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Dynamic aesthetics of generative two-dimensional geometric art

Abstract
We show two generators of abstract art works related to themes of cultural and aesthetic value (Mondrian and Pied de poule). The demonstration is not about the resulting pattern, but shows the dynamic process of the algorithm gradually building and refining the result. The generators are driven by random number generators, so each time the output is different.

1 Background
The areas of generative design and generative art are in the very heart of the intersection of art, design and mathematics. Examples are the seminal works by Michael A. Nol [1], Aristid Lindenmayer [2], the more recent Malevich paintings by Mirjam Haring [3], and Matt Pearson's book on generative art using processing [4]. Algorithms have the power to generate two- and three-dimensional patterns which are carriers of considerable aesthetic and cultural value or which are tools to study or revitalize existing artworks and patterns.
This plays an important role in our own research and in our teaching activities. Examples of our efforts are documented in Leonardo [5,6], Bridges [7,8,9,10] and related publications such as [11,12]. Examples designed by our students can be found in the Mathematical Art Galleries [13,14]. We use languages such as Mathematica, Processing and the turtle graphics library *Oogway* designed by Jun Hu [8]. Oogway (github.com/iddi/oogway) is great for Escher-style tessellations and for fractal structures. Other popular languages are *grasshopper* for three dimensional work and *Arduino* for interactive work. For the Drapely-o-lightment interactive skirt [6], Loe Feijs joined forces with fashion designer Marina Toeters to explore the interplay between soft textiles and hard electronic components, combining the themes of drapability, sensing the body, and generative art.
In the proposed demonstrators we show the dynamic process of the algorithms gradually building and refining their result. An algorithm is not just a blackbox producing an interesting pattern, but it is an active element with intriguing dynamic behavior which can be made visible while growing (colliding, aligning, fractalising) the intermediate results. The generators also have an X-ray button to see hidden yet essential internal data.

2 Techniques
We found the following algorithmic techniques to be powerful and frequently usable:
1. generate and test;
2. collision detection;
3. random number generation;
4. object-oriented programming;
5. competitive growth and alignment;
6. fractals, recursion and turtle graphics;
7. symmetry theory and tessellation topologies;
8. geometric and art-theoretic analysis of existing art.

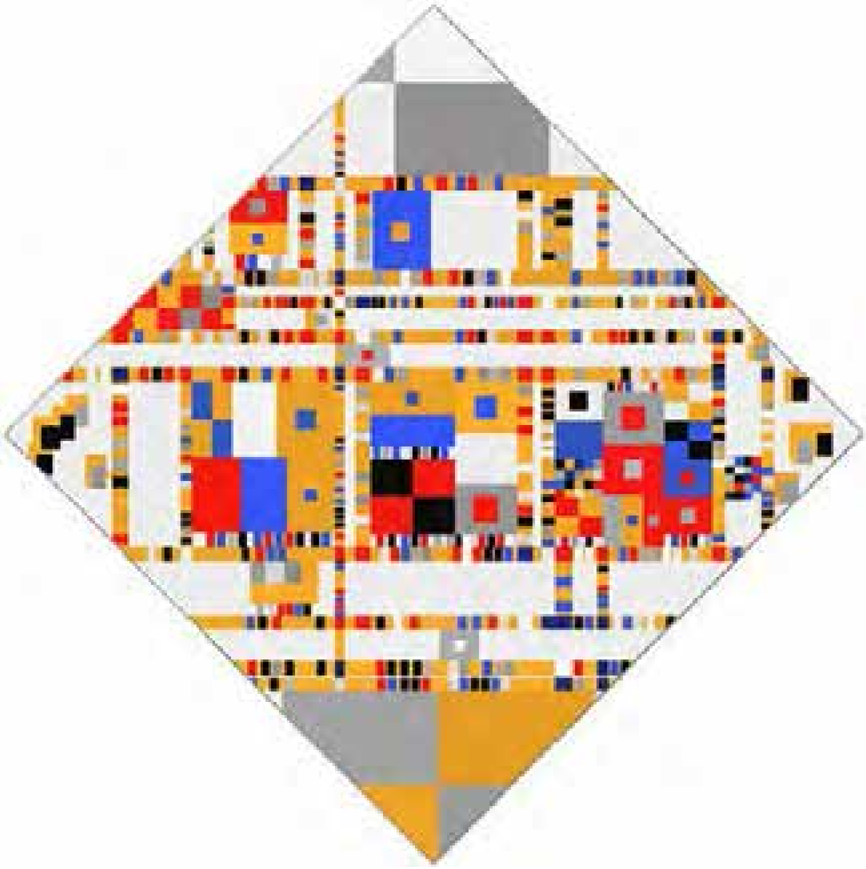

Fig. 1. Computer-generated Mondrian-style Boogie-Woogie.

