Nanocosm
(Artwork)

Topic: Art

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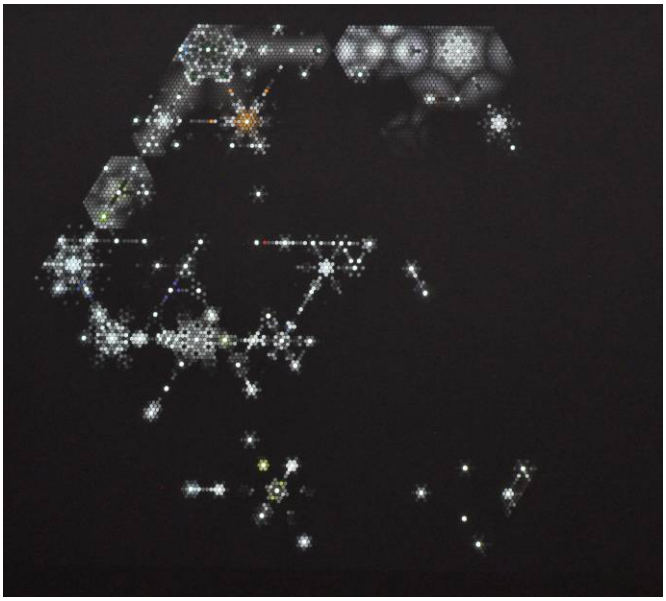
Abstract

Nanocosm is a computer-based generative artwork that unfolds in real time, showing a world of hexagonal “plates” that spawn, move and fuse to make larger plates. The larger plates constitute the environment for the smaller ones. The world is based on a multi-level hexagonal grid that strongly conditions the actions taking place within it.

There is an evolutionary component: a plate has “DNA” that controls its form; a plate has certain preferences for its environment, and plates whose preferences are met have a better chance of spawning new ones. When the larger plates move, they destroy any smaller plates in their way, so there is a constant cycle of creation and destruction.

Nanocosm attempts to balance geometric and biomorphic aspects, both in the visual appearance of the work and in the metaphors governing the operation of the generative process.



Photograph of projection from *Nanocosm*.

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Key words: Generative art, Evolutionary art, Hexagonal grid

The Role of Mathematics in *Nanocosm*

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Abstract

I discuss my work *Nanocosm* as an example of the different ways into which mathematics can enter into a computer-based work of generative art. Mathematics can be used behind the scenes in a utilitarian way to assist with the generation of forms and colours. A work can also be perceived as having a “mathematical” character; such a perception brings with it the associations that mathematics has as a study concerned with Platonic absolutes. Finally, I consider that a work can be based on mathematical virtues such as a clear formal structure and a lack of gratuitous elements. These virtues can be present even if a work is not explicitly based on mathematics.

Introduction

Nanocosm is a computer-based generative artwork that unfolds in real time, showing an alien world of hexagonal “plates” that spawn, move and fuse to make larger plates. I discuss the role of mathematics in *Nanocosm*, taking the work as an example of computer-based generative art.

I consider that mathematics plays three roles in *Nanocosm*. Firstly, the work uses mathematics in a utilitarian way, as a tool in a form-generating procedure. This use of mathematics need not be visible to anyone viewing the work. Secondly, the work has to some extent a “mathematical” appearance, bringing with it the associations mathematics has as a Platonic study, one that deals with absolutes that lie beyond this world. Thirdly, I consider that the work has what I call “mathematical virtues”: clear formal structures, a lack of gratuitous elements, an unfolding of consequences from a set of rules, unity in multiplicity. Such virtues can be found in works that do not appear overtly mathematical.

An overview of *Nanocosm*

Nanocosm is an artwork that presents a miniature world with its own rules and imperatives; a world that is beyond human needs and desires. This miniature world is called the *Nanocosm*; the word “nanocosm” is formed on the model of “microcosm”. The entire work is based on a hexagonal grid of small cells that I call “hexels” (short for “hexagonal pixels”).

