A Collaborative, Interdisciplinary, Undergraduate Course on Generative Art

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DOI: 10.3217/978-3-85125-932-2-09

Abstract. We describe an undergraduate course on generative art, co-taught by a professor of Fine Arts and a professor of Mathematics, offered at Ohio Wesleyan University in Spring 2020. Starting with a definition of generative art as "art in which the artist deliberately cedes control over some significant aspect of their work to an external agent," twelve undergraduate students worked to create generative art across a range of two-dimensional media, both digital and physical. Principles of design, color, and computation were emphasized throughout. In this paper we describe the overall aims of the course as well as some of its key assignments and outcomes.

1 Introduction

The meaning of the term "generative art" is somewhat contested. A reasonably broad definition would be *art in which the artist deliberately cedes control over some significant aspect of their work to an external agent*. This external agent can take the form of natural or mathematical processes, machine-driven randomness, other individuals (e.g., the audience), etc. (cf. Galanter 2008). This description encompasses a more typical, and more restrictive, definition of generative art as *art that is created using processes or systems that are autonomous or semi-autonomous*. These processes can be variously deterministic or random, digital or mechanical, human guided or fully automated. In general, autonomous systems are those which progress and evolve according to predefined rules, often generating tremendous complexity out of the iteration of many simple operations. These systems, and the manner in which they are interpreted/visualized, determine the form and composition of the piece without direct intervention by the artist.

A good discussion on the distinction between art that is (and is not) "generative" can be found in Galanter (2016) where he traces the origin of the genre to early computer/electronic music, advances in computer graphics and animation, and various youth cultural scenes (demoscene, VJ culture, etc.). Contemporary examples of generative art include, to name only a few: the combinatorial sculptures of Sol LeWitt; the computer-plotted drawings of Peter Beyls (Beyls 2014); the machine wall drawings of Tristan Perich; the wind-driven machine drawings of Cameron Robbins; Harvey Moon's drawings in which an automatic plotter traces the path of a caged cricket; Angela Bulloch's bench-activated drawing machines; Jason Salavon's composite averages of hundreds of thematically similar digital images.

A key feature of most generative art is its ability to straddle the line between complete symmetry/order and total asymmetry/disorder. This in-between space tends to exclude works of art determined fully by human intention as well as more chaotic pieces in which the organizing principle or underlying structure is unapparent. Aesthetically, we often see pure symmetry as sterile and uninteresting, while total asymmetry is often seen as just noise. According to McManus, "asymmetry probably results most effectively in beauty when the underlying symmetry upon which it is built is still apparent" (McManus 2005). This tendency for generative art to both be guided by human intention, but not to be bound by it, is a key topic we emphasize on our course.

Many of the artists we shared with our students over the course of the semester are/were not working in the realm of generative art per se. However, we explored parallel concerns in the relationships between order and disorder in their work – pattern and pattern disruption. When the particular art medium requires the artist to make a mark, weave a row, etc, how can the artist build in chance? In what ways can they improvise without the piece feeling contrived, like an illustration of chance and discord, rather than a true tension between repetition and anomaly?

When talking about improvisation in visual art people often draw parallels with jazz. In both music and art, establishing a basic understanding of how formal elements function allows for more freedom when improvising. For example, the works of both Anni Albers and the weavers of Gee's Bend find freedom within certain boundaries, dictated by incorporating known patterns and shape motifs, harmony and rhythm. With computer generated randomness (improvisation), harmony and gestalt also depend upon small patterns/motifs to appear within the seemingly random noise.

Having acknowledged that generative art can be (and often is!) produced using many different artistic media (e.g., sculpture, photography, textiles, etc.), nevertheless, it is certainly true that the bulk of generative artists today work with a computer and utilize algorithmic processes implemented in various programming languages (e.g., Processing). Hence, it is natural that an interest in generative art might lead to collaborations between artists and computer programmers. The authors of this paper represent one such collaboration. Jeff Nilan is an artist who works in photography, book arts, and textiles. Craig Jackson is a mathematician who works with computational models of complex systems such as the Earth's climate.

