiles, which is in the technique of weaving. So as to not repeat the same presupposition in the Go and knitting experiment, which was to assume that the shared grid is enough upon which to base transfers of strategy—the next step in the research was to learn weaving from first principles: to learn the technique of hand weaving. The following chapter will demonstrate the insights made through the act of learning hand weaving, and experiments conducted to interrogate hand weaving and woven structures for their suitability for transfers of strategy from new media art.

2. Pattern





2.1 Introduction

The previous chapter presented an exploration that employed the grid as a medium for transferring structures between new media art and knitting, with the aim of discovering creative possibilities in transfers of strategy from new media art to textile techniques. The exploration did not yield productive transfers of strategy that could be further explored or employed, nor did they suggest a way forward to further develop or refine the strategies. As a result, the subsequent research actions, presented in this chapter, were an attempt to return to another object and technique that is often made between textiles and computation: the loom and weaving. Automated weaving, the Jacquard loom, is often mentioned in connection with computation because of its importance in the development of automated machinery, and because of its use of punched cards as a means of "programming" a loom for different patterns. Punched cards were later used to programme early computers, and this fact is often cited as a meaningful connection between weaving and computation.

This chapter also presents a second enquiry, using a machine for constructing bobbin lace. This inquiry was not undertaken as an obvious extension of the research actions, but was a research opportunity that presented itself during the research process. Although it was performed later in the research, it is placed in this chapter because of its thematic relevance to the work presented here.

The first line of enquiry is a return to the common comparison between computation and weaving.[91] I learned to weave by hand to better understand the craft that is often connected to computation. It was possible through engagement with the basics of the craft to identify opportunities for possible transfers of strategy that would not have been possible by examining the craft solely through its abstractions: the grid, weaving notation and instructions. Indeed, the work presented in the first chapter demonstrated possible unintended consequences when examining a craft in this manner. This chapter contains a description of this process of learning and the experiments to see if that process of learning might open up possible transfers of strategy otherwise not immediately apparent or already established in practice.

The work presented here is exploratory. I have tried to better understand weaving and satin through a hands-on engagement with the practice, to see if opportunities for transfer of strategy present themselves through the process of learning the craft from its basic principles. The artistic experimentation involves manipulation of scale of the satin pattern as a means to understand the technique and structure. This is not an explicit transfer of strategy from new media art, but an approach to better understand the technique and structure of weaving. Transfers of scale is a strategy that can be employed to gain new understandings about a subject. The change in scale changes the relationship between the object and the observer, and it was hoped that this change of scale would produce new insights into the satin pattern, and perhaps woven patterns in general, that would open up for transfers of strategy from new media art.

The second line of enquiry presented in this chapter was not a considered research action that arose from previous results, but was an opportunity that presented itself during the research process. A teaching opportunity at a former textile mill provided access to early industrial bobbin lace machines, and the opportunity to investigate the machine and its operation. The machine itself reflected goals of the research by representing the textile structure in the machine's movement, allowing for another way of knowing the structure. This strategy is similar to the manipulation of scale, that by retaining some features of the object of study (such as the lace structure, and bobbin movement) that the alteration of other features (the automation of construction, and the placement of the bobbins) will yield a new perspective that may open up to transfers of strategy from new media art.

91 For example, Plant, Sadie. *Zeros + Ones: Digital Women + the New Technoculture*. London: Fourth Estate, 1997.

The exploration with the bobbin lace machine shifted the function of the machine from a device that generates a textile, to a device that generates a visual experience. The operation of the machine was not altered, but its movements were highlighted through the use of LEDs placed on the machine's bobbins as they moved on their paths, creating the lace.

The chapter presents a reflection upon both of these experiments. The bobbin lace machine created an artwork that allowed the machine and the source textile pattern to communicate something new. This project demonstrated a transfer of strategy that generates an interesting result, that can be replicated, and also presented possible future avenues of exploration. It was not, however, pursued, due to its disconnect with the main lines of enquiry in the research. This chapter presents a contribution to knowledge by demonstrating that textile machinery can be used as an expressive object when augmented with electronics, and time-lapse photography can be a useful way to gain insight into the pattern of the machine.

Powers of Satin presented opportunities for a transfer of strategy from glitch art, the introduction of error into algorithms, specifically algorithms that create textile patterns and weaving instructions. This provided the basis for the next phase of the work, as described in the next chapter of the dissertation, the considered insertion of error into a satin-generating algorithm, and the evaluation of the results of this action.

2.2 *Powers of Satin*

The first half of this chapter discusses investigations into weaving and the possibilities for transfers of strategy from new media art. This section presents the process of learning to weave, the fascination with the satin weaving pattern, and the exploration of the impact of changes of scale on woven objects, resulting in *Powers of Satin*: an artwork exploring satin in many scales. *Powers of Satin* revealed an opportunity for error to creep into woven patterns generated by algorithms, providing an opportunity for further exploration that is presented in the next chapter.

IMAGE 2.1 *Powers of Satin*, after completion on site. In the background, the rope satin in frame, in the foreground, a plinth holding the handwoven silk satin and the hand-drawn satin notation.

IMAGE 2.2 *Powers of Satin,* detail of the front of the rope weave.

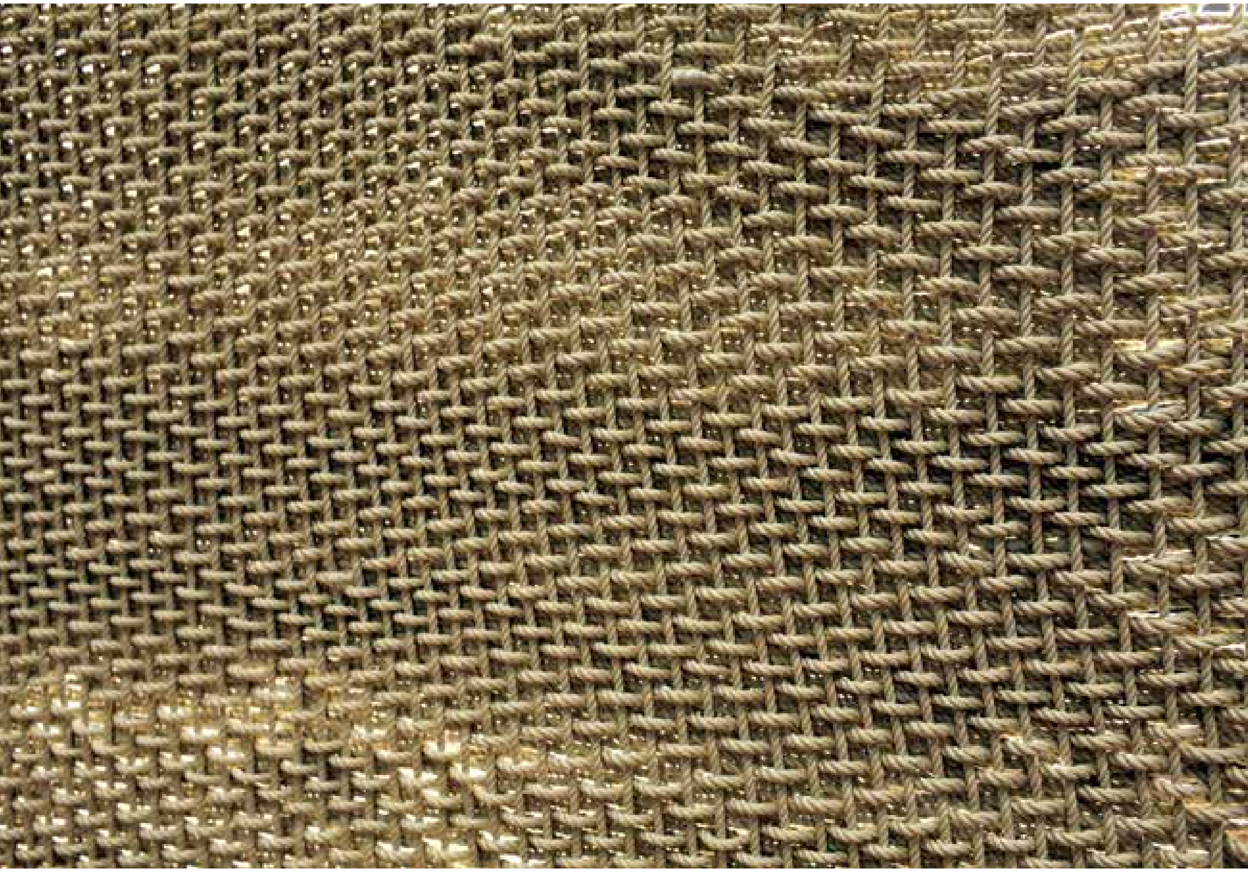


IMAGE 2.3 *Powers of Satin*, detail of the rear of the rope weave.

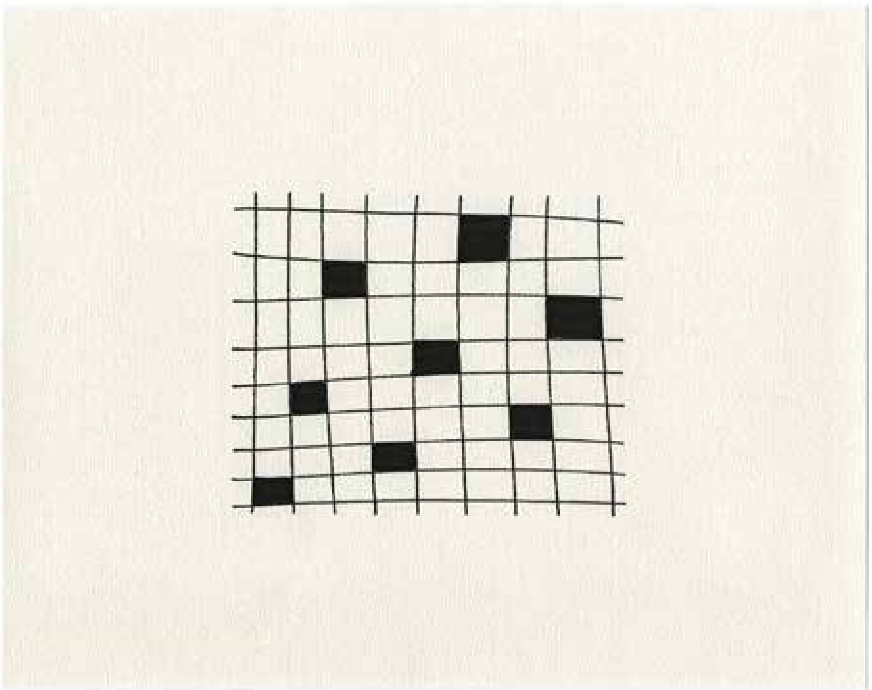


IMAGE 2.4 ***Powers of Satin*, the hand-drawn satin weaver's notation.**

2.2.1 Weaving

Diary: weaving

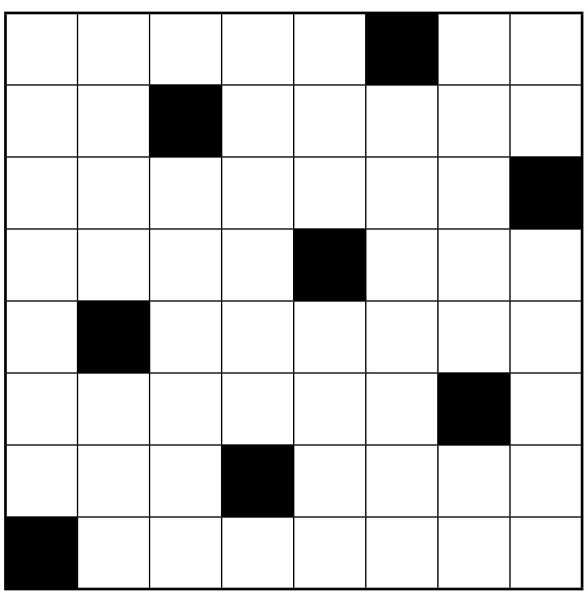
I learned how to weave. I learned and practiced the gestures of weaving. Calculating and winding the warp thread, the vertical threads mounted on the loom. Setting up the loom by drawing the warp thread onto the loom. Adjusting the warp tension by carefully patting the warp, tugging here or there to even the tension. Setting up the loom's pedals, threading the warp through the heddles, so that a pedalling pattern creates the desired woven pattern. Winding a bobbin of weft thread, the horizontal thread of the weave. Placing the bobbin in the shuttle, a wooden torpedo to hold the bobbin. Guiding the shuttle through the shed, the tunnel created between raised and lowered warp threads. Moving the beater, a large comb that packs that the weft threads, after laying each of those threads. Setting weft tension by tugging on the laid weft thread before beating it into place, to aim for perfectly straight and clean edges of the weave. Patience. Back and forth. Removing the material from the loom. See the difference when the warp tension is released.

As was outlined in the first section of this dissertation, the textile technique that is most often associated with computation is weaving. Specifically, it is the Jacquard automated loom and its proposed role within the history of computing machines that has created this association. Because of the lack of direction with *Sticks and Stones*, the research then shifted focus to weaving, in the hopes of discovering useful transfers of strategy. It was also hoped that it would be possible to find transfers of strategy that did not rely on the grid, a feature shared by weaving and computation. The grid in *Sticks and Stone*s proved to be a metaphor whose narrowness created unintended consequences in the transfer of strategies.

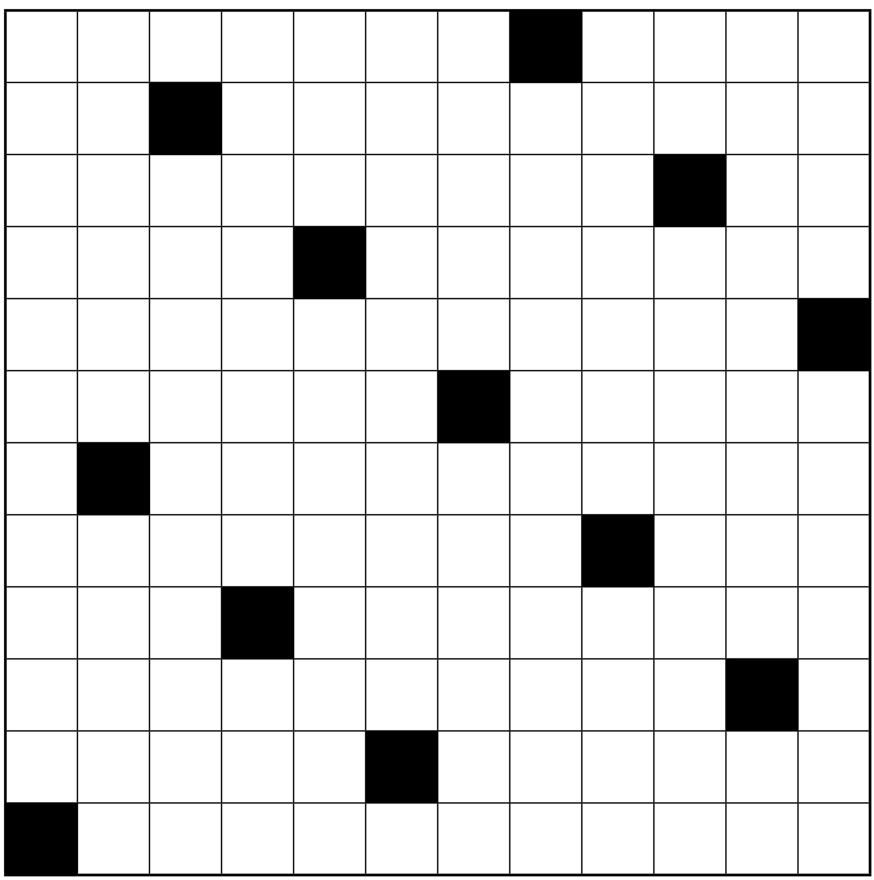
I learned to weave by hand on a floor loom with the intention that this would produce a more full and nuanced understanding of what weaving was comprised of, and allow me to see beyond grid equivalence in the digital and textile. This required me to learn how to read and construct weaver's notation, how to set up a loom based on a pattern's notation, how to calculate yarn requirements based on sizing and tension, how to prepare and mount the loom's warp, how to prepare a shuttle with weft yarn, and how to weave by operating the loom's pedals, manipulating the beater, running the shuttle through the shed, and regulating the tension so as to have even selvedges.

I wove some very basic fabric, a plain weave in linen and cotton, to first understand the principles. But my curiosity was piqued when I learned that weaving can be categorised by three basic weaving patterns, upon which all weaving is based: plain weave (or *tabby*), twill, and satin. What I found especially interesting, though not fundamental to this research, was that of those three patterns, I had previously understood satin to have such strong visual and tactile expressions, even though it could also be described simply by its notation. I was determined then to weave white, silk satin—the most archetypal satin—by hand. This process of weaving the most quintessential satin caused me to consider what specifically was important about satin, and why, although it is a pattern, it is most commonly associated with white, thin silk, and what happens to satin when these parameters deviate from the archetype. This can be seen in the images zooming into the woven piece at the beginning of this chapter.

All experiments with satin, and ultimately *Powers of Satin*, were woven using an 8-shaft satin pattern with an *interruption factor* of 3, which is a generic form of satin. This means that the width of the repeating basic satin pattern is 8 warp threads wide, and 8 weft threads high. The weaver's notation presented here is of this form of satin.



Each row represents a weft thread; each column represents a warp thread. The dimensions of this pattern are 8 × 8 squares, because it is an 8-shaft pattern. Empty squares represent the weft thread lying *over* the warp thread, and filled squares represent the weft thread lying *under* the warp thread. In effect, a single filled square represents a satin binding point, where the weft thread ducks behind a warp thread and then back out. The interruption factor is the horizontal or vertical distance between binding points of adjacent weft or warp lines. There is one binding point per weft row and warp row column. The interruption factor is the horizontal distance between binding points on neighbouring warp threads, or the vertical distance between binding points on neighbouring weft threads. For comparison, the notation for a 12-shaft satin pattern with an interruption factor of 5 would look like this:



2.2.2 The process of *Powers of Satin*

This consideration of satin and its parameters coincided with another exploration with a “linen tester”, a magnifying glass specifically designed for inspection of fabric. I had examined my shirt with the linen tester. This garment that I had chosen that morning occupied primarily a social place in my mind: I must have thought that the style and colour presented me to the world in a certain way. The existence of the shirt as a thing with features, construction, a back story, a history and a future, had not entered my mind.

The world through the linen tester was something entirely unlike that garment that had been chosen. It performed such a striking stepping back, a removal from the fabric as garment. Underneath the glass was a topography of peaks and valleys, wispy tufts, and most strikingly a kind of soothing regularity in its undulations. What was now visible were the fine cotton fibres that had been woven into threads, mostly twining with each other but sometimes reaching out of the fabric like tendrils, dyed, and packed together by a loom, likely somewhere far away, then cut into pieces, sewn into a garment, and come to me by whichever store or flea market I had bought it from. This was no longer only a serviceable garment, at least this round area under the lens wasn’t, but a landscape with distinguishable features and a clear pattern.

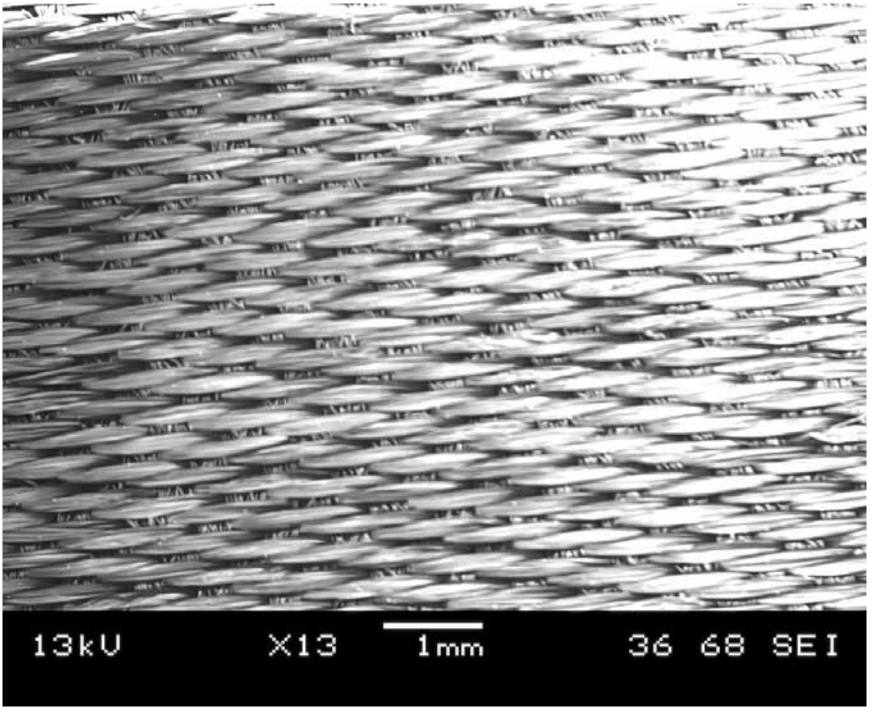


IMAGE 2.5 **The view of satin through a microscope.**

PHOTO BY CELESTE MAISEL

"Satin" is the name given to a specific structure of horizontal and vertical threads.[92] The characteristics often associated with satin, that it is shiny and drapes well, are features of fabrics woven using this structure. The sparse binding points create the drape in the fabric, and the long, exposed threads reflect light in a way that creates the shine. Because satin, from a weaver's perspective, is defined by its woven structure and not from its characteristics, it could happen at any scale and it would still be a satin, from the thinnest silk threads to rope to anything larger. American artist Dave Cole used industrial felt in *Knitting Machine*[93] to knit an American flag so large that the "knitting needles" were actually utility poles held by construction excavators. Cole's use of scale presented a familiar knitted structure in a manner that emphasised its construction of "threads" in a way that a knitted garment rarely does. At a smaller, garment scale, knitted garments resemble a texture rather than a construction. This is especially true of jersey, the finely knitted material used to make T-shirts, where the threads are so small that the structure is perceived as a texture. Just as Cole's American flag was also a knitted structure, so too would something on that scale also be satin. Satin is also strongly associated with silk because silk brings out the most desirable qualities in satin: its softness, slipperiness, and shininess. But because satin is only a structure, it could be made out of wool, cotton, polyester, steel, rope and still also be satin.

92 Ulla Cyrus-Zetterström, *Manual Of Swedish Handweaving*, 3rd Edition (LTs, 1984).

93 Dave Cole, *Knitting Machine*, acrylic felt, excavators, utility poles, 2005, http://www.massmoca.org/event_details.php?id=37.

IMAGE 2.6 *Knitting Machine*, Dave Cole.

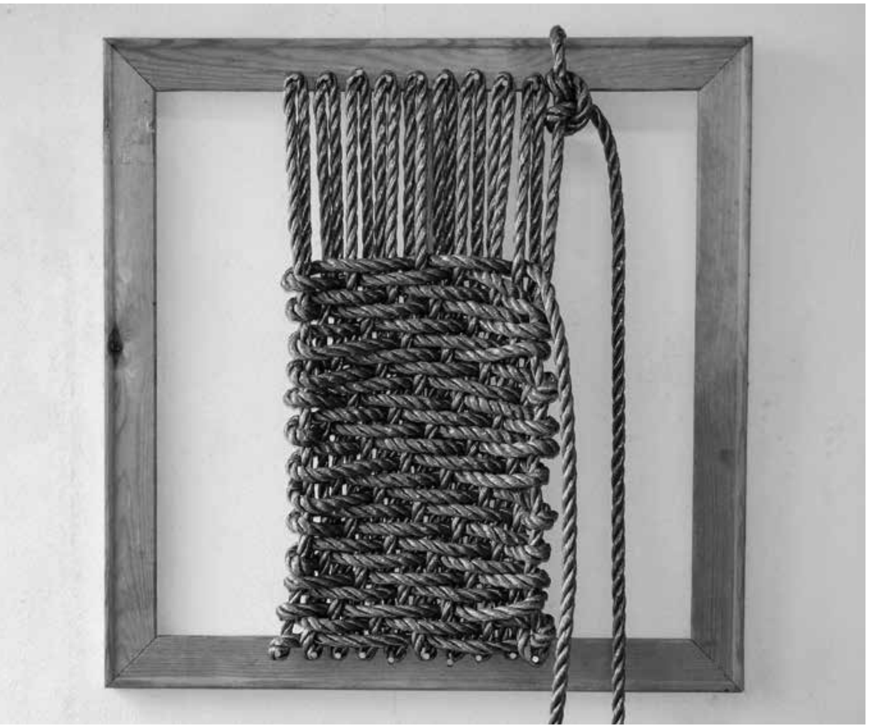


IMAGE 2.7 **Early rope satin experiment, blue nylon rope.**

The early experiments preceding *Powers of Satin* were simply explorations of the practicalities of constructing a satin weave out of a yarn larger than thin silk, or other standard weaving yarns such as cotton or linen. Experiments were made testing the method of weaving something at such a scale, using large, blue, nylon rope on picture frames approximately 30 cm x 30 cm. This size proved too small to observe anything meaningful of a satin weave at a larger scale.

Different materials were explored, such as foam insulation for water pipes, mesh material stuffed with cotton wadding, and various thicknesses and materials of rope. Ultimately, the material that was chosen was 10-mm-thick, 3-ply white cotton rope. It was chosen for its structural features. As a white, twined, multi-ply construction, it was the material that most closely resembled an enlarged weaving yarn. Its thickness allowed for a noticeable increase in scale of the satin pattern, while still being thin enough to manipulate by hand. It was also chosen for practical reasons, because it was easily available in large quantities.

IMAGE 2.8 **Weaving the rope satin on a standard floor loom.**

After the initial experiment with the small picture frame, different kinds of frames were experimented with. Initially a floor loom was warped with the rope, which proved to be cumbersome to work with, but produced a reasonably satisfactory result of a piece of rope satin of approximately one square metre. Other frames for weaving the rope that were tested were standing tapestry looms, and a makeshift standing loom constructed by suspending a wooden dowel, and wrapping the bottom of the warp around another dowel that was weighted to apply downward pressure to maintain warp tightness, making it a kind of warp-weighted loom. Ultimately, this became a model for the later construction of *Powers of Satin*.

Usage of the cotton rope also required my familiarisation with rope techniques for the construction of the weaving frame, attaching the warp rope to frame, and for joining pieces of rope to give the impression of a continuous weft thread. This involved learning basic knot-making techniques, as well as rope-splicing techniques.

IMAGE 2.9 **Loom-woven rope satin, displaying some of the draping qualities of satin.**

After these initial experiments, the final structure of *Powers of Satin* was conceived. *Powers of Satin* is a collection of pieces of satin fabric of varying scales. Each object follows the structures of satin, and so *is* satin, though it may not look like satin. It is:

1. an illustration of the weaver's notation of satin
2. an industrial, machine-woven silk satin
3. a hand-woven silk satin as fine as possible, though not as fine as machine-made
4. a satin woven with thick white cotton rope

The weaving of the rope portion of *Powers of Satin* used a loom structure similar to the ceiling-suspended structure of the initial tests. A large, wooden frame was constructed. Suspended between the top and bottom of the frame were large wooden dowels, one attached by rope to the top of the frame, and the other attached to the bottom of the frame. The warp rope was wrapped around these dowels, and the warp tension could be adjusted by tightening or loosening the ropes attaching the dowels to the frame.

The ropes were wrapped over the top bar of the loom frame, and under the bottom bar, creating 36 warp ropes, enough for four repetitions of an 8-shaft satin with 2 outside ropes to create a plain-weave selvage to strengthen the material, as satin will otherwise curl at the edges.

Because of the weight and lengths of the rope, it was not possible to recreate a kind of shuttle for weaving the weft. After testing several lengths, the rope to be used for the weft was cut into lengths of approximately 20 metres. As a new length of weft rope was added to the loom, it was spliced into the previous length of weft rope using a *fid*, a kind of conical needle used for splicing rope.

The weaving of the weft was done manually. Because there were no pedals, heddles or shafts on the loom—none of the loom machinery—I had to calculate the binding points myself. The algorithm would have been:

```
1. Establish the first row by weaving the weft rope
   behind each eighth warp rope until the end of the row.

2. Next row: identify the nearest binding point in the
   previous row, weave the weft behind the warp rope
   3 points to the right of that binding point.

3. Repeat 2 until the end of the row.

4. Repeat 3 until there is no more room on the loom
   or no more rope with which to weave.
```

The algorithm for the weaving much more closely resembles a software language: a set of conditional statements with a distinct order of operations. The algorithm is not present in the standard satin notation, but it exists within the space of possibilities provided by the satin notation.

The weaving was a process of walking back and forth across the material, much like the head of an inkjet printer on paper, slowly building the piece line by line. After a few minutes of walking I would have to sit on the ground with the fid, splicing the two pieces of rope together, and then continue until the next piece of rope ran its course. Every day for a week was the same, slowly wending the 20-metre pieces of rope through the weft pieces. Stopping to rest as my arms grew tired of holding these heavy coils of rope.

The beauty of the satin pattern is embodied in all of the adjectives that we attribute to the textile. It is shiny, smooth, elegant, luxurious . These qualities are foremost strengthened by the use of silk—though silk is not necessary for satin—and made possible by satin's structure.

For satin to be shiny it must have long, unbroken, exposed threads. This is determined by the spacing between binding points. In a standard tabby this is every two threads. In a standard twill this is either one or three threads apart. For a basic satin this could be every eight threads, though no less than 5.

For satin to drape in its most beautiful and effective way, the binding points should not be too close together, nor evenly spaced. This means that the number that I count in step 2 of my *Powers of Satin* algorithm must be either 3 or 5, which are in fact mirror images in the 8-shaft satin.

The algorithm can produce *every* possible regularly spaced satin, provided the rules are followed. In my explorations generating satin weaving patterns for the digital loom, later in this text, a general-purpose algorithm was produced that strongly resembles the algorithm that was followed mentally while constructing *Powers of Satin*, and generated many different regular satin algorithms simply by changing the values of the parameters.

This cannot be said of the grid notation used by weavers to weave satin. When a skilled weaver generates a satin pattern using the grid notation the rules about thread spacing have been absorbed by the weaver and are used to generate the notation. But the rules themselves are not implicit in the grid notation. One cannot create other regular satins from a standard satin grid notation.

2.2.3 Creating *Powers of Satin*

Powers of Satin was presented in the library at the School of Design and Crafts, a large atrium on the ground floor of the school. The space extended up three storeys to a ceiling that bathed the space in sunlight through windows, sometimes shielded by a series of four sailboat sails stretched around the edges of the ceiling, forming a shape like a camera iris. Throughout the week the brightness of the space undulated as clouds gliding overhead dimmed the sun's light, then revealed it again. When the space was particularly dark I could hear the pinging of raindrops on the skylights. It was a quiet, open-sounding space. The occasional sounds of activity would quickly burst and then reverberate through the empty space: students or staff using the mezzanine walkways along the walls at the upper storeys, footfalls and doors opening and closing, the occasional conversation, the large spools of ropes being rolled across the floor to produce the next 20-metre length to be woven.

The rope weave was displayed in the centre of the room, where it was illuminated directly by skylights. The centre of the space was also the focal point for echoes in the room, turning every sound into an uncomfortable ping pong. The rope weave towered over a relatively small plinth, draped in a black satin fabric, supporting a piece of handwoven silk satin, and a piece of watercolour paper with a hand-drawn weaver's notation of satin in black marker.

The piece of handwoven silk satin was one of the first pieces that I had ever woven. After having learned the basics of the craft on looms whose warp had already been set up, I began learning how to weave from scratch. It involves calculating the length of the warp, balancing the cost of the material with the size of the product, and then wrapping the warp in large loops around a frame to prepare the material to be placed on the loom. It involves patiently pulling each loop through its own opening in a beater, a large comb-like structure the length of the loom, pulling each loop between two teeth in the comb. And then, configuring the peddles and the heddles—yet more loops through which the warp is pulled—to produce a satin pattern when the peddles are played in the right order, and cutting each loop of thread and pulling each thread through a heddle. When a peddle is pressed it raises the appropriate heddles—and threads—so that the weft thread can be laid over and under the correct warp threads to create a satin. The warp threads were then attached to a final beam, which was slowly rotated to wrap the entire warp around itself, ready to be slowly unravelled as the fabric is woven. 660 silk threads, to produce a piece of silk 20 cm wide. Patient, delicate, physical, work to produce a small, light thing.

The resulting square of silk satin shines like satin, drapes like satin. Near one of the longer sides are two red weft threads, intended to show the scale of the thread relative to the artefact. On the plinth was also a linen tester, allowing for a closer look at the fabric, and a comparison with the rope weave.

As the rope weave was created, it was woven so that the outer warp ropes were woven in a tabby weave to strengthen the sides, but the sides still managed to slowly curve inwards, giving the piece a drooped expression. I wrapped rope around the outside warp ropes and the side beam of the weaving frame in an attempt to pull the piece straight. The result was an inelegant mess of criss-crossed ropes. The final result was a monumental 2 × 3-metre piece of rope satin.

The rope weave, surprisingly, exhibited some of the same qualities as the handwoven silk satin. It could not have been said to shine like the handwoven satin, but there was a definite change in the brightness of the piece as I walked around it, observing it from different angles, underneath and above.

2.2.4 The mistake in *Powers of Satin*

When weaving satin on a loom, the pedals, heddles and shafts are set up in such a way as to allow the weaver to create satin through a specific order of pedalling. One effective function of the traditional floor loom is to simplify and automate aspects of the weaving process. Rather than wending a weft thread over and under warp threads to construct a specific weave, the configuration of the floor loom's heddles and pedals allows the weaver to raise all warp threads in a specific row that the weft thread must travel under. This constructs what is known as a *shed*, a gap between raised and un-raised threads large enough for a shuttle containing weft thread to be passed. For example, for an 8-shaft satin, pressing a pedal on the floor loom would raise every eighth warp thread, under which the shuttle would pass, creating the binding points for one row of satin.

Because *Powers of Satin* was not possible on a floor loom, a frame was constructed out of lumber. And because this frame did not have the pedals and heddles of the floor loom, the process of weaving the weft rope in front of or behind select warp ropes had to be done by hand. To accomplish this, the process doing these calculations was reduced to what is essentially an algorithm.

After the weaving was completed, I spent an evening documenting the installation. I had spent the week with my head down, gradually unwinding a kilometre of rope from large spindles, splicing the ropes together, and weaving them through the warp ropes. I had not taken the time to examine the piece as a whole.

When examining the rope weave of *Powers of Satin* it became evident that there was a problem in its structure. There were several irregularities in the surface that were likely from an unevenly packed weft. But one artefact was different. It was pronounced and sustained across the surface. It was a diagonally sloping pucker that could be seen on the front and the back. When examined closely it led downwards to its lowest point,

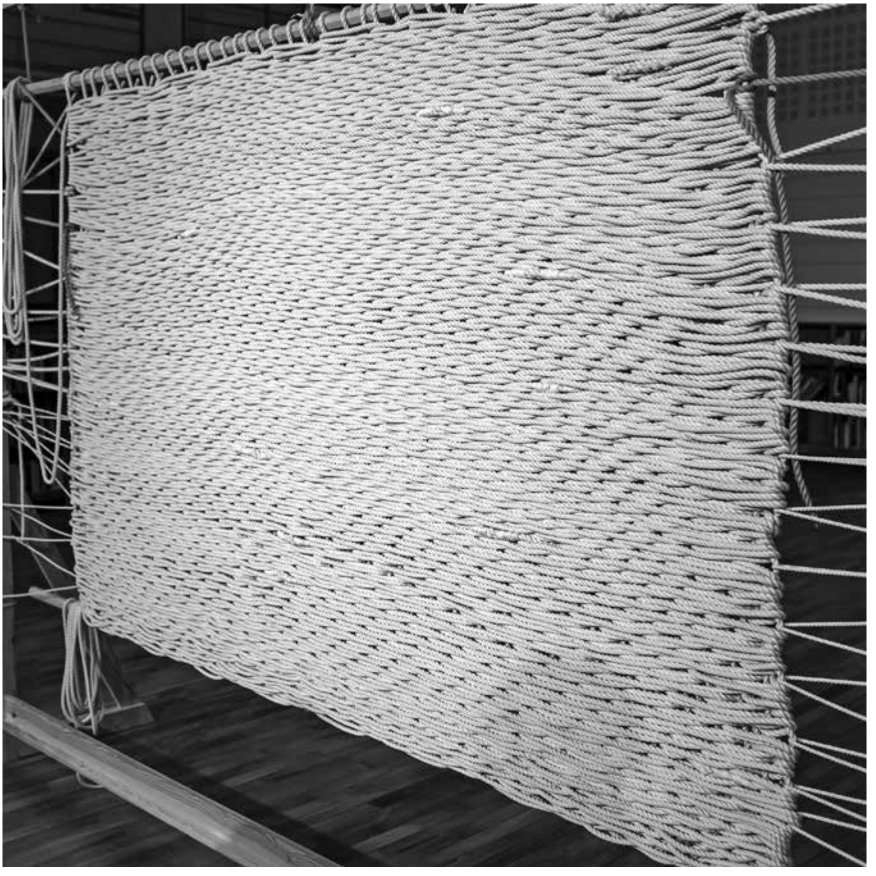


IMAGE 2.10 **The pucker in *Powers of Satin,* seen from the front.**

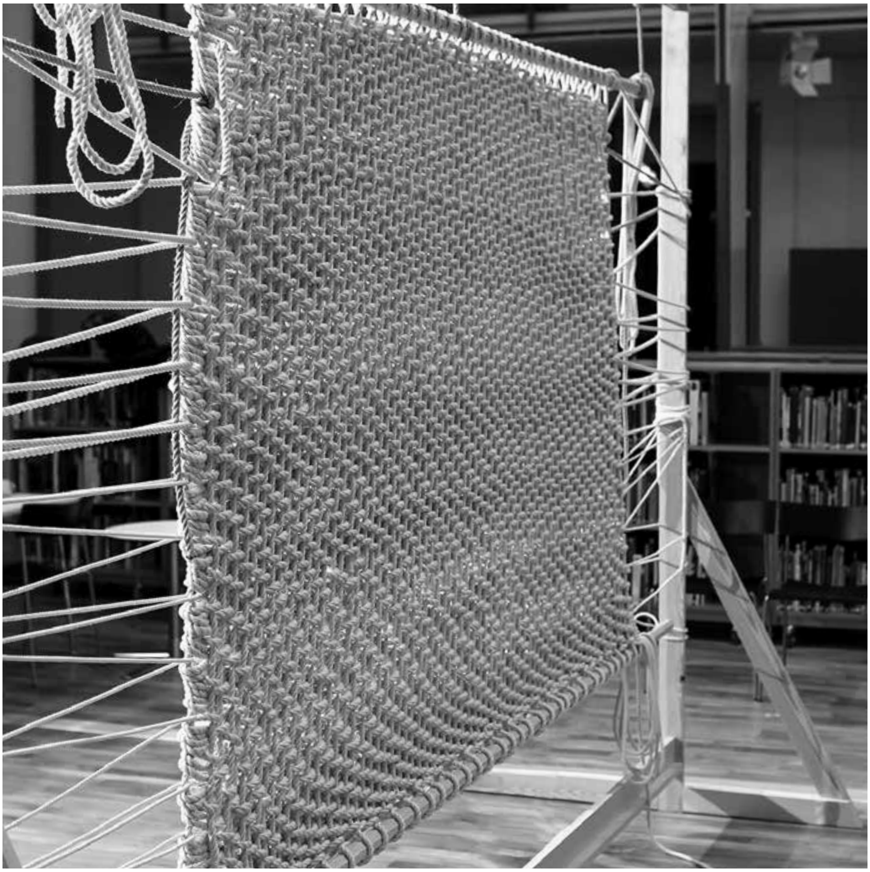


IMAGE 2.11 The pucker in *Powers of Satin*, seen from the back.

where its cause was revealed. In the manual weaving of the satin pattern there had been a misplaced binding point. That point was to have been three warp strands away from the previous binding point, but it had only been woven two warp threads away. Because every row's binding points are determined from the previous row, this mistake was propagated all the way across the fabric. The algorithm had no error-checking feature, and so it could not compensate for a mistake. This is similar to certain kinds of software bugs: the use of an algorithm to construct the weave meant that the process was susceptible to error. Specifically, it is difficult for algorithms to fully encompass an understanding of the world in which it resides, and to accommodate all eventualities. This algorithm contained no error checking, no instructions that ensured that previous steps were taken faithfully. This allowed the weaving to be affected by human error. The emergence of error in the process of constructing this form shows an opening for the introduction of strategies from glitch art. Glitch art requires there to be a possibility for error in a system, and the recursive error in *Powers of Satin* showed that when using such techniques as constructing textile patterns with an algorithm, error is possible. If error is possible, it means that the error can be explored, and hopefully, exploited. The following stages of the research, presented in the next chapter, explore the possibilities latent in this idea of error or noise in a satin pattern, by pursuing lines of creation similar to glitch art.

Powers of Satin also demonstrated the usefulness of looking at textile construction from different angles. *Powers of Satin* was an experimentation with expanded scale. This second half of this chapter presents an artwork exploring an industrial bobbin-lace machine, and using the construction of the textile to generate material and observations other than the textile itself. A bobbin-lace machine was augmented with LEDs that responded to the movement of the spools around the machine's platter. Although this proved to be a successful strategy, the rest of the research actions focused on glitch art and algorithm manipulation, and did not return to this line of enquiry. This bobbin-lace work is presented in the rest of this chapter.

2.3 *Critters*

This half of the chapter discusses a tangential strategy, using an industrial textile machine to investigate the structures and gestures of industrially created textiles. Presented here is *Critters*, a piece created in 2013 at Remfabriken, a museum and former textile mill in Gothenburg. The bobbins of an antique industrial bobbin-lace machine were augmented with custom circuitboards and LEDs that accented the movement of the bobbins throughout the dark space, tracing the pattern of the machine's movement through the air as it was braiding the lace.