Nanocosm is in part based on the idea of an ecosystem. The “inhabitants” of the *Nanocosm* are “plates” with sixfold symmetry. They come in a range of sizes; each is made up of small hexagonal cells. Plates spawn at the smallest size. They can move, and, if they meet in the right configurations, can fuse to make a plate of the next larger size. Smaller plates can climb on top of larger ones; the larger plates form the environment for the smaller ones. When a larger plate moves, any smaller ones on top of it move with it, but any plates in the path of the larger one are destroyed; additionally any smaller plates above plates that are fusing are also destroyed; there is a constant cycle of creation and destruction. The environment the larger plates provide for the smaller ones is not always benign.

There is an evolutionary element. Each plate has “DNA”, which specifies its form. Only the smallest plates spawn new ones, with a probability according to their “affinity” for their surroundings. A newly spawned plate has a slightly mutated version of the DNA of its (one) parent.

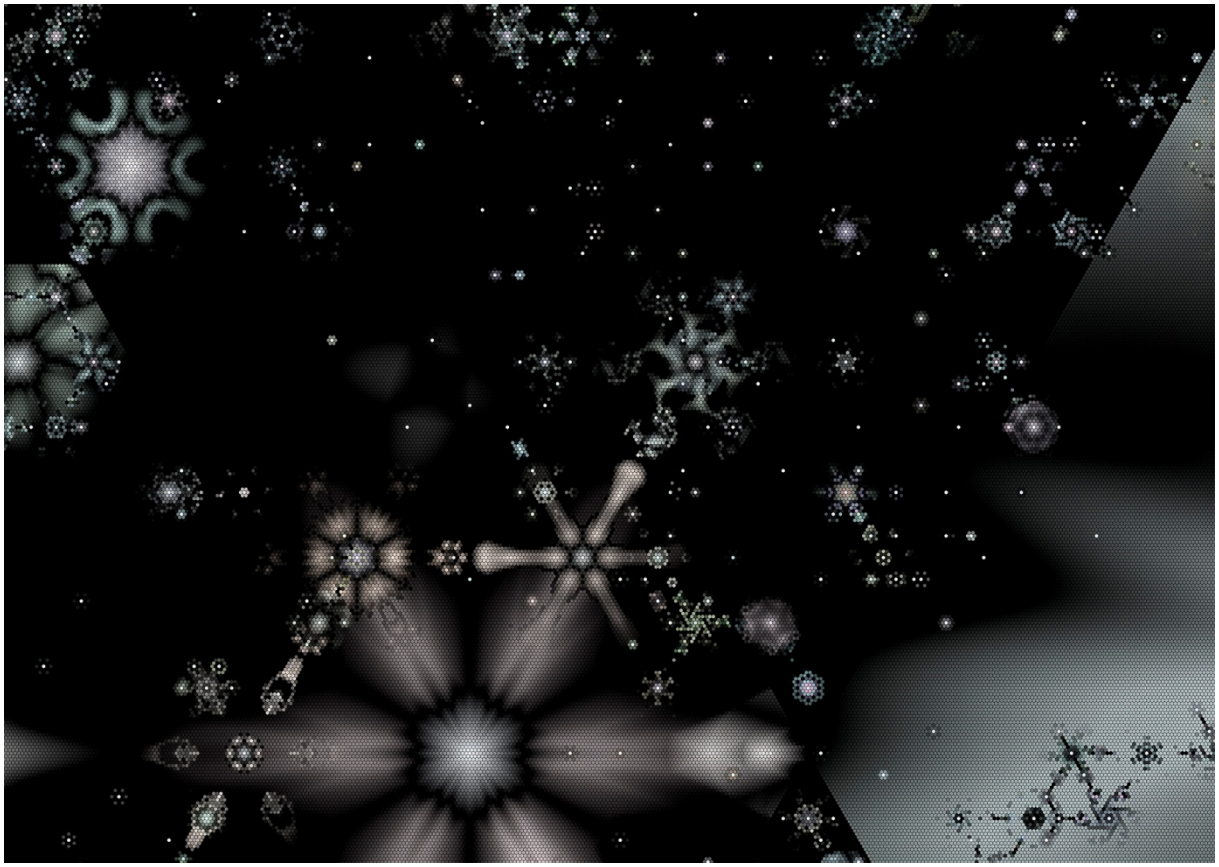

Figure 1. A snapshot of part of the Nanocosm.

