Weaving is a Way of Doing Math

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Abstract

In this essay, I specify some of the ways that the planning and execution of woven cloth require a distinctive kind of mathematical thinking. Three aspects of my weaving practice are interrelated: first, making connections between ideas means finding inspiration and making colour and aesthetic choices. Second, reasoning involves the mathematical skills of working with numbers, patterns, and geometries. Third, modelling is the actual making stage. Doing mathematics in a weaving practice is inseparable from the physical activity of manipulating the threads. Weaving is a game of patterns: as much as it is my way of producing woven cloth, it is my way of doing math.

Introduction

Weaving has sometimes been called an art practice by writers and theorists in the visual arts [2][5], but it has more often been considered a craft activity—with all the hierarchy of values these terms imply [3]. For a time in the twentieth century, weaving was also considered an excellent form of occupational therapy [3]. None of these characterizations completely captures the practice. I propose an alternate view: weaving is a way of doing math. In this essay, I specify some of the ways that the planning and execution of woven cloth require a distinctive kind of mathematical thinking.

Planning any cloth of more than the simplest structure demands that the weaver knows where every thread of warp (the set of threads held taut by the loom) and weft (the threads passed through the warp to make the cloth) will go (Figure 2). Numeracy skills are a must: even one thread out of place results in a glaring and obvious error in the finished fabric. Nevertheless, weaving as a way of doing math goes far beyond the ability to count threads.

Mathematical thinking has problem solving at its core. Educator Kaye Stacey lays out a framework for mathematical problem-solving that involves “reasoning, modelling, and making connections between ideas” [9]. I compare these cognitive processes to three aspects of my weaving practice that are closely interrelated, and I list them in the order they are dealt with when planning and achieving a weaving project. First, “making connections between ideas” means finding inspiration and making colour and aesthetic choices. Second, “reasoning” involves the mathematical skills of working with numbers, patterns, and geometries. Third, “modelling” is the actual making stage of a project. Dexterous skills are important in this phase. These three aspects of weaving are intertwined, and they usually overlap or even occur concurrently. They are reciprocal—one process cannot be considered in isolation from the other two.

Making Connections Between Ideas

Mathematics and weaving both have deep roots in antiquity. Each discipline builds upon millennia of human knowledge and creative problem-solving. Therefore, a first step in weaving, as in math, is to find inspiration in what has been done before.

I often turn to two sources to stimulate my notions of shapes and colours for a weave design. One source is the mid-century artist Anni Albers [6],[1] and the other is the body of work known as the quilts of Gee’s Bend [4].[2] Albers deeply mined the geometric nature of woven cloth for her designs. She was also interested in knot theory, a branch of topology, and made several drawings of interlaced threads [6]. The quiltmakers of Gee’s Bend, while perhaps driven primarily by their need to keep their families warm, nevertheless consistently worked out complex configurations of the plane in their quilts.

Reasoning

What kind of mathematics does a weaver use in designing, calculating, and making a piece of cloth? My viewpoint here is not that of a mathematician. Rather, it is of a maker who uses mathematical principles and practices because they are inherent in and necessary to the achievement of a woven piece of cloth. Counting and calculating, proportions and ratios, geometry and patterns, and modular arithmetic are the ones I use the most.

Counting and calculating numbers of threads is essential to weaving. I constantly add, subtract, and multiply numbers in a prospective project to adjust the numbers and sizes of motifs that will fill the space of the cloth that I can weave on my thirty-two-shaft loom. Prime factorization is important here: dividing a number down to its primes tells me how many motifs I can arrange evenly across the warp. If I am designing a series of graduated colours in the warp threads, I use proportions and ratios: for example, to change from blue to green I would organize the threads left to right in 5-thread colour sequences of 4:1, then 3:2, then 2:3, and so on, to make one colour appear to shade into another (Figure 1).

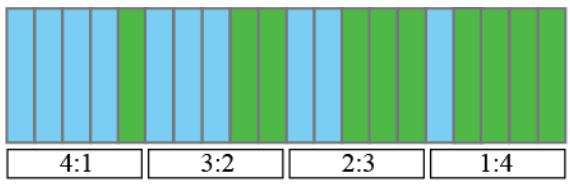

Figure 1: *Ratios of colour changes in a graduated warp. Drawing by the author.*

In any artistic practice, pattern design starts with a clear understanding of media and tools and what can be accomplished with them. At bottom, weaving is binary: like machine languages of zeroes and ones, a warp thread has a binary choice: it can only be held either up or down. The weft threads can only travel over or under the longitudinal warp threads stretched on the loom frame. Given this binary nature of the threads' interlacement, patterns are made possible through the grouping of the threads, so they pass together over and under one another. They do this on a shaft loom by being threaded on needles, or heddles, on rigid frames called shafts (Figure 2).