In this paper we describe one outcome of the authors' ongoing collaboration: an undergraduate course offered in Spring 2020 on generative art. The students who enrolled in the course largely came from two distinct backgrounds: first, traditional fine arts students who had a good exposure to principles of design, form, color, and composition; second, science students with a background in mathematics, data analytics, and/or computer programming. Each of these groups of students lacked one set of key skills to complete the weekly assignments on their own. Therefore one of the primary aims of the course was to fill in these missing gaps in order to utilize computation and algorithmic thinking, as well as a variety of photo and textile processes, to produce interesting generative art in both digital and physical form.

2 Selected Course Aims and Assignments

Our course is designed around approximately 12 individual, yet related assignments. Students submit their work in advance to be followed by a group critique. A third of the assignments are related to programming a computer to make "random drawings," the next third are related to random tilings, and the last third are a mix of more advanced topics that allow for a deeper exploration and which may serve as the basis for a substantial final project.

At the core of the course's visual concerns are principles of design and color interaction. In our initial assignments we were primarily focused on non-representational design and color compositions – imagery that does not represent or depict any identifiable person, place or thing. As such, our concerns were with formal elements and the resulting "content" of the work is its color relationships, shape variation, texture, size and scale. With design, our primary concern was that of creating illusionistic movement and illusionistic space – making something flat and static to appear dimensional and in flux. With color, our primary concern was that of color interaction – exploring how hues are always influenced by one another, are not static but relative and changeable.

In this section we describe the aims and outcomes of five different assignments. All of the programming necessary for each assignment was carried out using the Mathematica scientific programming software.

2.1 Constrained Random Drawings

The first several assignments in our course involve getting a computer to make a "random drawing." Of course, the precise meaning of the word "random" is unclear at first and requires a precise meaning if we are going to be able to get the computer to make any kind of drawing at all. A good starting place for this kind of exercise is to learn how to make a simple random walk. Further refinements can then be made in order to change the manner in which the random walk is performed and to constrain it to lie within a prescribed area.

A random walk is a recursive process that traces out a path by repeatedly deciding to move randomly in one of any number of preselected directions. For example, the following code will begin with a point at the origin and repeatedly move in one of four randomly chosen directions (right, left, up, down).

```
directions = {{1,0}, {-1,0}, {0,1}, {0,-1}};
pt = {0,0};
walklist = {pt};
For[j=1, j<=100, j++,
  pt = pt + RandomChoice[directions];
  AppendTo[walklist, pt]
]
```

The points that are visited in this process are recorded in the list `walklist` which can then be visualized by joining the points sequentially together with a drawn line (see Figure 1).

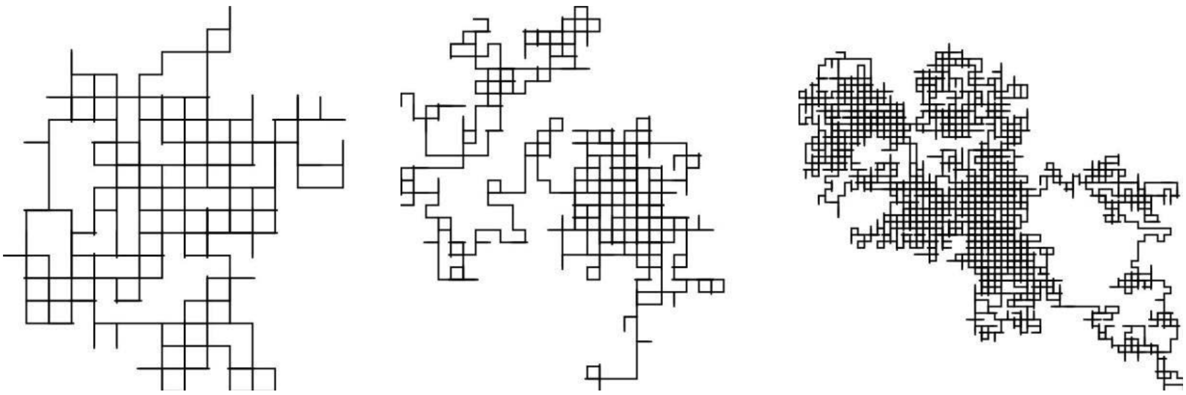

Fig. 1. Random walks. From left to right: 500, 1000, 5000 iterations.