The form-generating procedure

For the form-generated procedure I needed something that was evolvable; I chose the usual model of having some data that plays the role of DNA, and that generates the visible image. I also wanted the same DNA to be able to generate different sizes of image.

I adopted a procedure that generates a continuous image. I then sample this image at the centre points of an array of hexagonal cells, each cell being coloured uniformly according to the colour the image has at its centre. By varying the number of cells I can make a smaller or larger “plate”. The form-generating procedure operates by a process of distortion, based on Fourier series. There is a single starting image that I call the “Urform”. “Neutral” DNA will produce a sampled version of this image, as in Figure 2.

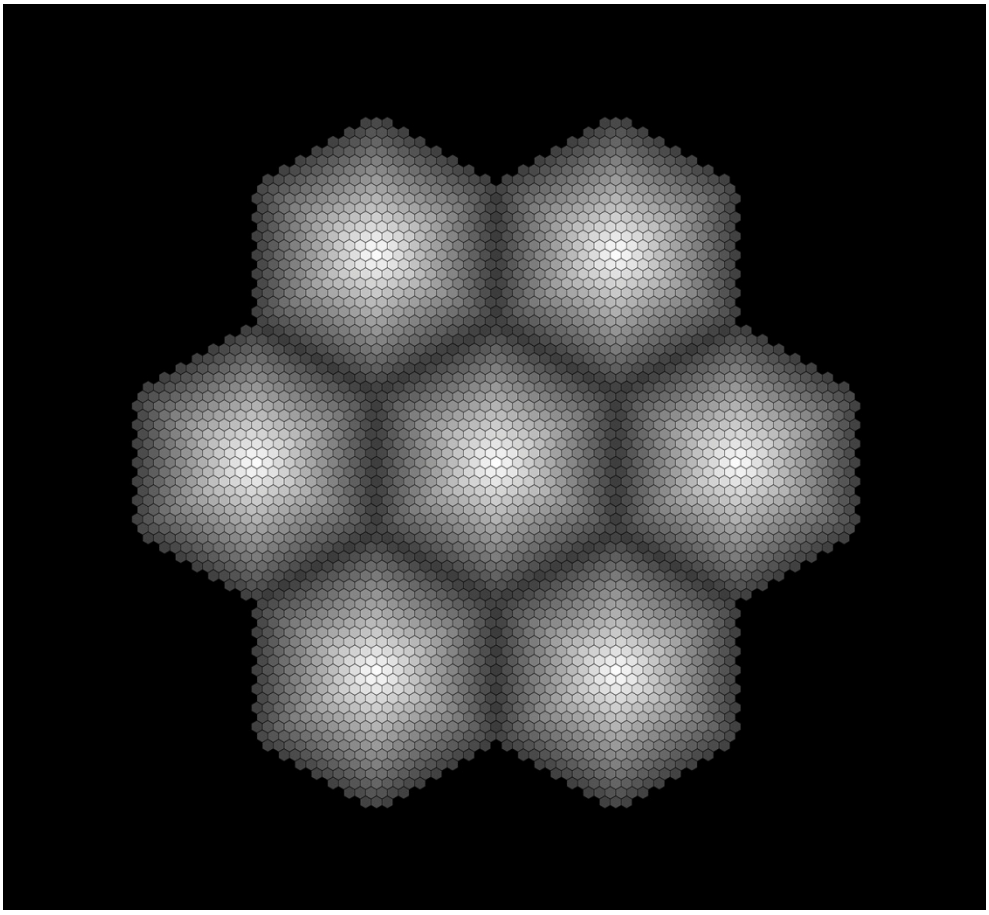

Figure 2. The Urform, drawn with a substantial number of hexels

A Fourier series is associated with a periodic function. Usually such are shown as ordinary x-y graphs, but actually they live on a circle (Figure 3). This led to the idea of using a Fourier series to specify a radial distortion.

