3D Positioning Techniques for Multi-touch Displays

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Abstract

Multi-touch displays represent a promising technology for the display and manipulation of 3D data. To fully exploit their capabilities, appropriate interaction techniques must be designed. In this paper, we explore the design of free 3D positioning techniques for multi-touch displays to exploit the additional degrees of freedom provided by this technology. We present a first interaction technique to extend the standard four viewports technique found in commercial CAD applications and a second technique designed to allow free 3D positioning with a single view of the scene.

CR Categories: H.5.2 [User Interfaces]: Input devices and strategies.

Keywords: Multi-touch displays, 3D positioning task, direct manipulation

1 Introduction

Multi-touch input enables users to manipulate and display information in unprecedented ways by using fingers and hand gestures. Multi-touch displays offer a direct interaction using fingers to translate, rotate and scale two dimensional (2D) objects in a natural way. 3D interaction techniques for multi-touch displays focus mainly 3D object rotation [Hancock et al. 2007]. However to the best of our knowledge, no interaction technique has been proposed to exploit multi-touch displays to freely position objects in 3D environments. In this paper, we explore the development of 3D positioning techniques for multi-touch displays. How can we exploit the additional DOF provided by this technology to develop intuitive and efficient 3D positioning techniques? How to map finger gestures to 3D movements?

2 Related Work

To manipulate 3D objects on tabletop displays with limited depth, Hancock et al. [2007] present one, two and three touch input interaction techniques. With one touch input, their technique achieves 5 DOF movement for 3D rotations coupled with 2D positioning. Two-touch interaction allows performing pitch and roll rotations with a second finger on the non-dominant hand. With three-touch interaction, users can perform a simultaneous translation and rotation on the surface of the table. Positioning along the depth is proposed as an option by measuring the distance between two fingers.

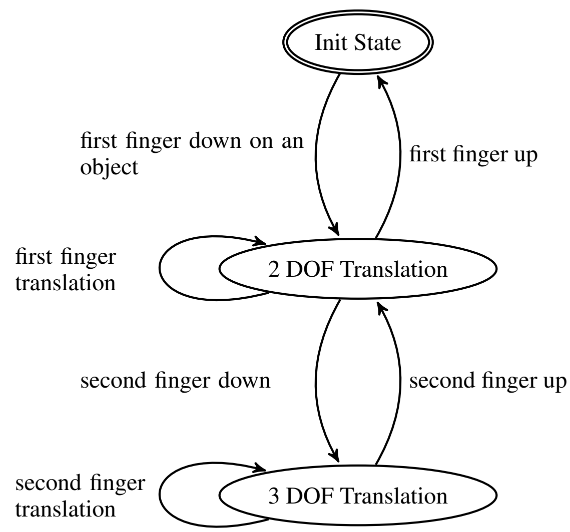

Figure 1: *State transition diagram representing the techniques*

However the technique was mainly designed to control the orientation of a 3D object with 2D positioning. Zeleznik et al. [1997] provided techniques that use two pointers to translate and rotate objects using multi-touch indirect interactions. However, translation was constraint to the plane associated to the manipulated object.

To sum up, several techniques exist to manipulate 3D objects on multi-touch displays but none allows free 3D positioning. In contrast, free 3D positioning with a computer mouse is a common task and the four-view technique represents the most widely used technique. It consists in displaying on screen 3 orthogonal views and one perspective view of the 3D scene. The object position is controlled 2 DOF at a time using one of the orthogonal view.

3 Our approach

Our primary goal was to focus our design on free 3D positioning techniques for multi-touch displays. During the design process we noticed that multi-touch displays can reach their full potential when used with direct interaction. As a result, we wanted to develop interaction techniques that extend current techniques using the screen plane to control 2 DOF in a direct way. The question was then to control the third degree of freedom to change the objects depth position. We present here two techniques that allow full control of the third degree of freedom. The state transition diagram in Figure 1 describes both techniques.

3.1 Multi-touch viewport

Most CAD softwares propose a 3D positioning technique dividing the screen into three or four views (also called viewports) as previously described. We developed a technique to take advantage of the

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multiple viewports adapted to multi-touch inputs.