This simple example allows for variations to the algorithm that produce different types of drawings. For example, we can allow a larger set of directions, even infinitely many, in which to move. We can select the direction in which to move at any given step in such a way as to prioritize some directions over others. Finally, we can insert conditionals (if/else statements) in order to prevent the random walk from crossing obstructions or moving outside a predetermined area. Altogether, though, the many possible variations on this simple random walk code leads to a vast array of possible "styles" for a computer-generated random drawing. Three examples, created by students, are shown in Figure 2.

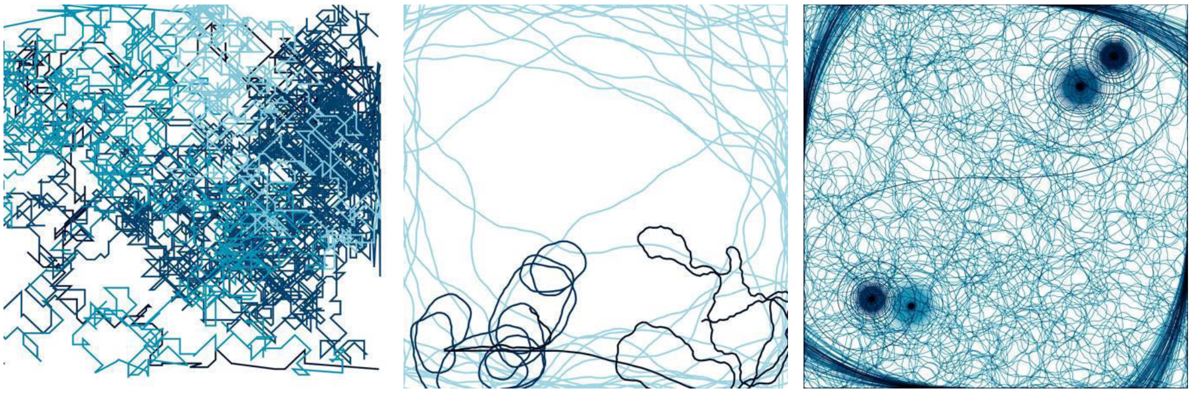

Fig. 2. Constrained random drawings. Work by Madeline Henson, Clay Sturts, and Max Goulakos (left to right).

From a design standpoint the first assignment introduces the problem of how to create illusionistic space and movement with a single line-weight thickness. When line thickness is undifferentiated throughout a drawing, spatial illusion can only happen with variation in the relative lightness and darkness of the lines. Incorporating value (relative lightness or darkness) of line creates illusionistic space and movement. Even with uniform line thickness, light lines tend to advance, darker lines tend to recede. Hence, students discover, in a very fundamental way, how to manipulate a 2D picture plane through value alone.

2.2 Filling Voids with Value

While the constrained random drawing assignment focuses on principles of design like line value, density and movement we use the subsequent assignment to focus on a different set of design and color principles simply by giving students the task of filling in the gaps in their existing constrained random drawing with shades of various values. Specifically, students are constrained to select values that are neither fully black nor fully white. The process of filling the voids was not automated, but was done manually in photo editing software (GIMP). The intention behind the assignment is to use contrasting values to add depth and complexity to a line drawing. In particular, students were advised to consider the phenomenon by which a darker value next to a lighter one can act to steal even more of the lighter region's value, enhancing color contrast and therefore illusionistic depth.

While the initial assignment allowed for illusionistic movement and depth in an otherwise static line drawing, Filling Voids with Value introduces the potential for scale to further manipulate our sense of space and movement. For example, small spaces (cavities) between line loops can be emphasized through value, therefore appearing closer and more prominent. The same line drawing can be filled with different densities (value levels) therefore altering our perception of how it functions spatially. Three examples of student work are shown in Figure 3. Note that the images shown in Figure 3 are the same as those shown in Figure 2, only the voids have been filled.