Most of these techniques can be found in [15]. We add one or two lines of explanation for each technique. *Generate and test* works by invoking a random-number generator and later testing the results to select a satisfactory or optimal outcome. The result of random generators in art and design goes back to Marcel Duchamp in 1913 [16]. *Collision detection* is not only essential in generative art and design, but lies also in the heart of game design (the classic example being the pacman colliding with the ghost, one of them being eaten by the other). *Object oriented programing* and design [17] is helpful for organizing complex software in a way which is aligned with the objects' real world semantics. *Competitive growth and alignment* simulate the way cells grow in plants, pushing against each other [5]. *Fractals* are structures which are self-similar when zooming-in [18]; they are formalized by Lindenmayer [2] who found that *recursion and turtle graphics* are useful for programming generators. Other fractals we designed are described in [9] and [10]. *Symmetry theory and tessellation topologies* are essential for Escher-style works and Islamic art such as the famous Alhambra in Granada. The classic mathematical reference is by Heesch and Kienzle [19]. *Geometric and art-theoretic analysis of existing ar*t has been applied for many artists, of whom we only mention Malevich [3], Mondrian [1,5,11], and Griz [20].

Other techniques such as Voronoi diagrams [6,21], trigonometric calculations, physics simulation, and transformations of color space are useful too.

3 Demonstrators

Two important and recurring themes in our work, both being related to famous patterns of cultural value are:

- Mondrian's non-figurative compositions;
- Pied de poule patterns, also known as houndstooth.

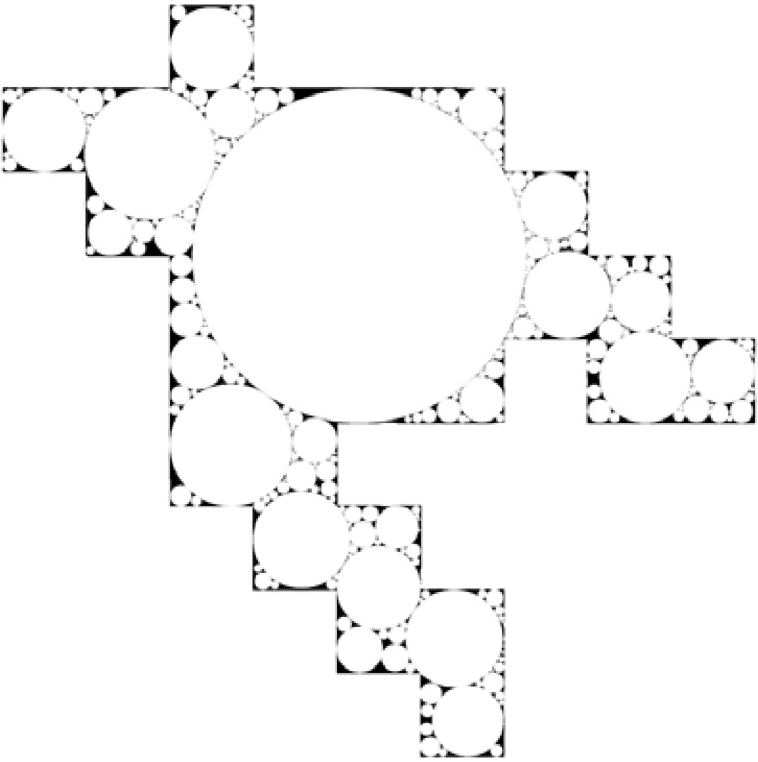

Fig. 2. Computer-generated fractal Apollonian Pied de poule.

We discuss each of these next. Besides the early 2004 generative explorations of Mondrian's works [5,11], Feijs entered the Dutch competition of programming the best Victory Boogie-Woogie in 2013. Feijs won the competition (among 34 other submissions, developed in Matlab, Processing, Javascript, Python, Java, Common Lisp, Shell, Perl, Microsoft tag, R, scratch, C#, and Php). More details can be found on the website of Setup: http://elegant.setup.nl/ and on Github: github.com/Elegant-Setup/. The program is described in detail in an article submitted to the Journal of Mathematics and the Arts. At DeSForM we shall show the working program as a demonstrator (Figure 1).

Pied de poule (houndstooth) is an ancient textile pattern, already applied by the Vikings in the era before BC and made famous by the tailors of the Prince of Wales in the 1930s and by Christian Dior in France in the 1950s. It is still very much alive and can be seen on the catwalks of Paris, Milano, London and New York and in the streets all over the world. We re-interpreted the pattern in a variety of ways, notably by inventing new and fractal versions of it. Marina Toeters created novel garments with these fractals, documented amongst others in [9,10]. They are also discussed by houndstooth blogger Anti-houndstooth (anti-houndstooth.blogspot.nl/). Especially for DeSForM we created yet another fractal pied de poule, called *Apollonian Pied de poule*, to be shown at DeSForM for the first time (Figure 2).

