Back and Forth – pneumatic anadrome

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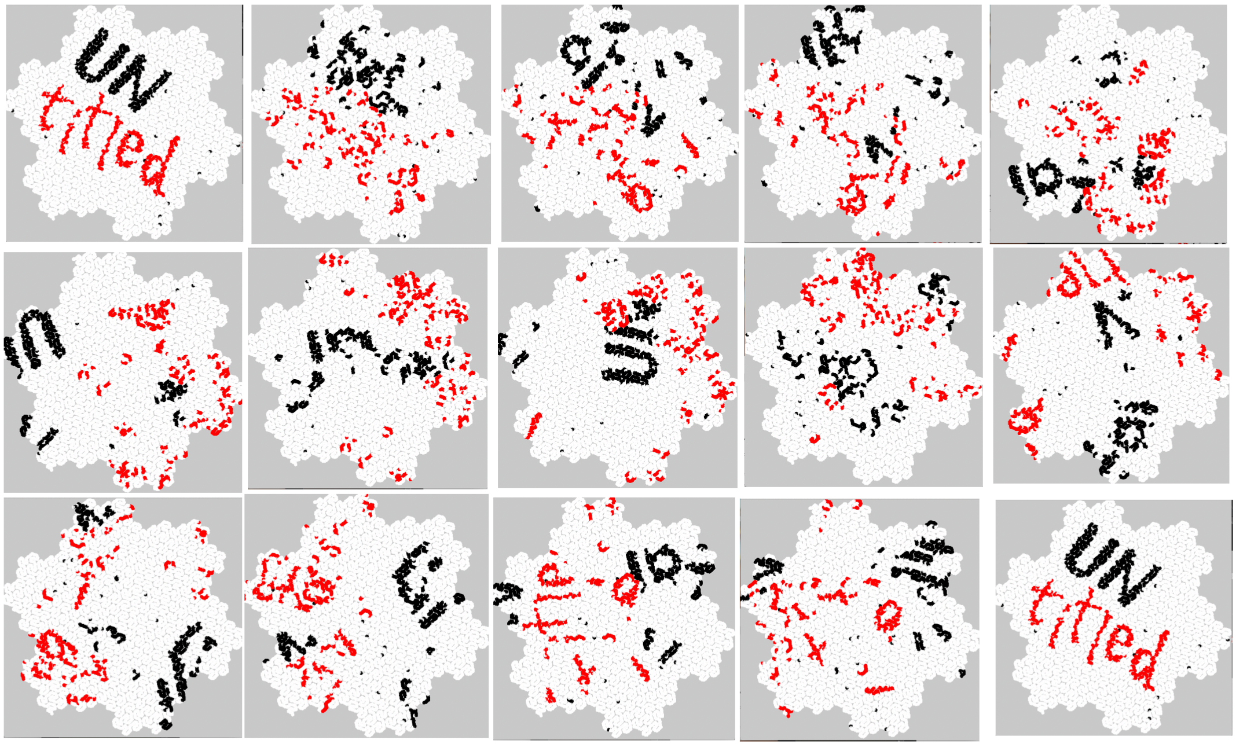
Full cyclic evolution of an image wandering around a fractal route (Gosper curve)

