Digital Art: A Long History

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Abstract

A *digital* representation is one based on countable, discrete values, but definitions of Digital Art do not always take account of this. We examine the nature of digital and analogue representations, and draw from a rich pre-industrial and ancient history of their presence in the arts, with emphasis on textile weaves. We reflect on how this approach opens up a long, rich history, arguing that our understanding of digital art should be based on discrete pattern, rather than technological fashion.

Keywords: digital art, representation, digital art history, weaving, pattern

Introduction

A *digital* representation is one based on countable, discrete values, whereas an *analogue* representation is based on uncountable, continuous values. This is a core distinction in the design and use of Live Interfaces in the performing arts, the topic of the present conference. For example, does an interface capture digital gestures such as the flick of a switch or press of a button, or analogue ones such as the particular arc of movement taken by a hand? Or indeed, both?

When the word *digital* is used in a technology context, its use drifts from the standard dictionary definition expressed above. Instead of referring to discrete representation, *digital* is used to refer to contemporary technology in general; computers, databases, the internet, blockchain, and so on. In an online survey advertised on the eu-gene discussion forum for generative art, as well as social media, 98 respondents were asked to define the word *digital* and phrase *digital art*. Of these, 53 defined *digital* as referring to a discrete (or binary) representation, whereas 32 defined it more generally in terms of technology, algorithms or computers. This changed with the phrase *digital art*; 27 defined it in terms of discrete representation, and 52 gave a more general answer around computers or technology.[1] In wider culture, the word *digital* is increasingly used as a noun, apparently referring to 'digital industries' reliant on such technology. This vague notion of the digital is present also in digital art; practitioners know that the *digital* in digital art relates to discrete representations, but nonetheless treat *digital art* as a category or genre broadly engaged with contemporary technology. As a result it can be difficult to know what digital art is really about, particularly with technology becoming pervasive.

In the following, we clarify the nature of analogue and digital representations, and to some extent, how they relate to human perception and cognition in the making and experience of art, music and craft. In doing so we take a long view, tracing the use of discrete representations in art back millennia, in order to untether the notion of digital art from recent technology. Taking this longer view, we are able to more fully appreciate the fundamental human fascination with discrete structures, carried on through art history.

[1] For the raw survey results and our coding of them, see http://goo.gl/2gyNDR

Analogue and Digital: layers of representation

Digital is defined in relation to *analogue*, and vice-versa, so in order to continue on firm ground, we must first understand how they fit together. The analogue-digital relation runs through everything, and accordingly goes by many names: real/integral, smooth/striated, amorphous/pulsating, plane/grid, articulation/sequence, wave/particle, and so on. We cannot, however, divide the world into things which are digital and things which are analogue. For example, a tape measure is a continuous strip, but has discrete markings along it; whether we consider it a digital or analogue device simply depends on which aspect we are attending to. This is true also of the electronic transistor at the heart of modern technology; the very same transistor may be used as a digital switch or an analogue amplifier.

The psychologist Allan Paivio (1990) dedicated much of his study to digital and analogue phenomena in human cognition, conducting a great deal of experimental work to refine his Dual Coding theory. This theory holds that we experience phenomena along separate channels, where continuous images (including continuous forms in aural and other senses as well as visual) are processed separately from (and so do not contend with) discrete symbols. These analogue and digital 'codes' are experienced in parallel, and integrated into a whole experience. The human voice is a fine example of this, where discrete words are perceived alongside the continuous gesture of prosody, and integrated into a whole experience of speech. The work of Paivio and others in this area makes clear that although analogue and digital are distinct, they do not necessarily contend with one another in cognition.

