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Haptically extended augmented prototyping

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Haptically Extended Augmented Prototyping

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ABSTRACT

This project presents a new display concept, which brings together Haptics, Augmented and Mixed Reality and Tangible Computing within the context of an intuitive conceptual design environment. The project extends the paradigm of Augmented Prototyping by allowing modelling of virtual geometry on the physical prototype, which can be touched by means of a haptic device. Wireless tracking of the physical prototype is achieved in three different ways by attaching to it a 'Speck', a tracker and Nintendo Wii Remote and it provides continuous tangible interaction. The physical prototype becomes a tangible interface augmented with Mixed Reality and with a novel 3D haptic design system.

KEYWORDS: Tangible Computing, Mixed Reality, Augmented Reality, Product Design, Tactile & Haptic UIs

INDEX TERMS: H.5.2 User Interfaces.

1 INTRODUCTION

Designers use rapid prototypes to aid the design process. Motivations for their use include visualization, ergonomics, communication and mechanical verification such as fit of internal mechanisms. A physical object can be perceived more naturally and directly in relation to the real world than a 2D projection of a model on a computer screen. Furthermore, real objects afford simultaneous bi-manual manipulation with the whole hand coupled with natural stereo viewing. Recently, Augmented Prototyping has allowed the addition of effects such as texture and lighting onto the surface of prototypes, typically by projection. This paper introduces novel work which extends this paradigm by allowing the modification and addition of virtual geometry to the physical prototype which can be touched by means of a haptic device.

2 THEORY

Augmented Prototypes are a form of Augmented Reality (AR) display where the physical and virtual are displayed together in various ways [2]. A defining feature of Augmented Prototyping is that a featureless physical model is augmented graphically. There are three display types; direct projective, optical see-through or small embedded screens. The above survey also suggests three issues of relevance; Threshold (ease of set up); Interaction (scope of use); Insight (understanding of design) that the system provides.

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An Augmented Engineering system [3] used a see through half transparent mirror and is similar to our design in this regard. The 'Spinnstube' AR-system also employs a see-through mirror similar to our project but is not haptically augmented [6]. Rapid prototype has been used for car design using a projector approach [7].

2.1 Contribution

This paper makes the following explicit contributions:
- Extends the augmented prototyping paradigm to include the addition of virtual geometry which can be touched by means of a Haptic device. This widens the use of the augmented prototype from visualization (to assess progress of a design to the present) to activities such as proposing and carrying out further design changes.
- Use of tracking device that provides unhindered manipulation of the prototype.
- The context of use in a complete Haptic 3D conceptual design system. This extends interaction with augmented prototyping from single tasks such as "snap shot" visualization to continuous interactive integration with the design process.
- Haptically extended Augmented Prototypes will be of general interest to the HCI community as a hybrid Tangible/Haptic Augmented Reality interaction technique.

2.2 Design Context

Traditional digital design support tools such as CAD are well suited to the unambiguous mechanical specification of design in the practical phase. However, they are ill suited to the rapid free form exploration of the early conceptual design phase. Complex interfaces are hard to learn and constraining and disruptive to the rapid cognitive flow of conceptualization. Furthermore, the conventional 2D mouse interface is ill suited to conceptual design because of the mismatch between the 2D control space of the mouse and the 3D task space of designing physical artifacts. These observations motivated us to develop a new design medium for rapid conceptual design with which users can draw in 3D and manipulate surfaces and paint on them by means of a haptic device. The system is capable of direct output to rapid prototyping using the standard STL file format. The system has been exposed to a series of designer/users throughout development. We have shown that such an interface is highly efficient compared to a conventional 3D modeler [5]. A Jeweler has created a design for a new necklace in less than 30 minutes which was then exported and made into a rapid prototype. We see the integration of Haptic Augmented Prototyping as a natural and powerful extension of this 3D haptic conceptual design tool which could change the role of prototyping in the design process.