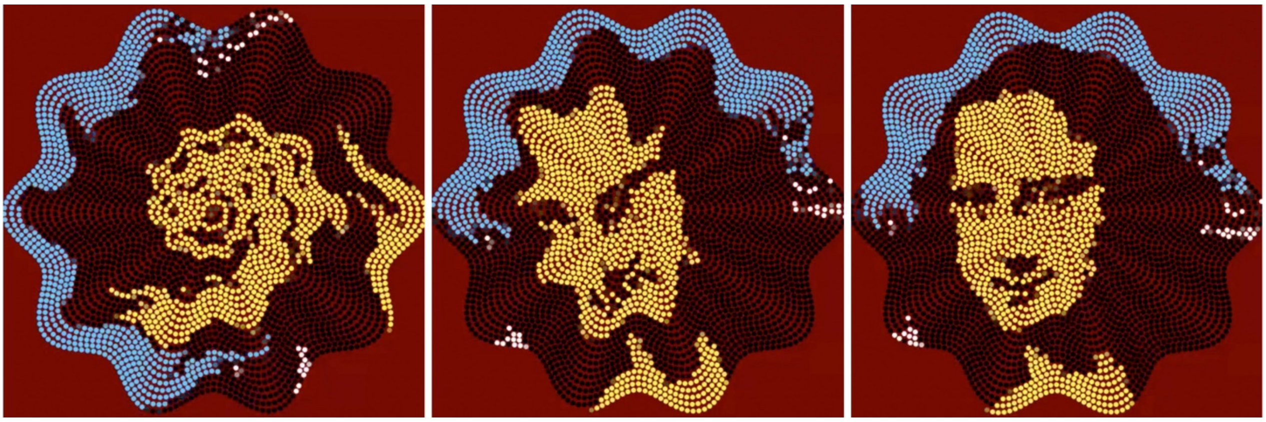


Abstract

Serial Paintings aims at revealing the hidden physical and mathematical relationships between a perceived image and its material support. In “**Back and Forth – anadromes pneumatiques**“, the first work in the series, a string of colored beads is pushed back and forth between two canvases using compressed air. Without rearranging the order of the beads, the sequence is forced to coil into a spiral. It's folding and unfolding alternatively reveals images with opposite meanings. Each image has to be destroyed in order to create the other; this cyclic process of creation and destruction is purposefully revealed and triggered by the viewer.

<1> The canvas as a decrypting/encrypting mechanism

The canvas of a traditional painting is a surface supporting pigments. The “canvases” of our Serial Paintings are instead labyrinths of convoluted plumbing covering that surface, guiding strings of colored beads. They are capable of displaying several images in the process (our display behaves true to the original meaning of the word, which is to "unfold, spread out, unfurl ", from old French *desploiir*, modern *deployer* and from Latin *displicare*). Without rearranging the order of the beads, the string is forced into the particular shape of the guide; this process *decrypts* the sequence as a two-dimensional image. Since the sequence is fixed, the display can only contain a limited number of images. They cannot be seen at the same time but can be retrieved by pushing the beads an exact amount of distance. This is in contrast with ordinary ways of creating images, including displays or printers, that require a mechanism to arbitrarily position a “writing head” in two-dimensional space (regardless of the way of addressing - be it raster scan or vector). It is this “random access” to the surface that render them capable of producing arbitrary images.



<2> A convoluted path to reveals hidden self-similarities

In a Serial Painting, one or more images are encoded as linear strings of "pixels" constrained in a curvilinear guide covering a surface. As a consequence, only *one coordinate*, or index, is necessary to address pixels. Translating the pixels along this coordinate (even by a single step) can distort the entire image and render it instantly unrecognizable. This is to our advantage: several images can be encoded in the sequence, since when one is clear, the other appear as background noise. We created two Processing sketches, the first one to produce space-filling curves (the canvas shape), and another to calculate the sequence of colors corresponding to the images. It is easy to create space-filling curves as fractals [4] determined with a simple set of rules, using an L-system [1]. Our sketch produced SVG files representing several typical fractal curves having a fractal dimension equal to two (strictly space-filling) such as the Sierpiński curve, the H-three, the Hilbert curve, or the Gosper curve; we also explored fractals of lower dimension or non-self-similar curves (such as a spirals or a raster scans) roughly covering the surface because the physical size of the beads makes the it unnecessary. The second sketch takes as input one or more images and help us visualize the transformation as they fold/unfold on the canvas. Images can be "injected" (without distortion) at any time in the process, thus becoming entangled with the others. The process is manual (including tweaking some pixels to clear superpositions) but could be automated to obtain more optimal entanglements penalizing crossovers, thus enhancing the perceptual quality of the images (i.e. one image appears clearly while the other resembles background pepper noise - see Fig.1).

