Transition: re-thinking textiles and surfaces

Final paper submission for Track 1: Science and Technology

Title

Repeatless: combining science, technology and design to re-think print and pattern for the future

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Abstract

Digital technology offers a method to fundamentally change the way printed textile designs and surface patterns are created and applied. Within industry, pre-digital textile printing processes mechanically transfer the same design again and again down the entire substrate's length. The patterns they reproduce have to repeat identically and cannot be altered without stopping and reconfiguring the printer. The practice-led research in this paper firstly proposes that digital technology could allow a design to change as it is being printed. The application of dyestuff or other colour by a digital printer is controlled by data

corresponding to the design. This need not be static; the printer could be receiving constantly evolving information, producing pattern that need never do the same thing twice.

The second proposal is that generative systems be used to create evolving pattern. The possibility that digital fabric printing could remove the need for repeating pattern has been identified (Briggs and Bunce, 1995) and others have considered its implications on pattern design (Ujiie, 2006; Tallon, 2011; Bowles and Isaac, 2012). Within a textiles context, interactive design (Paramanik, 2013), the use of randomness to create non-repeating design (Carlisle, 2002), animated pattern (Richardson, 2007 and 2009) and tapestry-based applications (Sutton, 1981; Moallemi and Wainer, 2008) have been considered. However, in comparison with other creative industries such as architecture (Fraser, 1995) and graphics (Maeda, 2000) that have established areas of practice where generative systems produce design outcomes, the field has been relatively unexplored in textiles. In this research, a software application uses cellular automata, a method of mathematical modelling that allows the elements within a system to evolve in relation to each other (Wolfram, 1994). Here, the elements are the motifs or other individual images and the system is the overall design.

The final proposal concerns the rules by which the elements interact; it is here that the traditions of printed textiles can be exploited. When designing a repeat pattern, practitioners use a number of methods to ensure that the eye can roam freely over a design, balancing the arrangement and scale of the motifs, for example, or the negative space between them (Day, 1903; Bowles and Isaac, 2012). Whilst these are generally used to disguise the repetitive structure that underlies such designs, the methods have two distinctive points of interest in this context. Firstly, they determine the compositional quality of the design. Secondly, they can be quantified to a workable degree as design rules. These rules can be used to create algorithms, which can in turn be translated into the code (in this case Processing (Reas and Fry, 2007)) that forms the generative software application.

The output is a repeatless design of any length that can be saved section by section to be streamed to a digital printer for application to fabric or other substrates, exploiting the technology in an entirely novel fashion. The outcomes demonstrate a method of re-thinking print and pattern for the future, providing a new way of exploiting digital technology that is workable on an industrial scale.

Keywords

generative design, digital fabric printing, printed textile design, surface pattern, non-repeating pattern, cellular automata, repeatless

Introduction

This paper proposes a method of re-thinking how surface pattern and printed textiles are created and printed. The research behind it is practice-led and interdisciplinary, spanning the fields of science, technology and design. Science offers processes by which to model patterns with a high degree of complexity. In this instance, cellular automata are used to develop algorithms based on traditional print and pattern design processes. Technology in its digital guise offers a novel method to both create and print the designs. Software applications are developed from the algorithms and the designs they generate can be printed by exploiting a new possibility that digital printing hardware has over its forebears. The outputs reside firmly in a design context, as potentially infinite lengths of non-repeating pattern that can be printed onto fabric or other substrates. This can be done on an industrial scale using any visual subject matter and is therefore applicable to commercial use.

What follows is an overview of some sections of an ongoing MPhil/PhD. As such, there is not space here to go into full details of all aspects of the research contained within the project as a whole. The intention here is propose three new research contributions and to provide adequate context to explain their originality.

The first proposal here identifies a crucial difference between digital fabric printing technology and the industrial methods that preceded it. This difference allows a design to change during the print process, giving the possibility of outputting a pattern that never repeats. The next proposal suggests a method of creating such repeatless pattern. Designs that dynamically change in real time are created by computer programming. Whilst there has been some use of generative processes in textile design, the practice is far from being as established as it is in other creative industries such as architecture and graphic design. The programming herein applies models developed to help understand how complex systems interact in order to generate the ever-changing designs. The final proposal seeks to draw on the traditions of print and pattern design to ensure the quality of the designs and their applicability within commercial, industrial contexts. The complex systems, in this case cellular automata, use rules derived from existing design processes to write the code that generates the designs. Overall, the paper offers a new way to design and manufacture repeatless pattern, providing a transitional route that draws on a rich past, yet moves firmly to the future.

