Spatial Correlation: An Interactive Display of Virtual Gesture Sculpture

Jung Nam and Daniel F. Keefe*

Department of Computer Science and Engineering, University of Minnesota

ABSTRACT

Spatial Correlation is an interactive digital artwork that provides a new window into the process of creating handcrafted virtual sculpture in a Cave virtual reality (VR) environment. The artwork displays a series of original sculptures that were created using a 3D user interface that turns sweeping physical movements of the artist's hands into 3D virtual forms. The artist's movements are gestural, almost like a dance. Each movement was recorded using 3D motion capture technologies and an array of video cameras. Spatial Correlation replays the sculptural process for viewers by visualizing the video data side-by-side with the virtual sculptures and synchronously animating these visualizations to show each physical body movement of the artist and the corresponding sculptural result over the several minutes it took to complete each sculpture. The visualizations also respond to the position of viewers within the gallery space. As viewers walk around Spatial Correlation, the viewing angles for the video and computer graphics displays change dynamically so as to create the effect of looking through two virtual windows: one pointing into the physical world in which the piece was created and the other into the virtual world in which the sculpture now exists as 3D computer graphics lines in space.

Keywords: CavePainting, 3D sketching, virtual reality.

Index Terms: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual Reality; J.5 [Arts and Humanities]: Fine Arts

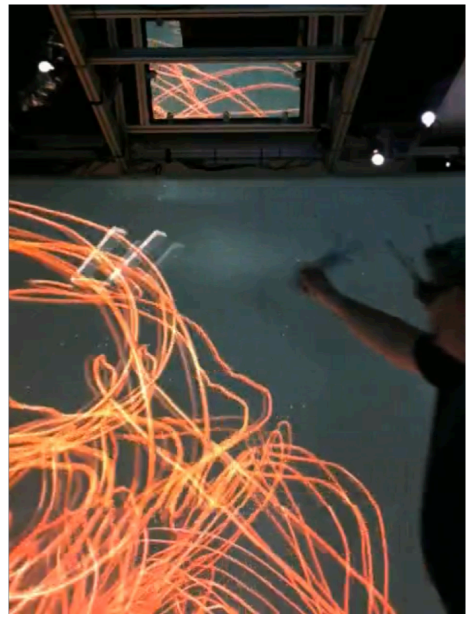

Figure 1: Sculpting process – virtual 3D sculpture is created by drawing with the hands in a 4-wall immersive Cave virtual reality environment. The artist's process and the sculptural artefact are later displayed in Spatial Correlation.

1 INTRODUCTION

Sketching, painting, touching, sculpting, dancing – we typically think of these physical human actions as being closely linked to creativity and art making. What role will these physical actions have in a new data-intensive virtual world? Will future virtual creations show any evidence of a human form maker or the spontaneity and organic detail we find in the physical world?

These questions provide a framework for our investigations, which began in 2001 with the 3D freeform modeling system, CavePainting [1], pictured in Figure 1. CavePainting tracks the 3D movement (position and orientation) of the artist's hands in space and creates a trail of "virtual paint" in the wake of a "3D brush" that the artist moves through space. Although it is possible to program the brush to generate almost any style of form, we find that simple ribbons, tubes, and other 3D "lines" are often most effective, as they provide such a direct visual interpretation of the artist's hands. This 3D user interface could be utilized in a number of different computing environments, but we find it is essential for creating compelling virtual sculptures that the environment include head-tracked stereoscopic 3D graphics (i.e., virtual reality) and that the space is physically large enough for the artist to move and use his/her whole body while interacting with the computer. For these reasons, we work most often in a Cave virtual reality (VR) environment, such as the one pictured in Figure 1, which is an 8x8x8ft cube made of projection screen walls.

We think of the handcrafted style of virtual form that can be created with this approach as a modern-day interpretation of Picasso's light pen drawings [2]. Our work is also influenced by Csuri's early computer graphics Lines in Space [3], but we are particularly interested in creating 3D lines directly from gestural human movements made in immersive environments.

Captivated by this style of form making and related computer graphics, over the past decade we have created a number of 3D sculptures using CavePainting and follow-on 3D user interfaces [4-6]. However, we are always frustrated by the lack of an appropriate method to convey the active spatial and gestural process of creating these sculptures to audiences in a gallery setting. Our wish for the future is that a virtual environment could somehow link a physical gallery space with the physical Cave space in which these works were created. This motivated us to develop new sensing techniques to better capture and record the process of virtual sculpting, and to develop a new 3D interactive visualization of the sculpting process that can be installed in gallery spaces. We call the result Spatial Correlation.