So there is not an analogue world and a digital world. Rather, layers of interoperating analogue and digital representations. If we take the commonly held view that our physical reality is analogue, then the job of a electronic computer hardware is to create a digital reality inside it, by imposing thresholds on continuously varying signals, in order to create discrete states. These states are usually binary (base 2) states, following from high/low thresholds, but other bases are possible, for example the early ENIAC and Decatron computers work in base 10; a digital computer is simply one that works with discrete values.[2]

Digital computers have a somewhat fragile existence within an analogue world, battling against analogue interference and corruption, by using digital checksums and error correction. Despite this, we rightly call them digital in nature, rather than analogue. Digital computers create a layer of digital representation within an analogue one. But the layering does not stop there. Much of what digital computers do is the simulation of analogue systems, for example applying computational geometry to manipulate photographs, simulating three-dimensional worlds, or synthesising audio signals. Of course an analogue representation inside a digital one may itself host a digital representation in turn, a simulation within a simulation; digital and analogue turtles on each other's back, all the way down. If everything involves layers of both digital and analogue representation, where does this leave digital art?

The Digital in Art and Craft

A good place to look for the digital in art, music and craft, is in notation. Here notation involves discrete symbols, whether source code for notating software run by computers, punched cards for notating weave structures run by powerlooms, or staff notation for musical pitches. Musical notation is the 'odd one out' in these examples, since it is used by humans to instruct other humans, and is incomplete, in that the discrete notes are specified in detail, but the articulatory movements are not. By contrast in the oral ('vocable') transmission of instrumental sounds, for example the *Canntaireachd* (chanting) of Scottish highland pipers, and the *Bol* syllables of Indian Classical tabla players, the continuous gesture is foregrounded. Digital representation tends towards the general, and analogue towards the specific, and it is easier to notate music as discrete notes, than the continuous articulation of sound. In this shift from oral to written tradition in music culture, we see a shift from analogue to digital communication, and therefore a shift of emphasis from the specific to the general.

[2] Analogue computers of course also exist, for example early flight computers using analogue gear ratios.

Discrete musical notation is hardly a problem for instrumental musicians, because they are happy to contribute continuous articulation themselves, informed by written prompts in the sheet music. It can become more of a problem when the notation is intended for a computer; where music is translated from sheet music to computer MIDI files for playback, the lack of continuous articulation can be sorely felt. Of course in a different context this mechanistic feel can become highly desirable, for example it is core to the aesthetic of industrial techno.

As well as feeding early electronic digital computers, punched tape is also used to feed music machines, such as the music box. On close examination, it becomes clear that musical punched tape is half digital, and half analogue. In one dimension we specify the discrete notes - at any one position the hole is either punched, or it is not. However in the other dimension we specify *when* the note plays, and this can be in any position. Here the relation between digital and analogue is as clear as X and Y, literally orthogonal.

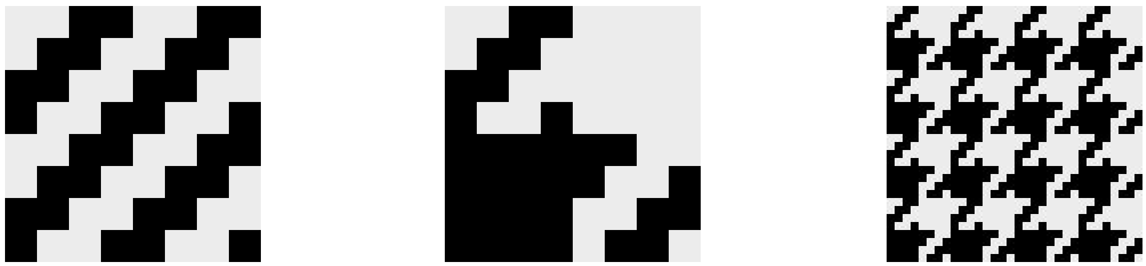
Whereas the historical development of written notation has imposed discrete scores on oral traditions (Chambers, 1980), some traditions have always been based on digital representations, one of the clearest examples being *Quipu* (or *Khipu*) once in common use in the Andean region of South America, for example used by the Inca people to record bureaucratic data (e.g. agricultural and tax records). Each Quipu consists of textile cords and yarns, hitched together into a non-cyclic branching structure, using a base-10 system of knots to represent numerical data. Quipus are not fully decoded and understood, but in modern terms, we can say that Quipu is analogous to a database, perhaps storing numerical calculations done with a *yupana* system of pebbles. Gary Urton's Quipu database (Urton, 2003) identifies several discrete channels of information; the structure of the Quipus and the arrangement of knots, but also less well-understood parameters such as spin direction, colour, material and the orientation of the hitch used. Rohrhuber and Griffiths (2017) have explored these parameters by translating them into digital pixel art and sound, emphasising the less well understood aspects.