Re-thinking printing

Anstey and Weston (1997: no page number) define textile printing as the '… process of putting a pattern onto cloth by applying colour to part of the fabric'. All pre-digital printing technologies do this in a similar way. The design is a physical part of the mechanics of the printer, whether as the raised areas of a woodblock, the engraved lines of a copper roller or the mesh of a rotary screen. The process allows the design to be printed over and over again down a length of fabric. Once the technology has been set up to apply the design, it can continue to do so indefinitely. With the prevailing rotary screen method (Ujiie, 2006: 338), it is also very quick; speeds of up to 120 metres of fabric a minute are possible (Briggs-Goode, 2013: 137). This ability to rapidly cover large expanses of substrate with the same pattern is of fundamental importance to industry.

Digital fabric printing also uses a mechanical process to apply the design. In simple terms, a jet of colour is sprayed onto the textile. However, in contrast with the previous technologies, the design itself is not a physical part of the printer. As the print-head moves over the surface, it receives a stream of data that switches the spray of different colours on or off. The data ensures that the colour at each point of the original design is transferred to the corresponding point on the fabric. Within the printer, the pattern is a flow of digital information, not, for example, the areas of mesh on a rotary screen. This is a crucial difference from the previous technologies, where the design is a material part of the printer that cannot be altered without stopping production and physically changing the printer. Currently, this property of digital printing is seen as advantageous because it makes sampling or short print runs far easier and cheaper that its forerunners (Nicoll, 2006: 22; Ujiie, 2006: 338-341; Tallon, 2011: 8). It has also been identified that much larger designs can be printed than the previous technologies would cater for and that this scale might eliminate the need for repeat (Bowles and Isaac, 2012: 12; Braddock-Clarke and Harris, 2012: 163; Briggs-Goode, 2013: 112).

This difference in technology affords another opportunity that gives rise to paper's first proposal. At present, the design is finished and then sent as data to the printer. If the design is to repeat down the fabric, the same data is sent to the printer again and again. However, if the data changed all the time, then so would the pattern. If it were possible to create a design that dynamically evolved, it could stream section by section to a digital printer. The print-head only needs to know what colours to apply at a particular moment; it doesn't need to know what it's already printed or what it will print next. Rather than completing a design of fixed dimensions and then sending it to print, a design that changed in real time and was of potentially infinite length could be digitally printed. All pre-digital print processes could create outputs that were as long as the bolt of fabric they were working with, but in order to do this, they had to repeat, printing the same thing over and over again. Digital printing eliminates this need; the pattern need never do the same thing twice. This research identifies that new technology offers something entirely new: a method of continuously printing repeatless pattern on an industrial scale.

Re-thinking pattern

Identifying that digital technology removes the need for a design to repeat prompts the question of how to actually create a pattern that dynamically changes. To resolve this, it is proposed that generative design be used. This is defined by Bruton and Radford (2012: 166) as '… the generation of designs by a set of rules or an algorithm, usually using computers'. Generative design has been relatively well established in fields of creative practice beyond textiles such as graphics (Maeda, 2000 and 2004) and architecture (Fraser, 1996 and Burry, 2011). Within textiles, however, it remains a comparatively unexplored area. Paramanik (2013) considered the use of motion capture technology to create generative designs and McDonald (2013) employed generative methods to improve interfaces for mass customizable product. Reas and Reas (2014) have used created garments from fabric printed with generative designs and Richardson (2007 and 2009) has created animated generative pattern. Stephens' (2014) practice focuses on creating woven textile designs with code; generative approaches to tapestry (Moallemi and Wainer, 2008) and floor-coverings (Sutton, 1981 and Schofield, 2012) have also been considered. Closer to this research in this paper, Carlisle (2002) considers the use of random numbers in generating non-repeating pattern and Häberle's [mustercode] project (2013) considers the mass customization of product with generative designs, proposing that pattern might change over large lengths of fabric, or that natural forms might be modelled.