* keefe@cs.umn.edu

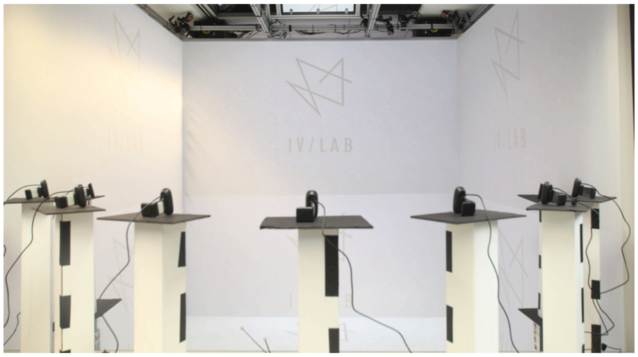

Figure 2: Data capture – during the sculpting process, a custom camera rig captures synchronized video of the artist's physical movements within the Cave space from 9 different viewpoints arranged in a semi-circle around the opening of the Cave.

2 Spatial Correlation

Spatial Correlation is an interactive artwork that provides a unique view of both the process and outcome of handcrafted 3D virtual sculpture. To create the piece, we first developed a custom camera rig (Figure 2) and associated software to capture the artist's virtual sculpting process from multiple viewpoints. Then, we developed an interactive computer graphics visualization (Figure 3) that combines the process data with the resulting sculpture in an integrated display that can be installed in a gallery space.

2.1 Capturing and Recording the Sculpting Process

Since handcrafted virtual form is not commonplace, we find that viewers' interpretations of virtual sculpture are closely linked to their understandings of the process by which the form was created. Thus, in developing Spatial Correlation, we sought new ways to capture this process.

The result is the multi-perspective camera rig pictured in Figure 2. The cameras are arranged in a semi-circle pattern around the entrance to the Cave, and each camera is calibrated to focus on the center of the Cave so as to capture the artist's movements there. At the beginning of a sculpting session, the cameras are initialized to all begin recording at the same moment and frame rate. Thus, the collection of 9 synchronous video streams can be used to view the sculpting process at any moment in time from any of the 9 viewpoints captured by the cameras. These data provide a much more complete description of the artist's physical movements within the space than would, for example, a single video camera.

The multi-viewpoint video data are complemented by a second data source – the artist's hands are tracked using the Cave's 3D optical tracking system that reports the position and orientation of each hand with millimeter accuracy at about 60 frames-per-second. These accurate hand tracking data are what the sculpting software uses to create virtual lines in space. (The path the hand takes through space is recorded whenever the artist presses a button, and a trail of virtual paint is displayed to mark this path.) We save each 3D hand tracking reading with a timestamp that enables the Spatial Correlation software to later link the accurate hand tracking data together with the multi-viewpoint video data. Thus, together, these two data streams capture the full-body physical movements of the artist as seen from multiple physical viewpoints surrounding the Cave *and* the very accurate 3D positioning of the artists hands while sculpting.

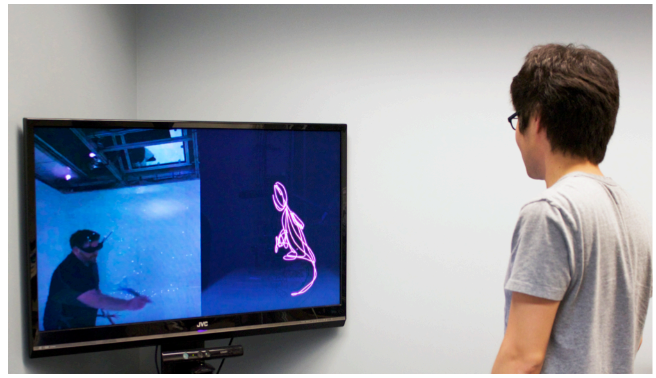

Figure 3: Gallery installation – Spatial Correlation visualizes the virtual sculpting process for gallery visitors using a flat panel display that acts like two synchronized windows into the artist's space. The left half of the visualization uses the video stream data to create a virtual window into the physical space of the Cave at the time the artwork was created, while the right half of the visualization uses 3D computer graphics to create a window into the virtual space of the sculpture. Both visualizations animate synchronously to convey the progression of the artwork over time.

