Passive Deformable Haptic Glove to Support 3D Interactions in Mobile Augmented Reality Environments

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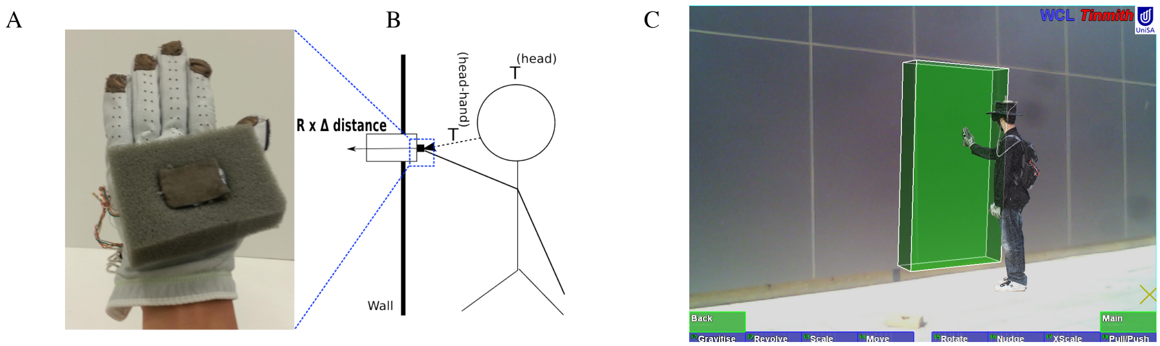

Figure 1: Passive deformable haptic glove and an example usage: carving a virtual door into a physical wall. From left: A) the glove, B) the transformation model, C) Door cut-out model added to the wall, also showing the user (artificially overlaid) performing the task.

Abstract

We present a passive deformable haptic (PDH) glove to enhance mobile immersive augmented reality manipulation with a sense of computer-captured touch, responding to objects in the physical environment. We extend our existing pinch glove design with a Digital Foam sensor, placed under the palm of the hand. The novel glove input device supports a range of touch-activated, precise, direct manipulation modeling techniques with tactile feedback including hole-punching, trench cutting, and chamfer creation. The PDH glove helps improve a user's task performance time, decrease error rate and erroneous hand movements, and reduce fatigue.

Keywords: Passive Haptics, Augmented Reality, Pinch Gloves, Input Device, Interaction Technique.

Index Terms: H.5.2 [Information Interfaces and Presentation]: Graphical User Interfaces—Input Devices and Strategies; I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction Techniques

1 Introduction

Precise methods for 3D data manipulation in both augmented and virtual worlds has been our main research focus [1]. This paper explores the use of a passive deformable haptic (PDH) glove that captures when a user touches physical objects and the force applied to develop touch-based mobile augmented reality (AR) interaction techniques. PDHs are non-rigid objects that can change shape when a force is applied [2-4]. Our primary goal is to improve precision, accuracy and reduce fatigue for users by use of a deformable material. Deformable materials provide physical support and sensory feedback to the users while performing tasks, such as manipulation and command control, on real-world objects. We are interested in attaching a PDH device to a user's palm as a one-dimensional distance sensor that provides tactile feedback to the user to improve their spatial understanding and control of depth manipulations.

We are exploring the idea of enhancing physical objects, such as buildings, with overlaid virtual features through direct touch, especially the interactive creation of virtual features that *cut into* or *extrude* from the surface of a physical object. The PDH material for the glove is the Digital Foam sensor [4, 5] that uses conductive foam whose resistance changes when deformed. Previously, Digital Foam has been used to create interactive devices that allow clay-like interactions, only as a covering on physical objects. Our new device removes the Digital Foam from the physical object and attaches it to a glove worn on the user's hand. This glove-mounted sensor allows the user to perform touch-based interactions on a multitude of physical objects and surfaces, converting a stationary device into a mobile input device. Figure 1 depicts our new PDH glove and an example of a touch-based interaction process creating a new virtual door into a building.

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2 Related Work

Glove-based technologies capture real-time finger movements and gestures with high degrees of freedom. Immersion CyberGloves™ use bend sensors to measure joint angles and capture the finger pose. Pinch glove designs use fabric switches attached to the finger tips [6], for command entry. Piekarski and Thomas [7] extended the pinch gloves with an additional switch in the palm for menu control. Hoang and Thomas developed an ultrasonic glove-based input device for distance based manipulation techniques [1].

Passive haptics have been employed in virtual and augmented environments to assist with realism and improve immersion [8]. A study by Viciana-Abad et al. [2] demonstrates that passive haptic feedback improves task performance with reduced errors. A table-mounted sheet of 'soft foam rubber' was used to support pointing gestures using fingers or with a stylus. The non-haptic condition has participants perform the task by stretching out their hands in mid-air. Kohli [9] explored a deployable substrate used with an AR system for a military training system. This system explored the idea of warping the augmented models so that the physical and virtual systems do not align exactly, and thus extends the deployable substrate to a range of virtual content. These passive haptic examples have not attached the soft materials directly to the user's body to enhance the interaction experience.