The generative process in this instance needs to create any length of repeatless pattern. In practical terms, this is done by the authorship of a software application that will generate the required output. In order to do this, parts of the design process have to be modelled. At the heart of this model is the idea that a pattern is the arrangement of imagery in a two dimensional space. Newall and Unwin (2011: 6) define patterns as being '… composed of motifs that interrelate with each other as repeated, varied, alternating, symmetrical or asymmetrical shapes.' This implies that there are two separate properties to the design. Firstly, it's motifs: the individual elements contained within it. Secondly, the interrelation between the motifs: how these elements are composed to form the design. This separation of content and composition is crucial because it means that any motifs can be used; in this case, the generative process will govern how the motifs are arranged, not their individual appearance. The elements within the design could be any type of image (floral, geometric or conversational, for example) and be in any style (hand drawn, photographic or redolent of a specific historical era, for instance). It is suggested that if the motifs are individually of good quality, then the quality of the overall design will be determined by the generative software that arranges them. The rules by which the software produces the composition need not be dependent on the content or style of the elements. As one of the intentions of the research is to produce commercially viable designs, it is imperative to locate any resultant designs in an industrial context. Being able to produce repeatless pattern with any visual source material means the outputs can be used in almost any instance where a repeat pattern might previously have been used. Furthermore, designers would not have to have any knowledge of programming to generate their own non-repeating designs; the code would do this automatically from whatever motifs that they had created and selected.

To contextualise the development of such a model, it is helpful to cite a historical example. Day (1903: 128-138) outlines a method of designing small-scale patterns that draws on techniques used by weavers working on sateen fabrics. The goal is balance; no part of the design should stand out. This is an important consideration that will be returned to later. A grid is drawn within which motifs are arranged so that none are in the same row or column. The grid is then repeated as a whole and the resultant design is unlikely to have obvious vertical or horizontal lines that are likely to be seen as dominant, upsetting the balance of the whole (Figure 01). The system behind the arrangement works with any motifs. This is important because it suggests a degree of universality; the method is not dependent on the nature of the motifs themselves, but on an underlying structure. Day's process produces relatively simple repeat designs, but it serves to illustrate a working method where a design's motifs and structure are separate.

The goal here is a pattern that evolves, dynamically changing over time, with the output being sent section by section to a digital fabric printer. What if a library of motifs could be saved on a computer, and then a software application use them to generate a non-repeating pattern? The programming would determine the ever-changing structure of the design, working with the images in the library, regardless of their content or style. Day's repeating sateen method would be quite straightforward to convert to generative code; might it be possible to code a much richer, non-repeating pattern?

Complexity, a field of science and mathematics, offers a strategy that might be employed to achieve this. Waldrop (1994: 12) describes a complex system as one that has:

> … acquired the ability to bring order and chaos into a special kind of balance. … [where] the components of a system never quite lock into place, and yet never quite dissolve into turbulence, either.

If, in these terms, the individual motifs are thought of as the components and the design they make is the system, this is a good description of the desired result. The motifs will continue to move dynamically, but arrange and re-arrange themselves with some kind of underlying structure. This structure could adhere to a similar notion of balance to that of Day's method. Another definition of investigating complex systems is equally analogous, suggesting that such:

> … research … seeks to explain how large numbers of relatively simple entities organize themselves … into a collective whole that creates patterns, uses information and in some cases, evolves and learns. (Mitchell, 2009: 4)

Here, a simple entity might be a motif and, clearly, the pattern is the design they combine to make.

The next step is finding a specific type of complex system that might be applicable to generating repeatless pattern. Within the field of complexity, mathematical models can be used to research how the components of a system interact. One such model is a cellular automaton, defined by Wolfram (1994: 412) as:

> … a lattice of discrete individual sites, each site taking on a finite set of, say integer values. The values of the sites evolve in discrete time steps according to deterministic rules that specify the value of each site in terms of the values of neighboring sites.

