

Dextrous and Shared Interaction with Medical Data: stereoscopic vision is more important than hand-image collocation

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1. Introduction

Dextrous interaction refers to the use of non-immersive virtual reality to explore detailed medical (or other) data for diagnostic, surgery planning and educational purposes (Poston and Serra, 1996). It typically uses a mirror to produce a virtual work volume into which the user can reach. Our earlier research (Waterworth, 2000) tested the importance of stereoscopic vision and hand-image collocation for a task requiring dextrous interaction with a virtual display (Serra et al. 1995). The task - the Dexterity Game (Poston and Serra, 1996) - consists of a virtual version of the familiar "pass the loop over the wire without touching it" game. The player manipulates a tool, which corresponds to the "loop and handle" with his or her dominant hand. The task is to traverse from one end of a virtual wire to the other while "touching" the wire as little as possible. The non-dominant hand holds another tool, which allows the player to adjust the overall position of the wire and frame. When a virtual touch is detected, a sound is heard and the wire changes colour. There is no haptic feedback when the wire is touched.

In that earlier study (Waterworth, 2000) we compared performance on a trial task in a virtual environment, with and without stereoscopic display, and with and without hand-image collocation. Although both factors affected speed and accuracy of task completion, adding stereoscopy to desktop VR gave significantly greater benefits than adding hand-image collocation. Surprisingly, there was no additional benefit from combining the two.

2. The Volumetric Dexterity Test

The Dexterity Game is not a truly volumetric task, and there may be no deviation of the virtual wire in the third dimension (depth, in the z-plane) if the participant does not adjust the orientation of the virtual wire frame with the non-dominant hand. Even so, observing participants attempt this task brought home to us how difficult it is to work dextrously in three dimensions. Even when both cues are present the game is not easy. Another weakness of the earlier study was that we collected no data from the non-dominant hand, and so we could not tell, for example, if people moved the task object more often in the no stereo viewing conditions.

The current experiment was carried out to rectify these weaknesses, and extend our knowledge about the relative importance of stereoscopic display and hand-image collocation for dextrous interaction. We devised a new task, the Volumetric Dexterity Test (VDT), which quite accurately duplicates the way professional personnel such as surgeons and radiologists interact with detailed medical data. The VDT comprises a complex, three-dimensional structure composed of magenta voxels (see Figure 1 below). A thread, composed of blue voxels, winds in and around this structure. The task is to remove the blue thread while damaging the magenta structure as little as possible.

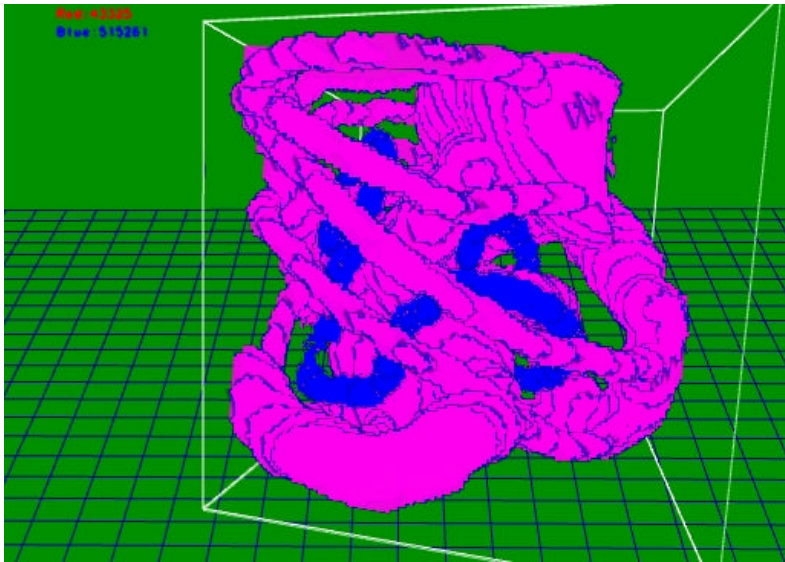


Figure 1 – The Voxel Dexterity Test

3. The Experiment

There were three completely different work-settings. The first offered hand-eye-collocation to the user. The second used a standard monitor with no mirror and no hand-image collocation, while the third was similar to the second but used a large projector-screen. Our interest in the projected display stemmed from the fact that medical users frequently want to examine visualised data in a teaching or other group setting.