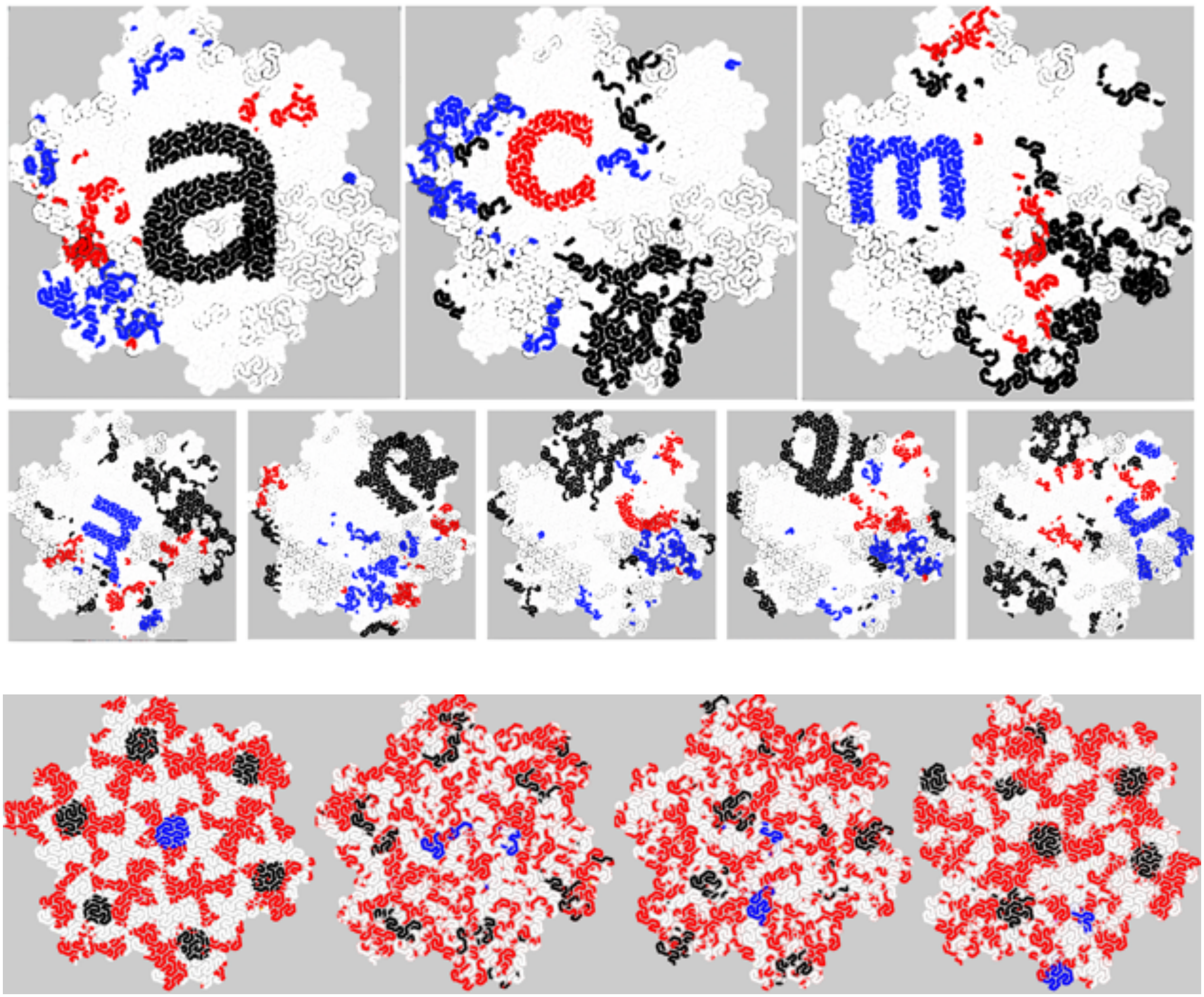


Figure 1. Top: "a", "c" and "m" entangled in a Gosper fractal; Bottom: the symmetries of the Esher fishes match some self-similarities of the fractal guide. This is revealed by a curious "crawling" of the image through the surface (bottom) (© A.Cassinelli. Photo: A.Cassinelli)

As the pixels circulate in the guide, the images seem to break into pieces to suddenly reappear, but with subtle errors, missing parts, rotations or translations. The phenomena come directly from the rules of generation of the fractal. Parts of the image (or the image as a hole) crystallizes and becomes recognizable if it possesses this hidden structure itself to a certain degree. Real images are not mathematical fractals, but they have a certain degree of self-similarity (this observation is behind the fractal *lossy* compression algorithm [2]).