Whilst Day's grid is not a cellular automata, consider for a moment that it might in some way map onto Wolfram's lattice. The motifs could be thought of as the values of the sites and arranging them so that none are in the same row or column could be a deterministic rule. If, for example, a motif is aware that one of its neighbours is in the same row, a rule could make it move elsewhere. Wolfram (1994: 423) suggests that the behaviour of cellular automata falls into four qualitative classes. The third is of interest here as it '… can produce patterns whose features cannot be readily predicted in detail' (Wolfram, 1994: 271). The rules that govern how the cellular automaton will evolve can be very simple, yet produce rich, non-repeating pattern. It is therefore proposed that a cellular automata will be developed upon which the generative design programme can be based. Toffoli and Margolus (1987: 5) suggest that:

> A cellular automata machine is a universe synthesizer. … Its color screen is a window through which one can watch the universe that is being "played".

The universe that this research seeks to create is a visual one of ever-changing pattern. The proposal here differs from previous generative research in textiles on two counts. Firstly, it capitalizes on the new possibilities of digital printing outlined above, integrating the printer hardware with generative software that uses a complex system to create ever-changing repeatless pattern. Secondly, the designs it produces can use any visual content; the output can be tailored to suit almost any brief and be commercially applicable in any instance where a repeat design could be employed.

Re-thinking design

It is now important to establish a method of ensuring the quality of the composition. In this case, the rules that govern the cellular automata should not only ensure that the motifs position themselves in an ever-changing composition, but also that this is always of sufficient standard for commercial application. The next step is to develop quantifiable criteria that will form these rules.

Rather paradoxically, it is suggested here that some of the criteria that help ensure the quality of a repeat design can be used as a basis for non-repeating pattern. When working on a repeat pattern, designers will generally try to ensure that the eye can move freely over the design. If something stands out, every instance of it will stand out, making the viewer focus on the repeat structure rather that the design itself. Bowles and Isaac (2012: 88) discuss an example:

> This problem, known as 'tracking' within the surface design industry, where an unintentional stripe or diagonal has been created, can be resolved by scattering copies or variations of noticeable elements in a design in such a way that they appear to be randomly placed and equally balanced with other similar motifs or coloured areas … A balanced distribution of negative space is also critical.

Day's sateen method is borne of a desire to avoid such problems, offering 'a system by which the danger of apparent lines … is minimised' (1903: 128). The lines referred to here are strong horizontals or verticals within the design that will stand out from the whole. Nearly 110 years later, Bowles and Issac (2012: 96) outline a method of converting an image into a half-drop repeat in Adobe Photoshop. Again, concealing the repeat is vital: '… you will need patience to mend the seams so that they flow with the design to achieve a fluid repeat.' Tallon (2011: 154) highlights almost identical issues when using Adobe Illustrator, stating that '… the main challenge … is to complete the gaps and create a fluid repeat pattern.' All these citations identify that the design should be balanced and go on to suggest practical methods of doing this.

It is worth noting at this point that if the motifs were randomly arranged, sections of the resulting compositions would have tracking issues. When Bowles and Isaac (2012: 88) suggest that the elements should '... appear to be randomly placed …', the inference is that the eye should not be able to easily discern any obvious underlying structure such as strong horizontal lines of motifs or spaces.

Earlier in the paper, the importance of being able to use any type of motif within repeatless designs was stressed. Three further considerations should also be given to ensure that the designs have commercial relevance. Firstly that the design should be able to continue for any length; the size should be governed by the length of the substrate or the capacity of the printers dye reservoirs. Not only this, but it should do so seamlessly; the design should flow continuously down the substrate so that any section of it is capable of forming part of a resultant product. Finally, it is important that although the design will change all the time, it will remain as an identifiable pattern; different areas of the resultant substrate, however far apart, should be visually coherent. To a large extent, this will be ensured by the choice of motifs, but it remains an important consideration when ensuring the output's commercial viability.

