A Literal Digital Clay Medium

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ABSTRACT

Clay sculpting is one of the most studied and refined methods of artistic expression and communication. Although this makes it very attractive as a general model of shape interaction, it has proven difficult to combine an interactive interface with geometric acquisition. This note presents a shape input device consisting of a clay composed of wireless position trackers held together by a binding agent. These trackers provide position data in real time while isosurface extraction reconstructs the surface of the model as the user deforms it. Preliminary results are shown of this system performing geometry capture, and its utility as a new interface in an augmented reality environment is discussed.

Keywords: digital modeling, tangible user interface, augmented reality

INTRODUCTION

Interfaces that are based on interaction with shape often rely on some form of shape capture. This has typically been performed in three ways: via classical computer vision which relies on general environment sensors, via instrumentation of the hands and/or tools to capture their position and orientation (e.g. [3]), or by applying instrumentation to the medium itself, i.e. inserting digital sensors into the surface. We are interested in the latter approach because it most naturally mimics the task of sculpting, and because of its potential to capture real-time deformation without regard to occlusions and lighting.

Direct instrumentation of the medium has been previously explored to some extent. A digital foam which contains a fixed grid of sensors and allows the user to deform its surface is presented in [6]. However, the topology of the surface cannot be altered, i.e. material cannot be added or removed from the surface by the user during interaction. A surface model composed of a responsive material that can self-deform is proposed in [4], but its prototype uses a Phantom force-feedback system, which instruments the user's hand instead of the material itself. To our knowledge, no one has created a volumetric instrumentation of the medium; that is, one that captures not just model's surface shape, but also the volume occupied by the material, and therefore the shape of interior voids as well.

This new shape interface is based on a literal interpretation of "coupling bits and atoms" [1][2] and is implemented by embedding a number of independent wireless locators in a sculpting clay. The user's hands are not instrumented, as they might be with a dataglove in an alternative technique, and so do not interfere with interaction. This method allows shape alterations that change volume by material addition and subtraction (see Figure 1), and can contain holes, disjoint volumes, and even multiple shells (i.e. a hollow sphere). The material itself is not restricted by position or orientation; it is only required to be within range of the locator's receiver during the period of time that digital interaction is required.

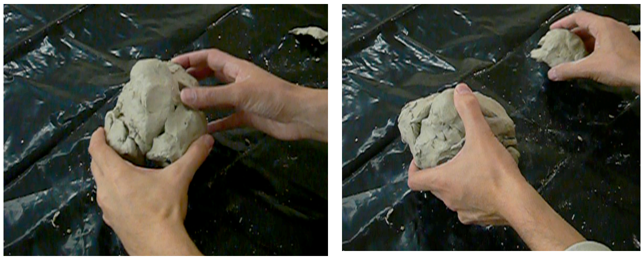

Figure 1. Left: interacting with a model composed of 6 sensors. Right: additive and subtractive modeling is supported. Here a piece of clay containing one sensor is removed.

APPROACH

In the ideal implementation, the clay would consist of thousands of 3D locators. The technology for this does not exist currently, however a prototype system containing tens of locators is feasible today with off-the shelf components. The size of the locators (7x4x2cm, 56g, in this implementation) determines the resolution of the surface in accordance with the Nyquist Theorem. Although those used in this work are too large to capture significant detail, they are small enough to capture sketch-like characteristics of general form. The rate of microelectronics miniaturization will increase the resolution by shrinking the locators; eventually, it is hoped, to nano scale.

This implementation uses a wireless tracking system built by Polhemus, Inc. whose locator positions are captured at 94Hz with 5ms latency. The batteries last 2.5 hours, and the streamed locator coordinates are within the accuracy constraints for this task. The tracking principle is that of magnetic field sensing, which does not suffer from the correspondence and occlusion issues that make real-time shape acquisition in an interactive environment so difficult for conventional vision systems.

UIST'08, October 19-22, 2008, Monterey, California, USA
ACM 978-1-59593-975-3/08/10.