Weaving digital interference patterns

Where the relation between textiles and computation is discussed, the Jacquard Loom is almost always raised. However, we argue that if we are to progress discussion of digital art, we should cast all thoughts of the Jacquard loom to one side. In fact there is no such thing as a Jacquard loom, but a Jacquard *device*, placed upon a traditional loom to replace the human drawboy. The Jacquard device did not make an analogue loom digital, but provided one way (among others already established) to make an already digital loom programmable. Before then, a program of discrete movements was executed by a person, without the need for electricity. Once we look beyond the Jacquard device, we see that all weaving is digital, with its own complex, binary logic (Harlizius-Klück, 2017).

Weaving has a distinct structure, indeed it is true to say that the structure of weaving is as different from other textiles, e.g. knitting, crochet, braids, as it is from the structure of computer source code. We could almost consider these five structures as equidistant. The logic of weaving is formed by the interactions between warp, under tension while on a loom, and weft, running perpendicular to the warp. Each time a weft thread meets a warp thread, it may either go over, or under it, giving weave its binary nature. In general, a weave is to a large extent 'programmed' not in the weaving itself but in the particular setting up of a loom, which sets the possibilities for what may later be woven. Warp threads may be grouped together into a number of shafts for instance, so that patterns are formed not by one-by-one selection of up and downs, but by combining groups of warp threads. The warp is lifted in these additive combinations, creating a gap or shed for the weft to pass through, but the weaver must stay aware of the structure that results, ensuring that the weave holds together, avoiding lengths of thread which 'float' above or below the weave. There are many constraints at play, which the weaver must work with and against, in order to feel their way to creating a fabric.

Colour-weave effect patterns (Takatera and Akira, 1998; Sutton, 1984; Harlizius-Klück, 2012) are of particular interest when considering the binary logic of weaving. This is where the colours of warp and weft follow their own respective patterns, which interfere through the up-down structure of the weave, to create an often surprising end result. Colour-weave effects can be strikingly complex, but Figure 1 illustrates a simple example, showing a houndstooth pattern. In this example the warp and weft are striped, both alternating between groups of four black and grey threads, but then interact with each other through the diagonal twill structure of the weave seen in Figure 1a. The resulting weave is the jagged star pattern seen in Figure 1c. This houndstooth pattern is in common use, but what we see in it is not the colour pattern of warp or of weft, or the structure of the weave alone, but an interference pattern between all three. Furthermore this is not a design dreamt up by a textile designer, but rather a visual outcome of the process of weaving.



a) A 2:2 twill weave, where warp (vertical) threads are black, and weft (horizontal) threads are grey. Each weft alternates between going over and under two warps at a time, with the pattern shifting one thread to the left each row.

b) The same 2:2 twill weave structure as in a), but where warp and weft threads change colour. The first four warp (left) and first four weft (top) threads are black, and the others are grey.

c) The same weave as b), but repeated four times (and scaled down in size accordingly). This reveals the traditional houndstooth weave.

Figure 1. The colour-weave effect of the Houndstooth weave.

Digital information has specific properties making it robust to transmission over long distances in space or through time. These properties are the reason for the gradual changeover from analogue to digital signals in the recent past, as the same information can be broadcast at lower energies. One example of this property in weaving is the ability for an archaeologist to discover a woven artefact (Barber, 1991) preserved in a burial site for thousands of years, and 'read' it to recreate the weavers actions exactly, step by step, including mistakes. It is then possible to replicate the fabric by weaving a new textile, essentially as a digital copy (a process involving various layers of notation and interpretation). Regardless of the complexity of the weave, the crossings of thread are discrete (over or under) making the information legible even in decayed samples.

