What are you looking at?

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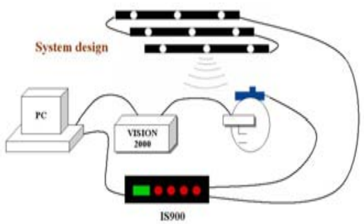
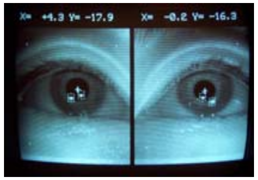
Introduction

Eye-movement research is not a new topic. Fixation, saccade, smooth pursuit and blinking are of great interest to researchers and are widely studied. We are interested in how the saccade eye movement can be used in VR research and how to estimate the human eye gaze position (point of regard) in a dynamic situation (the head is not stationary).

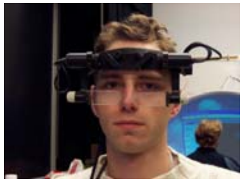


Equipments

We use the **EL-MAR (Vision 2000)** eye tracker: a video-based head-mounted eye tracking system (VTS). Binocular horizontal and vertical eye position estimates are derived from the relative positions of multiple corneal reflections and the center of the pupil.



Pupil and corneal reflections



Head mounted eye tracker

For the head free eye tracking project, **InterSense IS900** tracker is used. It is a Large Area Tracking system, which uses ultrasound and inertial sensors to determine the position and orientation (6DOF) of trackers within the lab

Sonistrip array

Head tracker

Project description

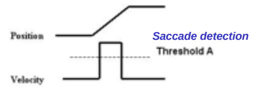
Analysis of Saccadic Eye Movement for Scene Corrections in Virtual Environment (VE)

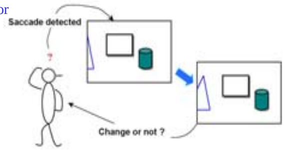
Assumed position prediction is used in distribute virtual environment to compensate for network delays. Due to the prediction error, updating the VE instantaneously upon receiving remote data would cause disturbing discontinuities, so temporal filtering is normally used to gradually correct the error. However, this introduces lag in the VE. A more efficient method would be to detect the user's saccadic eye movement, and use the time of insensitivity to movements and changes, to correct the object position. We have to investigate how big modifications can be and how much time is left after the detection of a saccade to safely perform a change without being noticed.

Velocity estimation: Five-point differentiator

$$V = (a_1*Xn-2 + a_2*Xn-1 + a_3*Xn + a_4*Xn+1 + a_5*Xn+2) /Factor$$

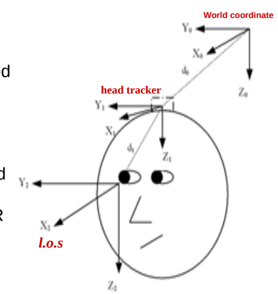
(X : *position*, V: *estimated velocity*)





Estimation of the eye gaze position

Until now, most experiments on eye tracking related research have required the subject to sit with their head fixed. However, free head motion is mostly desired in many situations. For example, the vestibulo-ocular reflex(VOR) generates compensatory eye movements in response to head motion detected by the vestibular sense organs located in the inner ear. in order to study the VOR under natural conditions, both head and eye movements must be measured accurately during free head motion (Allison, 1996).



Measurement of eye and head position and orientation allows for estimation of the point of regard (gaze position). To measure the position of regard (POR) the intersection of the line of sight (l.o.s.) with the stimulus plane must be determined.

$$\mathbf{d}_2 = \mathbf{d}_0 + \mathbf{R}_{01}\mathbf{d}_1 = \begin{bmatrix} Xe \\ Ye \\ Ze \end{bmatrix}$$

$\boldsymbol{R_{01}}$: rotation matrix of the tracker frame with respect to the world frame

The l.o.s is along the x axis in the eye coordinate frame and is described by the unit direction vector corresponding to the x axis of the eye frame in world (fixed) coordinate.

$$\text{l.o.s.} = R_{01}\, i_{12} = R_{01} \begin{bmatrix} \cos(\theta)\cos(\phi) \\ \sin(\theta)\cos(\phi) \\ -\sin(\phi) \end{bmatrix} = \begin{bmatrix} Sx \\ Sy \\ Sz \end{bmatrix}$$

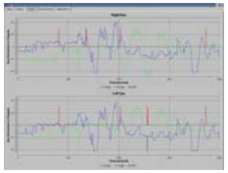
θ : eye x angle (azimuth)

ϕ : eye y angle (elevation)

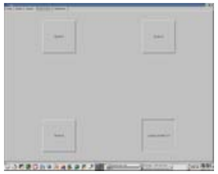
point of regard

$$\mathbf{x} = \mathbf{d}$$
$$\mathbf{y} = \frac{Sy}{Sx}(d - Xe) + Ye$$
$$\mathbf{z} = \frac{Sz}{Sx}(d - Xe) + Ze$$

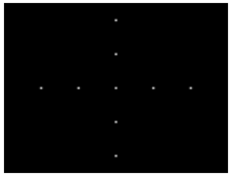
Project implementation



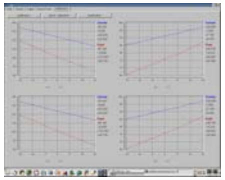
The eye position (in angle) diagram, the red pulse represents blink.



Snapshot of a simple application (eye push-button).



Calibration procedure: 5 points in both horizontal and vertical directions



Calibration result for both eyes

Discussion

IS900 has high accuracy (less than 1mm mean error) when tracker is stationary, however, it has big dynamic error (claimed by Stuart *et al*. 2003). We are performing the evaluation experiment.

Delay of the system will affect the result of the research: How long it takes for the saccade detection must be determined (The VTS can work at 120Hz and a low pass filter is used in the velocity estimation, so the system baseline delay is around 20 – 30ms).

The relative position of the head tracker receiver with respect to the center of rotation of the eye was previously manually measured (Allison, 1996), automatic calibration will be implemented in this project.

References

1. Andrew T. Duchowski, Eye Tracking Methodology Theory and Practice, Springer, 2002.
2. Robert S. Allison, Combined head and eye tracking system for dynamic testing of the vestibular system, 1996.
3. Stuart Gilson et al. Dynamic performance of a tracking system used in Virtual Reality displays, 2003.

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