Video documentation of *Critters* can be seen at the GUPEA link:

http://hdl.handle.net/2077/57324

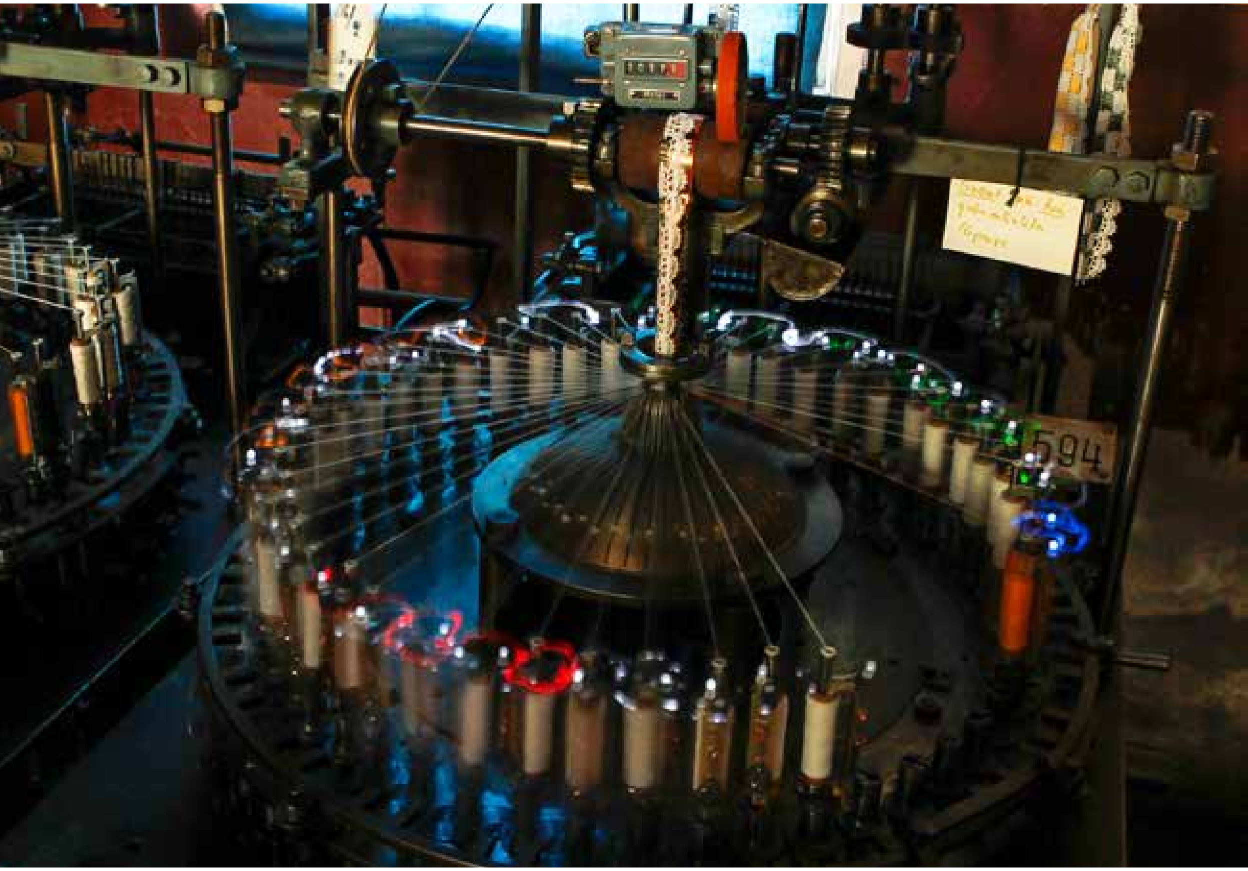


IMAGE 2.12 *Critters*, long-exposure photograph.

IMAGE 2.13 *Critters*, detail of circuit boards on bobbins.

IMAGE 2.14 *Critters*, detail of the lace produced by the machine, slowly moving up the central column.

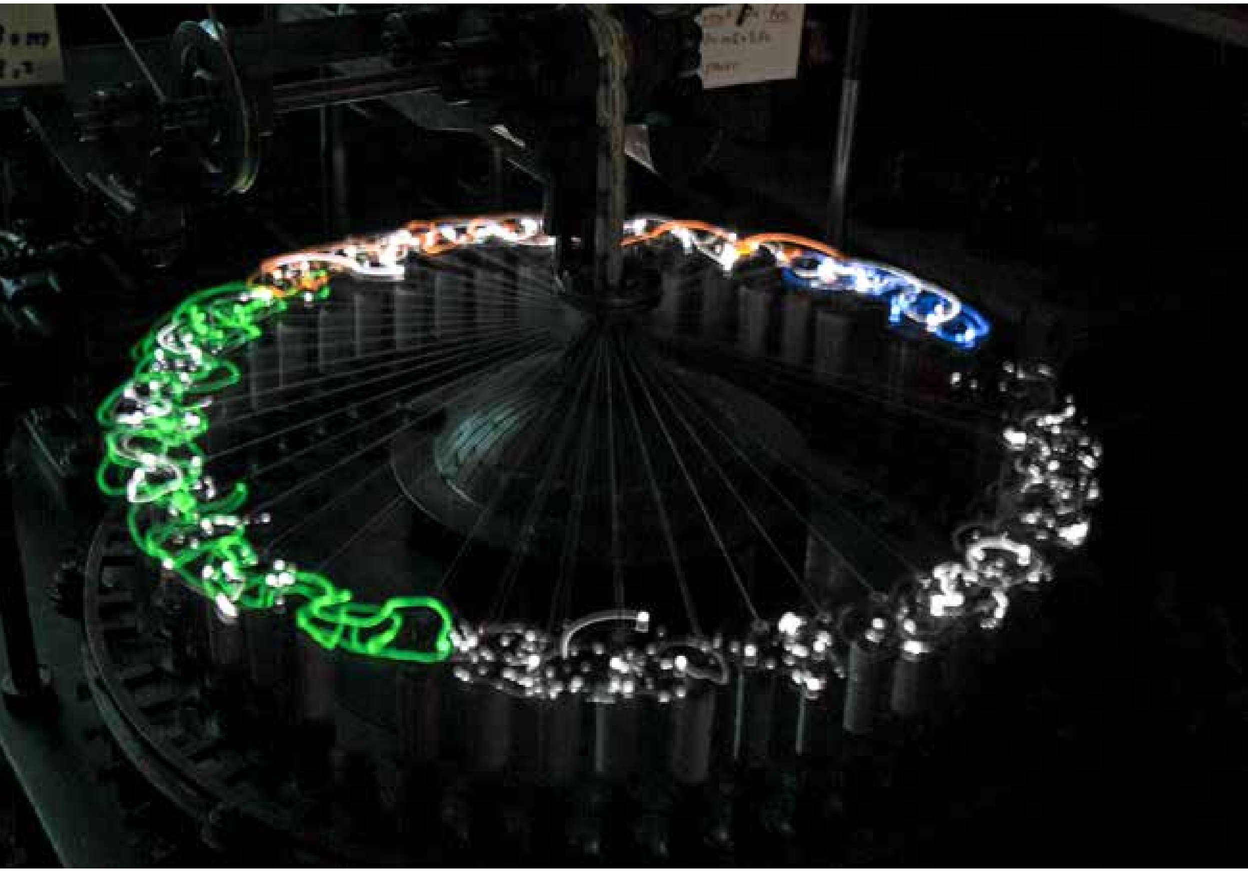


IMAGE 2.15 ***Critters*** **long-exposure photograph.**

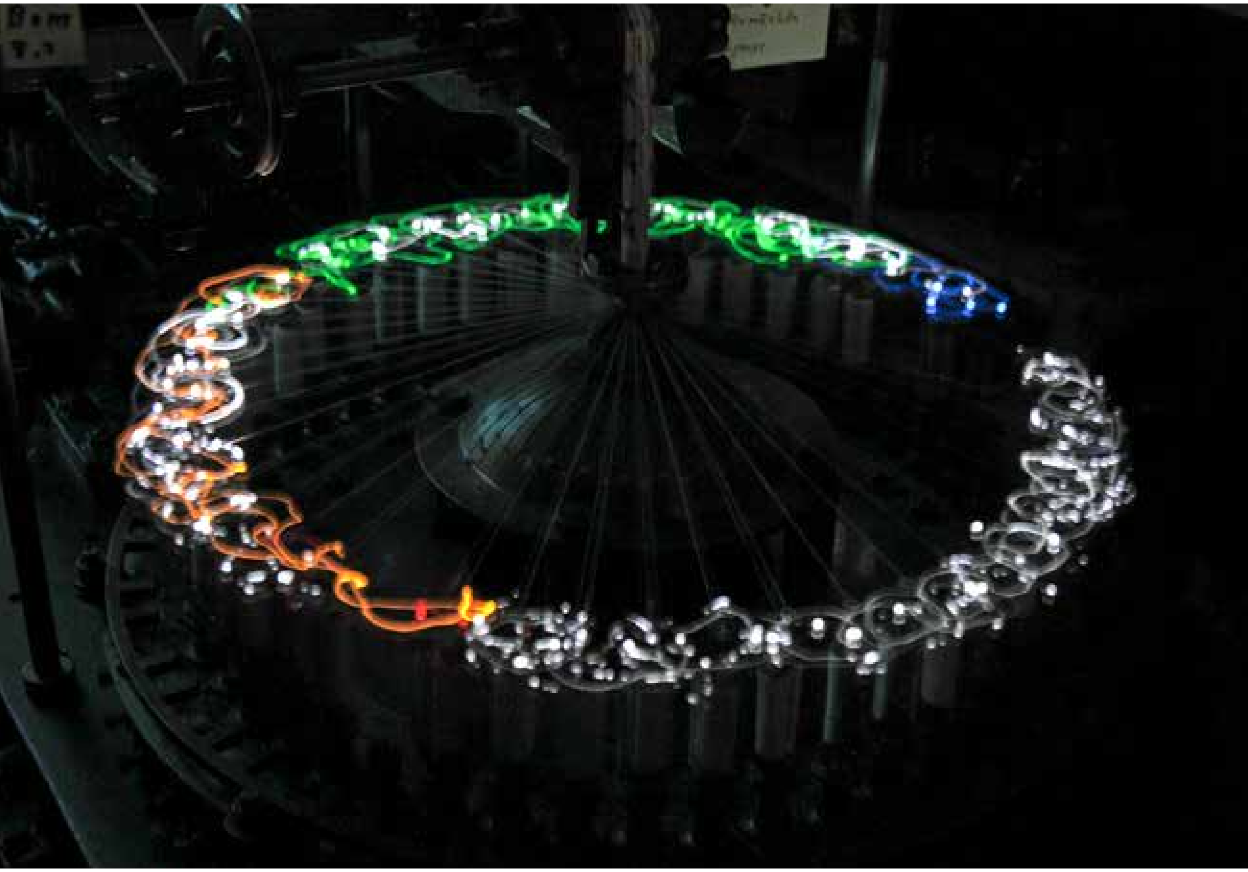


IMAGE 2.16 *Critters* long-exposure photograph.

Powers of Satin attempted to communicate and understand a pattern by enlarging it, but the enlarging was also an attempt to make the pattern visible, to strengthen it and make it known. *Critters* was also an attempt to strengthen a pattern, using other methods. Though the piece did not lead to further explorations, it is presented here as an artefact of the research process.

During this PhD research I had the opportunity to teach a course to textile-design students at the School of Design and Crafts in Gothenburg with my secondary supervisor, Birgitta Nordström. The course was taught on site, and in collaboration with Remfabriken, a textile museum housed in a former textile mill. Remfabriken contains many of the original textile-producing machines, still in working order. The museum's enthusiastic staff has also collected working textile machines from various Swedish textile mills that have ceased operations. The students in the course were allowed to work at the museum, using the museum's machines, and produce works that would be presented in an exhibition on site, spread throughout the museum's premises. This seemed a rare opportunity fro me, to also create a work using the museum's machines.

Remfabriken was originally a mill for constructing drive belts for machinery, and so contained several working looms designed to create heavy woven material. And although my work at this point was focused on weaving, it was the museum's lace machines that I found the most interesting. The choice to use the lace machine arose purely from this fascination, and was not a considered choice for the research. At the time, it was not clear whether the work developed in the museum would be included in my PhD research, or would be simply an unrelated artistic project.

Because lace can now be mass produced, it is difficult to imagine a time when it was seen as a luxury, but remnants of this status still persist in its use in luxury garments, such as lingerie, or garments with a social and cultural importance, such as the wedding dress. Lace's value comes from the labour-intensive production process. Lace is essentially an incredibly complicated form of braiding, where, rather than the standard three-ply braiding we associate with hair, it can be composed of a row of dozens of bobbins of thread. The lace is produced through the painstaking process of twisting the threads by alternating bobbin positions. Each tiny twist of thread slowly builds the lace up.

The industrial lace machines at Remfabriken have taken the traditional row of bobbins and placed them around the edge of a round platter, so that the first and last bobbins of the row stand beside each other. Bobbins swap positions with their neighbours, driven by a series of punch cards, similar to Jacquard loom cards, that dictate which spools should trade places. For the sake of manufacturing, the lace is produced not as a flat ribbon but as a tube. Just as the ends of the bobbin row curve around to meet each other, so do the outside edges of the lace ribbon meet each other, bound together by a thread that will later be removed.

The beauty of the lace machine is that it magnifies the lace-making process. Lace is a fine, delicate thing. It is small. There is a density to it, and not a density like in a woven fabric where many threads are packed into a tight space, but a density of gestures—many knots by many threads in a very small space. The machine takes that density and explodes it into space, like an ever-expanding universe where every particle is getting further away from everything else. The density became an airiness, though it was a firm airiness, regulated by a steel machine and a powerful motor.

Where the weaving work of this research was conducted by learning the craft by hand, the work with lace did not begin with the hands. Working with the lace machine was a backwards way of getting to know a craft, looking at the machine first is like reverse engineering it. What is presented by the machine is the dance of the movement of the bobbins. Each bobbin operates with its own purpose, almost with its own intelligence—for as the view rests with the machine, follows the bobbins of white thread, or the handful of bobbins with coloured thread, the pattern emerges. A bobbin in front hops several places to the right… waits… hops back to its original place… waits… and repeats.

A pair of bobbins with green thread runs back and forth, evenly, like a pair of rabbits running across a lawn—first on one side of the ring of bobbins, and then on the other.

What initially appeared to be a chaotic movement of many things—a riot, a swarm, a melee, revealing itself to be a highly coordinated enmeshing of interdependent actors. There is purpose in everything towards the final goal of making a specific pattern of lace.

2.3.1 Constructing *Critters*

The objective of *Critters* was to strengthen the movement of the bobbins with light. Each bobbin would be outfitted with identical electronics to illuminate its movement. The electronics went through several iterations to balance the desired behaviour with the practicality of the electronics design. A light was required for the illumination (an LED), and a power source for the light (a battery).

This led to practical considerations of power consumption. If the installation were to be running throughout a day, the circuit could not be constantly active, but must stop operating when the machine was not active. A solution was a vibration sensor to activate the circuit while the bobbin was in motion. A microcontroller was considered as a possible brain to read such a vibration sensor, but it was determined that, in order to reduce cost and complexity, it would be better to have the circuit controlled by a vibration switch that allowed the electricity to flow while the bobbin was moving. A suitable component solution could not be found in the time available, so such a sensor was constructed out of copper wire. With a horizontal circuit board attached to the bobbin, a copper pin dangled vertically in a horizontal copper ring. This pin-and-ring system provided an electrical switch for the circuit. When the bobbin moved, the pin would swing and touch the ring, momentarily closing the electrical circuit, allowing power to flow from the battery to the LED. This system can be seen in Image 2.13.

The result was a lighting behaviour that was deemed inelegant. The LED would flash brightly, briefly, and intermittently. To smooth out this behaviour, a capacitor was added to the circuit. As the switch was momentarily closed, the capacitor would store power from the battery, and would discharge to the LED. The LED would draw its power from the capacitor, not the battery. The result was brief flashes when the bobbin jiggled, and then a slow fade when the bobbin was still. The circuit design can be

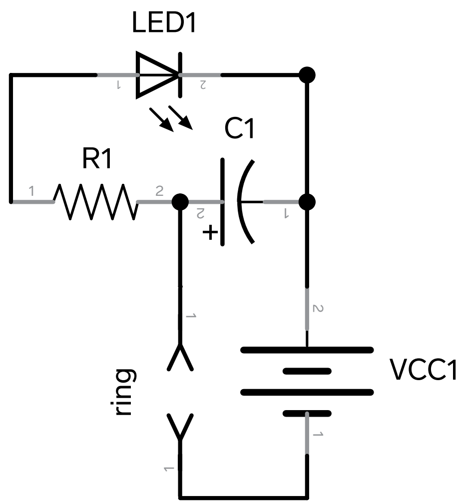


IMAGE 2.17 *Critters* circuit schematic.

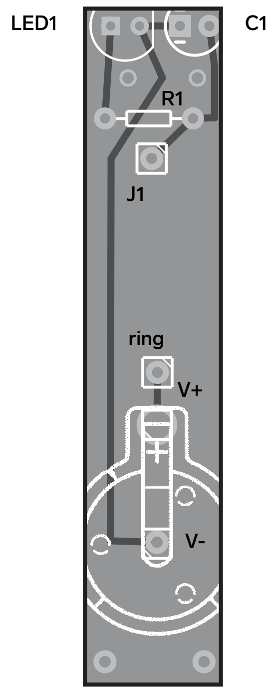


IMAGE 2.18 *Critters* circuitboard design.

seen in Image 2.17 and the circuit board design can be seen in Image 2.18.

Each component choice and mechanism construction of this circuit had several alternatives tested, leading to choices that balanced behavioural requirements and physical requirements, including size (battery, LED, capacitor, and copper wire sizes and forms) and component capacity (battery capacity, capacitor capacity and discharge rate, LED strength).

2.3.2 Considering *Critters*

While *Powers of Satin* was an attempt to intervene in a textile pattern by altering scale to provide a new perspective, *Critters* was an attempt to intervene in the operations of a textile-producing machine by hacking it to produce a new output, the movement of the LEDs. The expectation was that by hacking the machine's natural movement to produce a different kind of output, that this might reveal a possible strategy in the transfer of techniques from new media art to textiles. By hacking a textile-producing machine's output, we might uncover a new space of expressive output. The LEDs on the bobbins strengthened aspects of the dance. First and foremost was the movement and trajectory. In the darkness the bobbins disappeared. The machine disappeared. All that was present was the glowing insects, the critters, intertwining with each other. The machine fades away and the pattern is all that is visible.

The LEDs presented a density of movement. The nature of the circuit construction was such that the LEDs shone brightest when they moved. When still, they faded as the capacitor discharged its stored energy. As a result, when active bobbins pass by passive bobbins, the changing of place caused a trail of fading light behind them as the passive bobbins were briefly activated. What became visible was not only the object itself, but a representation of its velocity, a ghost of it passing, like the tail of a comet or the wake of a ship on the water.

Long-exposure images of the work (seen in Image 2.15 and Image 2.16) showed densities of light as elements of the machine stayed within one area of the ring, or travelled wildly this way and that. The production of the lace required a cooperation where some actors stayed put, and others travelled.

These long-exposure images that were taken for artistic purpose quickly became observations. The long exposure allowed for a kind of mapping of the movement of the bobbins. The particular lace pattern of this machine involved a chequered patterned with a frilly border, seen in Image 2.14 snaking up the centre pillar . The four sets of bobbins responsible for the checks were given green and orange LEDs. Image 2.15 shows the pattern of these pairs of bobbins occupying the space along the ring for constructing the checks. The light of these bobbins was never seen to overlap, because that was not the function of those bobbins.

These bobbins containing the threads that bound the edges of the lace in a tube were given blue LEDs. Image 2.16 shows a moment in the pattern where the binding threads are attaching themselves to one edge of the lace—showing slight movement but nothing significant. The edges of the lace are made clear by the black area in the right of the ring, a space that will be travelled by the blue bobbins on their way to bind with the other edge of the lace.

Stepping behind the machine shows the set of punch cards that contain the instructions for the lace, seen in Image 2.19. As the machine chugged through the cards, it produced an animation as our persistence-of-vision blends one card's encoding with the next. The rabbit-like patterns of the

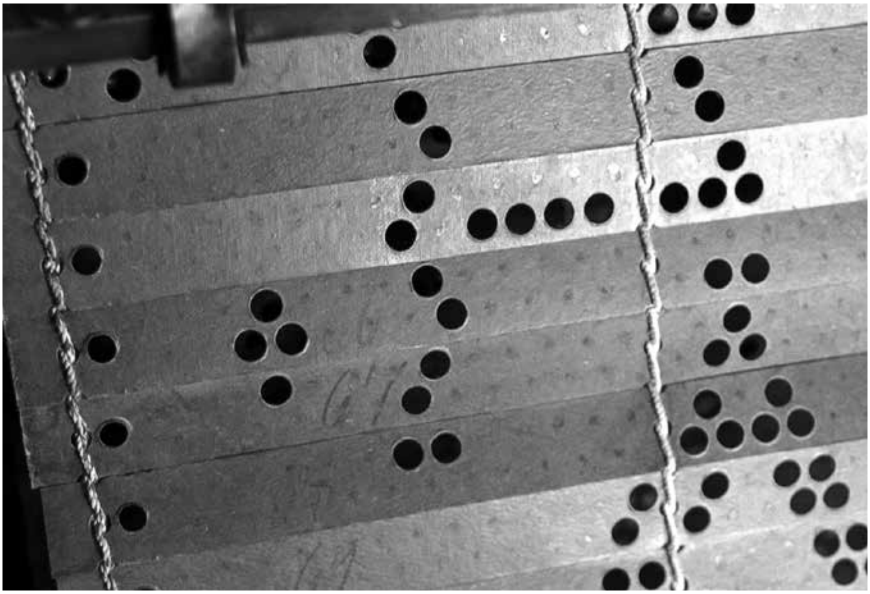


IMAGE 2.19 **The punch cards containing the machine instructions for constructing the lace.**

LEDs is shown in the travel of the holes across the cards, the bit-shifting of the data from one register to the next.

My love for the industrial bobbin-lace machine came because of the way that the machine exploded the pattern into something visual, knowable, tangible. Much of my work has been trying to make these unseen patterns visible and knowable.

As with satin, I was attracted by the machine's beauty. Though it was not just an aesthetic beauty, it was also an intellectual beauty. My first encounter with the lace machine was to see it simply moving. It was this experience that showed me that there is something more going on with lace than my previous associations allowed. The elegance also lay in the machine. The machine was terrifying, powerful, dangerous and precise. Seeing Remfabriken gives an understanding of the danger of working in factories, and the terrible conditions that the 19th-century working class would have endured.

2.4 Conclusion

This chapter presented examination of textile patterns and construction, to search for possible transfers of strategy from new media art. While teaching, there arose an opportunity to work with older industrial textile machines. This led to the creation of *Critters*, an artwork that sought to examine the textile structure by augmenting industrial machinery to create another output than the textile itself. Lights were attached to each bobbin of an industrial lace machine, and the machine's movement created patterns with the lights. The piece created interesting visualisations of the bobbins' movements, allowing the machine to create both a piece of textile and a visual experience. Long-exposure photographs of the installation presented a kind of bobbin density of the pattern and the bobbin movement. This work was seen at the time as a diversion from the main thrust of this research, and so was not continued further in this research project.

As was presented in the previous chapter, the decision was made to examine weaving, a textile technique traditionally linked to computation, to see if transfers of strategy were possible that did not rely in the grid feature shared by computation and textile notation. The grid was shown with *Sticks and Stones* to be a narrow and sometimes misleading metaphor when used as a unifying feature.

Hand weaving was learned as a way to understand many aspects of the craft, rather than observing it as an outsider. After weaving basic patterns on hand looms, the satin weaving pattern was chosen as a subject of study. This resulted in the work *Powers of Satin*, an exploration of satin woven at many scales, from fine silk satin, to a large piece woven from thick cotton rope. Playing with scale has been a common tool in contemporary art, and not specifically to new media art. While the artwork created interesting aesthetic results, and created a large piece of rope satin that could be compared to traditional, fine satin, the most valuable result for this research was the discovery of an error created while weaving the rope by hand. A miscalculation of a single binding point created a disturbance along the surface of the weave, a feature similar to a software bug.

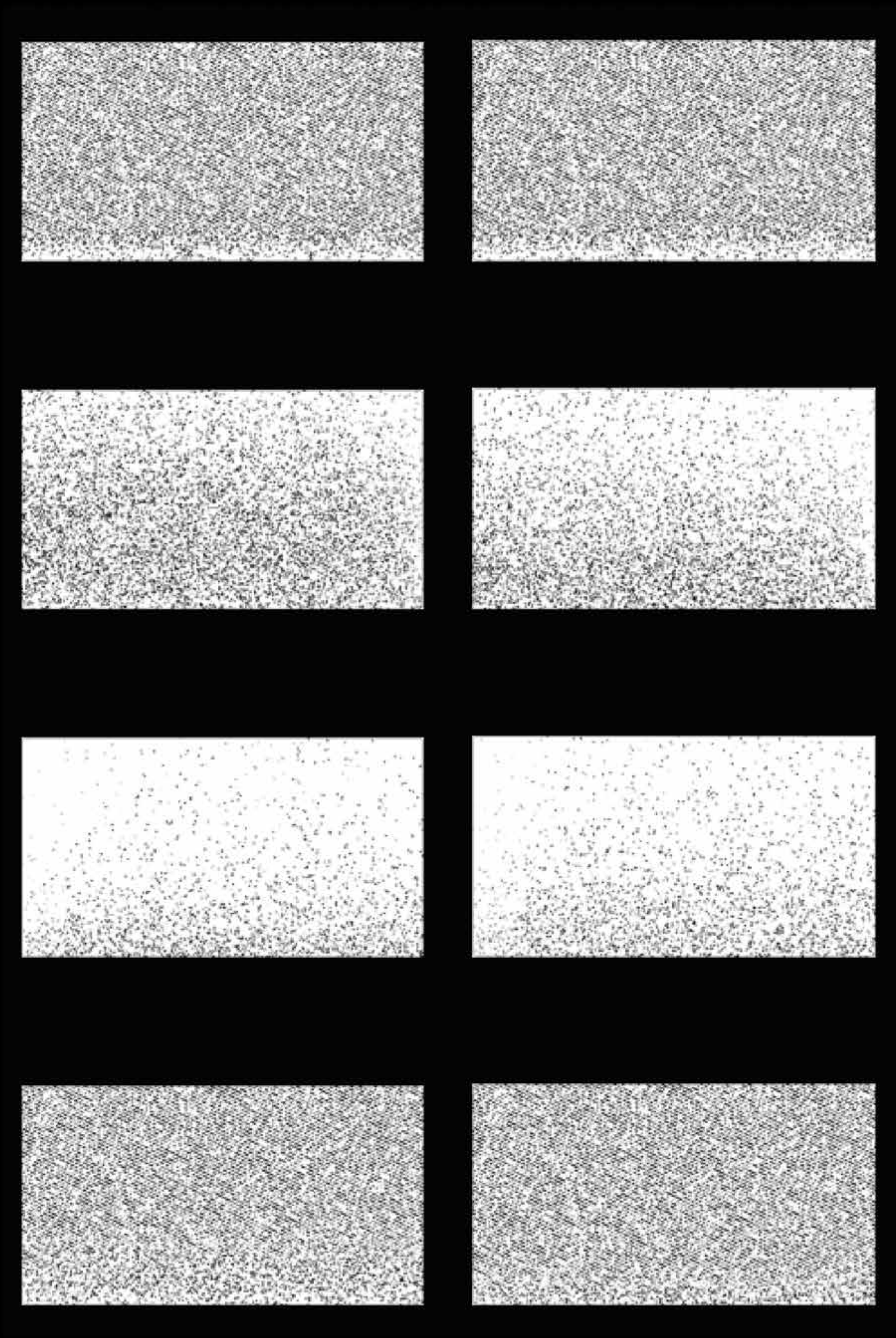
This bug in the satin provides the basis for the next chapter in this dissertation, which is the deliberate exploration of error as a design feature in textile construction. The work will borrow from the practise of glitch art, a form of new media art that exploits error and its artefacts in the generation of artwork.

3. Failure

3.1 *Slow Explosion, Bang and Crunch*

A generative exploding satin structure. Video documentation and the code can be seen at the GUPEA link:

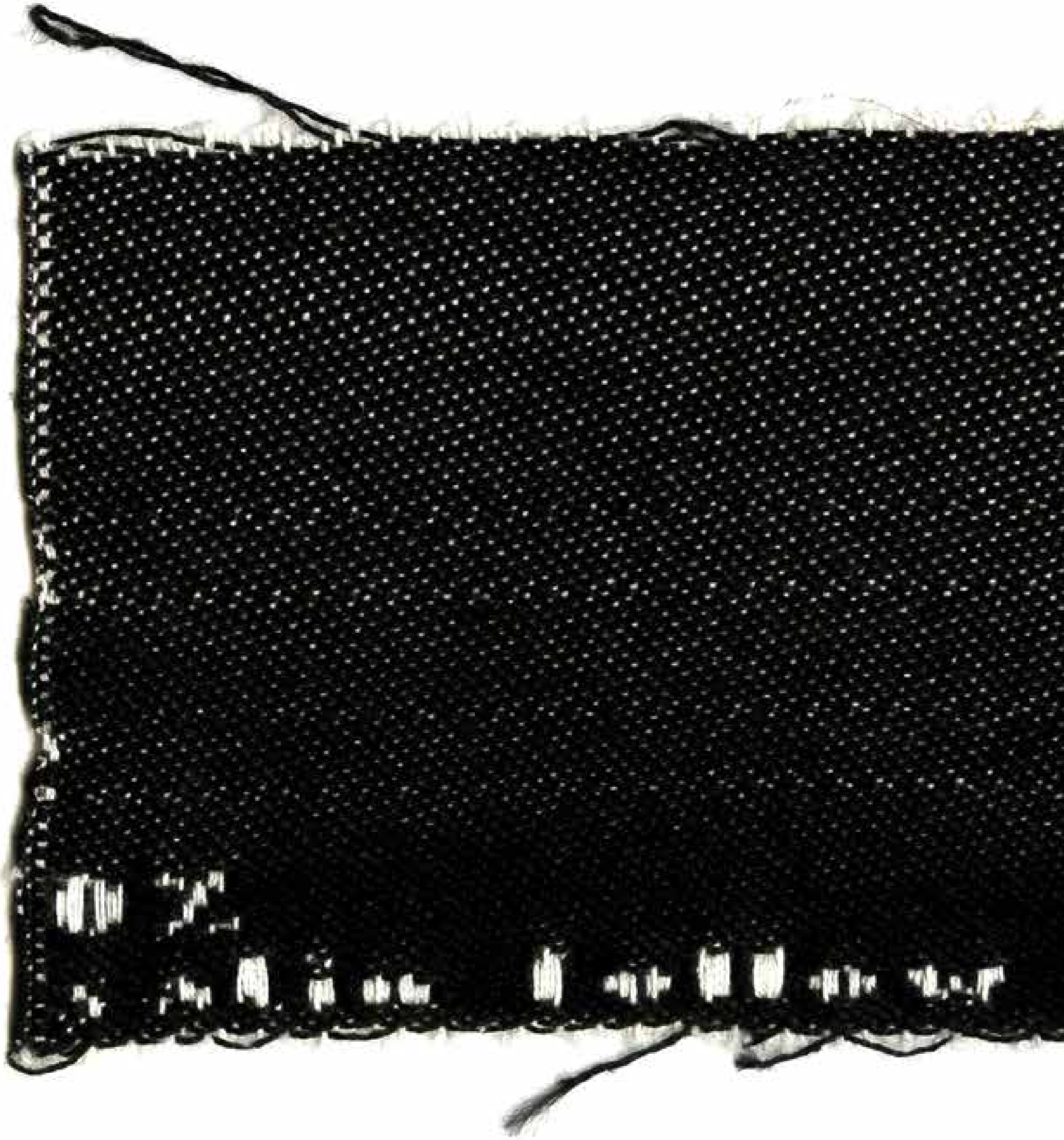
http://hdl.handle.net/2077/57324



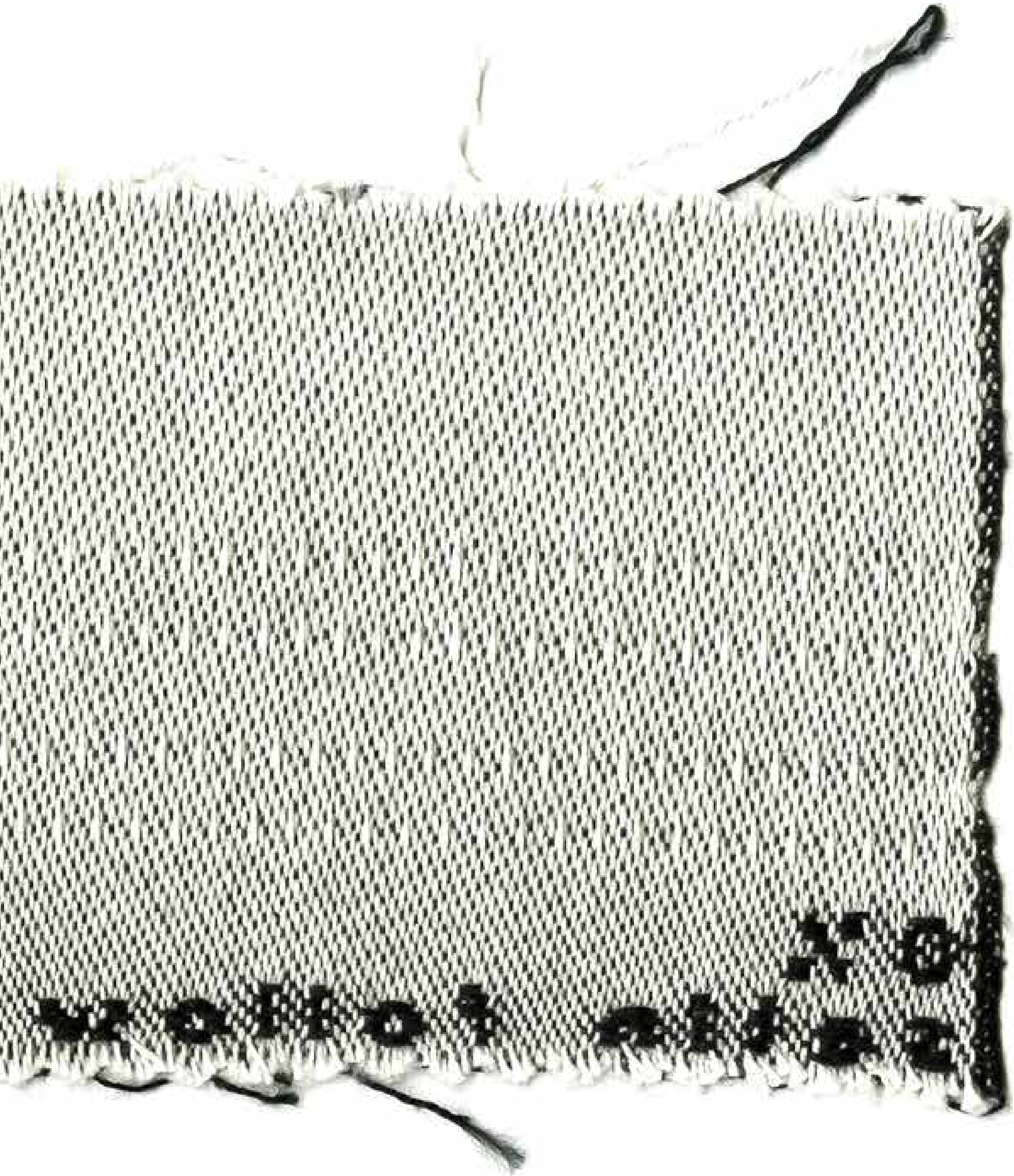
3.2 Woven error samples

Recursive error

0% algorithm error. Cotton. White warp, black weft.



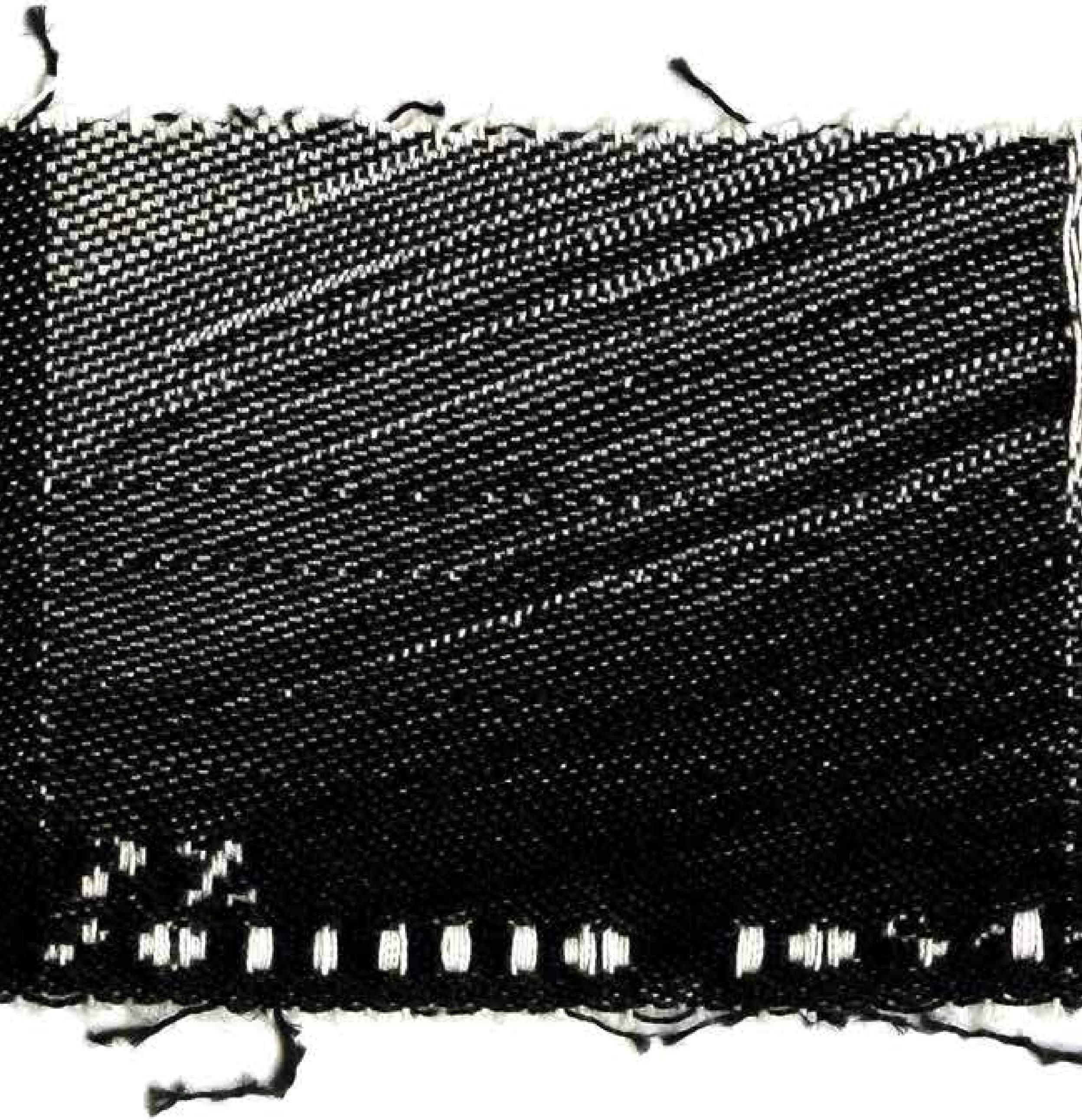
FRONT



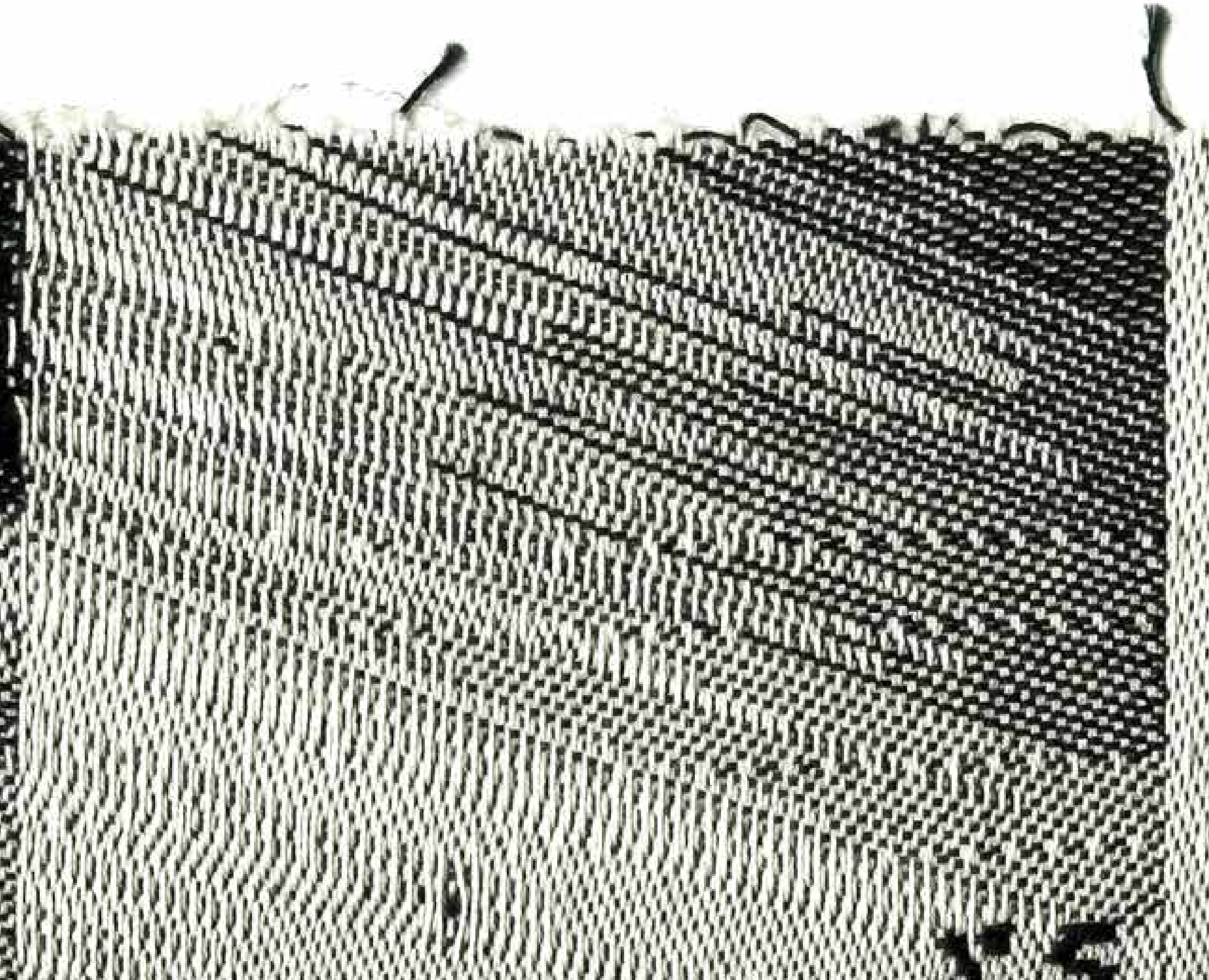
BACK

Recursive error

2% algorithm error. Cotton. White warp, black weft.



