Bi-manual 3D Painting: an interaction paradigm for augmented reality live performance

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Abstract. The rise of gestural interaction led artists to produce shows, or installations based on this paradigm. We present the first stages of the « Sculpture numérique » (Virtual Sculpture) project. This project was born from a collaboration with dancers. Its goal is to propose bi-manual interactions in a large augmented space: we aim at giving dancers the possibility to generate and manipulate virtual elements on stage using their hands. The first set of interactions we present in this paper is 3D painting, where the user can generate 3D virtual matter from his hands. The movement of the hand defines a stroke, which shape is controlled by the shape of the hand. Changing the shape and orientation of the hand allows switching between three interaction modes to produce volumes, surfaces or curves in space. We explore the applicative case of dance, with the goal of producing a plastic creation from choreography.

Keywords: Virtual Sculpture; CAVE; surface generation; digital arts; virtual reality, Arts and Humanities – Arts, fine and performing, Information interfaces and presentation – User Interface, Human Factors, Design.

1 INTRODUCTION

The CARE project (Cultural Experience: Augmented Reality and Emotions), which ended in march 2011, aimed at setting up several design tools, interaction techniques and devices to augment a cultural event with emotions. With augmented ballet as one application case, our goal was to augment a ballet performance and to make a dancer interact with virtual elements on stage. This project ended in a staged demonstration that took the form of an augmented show, entitled "CARE: staging of a research project".

The Virtual Sculpture project is in the continuity of the CARE project. Our goal is to give the dancer the ability to create 3D objects and shapes on stage. Those 3D elements should be visible by the audience. Our goal was hence twofold. First, we designed interactions to create 3D objects. As dance is our applicative case, we focused on body interaction and especially hand-based interaction. Natural interactions is much more understood by the audience and let a vast and free field of investigation for choreographers and dancers; enabling a technology better integration in the artistic proposal. As such, we focused on very direct interaction techniques. Second, we developed two prototypes, one in an immersive environment for training purposes and another one for a live show context.

In this paper we describe the work achieved during the first interaction set up, part of the Virtual Sculpture project: 3D Painting, which provides matter creation from hands in a large space. That is how the user is capable of generating surfaces or volumes in a 3D space, which section is defined by his hand conformation, and which longitudinal draw is defined by his hand movement. Metaphor is direct: virtual matter seems to be generated right under the artist hand and stay fixed in space. Starting from there, space becomes a blank support where you can paint. Although we designed this interaction keeping our applicative case in mind, the metaphor uses natural aspects which makes this interaction extensible to other fields.

After a short state of the art, we describe the three interactions we suggest. Then we describe two prototypes creating 3D Painting, applying different technologies. Finally, we will discuss about future works before concluding.

2 STATE OF THE ART

The goal of our system is to allow the user to draw directly in a 3D space. We do not seek, however, to provide with some kind of modeling tool (like 3dsMax). Rather, we seek to give the user the ability to sketch in space. Several techniques already exist to draw directly in a 3D immersive environment. Deisinger *et al.* [2] led a CAVE experimentation (Cave Automatic Virtual Environment) on several modeling systems calling three different techniques. The first one is matter creation by “substance” injection on a given point. In this approach, the artist adds volume to matter, and his movement creates the shape. In the same manner, the *BLUISculpt* system [3] divides space into voxels, which the artist can paint. The second approach is surface generation. In the system being tested in [2], the artist defines a flat polygon by points in space, and successively attaches created polygons to his sketch. Finally, the third technique, used by the third system in [2] uses automatic surfaces generation from directives curves being drawn by the artist. This principle has been taken back from the *FreeDrawer* [5] system where the user traces B-splines in 3D space; lines defining a closed loop can be fulfilled with surfaces. Deisinger *et al.* noticed several recommendations for designing an immersive sketching tool from their experimentations. An ideal sketching tool should 1) be a conceptual phase tool towards a certain elaboration degree, 2) hide its mathematical complexity, 3) provides a real time and direct interaction, 4) allow large scale and volume modeling, and 5) be intuitive.

