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Visual analogy in creative design: case study of fractals and crochet lace

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Visual analogy in creative design: case study of fractals and crochet lace

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Abstract: One powerful technique for supporting creativity in design is analogy: drawing similarities between seemingly unrelated objects taken from different domain. A case study is presented in which fractal images serve as a source for novel crochet lace patterns. The human designer searches a potential design space by manipulating the parameters of fractal systems, and then translates portions of fractal forms to lacework. This approach to supporting innovation in design is compared with previous work based on formal modelling of the domain with generative grammars.

1. Introduction

This paper describes an ongoing investigation into tools or techniques to support creative design—specifically, of crochet lacework. Two threads of research have been explored: generative grammar design tools, and less formal analogical design aids.

An eclectic set of applications for using formal rule or grammar systems to support the design process or to describe existing designs have been discussed extensively in the literature, ranging from the generation of a new form of video art [Edmonds, 1993] to describing the landscaping of Mughul gardens [Knight, 1990] to the creation of new works in the style of Diebenkorn's Ocean Park series [Kirsch and Kirsch, 1988]. The random or guided application of these grammar rules can be used to generate novel examples of a the genre, and in the case of computer-implemented models, can autonomously explore the genre's instance space. Earlier work on CADD (Computer-Aided Doily Design) followed in this mould: we specified a piece of software that could design novel crochet doilies by applying a set of simple constructive constraints (possible ways in which individual crochet stitches may "legally" be connected to each other), geometric constraints (involving the physical dimensions of stitches, and the geometric properties necessary to ensure a flat piece of finished work), and a generative grammar for motifs (common sets of stitches, such as the "pineapple" or "shell cluster") [Cunningham and Denize, 1992].

By making explicit the generally implicit rules for an instance of a genre, insight is gained into the fundamental structures of the form itself. The grammars can, for example be, used as a quantifiable support for qualitative critiques. In this way T.W. Knight models changes in the styles of two artists of the De Stijl school over two decades [Knight, 1989], and shows that broad trends in their work (one artist became more constrained, and the other became less so) could be matched to a corresponding evolution in their respective descriptive grammars (one grammar added new rules and modified older rules to increase their complexity, and the other grammar was simplified by deleting rules).

The process of building the rule set is also useful for stirring the creative processes in the human designer. In our earlier work, as we codified the parameters defining a particular type of lace—the symmetric, flat, circular doily—we were, in essence, exploring the limits of that form. Indeed, one of the early versions of CADD contained an incorrect algorithm for the method by which the number of stitches in a round increases as the doily grows in size; interestingly, this version re-created the "ruffled" doily popular in the 1950s. Another version of CADD contained an incomplete geometric model, and produced designs in which rows could overlap. Several of these "mistakes" proved intriguing, and have motivated experimentation with novel forms of three-dimensional lacework.

A second thread influencing the present work has been the analogical use of scientific/mathematical artefacts, by artists, as a source of structure for the development of new, creative works. Perhaps the most prolific cross-fertilization of this types comes from the deliberate use of mathematical principles by musical composers: for example, translating portions of the Fibonacci sequence into a boogie tune [Turner, 1993] or Indonesian gamelan rhythms [Canright, 1990]. These efforts do not simply mechanistically transform a scientific/mathematical structure into a musical or visual composition, but instead attempt to translate the *spirit* of the structure. This process can enhance the designer's creativity by forcing him/her into new perceptions, new modes of thought or analysis. For example, the composer Marcel Fremiot reports collaborating with, among others, a mathematician (Jean-Paul Allouche) and a theoretical physicist (Jacques Mandelbrojt) to incorporate analytic functions into a piano piece; the composer did not "voice" the functions described to him, but instead considered them "a tool, a formal model that musical tradition could not provide me with; they enabled me to move along in a way that was appropriate for what I wanted to express" [Fremiot, 1994].

This approach is particularly attractive in that it provides a greater possibility of engendering truly creative, rather than merely novel, new designs. A generative grammar approach cannot, by definition, produce designs that go beyond the paradigm embodied in the grammar; while the set of potential designs that could be generated may be infinite, they are also predictable, in a very real sense. Moreover, many—perhaps the vast majority—of the potential designs are not "interesting" to the human eye or ear, as they vary only slightly from known designs and from each other. This quality of "interestingness" cannot be readily reduced to a calculation or rule itself; the ability to surprise, to combine hitherto unrelated concepts in a meaningful way is difficult to automate!