In the same way it is possible to demonstrate the physical limitations of digital information using weaves. A pattern can be woven in a textile via manipulation of *tablets*, an ancient form of weaving which incorporates a discrete sequence of tablet rotations to select sets of warp threads. The specific sequence of rotations used to weave the pattern can itself be encoded as a binary string, and therefore woven in turn. This second pattern can theoretically be 'read' and interpreted in order to recreate the first one. This is a form of lossless digital compression, as the second pattern is shorter than the first, exhibiting Shannon's physical laws of information (Shannon, 1948). The compressed pattern contains higher entropy than the first, with more disorder and less visually pleasing repetition or redundancy even though the same information is represented.

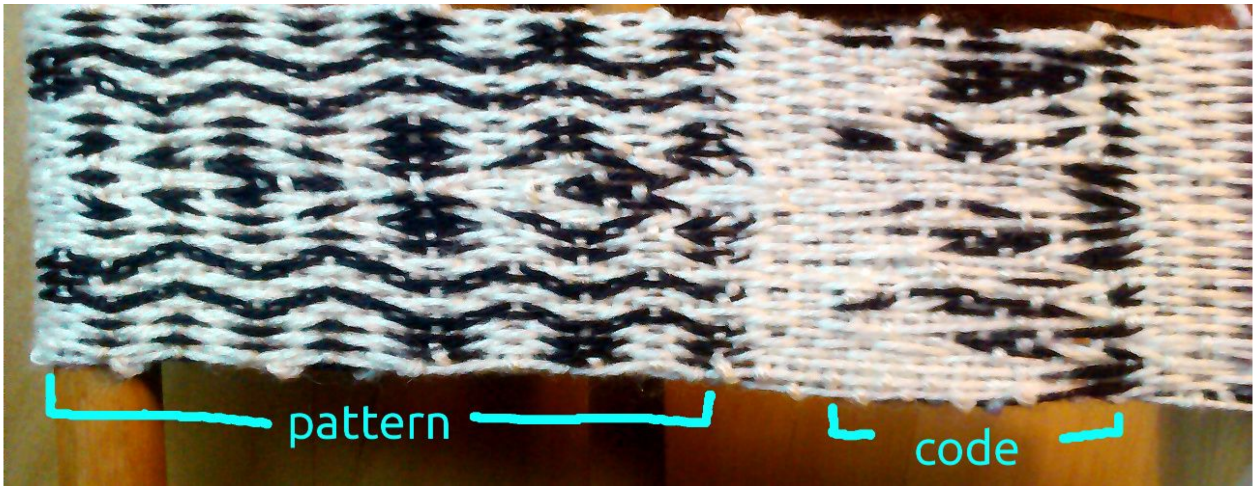


Figure 2: a pattern and its losslessly compressed digital representation

Taking the long view of Digital Art

Taking *digital* for its fundamental definition as discrete representation, we've reviewed historical examples of digital art, including the ancient craft of weaving and tablet weaving. A fair question is, what is gained by taking this approach? Why *not* simply accept the pervasive view of digital art, as involving modern computing technology?

Our argument is that taking this longer view opens up an alternative historical narrative, which is culturally richer than the one we have. As generally held, the history of computing begins in the mid 20th century, with some reference to 19th century mechanical computers. This is an industrial and post-industrial history, with its development stemming from the military motivations of ballistics calculation and code-breaking. Despite efforts to recognise the early key contributions from figures such as Ada Lovelace and Grace Hopper, this historical view of digital technology is overwhelmingly dominated by men, a tendency which is only recently begun to be widely challenged. From this viewpoint, digital art is the repurposing of military equipment for the arts (Usselmann, 2003), an association that the field still struggles to shake off.

By focussing on the affordances of discrete representation that are visible in digital art, we open up a field that runs across human history. The emphasis moves from a *digital* defined by whatever is in vogue (computer vision one day, augmented reality the next), to one which centres instead by discrete *patterns*, including patterns of imagery (e.g. cave paintings, mosaics), of textile craft (weaving, knitting, tablet weaving, embroidery), of dance (morris dancing, maypole dance), and of sound (rounds, arpeggios, inversions). These patterns breathe meaning into our lives, and connect the pattern-based digital machinations of contemporary technology, such as the shifting and combination of bitwise operations, with the pattern manipulations of the ancients. We argue that the human desire to engage with the discrete symbols of pattern is what makes us truly digital, allowing us to make generalisations and metaphorical inferences across domains.

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