Comparative Visual Aesthetics in Synesthetic Structures

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ABSTRACT

We describe a means of co-evolving parameters for procedural animation generation. Several experiments were completed in order to find an aesthetically pleasing animation mechanism, which could be modulated by music and have its parameters evolved over time. The selected music visualization is a set of vector fields for the purpose of moving particles whose paths create visual interest. To cause emergence of pleasing patterns in particle behaviour, several metrics were incorporated into the fitness function. To reflect the spatial characteristics of the vector fields a crossover operator was developed. The most critical aspect in creating a vector field which animates particle paths over time is that the vector field not allow the particles to become static or too tightly clustered, as either indicates the particles will no longer be circulating in interesting ways. We are interested in encouraging certain behaviours of the particles without doing so explicitly so that a local interaction approach allow for many aesthetically pleasing solutions to be reached, and rendered. This complex systems approach continues to work as interesting patterns emerge. We provide several examples with later generations creating more aesthetically complex renderings. Comparative visual aesthetics as a measure of such visual refinement is introduced. If pleasing patterns can be made implicitly with the vector fields in this specific audio-visual composition, it stands to reason that parameters for other visualizations may be evolved as well and this work serves as an argument for computer assisted comparative aesthetic refinement.

Keywords
Particle animation driven by music; vector field rendering; local interactions creating global effect

1. INTRODUCTION

One purpose of this paper is to explore computer assisted generation of audio-visual art. The question of what is interesting is usually based on the observer [Ols05]. Just as impressionist paintings are pleasing from a great distance when the artist's dithering and the interpolation by the human visual system and have an interplay; those same paintings have fascinating brush strokes when viewed up close. The link between music consumption and the emotional state of a person is not entirely understood, but a connection between the two has been proven many times [Cam01]. One successful examples of interactive is the pleasing works through an understanding of aesthetics [Kur00].

2. VISUAL AESTHETICS

Computational aesthetics incorporates computer science, neuroscience, and visual art. It is known that symmetry plays a part in our determination of what we consider beautiful [Tyl00]. Synesthesia occurs when several phenomena are perceived in unison [Joh07, Hub05].

When a collection of entities move together, using rules which govern individuals within the group, swarming behavior results and has been modeled computationally [Tho05] and cellular automata earlier [Joh02; Cho00; Gol89; Wol02; Sim94]. (Figure 1).

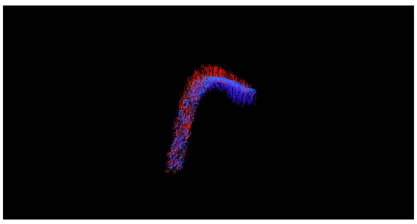

Figure 1: Structures imposed on the swarm through initial position and vector field edges.

Our second example is a frames of flowing river which provides rich textures found in the water. We experimented with accentuating theses characteristics – either strong lines or indistinct splashes of texture – by using the images as height maps (Figure 2). Each pixel corresponds to a color and z component which was rendered using mesh using openGL™.

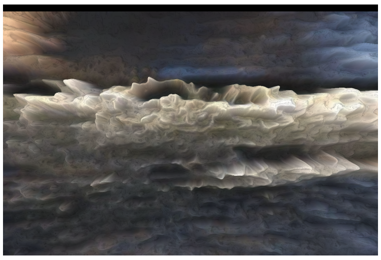

Figure 2: Height Map interpretation of river video frame.

We ran a Gaussian filter on the video frame to tune the amount of noise and the sharpness of the resultant geometry (Figure 3), including text and a grid of squares.

Study of Figure 1-3 provides us the opportunity to define the *comparative visual aesthetics* which is defined as a measure of visual-interest an image or a piece of art generates when compared with another. Figure 1 does not have the same visual interest as in Figures 2 and 3. Figure 2 and 3 create similar visual interest, and so the measure of their visual interest is similar to us. This measure is both subjective and relative and is proportional to time we want to gaze, admire, or look at the piece of art or image. As visual aesthetics is based on perception, large variation of measures can occur. Yet it is much easier to be consistent when one image or art piece is compared side by side with another for developing sense of relative measures instead of absolute measures. Comparative visual aesthetics provides one relative and subjective measure. Computational measure of complexity of an art pieces is an open area of research. Our measurement of aesthetic complexity is along several lines of current research such as the work by Itti, Dhavale and Pighin [Itt04] and Santella [San05]. Yevin's [Yev02] notion that the criticality of the art is related to patterns and rhythms is of major interest for us in developing our concept of *comparative* visual aesthetics.