<3> A pneumatic spiral canvas and its visual anadromes

In our first work, two spirals are used as the guiding medium. This allows for a unique (but straightforward) encoding, equivalent to the linguistic anadrome: “spelling” the image backwards (the sequence is reversed when moving from one spiral to another) reveals a new image with a different meaning - perhaps even its opposite.

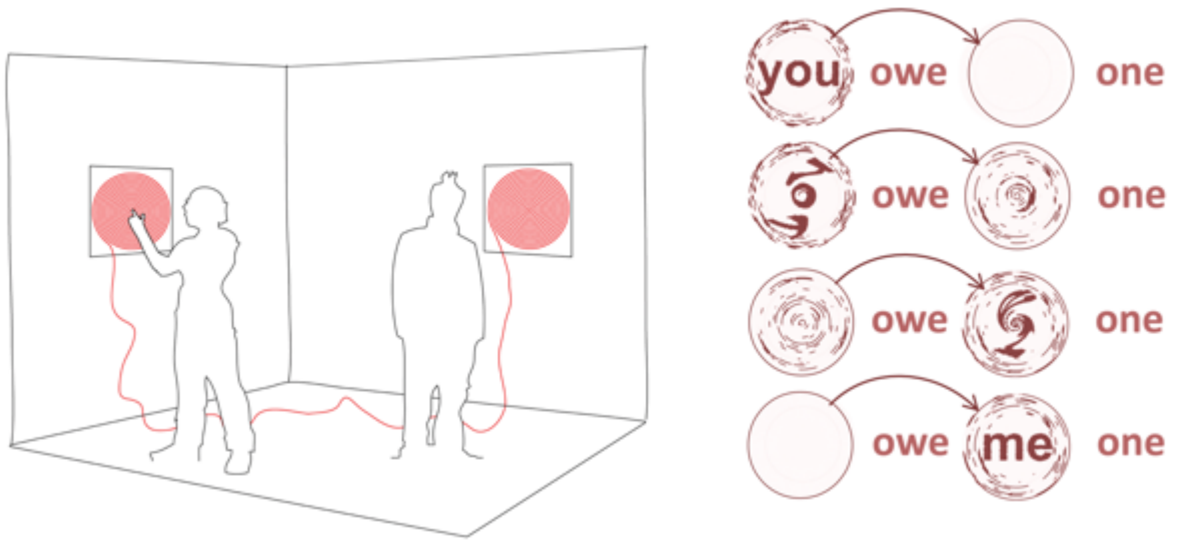


Figure 2. The installation setup invites a dialogue between the viewers (© A.Cassinelli. Photo: A.Cassinelli)

This piece is made out of laser cut acrylic, metallic strip and plastic beads. The canvases are placed far away (either hanging on the wall or attached to the ceiling - Fig.2). Images are “sent” back-and-forth through a long transparent plastic tube.