For *Nanocosm* I wanted six-fold symmetry, and this led to the use of two Fourier series and seven “distortion centres”, where the six outer ones all have the same Fourier series (except for a phase shift). The arrangement is as in Figure 4.

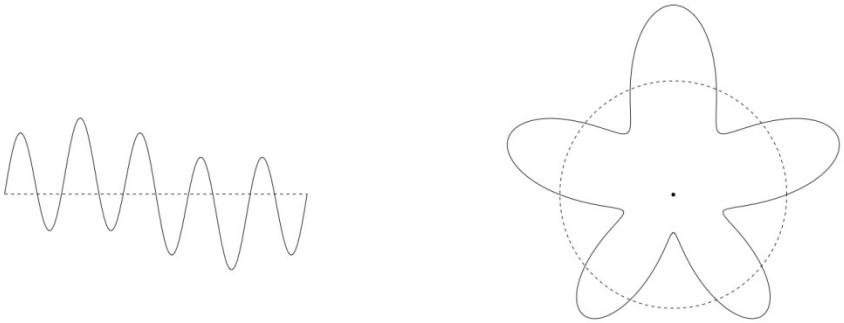

Figure 3. Left: *One cycle of a periodic waveform,* sin*(t)* + *2.*5sin*(5t).* Right: *The waveform bent round into a circle. For each direction from the centre of the circle, the waveform can be used to specify the amount of stretching in that direction.*

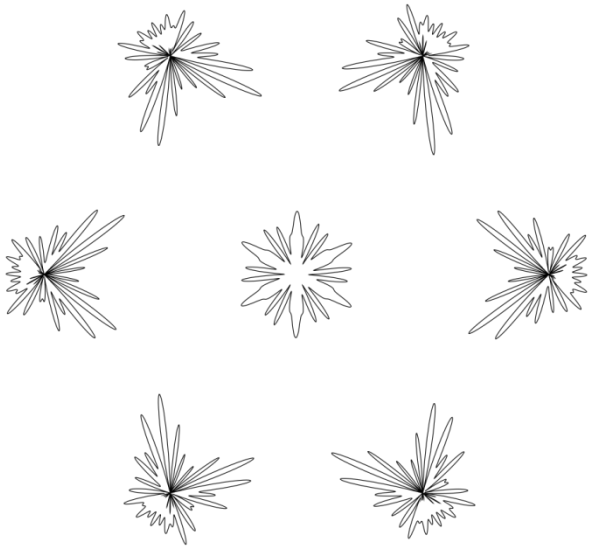

Figure 4. The seven distortion centres in the DNA for one plate.

The DNA for a plate contains the coefficients for two Fourier series, and also two colours. Initially these colours are latent, in that if there is no distortion the image is grey-scale only. The intensity of the colours depends on the degree of distortion. One of the resulting plates is shown in Figure 5. The plates that are produced from the DNA by this process have either six-fold rotational symmetry (without any mirror symmetry) or the full symmetry of the hexagon.