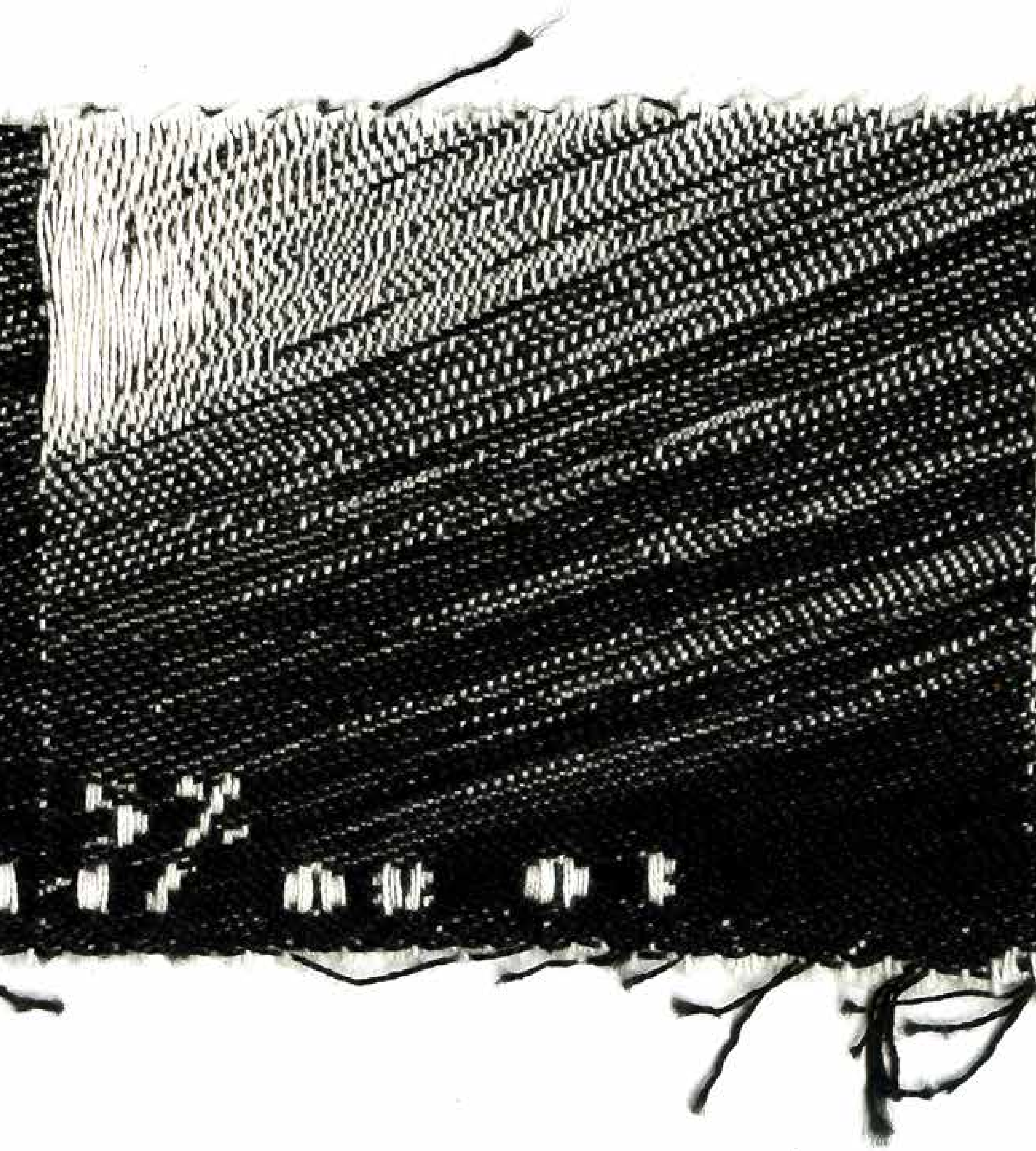
FRONT



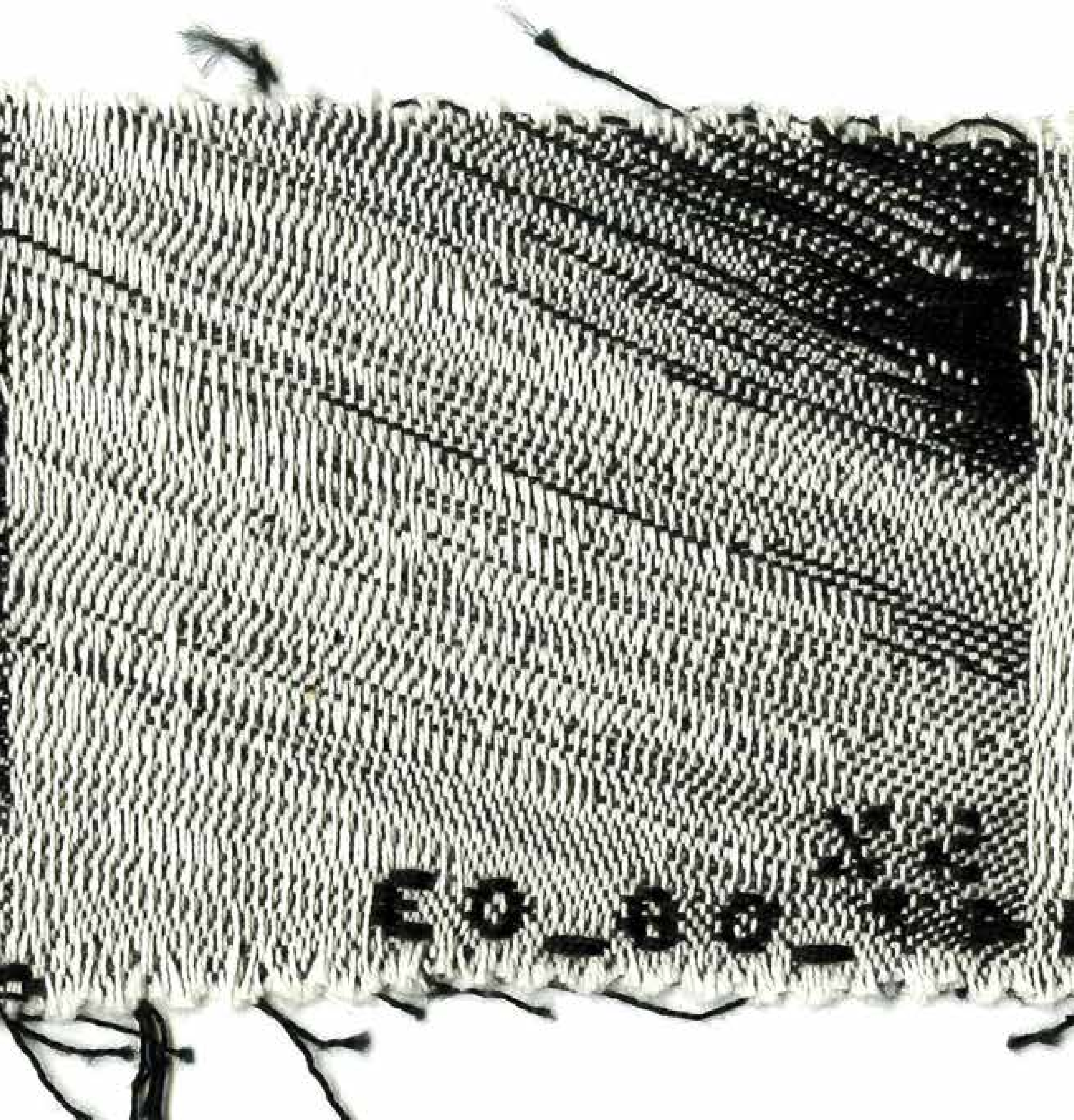
BACK

Recursive error

5% algorithm error. Cotton. White warp, black weft.



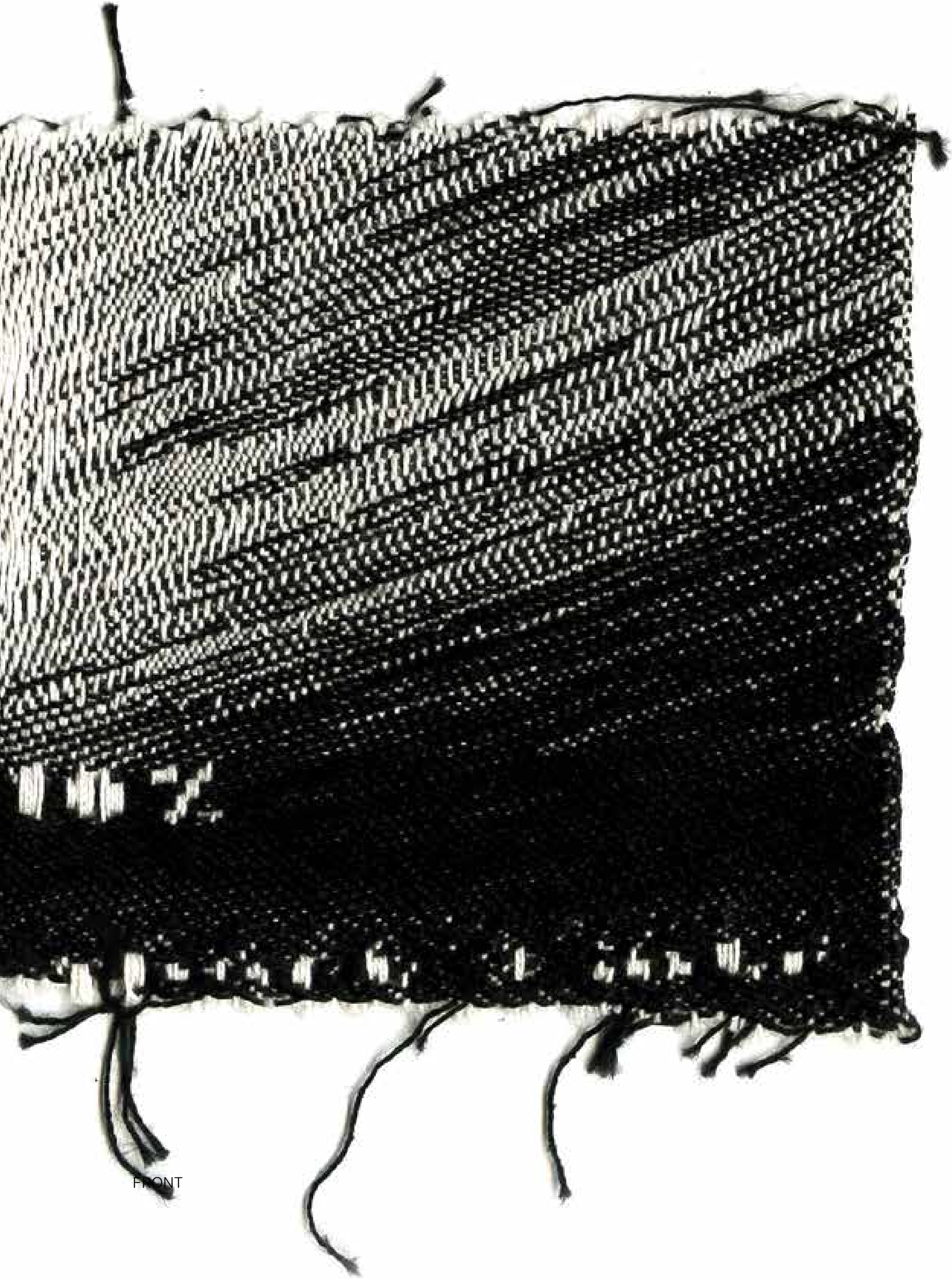
FRONT



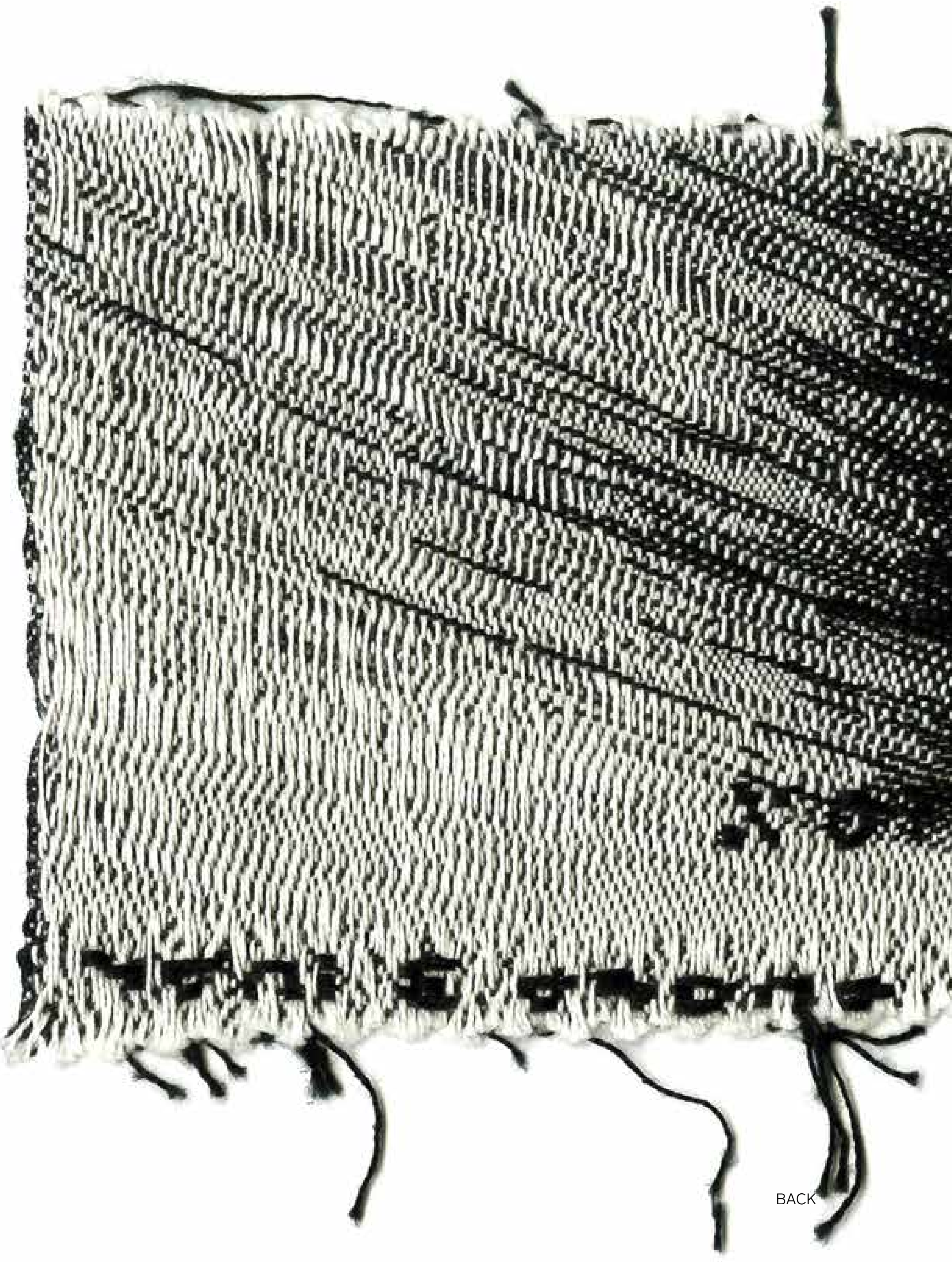
BACK

Recursive error

10% algorithm error. Cotton. White warp, black weft.



FRONT



BACK

Recursive error

0% algorithm error. White cotton.

FRONT

BACK

Recursive error

0.1% algorithm error. White cotton.

FRONT

Recursive error

0.5% algorithm error. White cotton.

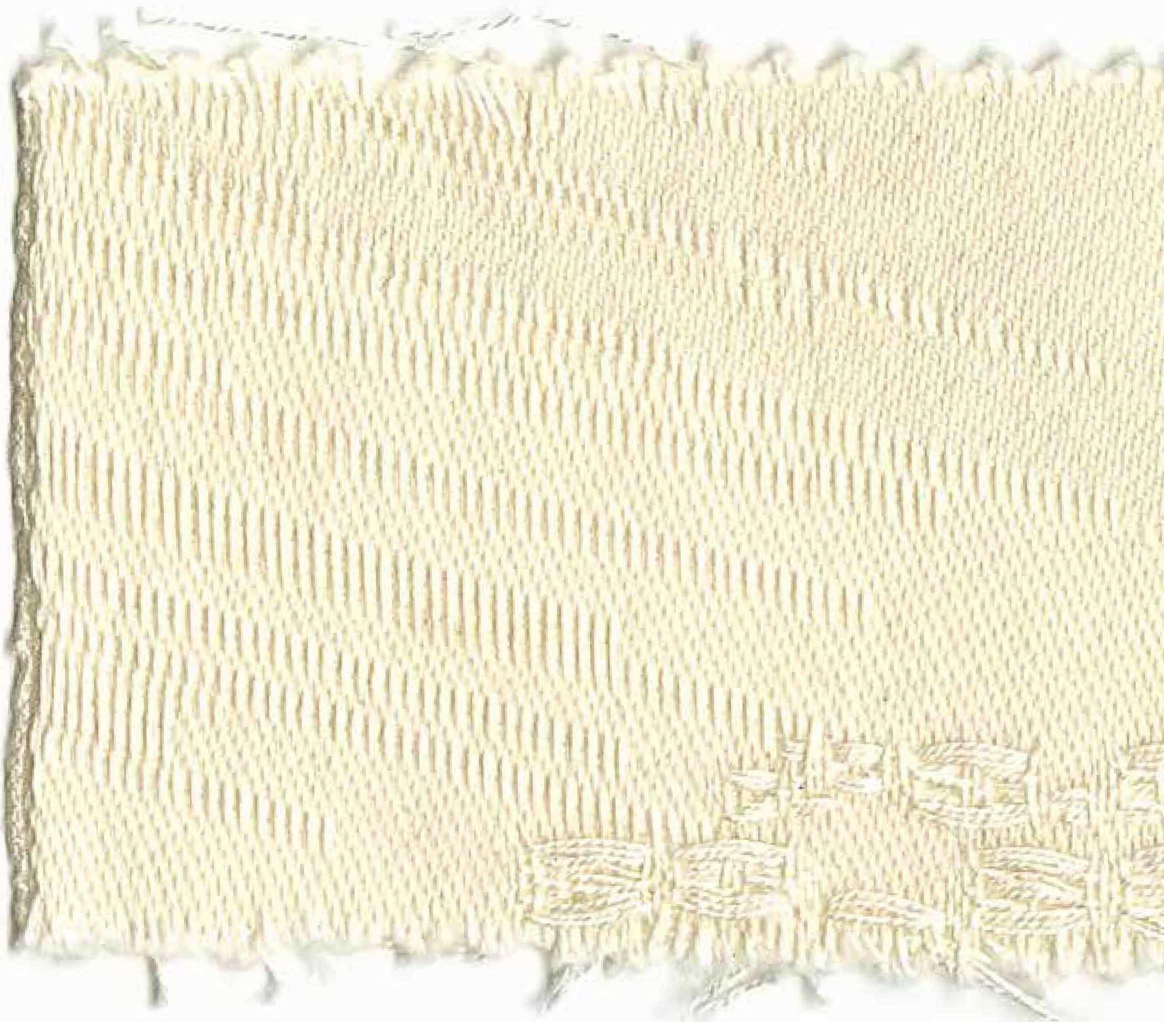
FRONT

BACK

Recursive error

1% algorithm error. White cotton.

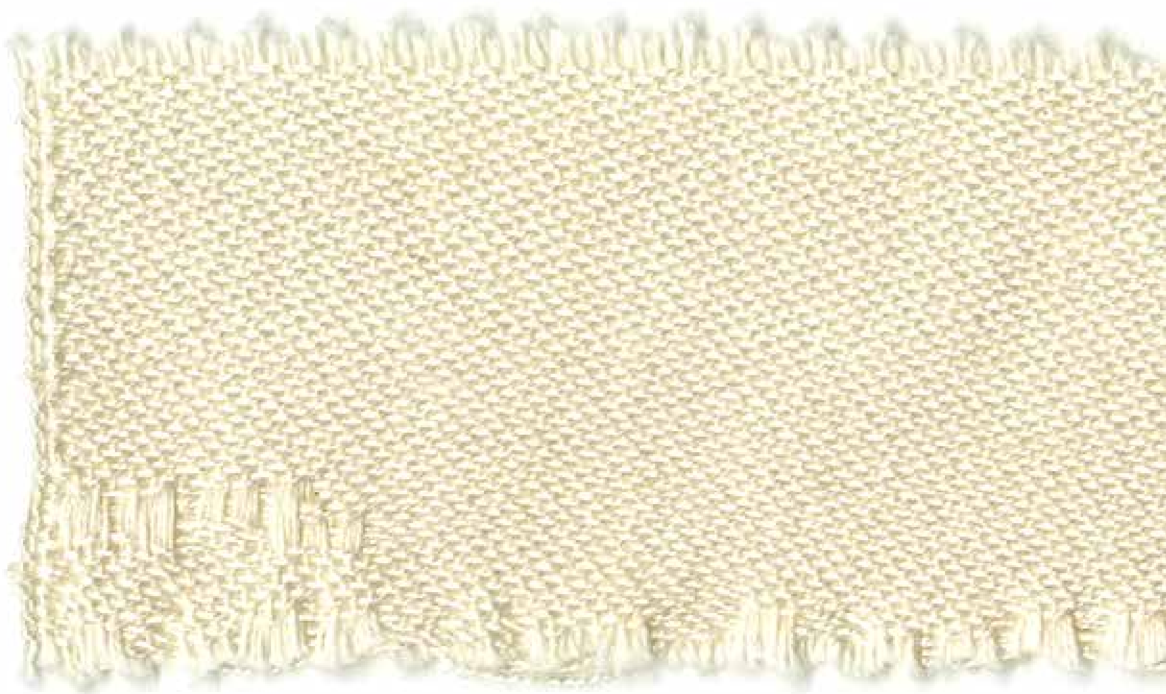
FRONT



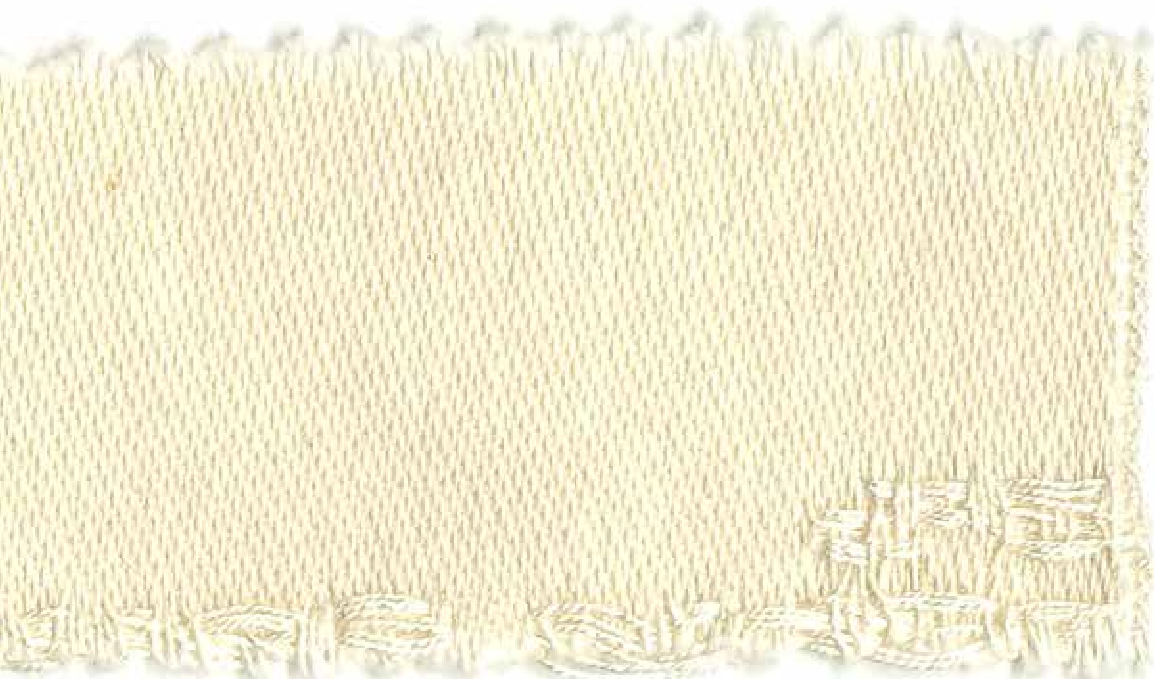
BACK

Recursive error

1% algorithm error. White cotton.



FRONT

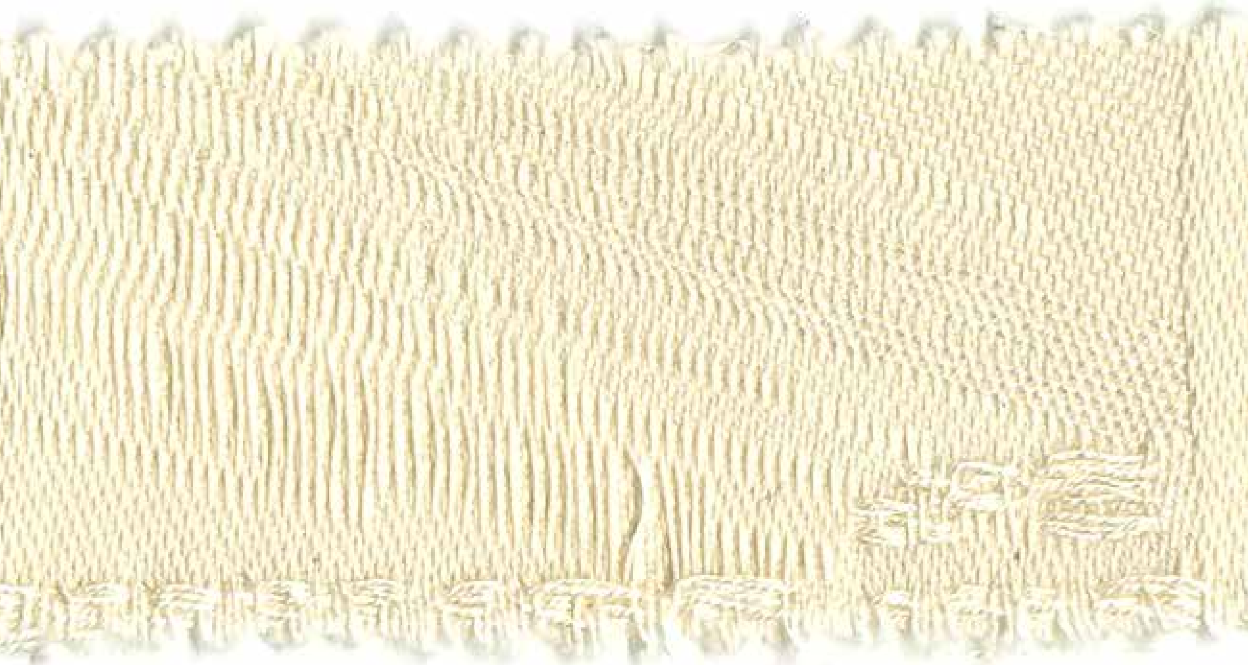


BACK

Recursive error

2% algorithm error. White cotton.

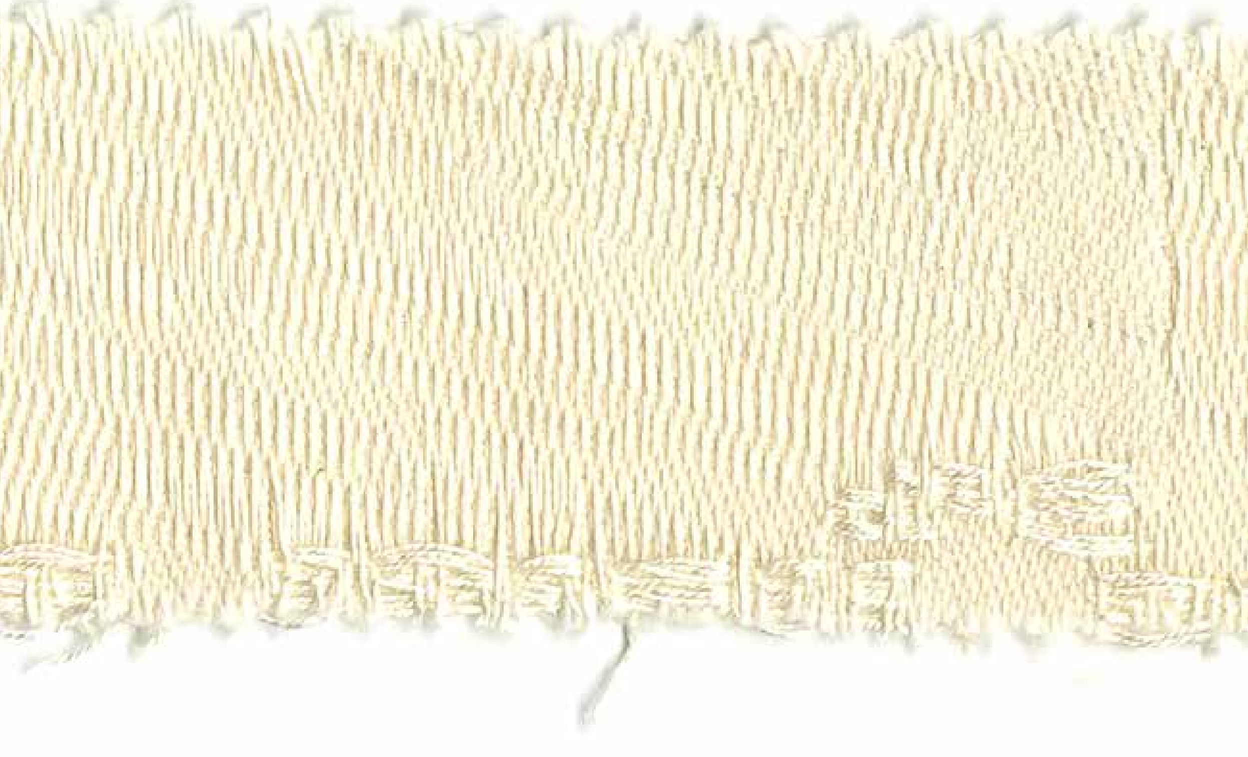
FRONT



Recursive error

5% algorithm error. White cotton.

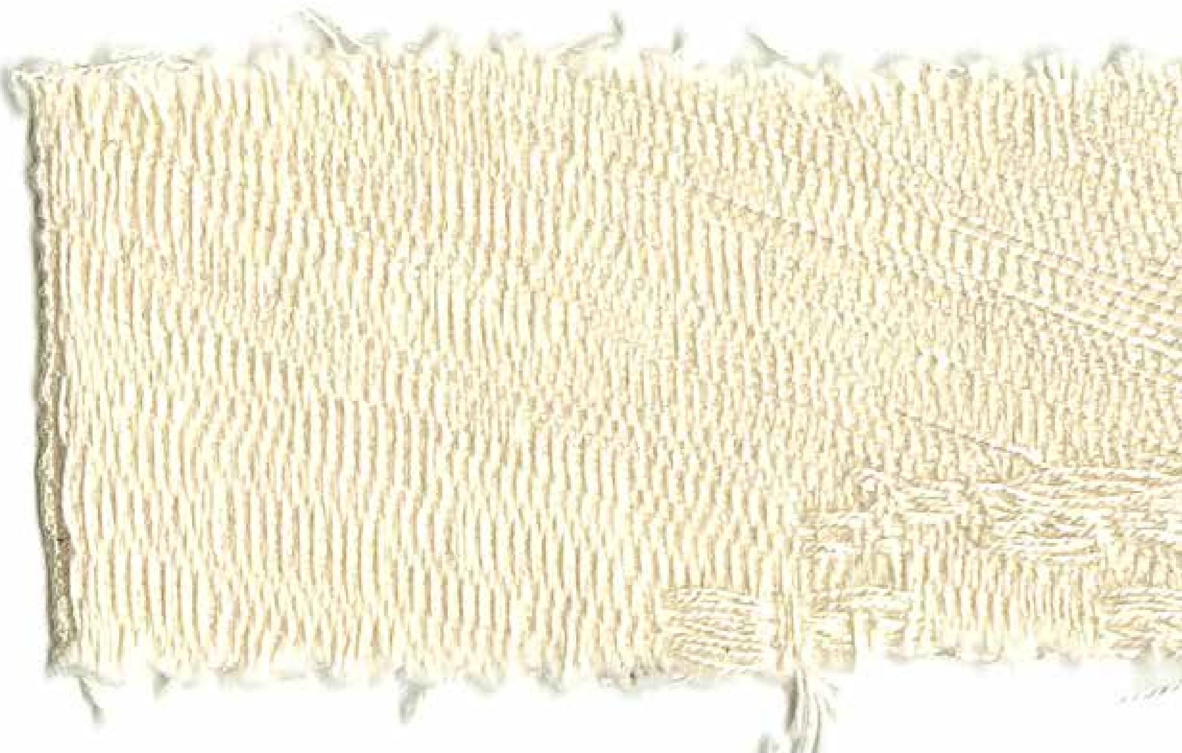
FRONT



Recursive error

10% algorithm error. White cotton.

FRONT



BACK

Wrong-pedal error

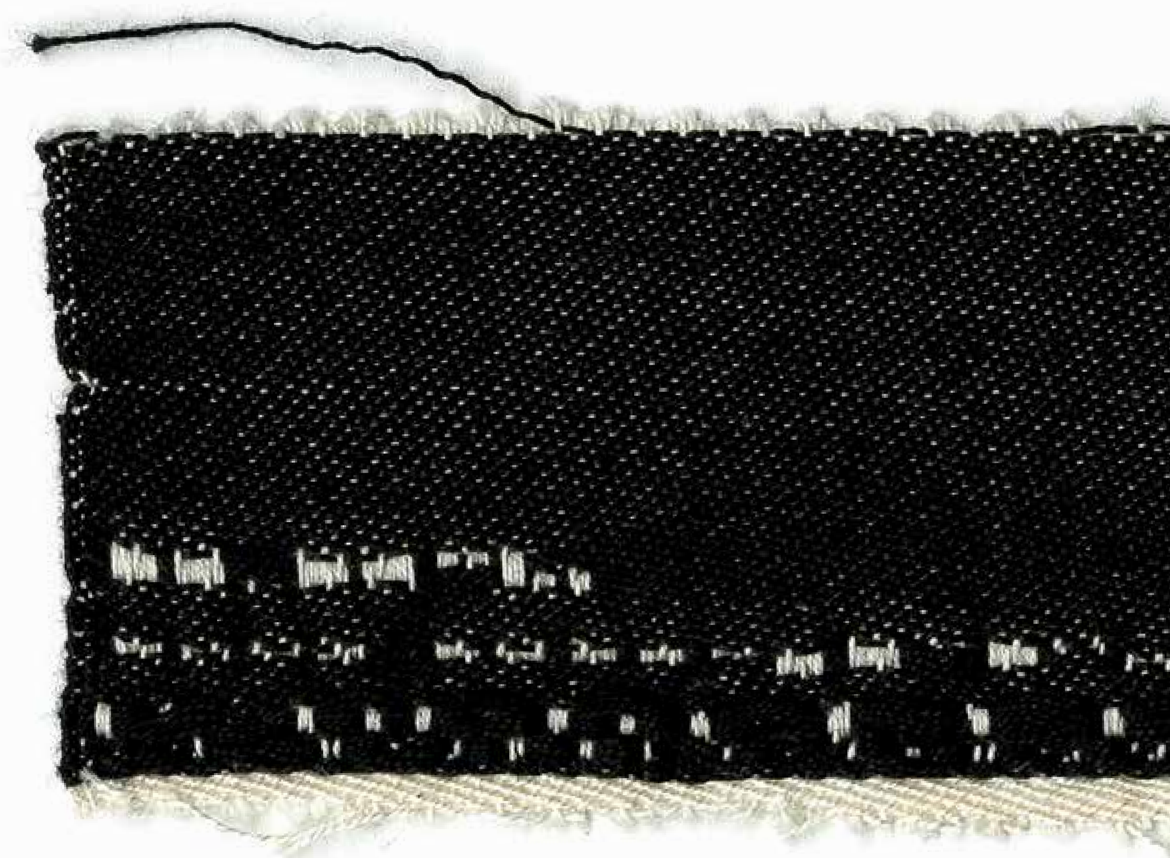
Digital output.

0.3% 1.0%

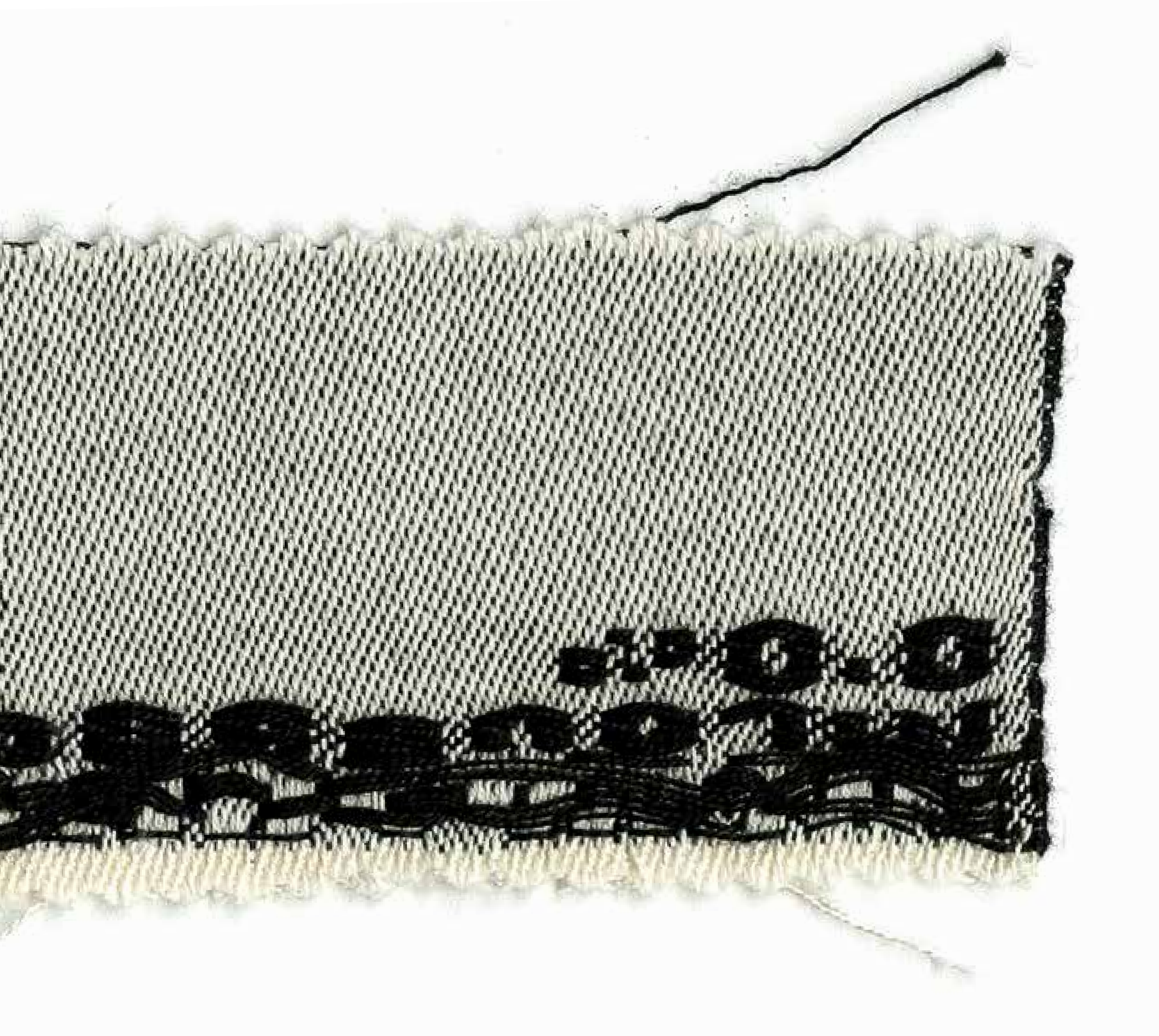
_104358_08_03

Wrong-pedal error

0% algorithm error. Cotton. White warp, black weft.