In this work we took a more artistic approach that led us to focus on the three last points. In particular, we inspired ourselves from two systems from the literature. Schkolne *et al.'s SurfaceDrawing* [4] allows the user to generate 3D surfaces directly from his hands, using data gloves. 3D display of the generated surfaces is performed by the *responsive workbench*, a horizontal screen able to track the user's head and therefore display stereoscopic 3D from the corresponding point of view (figure 1.a). The user wears glasses provided with position trackers, allowing the *responsive workbench* to modify the display according to the user position. Keefe *et al*.'s *CavePainting* [3], provides several tangible interfaces (brush and paint bucket for example) to allow painting in the volume defined by CAVE device. The painter can trace paint strokes in the 3D space where he can stand and move (figure 1.b). Our Virtual Sculpture prototype merges the both approaches, associating freehand Schkolne *et al.'s* interaction and Keefe *et al.'s* CAVE visualization.

(a)

(b)

Figure 1 (a). Surface Drawing [4]. (b) CavePainting[3]

SurfaceDrawing and *CavePainting* both suggest a group of interactions relative to the task to be carried out: drawing on the responsive workbench for the first one, and 3D painting for the other one. With the exception of *SurfaceDrawing* shapes generation by hand, those interactions make intervened tangible interfaces. With the aim of providing 3D Painting to dance, we want to limit interactions to hands at first.

The prototypes that we present in this paper aim at combining the approaches from Surface Drawing and Cave Painting, bringing together hand-based interaction with painting in a large space, in which the user can move.

3 3D PAINTING MANUAL INTERACTIONS

The experience we acquired in the CARE project on interaction design for augmenting dance shows lead us to promote simple and direct interactions. It is also the second guideline from [2]. We imagined three interaction techniques to set the bases for 3D Painting. Independently of the devices used, we rely on the capacity to measure the position/orientation of several points on both hands given an absolute frame of reference.

The first interaction directly comes from [4] and allows hand surface generation. The hand conformation at a given moment defines the shape of the generated surface. At a time *t*, we consider the wrists' positions, and the articulations an tip positions of the middle finger. The curve traced by those points at *t* instant defines surface section at *t.* This section curve is periodically sampled (typically between 2 and 10 times per second). For each new curve record, surface between *t* and *t-1* sections is being generated (see figure 2). Surface generation is achieved by performing a movement parallel to the palm's surface.

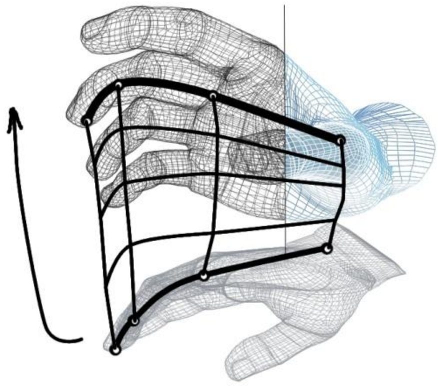
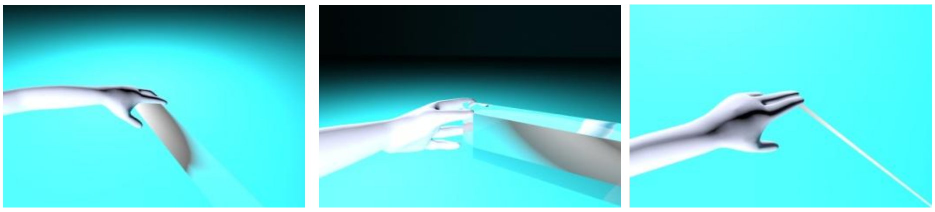


Figure 2. Bézier surface drawn by hand movement.

The second interaction allows volumes creation by moving the hand perpendicularly to the palm's surface (like a slap gesture). To preserve the "matter generation by hand" metaphor, the volume section being generated is equal to the visual surface occupied by the user's hand: a flat hand will generate a larger volume than a closed one.