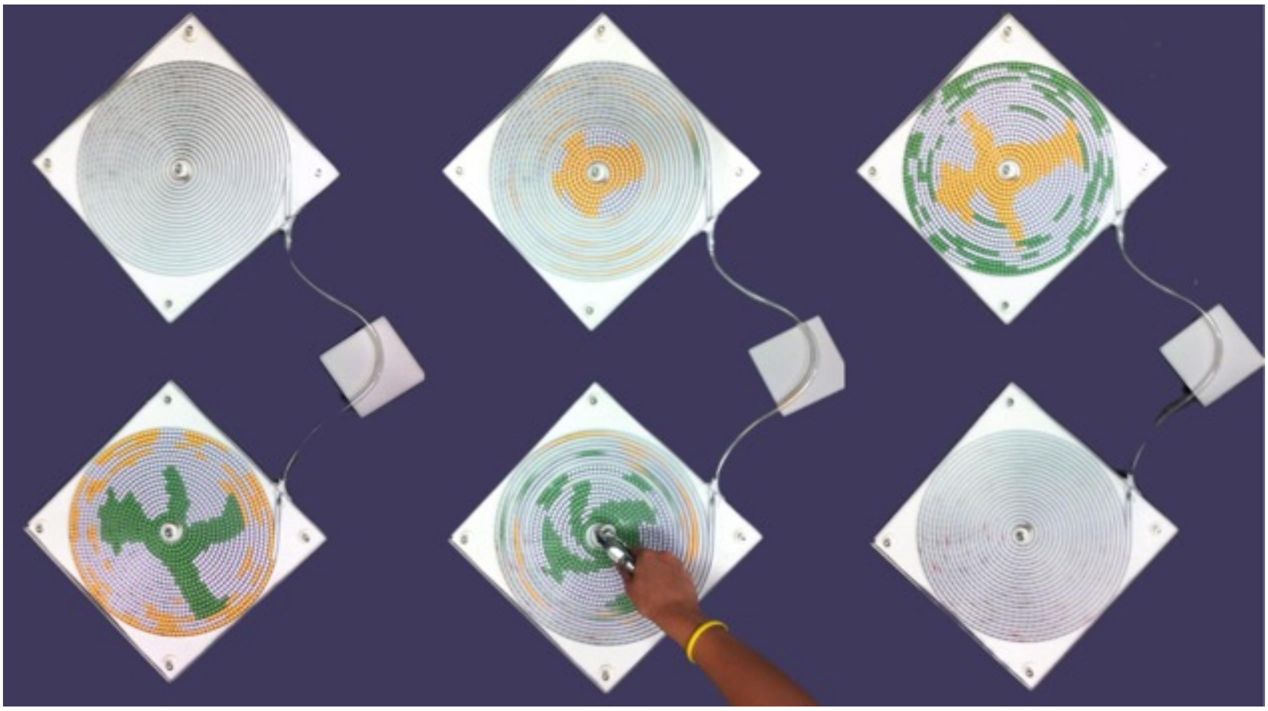


Figure 3. A prototype of a pneumatic anadrome (© A.Cassinelli. Photo: A.Cassinelli)

These "pneumatic paintings" are operated by the public using an air compressor. Another possibility is to use a hand pump, requiring an interesting and suggestive form of exertion (both methods are shown in the video). More poetically perhaps, it is possible to directly blow through a hole in the canvas. The *breathing* from order to chaos and back constitutes an exciting moment of the painting: a swirling (and noisy) visual abstraction representing cycles of creation and destruction of *subjectively* perceived form.

<4> Fabrication

The air guide has to be air-tight and designed to minimize the distance between beads in adjacent arcs, what we could achieve after several design iterations. The first attempt was to sandwich two CNC cut acrylic plates both with a spiral and half circle cross section. Polishing the cut-out spiral was critical point in manufacturing (rugosities can jam the flow of beads or produce visual artifacts). Grinding square cross-sections were tried in a next iteration but the separation between the spiral arms was too large, thus decreasing the resolution. We finally settled on a laser cutter to create a fine but deep groove on the acrylic plate, and manually inserted a metallic tape approximately 150 microns thick, visible in Fig.4 (right).