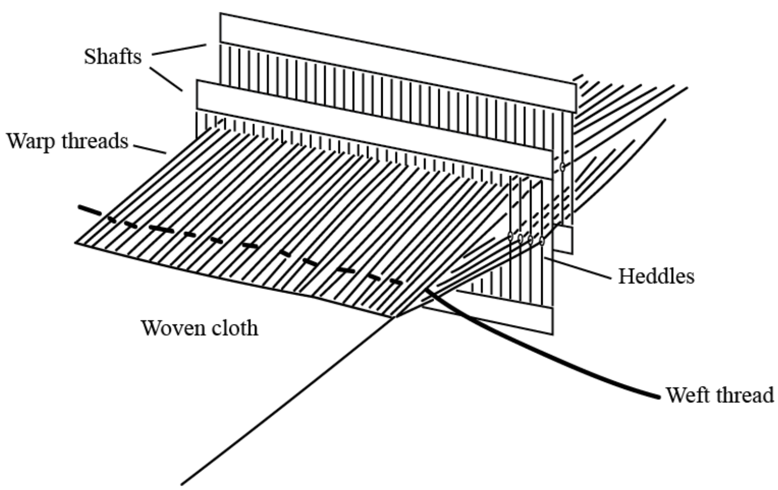

Figure 2: *Diagram of a loom. Drawing by the author.*

Woven cloth is patterned by its structure, not by printing on its surface. The pattern ranges from the simplest over-one, under-one of plain weave, all the way up to each thread being raised and lowered individually, as happens on a jacquard loom. The level of detail in a weave design is controlled by the right-angled grid of warp and weft threads; just like a pixel on a computer screen, the interlace of one warp and one weft is the smallest unit of design. In the design process, images with fine detail must be converted to a grid whose size is determined both by the thickness of the thread and by the number of shafts available for raising and lowering the threads, as discussed by Ahmed [1]. The requirement of designing for the grid explains why weaving lends itself so well to geometric patterns.

Modular arithmetic describes a number system that is limited to a set integer, called the modulus. A mathematical operation may seek a remainder after an operation is performed; for example, on a twelve-hour clock, four hours after nine o'clock is one o'clock since the clock goes around to the start after twelve hours with a remainder of one. This operation is written: 9 + 4 = 1 mod 12, where 1 is the remainder.

How does this relate to the technology of weaving? I am interested in how many repeats of a pattern can fit into a modulus with no remainder. A shaft loom is a modular machine. Four shafts are modulo 4, eight shafts are modulo 8, and so on. The weaving draft in Figure 3 is for a twill pattern seen in cloth everywhere, most notably in denim jeans. The twill line is continuous, but the pattern sequence goes up to shaft 4 and then swings back down to shaft 1, again and again.

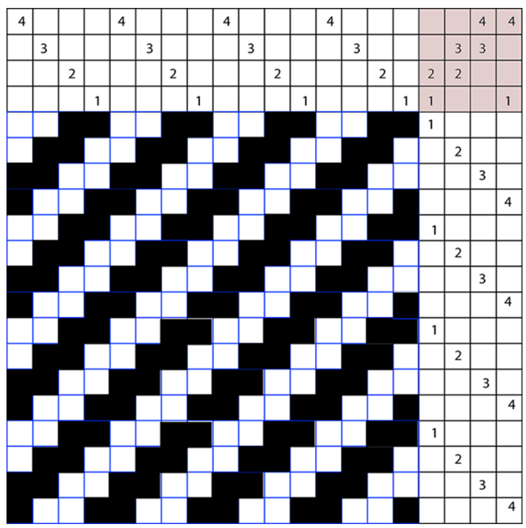

Figure 3: *A weaving draft for a four-shaft loom. Drawing by the author.*

Modelling

A length of thread, the fundamental element of a warp, is an exacting taskmaster. Each thread must be kept taut, and all threads must be held in the exact same tension. This prerequisite to weaving led to the development of the loom, whose primary function is to hold the warp and keep it in this ideal condition [2]. Furthermore, textile materials are governed by physical forces that make them behave in ways that can work against the will of the weaver. Slack threads tangle, linen yarns break in dry weather, and uneven warps spring out of alignment. A weaver does not impose her design on inert matter but works with the properties of the material.

Anthropologist Tim Ingold proposes a process of making that occurs in a relational field of maker and material, out of which comes the finished product produced by them both. He writes, "To emphasize making is to regard the object as the expression of an idea; to emphasize weaving is to regard it as the embodiment of a rhythmic movement" [8]. I take his meaning to be an affirmation of weaving itself as patterned movement of both maker and material. Doing mathematics in a weaving practice is inseparable from the physical activity of manipulating the threads. The mathematical principles are embodied in the action. Indeed, as Ingold suggests, these principles are not imposed on the activity from a cerebral plane of thought but arise from the action itself.

Summary and Conclusions

Islamic art historian Oleg Grabar writes that ornament is "a game of dividing the plane" [7]. In my practice, weaving entails mathematical thinking, and the play of puzzle-solving involved in weaving does come to resemble a game. My game is played on a grid, is executed in a constant rhythm, and repeats a sequence endlessly from one to thirty-two, around and around (Figure 4). As much as it is my way of producing woven cloth, it is my way of doing math.

Figure 4: *The 32-shaft computer-aided loom in the author's studio. Photo credit: Patricia Bentley.*

Notes

1. Anni Albers' work can be viewed at https://www.albersfoundation.org/tags/anni-albers.
2. Quilts made by the Gee's Bend artists can be viewed at https://www.arts.gov/stories/blog/2015/quilts-gees-bend-slideshow.

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