The factors outlined here that govern the quality of the design can be expressed as instructions. For example, to achieve balance, strong horizontals or verticals should be avoided; furthermore the motifs should flow over the surface of the fabric without any apparent joins or obvious gaps. By quantifying these instructions, rules can be developed for a cellular automaton. Using Processing, '… a text programming language specifically designed to generate and modify images' (Reas and Fry, 2007: 1), code was written that allowed the rules to be visually tested and then implemented to generate the repeatless output. To facilitate this, the generative design process was divided in two. The rationale for this was in part derived from the use of biological taxonomy in some studies of complex systems (Bentley, 1999: 8; As and Schodek, 2008: 173). The first part of the generative process is the cellular automaton. Each of cells of a grid has a range of data assigned to it. In biological terms, this data could be deemed as the cell's genotype: coded information that forms its genes. The cells interact with each other using the rules developed from the traditional repeat design process. Depending on the location and characteristics of its neighbours, any genotype might alter, move, die or be reborn with each time step. With every cycle, each row of the grid moves down; the top row is seeded with new genotypes and the bottom row is passed onto the second stage of the generative process (Figure 02). At this point the data is converted to what could be thought of as the cell's phenotype: the physical characteristics that its genes give rise to. In this case, this includes the choice of motif and its visual characteristics (scale or degree of rotation, for example). If the library of visual elements are hand-drawn flowers, the final design will be a hand-drawn floral; if they are abstract shapes, the output will be geometric. Each genotype maps onto a particular motif from the library, dictating where it will be placed in the design and (for example) how big it will be. This produces the phenotype (Figure 03). Once a number of rows of the phenotype grid have been completed, they can be sent to print (Figure 04). The code that governed the cellular automaton's rules, their parameters and the number of cycles within the grid were developed and tested practically until balanced, non-repeating pattern was achieved (Figure 05). The process can continue indefinitely, generating phenotype sections that fit seamlessly together, creating any length of repeatless pattern in any style.

Conclusion

The application of digital technology to the creation and manufacture of printed textiles and surface pattern is already having a profound effect, one that Bowles and Isaac (2012: 10) suggest is '… bringing about a revolution in textile design'. Indeed, Dawber (2008: 9) proposes that 'the impact of digital printing has changed the rules of engagement forever …'.

This paper offers three further contributions to the field. Because a physical version of the design is no longer part of the mechanics of the printer, for the first time the opportunity arises for a design to change as it is being printed. The whole ethos of pre-digital printing on an industrial scale was to allow large areas of fabric to be covered with pattern as quickly as possible; one of the trade-offs for this was that the design had to do the same thing over and over again. The initial proposition here is that digital hardware allows printing to be re-imagined; designs could now be printed that do not repeat. However, this presents the problem of how a repeatless pattern of any length might actually be created. The next suggestion is that generative design offers a solution. It would allow ever-changing pattern to be produced in real time that could be streamed to a digital printer. At the heart of the programming is a cellular automaton, a complex system governed by simple rules, yet capable of displaying ever-changing behaviour. This provides a way to re-think pattern, arranging any combination of predetermined motifs into a dynamic design. The motifs themselves could be in any style, crucial if the resultant design was to be of industrial use. Whilst the rules that control the cellular automaton could be developed from any starting point, the final proposal is that existing methods of repeat design be quantified to form them. This might seem contradictory, yet the processes used by practitioners to conceal repeat in the past can be used to develop algorithms that allow the quality of repeatless design to be maintained at a consistently high level. The existing rules of balanced design composition still apply; the cellular automaton uses these rules to output complex motif arrangements that obey their guidelines yet never do the same thing twice. Interdisciplinary research across science, technology and design provides a method of re-thinking pattern. The need for repeat is eradicated without losing any of the rich legacy of the practise of printed textiles and surface pattern. The combination of complexity, digital systems and traditional design techniques provides an innovative means of allowing textile designers an expansive new opportunity for the future.

