Anamorphic Fluid: Exploring Spatial Organization and Movements of Images in A Simulated Fluid Environment

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ABSTRACT

In this paper, we propose a method to generate a simulated physical virtual environment in which a collection of images projected on a large screen are continuously moved around in response to spectators' movements and actions captured by a sensing device. The innovative feature of the project is the application of forces generated by a fluid physical model to spatially reposition each image in the virtual environment according to their position in relation to the source of the sensed forces.

CCS CONCEPTS

• **Applied computing → Fine arts**;

KEYWORDS

Human-Computer Interaction, Physical Simulation, Generative Art

1 INTRODUCTION

Anamorphic Fluid was realized as an artistic project to generate a continuously changing configuration in a simulated fluid environment where image-objects suspended in a liquid state are disrupted by external forces. The motivation was to create a human-computer interactive system that dynamically generates non-repeating structures in a virtual environment to allow observers to experience new perspectives that go beyond the original input images.

Many interactive art installations have explored creating unpredictable non-linear narratives through interaction. In *Videoplace* (mid-1970s)[2], Krueger utilized motion-sensing and image capture having participants' tinted silhouettes merge others on a see-through large-scale projection. Utterback's *Untitled 5* (2004)[3], a dynamically evolving, abstract visualization, used video capture to allow past movements to build up a continuously transforming image. *Anamorphic Fluid*'s behavior also engages motion-sensing but with the intent to explore how the presence of the spectator can be used to organically reconfigure a collection of images.

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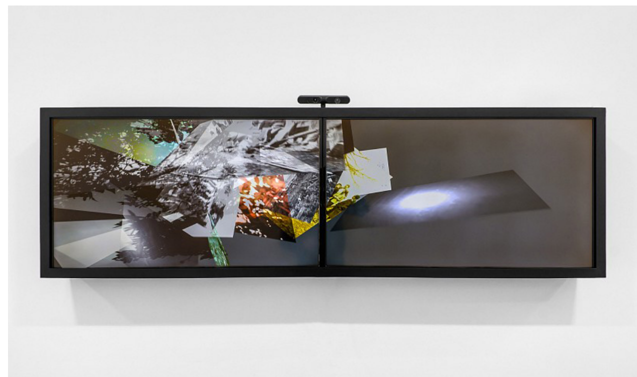

Figure 1: One version of *Anamorphic Fluid* Installation

2 SYSTEM DESIGN

The overall workflow of the system can be seen in Figure 2. The elements in the system consist of a collection of pre-selected images that are suspended and floating in a virtual environment. The system switches between rest and motion states triggered by external forces, namely, the presence of people and their movements. The distinctions between the two states are reflected in the apparent differences in the movements and visual representations of the images as well as the overall acoustic effects in the environment. The system was programmed using java-based Processing[1]. In terms of hardware, the system consists of a display, a motion capture device, and a stereo audio output. The installation can be customized to include any number of images, sounds, and also the scale of visualization from screens to cinematic projection. An example of one version of the installation can be seen in Figure 1.

3 PHYSICAL SIMULATION

Once the data of both hands' positions and velocities have been acquired through the motion-capture device, they are applied as simulated physical forces to move the images within the virtual 3D environment. Each image is modeled as a rigid body in the physical simulation. The algorithm transforms motion data to rigid-body forces and torques based on the velocity of each hand to simulate a wind-like effect. To spatialize the effect, a Gaussian function based on the distance between the hand and the image is used for

[1] https://processing.org/

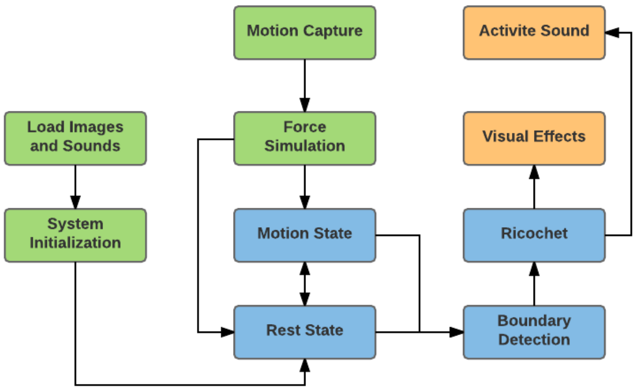

Figure 2: A diagram illustrating how the system is structured

attenuation. The mathematical formulas for forces and torques are:

$$- force = velocity * Gaussian(distance, sigma1) \quad (1)$$

$$\begin{aligned} -torque = normalize(handPosition - imageCenter) \\ \times velocity * Gaussian(distance, sigma2) \end{aligned} \quad (2)$$