FRONT

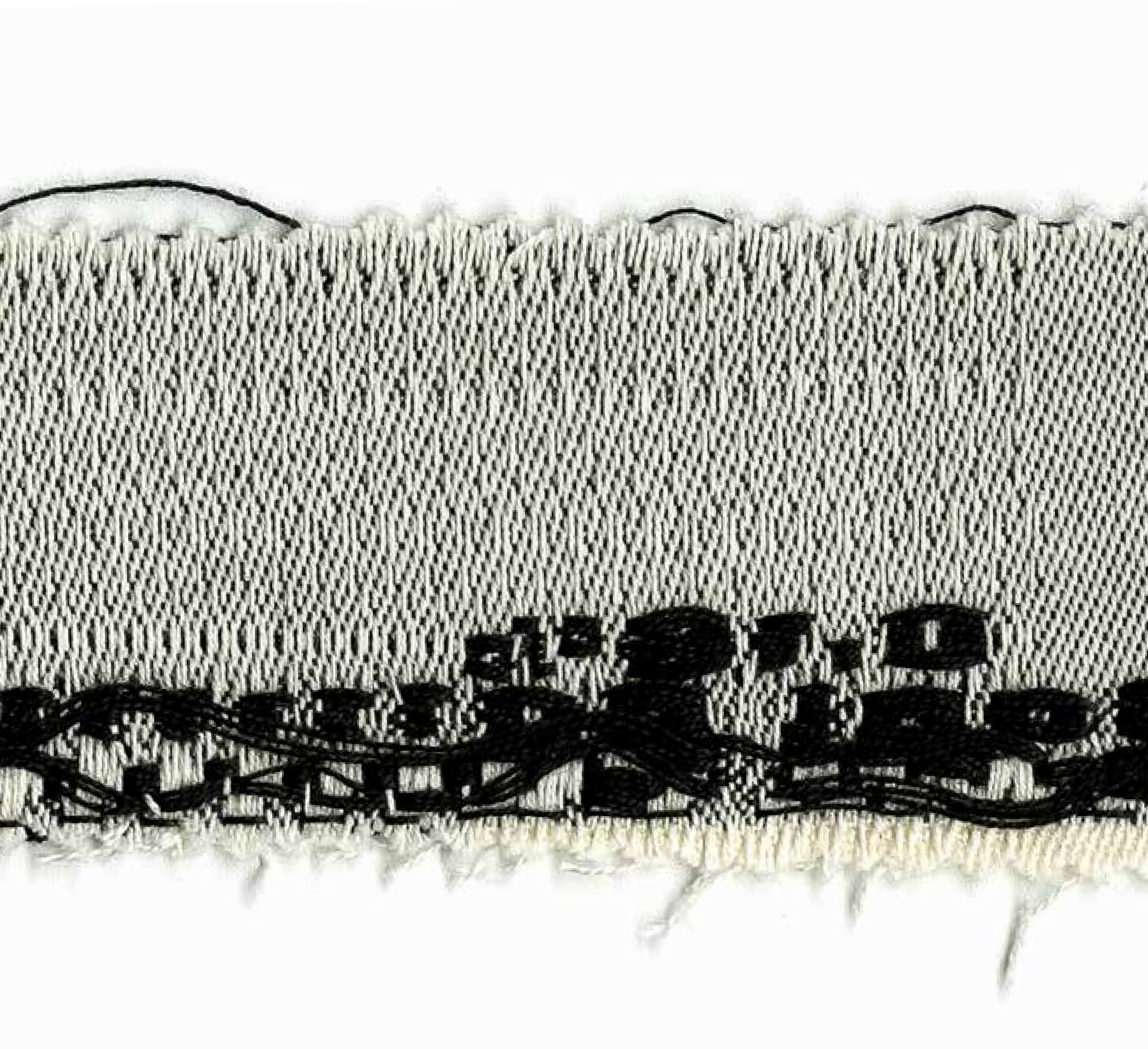


BACK

Wrong-pedal error

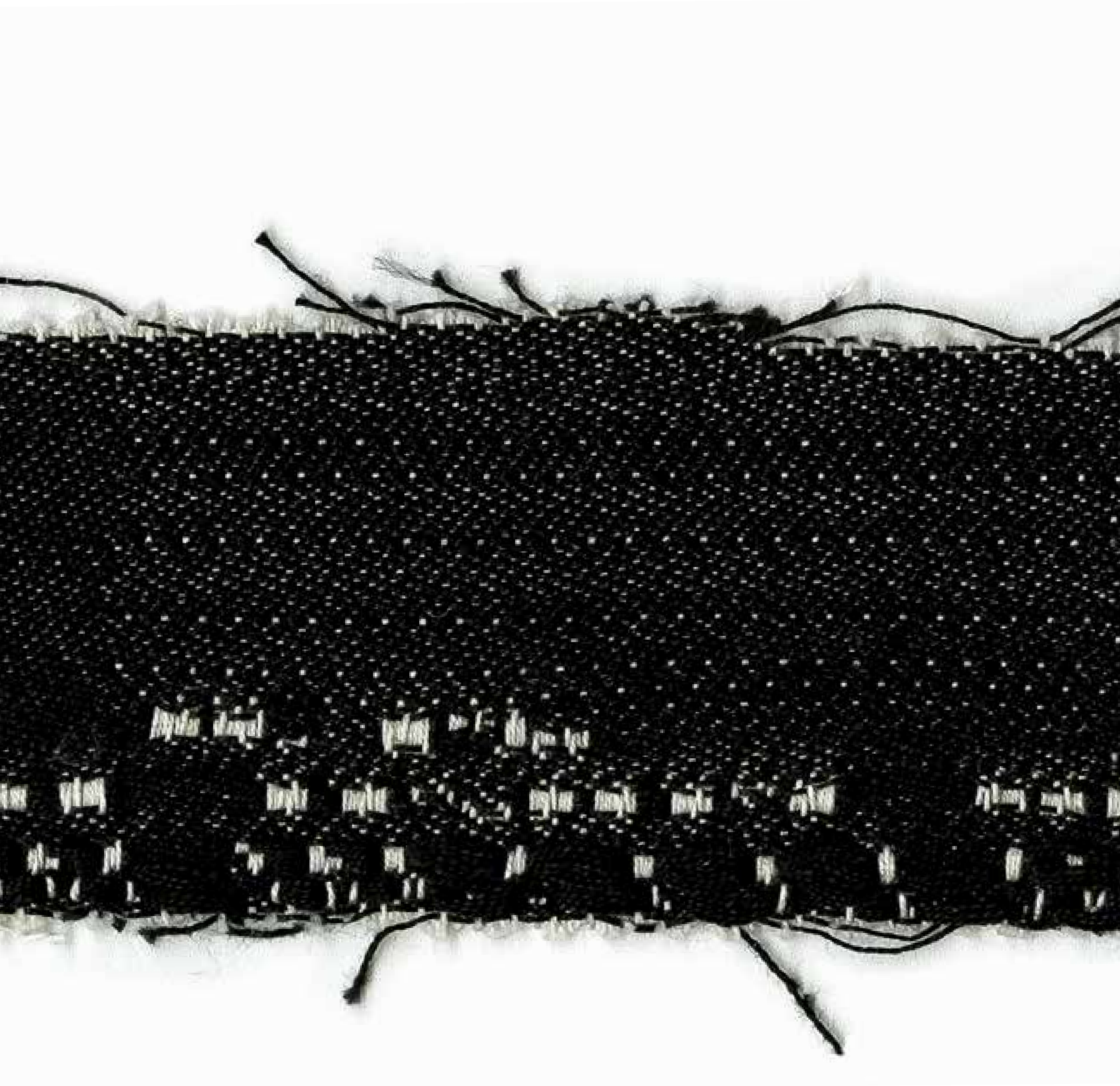
0.15% algorithm error. Cotton. White warp, black weft.

FRONT

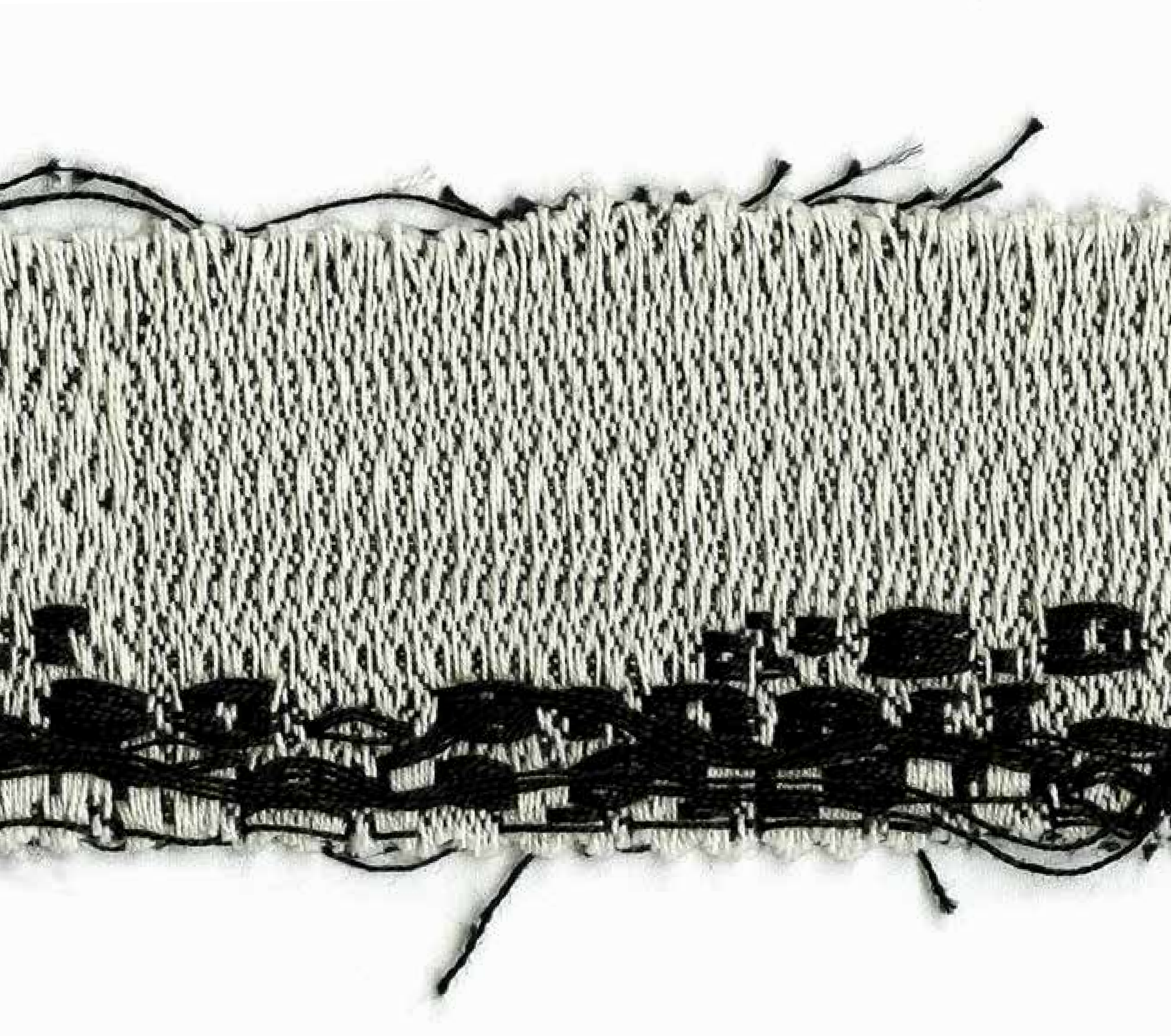


Wrong-pedal error

0.3% algorithm error. Cotton. White warp, black weft.



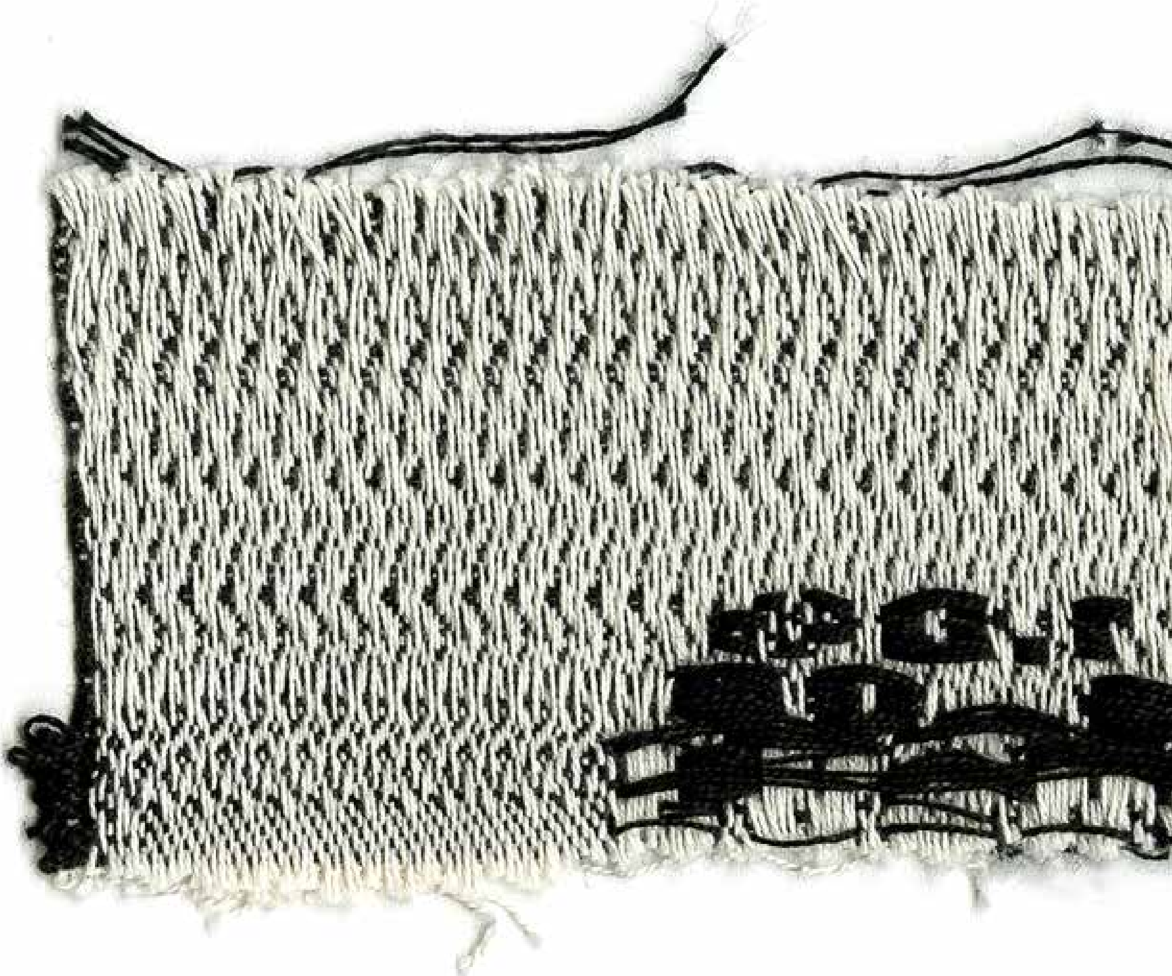
FRONT



Wrong-pedal error

1% algorithm error. Cotton. White warp, black weft.

FRONT



Wrong-pedal error

0% algorithm error. White cotton.

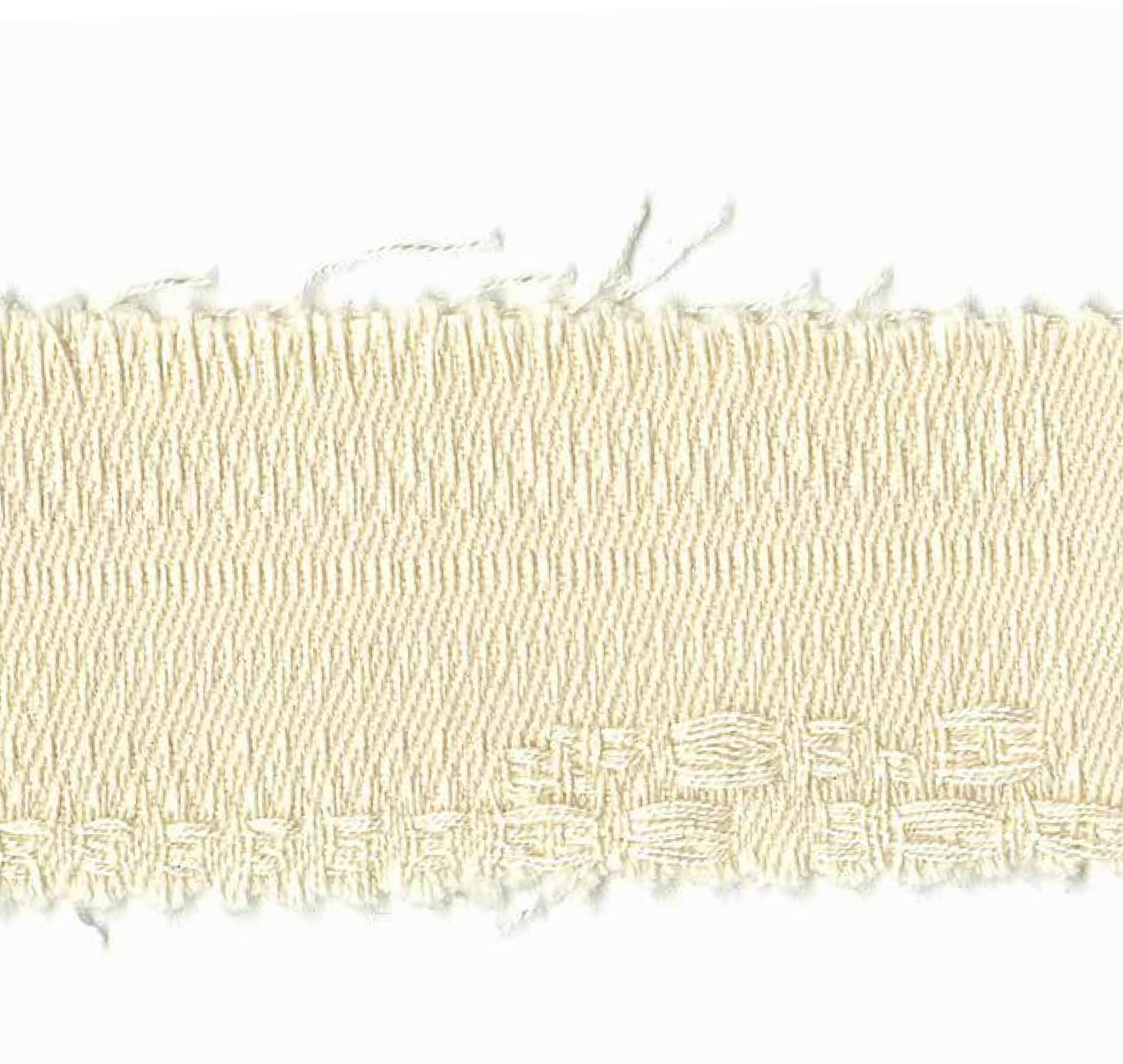
FRONT

BACK

Wrong-pedal error

0.15% algorithm error. White cotton.

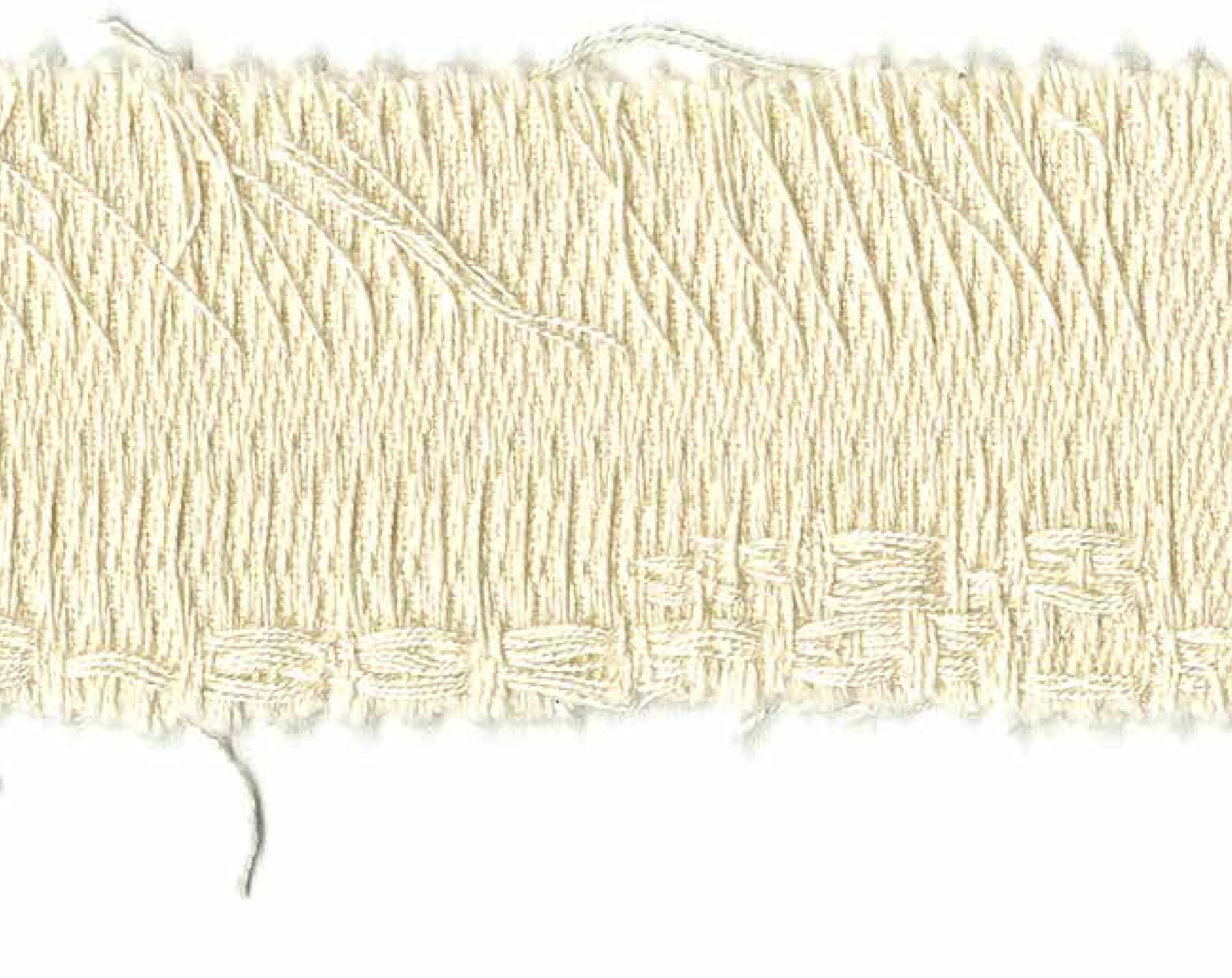
FRONT



Wrong-pedal error

0.3% algorithm error. White cotton.

FRONT



BACK

Wrong-pedal error

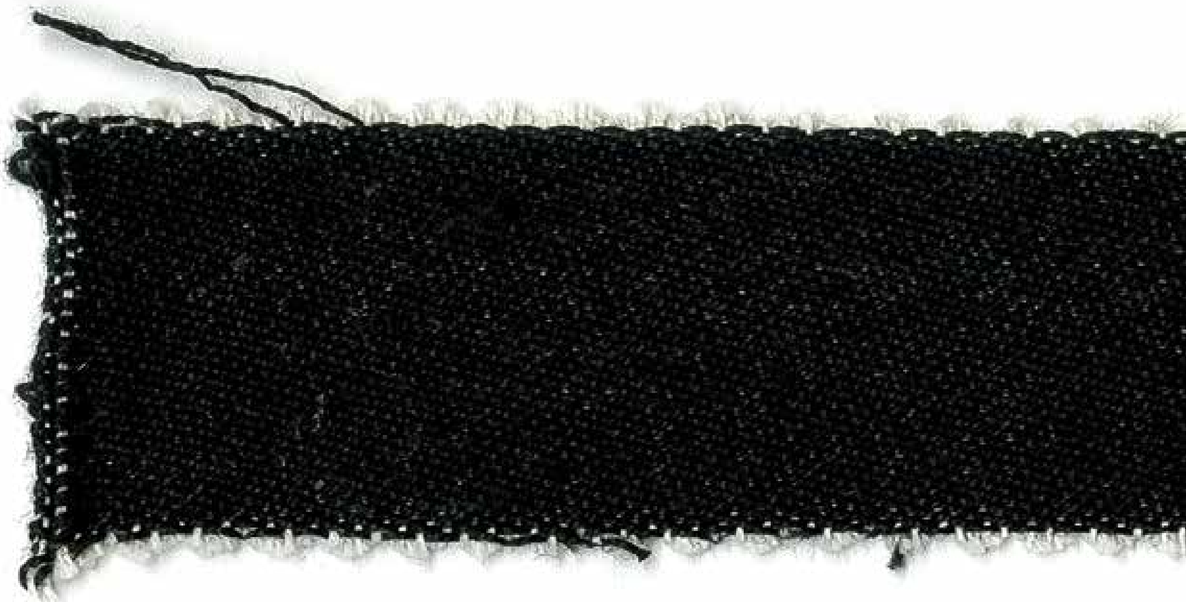
1% algorithm error. White cotton.

FRONT

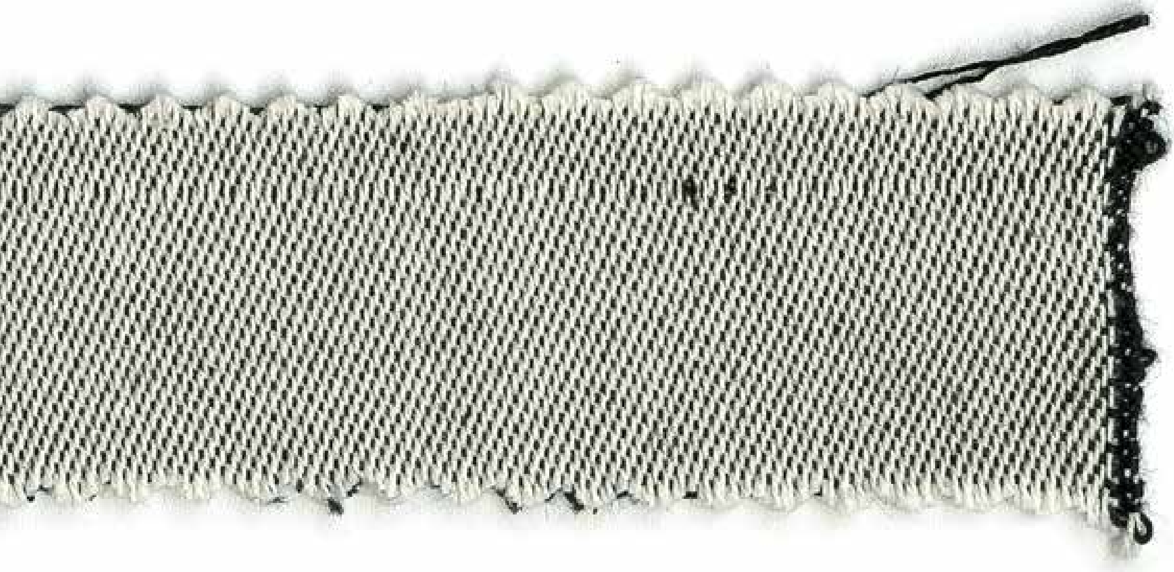
BACK

Noise-error

0% algorithm error. Cotton. White warp, black weft.



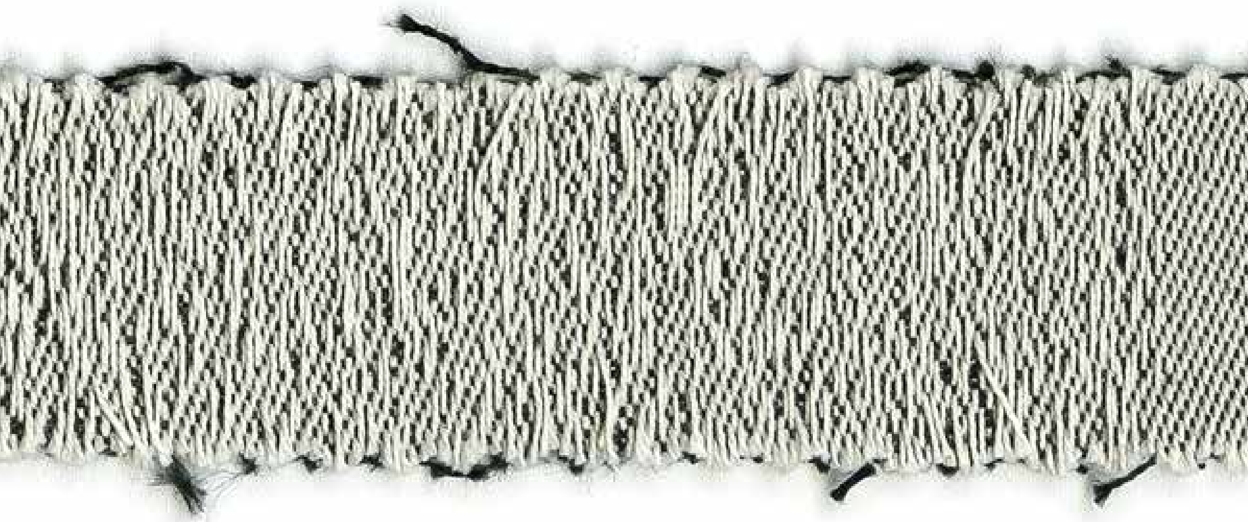
FRONT



Noise-error

0.5% algorithm error. Cotton. White warp, black weft.

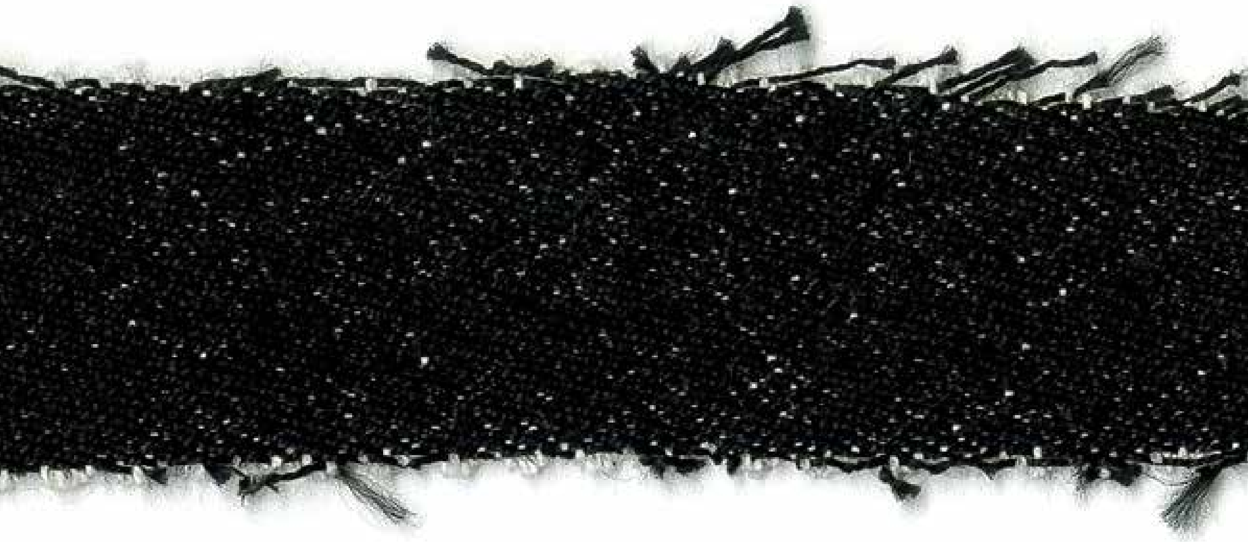
FRONT



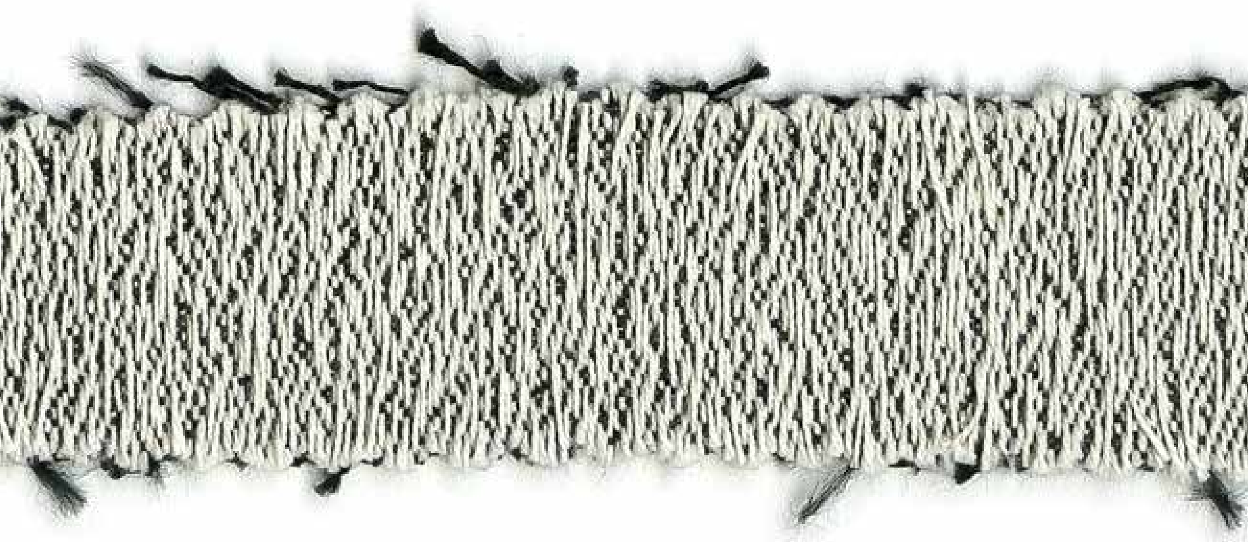
BACK

Noise-error

0.75% algorithm error. Cotton. White warp, black weft.



FRONT



Noise-error

1% algorithm error. Cotton. White warp, black weft.

FRONT

3.3 Introduction

The goal of the research is to explore the creative possibilities of transfers of approach and strategy from new media art to textiles. In the course of the enquiry it emerged that it was possible to construct a satin pattern using a basic algorithm, as was demonstrated in the previous chapter. Weaving the satin by hand allowed for accidental human error that created artefacts in the woven fabric, a process that is similar to a bug in an algorithm. This chapter describes this strategy of deliberately creating satin-generating algorithms that deviate from the traditional form—though inspired by legitimate errors—and presents further development and refinement of the technique. This presents a clear transfer of strategy from glitch art to weaving production.

This chapter will present software created to explore ways in which "error" can be inserted into satin-generating algorithms, and the visual results of this process, both in representations of the weaving notation, and in samples of textiles woven by digital looms. The chapter also presents discussions on the nature of algorithms and how they are constructed, and how one can frame and categorise "error", either as a mistake in the algorithm construction, as an anomaly that the algorithm is incapable of accommodating, or as an algorithm that deliberate generates deviations from a traditional form. This discussion helps to explain why these transfers of strategy are possible. The operation of error presented in this chapter forms a basic software structure, the construction of a weaving pattern through an algorithm, and the expressive possibilities created when manipulating the algorithm and its parameters. This structure is employed in the following chapter, where it is applied to the houndstooth weaving pattern.

3.4 Injecting error

The error created by hand when creating *Powers of Satin* suggested a course of enquiry where "error" was a considered design choice, rather than a bug that arose from careless construction or algorithm generation. For this enquiry, software was created to generate weaving patterns that investigated this considered use of error. Where the work with *Powers of Satin* employed an algorithm that was incidental to the process, when creating software that generates a weaving pattern, it became essential to construct algorithms to generate the pattern. This chapter presents this method of woven-pattern-generating algorithms and the exploitation of latent error possibilities as a contribution to new knowledge. The methods are directly borrowed from glitch art, but the subject matter of weaving patterns is novel.

Much of the initial explorations with error in weaving patterns were woven using a Digital Weaving Norway TC1 digital loom. All of the woven swatches at the beginning of this chapter were created with this machine. This piece of machinery leant itself incredibly well to the investigation because its software received BMP image files as weaving instructions. It is a common practice for contemporary textile designers to create their patterns using image software such as Adobe Photoshop, and so the processing of an image file format allows for easy transference of weaving patterns to the loom. The weaving patterns created in this research required a method of writing algorithms to generate them, and so the process depended on software to create them. The artist- and designer-focused software, Processing,[94] was used to generate the weaving patterns. As it was designed for artists, it is well equipped to generate and export image files, which made it a suitable tool for the pattern generation.

Later weaving was done using the automated weaving machines at the weaving lab of the Swedish School of Textiles, using large, industrial Jacquard looms. The proprietary software for these machines assumed a different workflow than that of the TC1, and so required various forms of translation of the original image files to make them weavable.

Notation is an important tool for communicating a structure. As the research in this project uses concepts from several disciplines, some of the notations employed may be familiar to some readers and not others.

94 "Processing," n.d., http://processing.org/.

The weaver's grid has already been introduced as a way of representing a woven structure, as has the concept of pseudocode to describe software structures. This chapter and the following ones specifically deal with the manipulation of individual points of thread intersection in a woven structure. The section will use a Cartesian notation to refer to woven intersections and binding points, given that woven intersections can been thought of as existing within a grid. This text will discuss points of intersection using the notation $P(x,y)$, where a point of thread intersection named P exists at a location in the grid at a horizontal position x and a vertical position y.

The insertion of deliberate errors into a woven structure necessitated the generation of systems of error. If errors are to be inserted, what kinds of error are possible? Three systems of error were generated and explored in this research.

The first error type was a replication of the error discovered in *Powers of Satin*, the misplacement of binding points in a recursive, satin-generating algorithm. The position of each binding point was calculated from a previous binding point, and was displaced by a random distance. Because each binding point's position depended on the location of a previous binding points, each error was propagated throughout the fabric. Examples of this are seen in pages 214-237.

If the first error considered a mistake that was made while weaving on a frame loom, the second error considered the kinds of mistakes a weaver could make on a floor loom. There are many possibilities, such as slipping the shuttle under or over the wrong warp threads, thread through the wrong heddles when setting up the loom, counting the wrong number of warp threads, miscalculating the thread density, or transcribing the notation incorrectly so that the loom setup is incorrect. Some of these are difficult to model as errors, but one that is easy to construct a model from is pressing an incorrect pedal, and this is an error that I encountered while learning to weave, which may not have presented itself had I not learned to weave. When a loom is set up to weave a certain pattern, the weaver progresses along the rows of the pattern by pressing a specific pedal. A basic satin pattern will have a loom configured to use a linear pedal sequence (such as 1, 2, 3, etc.). An algorithm was constructed to generate a basic satin pattern, and then constructing the pattern to occasionally choose the wrong row of the pattern. The likelihood that the programme would choose an incorrect row could be varied, creating the possibility to alter the density of the error. Examples of this are seen in pages 240-255.

The third error form was to add noise generally to the pattern, that is the independent calculation of each binding-point placement, unlike the recursive structure of the first pattern, and add a random displacement to each binding point. The displacement distance was determined randomly, while the probability of the maximum displacement was variable, controlling the density of the noise in the pattern. Examples of this are seen in pages 256-263.

When deliberately constructing an error it has to be placed within a system; an error system. The way to achieve the error has to be deliberate and logical, and the system must have variables that can be altered to change the nature of the error's outcome. Glitch art is often possible because errors can be constructed as systems, allowing for dependable behaviour, even if it deviates from the traditionally desired behaviour of the system. An example of this would be the mazes of World Wide Web pages created by Jodi, mentioned in the first chapter, whose content is a deliberate deviation from the expected experience of the Web, though they appear to be meticulously created.

3.5 Reverse-engineering the algorithm

To create an algorithm from a pattern it must be dissected and its underlying logic must be understood. Many algorithms may produce the same pattern or, a pattern may be created in a multitude of ways. An arithmetic example may be that we can generate the number 4 by calculating $2 + 2$, or $5 - 1$. The needs of the system will dictate which of those equations will be most relevant. What the numbers 1, 2, and 5 represent will strongly influence which equation to choose. In the case of the algorithms to generate satin, the question is largely one of whether the algorithm should generate the absolute position of all bindings points independently, or whether the position of each binding point is generated relatively to other binding points. The form of the algorithm should reflect the requirements of the outcome.

What is repeating in the pattern? What can be formalized? How can it be represented?

When creating the algorithms for the textile patterns the direction of the algorithm is strongly tied to the physical construction of the pattern.

How is this pattern being traversed as it is being made? What must be done first before the next steps are taken?

Along this path is a set of rules that create the structure of the algorithm. By following the path and obeying the rules the pattern is created.

This process is in effect reverse engineering. Given the output, what kinds of instructions can we imagine would create the desired output? As an example, you are to draw a circle on a piece of paper. What are the instructions for creating this circle? The first example,

```
place the tip of the pen on the paper, then move it
counterclockwise so that the tip of the pen is always
x centimetres away from a central point until you have
reached your original point.
```

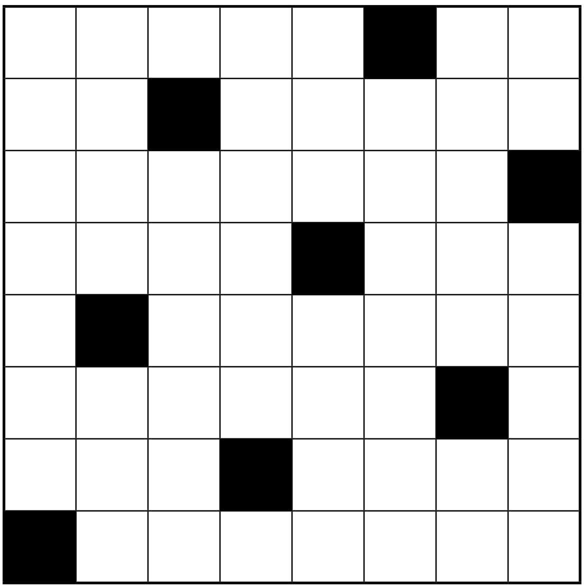
Or the clockwise example:

```
place the tip of the pen on the paper, then move it
clockwise so that the tip of the pen is always x
centimetres away from a central point until you have
reached your original point.
```

Both achieve the same final product while taking different paths, though in this case the conceptual paths are similar.

3.6 Sculpting noise

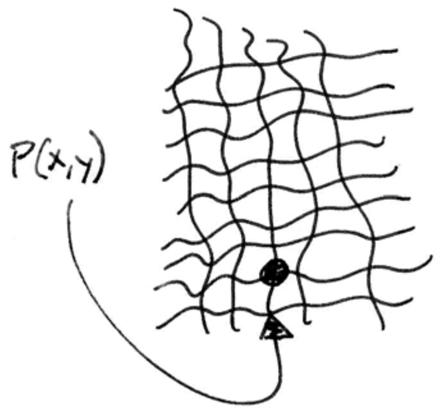
Two of the error systems rely on the generation of a general satin pattern, and so require a generalised algorithm to create all possible satin basic patterns. Let us examine a basic 8-shaft satin, the pattern used for all satin in this research:



If we were to zoom out and examine the entire fabric we would see this pattern repeating across it in all directions.