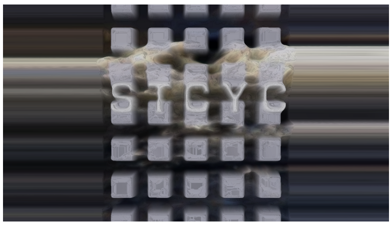

Figure 3: Addition of graphics elements to the height map.

3. SYNESTHETIC STRUCTURES

As generations of work can be visually compared to each other and only visually interesting pieces survive, one of the thoughts we have pursued is that we would definitely need a generative-system, which inherently contains, and which can match the desired aesthetic-complexity. Since we had used music as an input device in our earlier work [Joh04, Joh07], we decided that music could also drive the generation of such synesthetic shapes. So synesthetic shapes are generated by varying the properties of particles or cylinders based on the analysis of the music. For example, thickness or radius of cylindrical shape could be dependent upon the presence and amplitude of certain range of frequencies. The trace of the particles could be thought of as vector fields being created at many levels of resolution and in some ways being affected by a weighted combination of nearby vectors. With that in mind we added a few more stochastic mutations of the vector field resulting in synesthetic structures as rendering of these vector fields as 2D ribbons [Joh07]. The 2D ribbons' paths were created by using square tubes which followed the particle paths created by vector fields. We formed these tubes by finding the normal of the most recent segment of path and a vector from the most recent point to the origin. An orthogonal vector was then found using the first normal and the vector from the most recent point to the origin and taking their cross product. Those two vectors were reversed to determine the corresponding points on the opposite side of the path. Triangles were used to create a tube (Figure 4) between determined set of points. We used the kick drum events to drive one particle-swarm (the grey particles in Figure 5) and the snare drum events to drive another, ignoring other events in the MIDI sequence. Because the snare events were more prevalent than kick drum events, the kick drum events were weighted higher to cause both particle-swarms to contribute structure to the swarm based sculpture almost equally. When the particles intersected each other we caused the growth to pause, and the path would be rendered white to show the particle was no longer contributing to the structure. One can see the lines in several states of construction (Figure 5), from barely growing to many particles intersecting. As shown in Figure 6, the reddish swarm becomes more orange as the particles age, with only the most recent path segments being red. The grey swarm becomes predominantly white as its members are driven to an edge within the vector field's cube of influence (Figure 6).

Particles from the same swarm tend to weave concentric patterns and slight intersection in tube geometry is visually interesting when rendered, it looks like fluid wires melting together and then diverging again. Instead of tubes with equal width and thickness, we caused the thickness to be somewhat less than the width, giving us something of a ribbon effect. This made the paths' position relative to the origin very interesting, causing the ribbon to twist during turns. This twisting is due to the use of the cross product of the vector from the particle to the origin being used to calculate the initial normal used in constructing the tube geometry. We then had the particles create the tube geometry using not the origin for the initial normal, but an animated point near the origin. The point is at the origin in the X and Y dimensions, but varies with the MIDI impulse along the Z dimension. This point was different for each particle-swarm since each particle-swarm is driven by different MIDI events, causing the swarms to appear to *breathe and pulsate* in rhythmic harmony. Lastly, to have some interplay between swarms, each swarm is affected by 100% of its vector field's strength and 10% of each of the other vector fields. This manifests in patterns of similarity between particle-swarms, as though the swarms were slightly chasing each other. The most interesting part of Figure 7 is that, comparatively, we feel that it has more visual aesthetic-complexity or visual interest then images in Figure 6.

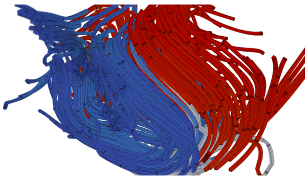

Figure 4: Depth of field effects with geometry overlay.

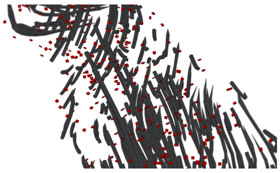

Figure 5: Early stages of synesthetic sculpture.

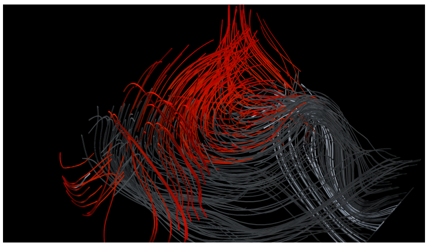

Figure 6: A frame showing complexity growth in synesthetic structures simulation.