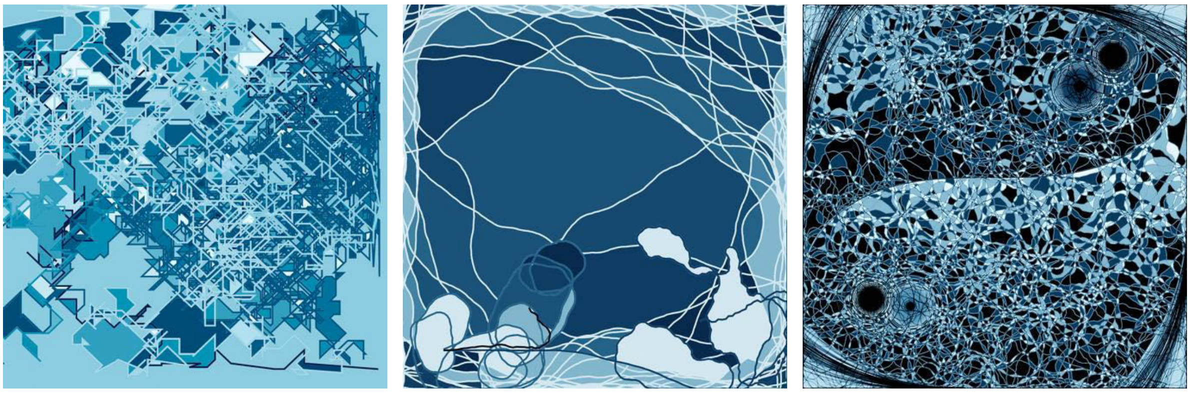

Fig. 3. Constrained random drawings in which voids have been filled with value. Work by Madeline Henson, Clay Sturts, and Max Goulakos (left to right).

This void filling assignment also introduces color in a limited but fundamental sense. We use shades (base hue + black) and tints (base hue + white) of a single color to create a value range. Avoiding absolute black and white keeps the students within the value range of a particular color – holding onto the "color identity" throughout the value spectrum. The monochromatic spectrum allows for both contrast and smooth progressions between values and avoids more complex combinations between hues, such as complementary contrast/vibration.

Technically speaking, this assignment is not difficult since we allow the students to manually fill their voids using the paint bucket tool in a digital image editor such as GIMP or Photoshop.

2.3 Triangular Tilings

"Tilings" are a regimented way to subdivide the two-dimensional plane into a discrete set of regular pieces (tiles) that fit together evenly. The tiles themselves can be of any shape. For our course we focused on simple shapes such as triangles and squares. In contrast to the previous assignment where "shapes" were created by intersecting lines and then filled with a value range of hues to create depth, the Tiling with Triangles assignment introduces shape as a fixed repeated motif. The initial shapes (in this case triangles) do not vary in size or value but only in arrangement within a square. As such, the design focus is initially on pattern (and pattern disruption), repetition of form, theme/variation and anomaly, rather than on illusionistic space.

Our work here was particularly inspired by the notebooks of Anni Albers (Albers 2017) in which Albers experimented with many variations of triangular tilings hand-drawn on gridded paper. Triangular tilings are also featured in many of Albers more formal pieces including her large tapestry "Camino Real" (1967). For this assignment, students need to write an algorithm that will produce a random triangular tiling (though the exact nature of the tiling is up to them) from a collection of colored tiles.

In order to accomplish this, students can pre-generate a set of tiles stored as graphics primitives and fill out an array/matrix of these tiles using random selection. The precise randomness of the selection can be influenced by its place in the array, by the tiles already chosen, by pure chance, and so forth. After the array of tiles has been selected, the entire piece is visualized. Two examples of student work are shown in Figure 4.