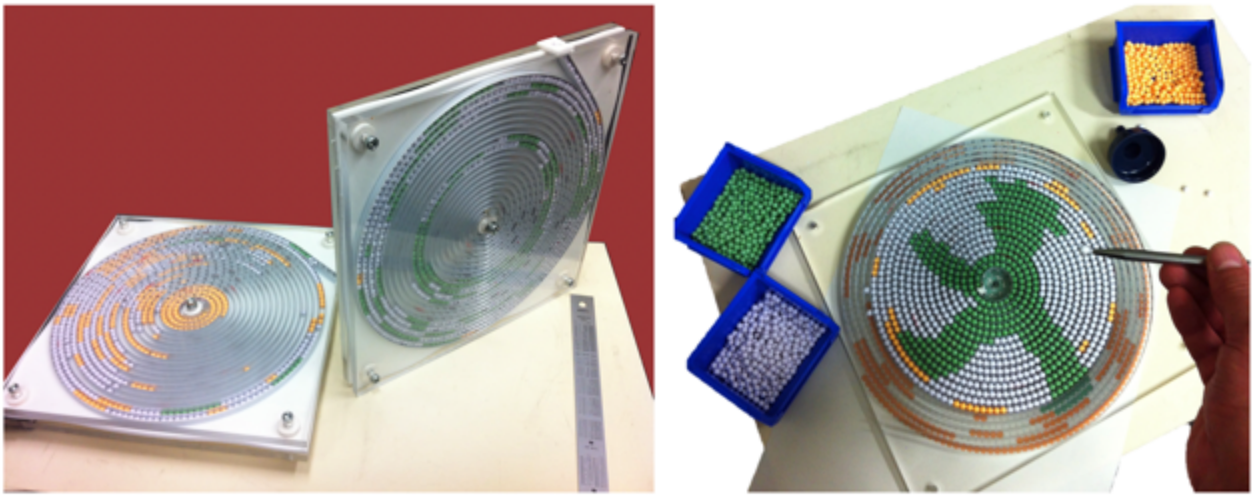


Figure 4. Construction of the "Ampelman" spiral anadrome (© A.Cassinelli. Photo: A.Cassinelli)

Control of the airflow and uniform pressure are critical construction factors in this design, as the acrylic plates tend to bend with air pressure, and the beads may get stuck. Using water instead of air was also explored and we consider it a better alternative for future works in the series. Indeed, water has several advantages: it is incompressible and produces a smooth drag of the beads; it also renders the frame almost transparent because of a relatively similar index of refraction with respect to acrylic or glass. Finally, transparent beads can be used to create spaces between colors, thus permitting modulation of the sunlight if the "painting" is used as a window.

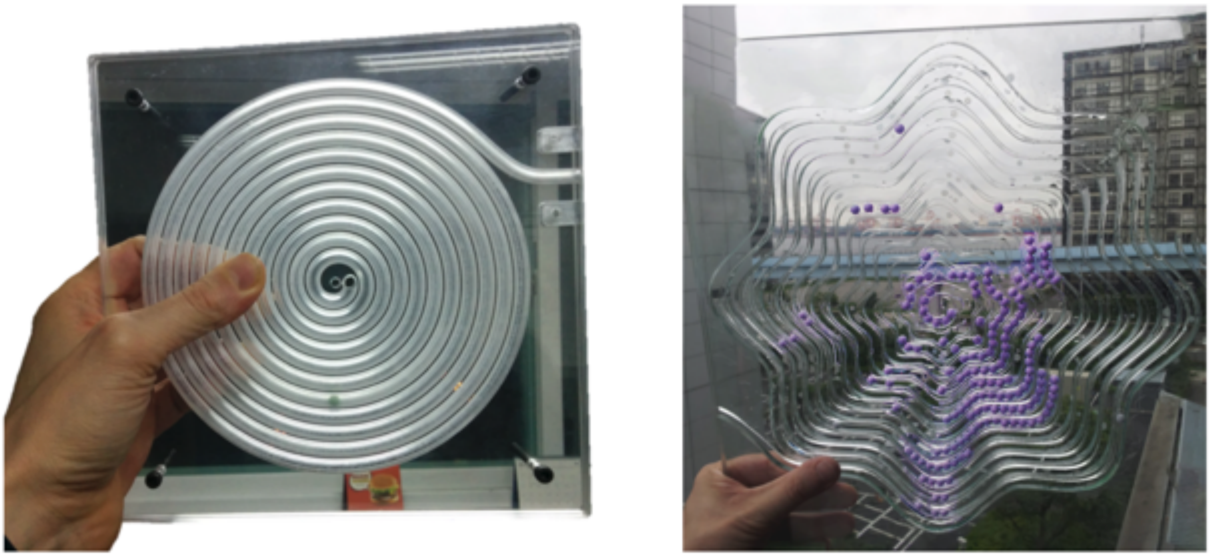


Figure 5. Left: Prototype guide for a water based spiral display, without water (hence non perfect transparent); Right: a wavy spiral made of sandwiched laser cut acrylic pieces, to be used as a light modulating window (© A.Cassinelli. Photo: A.Cassinelli)

The position of the colored beads (pre-computed the Processing sketches described above), have been placed manually in a long, patient operation while the spiral is open. A pick-and-place machine could be used to fill the spiral from the top, but we are in the process of designing a mechanical bead selector so as to introduce the beads serially in the guide.