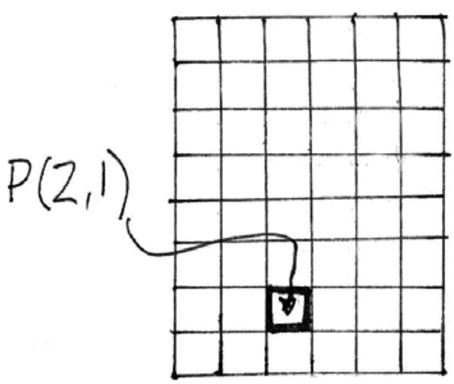
There are two basic numbers to a satin pattern. The number of shafts, which is effectively the width and height of the pattern, and the *interruption factor*, which is the horizontal distance between points on successive rows. If we look at the binding points on the first and second rows in this diagram we see that the second binding point is three columns—or warp threads—to the right of the first, so its interruption factor is 3.

To generalise this for software, we must be able to determine for a given point $P(x, y)$ whether it is a binding point, where x represents its warp thread (or position along an x-axis), and y will represent its weft row (or position along a y-axis). In a weave of threads, $P(x, y)$ might look like this:



The lowest left intersection will have the position (0,0) in this image, so P has the position (2,1), but we must think about a general point that could be any point on the weave.

P in a grid of weaver's notation, also at (2,1) would be identified here as the highlighted square:



Because the satin pattern is repeated across the whole fabric, any point $P(x,y)$ has a corresponding point on the basic satin pattern. To determine what that corresponding point is we can use the modulo operator provided in programming languages, which uses the symbol %.

Technically, the modulo is the amount remaining after dividing two numbers. So, for example,

7/3 = 2 remainder 1

Therefore 7 modulo 3 is 1. Or, 7 % 3 = 1. A continuum of numbers, *x*, and the same number's *modulo 3* would look like this:

x	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
x % 3	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2

What modulo can do functionally is to imagine a world where numbers do not increase forever, but loop continuously as the satin pattern repeats continuously across the fabric. Rather than numbers progressing to infinity, in our chart here, there are only the numbers 0, 1 and 2 cycling forever. This is also how the basic satin pattern would work. If we are examining a satin pattern with a width of 8, we will always be on one of columns 1-8 of the pattern. To modify it in a way that is easier for the computer, we start our counting from 0, so 0-7.

Our chart for satin rows could look like this:

Fabric column	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Basic satin column (column % 8)	0	1	2	3	4	5	6	7	0	1	2	3	4	5

This means that given any $P(x,y)$ is the same as a corresponding point in the basic satin, which we can call P_{basic}. We can treat the *x* position (the column, or warp thread), as though it were actually *x* % *shafts*, the width of the pattern. This is the same for the *y* (row, or weft thread): any *y* can be treated it as though it were $y \% shafts$. Which means that for any randomly chosen point, for example,

$$P(314,159)$$

it is actually the same value as

$$P_{basic} = P(314 \% 8, 159 \% 8)$$

which is, in fact

$$P_{basic} = P(2,7)$$

$P(2,7)$ is much easier to consider than $P(314,159)$. We can easily find out whether $P(2,7)$ is a binding point in the basic satin pattern.

Each row has one binding point, and the location of the binding point is related to both the row number and the interruption factor. Examining a chart of the basic satin pattern's rows and their binding points:

Satin Row	Binding point column
0	0
1	3
2	6
3	1
4	4
5	7
6	2
7	5

The relationship here between the row number and the column of its binding point for rows 0, 1 and 2 is:

column of binding point = row × interruption factor

For row 3, *row × interruption factor* = 9, which is outside of the basic satin pattern. But because the basic satin pattern repeats, we can calculate where 9 corresponds to in the basic pattern by modifying it with modulo and the width of the pattern. So:

9 % *shafts* = **1**

which exactly matches the basic pattern.

This can be all brought together to determine whether any given point $P(x,y,)$ is a binding point in satin if the position of x in the basic pattern matches the row multiplied by the interruption factor, shifted back to the basic pattern, or, any given point $P(x,y,)$ is a binding point if:

(*x* % *shafts*) **IS EQUAL TO** ((*y* × *interruption factor*) % *shafts*)

Where *shafts* is the number of shafts of the satin pattern—essentially the width of the basic pattern—and *interruption factor* is the interruption factor of the satin.

This process of determining whether a given intersection was a binding point was later replaced by a more efficient process of drawing each binding point by jumping across each row by the number of shafts, beginning at an x-value determined by the interruption factor and number of shafts.

As such, the starting x-value of a given row y is:

[(*y* % *shafts*) × *interruption factor*] % *shafts*

All subsequent binding points on the row are generated by adding the number of shafts to the x-value and repeating to the end of the row. So that for an 8/3 satin, the first binding point is 0, and subsequent binding points would be 0, 8, 16, 24, etc. And the second row's binding points would be, 3, 11, 19, 27, etc.

Later, to create the animation of the exploding satin pattern, a Java class was created for a binding point, and an instance of this class was created for each binding point, at x-y locations determined by the process just described in this entry.

3.7 Recursive error

To recreate the errors from *Powers of Satin*, the code had to establish the first row of the pattern so that it could base all subsequent binding points off of them.

To build the first row, given that *shafts* is the number of shafts in the satin pattern, essentially the width of the pattern, $P(x, 0)$ is a binding point if:

x *IS EQUAL TO shafts*

For all subsequent rows, find a previous binding point and create a binding point offset by the interruption factor of the satin.

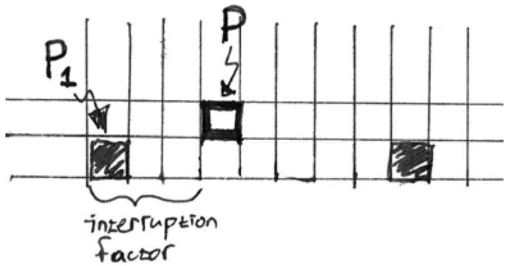


IMAGE 3.1 **The new point, *P*, shown in relation to the point from the previous line that it uses to derive its position, P_1, separated by the satin interruption factor.**

So a point $P(x, y)$ is a binding point if $P_1(x - \textit{interruption factor}, y - 1)$ is a binding point. To bring this into the world of executable code, there must also be some code that ensures that P_1 exists in the pattern, that is, that neither *x–interruption factor* nor $y-1$ are less than 0. This is error checking. If P_1 did not exist, the programme would not run.

Error must now be added to the binding points. After the first row has been plotted, for all new binding points, each $P(x, y)$ binding point should be displaced by a random amount. This exploration used a normal distribution, a common function for producing random numbers with a recognisable bell-curve shape of probabilities surrounding a desired value. Normal functions are employed when an application requires random numbers that tend to centre around a specific value. In this case, the centre of the distribution is the original satin binding point. A normal distribution was chosen because it was assumed to give a control of the density of the randomness in the weave. An increase in the width of the normal distribution would effectively add randomness to the weave. Though it was not explored in this research, it may be fruitful to explore the application of other types of random distributions in this experiment.

For each binding point a new random offset was created for both the x and the y coordinate, x_{random} and y_{random}. So now,

if P_1 exists and is a binding point
then P is a binding point

or, for each point $P(x, y)$ in the pattern,

if $(x - \text{interruption factor}, y - 1)$ is a binding point
then (x, y) is a binding point

and add some randomness so that P becomes $P_{shifted}$

$$P_{shifted} = P + (x_{random}, y_{random})$$
$$P_{shifted} = (x + x_{random}, y + y_{random})$$

3.8 Wrong pedal error

To create the error of the weaver pressing the wrong pedal in the weaving process, the code was virtually identical to the process of adding noise to every binding point, except that only one offset value was created per row, only for the x value, and it was applied to every binding point on that row. Because each row of satin is identical—that is, it is a line of binding points, each the same distance apart, the number of shafts of the pattern, then each row can be derived from each other by shifting all binding points the same amount to the left or right.

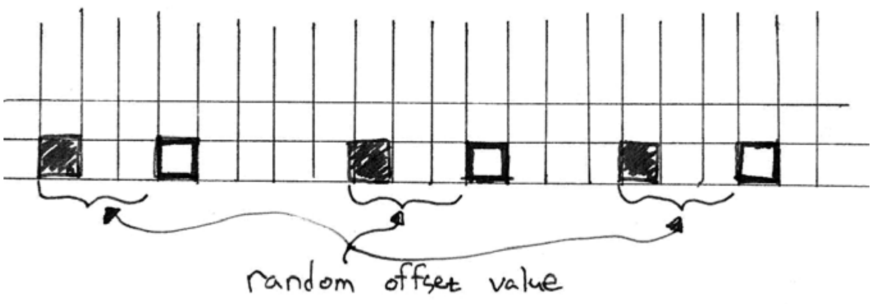


IMAGE 3.2 **Solid squares represent the original binding points, highlighted squares show the new binding point positions, shifted from the original positions, simulating an incorrect pedal choice by the weaver.**

3.9 Noise error

To add error to the satin pattern, each $P(x,y,)$ was displaced by a certain amount. Therefore, for each binding point in the satin pattern, a random value is added to the x and y values. Once again, a normal distribution was used. Early explorations in this experiment, shown in the hand-woven black-and-white examples at the beginning of this chapter shifted the binding point to the left or right, generating only an offset for the x value. Later versions of the software generated an offset for both the x and the y, moving the binding point in any direction across the pattern, which can be seen in the blue-grey machine-woven examples. The visible results of the woven material were not noticeably different, though both versions were not compared side-by-side. This result was not expected, and it is unclear why they should appear so similar. Especially when one is examining a weft-faced satin, where the visible threads are predominantly horizontal, it is unclear why horizontally-shifted binding points should look essentially unchanged when a random vertical shift is added. One would expect that the direction of random shifting would matter when considering a fabric whose threads are predominantly either vertical or horizontal.

3.10 Sculpting with noise

Some of these weaving patterns were tested on the industrial jacquard weaving machines at the Swedish School of Textiles, but all of the initial work was woven by hand on the TC1. This machine is a meeting point between automation and handicraft. The machine controls only the position of the heddles at a given row in the weaving pattern. The weaver advances the machine to the next row by depressing a pedal. But the insertion and packing of the weft, the regulation of the tension at the edges, and all of the common concerns of the hand weaver, are still done by hand. The experience is the slow, methodical process of sliding the shuttle through the shed—the open space created between raised and lowered warp threads—setting the tension of the edge, beating the weft fabric into place, and pressing the pedal to prepare for the next row. The slow rhythm gradually produces a pattern on the fabric, as if watching a dot-matrix printer slowly create its pages line by line, but somehow feeling we are a part of the printer.

The three methods of injecting noise into the satin patterns created a way of introducing a language of controllable artefacts into a basic satin pattern. A plain satin provides a smooth, continuous surface, something that is desirable for the common applications of satin. Bumps and grooves on a wedding dress or bedsheets would detract from the object's aesthetics.

The purpose of this work is not to generate new textile design methods for practical applications, but it is worth noting that the output of these explorations generated fabric that would be unfit for traditional uses of satin. The biggest effect of the noise on the pattern, and most unexpected, was the alterations to the fabric's density, and thus its weight and other characteristics such as pliability. Satin's importance lies not only in its visual appearance, but in the ways that it interacts with the body on a tactile level. Not only does it look shiny, but it feels smooth. Satin is also a light fabric, and its airiness is important to the experience of the fabric. Satin's sparse binding points cause it to drape well, curving around the body. With all of these changes comes the inevitable change of the fabric's visual appearance. Satin's shine comes from the many long, exposed pieces of thread. The applied error naturally interfered with the regular arrangement of long threads.

The noise disrupted all of these characteristics. To varying degrees, each of the noise processes affected the weight, density, drape and shine of the fabric, often diminishing the fabric's ability to perform its function as satin. All of the qualities that are desired of satin were affected. This is difficult to perceive in the scans of the fabric presented at the beginning of this chapter. These qualities are best perceived by handling the fabric itself.

All of the error techniques produced a denser, heavier fabric. A fabric's density, especially when woven by hand, is largely affected by the relationship between the density of the binding points of a row. Binding points create a transition between the two placements of the weft, overtop of the warp or underneath the warp, and it is the density of these transitions that affects tightness of the weft packing. Closely spaced pairs of binding points resist the movement of the beater—the large comb that is used to pack the weft—and so a row with a greater density of binding points would require a stronger force of beater than a row with a lower density of binding points. The introduction of the noise shifted the binding points, creating some areas with a high density of binding points, and others with a low density. These areas of high density create the resistance to the beater. If the weaver is then aware, they can compensate by trying to move the beater more forcefully, but there is also a limit of the beater force set by the strength of the weaver—though not present on an automated weaving machine—and the characteristics of the material.

The recursive satin error created diagonal artefacts, exactly as it did when first discovered in the *Powers of Satin*. In the other error forms—random noise or wrong pedal—each shifted binding pointed affected only itself. Not so, with the recursive error. Once an error was introduced into the pattern it was propagated to each following weft row, so that the progression throughout the weaving was an accumulation of error. These diagonal artefacts were often just lines, as could be seen in the black and white handwoven pieces at the beginning of section. But when these errors met, or were placed side by side, the artefact became a deeper disturbance of the surface of the fabric. They started to resemble features like the wales of corduroy. As with the other forms of error, the fabric becomes denser the more error there is. The wales produce portions of the fabric with longer floats of warp and weft thread, creating a greater density. The wales also produce a kind of tactile rhythm across the surface of the fabric. Clean satin's repetitions are so smooth that the fingers perceive them as a slippery surface. The wales in the recursive created a landscape of large and small ridges, a surface that vibrates as the fingers are drawn across it.

Though the purpose of the research was not to generate new forms of fabric, its disruption of the traditional qualities of satin may have generated fabrics that might fit well in other contexts—such as other kinds of clothing, architecture, furniture. This is a possible avenue for future explorations using the strategies developed in this research.

3.11 The pattern of noise

When a cement path is laid in a park, it provides general parameters for where people will walk. Not everyone will walk on the path, but a large portion of people will. Not everyone will walk down the middle of the path, but generally they will walk within its boundaries. Walkers go in a manner informed by the presence of the path. It guides the people into a space of possibility and expectation.

Creating these satin patterns with error is, in a sense, sculpting noise. Creating the ways in which noise is created controls the boundaries of the space. It is important to remember that noise is never random, not even in the natural world. Its possibility space is dictated by its environment.

There is something about repetition that makes noise manageable. Even irregular satin structures have regular repetition, a *systematic satin repeat.*[95] This is partly what makes them satin. It also makes them predictable and reliable. There is no real noise in the pattern of irregular satin, there is just a predictably varying structure. In the satin structures with error there is nothing actually predictable. Or, we can predict that there will be a binding somewhere within the area of every "true" binding, and knowing the parameters of the programme we know how far away it will be from the binding.

E.H. Gombrich had a biological foundation for the argument that ornament and our judgement of its beauty is based upon regularity and deviations.[96] In nature it is important to internalize repetition and expectation, that is, how an organism can create behaviour. It is likewise important to be aware of deviations from the behaviour, that is, how an organism survives unforeseen circumstances. As a result, organisms are constantly judging the amount of deviations from a standard

95 Ulla Cyrus-Zetterström, *Manual Of Swedish Handweaving*, 3rd Edition (LTs, 1984), 35.

96 E. H. Gombrich, *The Sense of Order: A Study in the Psychology of Decorative Art*, The Wrightsman Lectures 9 (Ithaca: Cornell U.P, 1979), xii.

form. Perception requires a framework against which to plot deviations from regularity.

After making a few tests with the weaving software, it is obvious that the randomness is predictable. When stepping back and examining the fabric at a broader scale it is obvious that there are trends in the construction. We may not be able to predict every single stitch, but we can see the shapes and movement arising.

Why are there visible artefacts in some of the test swatches? There are distinct diagonal lines. When following the instructions for *Powers of Satin* it was obvious that diagonal artefacts would arise. When adding randomness to the binding point positions it is not obvious that any particular kind of artefact should arise.

> *The effect of the noise added to the pattern becomes more interesting when the fabric is turned around, when the back is examined. While from the front the pattern appears to seem noisier, and it becomes heavier, thicker, from the back the effect is totally different. The effect of error on the back of the satin swatches was the creation of long, exposed threads. Some warp threads went many rows without meeting a binding point. All it took was to move a binding point one thread to the right or left to double the length of an exposed warp thread. The noise had created a new kind of predictability, but one that could not be seen at the stitch level. You have to step back and observe larger portions of the textile to see the pattern of noise.*

3.12 Conclusion

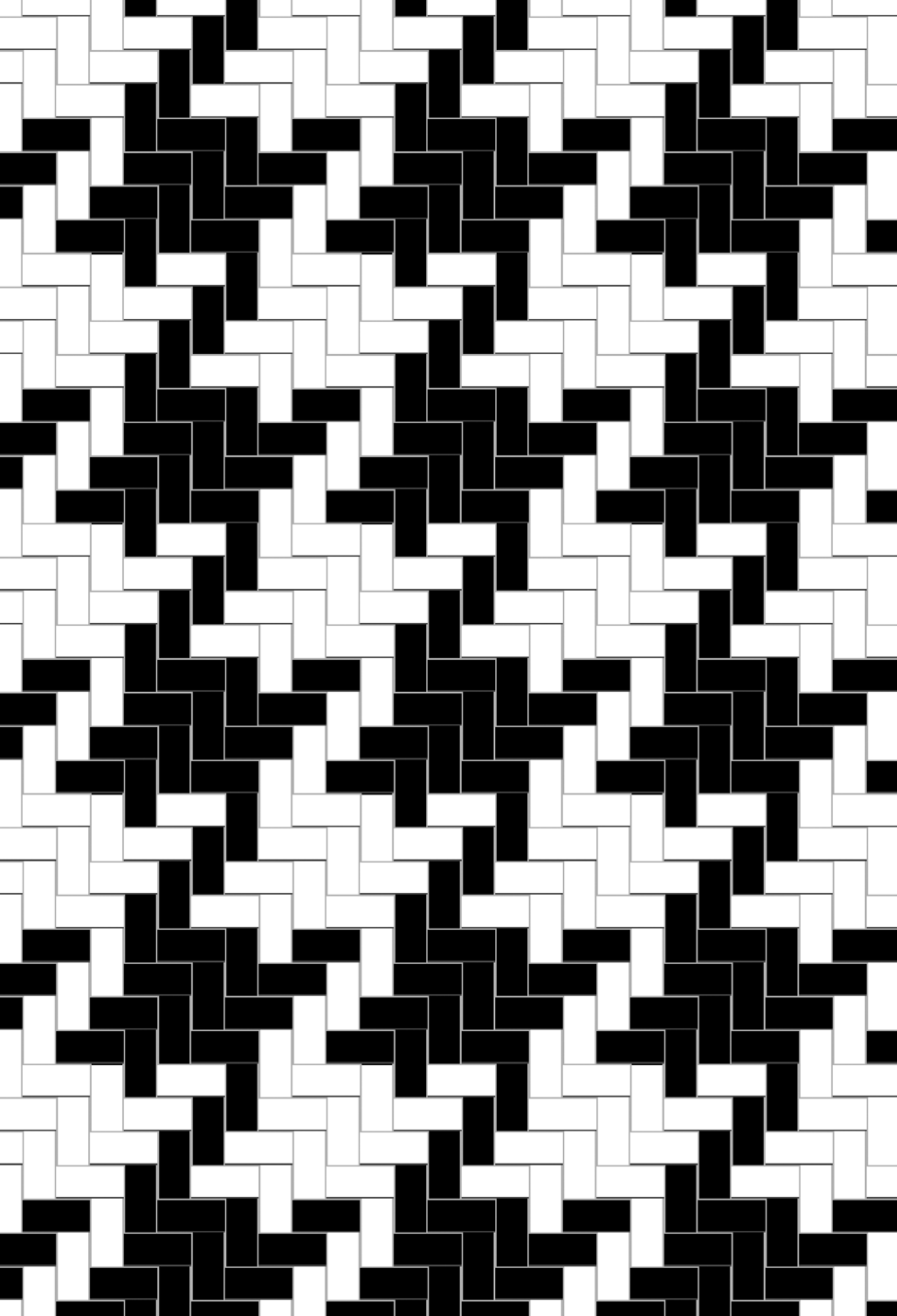
This chapter explored the creative opportunities of transferring strategies of glitch, or error, from glitch art, to woven satin. This was an extension of the previous chapter, which accidentally demonstrated the opening for flaws in algorithms to construct a woven structure, what is functionally similar to a software bug. The work of this chapter took the natural emergence of this failure and examined the possibility of its basis as a considered and deliberate strategy.

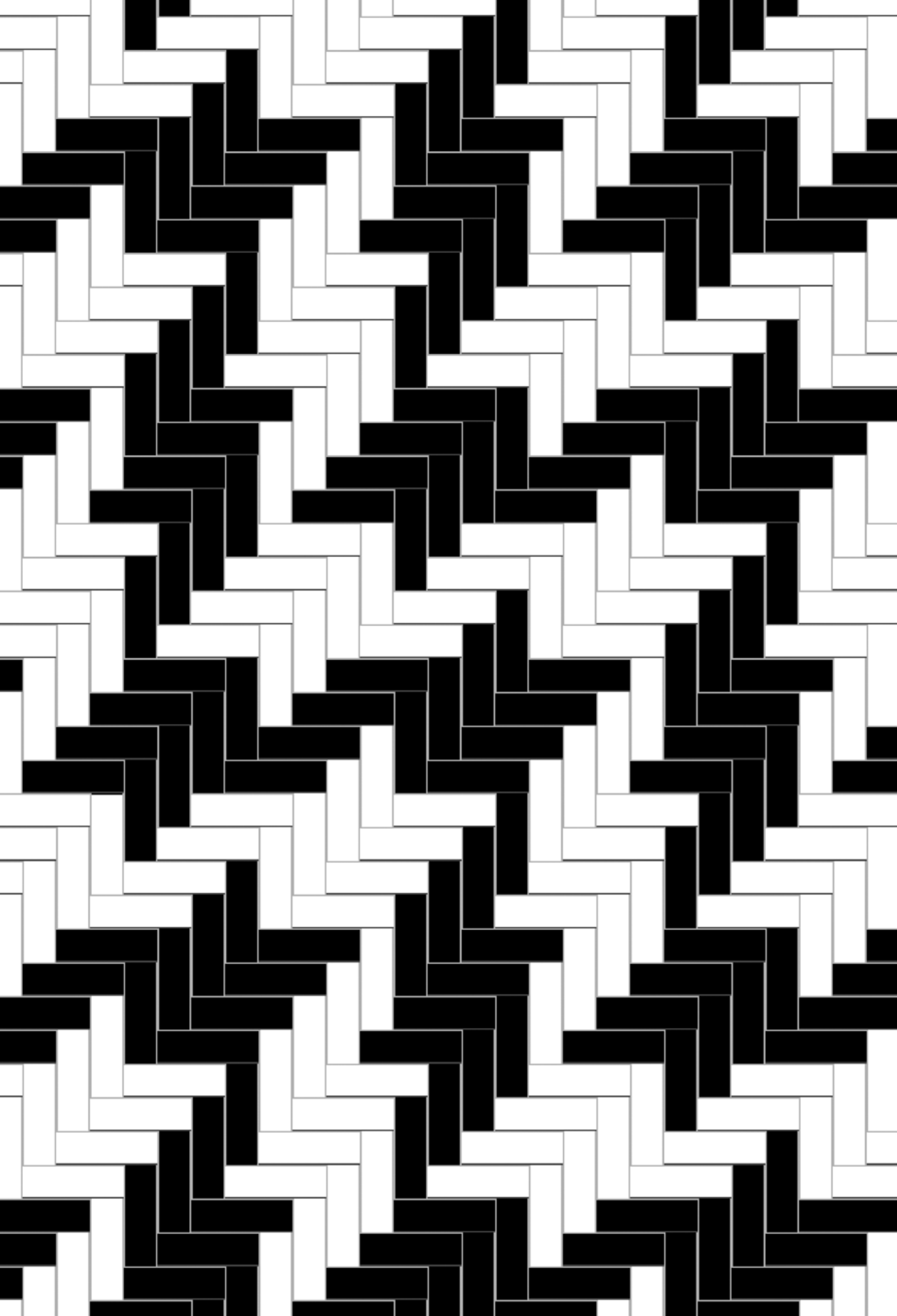
Several techniques in digital glitch art create artefacts and expressions by deliberately altering aspects of algorithms. The environmental conditions can be manipulated in such a way that the algorithm generates distorted content but still functions, as can be seen in video datamoshing, or the editing of image files with text editors. The work of this chapter used several techniques to create algorithms that would generate a satin pattern, but also created the techniques so that they could be glitched in very deliberate ways. An algorithm was created to mimic the human error of *Powers of Satin*. An algorithm was created to mimic the human error of pressing the incorrect pedal of a floor loom. And an algorithm was created to generate an effect that may have occurred on a frame loom, which is the displacement of individual binding points, effectively adding noise to the satin. The creation of these algorithms and the errors that they enabled, allowed for a navigation of a range of expressions by altering the parameters used to generate the fabric patterns and the errors.

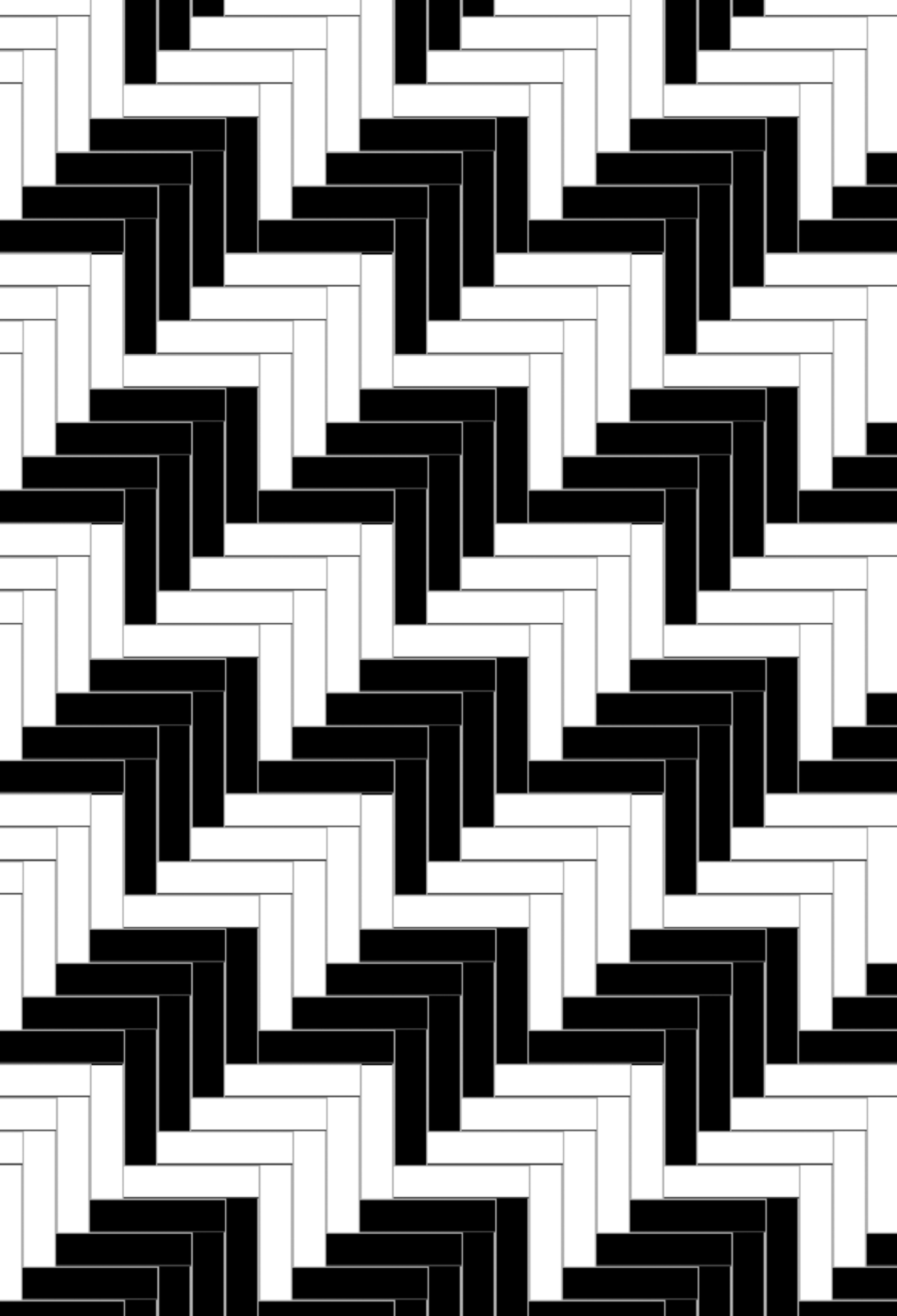
These patterns can be appreciated and examined as digital images reflecting the weaving notation, but were also woven using a digital loom, as well as a fully automated industrial loom. The errors created a range of altered textile expressions, deviating from the traditional satin characteristics. Each technique created a unique expression. These are textile expressions that would not have been possible through traditional construction of satin. It required the explicit process of creating satin-generating algorithms, and exploiting the error-potential latent in the algorithms, to create these new expressions.

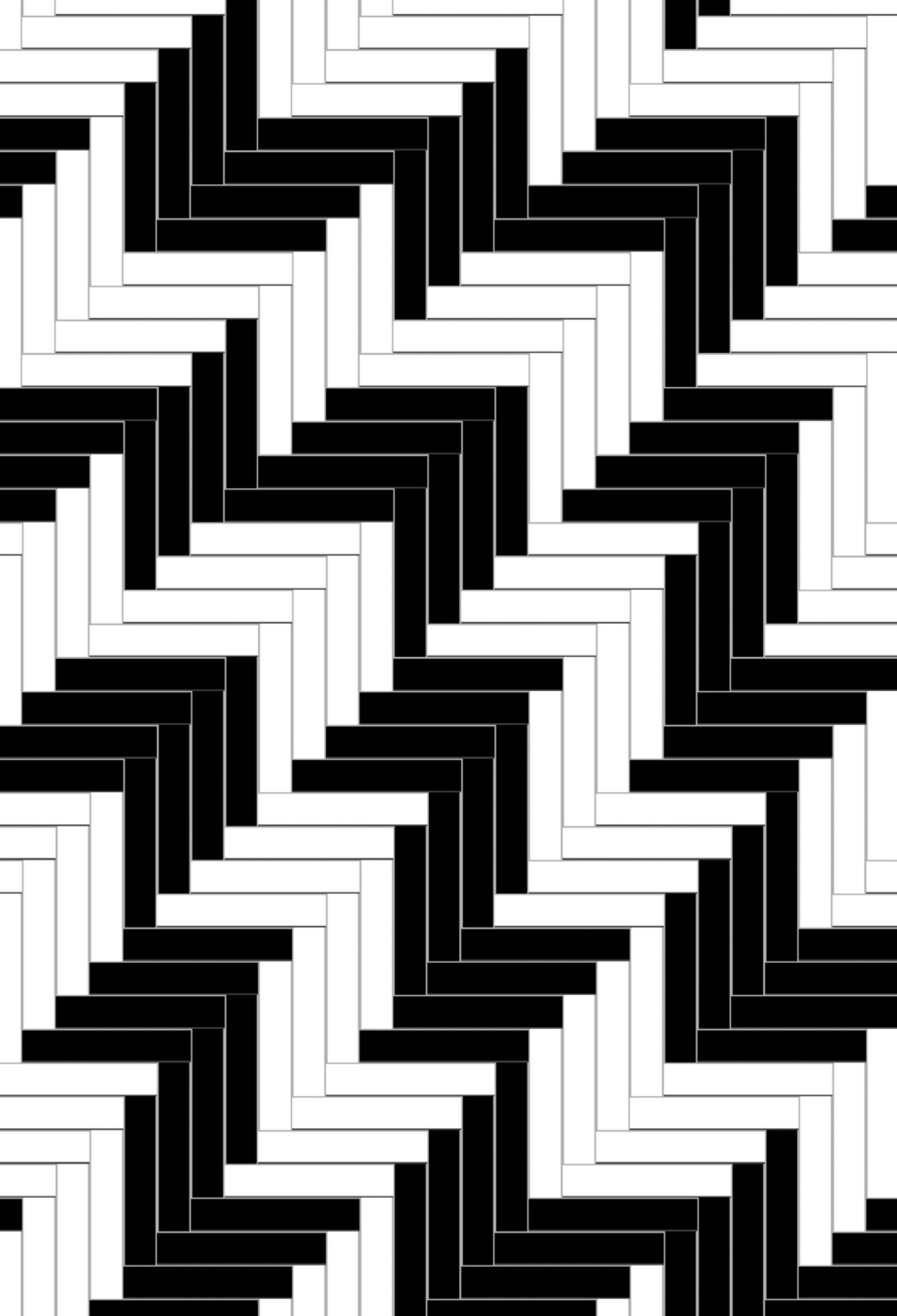
The manipulation of parameters in the algorithms, and the exploration of the spaces of expression created by the parameter manipulation, suggested the next step of the research. The exploration of the space of expressions was conducted in stages, where each parameter change created a weaving pattern and sometimes a woven fabric. Performative branches of new media art often involve the manipulation of parameters within an algorithm or performance interface. The construction of the satin-generating algorithm and its deliberately constructed errors is dependent on the presence and manipulation of these parameters. This leads to an opportunity to explore the performative potential of these algorithms. In essence, this would be a "performance" of the algorithm and the error system. This technique is explored in the following chapter, though using a different weaving pattern, houndstooth. Houndstooth offers a further variable not necessarily present in the satin pattern, which is the necessity of differently coloured yarn. The next chapter examines the expressive possibilities in the live manipulation of an algorithm that generates weaving patterns derived from houndstooth.