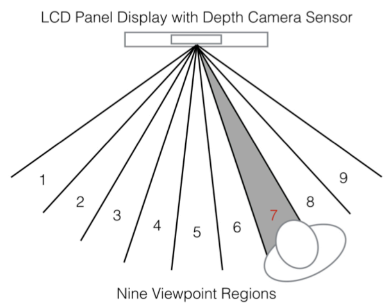

Figure 4: Viewers control the gallery visualization – both windows of the visualization are updated continuously in response to the position of the closest viewer to the piece in the gallery. As the viewer walks around, the viewpoint for both windows is updated to closely match the perspective of the viewer. For example, when the viewer stands in region 7, the video feed from camera #7 is displayed in the video window, and the 3D graphics window is also rendered from a corresponding viewpoint. To the gallery viewer, this use of "head-tracked perspective rendering" makes the visualization act like a real physical window – as in the real world, we see a different view out of a window when we move our head from side to side.

2.2 Interactive Gallery Space Visualization

Recall our vision that a virtual environment could somehow link the physical gallery space with the physical Cave space in which these works were created. This is what we strive to enable with the interactive gallery space visualization. As shown in Figure 3, a large flat panel display is hung in the gallery space and a depth sensor (Microsoft Kinect) is placed near the display.

The visualization displayed on the flat panel is divided into two synchronized virtual windows (Figure 2). The left window visualizes the physical space of the Cave during the sculpting process and the right window visualizes the virtual space.