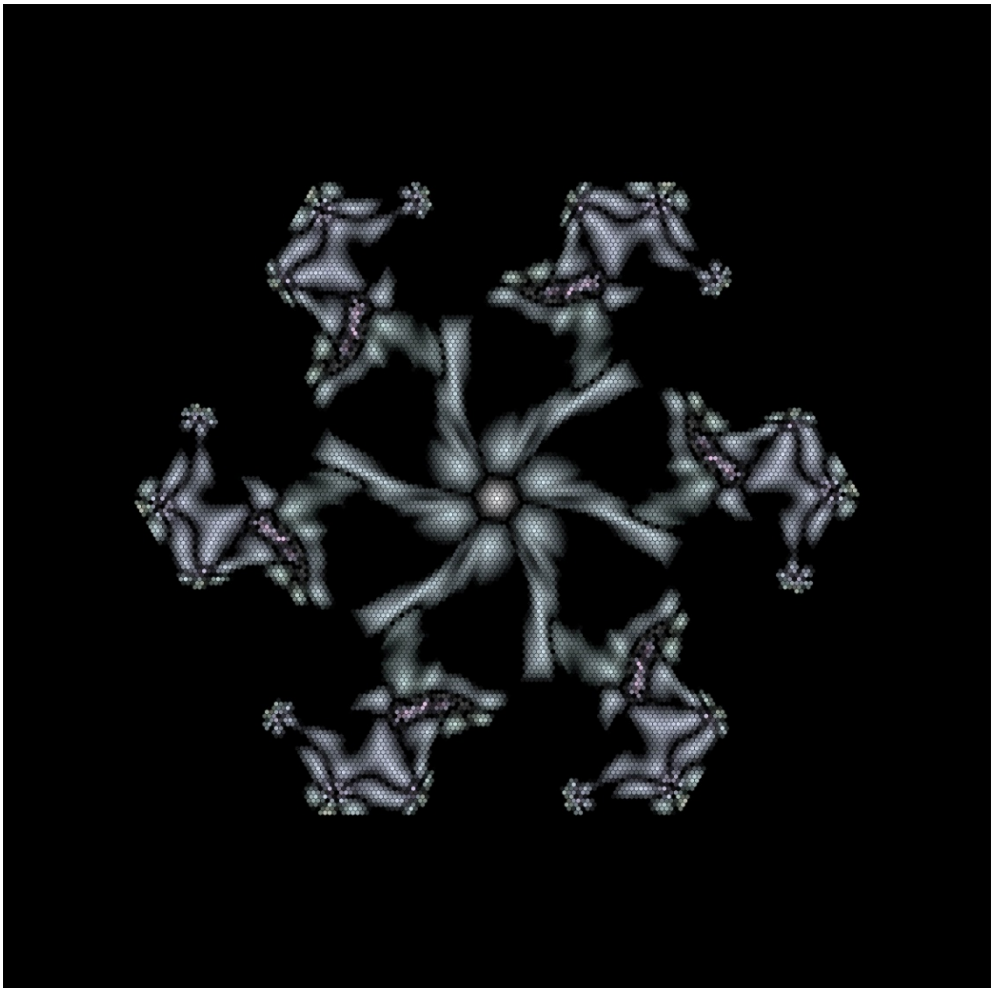

Figure 5. One of the inhabitants of the Nanocosm.

I consider the form-generating procedure just described to be a utilitarian application of mathematics. The outcome is an evolvable procedure that generates forms with the desired symmetry, so it serves the purpose of the work. But there is no particular significance, apart from the control of symmetry, in the use of distortion and Fourier series rather than some other procedure.

The large-scale geometric structure

The large-scale structure of *Nanocosm* is based on a multi-level hexagonal grid. This is very visible, and gives the work a “mathematical” character. The multi-level hexagonal grid was also used to structure most aspects of the work apart from the actual form-generation.

It turns out that there is no single obvious way to make a multi-level hexagonal grid. There are no long straight lines in a hexagonal grid, so it is not possible to make a large hexagon exactly out of small ones, but hexagonal shapes with zig-zag edges can be made. An

attempt to join these along their edges ends up with having the hexagonal regions overlapping (Figure 6, left). I ended up with hexagonal regions touching at their vertices only (Figure 6, right) with triangular interstices between them.