Finally, the third interaction features curves or points creation in space. To activate this mode, the user keeps his hand closed deploying only his index and middle fingers. Matter is being generated at the end of those two points; allowing generation accuracy improvement compared to entire hand (like a tinier brush). We chose this conformation where index and middle fingers are both tights for this interaction, in order to let conformation like only tight index for pointing tasks. We currently consider this interaction only for a direct and localized matter generation, another possibility could remains on a curve generation which makes automatic closed surfaces fulfillment possible (like [5]).



(a) (b) (c)

Figure 3 (a) Shapes. (b) Volumes. (c) Curves.

The main interest coming from those three interactions relies in their simplicity, based on a direct metaphor: virtual matter generated by hand (or fingers tips). Moreover, changing the active mode is being done naturally. To go from one interaction to another, we just need to change hand orientation or to tuck fingers during the movement.

We drew one last modal interaction from [4]. Complementing the three suggested interactions above, thumb position allows going from a “draw” to a “free to move” mode. This is equivalent to a drawer moving up his pen to draw a new line. When the thumb and the palm are stuck, surface or volume is being generated. In lax position (thumb unstuck), nothing is being generated, the user is free to move is hand and replace it in the 3D space.

All those interactions can be performed with only one hand. Conformation and movement define the drawing mode, while the thumb's position triggers or deactivates the virtual matter generation. In the frame of our applicative case, this allows using both hands simultaneously, preventing an asymmetric limitation during choreography execution.

4 ACHIEVED PROTOTYPES

We built two prototypes which explore 3D Painting in a large space. Those two prototypes are limited to hand surface generation by now. The first one has been developed for a CAVE immersive usage. This device has got the advantage to offer a large space where action and perception spaces are superposed from the user's point of view. This kind of setting, however, is not adapted to audience presence, as a CAVE system projects 3D for a single person only. This prototype was developed with the aim of familiarizing the artists with 3D Painting. In the CAVE environment, artists can see what they are creating. Once familiar with the system, they can begin to explore the interaction techniques we propose and to suggest new ones themselves. The second prototype, in progress, is being developed towards a stage environment use, where augmentations are projected and perceptible by audience (but the artist is blind from his creations).

5 CAVE 3D Painting with ISIVR

The developed prototype uses immersive cube (CAVE) from INRIA Sophia-Antipolis-Méditerrannée Research Centre *Gouraud-Phong* immersive room. This environment is composed of four projection surfaces (one on the ground, three on the walls), forming a 3mx3mx3m cube approximation. It is provided with an infra-red position follower optical device (AR-DTrack). The user wears glasses equipped with infra-red reflectors; the system calculates a stereoscopic display corresponding to the current point of view for each faces, giving the illusion that virtual elements are placed in the cube area. Reflectors also feature to have wrists, thumb, index, and middle fingers positions and orientations.

To facilitate *Gouraud-Phong* room appropriation by researchers and collaborators, INRIA developed isiVR, a middleware dealing with developer’s ready-to-use tools useful in any immersive applications. Based on OpenSceneGraph openSource render engine, isiVR makes management available for peripheral inputs, display devices, head-tracked stereoscopic render, and synchronized cluster utilization. This allows fellow researchers to focus on their specific issues. The developed application can be run without modifications on a standard work station as well as a high-performance immersive device (multi-display + cluster + position tracking). isiVR provides separation between physical inputs or outputs (*Devices*) and peripheral actions onto virtual scene (*Behaviors*). Its object design and plug-ins ability make behavior modifications (or additions) easy to implement. isiVR will be released under openSource license soon. Those functionalities allow us to use infra-red sensors in the immersive cube, but also to add a hand model template (*Behavior*), and finally 5DT data gloves management (*Device*) [9].

