Distance-Based Modeling and Manipulation Techniques Using Ultrasonic Gloves

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ABSTRACT

We present a set of distance-based interaction techniques for modeling and manipulation, enabled by a new input device called the ultrasonic gloves. The ultrasonic gloves are built upon the original design of the pinch glove device for virtual reality systems with a tilt sensor and a pair of ultrasonic transducers in the palms of the gloves. The transducers are distance-ranging sensors that allow the user to specify a range of distances by natural gestures such as facing the palms towards each other or towards other surfaces. The user is able to create virtual models of physical objects by specifying their dimensions with hand gestures. We combine the reported distance with the tilt orientation data to construct virtual models. We also map the distance data to create a set of affine transformation techniques, including relative and fixed scaling, translation, and rotation. Our techniques can be generalized to different sensor technologies.

Keywords: ultrasonic gloves, distance-based techniques, modeling, manipulation.

Index Terms: H.5.2 [Information Interfaces and Presentation]: Input devices and strategies; I.3.6 [Computer Graphics]: Interaction techniques.

1 INTRODUCTION

We present a new input device, called the *ultrasonic gloves,* to support a set of distance-based interaction techniques with the modeling and manipulation of virtual objects for augmented reality (AR) systems. The main goals of our new device and techniques are mobility and hands-free interaction to improve precise manipulation. The new technique must also enhance and not interfere with existing techniques. The ultrasonic glove is built upon the original Tinmith pinch gloves design [1], with the addition of a low cost tilt sensor and a pair of ultrasonic transducers. The ultrasonic transducers are mounted in the palms of the gloves and used to detect distance between the palms or from the palms to solid surfaces. The ultrasonic glove enables intuitive body gestures; an everyday example is when people describe measurements, such as "the TV in our room is *this* wide" and place their hands at such a distance apart. The tilt sensor provides coarse data to determine hand pose (one of six 90º orthogonal orientations to the ground). Our interaction techniques directly map the reported distance and hand poses to *modeling by measurements* interaction techniques (see Figure 1) and to support *affine transformation* interactions with virtual objects. The techniques supported by the ultrasonic glove only rely on the sensors on the gloves, thus are independent from other sensors in the AR system, such as head orientation and GPS location sensors. Traditionally interaction techniques for outdoor AR have supported action at the distance techniques [2]. *Our ultrasonic techniques offer the first within arms reach direct manipulation approach to modeling for wearable outdoor AR system*.

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Figure 1: Modeling by measurements using ultrasonic gloves on a filing cabinet (subfigures - a. length, b. width, and c. height)

The main contributions of this paper are as follows: 1) a modeling by measurement technique that supports gesture-based capturing of physical dimensions of real world objects and 2) affine transformation techniques with translation, rotation, and scaling of virtual objects for wearable AR system, using the ultrasonic glove input device.

2 BACKGROUND

Glove based input devices have attracted a considerable interest from the research community. A common sensing technology for a pinch glove input device is the attachment of conductive fabric pads onto the tips of the fingers and thumbs [1]. Piekarski and Thomas [3] extended the pinch glove with an additional pad on the palms for menu control. Ultrasonic sensors have also been popular in interaction research. Foxlin and Harrington [4] implement a system called WearTrack, where the receivers are head mounted to track the position of a transmitter that is worn on the finger. A combination of ultrasonic sensors and glove is presented by Han et al. [5] with the FutureGrab system and Hoefer [6] with the Tacit glove. The FutureGrab system is for sound synthesis that uses ultrasonic sensors to detect the height of the hand for pitch adjustment. The Tacit glove uses ultrasonic sensors to detect obstacles for the blind. HandSCAPE [7] is a digital tape measure that combines a tilt sensor and is used to create virtual models of physical objects based on direct measurements.

3 THE ULTRASONIC GLOVE INPUT DEVICE

The ultrasonic glove (see Figure 2) supports two main types of interaction technique: modeling by measurement and affine manipulation.

3.1 Modeling by measurement

Modeling by measurement is the process of creating virtual models to match the physical dimensions of objects in the world.