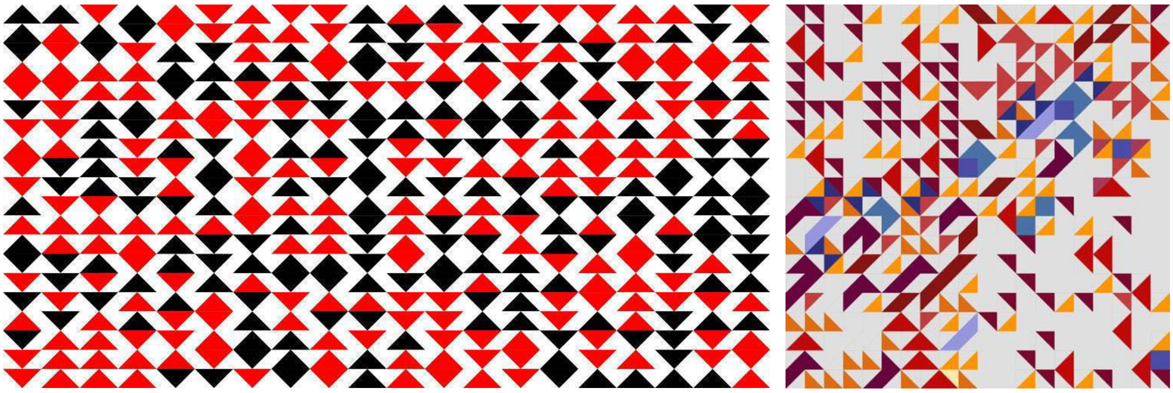

Fig. 4. Triangular tilings. Work by Madeline Henson and Isabelle Ammendola (left to right).

The entire process of creating a random triangular tiling requires list management techniques, nested loops, if/else statements, as well as the ability to produce a final composition by layering many different graphics primitives onto the same plot.

2.4 More Complex Tilings

The aim of our next assignment is to explore more aspects of color interactions by making tilings with more complex tiles and a constrained color palette. Specifically, an allowable palette must contain 1) two complementary colors; 2) one set of four colors that are analogous to one of the colors from (1); 3) one wildcard color (optional); and 4) at least four variations in shade and/or tint for each of the four complimentary colors. This seemingly simple palette allows for complex color effects including color contrast, optical blending and rhythmic progressions.

Inspiration for this assignment came largely from aerial landscape photographs of rural America in which the patterns created by subdivision of agricultural parcels and use of central pivot irrigation create a patchwork of circles and rectangles of various analogous shades and values.

Most of the technical aspects of this assignment are similar to the previous assignment on triangular tilings. However, here more complex tiles need to be stored as potentially long lists of graphics primitives, which themselves need to be selected according to some randomized algorithm.

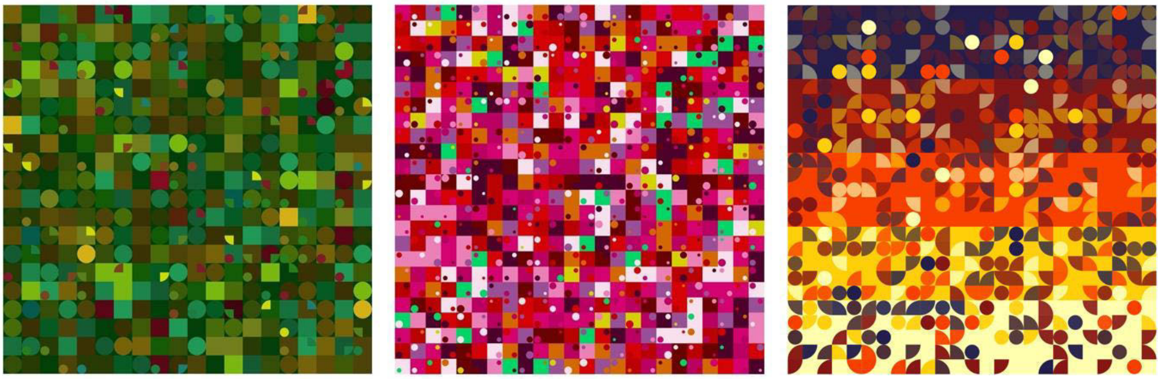

Fig. 5. Tilings with semi-complex tiles with color considerations. Work by Madeline Henson, Rand Barton, and Max Goulakos (left to right).