Genetic Algorithm

Figure 8 depicts an ending condition of an individual. The three swarms are grey, yellow-orange, and red, with particles that have collided with vector field borders rendered in a lighter version of those colors in order for the user to observe the relative success of the swarms. In these evolved sequences, the red particles are moved by the kick drum, the grey particles are linked to the snare drum, and the orange particles are moved by the high hat in the drum sequence. We experimented with different variations on the crossover, animation duration, and other aspects [Itt04], and started with the same initial particle positions and vector field configurations across all executions using (GA) operators [Gol89](Figure 10, 11).

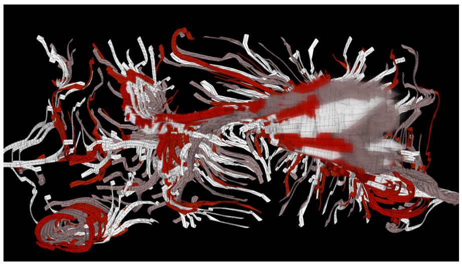

Figure 7: Visually interesting concentric paths shown on lower left and variation creates large aesthetic complexity compared to Figure 6.

Figure 8: Three swarms corresponding to drum components.

Implementation Details

SwarmGA, implemented using Java OpenGL bindings (JOGL) is explained in [Joh07]. SwarmsGA runs in batch, consisting of several, typically 100 generations, and takes on average six hours to complete on a 2.5 Ghz G5 computer. Fifty swarms over 100 generations were tracked, and displayed.

4. RESULTS

We will present the results of several configurations of the system, with revisions to the genetic operators interspersed. As a preface to the per-generation illustrations, in Figure 9 one may see a general example of an unfit system (generation 1) and a fit system (generation 100).

Emergent Behavior: An interesting thing to note is the emergence of different curvatures to prevent the particles from meeting boundaries in Figure 9. This took the form of switchbacks and vortices, which are always interesting shapes. The concentricity created patterns among members of the same swarm, and the slight weighting of the other vector fields to each swarm in addition to its vector field caused some interplay and co-evolution between vector fields.

Computational Visual Aesthetics: While we predicted some trends such as vortices would occur we were surprised at how much more appealing later generations appeared. The visual aesthetic value of generation 100 *is* more than that of generation 1 which is based on increase in folding patterns. In [Joh07], several swarms were traced and generally higher generation showed more comparative visual aesthetics, and thus better fit as vortices were encouraged during evolution and edges were discouraged from one generation to another. Generally, we can say that Figure 7 has higher comparative visual aesthetic value than Figure 6 due to color variation as well as variety. As we learn more about what contributes to beauty from a computational aesthetics point of view we will be able to expand upon the existing fitness function. When animations were created from the high fitness individuals, the concentric paths were especially appealing to watch being constructed. The degree of swarming and total motion in the scene was greater in highly fit individuals, contributing to the quality of the result a shown over several generations in [Joh07]. In a sense the later generations exhibited a greater aesthetic value, beauty.

5. CONCLUSION

The role of computers in the arts encourages comparisons based on aesthetic complexity. We proposed the concept of comparative visual aesthetic in this paper. Our work on musically driven synesthetic shapes and structures led to an implementation where we were able to compare the visual aesthetics across several generations and show the results. Fitness scores as a computational measure of visual aesthetics is an important area of research, which needs to be further investigated. Although correlation is expected, a direct relationship between visual aesthetics and fitness scores is not proven as different rendering styles can and do lead to different visual aesthetics. We would also like to study speciation in relation to this problem. A sharing function would enable us to refine a system with multiple potential swarms that evaluate with good fitness. Further exploration of the varying crossover operators would help to avoid destroying vector field features that contribute to the fitness. To improve execution speed, graphics processing unit (GPU) implementation will benefit the execution time. Rather than multi-thread the program, we could run an instance of the program per CPU core and should see dramatic improvement in execution speed. Finally, more evaluation of comparative computational aesthetics would be necessary to develop this field further.

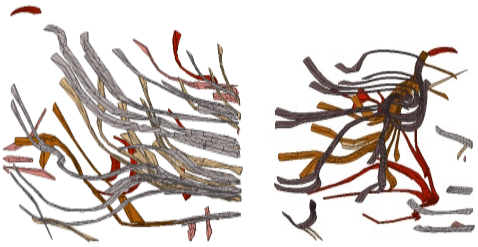

Figure 9: Substantial folding and complexity improvement in fitness between generation 1 (above) and generation 100 (below).

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