With CADD, we found that the designs produced by the software could be pleasing, and might be novel, but were not—could not be—radically different. Part of the problem appeared to be an over-specification of the final output: we required CADD to produce a complete crochet pattern, and the technical difficulties in handling round-off errors in the pattern geometry forced us to simplify the potential output at a number of points. Since crochet work is relatively forgiving (a slight tension or looseness added to an individual stitch, or the inclusion of an extra stitch, is often enough to ease out small flaws in a pattern), it is reasonable to consider producing general pattern *guides* rather than stitch-by-stitch pattern descriptions. To more deeply explore the potential design space, then, the designer would require only a technique for generating potentially interesting shapes, that the designer could him/herself translate to a formal pattern. With that end in mind, we examine the applicability of visual analogy to crochet lace design: fractal pictures are iteratively produced and visually examined, in a search for image portions that are both "interesting" and capable of being imitated in crochet.

Specifically, this paper examines the use of fractal images as a basis for lace design at several levels: in the development of new motifs, or relatively small pattern pieces that may be repeated throughout a work (Section 3); in creating interesting tilings or arrangements of blocks of lace (Section 4); and in developing novel designs at the "macro" level (Section 5). Section 2 presents a brief technical overview of crochet, as many readers may be unfamiliar with the process for creating crochet lace.

2. Crochet construction techniques

The most striking way in which crochet differs from knitting, with which it is frequently confused, is that crochet uses a single hooked tool rather than a pair of straight knitting needles. Crochet stitches are based on a loop of yarn or thread pulled through existing loops by a hook (see Figures 1 and 2). In crocheting each stitch is individually created, whereas in knitting an entire row is defined at a time.

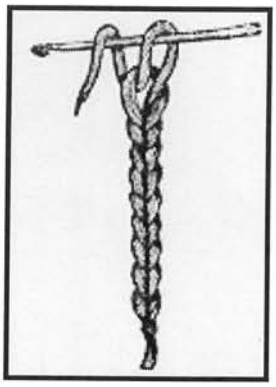
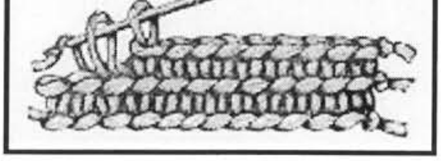


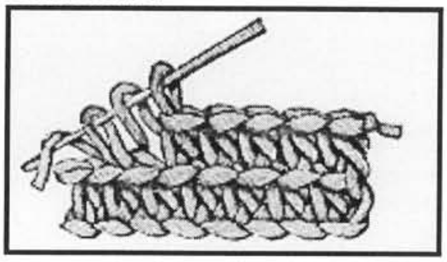
Figure 1. The chain stitch (Caulfeild and Saward, 1882)

The chain stitch is the simplest crochet stitch, and is based on the primitive "finger knitting" technique. A chain is constructed by first forming a grounded loop around the hook Additional chains are created by hooking the free end of the thread around the hook, and then drawing the free thread through the previous loop. Chain stitches have two uses in crochet work: as the components of a "base chain", and as a means for incorporating "holes" into the piece. Nearly all crochet pieces are started by creating a row of chain stitches that forms the "bottom" of the piece. In round crochet work, the end of the base chain is joined to its first stitch, creating a circular foundation chain. Chain stitches are also used to achieve a feeling of lightness and airiness in the body of the crochet work, by connecting denser single, double, and treble crochet stitches with one or more chains.

Other common stitches are the single and double crochets (Figure 2). These stitches are formed by: winding the loose end of the thread over the hook zero or more times; inserting the hook through the next stitch in previous row; and then drawing the hook back through the loops on the handle, two loops at a time. The more loops that were originally wound around the handle of the crochet hook, the taller the resulting stitch will be. While even taller stitches are possible (the treble, the double treble, triple treble, etc.), the treble is the longest stitch in common use.