2.5 Image Averaging

The last assignment we describe here is possibly the simplest in a technical sense. For this assignment students need to select a single object and photograph it from many different angles (or take a large number of photographs of different objects that fit a common theme) and make a single composite image by averaging.

To accomplish this students need to convert their digital images into a matrix of pixel values (e.g., grey levels or RGB values) and then simply compute a pixel-by-pixel numerical average. These numerical averages were the taken as the pixel values of the final, averaged image.

This assignment was inspired by the work of Jason Salavon, especially, but also much of the work in the cubist tradition. The idea is that even though the final composition is the direct result of deliberate choices made by the artist, the exact nature of the final image cannot be appreciated in advance. Ideally, the final composition should transcend being a mere assemblage of distinct subimages and invoke a sense of gestalt. That is, the final image should be something other than a sum of its parts. The irony here is that, in a technical sense, the final image is *nothing other* than a sum of its parts, since the final image is directly composed as an average.

This assignment allows for elements of the previous four assignments to be incorporated into objective subject matter through the use of photography. As such, the images become “abstractions” or alternate ways of looking at recognizable subject matter. Students attempt to make pictures of subject matter that already includes qualities of line, shape, motif, anomaly, illusionistic space and movement. In this case, image averaging may actually serve to reduce the clarity or alter the original connotation of the subject matter.

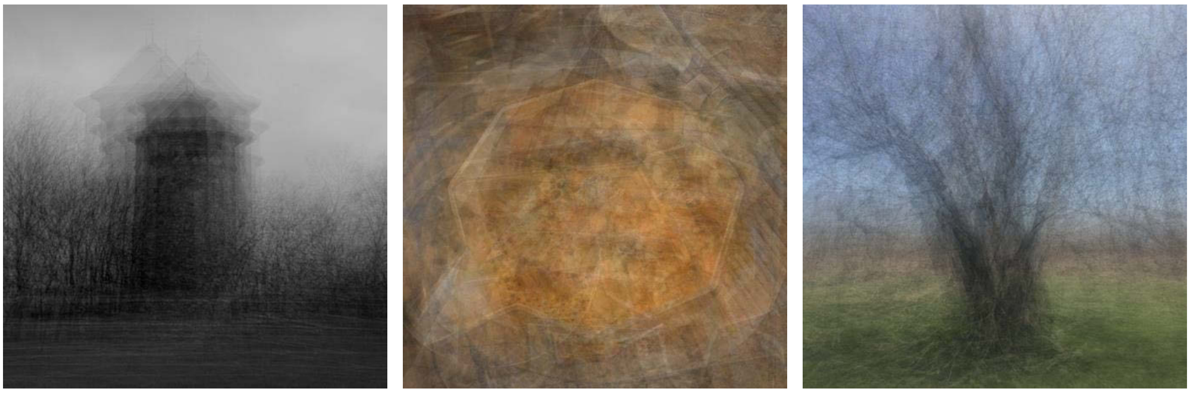

Fig. 6. Composite averaged images. Work by Rand Barton, Alexis Yracheta, and Max Goulakos (left to right).

3 Discussion

Courses on generative art, similar to that which we have sketched out above, can fit well within an undergraduate curriculum that values interdisciplinarity and cross-disciplinary collaboration. The course can be appealing to a wide variety of students including those that are firmly grounded in the arts as well as students from STEM majors. In fact, when we offered the course in Spring 2020 it was cross-listed as both an art course and a math course. Depending on which version a student signed up for, the course would meet either an arts or a math distribution requirement.

In future iterations of the course, we will seek to focus more on ways to take what students do in the computer and bring it into physical form using various artistic media. We had such plans in 2020 and we were able to have students employ several photographic processes (cyanotype and standard darkroom printing) to turn their digital work into physical artifacts. However, the covid pandemic that began in March 2020 resulted in our institution moving to remote education. Because of this, for the remainder of the course, we mostly focused on digital work that could be displayed on a screen.

We see some interesting potential to incorporate weaving and other textile/fiber arts into the next iteration of the course. Weaving, in particular, holds particular promise due to its combinatorial nature and the fact that weaving plans are often generated algorithmically.

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