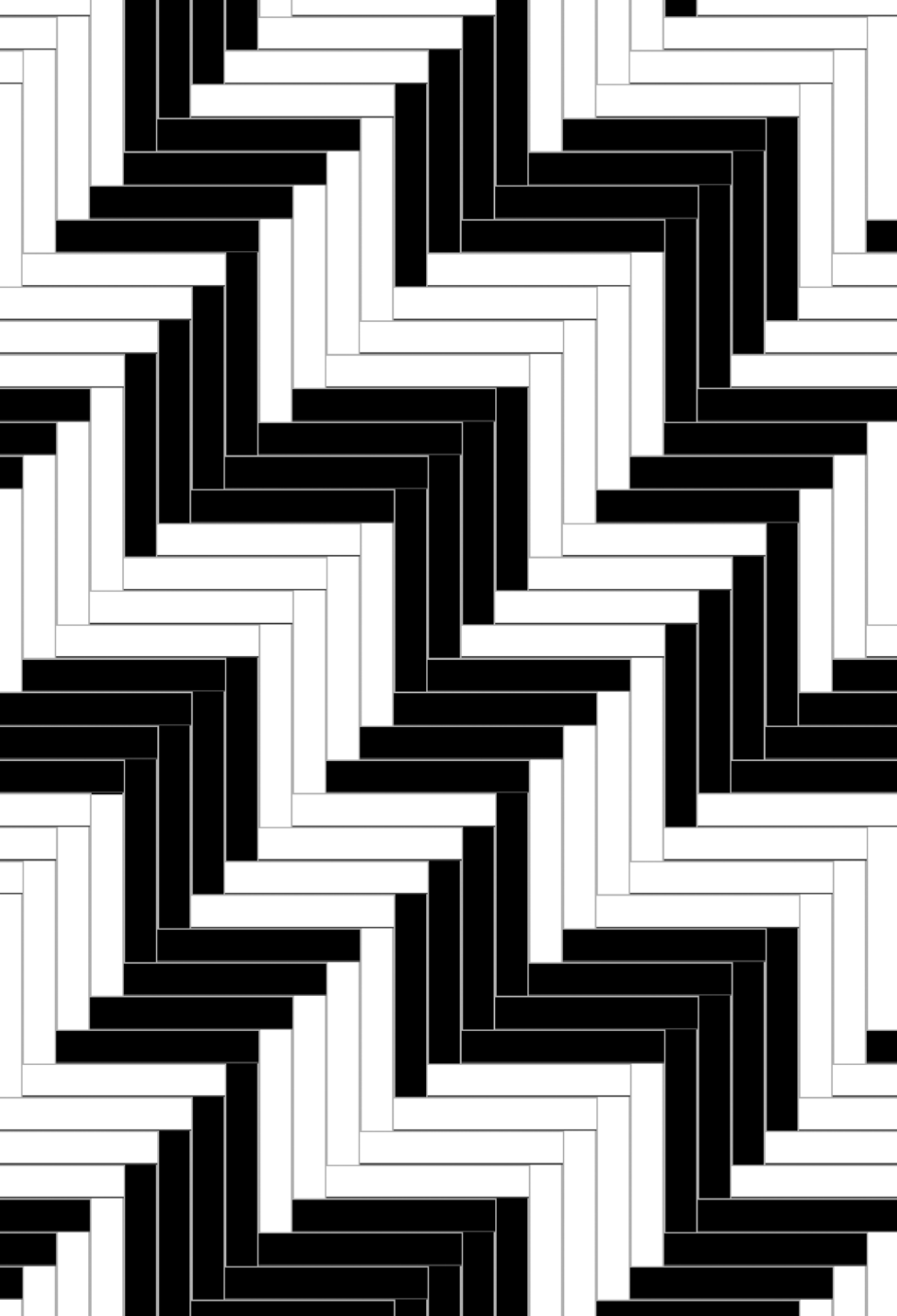
4. Control

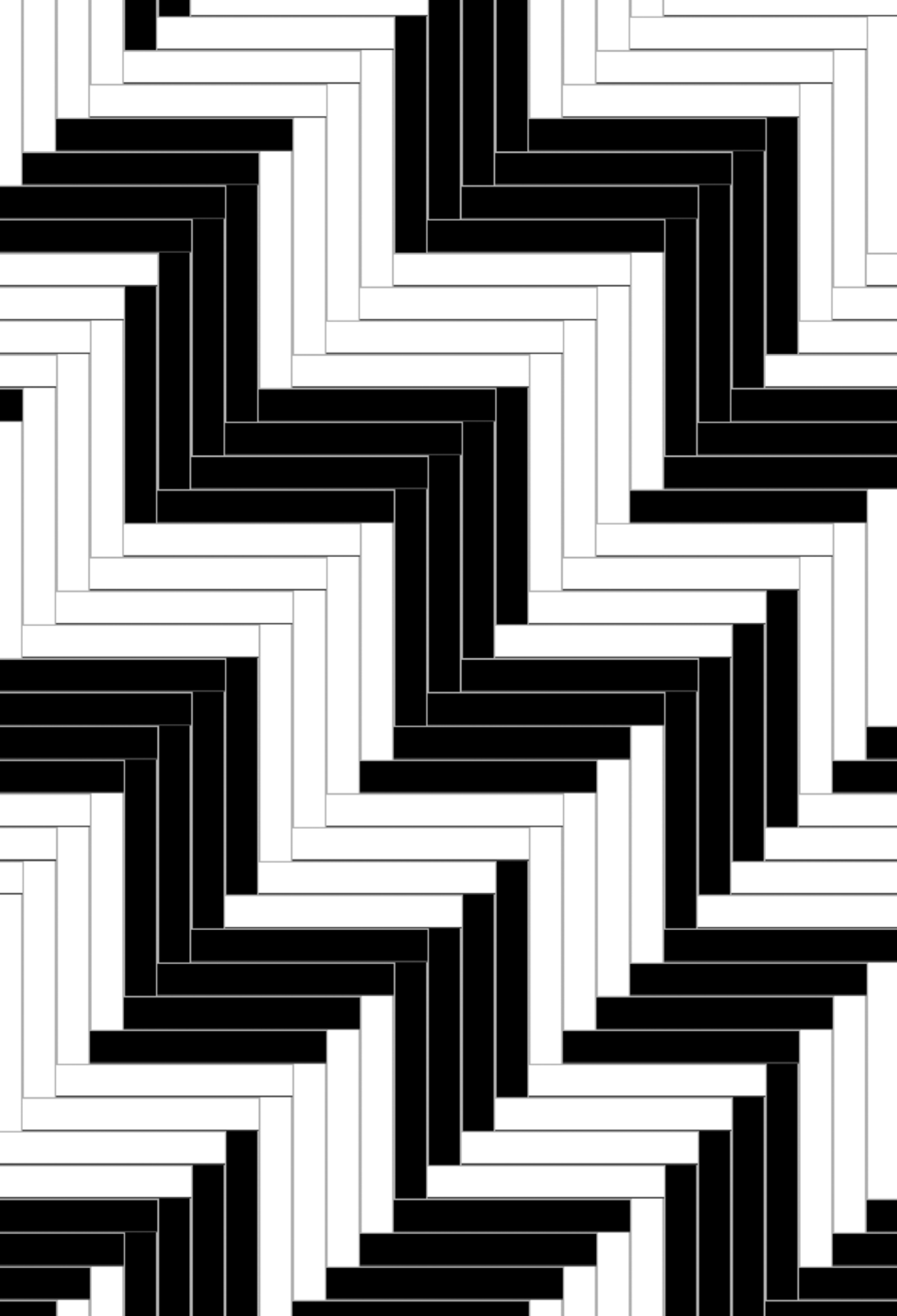


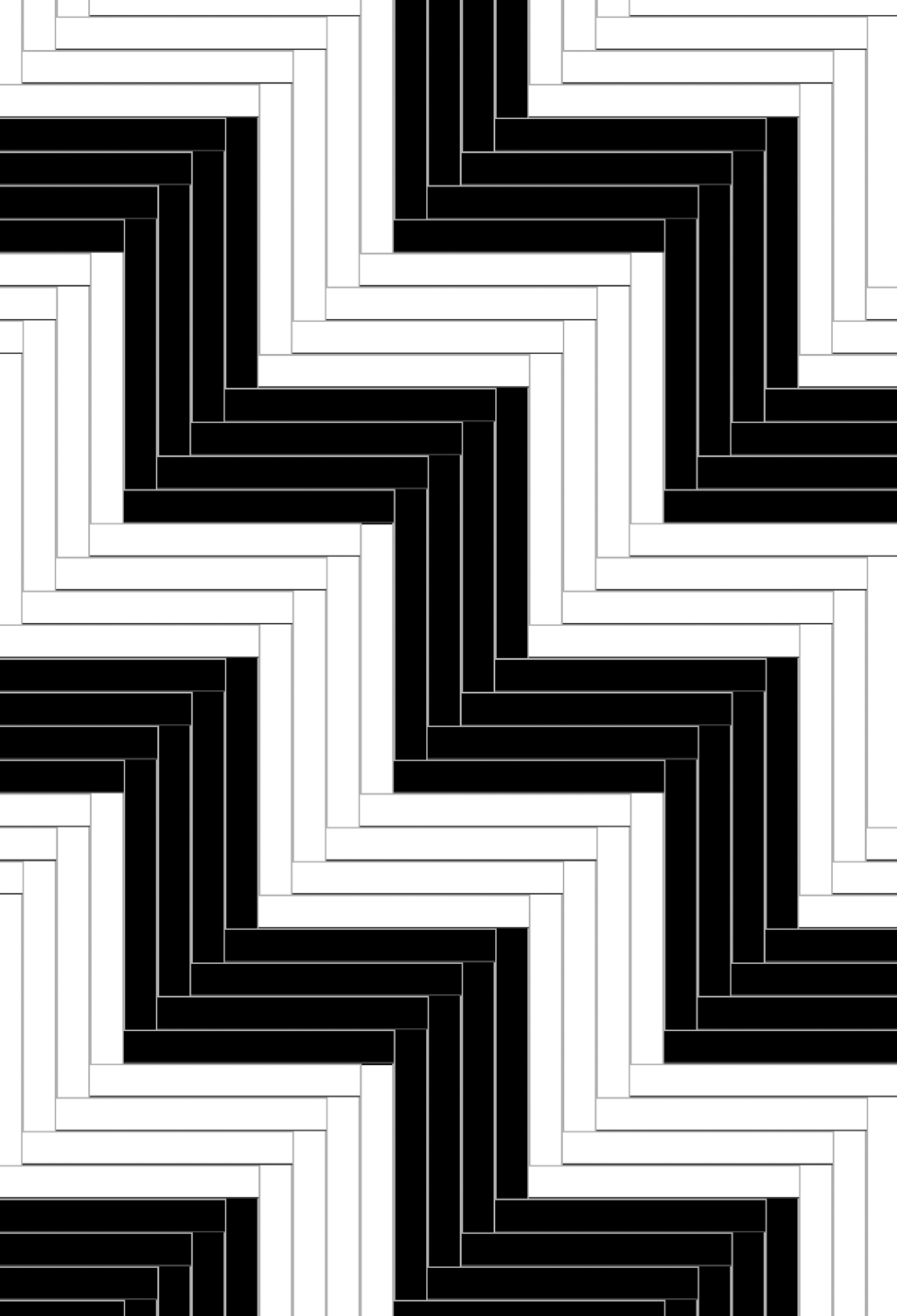


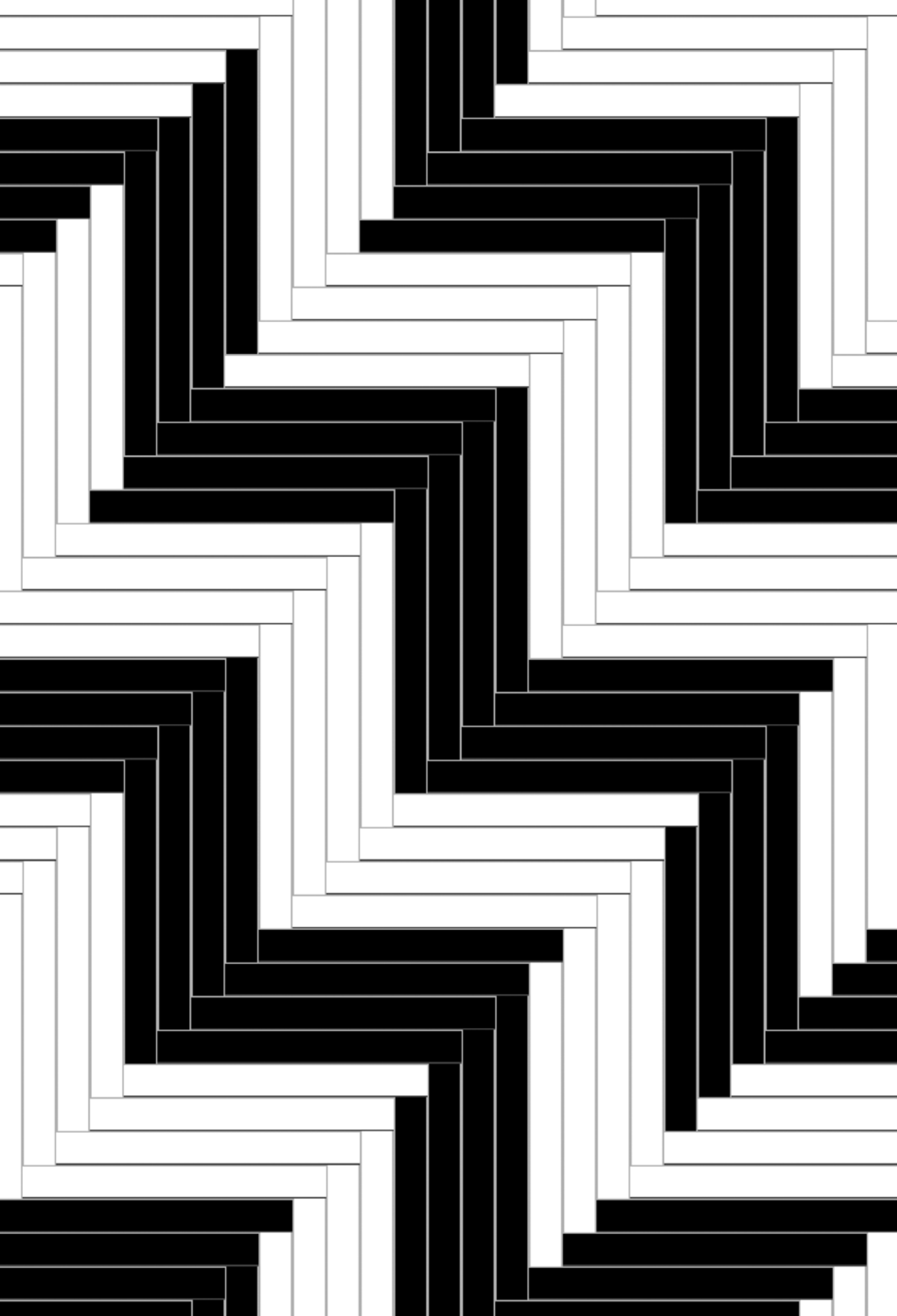


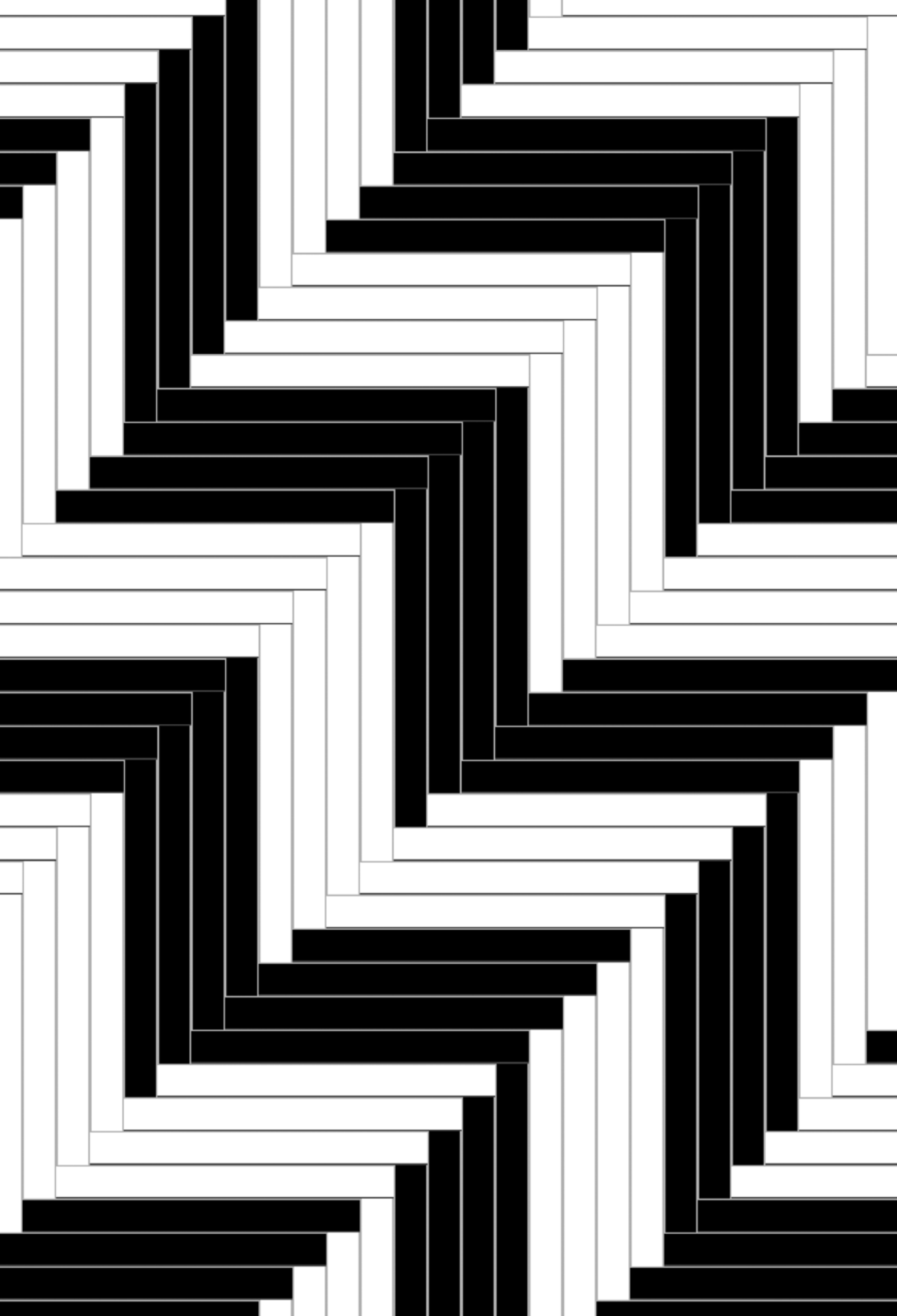


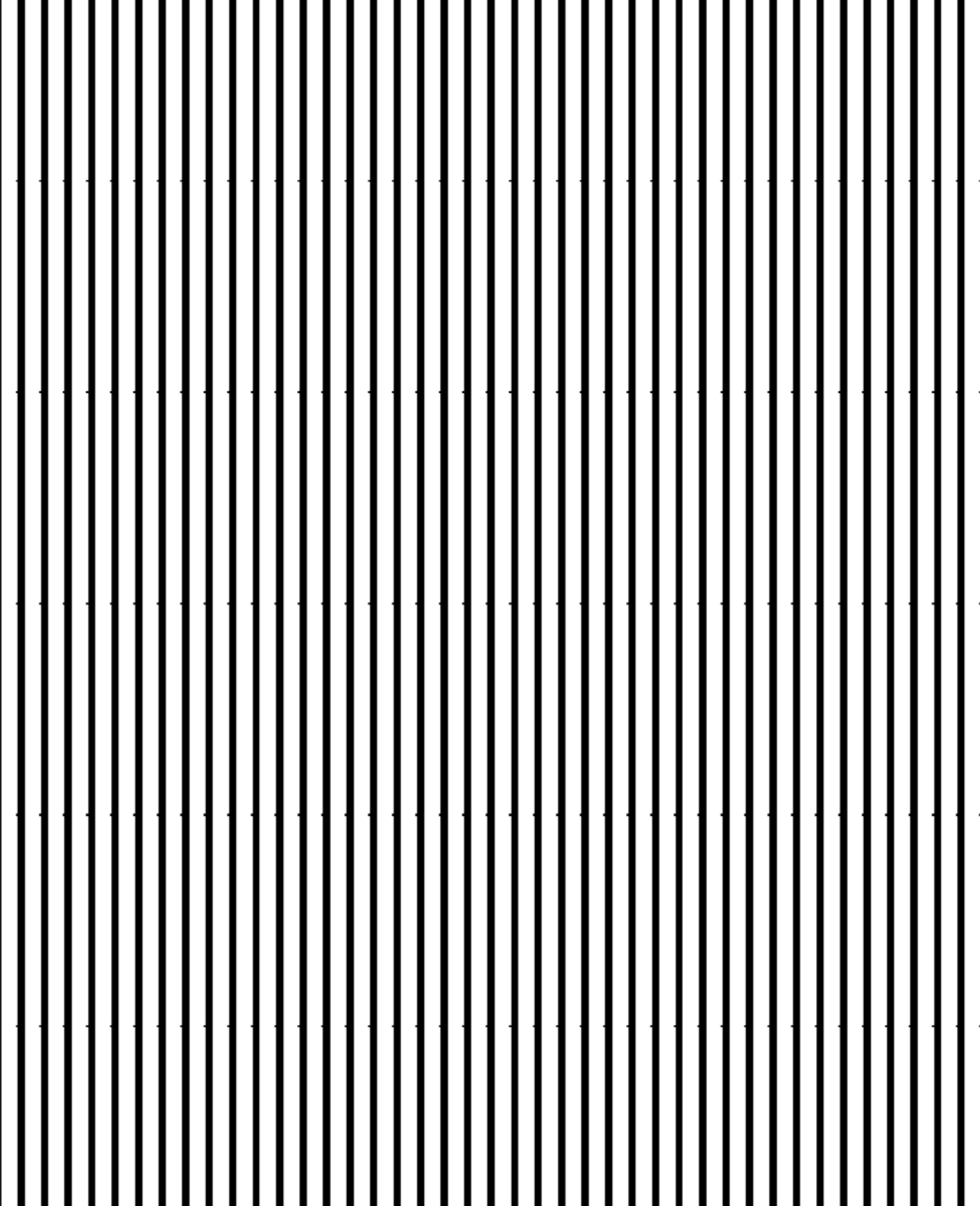






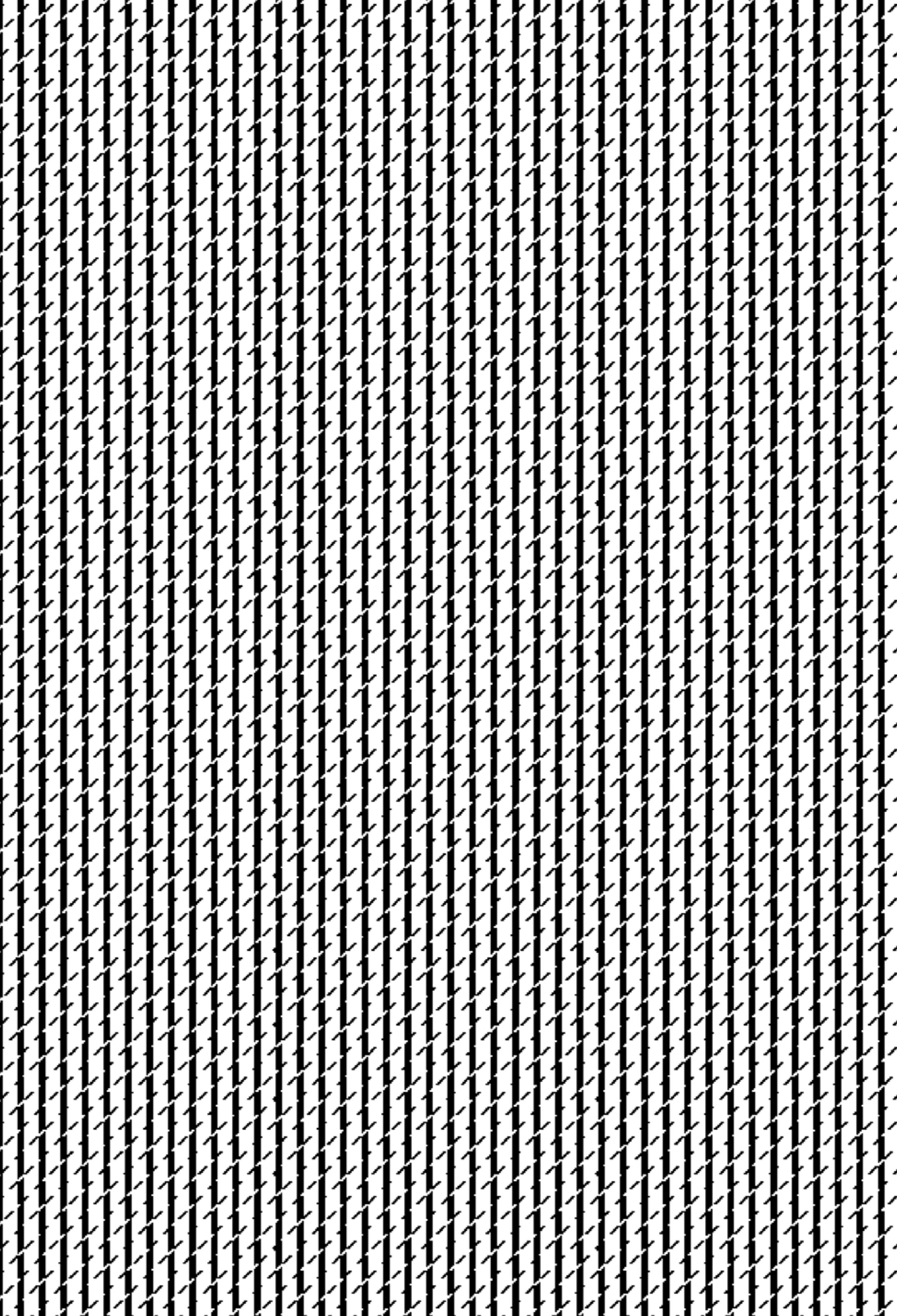


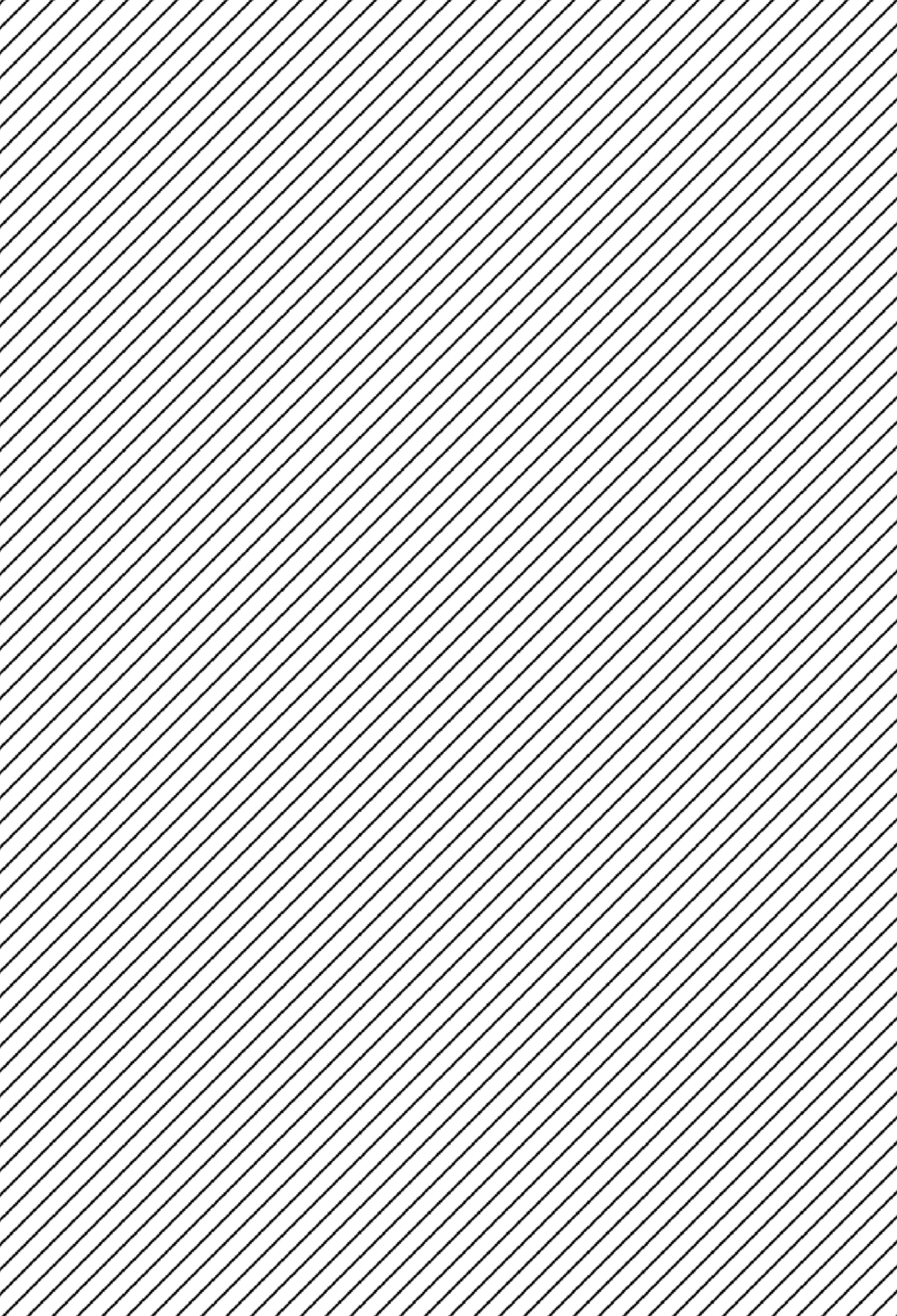


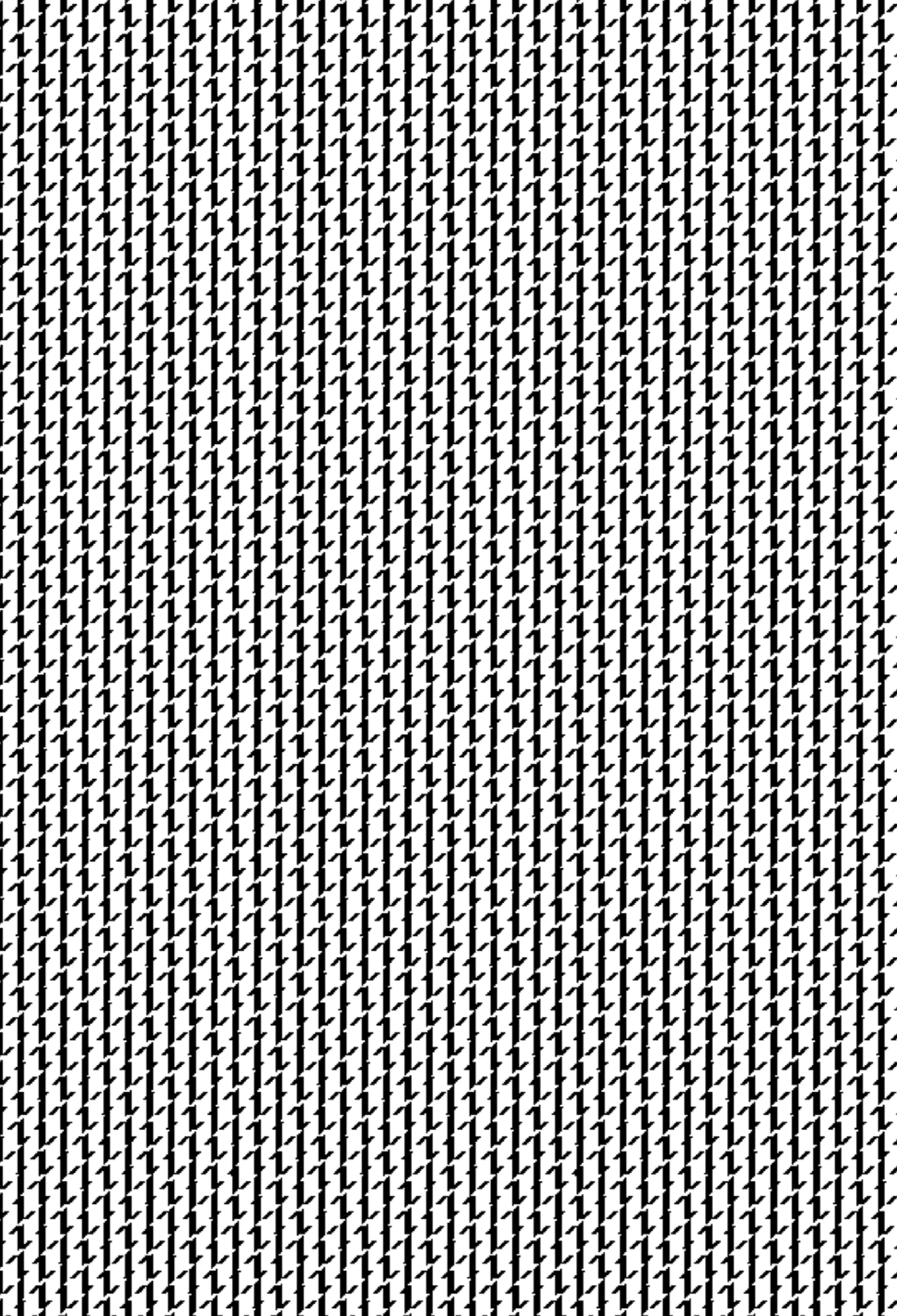


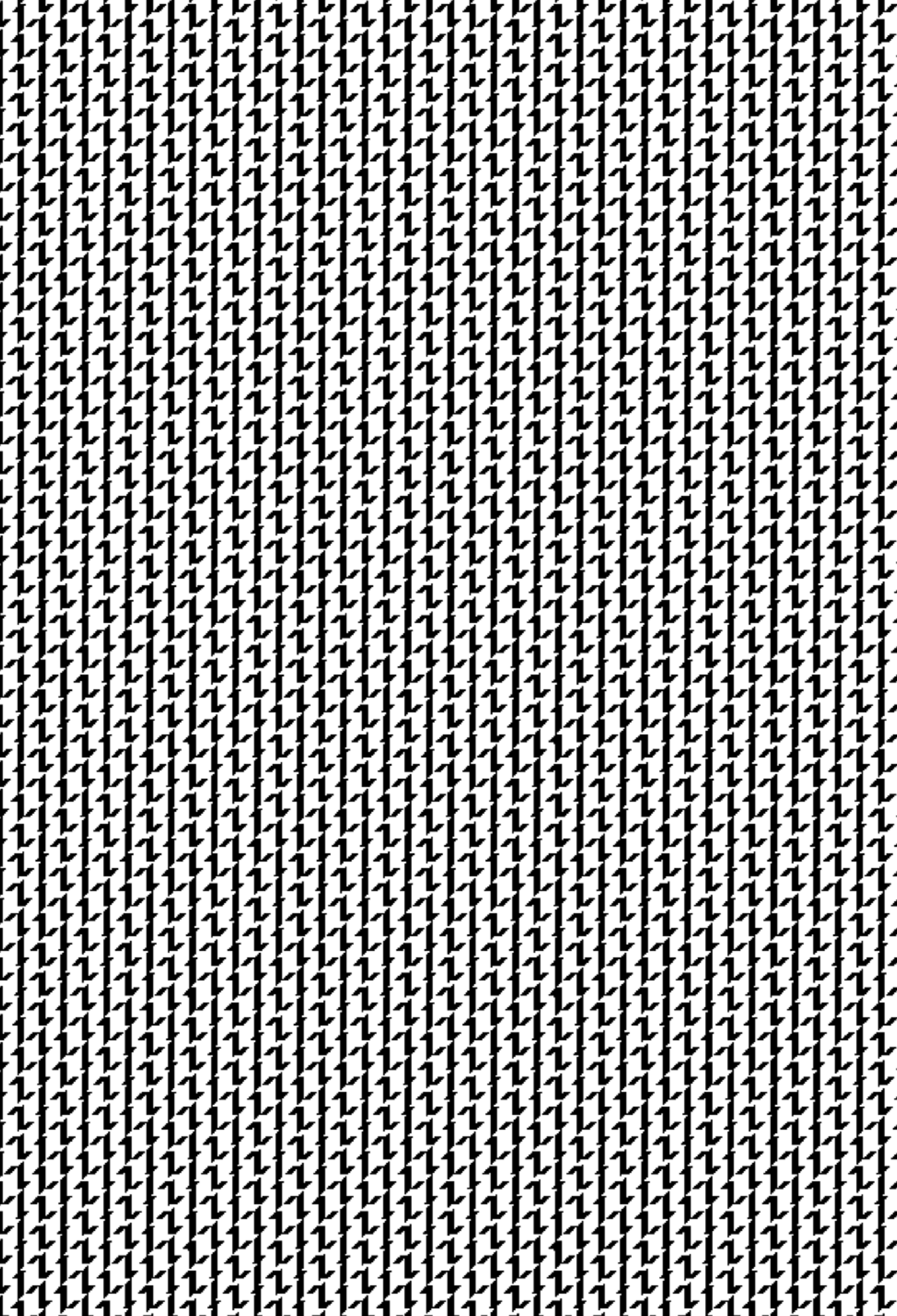
HOUNDSTOOTH VISUAL PATTERN

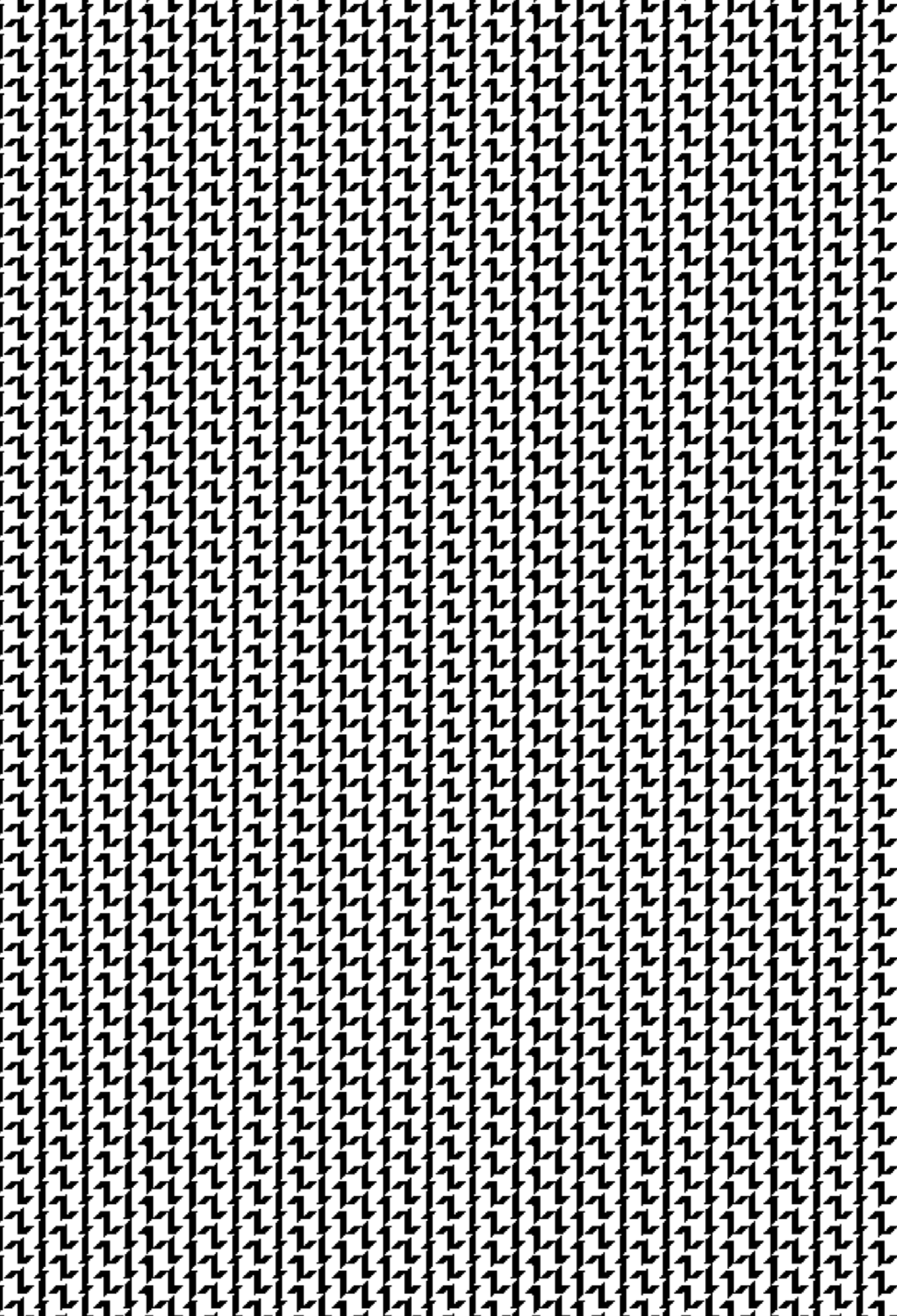
CORRESPONDING TWILL

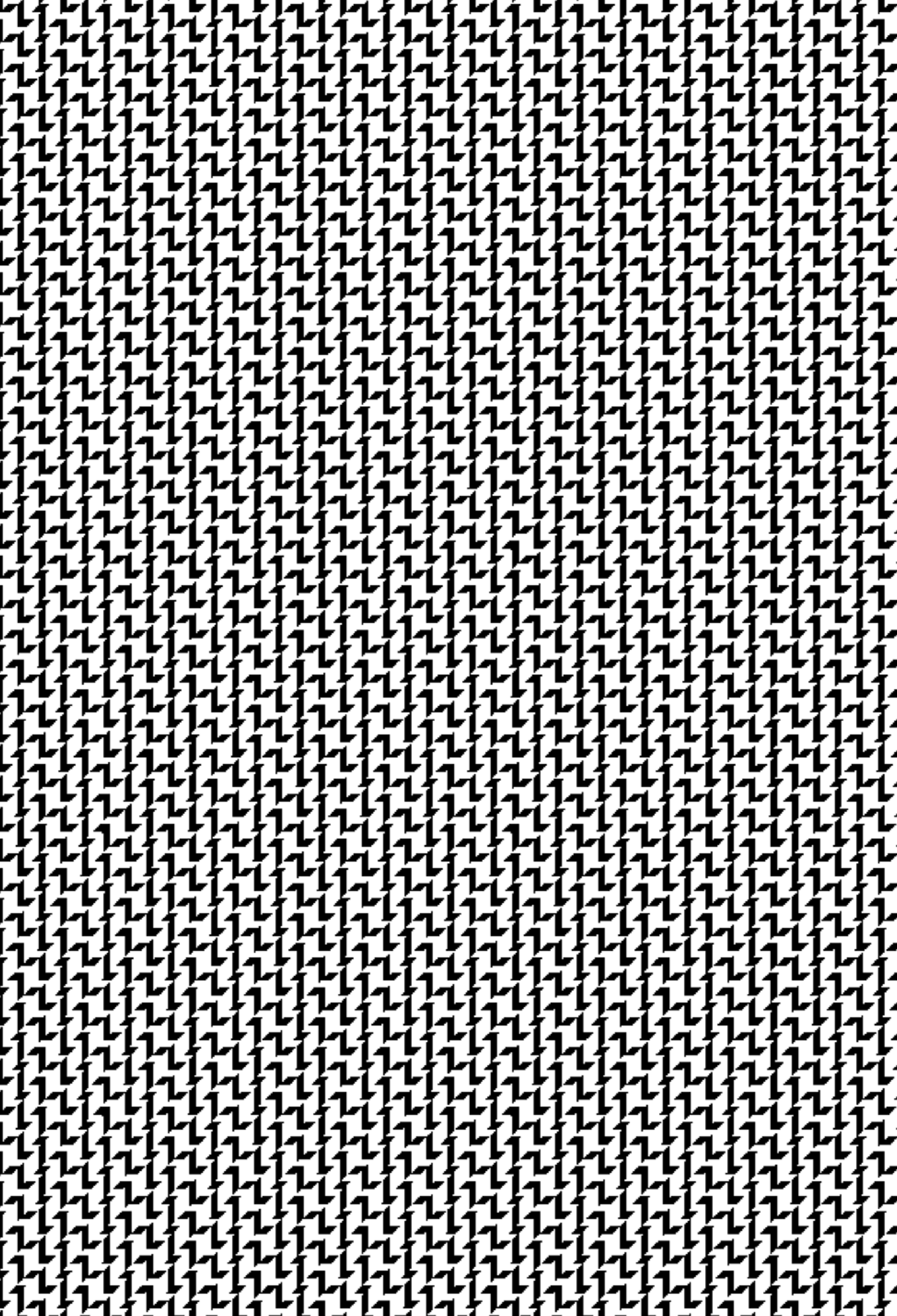


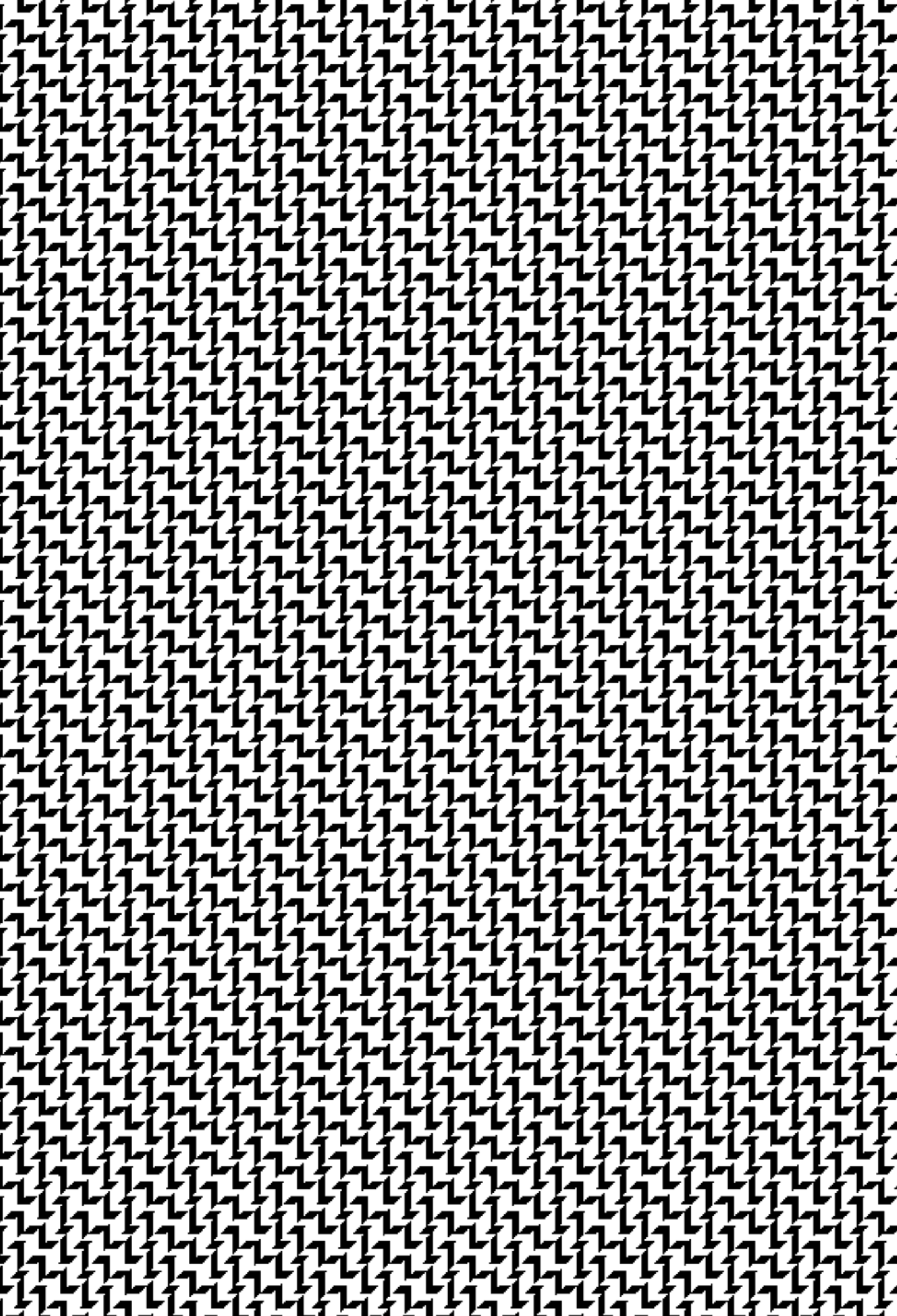


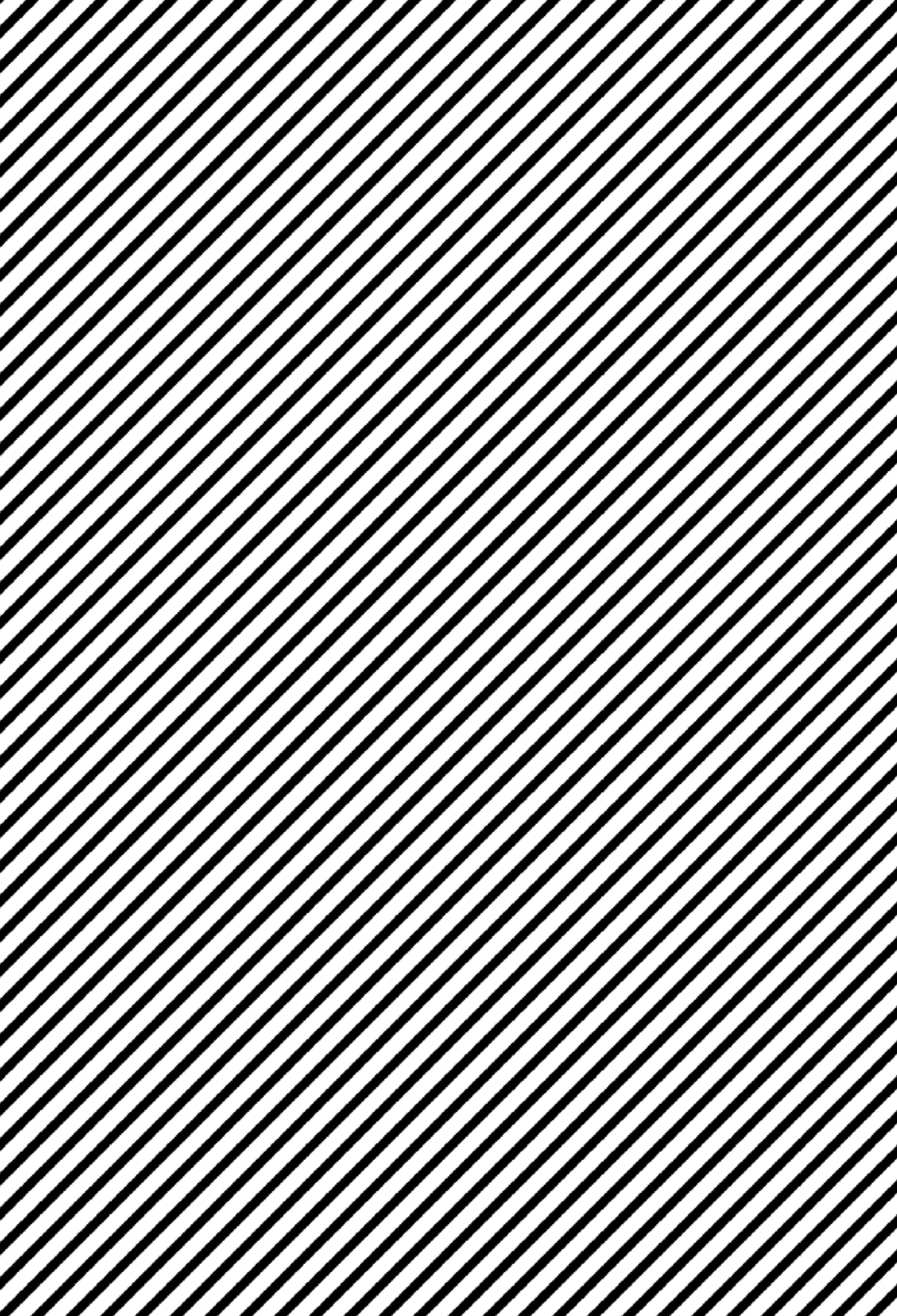






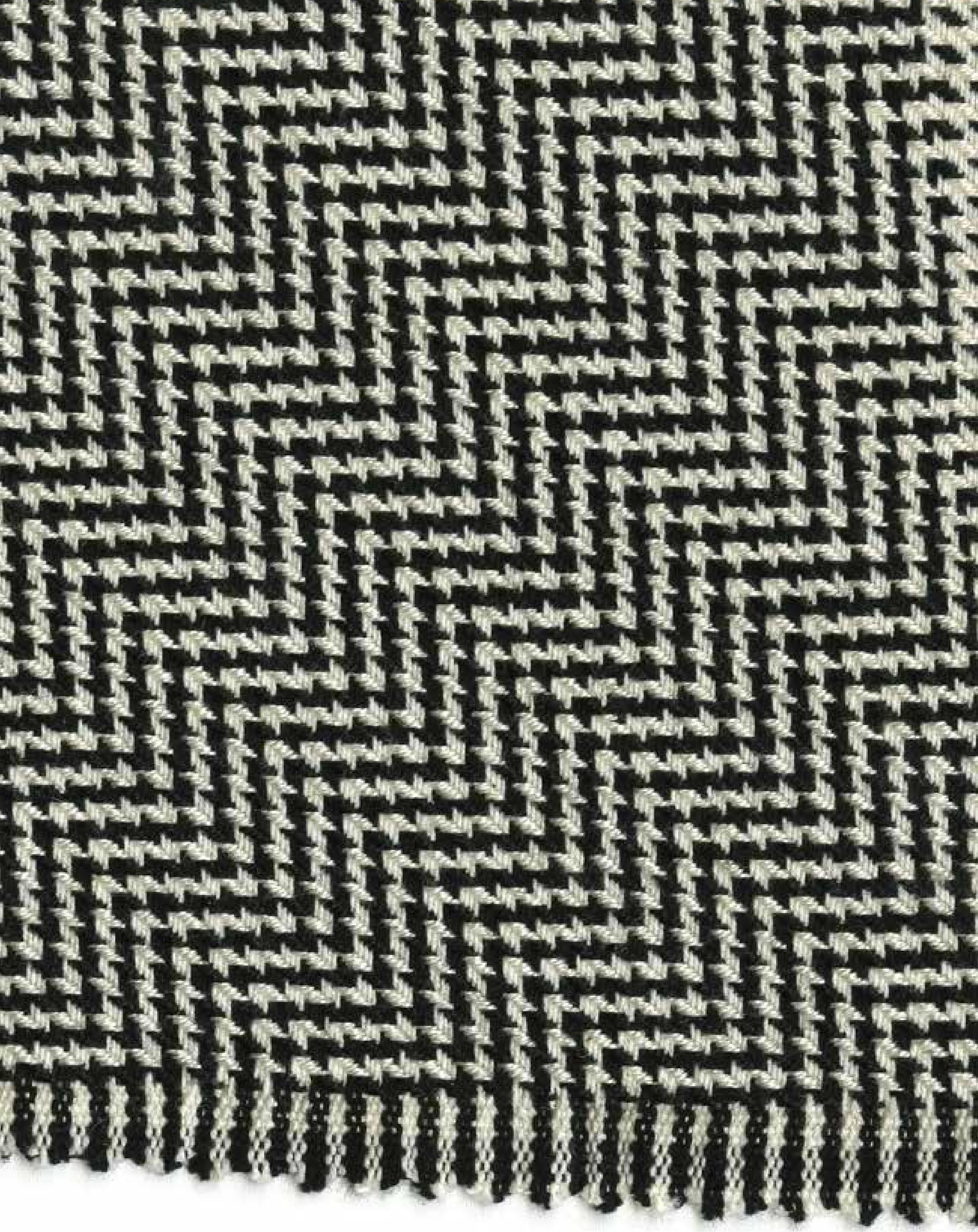




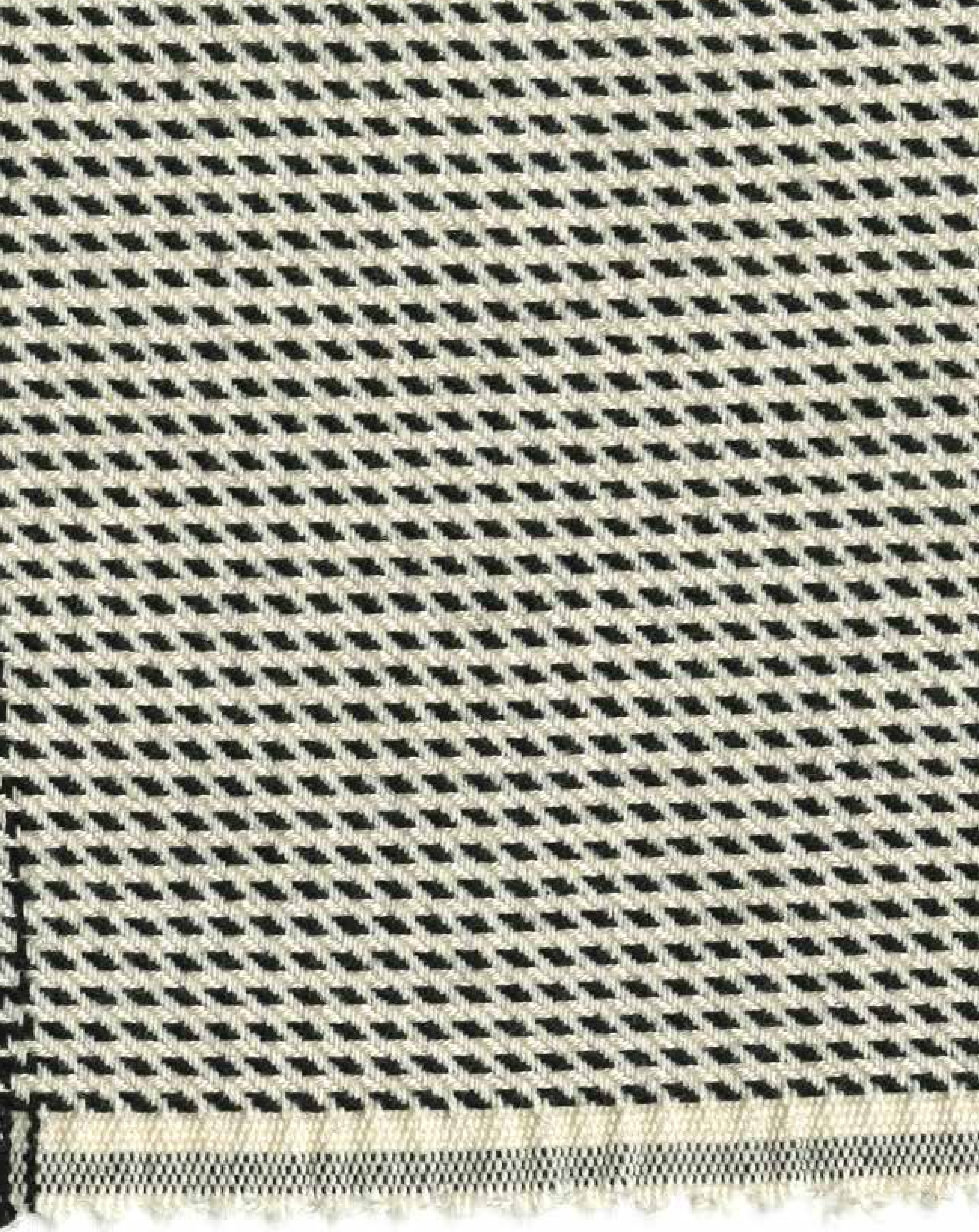


HANDWOVEN HOUNDSTOOTH

CORRESPONDING TWILL, STRIPED WEFT ONLY



HANDWOVEN HOUNDSTOOTH



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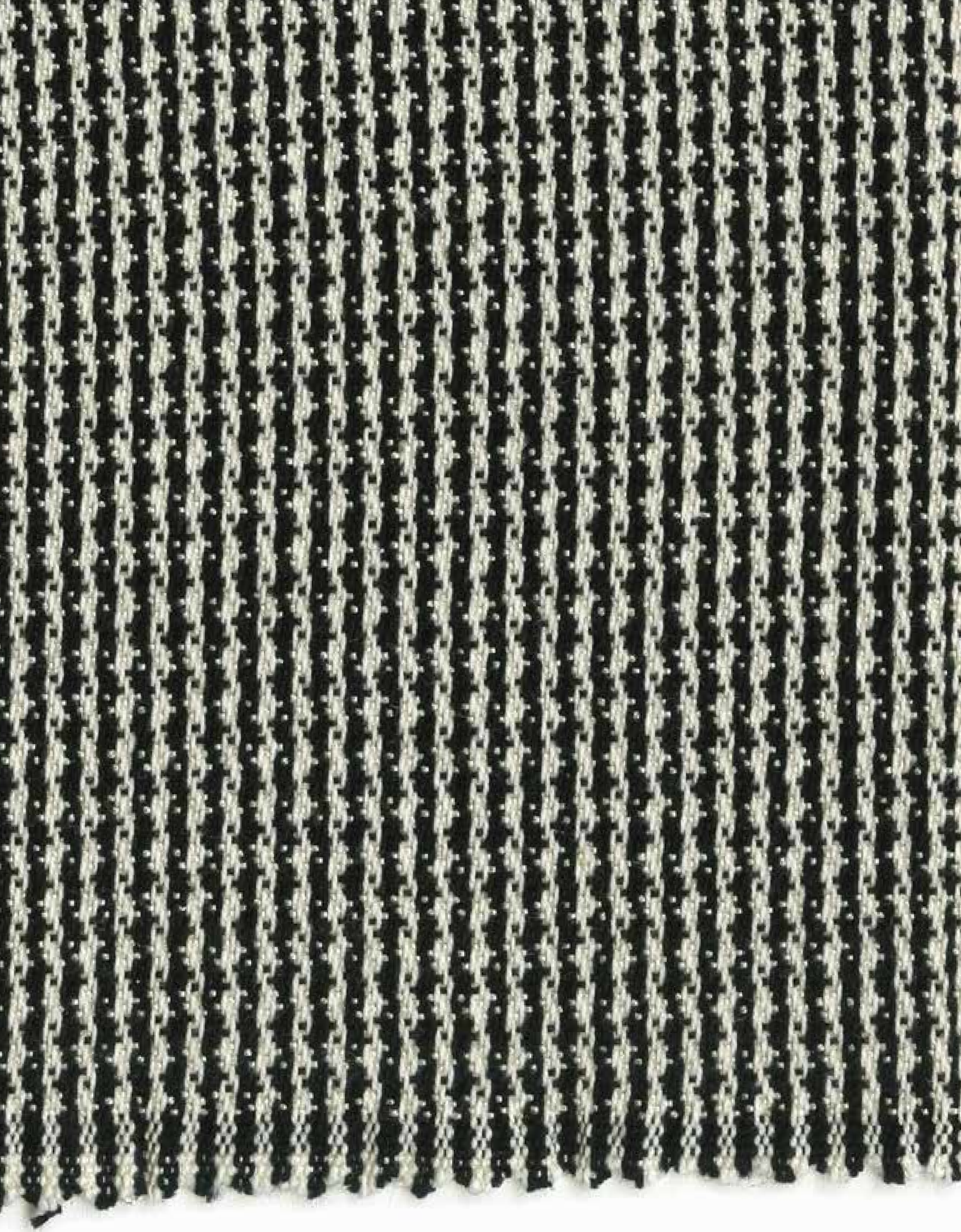

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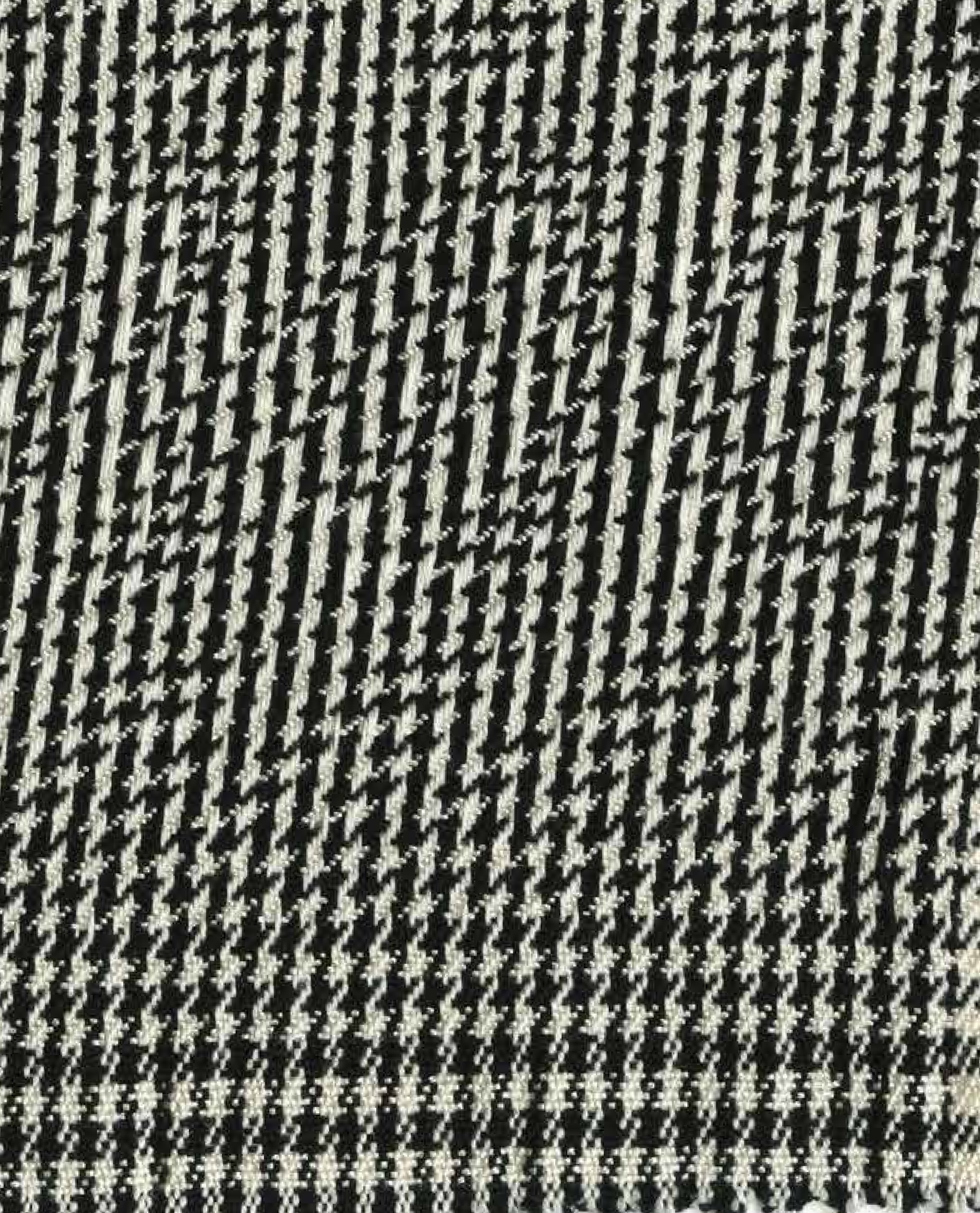

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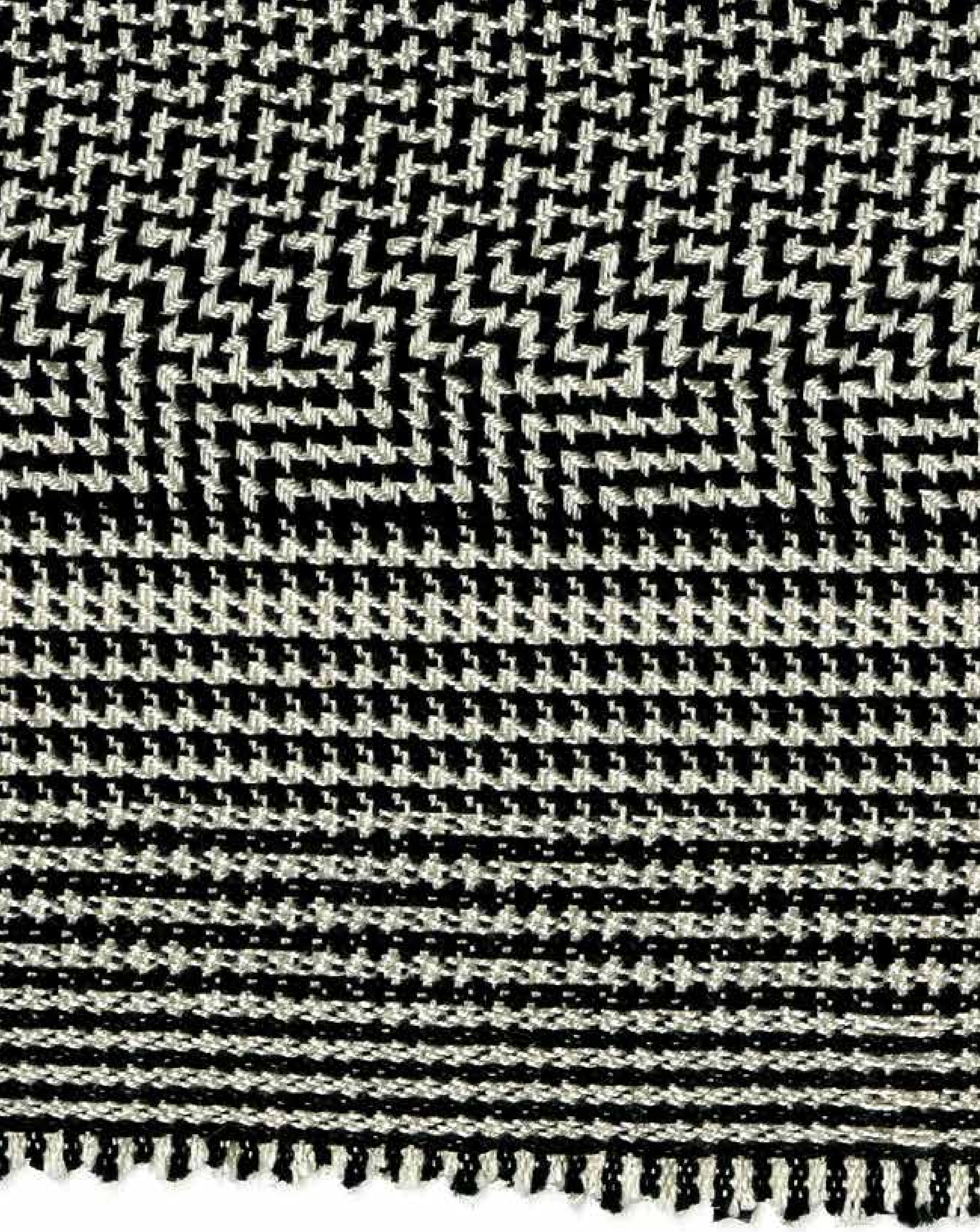
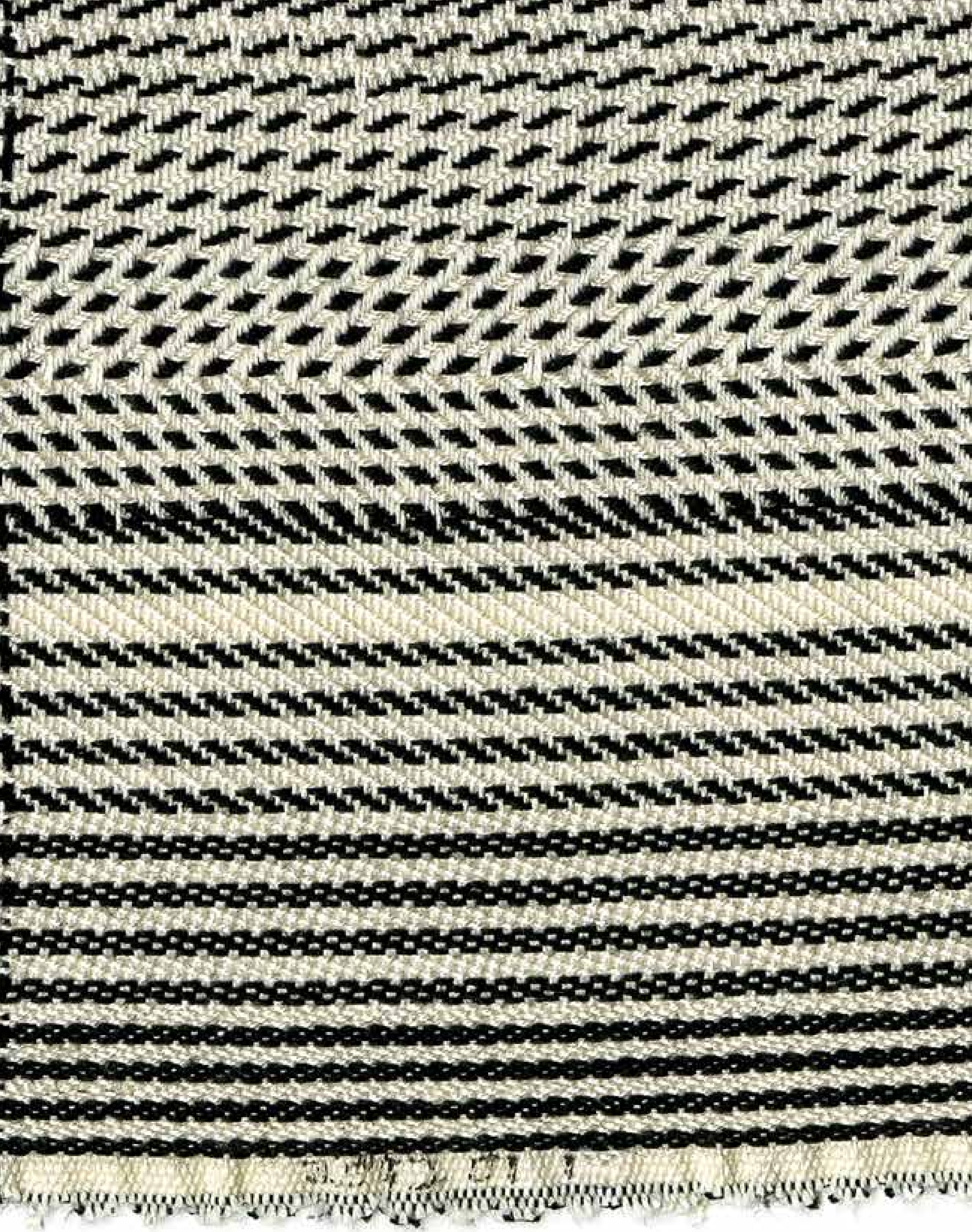
CORRESPONDING TWILL, STRIPED WEFT ONLY



HANDWOVEN HOUNDSTOOTH



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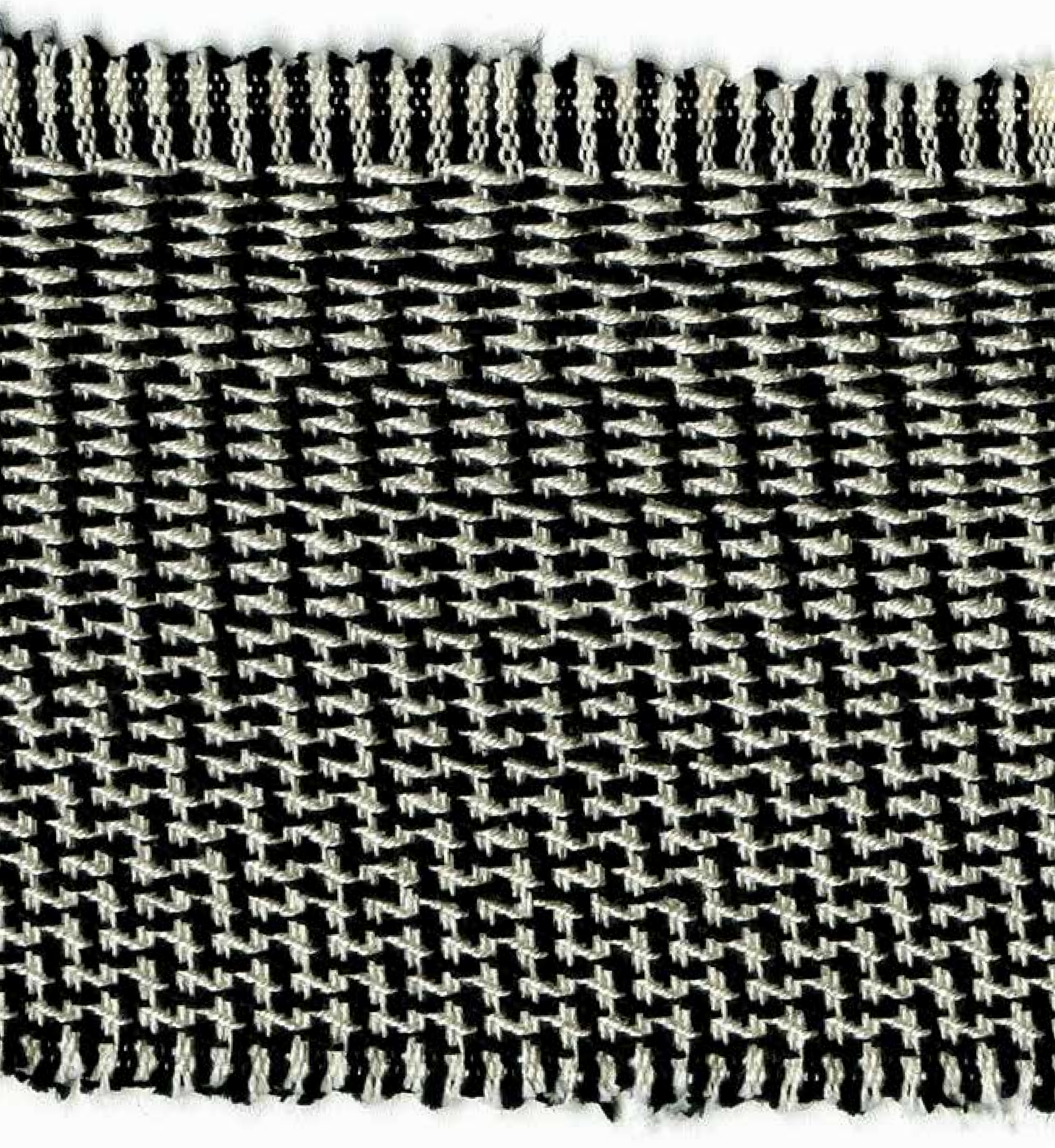
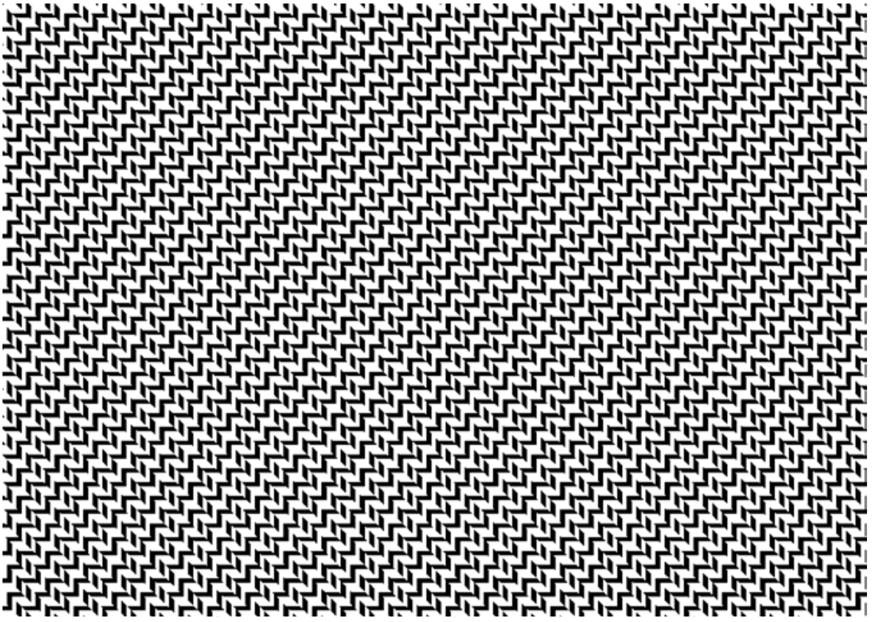


HANDWOVEN HOUNDSTOOTH

CORRESPONDING TWILL, STRIPED WEFT ONLY



Houndstooth software

Video documentation and a version of the houndstooth software presented in this chapter are available at the GUPEA link:

http://hdl.handle.net/2077/57324

4.1 Introduction

The previous chapter presented the opportunities that are created when an algorithm was created to generate a woven pattern, specifically the opportunities for the insertion of error and the artefacts that different kinds of errors create. Building upon this research to explore transfers of approach and strategy from new media art to textile techniques, this chapter presents software that was constructed to make such an algorithm-generating software performative, by manipulating the parameters of the algorithm.

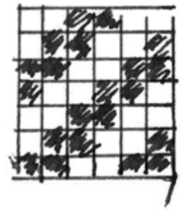
In this chapter, the textile focus is shifted from satin to another basic woven structure, twill, and specifically houndstooth, a checkered weaving effect that is constructed with a specific yarn colouration woven in twill. This work will present software that was created to allow for the navigation of a space of possible weaving patterns by manipulating the parameters of the houndstooth pattern. Houndstooth becomes a basic template that dictates a space of pattern and expression.

The construction of the houndstooth software required a step that was not present in previous explorations in this research, which is a specific consideration for yarn colouration and the visual effects that this produces. Because houndstooth is a visual effect created by the relationship between a weaving pattern and the thread colouration, this chapter presents the process of creating first an algorithm for generating the weaving pattern, and then augmented by an algorithm that uses the weaving pattern and colouration of the thread to create the visual effect based on the visibility of either warp or weft threads.

This chapter presents and reflects upon the notation and images generated by the software, as well as textile examples produced by a digital loom. The images and textiles created demonstrate the viability of the transfer of strategies from new media art to textiles: the creation of algorithms to construct weaving patterns, the opportunities for deliberate insertion of error afforded by these algorithms, and the ability to perform the algorithms to navigate the spaces of expression created and bounded by these algorithms.

4.2 Houndstooth as a space

Houndstooth is a twill weave with a specific warp and weft coloration. Twill is one of the three basic weaving patterns upon which all weaving are based—the others are satin and tabby. In a standard twill, the pattern used for houndstooth, the weft threads lie overtop and then underneath pairs of warp threads. Each row is shifted by one thread from the previous to create diagonal lines of these double binding points. The weaver's pattern for twill looks like this:



Each row represents a weft thread, each column a warp thread, and the colour of the square denotes whether the weft lies over or under the warp thread. Twills are incredibly common in shirt, skirt and trouser fabric. Examine jeans and you will see the diagonal lines of the twill. Houndstooth warp and weft coloration is particular. The warp is a series of threads of alternating colours, four black threads and four white threads, and the weft coloration follows the same pattern. When this configuration of warp and weft threads is woven into a standard twill it creates houndstooth, the twill provides a kind of filter whose binding points determine which threads are seen at the surface of the fabric, and at what points.

The existence of houndstooth is an example of the extraordinary complexity from simplicity that is possible with weaving. Houndstooth is a pattern whose visual characteristics allow it to exist in many different contexts, depending on scale. It is a pattern that exploits the physiological structures of the eye. Its behaviour of changing the brightness of things (a feature that helps in distinguishing plain objects) goes haywire when exposed to houndstooth. But the way that houndstooth is made is the meeting of two very simple structures: striped threads, and a twill.

Walking down the street you walk alongside a fence. As you walk, the fence shimmers as another fence behind makes itself barely visible. The straight, regular posts of the fence suddenly produce a moving angular pattern. This is moiré, the interference of two regular, porous patterns.

Moiré has its origins in textiles, where a sheer fabric is folded over itself. The regularity of the sheer textile's weave works in the same way as the grates or fences we notice interfering with each other as we walk by. Though because the surface of a textile is unpredictable, as in draping over the body, its moiré effect is not regular like those we notice from machine-made grids. It has the appearance of an oil slick, or the surface of water.

It is an optical phenomenon. Two structures interfering with each other, adding at spaces where they both exist, subtracting at spaces where they do not. In acoustics there is the phenomenon of "ghost tones", a third tone that appears out of the addition of two others. If the two tones are close together in pitch they produce a warbling, if they are farther apart they can produce a difference tone, a third distinct tone.

Houndstooth is produced by layering two things on top of each other. Nothing is remarkable until the warp and weft are woven together in a twill pattern and the houndstooth magically appears. This is not a moiré, but it is a kind of interference. The placement of a twill on the thread structure creates the houndstooth. This section discusses software that changes the twill pattern, shifting the resulting houndstooth pattern in much the same way that moving two meshes across each other will produce different moiré patterns.

Two objects in one space—the threads and the weaving pattern—are being manipulated to create a third space, the space of the resulting pattern, a space that is only visible when everything is overlaid. Like the moiré, it is not visible without the combination of all the elements.

If we were to list the features of houndstooth we would say that it is comprised of a twill whose weft threads follow the pattern of over 2 warp threads, under 2 warp threads, and each row is shifted to the right by 1 thread. The warp is constructed by an alternating pattern of 4 black threads and 4 white threads. And the weft is constructed by an alternating of 4 black threads and 4 white threads. What this looks like is the beginning of an algorithm with a set of parameters.