Images

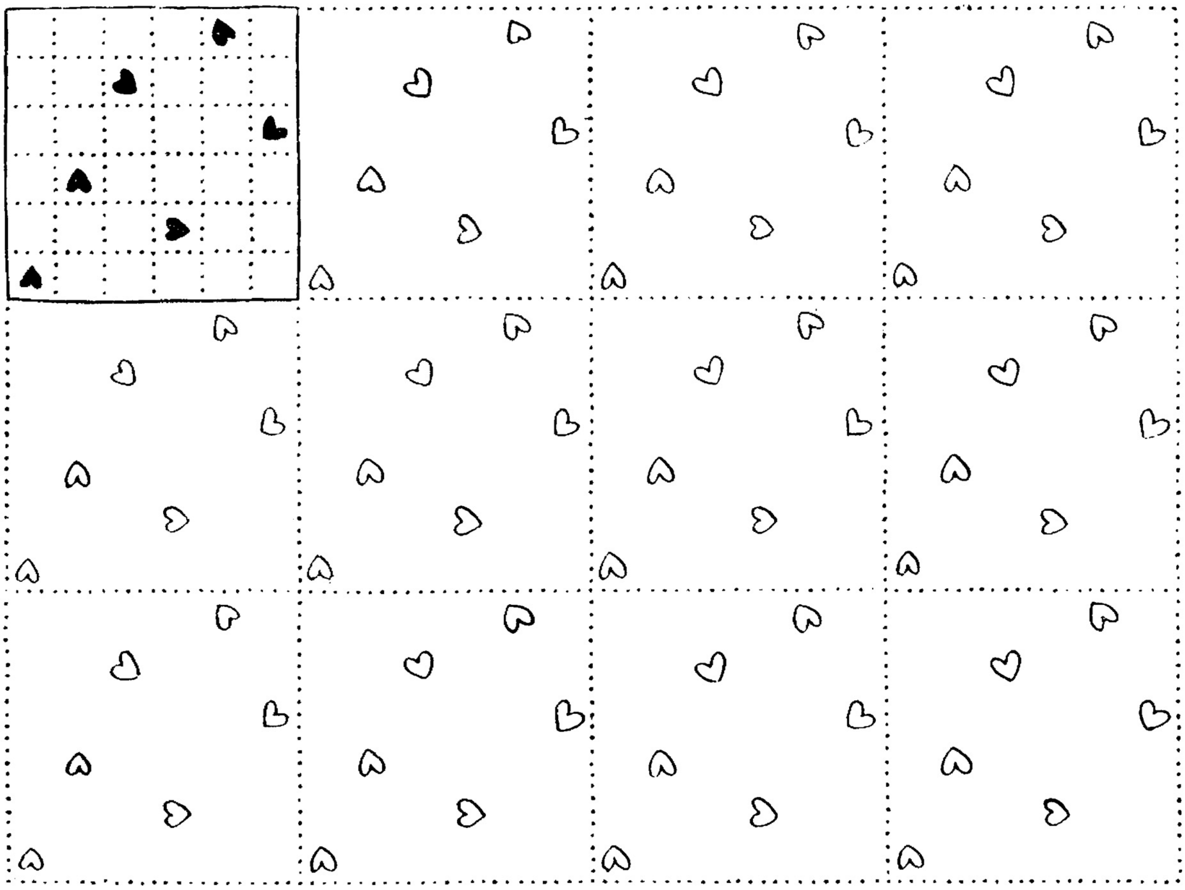

Figure 01. *Diagram of six-spot repeat.* (1903)

