A Study in Interactive 3-D Rotation Using 2–D Control Devices

Michael Chen
Department of Electrical Engineering/
Dynamic Graphics Project
University of Toronto†

S. Joy Mountford
Human Interface Group
Apple® Computer Inc.‡

Abigail Sellen
Institute for Cognitive Science
University of California, San Diego#

ABSTRACT

This paper describes and evaluates the design of four virtual controllers for use in rotating three-dimensional objects using the mouse. Three of four of these controllers are "new" in that they extend traditional direct manipulation techniques to a 3-D environment. User performance is compared during simple and complex rotation tasks. The results indicate faster performance for complex rotations using the new continuous axes controllers compared to more traditional slider approaches. No significant differences in accuracy for complex rotations were found across the virtual controllers.

A second study compared the best of these four virtual controllers (the Virtual Sphere) to a control device by Evans, Tanner and Wein. No significant differences either in time to complete rotation task or accuracy of performance were found. All but one subject indicated they preferred the Virtual Sphere because it seemed more "natural".

CR Categories and Subject Descriptors: I.3.6 [Computer Graphics]: Methodology and Techniques – interaction techniques; D.2.2 [Software Engineering]: Tools and Techniques – User interfaces; H.1.2 [Models and Principles]: User/Machine Systems – Human factors; B.4.2 [Input/Output devices]; J.6 [Computer-Aided Engineering]: Computer-aided manufacturing.

General Terms: Algorithms, Experimentation, Performance, Human Factors.

Additional Key Words and Phrases: input devices, virtual controllers, I/O devices, virtual sphere, mouse, interactive graphics, 3-D graphics, real-time graphics, rotation control, user performance.

† Department of Electrical Engineering, University of Toronto, Toronto, Ontario, Canada, M5S 1A4. Tel # (416) 978-6619.

‡ Apple Computer Inc., 20525 Mariani Ave MS 27A0, Cupertino, CA, 95014. Tel # (408) 973-4801.

Institute for Cognitive Science, C-015, University of California, San Diego, La Jolla, CA, 92093. Tel # (619) 534-2541.

1. INTRODUCTION

The recent increase in the available power of special purpose computer graphics machines has extended the operational range of capabilities for users. Objects can now be more easily generated in 3-D (in wireframe, solid and shaded forms), and manipulated in real-time. Despite advances in the ability to display 3-D objects, there is a lack of methods by which the user can easily manipulate and control the position of an object on the screen. Currently, simple direct manipulation controllers do not exist for 3-D object positioning. The design of such controllers could be important interface contributions for application environments such as manufacturing, architecture, and engineering design, which rely heavily on the display and control of three dimensions. The mouse is a successful interface tool, performing well for direct manipulation control of two-axis problems, either through manipulation of x and y separately, or the coupled control of x and y axes together. However, the issue of how best to extend the use of the mouse to accommodate the additional capabilities afforded by three-dimensional graphics is still relatively unexplored.

The ultimate goal is to provide users with an easy way of performing translation, rotation and sizing operations for complete manipulation of 3-D objects. This current performance study focuses on the use of virtual controllers in conjunction with a mouse to perform tasks involving rotation. In performing rotations users can manipulate all three axes simultaneously, whereas in performing translations and sizing operations users more often use fewer axes.

Most 3-D graphics machines use a mouse with one to three discrete buttons as the main input control device. Currently, there are four popular display techniques used to control object rotations:

1) Sliders: Typically the user adjusts the x, y and z sliders graphically displayed on the screen to indicate the amount of rotation in each axis independently. (Alternatively, physical sliders can be used).
2) Menu selection: The user first selects the axis from a text menu and then holds down the mouse button while moving the mouse in one dimension to indicate the amount of rotation.
3) Button press: The user holds down one of three buttons on the mouse or keyboard, and moves the mouse in one dimension to indicate the amount of rotation.
4) Two-axes valuator: The user moves the mouse in two dimensions to control rotation in two of the three axes.

The first three conventional approaches do allow access to rotation on all three axes but use the mouse as a one-dimensional input device. For example, the same left-and-right motion is used to control different rotation directions. However, there is little stimulus-response (S-R) compatibility or kinesthetic correspondence between the direction of mouse movement and direction of object rotation [7] Pique, 1986. The fourth conventional technique, (the two-axis valuator), does provide better S-R correspondence.