A Comparative Study of Monoscopic and Stereoscopic Display for a Probe-Positioning Task [1]

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Abstract. We conducted a comparative study of task performance under both monoscopic and stereoscopic display conditions, in order to assess the role of stereoscopy in supporting an understanding of three-dimensional content, and ease of interaction with the data. As our application context is that of neurosurgical visualization, the experimental goal we chose was to define a straight, vessel-free path from the cortical surface to a targeted tumor. The scene consists of a volumetric representation of the brain vasculature and a simulated tumor, as well as a separately controlled pen-like virtual probe. Under both viewing conditions, participants were able to manipulate the volume and probe using a tangible user interface, thus obtaining hand-coupled motion cues. Results indicate that on average, participants were able to perform the task in the stereographic mode in only 75% of the time and with half the error as in the monoscopic condition.

Keywords. Stereoscopic, Neurosurgical, Tangible user interface

1. Introduction

A critical challenge in neurosurgical imaging is to provide an effective means of visualizing and interacting with data of the patient's brain, in a manner that is natural to surgeons. For such tasks, we hypothesize that improved display of volumetric brain data is likely to aid in understanding of the 3D content. Previous studies have investigated the comparative benefits of depth cues versus 3D display [5], evaluated different motion cues (passive rotation, head-coupled motion, and hand-coupled motion) [4], and the improved understanding of complex 3D data provided by stereoscopy [1,4]. However, little quantitative investigation has been conducted to evaluate the role of stereoscopic display in conjunction with volumetric manipulation and exploration tasks, in particular when employing a tangible user interface for input.

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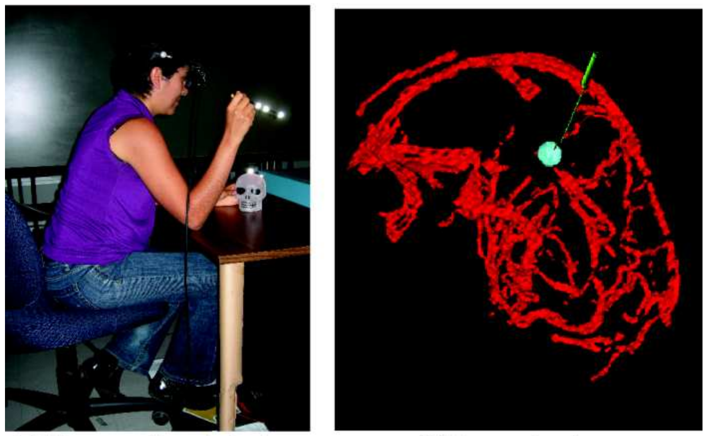


(a) The experimental setup (b) A sample view

Figure 1. (a) The experimental setup includes a plastic skull, a replica of the surgical probe, a head-mounted display, and a dance pad. (b) A sample view of the experimental configuration, presenting the vasculature (red), virtual probe (green) and tumor (blue).

2. Tools and Methods

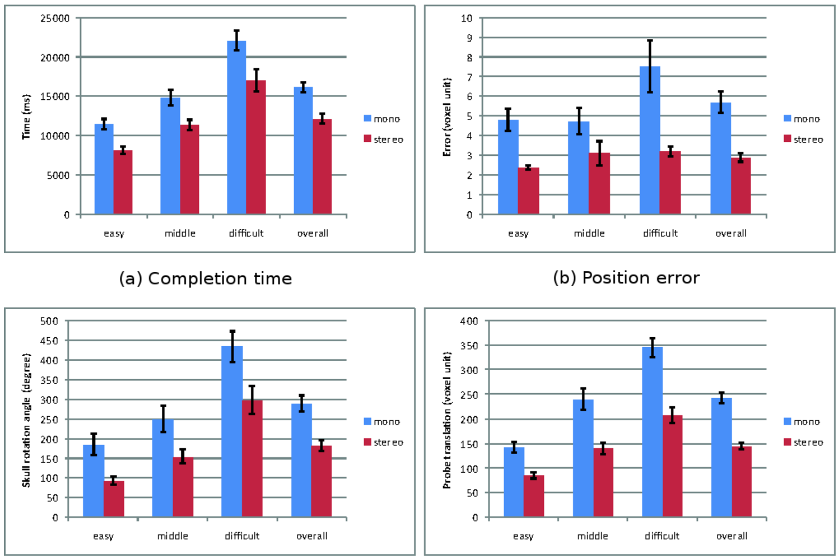
To address this need, we performed a comparative study to quantify the differences in task performance, as related to both completion time and number of errors, between monoscopic and stereoscopic viewing conditions. Participants were given the task of defining a straight, vessel-free path for a virtual biopsy probe, from the cortical surface to a targeted tumor. Because of the complex anatomical structure of the human brain and the topology of key blood vessels, defining such a path for insertion of probes and tools can be a challenging task in practice.

As illustrated in Figure 1(a), participants wore a head-mounted display, which was selectively activated in either 2D or 3D display mode during the experiment. In both cases, we render a representation of the vasculature, with a simulated tumor at positions of varying difficulty, defined according to the surrounding vessel density (Figure 1(b)).

Based on the results of Ware et al. [4], which found that the combination of stereo and hand-coupled motion offers the most effective 3D content understanding, we employed a plastic skull, held in the non-dominant hand, as a tangible user interface to manipulate (rotate and zoom) the view of the brain data. A replica of a surgical probe, held in the dominant hand, was mapped directly to the position and orientation of the virtual probe, used to reach the tumor. These tangible objects [3] serve as interfaces for direct manipulation of the data in a manner that is far more expressive than allowed by a computer mouse. Both objects were tracked with a motion capture system, using IR reflective markers. To minimize unintentional hand movement from pressing a button, participants were asked to step on a dance pad to indicate when they thought they had completed the task.

3. Results and Discussion

The study was conducted with 12 participants (8 male and 4 female, ranging in age between 22 and 37), divided into two groups, one starting in monoscopic viewing mode and the other in stereoscopic. Each participant ran 30 trials in the first mode, consisting



(a) Completion time

(b) Position error

(c) Rotation of the skull

(d) Translation of the probe

Figure 2. Statistic data from our experiment. Vertical bars represent on standard error about the mean.

of 10 examples each of easy, medium, and difficult tumor locations, and then repeated these trials in the second viewing mode. Tumor positions were presented in random order in both modes.

The results of this study are presented in Figure 2, including (a) the average task completion time (b) the average position error, computed here as the distance between the tip of the probe and the center of the tumor, (c) the average amount of skull rotation per trial (integrated over all manipulations of the display), and (d) the translation of the probe. Results are provided by difficulty level of tumor position as well as overall, across all three levels.

A later experiment will investigate the performance benefits of volume manipulation via head-tracking, using the virtual window [2] paradigm for control. We are also performing comparative studies of different stereoscopic display technologies (head-mounted display, stereoscopic projection with polarizing filters, and autostereoscopic display) to evaluate their performance for such three-dimensional tasks.

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