Twill parameters:
- amount over: 2
- amount under: 2
- amount shifted shifted: 1

Warp:
- first colour: black
- second colour: white
- amount of black threads: 4
- amount of white threads: 4

Weft:
- first colour: black
- second colour: white
- amount of black threads: 4
- amount of white threads: 4

There are many possible ways of notating a twill. Ralph Griswold, a computer scientist with an interest in textile patterns, in an analysis of twill notations, presented two.[97] The first, and also the notation used by Ani Albers,[98] was to present the sequence of warp threads crossed over and under by a weft thread by a series of numbers positioned overtop and underneath of a line, denoting the sequence of warp threads raised and lowered, such as:

$$\frac{2\quad\ }{\quad\ 2}$$

would represent the warp threads follow a pattern of lying overtop of two weft threads, and then underneath two weft threads. Griswold also presented another method of notation, which he termed "linear notation", where the previous pattern would be represented as 2/2. Both of these notations assume that each row of the twill is shifted by one warp thread.

The description of the houndstooth here requires far more variables

97 Ralph Griswold, "Twill Counters," *On-Line Digital Archive of Documents on Weaving and Related Topics* (blog), August 1, 2004, https://www2.cs.arizona.edu/patterns/weaving/webdocs/gre_tc.pdf.

98 Anni Albers, *On Designing* (Middletown, Connecticut: Wesleyan University Press, 1966), 41.

than are accounted for in this standard twill notation. To accommodate for this, I use a modified function notation, used in mathematics to denote equations that rely on the input of variables. If, for example, we have a function named *f* for calculating the length of the hypotenuse of a right-angle triangle with side-lengths *a* and *b*,[99] it would be written as: $f = \sqrt{a^2 + b^2}$, and the function could generically be referred to as $f(a,b)$, that is, the function *f* is dependent on the variables *a* and *b*. And $f(3,5)$ would be the result of the function calculated for triangle side-lengths 3 and 5.

This text uses a modified version of this format when discussing the twill and the yarn coloration. I notate the twill as *twill*(2,2,1), that is, over 2 threads, under 2 threads, shifted by 1. Although this notation gains the ability to to notate the number of threads shifted in each row, it loses the ability to denote longer twill patterns. For example, the previous notations could denote a twill pattern of an arbitrary length, such as 2/2/3/1/4, which my notation cannot.

The warp coloration will be notated as *warp*(4,4), alternating stripes created by 4 of the first colour and 4 of the second colour; and same for the weft. So the traditional houndstooth would be a combination of *twill*(2,2,1), *warp*(4,4) and *weft*(4,4)

Software programming refers to parameters as "variables", that is, quantities that can be varied. Obviously this specific construction of *twill*(2,2,1), *warp*(4,4) and *weft*(4,4) generates the familiar houndstooth. But the algorithm provided by the classic houndstooth sets the framework for a space of possible patterns, and this space can be navigated by changing the values of the variables. Why is it *twill*(2,2,1)? What does *twill*(3,2,1) look like? What does *twill*(7,6,3) look like? What does an irregular striping pattern look like, such as *warp*(3,1)?

The work of this final section of the dissertation is based on this deconstruction of the houndstooth pattern, and of a tool that was created to navigate this space of related houndstooth patterns. This pattern explores the control of the pattern, or the ability of a structure to be controlled.

The tool was created by constructing smaller programmes to perform separate functions of the houndstooth creation, then assembling them into the full tool. First, a software algorithm was created to produce a generalized twill pattern. The software could then alter the parameters to create other kinds of twill. The pattern did not allow for twills with irregular periods or other kinds of patterns.

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99 This is known as "the Pythagorean theorem".

The programme was then altered to include differently coloured warp and weft threads. This proved to be a major departure from the previous satin error programmes. Up until this point there was virtually no difference between the weaving pattern and the appearance of the textile. The textiles were a single colour, and so the weaving pattern in some way reflected the texture of the textile. The differences between the pattern and the textile produced turned out to be an interesting point of exploration.

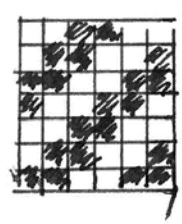
The new software was changed to produce two outputs. The first was the weaving pattern for the jacquard loom. This is the same as was produced for the satin programmes. The second output was a visual representation of what the textile should look like. This is different from the satin error software explorations, which only modelled the woven pattern, and not the appearance of the textile.

The final change to the programme was to allow the live manipulation of the twill using a controller. Three interfaces were explored: a combination of the computer mouse and keyboard, a MIDI slider box, and a Nintendo Wii remote. The images at the beginning of this chapter were taken from this software, using a variety of the interfaces, both digital image exports, and textile samples handwoven on the TC1 digital loom.

4.3 Generalising a twill pattern for software

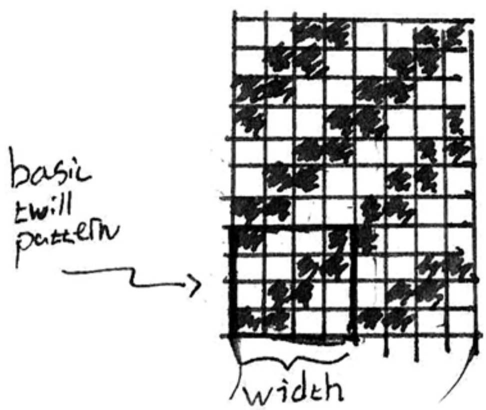
The first step to create this software was to generalise an even twill. Even twills have the pattern of the weft thread lying overtop several warp threads, then underneath another number, and repeating. For each row this amount is shifted by a certain amount.

The twill is essentially a pattern of one small line segment, repeated horizontally, and for every row shifted by a certain amount. This process will determine, given any random intersection in the twill pattern, which intersection it corresponds to in that basic, initial pattern, and then where it corresponds in that basic line.



This text will use the term *over* to denote the first portion of the line segment (the amount of weft threads that the warp thread lies over), *under* to denote the second half of the line segment (the amount of weft threads that the warp thread lies under), and *shift* to denote the amount by which each row is shifted from the previous. Using the twill notation previously described, this would appear as *twill*(*over*, *under*, *shift*).

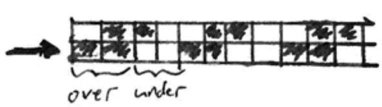
In order to draw a twill pattern the programme must be able to determine for a given point $P(x, y)$ whether the weft thread is over or under the warp. The twill pattern can be reduced to a small, simple square pattern that can be repeated across the whole pattern. Its height and width, here referred to as *twillwidth*, is the sum of the *over* and *under* values.



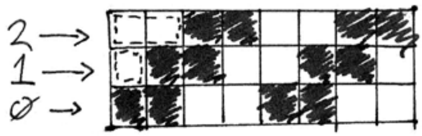
twillwidth* = over + *under

Because this pattern is repeated across the whole fabric, any point $P(x,y)$ has a corresponding point on the basic twill pattern. Determining that corresponding point can be accomplished by the use of the modulo operator. Modulo will cause a continuous series of numbers to repeatedly loop from 0 after a set length, so that every row in the fabric can be examined as though it were in the basic pattern.