Traditionally, the process is completed in two stages: 1) physically capture the measurement through surveying or manual capture and 2) enter them into a modeling system, such as desktop-based CAD programs to complete the modeling stage to construct virtual objects.

Figure 2: The ultrasonic glove

The modeling by measurement interaction technique employs body and hand gestures to support contextual AR modeling as a single process with a simultaneous capturing of measurements and applying them to create models. There are three different tilt modes to determine which dimension of the object the user will model. Placing the fingers parallel to the ground and the normal vector to the palm parallel to the ground places the gloves in the *length* capture mode. *Width* capture mode is when the fingers are pointing to the ground. Finally, when the normal vector to the palm is pointing towards the ground, the gloves are in the *height* capture mode.

The user can face the two palms towards each other at a set distance apart, and the ultrasonic transducers then report the distance to the AR system. The distance data is coupled with the dimension defined by the tilt mode of the palm to create measurement vectors, in width, height, and length dimensions. Therefore, the user can create models by capturing the dimensions of physical objects with palm extending gestures. Our ultrasonic glove supports proprioceptive body gestures, which is an improvement over other input devices such as the HandSCAPE. The tilt and ultrasonic sensors are small, low powered, inexpensive, and support high mobility.

An example task is the modeling of a standing filing cabinet, as illustrated in Figure 1 with three dimensions. The figures show the different orientations of the hand: both palms facing each other horizontally to capture the length (left), palms facing vertically for the width (middle), and the palm facing down to capture the height (right). To the user, the entire process seems natural: “So this filing cabinet is *this* wide, *this* long, and *this* high”. The user’s sense of proprioception allows them to place the palms facing each other without the need of visual feedback, enabling the effortless usage of both hands to *feel* the dimensions of the object. *The use of the ultrasonic gloves for modeling for measurement induces little cognitive load, where the user is not mindful of the input device and UI elements.*

3.2 Manipulation

The ultrasonic gloves provide an alternative method of affine transformations. For *relative scaling,* the user places their palms at a certain distance apart, which is captured as the initial distance. The user then adjusts the distance between the palms to scale the selected object, with a scaling factor that is the ratio between the current palm distance and the initial distance. The tilt orientation of the palm determines which dimension of the object the user is scaling. *Fixed scaling* option adds or subtracts the specified distance directly to the appropriate dimension of the object. This approach is useful for fine-tuning scaling operation. Figure 3 shows the view of the user while performing a scaling operation. The scaling ratio or distance is shown on the left hand side of the screen. A similar mapping is used for translation and rotation. With translation, the distance reported by the ultrasonic sensors is used directly to translate the object along the axis specified by the tilt sensor. For rotation, distance data is mapped to rotation angle, at 1 cm per Euler degree.

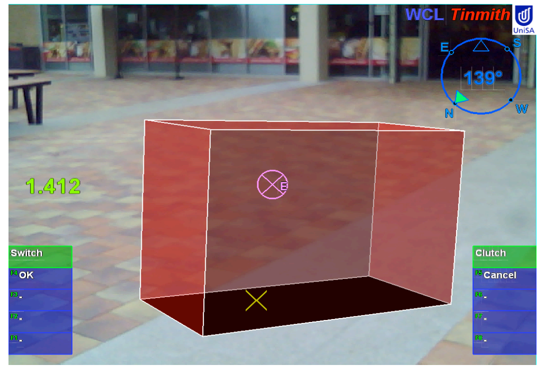

Figure 3: The view of the user while performing a scaling operation

The glove uses an Arduino Pro Mini microcontroller board[1], which is connected to a Bluetooth Mate board to provide Bluetooth serial connection. The Arduino board has both analog and digital pins, to which a 3-axis accelerometer board and a pair of ultrasonic sensors are connected. Different distance sensing technology maybe employed to our distance-based modeling and manipulation techniques, as the algorithm will remain the same.

4 Conclusion

The ultrasonic glove is a versatile input device that supports modeling interaction within a wearable AR system, including: modeling by measurements for physical objects and affine transformation of translation, scaling, and rotation. The ultrasonic glove retains all the existing functionality of the original Tinmith glove, as well as leverages its intuitive and natural nature.

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