3 Passive Deformable Haptic Glove

We are interested in supporting a mobile interaction scenario when a physical object is enhanced with object-referenced virtual information. One example of a scenario is the task of fixing virtual nails into a specific depth on a physical wall. Our focus is on a wearable mobile input device that leverages passive haptic feedback to complete such a task in a natural and intuitive manner: 1) The user walks up to the wall and places their hand equipped with a PDH glove on the surface to position the nail; 2) the user presses onto the PDH material against the wall to drive the nail into the desired depth. The PDH material provides physical support during the manipulation and the mapping of the PDH deformation supplies the additional 1DOF for depth information. The 6DOF pose of the glove is determined by existing tracking techniques, whose mechanism is outlined in Figure 1B. Combining the user's position matrix, **T**(head), and relative position of the hand, **T**(head-hand) determines the location of the glove. The Digital foam provides an additional 1DOF that captures depth information, **Δ**distance.

We use a Digital Foam [4, 5] sensor as the PDH material. Digital Foam is a 1DOF distance sensor that is lightweight, easily integrated into a glove-based input system and provides passive haptic feedback. The PDH glove supports mobile interactions that perform cutting and carving operations on existing models of physical objects using a variety of cutter shapes such as cylinder, prism, or plane. Similar to the nail fixing example, the user is able to cut a pre-defined shape to a certain depth on existing objects by pressing the PDH glove against a physical surface, or dragging the glove across the surface to carve trenches or valleys. The interaction is modeless wherein the task starts the moment the glove touches the surface and deforms the Digital Foam sensor. Figure 2 shows an example of trenches cut out by the PDH glove.

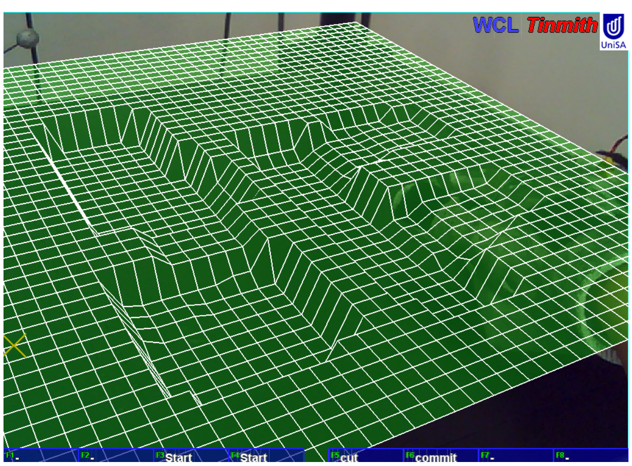

Figure 2: Trench cutting techniques on an existing model

The PDH glove is an extension to commonly employed pinch gloves [10] with the addition of a Digital Foam sensor [4] installed in the palm of the hand. A 25mm electrically conductive foam cylinder is supported with a square of polyurethane foam (shown in Figure 1A). Upon compression, the resistance of the conductive foam reduces, which is measured with a voltage dividing circuit on an Arduino Pro Mini, with a BluetoothMate transmitter board. Both circuit boards are mounted on the back of the glove. A rolling average value is taken for every ten measurements to reduce fluctuations. Moreover, by pressing the fingers on the Digital Foam sensor on the same hand, like making a fist, the user can deform the foam, thus utilizing the PDH glove as a one-handed 1D sensor, without a physical surface.

The amount of pressure required to depress the foam is one limitation of the PDH glove device, especially in the fully deformed state. Changing the size of the foam sensor and the density of the foam material used can help reduce the effort required. The depth of the actual foam sensor limits the range of manipulation distance. A thicker Digital Foam sensor with lower density can be used to increase the range of movement. Using 1-to-1 mapping gives a range of 25mm with 1mm resolution. We can apply a scaling factor to the mapping. A factor of 10 will allow for a range of up to 25cm manipulation with a 1cm resolution. There is a trade-off between accuracy and resolution, depending on the requirements of the task.

4 Conclusion

We have presented the Passive Deformable Haptic glove that employs the Digital Foam sensor to support precise direct touch manipulation modeling techniques. The glove is based on a pinch glove design with a Digital Foam sensor mounted in the palm. Our glove allows arbitrary physical objects to be modified with virtual information through direct touch with intuitive operations. The passive haptic feedback improves precision and reduces hand fatigue. In the future we would like to extend the sensor location to other parts of the user's hand, such as fingertips and the edge of the hand.

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