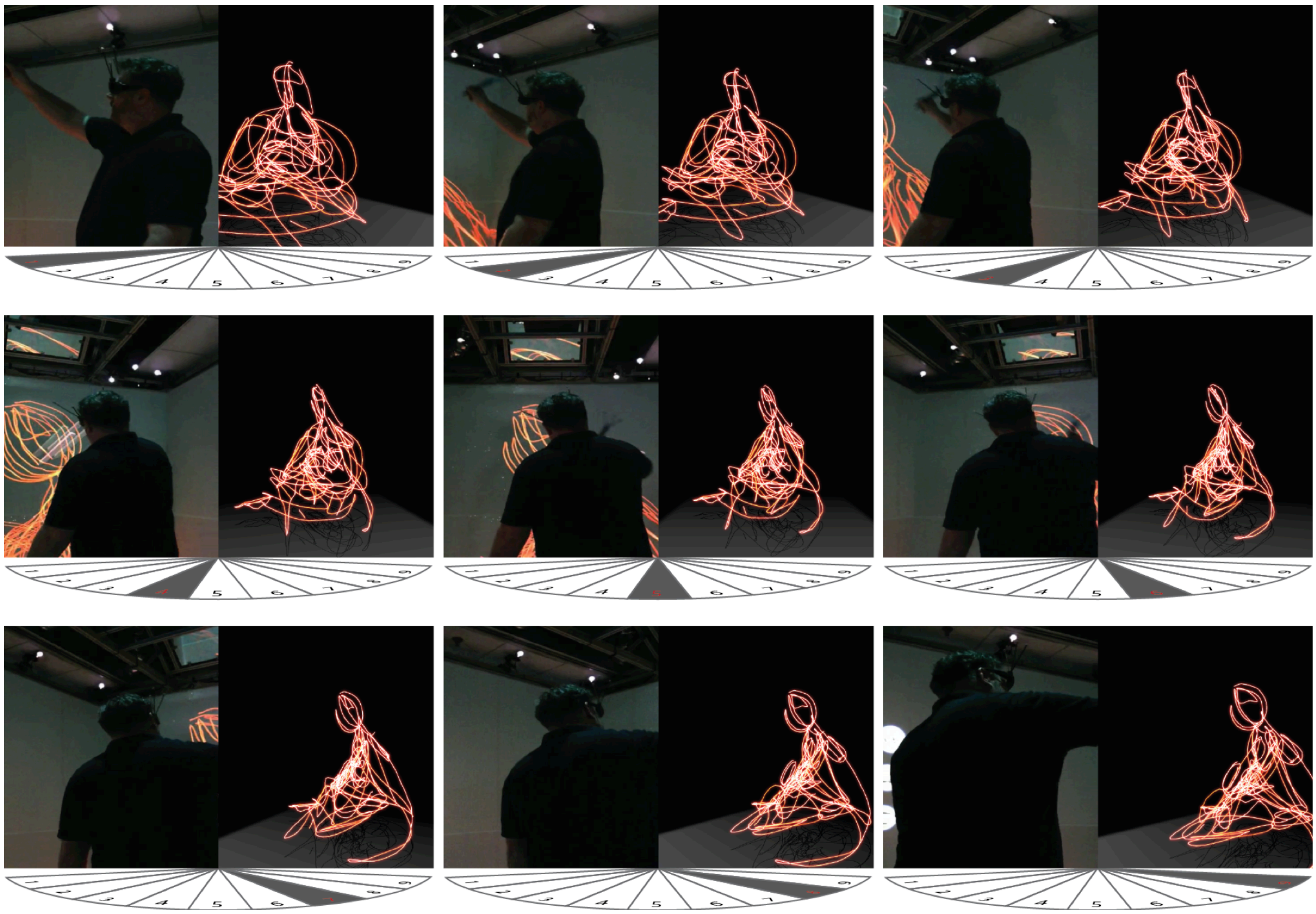

Figure 5: Detail of the sculpting process visualization as seen from different viewpoints – this series of images shows the video captured for one moment in time during the process of creating the virtual sculpture, *Mother Holding Child*, which was completed in the style of a quick 3D gesture sketch. From left to right then top to bottom, the images show how the viewpoints used in both the video and virtual sculpture windows update as the gallery viewer walks around the piece.

The virtual space visualization (in the right window) shows the 3D line sculpture created by the artist. A 3D floor plane and virtual shadows are also displayed in this view in order to help viewers establish the connection between this virtual space and the space of the Cave. In particular, the floor plane is drawn to correspond precisely with the 4ft x 4ft floor of the Cave. The sculpture itself is rendered using a custom OpenGL shader program that draws the lines in the style of a light pen drawing. Specifically, the line weight and brightness of the 3D lines is controlled by speed at which the artist drew them.

The physical space visualization (in the left window) plays back the video feed captured from one of the nine cameras arranged around the Cave as shown in Figure 2.

The choice of which video feed to display is controlled interactively (and, to some extent, subconsciously) by the gallery viewer. A depth camera tracks the viewer's position within the gallery space, and as the viewer moves within the gallery space, his current viewpoint relative to the flat panel display is compared to the nine views of the Cave captured by the camera array. As diagrammed in Figure 4, the camera with the closest matching viewpoint to that of the gallery viewer is selected.

Each time the viewer moves to a new "viewpoint region" as diagrammed in Figure 4, the video visualization will update accordingly, and the virtual space visualization of the virtual sculpture is programmed to update in sync. Since the sculpture exists in virtual space, computer graphics algorithms can be used to render it from any viewpoint. We select a viewpoint that corresponds exactly to the viewpoint of the currently selected video camera. In this way, all of the spaces involved in the piece are synchronized – the virtual space of the sculpture is rendered from the exact viewpoint of the video of the physical space of the cave, and the video of the physical space of the cave is rendered from the same viewpoint of the gallery viewer looking at the flat panel display in the gallery.

Figure 5 illustrates this effect of this synchronized display when walking around the piece in a gallery. To viewers, this interaction seems natural – to see a view of an object seen through a window, simply take a step to the side to get a different vantage point.

2.3 Example Gesture Sculpture: Mother Holding Child

The figures in this paper are based on one example virtual sculpture that was created in the style of a quick gesture sketch – a form of traditional drawing (e.g., using physical paper and charcoal) often used by artists. The subject here is a mother holding a child and the "gesture sculpture", as we call it, was created in just two minutes. The aesthetic is difficult to interpret on the printed page, but much easier when the perspective view of the sculpture changes in response to one's own movement around the piece. When animated, viewers can see that the sculpting process begins with the mother's head and shoulders and then moves to a child resting in her arms.

One of the aspects of this work that we find most interesting to consider is the use of "line" in this 3D context. This contributes to a different aesthetic than what is often seen in 3D computer graphics where watertight triangles meshes are used to mathematically define 3D surfaces. Here, there is no surface – no front and back – just lines hanging in space. We can see through the front of the mother character to lines that clearly depict the curve of her spine or the crest of her scapula on her back. Does this make for a confusing image, or, when viewed with head-tracked perspective, does the human perceptual system understand the 3D placement of the lines and how to reconcile them into a cohesive 3D form? Does this perceptual tension add intrigue to the 3D graphics? These are the types of questions that we hope viewers of this piece will consider. Ultimately, we believe the answers have implications not just for digital art practice but also for scientific and information visualization.

3 Conclusions

Ultimately, we believe the most enduring aspect of this artwork will be the demonstration and exploration of an interconnection between the virtual 3D space occupied by the sculptures, the physical Cave space in which they were originally created, and the physical gallery space in which they are now viewed. With the recent advent of VR technologies in the commodity electronics marketplace (e.g., low-cost head-worn stereoscopic displays and 3D trackers), it is clear that the human relationship to virtual space is going to radically change in the next 5-10 years. Through work in the style of Spatial Correlation, we hope to influence this future; in particular, defining a role for the creative human hand in virtual space and discovering new ways to link creative human activities in virtual space back to the physical world in which we live.

Acknowledgments

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