(a) Single crochet stitch



(b) Double crochet stitch

Figure 2. Single and Double stitches (Caulfeild and Saward, 1882)

3. Development of new motifs

A "motif" in crochet lacework is a small sub-pattern that is repeated in several places. The motif may be small—a three stitch "popcorn" cluster, for example—or may cover several rows and stitches on each row. Further, a motif may have a fixed description, or may vary in size and shape. The development of novel motifs has played a significant role in crochet lace design, particularly for Irish crochet (consisting of separate motif pieces sewn or crocheted together on an openwork crochet background; see Figure 3). The production of Irish crochet was a significant cottage industry during the Potato Famine. However, this craft originally viewed with suspicion by Victorian society, since it is much less formally structured than previous lace employment such as bobbin or pillow work. These latter laces were constructed from ready-printed patterns, and no deviations were permitted in the work. In contrast, Irish crochet was worked to no fixed pattern. Instead, the motifs were combined according to the joiner's talent for producing a pleasing overall effect, and motif workers were encouraged to invent new motifs. The crochet workers themselves preferred crochet work to traditional lacemaking, as the workers could exercise creativity and could directly control the designs [Cunningham, 1996]. As one worker eloquently explained,

> I likes the crochet best, ma'am, because there's hope in it. I *may* get ever so much for what I makes, if I happen to hit on a new stitch, and all the time I'm at it, I don't know but I may have a lot of money coming to me, and I'm kepin spirits like, to the last moment; but that pillow-work, och, 'tis horrid, ma'am! You're made sinsible from the beginning that you're only to get the trifle of a price, no more, nor no less, and no thoughts will help you, you must go on with the thing to your *ordthers*, which is what *I won't do*, until I can't help it, please God. [Meredith, 1865]

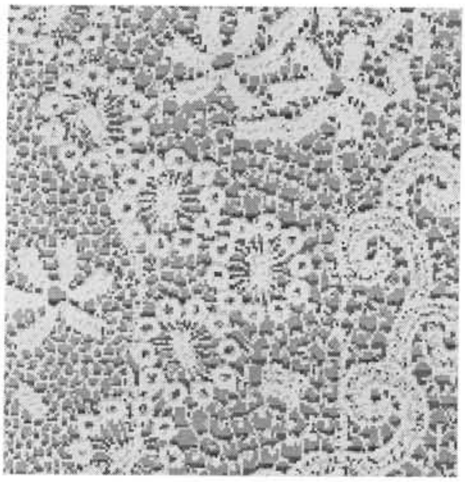


Figure 3. Portion of a nineteenth century Irish crochet collar, from the author's collection

The design process for motif development can be supported by generating sample sets of regularities. The designer uses the fractal images as a starting point for improvisation, manually searching the generated images for pleasing sub-patterns that could be manipulated so as to be produced by the crochet technique. So, for example, I am struck by the swirl pattern in the following fractal image[1]:

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[1]Created with the Fract(IFS) software, based on the "FractalSpirals" sample provided with the package.

Figure 4. Fractal pattern

Using this image as a seed, I create a variety of images "close" to that fractal, by mutating the underlying equations slightly. I continue iterating in this manner, until I discover one or more that would be suitable as the basis for a motif:

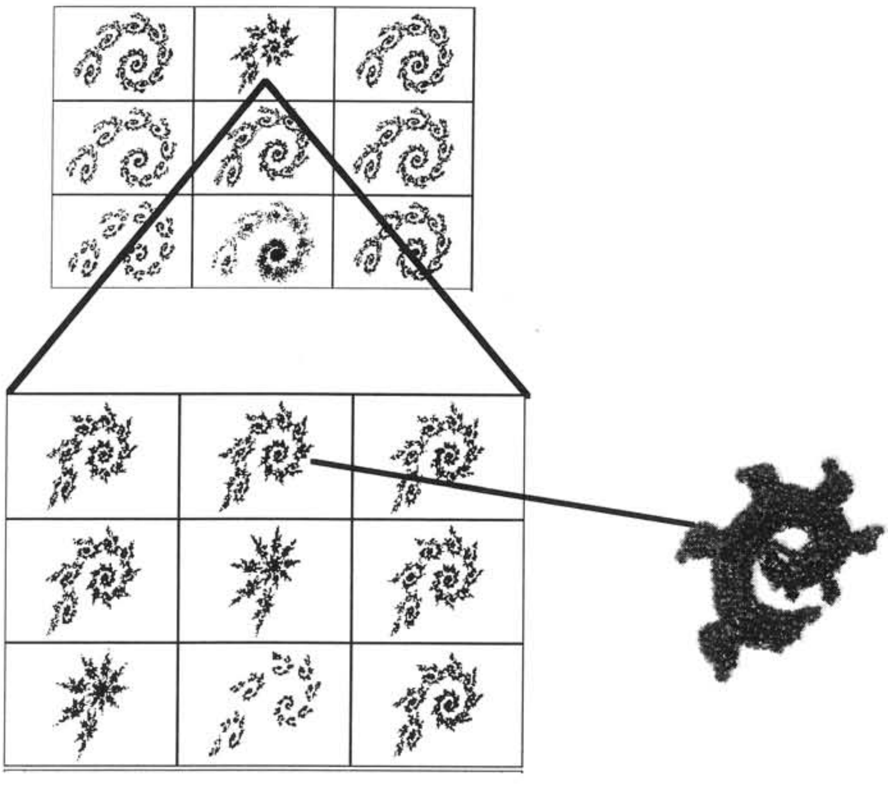

Figure 5. Design of a motif suitable for Irish crochet

4. Motif or sub-piece arrangement

One common type of style of lace involves creating a number of small pieces, arranging them in a symmetrical pattern, and sewing them together. The final piece is often composed of just one or two types of sub-patterns. Highly regular fractal images are particularly well-suited for reproduction in lace of this type. So, for example, consider the following fractal[2]:

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[2]Produced with Fractal Lab Kit v. 1.0, based on the "circles" sample image

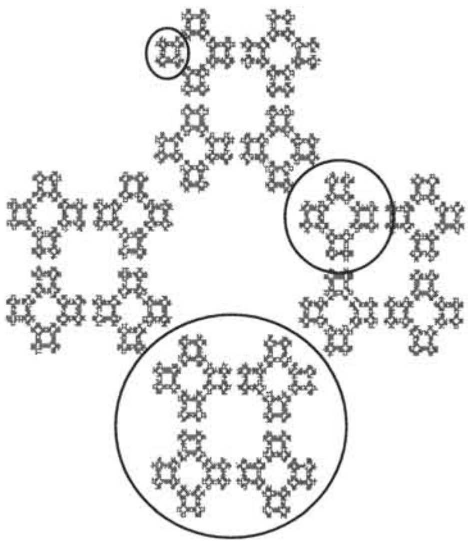

Figure 6. Fractal image

The image as a whole can be reproduced in crochet in several different ways, depending on the granularity of the motif selected (the circled portions of Figure 6), or whether multiple repetitions of the pattern are tiled (Figure 7). Here, the interest of the final work depends not simply on any attractive qualities of an individual motif, but in the emergent forms produced by the joining of motifs. These emergent qualities are notoriously difficult to specify algorithmically (since emergence occurs when the space is deconstructed by "re-viewing" portions of the defined structure in a previously unforseen manner [Stiny, 199?]). For that reason, it is more practical to utilize the human designer as a screen for detecting designs containing emergent properties.