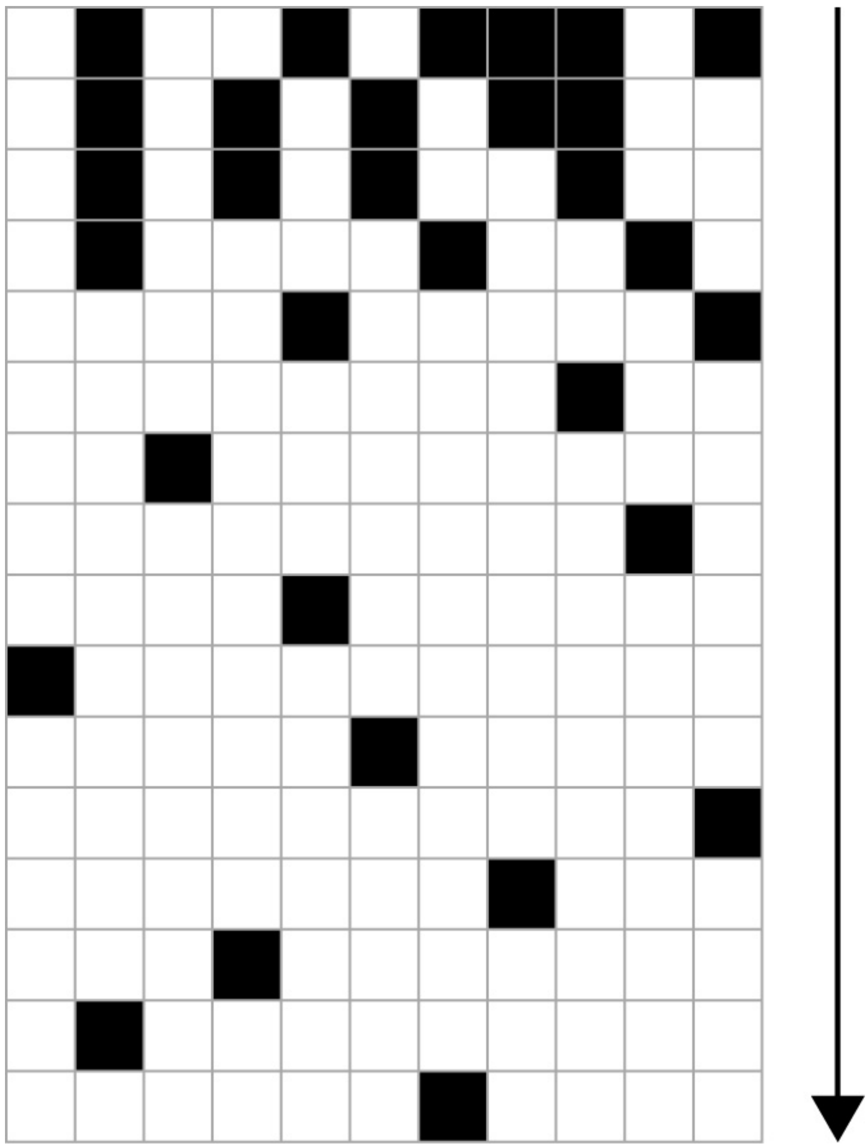

Figure 02. *Genotype stage: the cellular automaton.* (2013)

