EXPRESSIVE ENERGY: THE FLUID AUTOMATA PROJECT

Angus Forbes, Tobias Hollerer, George Legrady

UC SANTA BARBARA, MEDIA ARTS & TECHNOLOGY PROGRAM

Figure 1: A high-resolution image created using the Fluid Automata system.

ABSTRACT

Fluid Automata is a series of projects involving the interactive and stylized representation of a fluid system using custom image processing techniques. Together the hardware-accelerated fluid system and image processing techniques allow the user to create expressive representations of dynamic energy. Through the use of tablet computers (tablet), one or more users interact with the fluid system via multi-touch gestures. The technique has been used in a series of projects that have been shown in a variety of environments involving one or more people: as a multimedia art installation, within a 3D virtual reality environment, as a visual instrument in musical settings, and as a standalone generative art application for a tablet computer. This paper describes the basic algorithms governing the Fluid Automata technique as well as some of the installation configurations, and moreover explores the connection between aesthetic concerns and scientific visualization.

Introduction

Fluid Automata is an interactive generative art system that explores the relationship of aesthetics and scientific visualization, and the interplay between collaboration and discovery. The Fluid Automata system invites users to create dynamic generative art via responsive tactile gestures using a tablet. The aesthetic experience includes both controlling the system through multi-touch and also adjusting a wide range of parameters to discover new patterns and visual properties. The user manipulates both the underlying system and its visual representation.

Fluid Automata has been presented in a number of different environments, emphasizing different aspects of the project. For instance, one installation emphasized the collaborative experience, inviting multiple users to participate in shaping and interacting with a single system that was projected large-scale. Fluid Automata has also been used as a visual instrument to provide live accompaniment to a dynamic musical composition. The most current iteration will be installed in the AlloSphere Research Facility, a spherical virtual reality environment housed in the California NanoSystems Institute at the University of California, Santa Barbara [8]. In this project, the multi-touch, gyroscope, and accelerometer sensors in the tablet interface are used to navigate and interact with a 3D fluid system projected on the upper hemisphere of the AlloSphere. That is, although this project was initially created as a multimedia artwork, it also functions as contributing research to virtual environment visualization and interaction techniques. Below we describe the design choices and algorithms general to the previous installations.


Figure 2: Multiple users collaborate at an installation of the Fluid Automata project.

A perennial concern of scientific visualization is the effective visualization of salient features of a vector field as indicated by the wide variety of approaches to their representation [3]. A popular technique, introduced in 1993, called Line Integral Convolution effectively indentifies detailed curvature features of a vector field. In this technique each pixel of a background image is filtered along streamlines defined by the vector field [4]. Another early technique, Choreographed Image Flow, describes using image warping to generate animations for an animated representation of flow-fields [7]. A more recent technique called Image Based Flow Visualization represents flow using the iterative deformation of texture mesh along the directions of the vector fields. In this technique, an image is blended together with the distorted version of itself at each frame [6]. While the creators of these techniques recognize and discuss applications outside of scientific visualization, recent papers more closely examine the relationship between aesthetics and visualization. For instance, [6] specifically looking at the various stylized qualities involved in painting and the possibility of brushstroke techniques for inspiring more effective scientific visualization methods.

A number of interactive art projects use Fluid Simulation as a component of the work. A method developed created by Jos Stam in 1999 to create a stable fluid system, first made it possible to represent realistic looking fluids at real-time frame rates [10]. Many interactive artworks have made use of this technique. For instance, Memo Atken has created a series of demos based upon Stam's method, showcasing them using mobile devices for interaction and making the code available for OpenFrameworks and Processing multimedia frameworks [2]. Another example project that uses Stam's method is Wakefield and Ji's Artficial Nature. This project uses computer vision techniques to allow participants to use their bodies to interact with a 3D fluid representation [5]. Other fluid simulation methods, such as [9], are optimized for real-time interaction in video games. Fluid Automata builds upon this research in scientific visualization and fluid art projects to create an engaging interactive experience.

Fluid dynamics system

Since one of the goals of the Fluid Automata project is to emphasize creativity and interactivity, we created a more robust, albeit less physically realistic, system that allows a wider range of possibilities to be explored. Our system allows users to set parameters describing viscosity, rotational energy, and various momentum parameters. Various versions of this system have been implemented in the different iterations of the Fluid Automata project, taking advantage of available hardware on different devices, but at its most basic (in the 2D version), the system distributed a flow of energy throughout the system as follows:

1: The image is divided into a grid of cells. (The resolution of the grid depends on the effectiveness of the hardware. On a first generation iPad tablet, the maximum resolution at real-time frame rates is a grid 15 by 15, on a desktop computer with a modern graphics card, the grid can run at 100x100 with no particular optimizations).

2: New energy is added into the cells in a particular direction using the multi-touch capabilities of the tablet.

3: The sum of the newly added energy and the existing energy in the system is divided into (at least) 3 streams of momentum, one forward, and two at orthogonal directions, based on a specified ratio.

4: In each of the defined directions, the energy is moved into the neighboring cell via the following process:

   a. An outline of the cell is propelled the defined distance along the direction. For all cells it intersects with, a copy of the vector is places into the cell and scaled down to the size proportional to its intersection. For instance, if a vector of magnitude .5 is pushed upwards at 90 degrees, it would intersect with both the current cell and the neighbor cell above it. Since the outline of the cell would move 50% off of its current position, it would end up intersecting the current cell and the neighbor cell equally, and thus a copy of the vector scaled at 50% would end up in both cells.

   b. This is done for the orthogonal energies as well.

   c. The copy vectors are totaled up, and a new vector is calculated with the complete momentum and an average angle, and replaces the current vectors in each of the cells.