The two top states in Figure 1 correspond to the standard viewport technique. When a finger first touches the surface, the corresponding viewport is detected and a ray orthogonal to the view is projected into the scene. The first object in intersection is returned. Subsequent finger movements translate the object in the plane parallel to the view passing through the object center. The multi-touch viewport extension is activated only when a second finger touches **another viewport**. On the finger down event, the object is first teleported to the depth position associated to the second finger position. The user can then adjust the depth position in the direction orthogonal to the view associated to the first finger. We used a visual feedback represented as a line passing through the object center to represent this direction.

3.2 The Z-technique

We designed the second technique to allow 3D positioning using a single view of the scene. We believe this presentation increases the immersion of the user in the 3D environment compared to the multi-touch viewport technique. With this technique, we also use direct manipulation to control the position of objects in the screen plane. Backward and forward movements of a second touch point allow depth positioning.

When the first finger is in contact with the surface, a ray coming from the camera center through the finger position is casted in the scene and the closest object in intersection is returned. Positioning is then constraint to the plane parallel to the camera plane passing through the object center.

When a second finger is in contact with the surface we measure its relative motion on the surface and use backward forward movement to control the depth position. Backward - forward movements are measured relative to the user position. Forward movement moves away the object from the user and backward movement moves it closer to the user. As we measure the relative motion, a succession of finger touch and release, also known as clutching, can be used to position the object at any depth position.

As we control the depth position in an indirect way, we use a transfer function to map the finger movement to object displacement. During preliminary tests we first used a constant gain but it appeared that fine positioning was difficult due to the low resolution of our tracking system. We then implemented a non-linear function that map the displacement speed to a scale factor [Casiez et al. 2008]. To a slow displacement speed corresponds a low scale factor and a high displacement speed is associated to a much higher scale factor. It helps fine positioning as well as gross positioning with reduced finger displacement.

4 Pilot experiment and discussion

We wanted to investigate the impact of the information presentation and the directness of control for depth positioning on both performance and qualitative feedback. To do this, we used a three dimensional positioning task based on the docking task exposed by Zhai [1998]. Participants were asked to dock a blue sphere in a transparent grey sphere as quick as possible. The dependent variables for both techniques were positioning time and coordination value. We introduced a third variable to measure the frequency of use of two viewports for the multi-touch viewport technique. Precise details about this experiment can be found here [Martinet et al. 2009].

The first results incline us to conclude that the two techniques evaluated are equivalent in term of performance as we did not find any significant difference for the positioning time. We found a significant effect for the high precision condition in favor of the multi-touch viewport technique.

In the experiment the participants used two viewports simultaneously more than 80% of the time, making an effective use of the additional features provided by the multi-touch viewport technique. In addition the results show that participants emphasis the simultaneous use of two viewports with targets requiring coarse positioning showing that when the task become more difficult, users tend to adjust sequentially the degrees of freedom. We also showed that the two top viewports were nearly never used with our hardware configuration, suggesting that participants tried to reduce their fatigue using the two viewports close to them. This suggests that the perspective view can be extended to the entire width of the upper half of the screen.

Oh et al. [2005] showed that the classic four-view technique was significantly faster compared to other techniques using full screen in a manipulation task. Here we provide the Z-technique that reaches a similar level of performance compared to an improved version of the four-view technique. The interaction with the perspective view in full screen was in addition preferred by most participants. This makes the Z-technique a real alternative to the multi-touch viewport, especially when the display surface is limited (e.g. mobile phones).

5 Conclusion and Future Work

In this paper, we have introduced and compared two 3D positioning techniques that allow to freely position an object using a multi-touch display. In a controlled experiment we showed that these two techniques are equivalent in term of performance. However the Z-technique was preferred by most participants. Considering its performance and qualitative feedback, the Z-technique can be used as a base line comparison for other 3D positioning techniques designed for multi-touch displays. As future work, we plan to study and add the support for object rotation to control more degrees of freedom in an intuitive way.

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