We compared performance on the VDT in each of these conditions, with and without stereoscopic viewing. We measured how many blue voxels were correctly removed, how many magenta voxels were erroneously removed, how long the task took to complete, and how often the non-dominant hand was used to manipulate the work volume.

We used equipment provided by the VRLab located at Umeå University in Northern Sweden for this study, consisting of an SGI Onyx-2 with a 21-inch colour monitor, screen resolution 1280 X 1024 pixels (1026 X 768 pixels in stereo conditions). Hand-image collocation was provided by the Dextroscope™ (formerly known as the Virtual Workbench) developed by Luis Serra and his team at Volume Interactions in Singapore. A Polhemus FasTrack™ with pen-like receiver (held in the dominant hand) was used by participants for precise work, and a simple button and position sensor (held in the other

hand) for moving the virtual object of interest. CrystalEyes™ time-multiplexed LCD shutter glasses were used to provide stereo capability. Participants viewed both stereo and monoscopic displays through the glasses, with zero disparity in the latter case. The refresh rate was 96Hz (48Hz per eye) in all conditions.

4. Results and Discussion

Performance with stereo was much better than performance without, in terms of blue voxels correctly removed, magenta voxels erroneously removed, and time taken to perform the task. This was true wherever the image was located. For magenta voxels, the effect of stereo versus non-stereo was greater with the projector than for the standardly-placed monitor or for the condition with hand-image collocation.

The effects of image location were less clear-cut. With the projector, accuracy was much worse than both the other conditions in terms of the number of both blue and magenta voxels removed. Users appeared to have some difficulty transposing dextrous manipulations to and from the wall projection. But hand-image collocation did not result in significantly better performance than the standardly-placed monitor in terms of these two measures (blue and magenta voxel numbers). Completion was faster with hand-image collocation than with the other two conditions, although the difference was rather small.

The pattern of results is broadly compatible with those of our earlier study. In both experiments stereo was found to be more beneficial than hand-image collocation in improving performance. In both, hand-image collocation improved speed, but the benefit on performance was smaller in the present study. As in the first experiment, there were few interaction effects. Hand-image collocation was not more beneficial when combined with stereo than without.

Learning effects were revealed in terms of blue voxels removed and, more dramatically, magenta voxels removed in error. In the latter case, there was an interaction effect between learning and stereo/no stereo indicating that there was more improvement for stereo than non-stereo.

There were complex interactions between stereo versus non-stereo, hand-image collocation and its absence, and work object movements with the non-dominant hand. Although we are still trying to interpret these results, it appears that users compensated for the absence of stereo in different ways in conditions with hand-image collocation than in those without, in terms of the number of times they moved the work object and the duration of each move.

5. Conclusions

Our results were surprising. Stereo vision was very important to both accuracy and speed of task completion, as we found previously. But the presence of hand-image collocation did not improve accuracy, despite the fact that this was a truly three-dimensional task. It

may be that the ability to move the work object was much more important in this case than in the earlier study, and that object movement can adequately compensate for the absence of hand-image collocation.

If this finding is borne out it has important implications for the volumetric presentation of medical data to individual practitioners and in group settings. For example, the complication and expense involved in using a “reach in” style of collocated hand and image display may not be justified. And in a group setting, it may be advantageous if the practitioner currently manipulating the volume of interest does not rely on the projected image. However, we have further experiments planned to investigate ways of maximising the effectiveness of shared displays of detailed medical data.

Acknowledgements

The work reported was carried out by Daniel Bergh, a D-level student at the Department of Informatics, Umeå University, Sweden. The experiment used equipment and facilities provided by VRlab at Umeå University, Sweden.

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