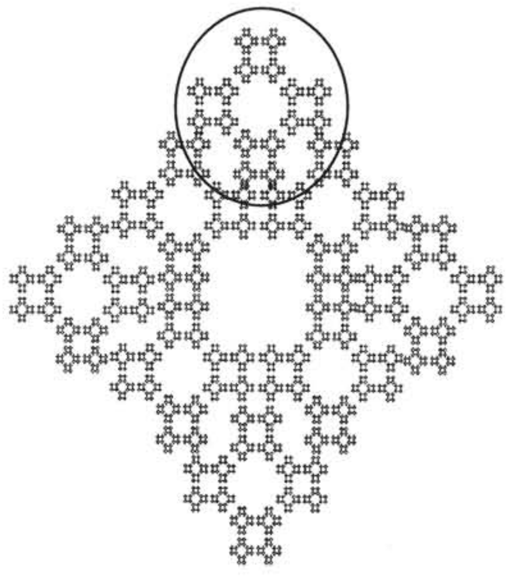

Figure 7. a sample tiling of 8 motifs, motif size circled

5. Novel application of a construction technique

Most crochet work is formed either from separate motifs joined together (as described in Sections 3 and 4), or as a single item from a continuous thread. A relatively little known technique that has become more popular in recent years is to create a "lace tape" that can be wound in complex patterns that imitate Brussels or Belgian lace. An that can be wound in complex patterns that imitate Brussels or Belgian lace. An interesting aspect of the crochet tape lace is that it can be constructed so that it branches without seams (by joining new threads at the branch point), and so that it curves (by slightly tightening/loosening stitches at the bends).

In exploring variations of the Hilbert and Koch curves[3], I encountered several that seemed appropriate for tape lace production. Figure 8 illustrates the process; a base line is added to the bottom of the curve, and the shapes defined by the curve are represented with solid stitches (here, treble crochet to show detail). Again, the key to the design was recognizing the emergent shape that could be created by "filling in" the curve. The further creative leap was utilizing the tape technique, which is always used to construct more traditional, rounded designs.

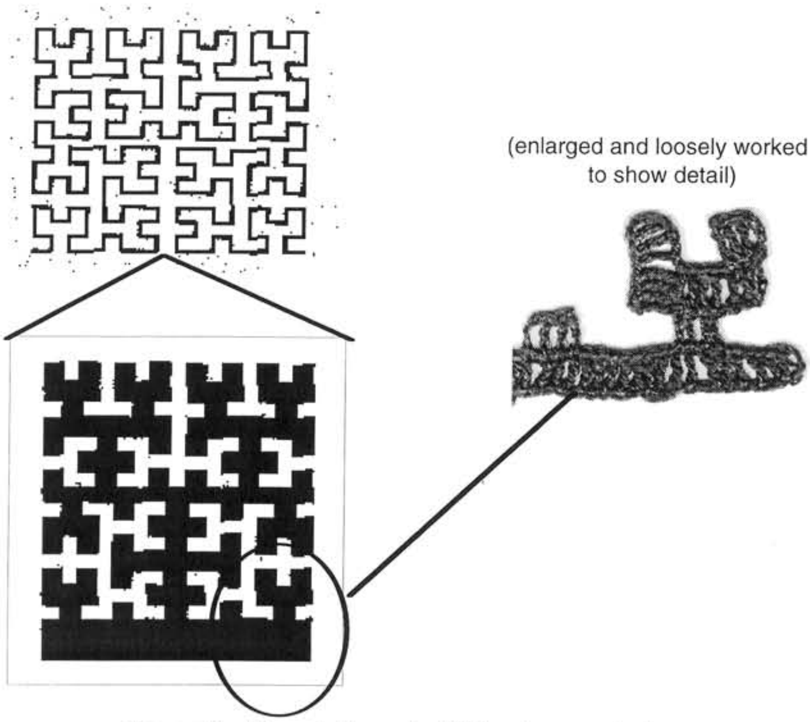

Figure 8. Translation of a Hilbert curve to lace

6. Conclusions

This paper presents a case study of the use of visual analogy in the development of novel designs: fractal images are explored with the aim of detecting images that can, in part or whole, be used as a basis for constructing novel crochet lace patterns. The technique can be used to inspire designs at the micro (motif) and macro (arrangement of motifs, overall design) levels. Unlike generative grammar approaches to exploring a potential design space, no explicit model is created; instead, the designer manipulates fractal parameters to generate a variety of images, searching through the image space for patterns that can be duplicated in crochet. Of particular advantage in this process is the high degree of variation shown in fractal families; slight changes to the fractal formula can produce great, and unpredictable, changes in the image produced. In practice, this variation can add an element of serendipity to the search process, helping the designer to avoid becoming stuck in local clusters of uninteresting images. New ways of thinking about the design domain, and new ways of applying existing construction methods, emerge from the development of new patterns.

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[3] In this case, with Fractal Lab Kit v1.0

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