During the DeSForM conference we shall alternatingly demonstrate the live generation Mondrian-style Boogie Woogie and the live generation of the Apollonian Pied de poule. In particular we shall demonstrate this for one Mondrian (the abovementioned award-winning Victory Boogie-Woogie algorithm) and for one fractal Pied de poule: a new variation designed and coded especially for DeSForM.

In both cases, technique numbers 5 and 6 (see the list of techniques in Section 2) which will be clearly visible: competitive growth and alignment, and recursion. The techniques 1–4 and 7–8 are used in the code too, but are less explicitly visible during the proposed demo. The program will run continuously on a computer and displayed on a beamer. The visitors can play with parameters and generate new versions within tens of seconds.

4 Dynamic aesthetics

We should discuss the aesthetic qualities of the proposed demonstrators and the theoretic background of the claim that they have both static and dynamic aesthetic qualities. In The Aesthetics of Movement by Souriau [22], a rigorous analysis is made of movements as a source of aesthetic values. For the rhythms in nature (including our moving bodies), according to Souriau, there are natural laws such as the laws of compensation (simplified: what goes up must come down) and tendency to repetition. For mechanical beauty, Souriau discusses moderation of pace, regularity of the rhythm, muscular synergy, problems of balance, and problems of support. Although it is possible to simulate all these effects in computer-generated movements, this is not what happens in the two proposed demonstrators. Computer-generated artifacts are not bound by natural laws.

The static aesthetics qualities of a generated form can originate from cultural values (art, fashion, history), resemblance to nature (flower motifs, plant-like fractals, Voronoi structures), Gestalt qualities (balance, proportion, intriguing foreground-background), symmetries (architecture, decorative patterns, frieze patterns, wallpaper patterns), religious symbols (not my topic of studies), or societal symbols (supporting preferred relationships or leadership). In the case of the two proposed demonstrators, the static aesthetics is based mostly on the underlying cultural values (Mondrian, pied de poule as cultural phenomenon) and to a lesser extent on Gestalt qualities (reasonable balance and proportion).

The dynamic qualities of the two proposed demonstrators are a different matter. For a large part they appeal to the ratio: it is intriguing to see the algorithms in action, gradually filling-in the details; and every now and then there are small surprises for emerging objects (the Apollonian circles whose complements get completely fragmented but do not vanish). At a larger time scale, the dynamics of the proposed demonstrators are not of a repetitive nature (swings or circadian rhythms with their eigen-frequencies). They are more like the eigenfrequency of a biological clock where an organism develops towards full maturity, gradually the size details which are being added getting smaller and smaller. For a discussion on eigenvalues as a source of aesthetic value we refer to [23]. Bråten [24] distinguishes three levels of human mental processes for dynamic aesthetics: sensing, rational thinking and interpretation. At the sensory level Bråten relies on Laban concepts: weight, flow, space and time. Of these, weight is relevant here, because in the two proposed demonstrators, there are heavy-weight actions in the begin phase, but gradually the actions become smaller and more light-weight. Unlike dance, the algorithms have not much classic movement, rather they show a gradual unfolding and filling-in of detail: something a dancer cannot sustain as our bodies have no fractal structure at the visible outside.

5 Relation to design

Algorithmic generators are increasingly important in a design perspective as more and more, the forms of a design will not be determined by drawing or sculpting by hand or working in sculpting-style editing tools. Instead, forms are determined by algorithms, either very innovative algorithms as shown here, or by algorithms from a library with personalized parameters. Unless the algorithm follows a straightforward process (repetitive tessellations), there is added value for the end-user to see the process by which the form was created. Not only the final implementation or reproduction, (cutting, stitching or 3D printing), but even more the creation process itself is interesting.

In particular this applies when the product is delivered in a system of mass-customization (every end-user gets his or her personal product). In case of wearables, the form may carry a clear "digital signature" and then the origin of that signature is interesting for the end-user. Examples of wearables with a clear digital signature are fPDP [9], Drapely-o-lightment [6], and This fits me [13]. One way to tell the story is to show the algorithm in action (which is an experience in itself). In other cases, the user could be not only an observer but an active contributor to the generation process. A very special example of the latter approach is the Origo system [25], where the end-users' own physiological measurements are fed into a generative art design. The art works are very, very personal. Another example is the generation of jigsaw puzzles by nervous system: featuring art by Jonathan McCabe, every puzzle has a unique image and unique pieces, as described by Rosenkrantz [26]. The pieces form in a simulation of a crystal growth by "dendritic solidifications", after which the pieces are laser cut.

6 Looking back

For this demo and short paper there is one claim: that not only the resulting pattern is interesting, but that also the build-up of the result during its construction. The user can become a co-designer by choosing parameters of the design (a philosophy demonstrated also by Leonie Tenthof van Noorden [13]). We envision new ways of designing in which algorithms play an essential role and the user is not only interested in the aesthetics of the result, but has access to the generation process itself and the aesthetic qualities of the process, before, during, and after the making.

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