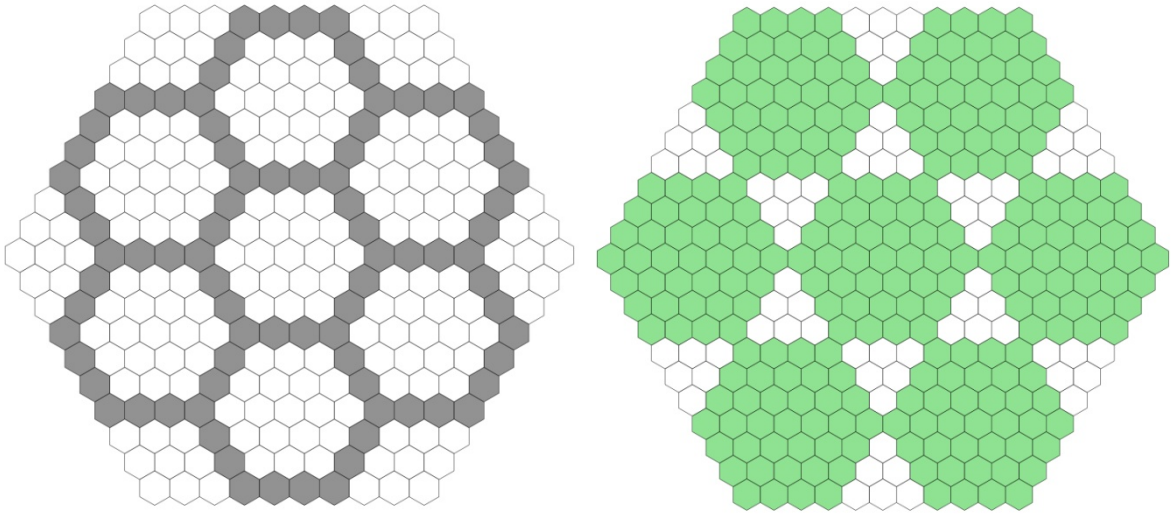

Figure 6. Left: *Hexagonal regions overlapping at their edges; hexels in an overlap are shaded.* Right: *Hexagonal regions (green), touching at their vertex hexels but not overlapping.*

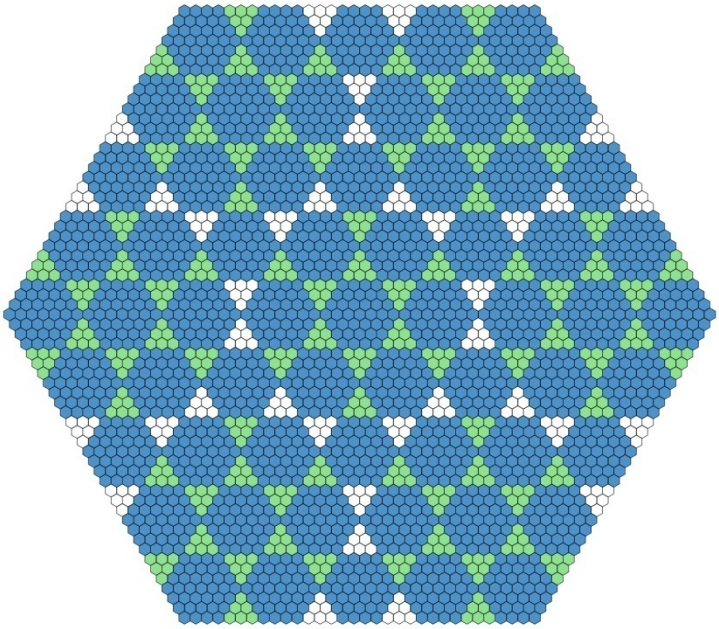

Figure 7. Two layers of hexagonal regions. The larger regions (considered as below the smaller ones) are green, the small regions (superimposed on the

larger ones) blue. The white hexels are outside both the small and the large hexagonal regions.

Figure 7 shows two levels of a multi-level hierarchy made in this way. In *Nanocosm* six levels are used: the smallest hexagonal region is seven hexels across. Then each successive size is three times the diameter of the previous one; the whole "world" is itself a hexagonal region, 1701 hexagonal cells across.