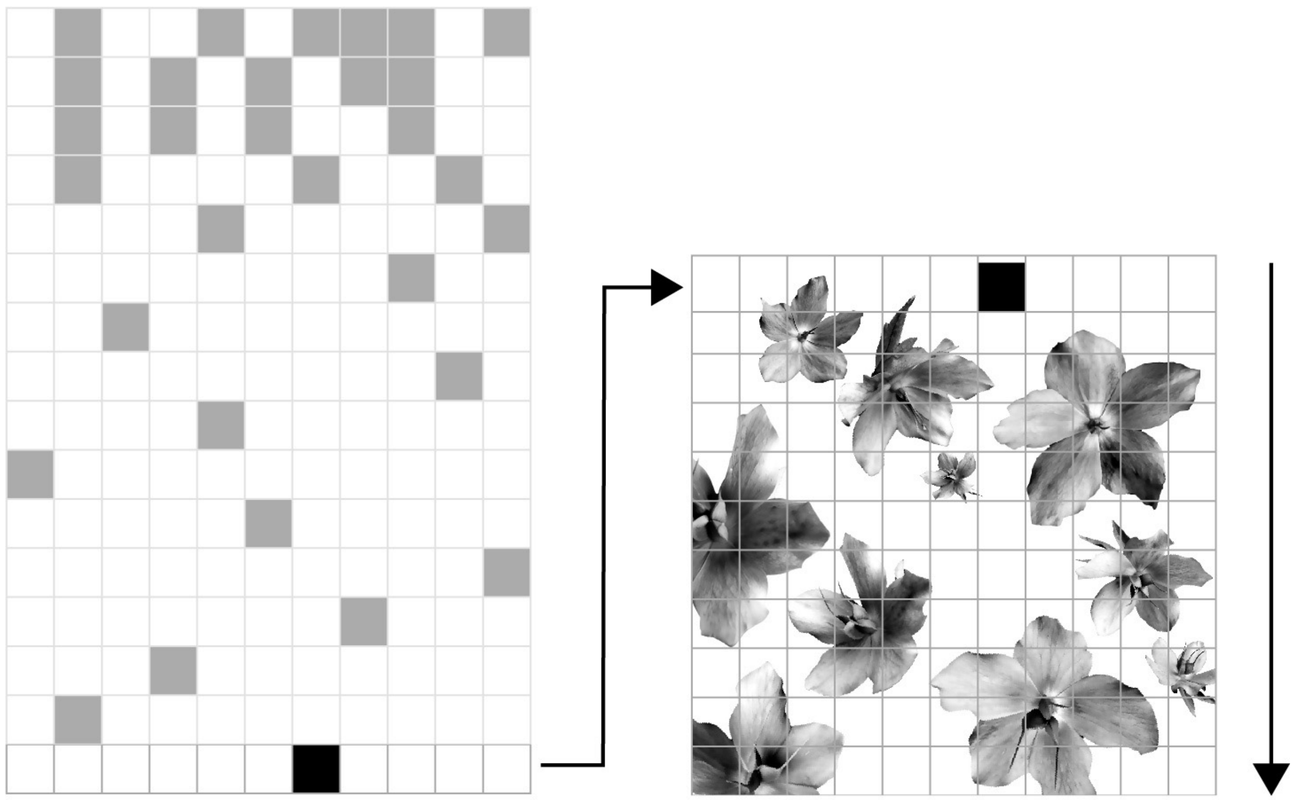

Figure 03. *Phenotype stage: mapping motifs into the design using the genotypes.* (2013)

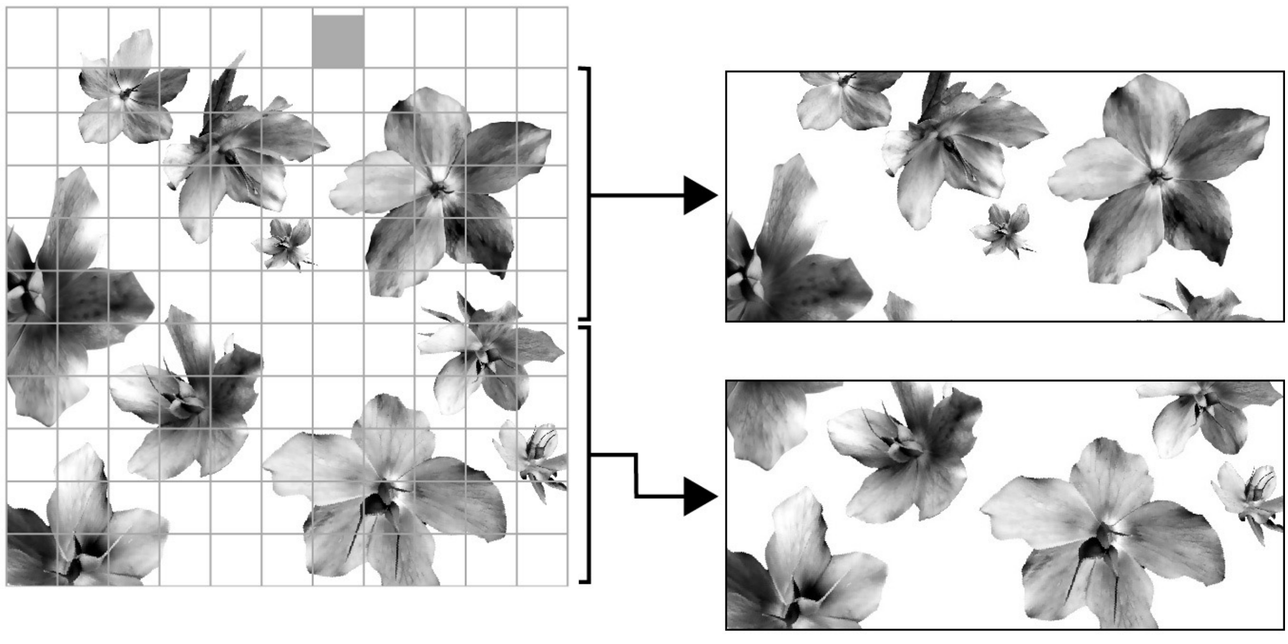

Figure 04. *Printing stage: images from the phenotype stage are streamed to a digital printer.* (2013)

Figure 05. *Cloth of Gold.* (2013-4)

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List of illustrations

Figure 01. *Diagram of six-spot repeat.* In: Day, L. F., (1903) *Pattern design: a book for students, treating in a practical way of the anatomy, planning and evolution of repeated ornament.* Figure 154. 1979 ed., London: B.T. Batsford Limited, p. 130.
Figure 02. Russell, A. (2013) *Genotype stage: the cellular automaton.* Digital illustration.
Figure 03. Russell, A. (2013) *Phenotype stage: mapping motifs into the design using the genotypes.* Digital illustration.
Figure 04. Russell, A. (2013) *Printing stage: images from the phenotype stage are streamed to a digital printer.* Digital illustration.
Figure 05. Russell, A. (2013-4) *Cloth of Gold.* Computer programme.