5: A small amount of energy is removed from the system specified by a dampening factor.

6: Steps 2 through 5 are iterated for each frame until there is no energy left in the system.

Other parameters can also be adjusted to create different fluid characteristics. These include: controlling the "jitter", or randomness of the system, specifying a deviation from orthogonality or an asymmetry of orthogonality, and clamping the maximum outflow of any particular cell. We experimented with a toroidal representation of the system where fluid energy wraps around the edges of the screen, instead of bouncing off the edges. The maximum outflow parameter creates the sense of ice cracking and melting when a particular threshold is exceeded. And different settings of viscosity and orthogonality can create more or less turbulent behaviors. While it may seem as though such a simple heuristic could not mimic the complexity of fluids, the iterative nature of the system in fact creates a wide variety of fluid-like structures, including the creation of eddies and waves (e.g. see Figure 3).

Just as simulations for realistic films and videogames do not feel constrained by a perfect representation of the physics of a visual effect, artists should not feel constrained by a perfect representation of existing algorithms and equations for a particular kind of effect. In our case, by creating our own fluid system with a wide range of parameter adjustment we were able to extend the use of the fluid system to make use of various image processing techniques. That is, we wanted the system to feel realistic, but at the same time to emphasize interactivity, expression, and experimentation.

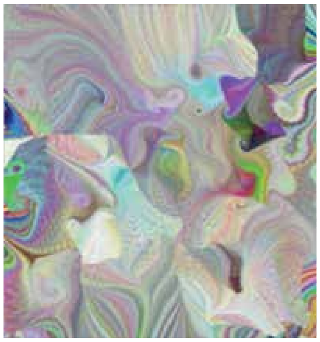

Figure 3: Screenshot of the standalone Fluid Automata application.

Image processing system

Figure 4: An example using a live video feed as the base texture for the image processing.

The main image processing scheme is based on a feedback loop whereby a high-resolution background image is perpetually blended together with a distorted version of itself. The characteristics of the distortion are based directly on the current state of the fluid system. This system is similar to Image Base Flow Visualization, which has been extended for use in a variety of scientific visualization applications, including animated and 3D flows [1]. Again, since the focus of the application is aesthetic exploration, we provide the user with a variety of tools to alter aspects of these blending operations. In addition, introduce an image processing layer whereby the user can change a variety of parameters, including: the rate and amount of blending, the type and quality of the background texture, and the brightness, contrast, and saturation of the blended image.

The default background texture is a black and white noise texture at a resolution exactly matching the display size. However, we have experimented with various textures, including lower resolution textures, static colored textures, static image textures, and using a live video feed (see Figure 4).

Interaction

The main interaction is through multi-touch using a tablet. Much experimentation went into making the reaction of the fluid feel responsive and inviting. By touching the screen the user adds energy to the system. Moving a finger across the screen overrides the fluid dynamic system by forcing the vector to move in the indicated direction. Multiple fingers can be used to push energy around in a more complex way.

Other gestures can also be enabled to cause changes to the fluid system or the image processing parameters. For instance, pinching with all five fingers simultaneously causes the entire noise texture is scaled up or down, causing an immediate zooming in or out. Similarly, a five-fingered panning gesture causes the entire noise texture to be translated in the direction of the pan (as determined by the centroid of the five fingers), shifting all vectors to move in that direction. Other types of interaction are specified for the different iterations of the project, described in the next section.

Configurations

The main components of the Fluid Automata system involve the multi-touch interaction using a tablet, the fluid dynamics system, and the image processing scheme. However, the system has been extended into various configurations which introduce new elements to the project.

Mobile version – A standalone version of Fluid Automata has been created for the iPad and is available via Apple's AppStore. In this version both the interaction and the visualization occur on the same display. This version has an expanded user interface that allows the user to adjust parameters that define both the fluid system and the image processing system.

Audio-visual composition – A version of Fluid Automata has been created for use as an instrument in an audio-visual composition. In this configuration the application is to be mirrored onto large display. In addition to being controlled by multi-touch, the system can respond to Open Sound Control (OSC) messages sent by the composition computer, for instance, to respond to musical events. Additionally, fluid data can be transmitted wirelessly via OSC to influence the composition. We have also experimented with attaching piezo sensors to the iPad itself in order to directly input data into the algorithmic composition engine.

Figure 6: A participant uses the iPad to explore the virtual fluid space.

Multi-user version – In this version, the tablet is used as an interface only. Multiple users can use different tablets to collaborate on a single fluid environment. Each interface tablet shows the underlying vector system of the entire fluid system and also the current touches of the other users. The actual visual output of the fluid system and image processing in projected large-scale on a wall.

3D version – In this version the tablet is again used as an interface, and operates as a "magic lens" showing a portion of the full fluid system at a given time. The fluid system is placed on a virtual sphere, projected onto an OpenGL cube map, and the user can think of as be thought of as being placed inside a sphere of fluids. Through the gyroscope sensor on the iPad, the user rotates around the system to see parts of the system at different orientations. Touching the screen at a certain point casts a ray to the cube map and updates the vector accordingly.

Conclusion

The Fluid Automata project exists at the crossroads of visualization and art, using scientific visualization methods as the basis of interactive art. Although the work is presented primarily as an interactive art piece, we hope that going forward some of the implementation ideas and extensions to IBFV may prove useful to the 2D and 3D visualization of interactive and/or dynamic vector fields.

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