A plate of a particular size is constrained to occupy only the appropriate-sized hexagonal regions in the multi-level hexagonal grid. This has the consequence that a smaller plate is either entirely on top of a larger one or misses it entirely; partial overlap cannot happen. The plates have a degree of translucency, so this is not completely obvious when viewing the work, but a sense of systematic arrangement comes through.

When a larger plate moves, it must move to an adjacent hexagonal region of the correct size. The fusion is also constrained by the multi-level hexagonal grid. For fusion to occur, one of the configurations in Figure 8 must occur, and further it must occur within one of the locations of plates of the next larger size and that location must be empty. I thought fusion would occur too rarely if I require that all seven of the locations that lie above a hexagonal region of the next bigger size be occupied, and I considered that the patterns in Figure 8 are consistent with the general spirit of the work.

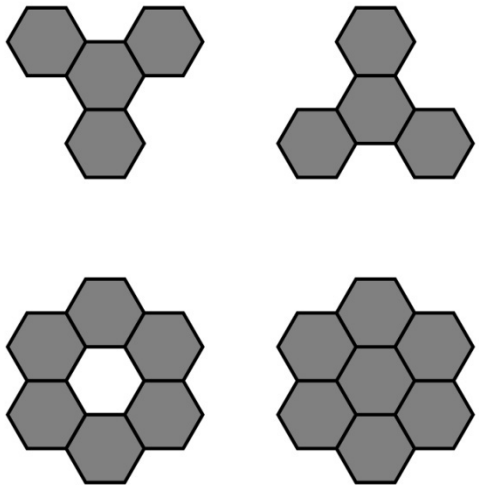

Figure 8. The four configurations of plates that lead to fusion.

Finally, the spawning is conditioned by the multi-level grid. Only the smallest plates spawn,

which is a perverse “biology”. The newly spawned plates appear in 324 specific locations, all the locations that are above no larger hexagonal region in the grid. This means that a newly spawned plate never appears above an existing plate.