The first row of the twill pattern is straightforward. If x is less than the *over* amount, then at that binding point the weft thread lies over the warp thread. Otherwise, P is in the second half of the twill pattern and the weft lies under the warp, so the warp is visible.



But what about other rows, where the pattern has been shifted? For every row, the twill pattern is shifted by the *shift* amount. The shift can be calculated by knowing which row is being inspected.



For every row y, the pattern has been shifted by *shift*. Any y corresponds to $y \,\%\, \mathit{twillwidth}$ in the basic twill pattern. The amount of threads that the row has shifted can be calculated by multiplying it by the *shift* amount. So the amount that the pattern has been shifted for any $P(x,y)$ is

$$\textbf{\textit{shifted amount}} = (\boldsymbol{y} \,\%\, \textbf{\textit{twillwidth}}) \times \textbf{\textit{shift}}$$

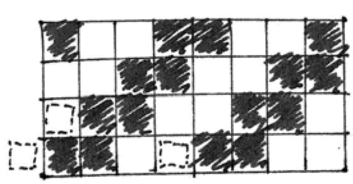
Since the pattern is shifted to the *right*, this is the same as considering the x value as being shifted to the left. So, this shifted amount can be used for any x to determine what its position would be on the initial line of the twill by subtracting the shift from the x value. We can call this new value $x_{\mathit{first\ line}}$. So:

$$x_{\mathit{first\ line}} = x - \mathit{shifted\ amount}$$

Replace *shifted amount* by our previous calculation, so that:

$$x_{\mathit{first\ line}} = x - ((\boldsymbol{y} \,\%\, \textbf{twillwidth}) \times \textbf{\textit{shift}})$$

This subtraction would generate a negative number if x is a low number,



This can be corrected by adding the amount of *twillwidth* to *x*, and which will not affect the % operation that follows in the next step. So now.

$$x_{first\ line} = (x + \boldsymbol{twillwidth}) - ((y \,\%\, twillwidth) \times shift)$$

This equation, for any point *P*(*x*,*y*), will tell us where the *x* value would be on the first line of the pattern. What is then needed to the corresponding location of the *x* in the basic twill pattern. For a basic houndstooth *twill*(2,2,1), this would be a square of 4 × 4 stitches. Because all points fit into the repeating value of the twill width, so that $x_{first\ line}$ can be generalised as a point in the basic twill pattern by performing a modulo with the twill width, which can be applied to the whole equation. This now becomes,

$$x_{basic\ pattern} = [(x + twillwidth) - ((y \,\%\, twillwidth) \times shift)] \,\%\, \boldsymbol{twillwidth}$$

The remaining step is to determine if the point lies over or under the weft thread, that is, if the warp thread is visible or the weft thread is visible. In the equations, this is determined by the placement of *x* in the first or second half of the basic twill unit, whether or not it is less than the *over* value. If *x* is less than *over*, then this point *P*(*x*,*y*) is a binding point with the weft over the warp (leading to a visible weft), and if *x* is greater than *over*, then the weft at *P*(*x*,*y*) is under the warp (leading to a visible warp).

Therefore, at point *P*(*x*,*y*), the weft is over the warp if:

$$\boldsymbol{x}_{\boldsymbol{basic\ pattern}} < over$$

or, if:

$$([(\boldsymbol{x} + \boldsymbol{twillwidth}) - ((\boldsymbol{y} \,\%\, \boldsymbol{twillwidth}) \times \boldsymbol{shift})] \,\%\, \boldsymbol{twillwidth}) < over$$

4.4 Generalising houndstooth from a general twill

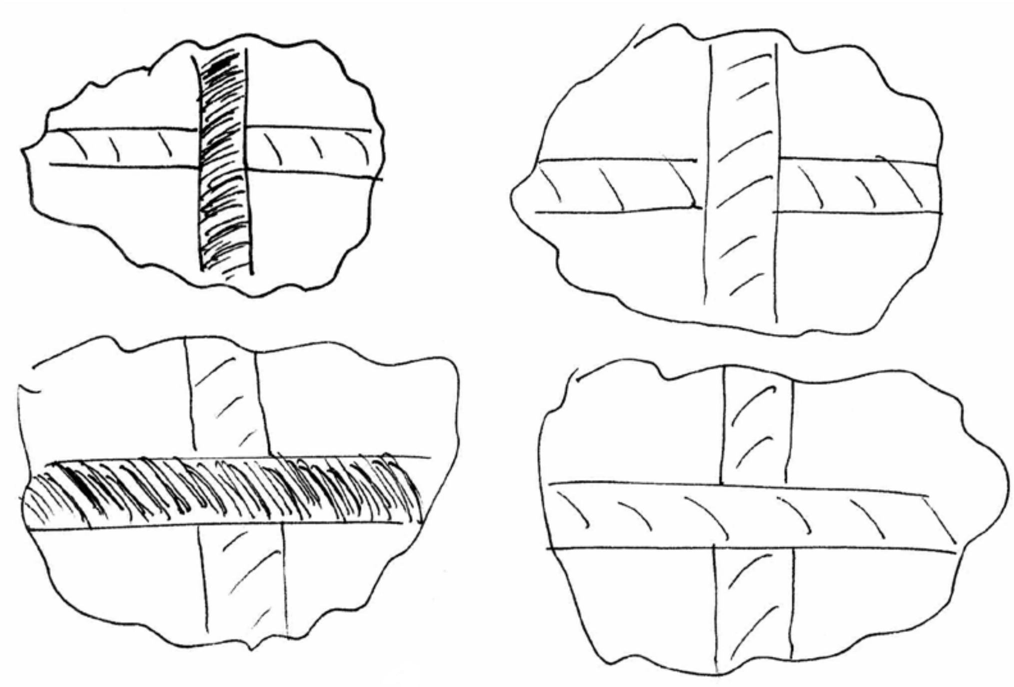


IMAGE 4.1 **Four possible warp–weft configurations. Clockwise from top left: black warp visible, white warp visible, black weft visible, white weft visible.**

With a generalised twill, houndstooth can then be visualised by determining which colour thread is showing. Illustration 1 shows four possible warp–weft configurations, where the thread laying overtop is the visible thread and will determine the colour of the intersection. In a traditional houndstooth both the warp and weft threads alternate 4 black threads, 4 white threads. This software will allow for the implementation of any variety of alternating warp and weft colours. In this model, the first colour for both warp and weft will be black threads.

Given an intersection $P(x,y)$ with a visible warp thread, meaning that the weft thread is underneath and not visible, the colour of the warp thread must be determined. In the same manner that the twill width was determined, a warp-colouration width can be determined. This will be referred to as *warpwidth*.

If a houndstooth alternates 4 black and 4 white, the pattern repeats every 8 threads. For an intersection $P(x,y)$, its warp thread x is the same colour as the warp thread x % *warpwidth*. Because the threads alternate black then white, then if this value is less than the number of black threads, referred to here as *blackwarpwidth*, then it is black, otherwise it is white.

If a warp thread is visible, it is black if:

$$(x \,\%\, warpwidth) < blackwarpwidth$$

By the same token, if a weft thread is visible, it is black if:

$$(y \,\%\, weftwidth) < blackweftwidth$$

Otherwise, the intersection will appear white.

The equation to calculate the twill can be combined with the calculation to determine colour to generate the intersection colour of a generalised houndstooth. To reiterate the variables:

Twill parameters

over: the number of warp threads the weft crosses over
under: the number of warp thread the weft crosses under
shift: the number of warp threads the pattern is shifted for each row
twillwidth = *over* + *under*

Colour parameters

warpwidth: the total width of the basic warp pattern (black + white)
weftwidth: the total width of the basic weft pattern (black + white)
blackwarpwidth: the number of black threads in the basic warp pattern
blackweftwidth: the number of black threads in the basic weft pattern

From the previous section, given an intersection $P(x,y)$, the weft is showing if:

$$([(x + twillwidth) - ((y \% twillwidth) \times shift)] \% twillwidth) < over$$

and it is black if:

$$(y \% weftwidth) < blackweftwidth$$

The warp is showing if the first statement is false, and it is black if:

$$(x \% warpwidth) < blackwarpwidth$$

If none of these is true then the intersection is white.

The colour of any intersection $P(x,y)$ of a generalised houndstooth can be determined with a known twill pattern and thread colouration, which could be represented by the following pseudo code:

```
IF [[(x + twillwidth) – ((y % twillwidth) × shift )] % twillwidth] < over
    AND (y % weftwidth) < blackweftwidth
OR IF (x % warpwidth) < blackwarpwidth
THEN P(x,y) IS BLACK
OTHERWISE P(x,y) IS WHITE
```

4.5 Optimisation

The first version of the software calculated the houndstooth in this manner, determining the colour of each intersection. It became readily apparent that this was incredibly taxing on the computer to calculate the value of each intersection. For a display of 880 pixels by 400 pixels, the software calculated the colour value of 352,000 pixels. This generated some interesting and impressive visual garbage, such as this:

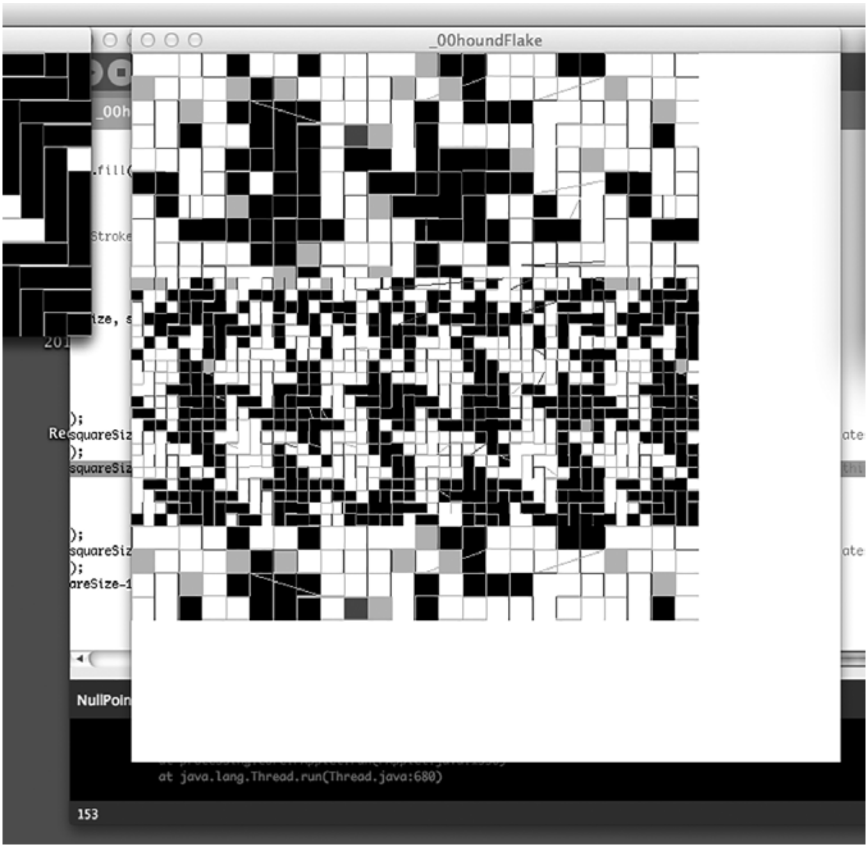


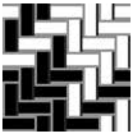
IMAGE 4.2 **The houndstooth software breaking under the weight of its own inefficiency.**

It may be interesting to revisit older versions of the software to explore the glitches created by inefficient software, but that was not done in this research. The objective was to create a system that could explore a space of patterns whose basic structure was dictated by a houndstooth structure. The code required refining and optimising to make it possible to navigate the space of possible houndstooth patterns without crashing the computer.

The solution to this problem was an optimisation of the code, so that the software could produce the same results while performing fewer calculations. Houndstooth and other textile patterns appear to be repeating, because they *are* repeating patterns. This was used in the optimisation process, to calculate the smallest version of a given houndstooth pattern that could be then tiled across the display.

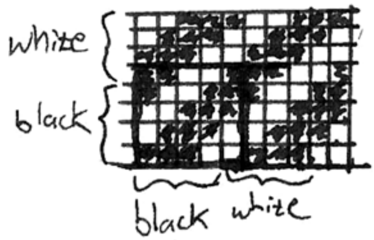
The houndstooth pattern was dependent on the width of the warp and weft colourations, and the width of the basic twill pattern. The width of the smallest houndstooth pattern was the least common multiple of the twill width and the warp width, which is the lowest number divisible by both numbers. Likewise, its height corresponds to the twill width and the weft width.

For a basic houndstooth composed of a *twill*(2,2,1) twill with a twill width of 4, and a warp and weft width of 8, the least common multiple is 8. Its basic square looks like:

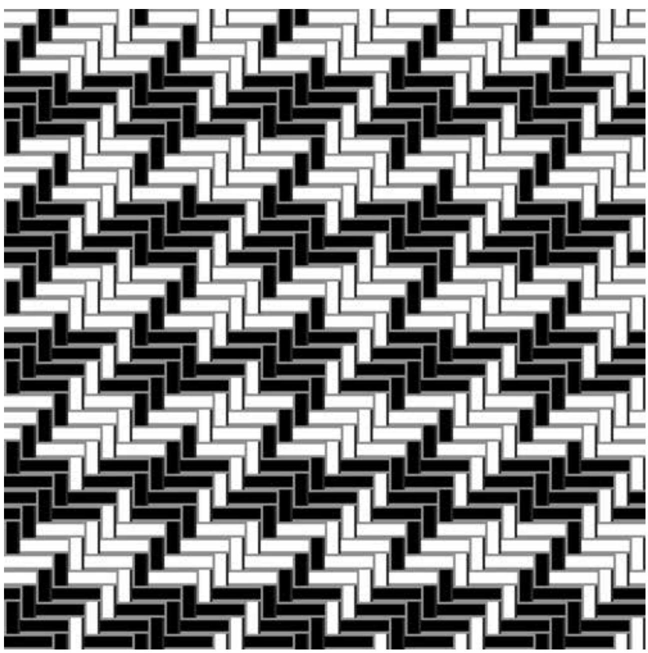


And in full, tiled, it looks like this:

In comparison, when considering *twill*(3,2,1), with the same basic yarn colouration:



The twill width is 5 and the warp and weft widths are both 8, and thus the lowest common multiple is 40. The basic pattern looks like this:



This size difference from a standard houndstooth is immediately obvious, and its visual difference becomes more obvious when the pattern is tiled:

When the software was reconstructed to tile a smallest houndstooth pattern, it then behaved smoothly.

4.6 Navigation with a controller

Navigation of the space of houndstooth patterns was tested using several different techniques. The first was in mapping the coordinates of the computer mouse to parameters of the houndstooth. The x and y values of the mouse would control, for example, the *up* and *down* parameters of the twill. The mouse coordinates could be mapped to other parameters by pressing a key on the keyboard, such as the black–white colouration of the warp or weft.

The mouse interface proved limiting for exploring the full range of the parameters of the houndstooth in a natural way. The second control method was to use a MIDI fader controller. Because most MIDI fader boxes are so similar in their design, the same effect could be had with almost any, but the experiment used a Korg nanoKONTROL. Three faders were assigned to the twill parameters, four rotary knobs were assigned to the warp and weft colouration (the width of the black and white portions of the yarn), and a final knob was assigned to zoom in and out of the pattern. This allowed for a more performative interaction with the houndstooth pattern.

The final method of navigation sought to achieve a more natural interaction with the pattern. This method used a Nintendo Wii Remote, which functioned as a readily available accelerometer and gesture controller. The pitch, rotation, and other movements of the Wii Remote were directly mapped to houndstooth variables, allowing a user to sweep and tilt through the houndstooth space. When depressed, the trigger of the Wii Remote controlled zooming of the pattern. This tool was used for an impromptu workshop at the Swedish School of Textiles with bachelor's level textile-design students, though the workshop was not a deliberate action of this research and was not documented.

Each control method allowed for a different kind of navigation of the space of houndstooth patterns. The mouse and keyboard created a more deliberate navigation of the pattern space, where the manipulation of a single parameter could be examined. This is represented in some of the images at the beginning of this chapter, where often a single parameter is changed by increments.

The MIDI controller allowed for a concurrent, multi-dimensional navigation of the space. It felt more like performing the space of patterns. The visual results appeared more like animations, or organic, almost living, alterations of the patterns.

Although the Nintendo Wii remote was intended to be an interface that was more “natural”, in that it used gestures of the body to navigate the space, it felt more unwieldy than the other interfaces. The navigation did not feel intuitive. It felt less predictable, and so it was less possible to revisit patterns that had previously been generated, or to know, in a performative sense, what effect a certain gesture would have on the pattern. This could be potentially remedied by two different approaches.

The first is that perhaps the mapping of the houndstooth parameters could be mapped differently to the axes of the Nintendo Wii remote. This could be done by simply shifting the parameters. The choice of mapping of the parameters was not carefully considered, and so it was not considered whether, for example, the yaw of the remote was best suited to the twill *up* parameter, or the twill *shift* parameter. All of the twill parameters, except for the zoom, were also assigned in a linear mapping. For example, if the tilt of the remote has a range of 180°, and the twill *up* varies between 1 and 19 steps, each 10° of the remote tilt would change the *up* parameters by 1 step. Certainly mapping the parameters using an exponential or logarithmic mapping would feel differently to the user, and has the potential to feel more natural. The mapping could also be done to first-order derivatives of the parameters, rather than the parameters themselves. The tilt could control, for example, the speed at which the twill *up* parameter is changing, rather than the parameter itself.

A second approach to solving the problem of the Nintendo Wii remote feeling unnatural, is to simply allow the user more time to acclimatise themselves to the controller. In the same manner that a beginner musician must spend time learning an instrument for it to feel natural, it may be possible for a user to develop an intuitive sense of the original mapping of the Nintendo Wii to the houndstooth parameters.

Experimenting with the mapping, and allowing a user to develop a performative instinct, are directions that future research can take to better explore this relationship between interfaces that control houndstooth and other textile patterns.

4.7 Seeing many things at once

In *The Sense of Order*, EH Gombrich based the need for ornament and its aesthetics on the biological need for seeing patterns and seeing the deviations from these patterns. It could also be that there is another biological motivator, which is to convert the world into patterns that turns it into a system understandable by us. Houndstooth presents itself as a strong visual statement. Why am I so drawn to houndstooth?

Houndstooth has been popular because it satisfies our need for recognizing patterns and deviations, as pointed out by Gombrich. Pattern is something present in other common visual structures. Checkerboard is a pattern symmetrical in almost every axis, and houndstooth is a member of the *check* family of textile patterns. Houndstooth is also a *counterchange*, familiar in the paintings and illustration of M. C. Escher, where the negative space created by a repeated pattern is an identifiable pattern in itself.

Both checks and counterchange have a strong place in patterns in human history, likely because they satisfy these aesthetic qualities that the human mind finds so fascinating.

Gombrich discussed the psychology and physiological processes of examining pattern. What is the eye able to resolve? What happens when the resolution is so fine that the eye no longer sees the artefacts as objects themselves but in texture? What happens in that transitional period between texture and detail?

This transitioning of detail to texture is important in the application of houndstooth. Houndstooth exists in many scales. As a chunky weave often found in outerwear it presents itself as a checkerboard, a configuration of black splotches on a white surface, or vice versa. As a fine weave—often found in scarves, ties and jackets—it is a shimmering grey. If it is very fine, it is grey. If it is a medium weave, it scintillates in that zone between texture and detail as the eye tries to resolve it. Although this is medium in size, it is what Gombrich referred to as the "extreme" of the perceptual zones, where the mind cannot decide whether it sees objects or texture.[100]

This is houndstooth at its most interesting, and it is often these forms and scales of the pattern that I linger on when playing with the software. Furthermore, in my working with the pattern, it appears that each has its

100 E. H. Gombrich, *The Sense of Order: A Study in the Psychology of Decorative Art*, The Wrightsman Lectures 9 (Ithaca: Cornell U.P, 1979), 95.

own perfect scale, the size at which the pattern's effects are the strongest. Why is this?

Satin does not function like this. Satin is a pattern that was never meant to be resolved as a series of objects. Because its construction means that it is primarily only the warp or weft that is showing, there is not the opportunity for the same kind of brightness interference of the black–white houndstooth check. The artefacts in satin are the individual threads, each of the same colour, and almost never large enough to be resolved as objects in themselves—although *Powers of Satin* was an attempt to create an instance where that was not the case. It is now obvious to me that the use of 3-ply rope, with the plies fully visible, interfered with the attempt of making the satin visible.

Satin is, in its purpose, a texture. Its function of shininess exists because the resolution is so fine that it appears as a texture. As a series of threads it is not particularly interesting because it loses many of the visual and tactile qualities for which it is prized.

The work with the software, and the weaving of the patterns, shows not only a multitude of numeric options—the many possible patterns—but a multitude of aesthetic options. The software was created to navigate a numeric space, but in doing so created the ability to navigate a parallel aesthetic space. The aesthetic space is not predictable in any way. We can know that a houndstooth cousin exists with *twill*(14,4,6), but we can never know what it says until we get there. Even the woven piece will differ drastically from the sterile representation of the screen. The scale of the pattern slips over a surface of visual interpretations, but the physical weaving of the pattern—with its possible material choices, thread-spin direction, packing density, dye intensity, to name a few—enters an entirely new world, one that could never be predicted by the machine. Just as George E.P. Box reminded us that all models are wrong,[101] these pattern numbers are only a model of what is.

Each individual set of numbers is not really a pattern, but it is the boundaries of an aesthetic and physical space. Each set of numbers is also a seed, the first crystal, and the beginning of the space. To define the space by its numbers does not limit it to one thing, it allows the pattern the possibility of being many things at once.

101 George E. P. Box and Norman Richard Draper, *Empirical Model-Building and Response Surfaces*, Wiley Series in Probability and Mathematical Statistics (Wiley, 1987).

4.8 Conclusion

This chapter explored houndstooth as a textile subject for the application of techniques from new media art, in the pursuit of exploring creating possibilities in such a transfer of strategies. The work that preceded this chapter explored the use of techniques from glitch art, such as the insertion of error into algorithms. This chapter explored opportunities for performative aspects of data manipulation.

The work presented in this chapter also differed from the previous work with error in that it differentiated between the woven pattern, and the appearance of the textile. This was necessitated because of houndstooth's dependence on yarn colouration. While satin is a woven pattern, houndstooth is a visual effect that arises from a specific warp and weft colouration pattern, woven using a specific twill pattern.

This chapter presented the techniques for constructing an algorithm that would generate a visual houndstooth effect, presented as the combination of a collection of different algorithms that each generated a portion of the needed information to create the houndstooth effect. This required an algorithm to create a generic twill weaving pattern, whose parameters could be manipulated. It also required an algorithm for processing the yarn colouration, and determining the colour of a given thread intersection. The combination of these two processes produced the houndstooth visual effect, as well as a space of possible patterns generated by the houndstooth pattern as a basic template.

Throughout the creation of these algorithms it was necessary to optimise the houndstooth-generating algorithms so that they could be manipulated by a user. The original algorithms caused the software to produce erroneous visual artefacts and to crash. This was identified as a possible future avenue of exploration, in keeping with the aesthetics and values of glitch art, but was not pursued. The optimisation was achieved by calculating the smallest possible unit of a generic houndstooth repeat, and tiling this pattern across the display screen. This perhaps is a new contribution to knowledge, the calculation of the smallest unit of a pattern related to houndstooth. Weaving texts have not been found that discuss the need for such an evaluation of the houndstooth pattern. This may be because the approach to patterns such as houndstooth on a physical loom is different to the process engaged in here. Looms cannot crash, as software crashes. Construction of a houndstooth or related pattern is a matter of choosing yarn colours and tying of the loom's heddles, and so the smallest possible houndstooth unit may be of less, or no, concern than the visual effect of the pattern. The software also generates patterns that may be unweavable, or not practically weavable, due to their long floats and other issues related to thread and packing density.

This chapter also presented methods for performing or navigating the houndstooth algorithms, including a mouse–keyboard combination, a MIDI slider box, and a Nintendo Wii remote. Each presented a unique approach to the performance of the pattern, with their own strengths and weaknesses. Methods for further exploring the mapping of the controllers was also proposed, though not explored in this research.

5. Conclusion

This work began with a proposal that the techniques from new media and glitch art could be applied to the encoding of textile objects in ways that were generative—and that could be used to create new objects and forms within an artistic or design practice. The original proposal was based on several cultures of practice and their features that made this proposal seem possible, and specifically they were new media art and its subgenre, glitch art, and the techniques of weaving and hand knitting. This conclusion will first present a brief overview of the cultures and their features, then an overview of the specific products and findings of the research, concluding with commentary on what subsequent research can be done that builds upon the work presented here.

The first practice presented was that of new media art, and of my position as a new media artist familiar with its approach, strategies and techniques. The research outlined some of the history of "new media art", an umbrella term encompassing a broad range of practices and cultures. It was proposed that Lev Manovich's Principles of New Media could be used as a tool for identifying principles that were also important to general practices in new media art, and would be shown to be relevant for the treatment of textile notation and coding later pursued in this dissertation. Manovich's Principles were intended to describe qualities of "new media objects", not necessarily related to the practice of new media art. The new media object is, for example, the JPG image, which Manovich proposed is drastically different from the image on the film negative or printed on a substrate (such as paper or canvas). The existence of the JPG image as a code, rather than a physical image, combined with computational power, allows for it to exist in an entirely different manner than a physical image might. The Principles outlined by Manovich illustrated the ways in which the new media object is different than the physical media object, and the implications that these principles enable.

Through examples of artwork provided in Manovich's *The Language of New Media*, and others provided in this dissertation, it was shown that these principles identified by Manovich are of importance to the practice of new media art, and constitute a way of examining and treating coding and notation of objects. The new media art techniques used to treat the code of digital objects have been used to treat traditional coding, such as written text. It was suggested that these techniques could be used in similar ways to treat traditional textile codes, and that this may have creative possibilities.

The techniques employed in much of the research presented in this dissertation borrow from the subgenre of new media art known as "glitch art". Glitch art was presented here as a way of exploiting the error of digital systems for creative expression. Glitch art practitioners are interested in the creative possibilities of error in digital systems. Error can be an aesthetic, but the glitch is also a phenomenon that reveals a system that might have otherwise been hidden or ignored. With the rise of digital technology through the 20th century, many glitch artists see the art form and the artefacts of error as a way of revealing the systems that control daily life. Artists working within glitch art employ strategies that disrupt autonomous digital systems, and also emulate them. Moradi divided these into the categories of "pure glitch" and "glitch-alike",[102] that is, "genuine" error from a system failing, and expressions that mimic the expressions generated by genuine error. Artists working with glitch have employed different strategies, such as deliberately confusing media codecs by manually editing JPG image files, or removing keyframes from video files to confuse video codecs, known as "datamoshing". Artists also use conventional methods to create artefacts that mimic the forms of glitch. The work of Rosa Menkman or Jon Cates often employ typesetting that appears to be the result of glitch, such as employing non-Roman characters that suggest Roman characters, or graphic design that appears as though the text is degrading. This is all meticulously constructed to appear as though a system is degrading, when it is not.

102 Iman Moradi, 'Glitch Aesthetics' 2004, 8.

Glitch has been applied to textiles, sometimes labelled "glitch textiles". Artists have rendered digital glitch in media such as weaving and knitting. Some artists embrace error in textiles in their expressions, such as Melissa Barron's woven 8-bit computer imagery, and Nukeme's digital manipulated machine-woven knitted lace. The use of textiles in glitch art has often been that of display medium, where glitched digital images are rendered in computer-controlled weaving or knitting machines. The treatment of the textile code using algorithmic can be seen in in the mid-20th-century weaving of Ada Dietz, who used various polynomial equations to determine the values of aspects of a loom's configuration, generating and range of novel expressions in the woven fabrics. The Weaving Codes – Coding Weaves project, ending in 2017, also took an algorithmic approach to various textile techniques. Weaving Codes was specifically the result of craft-minded computer programmers approaching the codes and methods of various textile techniques.

Knitting and weaving are generations-old textile practices that are often seen as important to the history and development of computation because of the mechanics developed for early automated weaving machines and the role of these mechanics later in computing machines. These textile techniques are the product of a limited number of elements arranged in strict, ordered, and repetitive systems. With hand knitting, two knitting needles and a single length of yarn are used to create a complex knot-work by repeating and sequencing a very small collection of possible knots. With weaving, a grid of orthogonal yarns are combined by controlling the overlapping of the intersection points of these yarns. Because both of these practices are highly structured, they have also created highly-structured notations. This structured notation is a form shared with computation and digital media encoding. Computer science and new media art has developed strategies for treating the structured encoding of digital and new media objects, and it was this shared form that allowed for the application of techniques from new media art to the objects of knitting and weaving.

In transferring strategies from new media art to knitting and weaving, this work has demonstrated the viability of employing methods traditionally employed to interpret and manipulate digital data to the traditional coding of weaving. The work created several algorithms and pieces of software that demonstrate ways that this can be achieved, and the use of such methods as techniques for generating unique modes of expression.

This strategy opens itself to other methods that manifest themselves from such an approach, such as the exploiting of glitch and "error" in the construction of such algorithms. By constructing algorithms to generate satin weaving patterns, and inserting forms of error—or deviation from a standard satin pattern—it was demonstrated that this approach leads to modes of expression that exist in the notational layer, and this also translates to unique modes of expression when the notation is woven. Specifically this was shown with a satin structure, but it would likely work with other woven structures.

When treating the houndstooth weaving pattern, it was shown that the parameters of woven patterns can be interpreted as variables in pattern-generating algorithms. These variables can be manipulated to navigate a space of related patterns defined by the original source pattern. This approach also allowed for a performative expression when manipulating the parameters. The mapping of parameters responsible for the generation of a houndstooth weaving pattern to performance controllers—such as the Wii remote and the MIDI slider box—allowed for a manipulation of the houndstooth pattern that was both performative and navigational. This construction can be used to perform digital models of the weave, to use the basic construction of a twill combined with banded yarn colouring as a set of boundaries for an expressive space that can be performed within. This parameter manipulation was also shown to be navigational and exploratory. This technique allowed for the "discovery" of other weaving patterns related to the basic structure of the houndstooth, and it was shown that these patterns can be woven, allowing for the expression to exist within its domain of origin, weaving, and not just in the digital and on the screen.

The research also demonstrated several smaller findings. The piece *Sticks and Stones*, where a game of Go was played by using knitted structures to substitute for the board and piece, showed that although new media objects and knitting and weaving notation are highly structured, this does not mean that all transfers of strategy from the digital to the textile will yield desirable results. Specifically with *Sticks and Stones*, the use of the grid to connect textile techniques and other tasks that use the grid may sometimes end unfruitfully. The grid is a useful structure and metaphor for many activities, such as computation, but it is an incomplete one, and activities that rely on the grid as a unifying feature will potentially face problems that make such a union unsuccessful. In *Sticks and Stones*, this led to a game that became unplayable due to the disintegrating structure of the knitting, and of a losing strategy when structures from knitting were used as a strategy for playing Go with a traditional board and pieces.

Critters, a piece that illuminated the bobbins of an industrial lace machine, demonstrated a technique for observing and analysing the movement of bobbins in a lace pattern. Long-exposure photographs demonstrated areas of density and activity in the bobbin movement, and by extension, in the pattern creation of the lace. *Critters* presented ways in which techniques from new media art can be used to analyse the movements that create textile structures. Adorning a machine's moving parts with lights is often a technique for aesthetic augmentation, but the artwork and the subsequent long-exposure photographs demonstrated that these techniques can be used to gain information about the pattern's creation and densities of movement and activity in the textile creation.

The work presented here is a beginning of the application of the sensibilities of new media art to several textile techniques, and each of these explorations suggest further exploration.

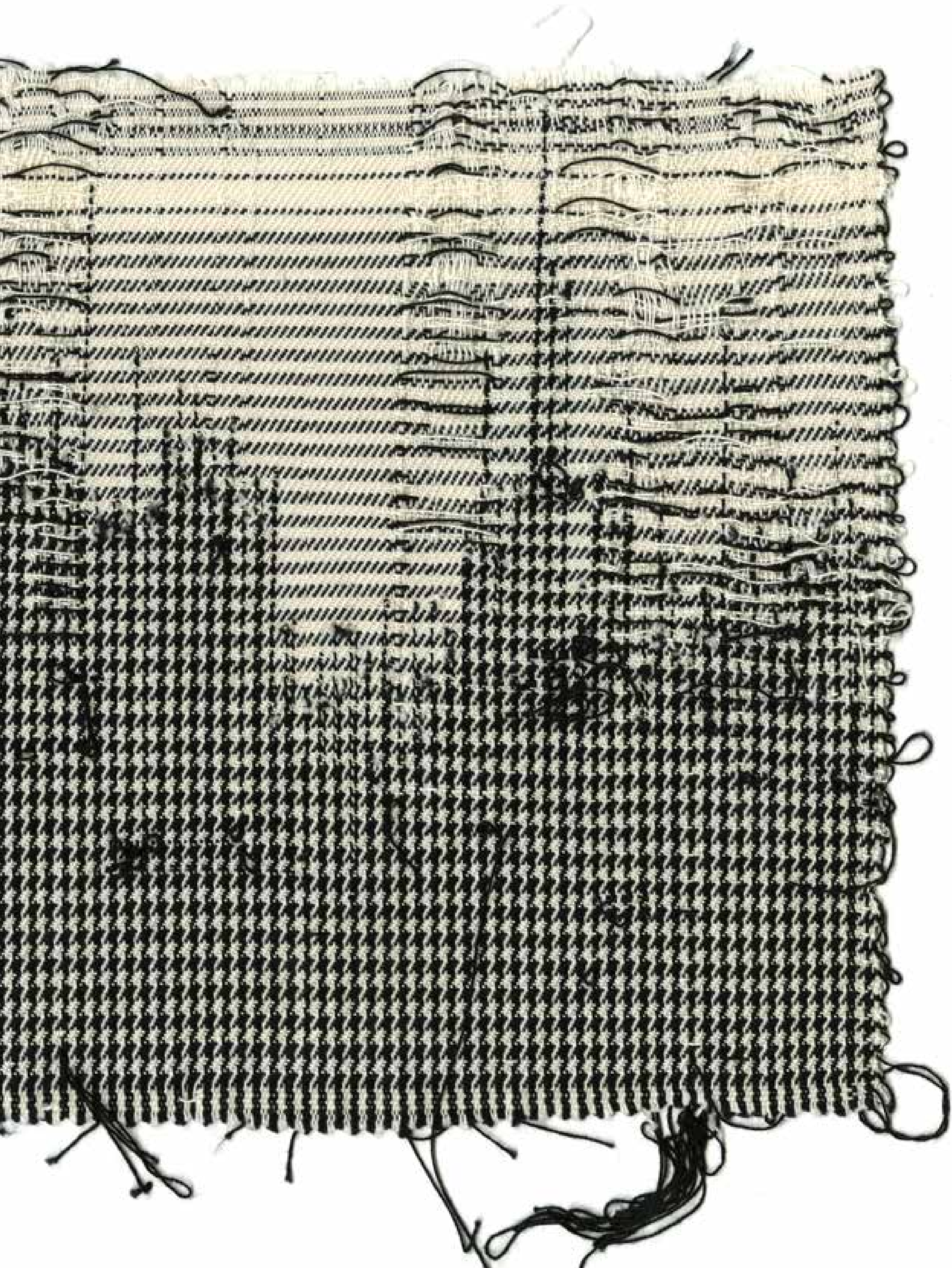
Sticks and Stones should be repeated with a change of several parameters to explore the potentials of the strategy. The multi-strand yarn specifically obstructs perception of the stitches as game units, and other yarns should be experimented with to compare their impact on the visual result, specifically single-strand yarns. The knitting techniques should also be modified. The pieces were knitted with a kind of blend of stranded and intarsia techniques, although the structural integrity may be better if the swatches were knitted entirely in a stranded technique with the unseen colours being carried at the back of the piece. The structure of the swatch can be changed, such as by removing or modifying the borders. Can the game be played with other textile techniques? How is it different when attempted with crochet or weaving? When stranded knitting patterns were used to play a game on a traditional Go board, the technique was unresponsive to the opponent's moves. Hand knitting is responsive to qualities such as tension, so what would the game look like if the player using the knitting structures was allowed to play in a more responsive manner?

If *Powers of Satin* were performed again, what other forms of error might arise? The piece can be repeated with other material. The multi-ply rope disrupted a visual integrity, adding noise to the piece, even though it reflected a multi-element spun silk yarn that might be used in a standard, woven silk satin. Several materials were explored before choosing the rope, but what other materials are available, and how would they affect the qualities of the piece? I conducted some informal experimentation with the woven piece off of the loom, improvising with it physically, rolling and wrapping it on my body and objects, but a more thorough analysis may uncover qualities of the physical piece. Can there be functional uses for it?

In exploring the satin error, it is worth determining what other forms of error are possible, exploring the space of possible expressions. The error systems that were examined in this dissertation could be examined more systematically, investigating the change in qualities from the change in parameters, specifically paying attention to the tactile qualities of the pieces. The material was a single kind of cotton, but how do the error systems react to different materials? There was also no analysis of the error systems' impacts on the suitability of the textiles for use. Can the products of the error systems be used in textile and garment design? How do they affect the suitability of the textile for different applications? Do the qualities of the error make the weave *more* suited to other possible applications? Can they be used expressively?

The houndstooth exploration showed what could be accomplished with a single woven pattern, but it can be extended to other woven patterns. It could also be extended to other textile techniques, such as knitting or crochet. The digital interface navigating the pattern space suggested something performative, though it was never used in such a context, and I would like to attempt to develop a performance using the software. If it is, in effect, an instrument that has been created, how would this be used by other creators and performers?

The work presented here is the beginning of an exploration of transfers of strategies from digital codes to the codes of textile techniques. It has shown that there is a capacity latent in knitting and weaving for this kind of treatment, and that these kinds of transfers of strategy can be generative in ways that can be useful in an artistic practice. This thesis work has given me the opportunity to immerse myself in textile practice, to acquire these skills, and to have gained a more nuanced understanding of textiles and their practices. I hope that textile artists and designers might discover an expanded pallet of techniques, and that new media artists might discover new ways to break free from the machine. Or, at the very least, to pick up a pair of knitting needles and a ball of yarn and re-evaluate the garments on their bodies.



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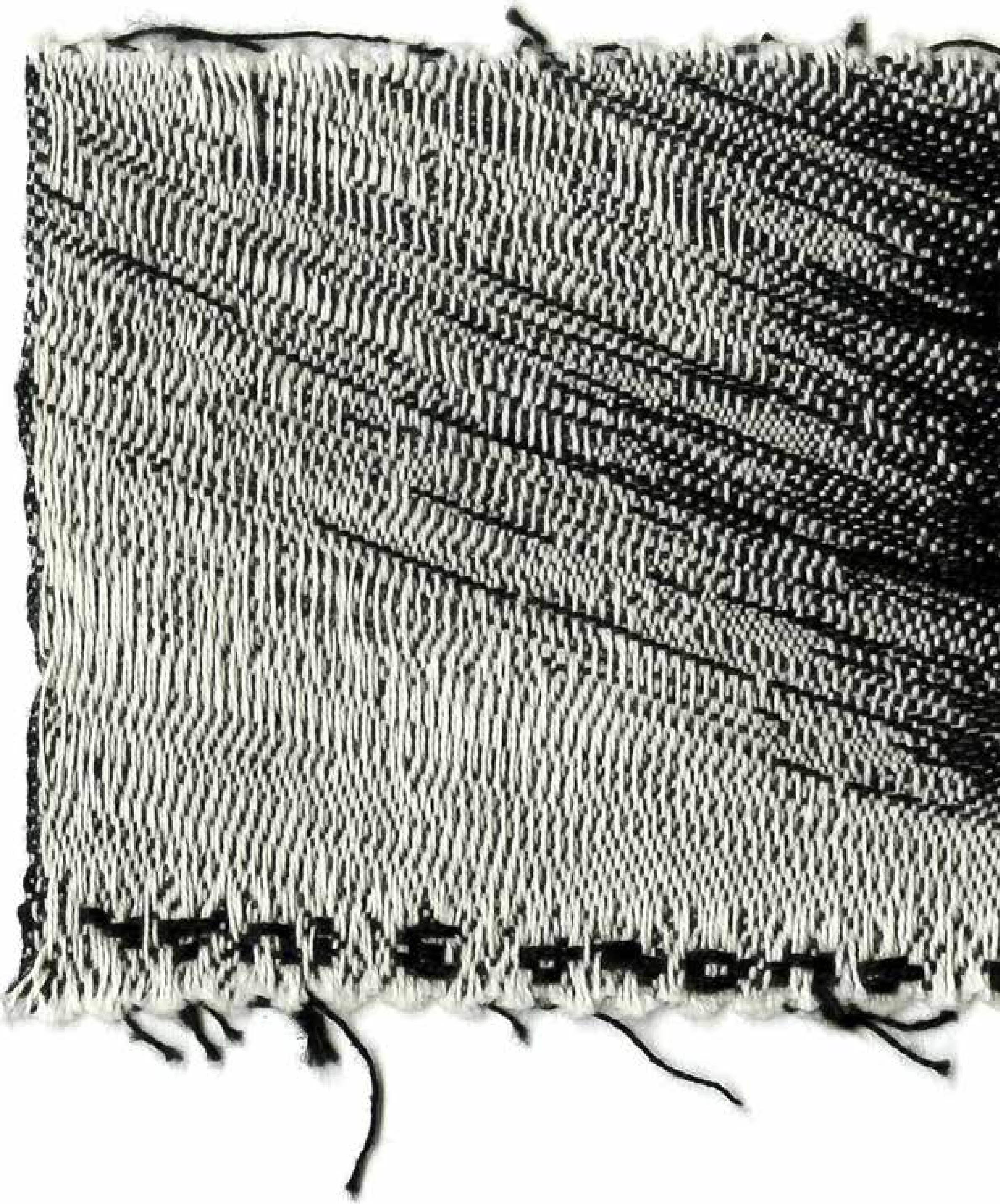

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