2.3   System Description

The system is shown in figure 1. It consists of a metal frame onto which is mounted a horizontal half silvered mirror. Users can peer thought the glass to see a dark image of the real rapid prototype. Above the mirror in the frame is mounted a laptop with an autostereoscopic screen. The image on the laptop screen is reflected in the mirror and appears co-located with the rapid prototype on the table.

Figure 1.   The system consists of a horizontal piece of glass above which is mounted a laptop with autostereoscopic screen. Below the glass or "mirror" is a rapid prototype.

The display is thus a form of optical see-through augmented reality system. As the rapid prototype is rotated by hand its orientation is tracked and the virtual collocated augmented imagery is updated to appear fixed to the prototype. To the right is an Omni Sensable Haptic device which can be used to interact with the co-located virtual geometry. The frame is adapted from a Reachin display working with shutter glasses and a conventional vacuum tube monitor. The monitor was replaced with an autostereoscopic laptop in a similar way to the Sensegraphics 3D-MIW display. The key difference from these systems is that the haptic device is moved to one side and its central co-located position is taken by a physical Rapid Prototype model. User interaction occurs with the rapid prototype held in the non-dominant hand as a kind of tangible interface. Simultaneously, users can interact haptically with the augmented co-located virtual model of the prototype by means of the haptic device held in the dominant hand, providing efficient two-handed interaction. Figure 2 shows the "reflection" users see in the mirror. It consists primarily of the virtual model but the actual rapid prototype can also be seen faintly. In the context of a design pipeline, a preliminary conceptual design can be created using the mirror and the haptic device alone. At some stage the designer can decide to export the virtual design as an STL file and have a Rapid Prototype made. While the model is being made the designer can carry on using the virtual model if they so wish. When the model is ready a tracking device is attached and the prototype is placed below the mirror. We have used three tracking methods, "specks", Nintendo's Wii Remote and a tethered magnetic tracker. "Specks" are designed to integrate sensing, processing and wireless capabilities in a minute semiconductor grain. They can be attached to a variety of sensors, actuators and other conventional computer infrastructure [1]. When the model is placed under the mirror then extra geometry and changes to the design can be seen augmented to it. The designer can continue conceptualizing and changing the design by physically holding and rotating the real physical prototype and seeing their changes in the mirror and feeling the extra geometry with the haptic device.

3   DISCUSSION

One of the general issues with Augmented Reality systems is the precision in the tracking of orientation. The Wii Remote produced a certain amount of drifting due to the use of accelerometers

alone. The 'specks' provided more accuracy due to the addition of magnetometers and gyroscopes on the platform which serve to correct the data that one received from the other. The tethered magnetic tracker provided the best accuracy but its wired use and its high price are important drawbacks. It should be noted that the slight drifting of the image does not destroy the illusion in the same way as in a direct projection system. If the physical prototype and user's hands are only dimly seen through the glass, then tracking and registration errors are less important than with a projection system.
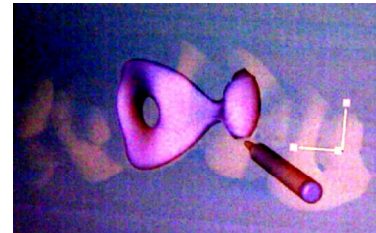

Figure 2. The faint image is the rapid prototype below the "mirror".

An interesting perceptual issue for future study is the extent to which the virtual and physical prototype can diverge in geometric detail before the illusion of their augmentation is broken. Future work will also include tracking of translation for unencumbered work on the prototype as well as optical tracking alternatives for the head. The same interaction technique could be applied in other domains such as museum exhibits.

4   CONCLUSION

This project extends the paradigm of Augmented Prototyping to include Haptics and the ability to change and interact with changed virtual geometry using a haptic device. The system is implemented within the context of a 3D haptic conceptual design package offering the potential to extend the use of rapid and augmented prototyping from "snap shot" visualization to continuous hybrid tangible/haptic interaction within the design process.

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