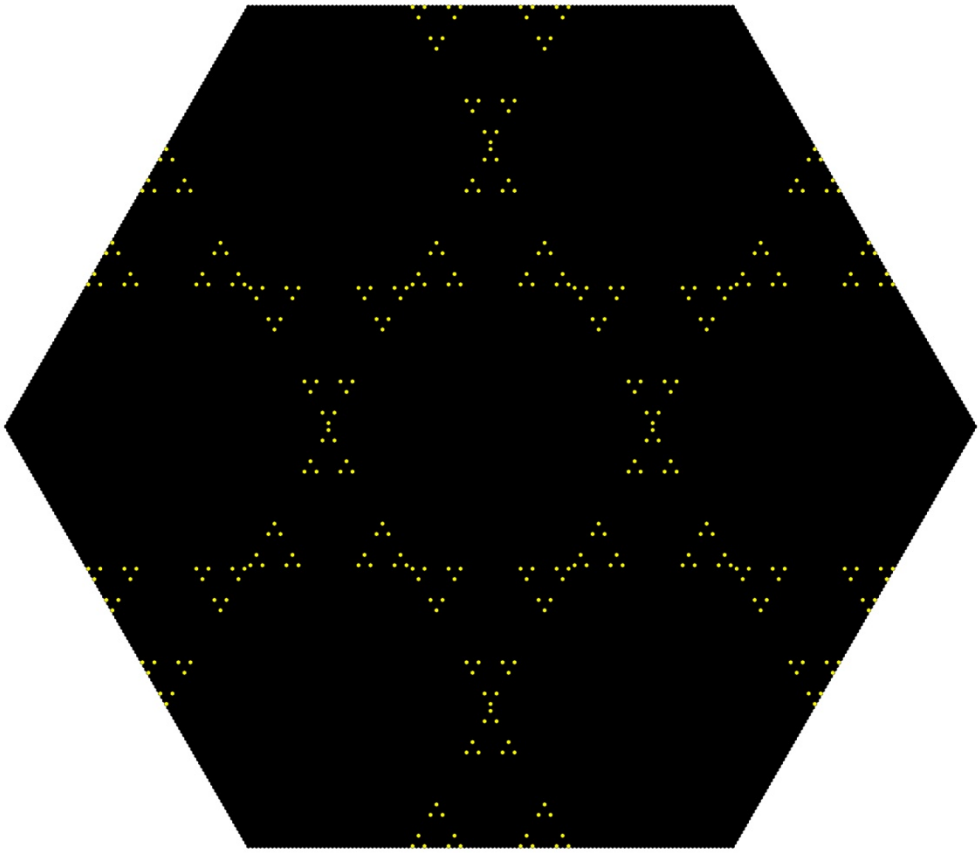

Figure 9. The 324 spawning locations in the Nanocosm. Each yellow dot is the size of one of the smallest plates (seven hexels across).

Mathematical virtues

The multi-level hexagonal grid is important in the visual appearance of *Nanocosm* and gives the work something of a perceived “mathematical” character, which helps the work to appear as a small world set apart, with its own rules, not ours. But the multi-level hexagonal grid also structures most aspects of the ecosystem, that is to say the generating procedure. This gives the work a conceptual unity.

Earlier I listed as “mathematical virtues” clear formal structures, a lack of gratuitous elements, an unfolding of consequences from a set of rules, unity in multiplicity. These are

things prized by mathematicians in their work. They were also prized by the artists of the Constructivist movement, in both Russia and the West. A striking statement is found in the first statement of Constructivism, the *Realistic Manifesto* of Naum Gabo and Antoine Pevsner (published in 1920): “We construct our work as the universe constructs its own, as the engineer constructs his bridges, as the mathematician his formula of the orbits.” [1] The name “Constructivism” came from the desire of Constructivist artists to “construct” work according to systematic logical principles, rather than relying on the “taste” of the artist. [2] Appreciation of mathematical virtues is not confined to mathematicians.

I regard generative art as the contemporary inheritor of the Constructivist spirit, with respect to logical construction and organisation.

Conclusion

I have taken *Nanocosm* as an example of a computer-based generative work, illustrating three different ways that mathematics can enter into such works. In computer-based work in general, mathematics can be expected to play a utilitarian role, used to assist with the generation of images and colours. This is the case even if the result is not particularly perceived as a “mathematical” work. I note that, especially in the twentieth century, mathematics expanded its coverage of form from traditional “geometric” shapes to include “biomorphic” shapes of many kinds; a pioneering work in this endeavour was the widely influential book *On Growth and Form* by D’Arcy Wentworth Thompson. [3]

The second way mathematics can enter into a generative work is as a visually obvious structuring principle. For a general audience this means some use of geometric forms as traditionally understood as well as a sense of an abstract structuring process. Where a piece conveys a sense of having mathematical underpinnings it brings with it the associations mathematics has as a study of absolutes beyond the human. (It is beyond the scope of this article to discuss the extent to which mathematics is a human construction; that belongs to the philosophy of mathematics. Mathematics has generally been considered to possess attributes beyond the human ever since Plato’s “God always geometrises”.)

Finally, a mathematical spirit can enter into a work through adhering to what I have described as mathematical virtues; I consider *Nanocosm* to be such a work. I think that, if a work is structured according to these mathematical virtues, a positive sense of this will come through to the experiencer of such a work, regardless of how much actual mathematics is used or how visible its use is. Generative art is ideally suited to make such works.

References

[1] Lodder, Christina, Russian Constructivism. New Haven: Yale University Press, 1983, 88-89.

[2] Bann, Stephen, ed. *The Tradition of Constructivism*. London: Thames and Hudson, 1974, 9.

[3] Thompson, D'Arcy Wentworth. *On Growth and Form*. Reprint edition. New York: Dover Publications, 1992. Reprint of the New edition, Cambridge University Press, 1942.