In addition to the hand effects, we also add a weak force to pull the images to the back, to create a resting state when users are not present and the system is inactive. Rigid body bouncing is implemented to prevent images from moving outside the viewing area. Friction is simulated by gradually decaying the velocities and angular velocities.

The rigid-body-simulation algorithm we implement is based on vectors and quaternions[1] which provides a convenient mathematical representation of 3D spatial positions and rotations respectively. Each image has a pair of position vector and orientation quaternion, and a pair of velocity vector and angular velocity vector. The position and orientation pair (v and q) is updated according to the velocity pair at each timestamp:

$$- v1 = v0 + a * dt \quad (3)$$

$$- q1 = q0 + w * q0 * dt/2 \quad (4)$$

The velocity pair (a and w) is updated according to the forces and torques computed from motion data:

$$- a = sum(force)/mass \quad (5)$$

$$- w = sum(torque)/mass \quad (6)$$

The visualization of the force simulation creates an illusion that the set of images are coming towards a detected user and following the hands' movements of the user. The images are bounced back following the same simulation formulas whenever they hit any of the boundaries of the virtual container.

4 OUTPUTS

The system generates a dynamic 3D image structure along with a combination of visual and audio effects. The most straightforward visual effect is the transformation of the images from rest to motion state when the presence and movements of users are detected. When the system is not activated by a viewer's presence, the fluid dynamic forces wind down to a low energy state resulting in subtle movements as if the images are floating in a stable liquid state. When spectators' presence and motions are sensed, the system generates turbulence which activate the images to move rapidly. Hand and body motions pull images on the screen directionally according to the motions. Viewers can raise, lower, push back and break forward the cluster of images through their gestures. The set of images are confined within an invisible enclosed virtual box the size of the screen, and whenever any of the images are pushed to collide with these boundaries they bounce back, each image according to the force of their initial movement. Whenever a collision occurs against a virtual boundary wall, the image flips to its negative, has a brief bright color shift, and triggers a sound, all of which indicate that the collision has occurred.

5 EXHIBITIONS

Anamorphic Fluid was realized by artist George Legrady, with software development by Donghao Ren (fluid dynamics, motion force) and Jieliang Luo (interaction design). It premiered in Legrady's solo exhibition "Day & Night" at the Edward Cella Gallery for Art + Architecture in Los Angeles, USA from December 12th, 2015 until January 23rd, 2016. The system was mounted on the wall of the hallway leading to the main gallery that visitors passed through, inevitably activating the motion sensor. As visitors passed by, their movements activated image movements. Attracted by the effect, many viewers chose to return to explore and understand the mechanism of the system through their movements and presence.

The installation was also featured in "SV + VS", a group exhibition curated by Yoon Chung Han for the Fellows of Contemporary Art, Los Angeles (January 23rd - March 18th, 2016) which then traveled to Dongdaemun Design Plaza Museum, Seoul, South Korea (August 20th - September 18th, 2016), and then to the "Currents New Media Festival", Santa Fe, New Mexico (June 9th - June 25th, 2017).

The images used in the first three exhibitions consisted of black and white photographs from a personal family archive. The updated version, exhibited in the "Currents New Media Festival" in Santa Fe, New Mexico, captures images of the spectators in the gallery space, triggered by viewers' interaction with the system.

6 CONCLUSION

In this paper, we are presenting a system for dynamically reconfiguring a set of images in a virtual 3D environment in which the images' positions are affected by rules of fluid dynamics. One remaining task is to design an effective user studies to evaluate the system. Another research issue is how to program the camera for searching and capturing visual interestingness defined by machine learning algorithms. An audiovisual demonstration that augments this article's description of *Anamorphic Fluid* is available at: https://vimeo.com/199071782

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