In this prototype, we use cube infrared sensors to follow wrists and fingers. To generate surfaces, we consider that two points defining the middle finger are directly obtained from isiVR (wrist and middle finger end). Intermediates coordinates are being obtained by a calculation composed by: wrist orientation (from distal phalanx), back hand length (from distal phalanx too). The four points define cubic Bézier curves control points. This Bézier curve is being used to set up Bézier surface according to hand’s movement. The surface could be defined mathematically instead of being defined by a vertex group. Main advantage coming from this technique is to facilitate data sampling and potentially manipulate generated surfaces level of detail (LOD); avoiding too many points number. Results are available with a video at [7].

6 3D Painting on stage for an audience

As being told before, the second prototype is still in progress. The aim this time is to take back the work done during CARE project to augment a ballet scene (see video [6]). For that purpose, we use rear projected screen on which generated surfaces will be display. Indeed, retro projection handles the problem of dancer shadow on projection surface. To record dancer movements we use MVN motion capture suit [8], associated with 5DT14U data gloves [9]. Those data gloves only give a torsion ratio (between 0 and 1) for each 14 degree of freedom of the hand (2 phalanxes per finger and 4 inter-fingers). We developed a system taking hand's measures to calculate each phalanx position according to the data from the gloves. The system manages data fusion between MVN and data gloves for both left and right hands (*Hand-Over*), delivering user body rigid kinematic chain segments coordinates in an absolute basis on stage.

We use Virtools software to handle graphical aspects of this second prototype. As isiVR, Virtools allows to define *Behaviors* and *Devices* to manage peripherals inputs and outputs. Virtools is based on visual programming (procedural approach like flowcharts), where behaviors are generated by logic bricks assemblies (*Building Blocks*). Coordinates flow has been implemented into Virtools to drive shapes generation. Virtools generic functions provide the two curves draws we need with that purpose. We developed a custom *Building-Block* to get back curves nodes (vertices), implement the mesh, then add the desired texture keeping in mind aesthetic strong requirements (UV-mapping).

The current issue we are tackling is the ability to modify shapes during a post processing step. With computational tessellation we will be able to add more points between those given by the motion capture. It will give a higher level of control on the shapes, dealing with multipoint modifications, smooth and textures placement for example. A maximum level of details is important to improve our generators/modifiers.

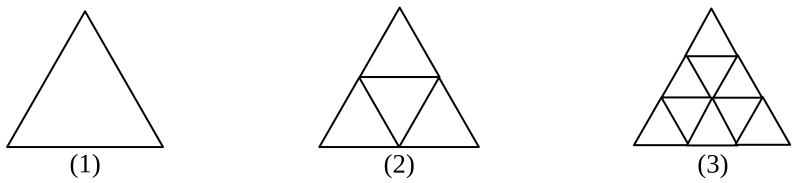


Figure 4 Tesselation (1) Initial mesh. (2) First iteration. (3) Second iteration.

7 Conclusion and Perspectives

We have presented in this paper our beginning work in 3D Painting, an interaction set allowing artist to draw in a large space making virtual matter emerging under his hands. 3D Painting takes place within the Virtual Sculpture project, which goal is to deliver 3D object modeling in a large space, itself part of the Augmented Ballet project, which goal is to provide original interactions and augmentations on stage.

We propose three interaction techniques generating shapes, volumes, or curves in space. Change interaction is being intuitively done changing hand's conformation or orientation. We have developed two prototypes for surface generation. The first prototype uses an immersive cube and allows artists to familiarize themselves with suggested techniques and to explore them. The second prototype has been built up under stage visualization requirements. The artist is blind from his creations but thanks to stereoscopic display, the audience has got the illusion that 3D shapes are part of the scenic space and emerge directly from the artist hands.

Those prototypes open numerous perspectives. Our first goal is to invite choreographers and dancers to use our prototype in immersive cube to explore tools and to suggest new interactions, promoting this way a user-centered design for newer interactions. In addition, this tool has got industrial applications too. This project particularly arouse interests in domains like mechanic interactive design (fast sketches or idea illustration), or in fiber orientation specification during composite pieces design.

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