FishTank Fitts: A Desktop VR Testbed for Evaluating 3D Pointing Techniques

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Abstract

We present a desktop or "fish tank" virtual reality system for evaluating 3D selection techniques. Motivated by the successful application of Fitts' law to 2D pointing evaluation, the system provides a testbed for consistent evaluation of 3D point-selection techniques. The primary design consideration of the system was to enable direct and fair comparison between 2D and 3D pointing techniques. To this end, the system presents a 3D version of the ISO 9241-9 pointing task. Targets can be displayed stereoscopically, with head-coupled viewing, and at varying depths. The system also supports various input devices, including the mouse as well as 3D trackers in direct touch and remote pointing modes.

Author Keywords

3D pointing; cursors; fish tank virtual reality; Fitts' law

ACM Classification Keywords

H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems – virtual reality. H.5.2 [Information Interfaces and Presentation]: User Interfaces – input devices, interaction styles.

Introduction

Point-select or pointing tasks are fundamental means of interaction in direct manipulation interfaces. This
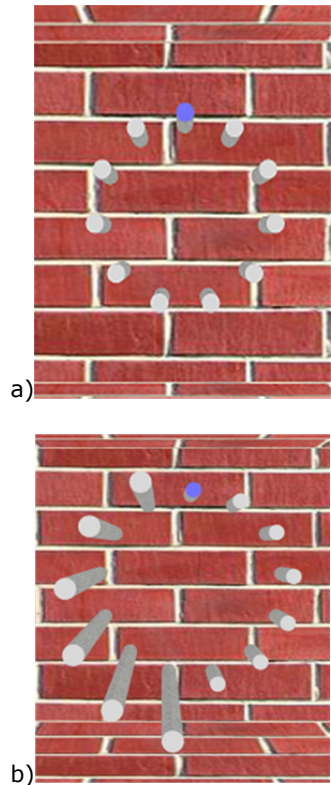
a)

b)

Figure 1. A target circle at constant (flat) -20 cm depth. (b) Mixed depth targets – those on the right are farther from the viewer than those on the left, necessitating depth movement with some pointing techniques, e.g., direct touch (see below).

paradigm is commonly employed in desktop systems using a mouse. Three-dimensional pointing is analogous to 2D pointing, and is similarly important in 3D user interfaces, such as virtual reality (VR). While 2D pointing techniques have been thoroughly investigated, and are well-understood [3, 5], 3D pointing is relatively less well understood. Direct comparisons between 2D and 3D pointing are rare. Yet such evaluations would help explain the relative absence of successful immersive 3D systems while providing insight on how to improve them. Hence we developed a system to evaluate 3D pointing tasks, but with the secondary objective to enable direct comparison between 2D and 3D pointing tasks under a variety of conditions. Our goal is to identify better methods for evaluating 3D pointing techniques using a well-established methodology commonly employed in the evaluation of 2D techniques.

The System
Our system runs on a 3 GHz PC, with an Nvidia Quadro 4400, and a 24" 120Hz stereo LCD. Stereo graphics are provided by NVidia 3DVision Pro shutter glasses. Five NaturalPoint Optitrack S250e cameras are used for 3D tracking. The system can display the scene in both stereo and mono and also supports head-tracking. It can also render the cursor in stereo or mono based on Ware's work on one-eyed cursors [9].

The systems presents a 3D extension of the ISO 9241-9 standard for evaluating (2D) pointing devices [4], based on Fitts' law [3]. The scene is a 30 cm deep box matching the display size, see Figure 1. Textures and cylinders are used to facilitate spatial perception of the 3D scene. Target spheres are centered on top of cylinders arranged in a circle. The active target

highlights blue and targets highlight red when selected. The cursor is a small 3D crosshair, either at the screen plane or in the 3D scene, depending on the current condition. In one-eyed mode, the cursor is displayed only to the viewer's dominant eye. In ray mode, the 3D device ray is also displayed. While the standard 2D experimental paradigm varies only target size and distance, our system can also vary target depth within the limitations of the screen geometry, tracking volume size, and device characteristics.

Pointing Techniques
The system supports several pointing techniques, intended to be representative of certain classes of 3D interaction. Since a primary motivation behind developing the system was to enable the *direct* and *fair* comparison of 2D and 3D pointing techniques, the system supports both mouse-based pointing and 3D tracker-based techniques.

The tracker-based techniques include "virtual hand" (depth cursor) type techniques. These necessitate intersecting a 3D cursor with the target volume. Remote pointing techniques are also supported. These merely require pointing the device at the target. The techniques are discussed in detail below.