<5> Discussion

We have explored the aesthetic possibilities of a new type of display working by moving *fixed* sequences of particles along fractal guides. The particular (fractal) shape of the guide dynamically reveal interesting hidden self-similarities in the images. Without rearranging the order of the balls, the string is forced into the shape of a spiral; this folding either *encrypts or decrypts* the sequence into each canvas, alternatively revealing a pair of images with opposite meanings. These images represent antithetic, crystallized phases of the 'painting' that cannot be perceived simultaneously as one image needs to be destroyed in order to create the other.

From a technical standpoint, the simplicity of the mechanism enables scaling in both directions. Indeed, it should be easy to cover large walls or columns, or even create slowly evolving stained glass windows by sandwiching a thin water guide between two transparent frames, and using translucent pieces of acrylic (Fig.5, right). Miniature systems such as microfluidics displays is another possibility (explored in [3] using colored oils in a raster scan guide).

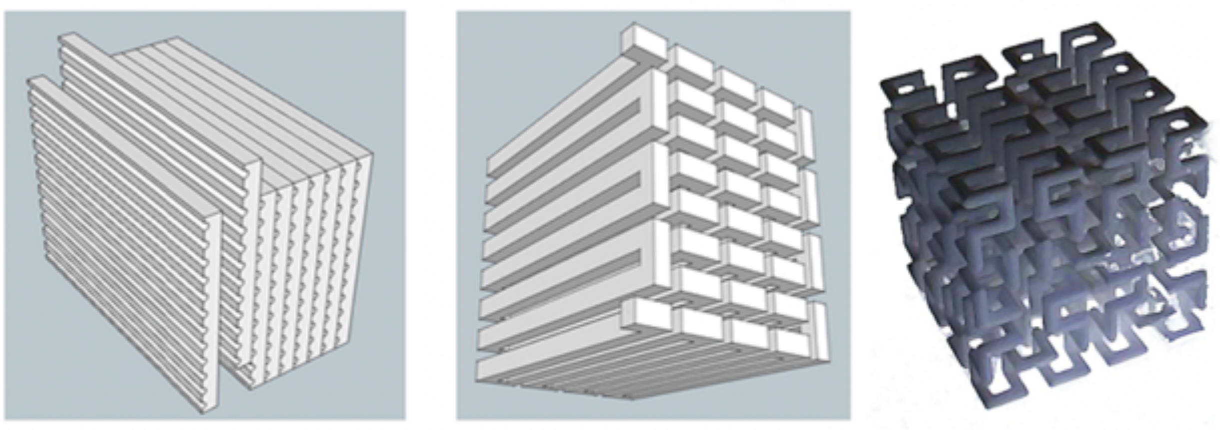


Figure 6. Stacking transparent 2d guiding structures to create a volume filling curve. Left: a simple volume raster scan (not a fractal); Right: the 3d Hilbert curve more difficult to fabricate. (© A.Cassinelli. Photo: A.Cassinelli)

Interestingly, a space-filling curve (a fractal curve) does not need to be flat - it could cover a *volume* (see Fig.6). In other words, it would be possible to extend the principles described here to dynamical “Serial Sculptures”. This also points to the interesting technological possibility to develop a *serial printer*, capable of producing arbitrary images or volumes. To create a final *solid volume*, the plastic beads could be melted together by heat, and the support dissolved or scratched manually.

<6> References and Notes

[1] Grzegorz Rozenberg and Arto Salomaa. The mathematical theory of L systems (Academic Press, New York, 1980)

[2] Yuval Fisher, Fractal Image Compression: Theory and Application, Springer-Verlag New York, 1995.

[3] Kazuhiro Kobayashi et al. Microfluidic-based flexible reflective multicolor display, *Microsystems & Nanoengineering* (2018).

[4] Mandelbrot, Benoit B.; The Fractal Geometry of Nature. New York: W. H. Freeman and Co., 1982