Model capture

The concept for model capture is shown in Figure 2; the locators stream their 3D positions, as well as their orientations, in real time, to the computer. A model of each sensor is used to compute an aggregate isosurface approximating the sculpted shape (Figure 3). In this experiment, the data was captured first, followed by the surface computation at a later time, but there is no technical reason preventing this computation from occurring in real time.

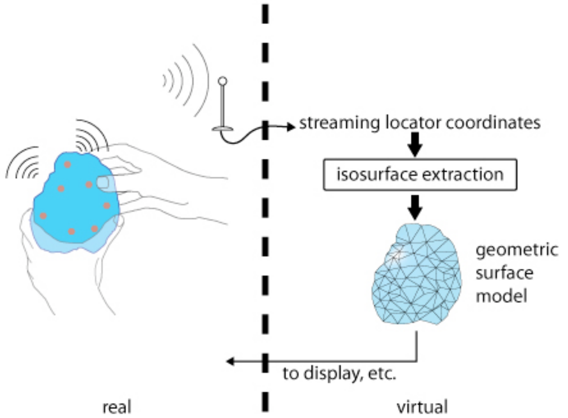

Figure 2. Embedded locators stream their locations, which are received and used to build a geometric model, which is then displayed or processed.

DISCUSSION AND FUTURE WORK

Although currently in a preliminary state, this system shows potential as a coarse modeling system that can support an augmented reality environment. Of particular interest is the fact that the position and orientation of the geometric surface model is known in real-world coordinates. This implies that any manner of projectors (traditional as well as HMD) can be used to augment the interface. For example, instructions could be projected on the surface of the clay; these instructions may be in the form of icons, text, or color maps. Relative differentiation between two models, displayed as a displacement map, could be used as a form of "consensus modeling" to address how digital clay might be shared across space. By using blue screen techniques for digital compositing, information can be displayed coincident with the clay surface yet not overlapping the user's hands or other occluding elements. It is our intention that the techniques shown here be advanced to the point of providing a robust testbed for design exploration.

ACKNOWLEDGMENTS

Thanks to Polhemus for the use of their LATUS system, and to sculptor Mike Defeo for his discussions on the art.

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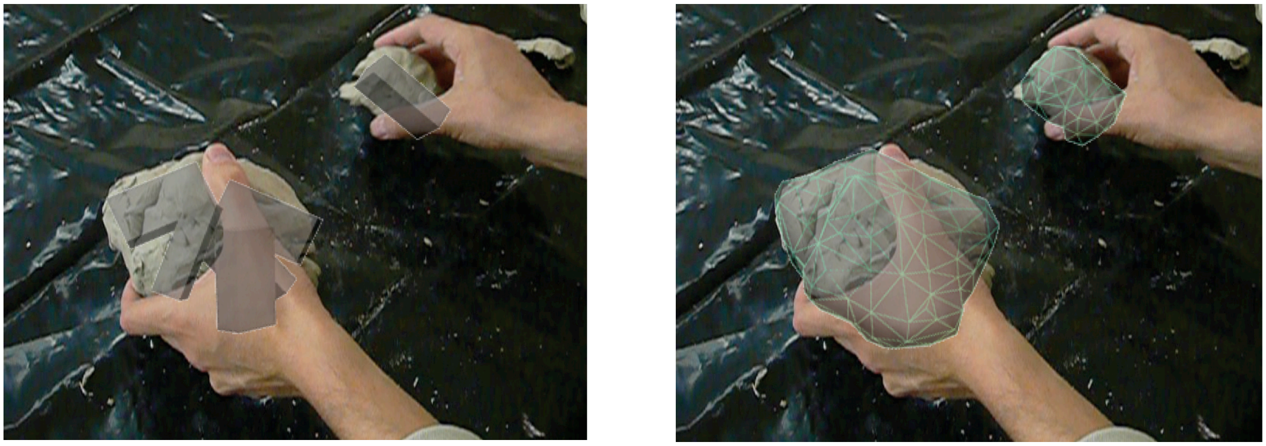

Figure 3: Sensor data (left) and corresponding isosurface (right) overlays on video image of sensors. (Registration of the images was done by hand, but all relative position & orientation is computed from the sensor data)