Mouse Cursor (MC)
This technique uses a mouse controlled cursor that moves in the screen plane. A ray from the dominant eye is cast through the cursor position to determine which target is hit. The z-buffer is disabled, so the cursor always occludes targets, much like a standard system mouse cursor. This technique represents "non-VR" 3D graphics software, such as games and CAD. More importantly, it also allows comparison with 2D
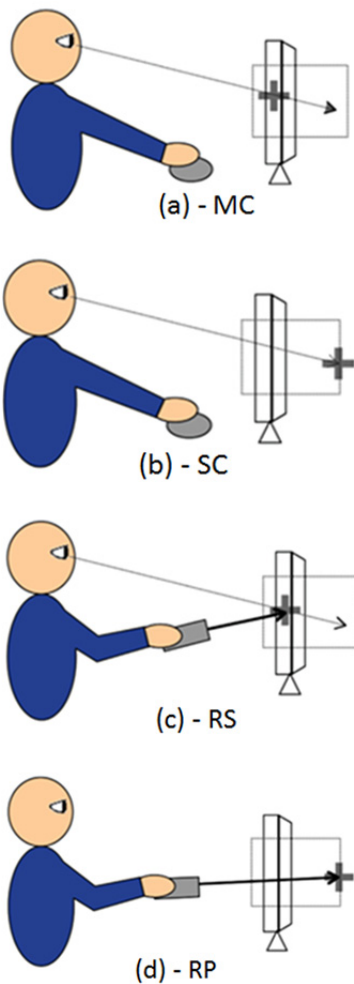
Figure 2. Mouse and remote pointing techniques. The "+" represents the cursor, and the box around the display represents the 3D scene.

work. The cursor is displayed as a 1 cm crosshair. See Figure 2a.

Sliding Cursor (SC)

The SC technique represents the "depth cursors" sometimes used in games and mouse-controlled 3D graphics systems. SC uses the position of both the system cursor and the eye to compute the position of a 3D cursor in the scene. A ray is cast from the eye through the system cursor (which is not displayed) and the 3D cursor is displayed where the ray intersects the scene. Thus, the cursor slides along the visible scene geometry, and enables 3DOF cursor control with only 2DOF input. See Figure 2b.

Ray Screen (RS)

The ray-screen technique, RS, (Figure 2c) displays a cursor in the screen-plane where the device ray intersects the screen. This ray is not used for selection. Instead, the ray from the eye and through this cursor is used for selection. This effectively affords selection of objects by way of selecting their projections via a user controlled cursor on the screen. This is somewhat similar to a mouse cursor, except the cursor is controlled by the remote pointing device.

Ray Pointing (RP)

The ray pointing technique uses "classical" ray casting. A ray emitted from the device and into the scene is tested for intersections with the scene. The cursor (cross-hair) is drawn at the intersection point. The ray itself is also displayed to improve feedback with the technique. This is depicted in Figure 2d.

Direct Touch (DT)

This technique used a tracked stylus and displays the cursor (the "virtual pen tip") co-located with the stylus tip. The virtual tip is tested for target intersections. This is representative of depth cursor techniques, or those that require intersection of a virtual hand (representation) with targets [2]. This technique also simulates pen-based input, if used on a 2D display surface. This permits direct comparisons with 2D results. See Figure 3a.

Indirect Touch (IT)

Like direct touch, this technique uses the full 6DOF pose of the device to control the position of a cursor. However, unlike DT, the cursor with this technique is not directly connected to the physical position of the remote. The cursor is offset, or disjoint, from the device position. The movement of the remote is mapped to absolute cursor movement. This technique thus allows selection of targets *behind* the display surface, which is impossible with DT. See Figure 3b.

Previous Evaluations

The FishTank Fitts system has been employed in several evaluations, in particular, in the comparison of 2D and 3D pointing techniques [6-8]. Our evaluations [7] show the mouse offered higher performance, but also that ray-screen outperformed traditional ray pointing [8].

Tactile feedback is also important to the direct touch technique [7]. Despite stereo viewing and head tracking, participants had difficulty selecting targets in the absence of tactile feedback [1]. At present, the indirect touch technique has not been evaluated. It will
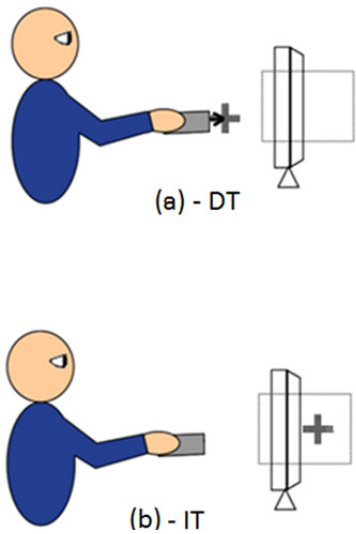
Figure 3. Touch-based techniques supported by the system, (a) direct touch, (b) indirect touch. The box represents the 3D scene extending into and out of the display. The "+" represents the cursor.

be compared to mouse-based techniques in forth-coming work on 1D pointing motions in 3D spaces.

Perhaps the most important feature of previous evaluations has been the consistency of throughput measures across studies - this is the primary advantage of using throughput as a performance metric. This has been reflected in our previous work using the system. Mouse throughput is consistently around 4 bps (similar to the 2D pointing literature). Throughput for similar conditions with tracker-based techniques is also consistent across the studies.

Conclusion

We presented the FishTank Fitts system for evaluating 3D pointing/selection techniques. The system supports various pointing techniques, including mouse-based (2D) techniques and tracker-based (3D) techniques. It also employs the 3D tracker for head-tracking, and combined with stereo display, creates a compelling illusion of a perceptually stable virtual reality scene. Users perceive that they can reach out and touch imagery in 3D. The system has thus been an invaluable tool for the empirical comparison of pointing techniques, especially across input devices with highly varying degrees of freedom.

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