3D Point-of-Gaze Estimation on a Volumetric Display

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INTRODUCTION

Eye-gaze tracking devices are typically used to estimate the point-of-gaze (POG) of a subject on a 2D surface such as a computer screen. Using model based methods for POG estimation we have developed a system based on the vergence of the eyes which can be used to estimate the POG on a real-world volumetric display.

Interaction in a virtual 3D environment is most often performed using a sequence of 2D mouse movements (rotations and translations). Direct input of real-world 3D positions can be performed using optical or electromagnetic tracking of a stylus held in 3D space. Neither method is ideal, as the 2D mouse requires a complex sequence of operations while the stylus must be held against gravity, resulting in fatigue.

Tools for 3D interaction will become increasingly important as 3D display technologies mature. Commercial 3D displays are already available based on parallax barrier, volumetric, and holographic techniques. We believe that 3D POG estimation will greatly enhance the ability of humans to interact with 3D displays and environments, as the technology is intuitive to use and requires little effort to operate. In this paper we will outline a preliminary design for 3D POG estimation and an application using a simple volumetric display.

METHODS

Using the model based methods for POG estimation described in [Hennessey *et al*, 2006] it is possible to determine the location of the eyes and the corresponding line-of-sight (LOS) vectors in real-world 3D space. The intersection (or rather closest point of approach) of the LOS vectors from both eyes is then readily computed and an estimate for the POG in 3D space determined. A calibration routine is required to correct for foveal offsets, in which the user observes known 3D positions while the calibration corrections are determined.

To demonstrate the 3D POG, a simple volumetric display was created using LED's located on a 3 x 3 x 3 grid throughout a workspace volume of 28 x 23 x 22 cm (W x H x D) as shown in Fig 1. The game of 3D Tic-Tac-Toe was then implemented with the player and computer positions denoted by different color LED's. The player position selection was achieved by simply observing the desired 3D location. To indicate the end of a turn, the player pressed a key on the keyboard.

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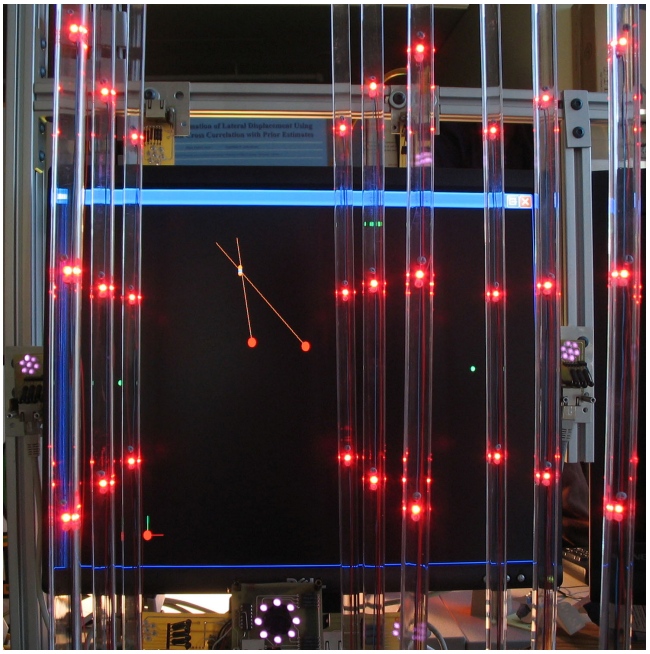

Figure 1. The 3 x 3 x 3 volumetric display and 3D eye-gaze tracking system are shown. The computer monitor only serves as a diagnostic tool showing the state of the internal system model including the location of the eyes, the 3D LOS vectors and the 3D LOS intersection point.

RESULTS AND CONCLUSION

While a thorough analysis of the performance of the system is still to be completed, the game can be successfully played. The system generates 3D POG estimates at 200 Hz, which are then stabilized with filtering. Even with filtering, the estimated 3D POG can transit between the furthest two positions (42.4 cm) in under 0.58 seconds. Over a series of 10 games, all 56 positions played were correctly selected by the player. An example of game play is available to view online [Hennessey, 2007].

With the implementation of a 3D POG estimation application, we have shown how 3D POG estimation can be used for interactive applications between humans and machines.

REFERENCES

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