Eye-Movement Based Active Calibration for Head Mounted Display with Eye Tracking

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Problem Statement

We will investigate eye-movement based active calibration for eye tracking. The first step in our plan is to establish the type of eye movement used in the Pupil Lab eye trackers. We will then modify the existing calibration method based on research on eye movement types and accuracy. Our goal is to find out if other calibration methods can be more effective than the current calibration technique used by Pupil Labs. We will implement our calibration using Pupil Labs's Oculus Rift DK2 Binocular Add-on Cup with the Oculus 2DK using Pupil Lab's open source documentation in Unity.

Introduction and Previous Work

Eye tracking is important tool for shaping the future of virtual reality headsets. The success of eye tracking has a direct impact on the commercial adoption of foveated rendering. Foveated rendering is a technique that uses eye tracking data to reduce the image resolution in peripheral vision. Effectively, foveated rendering has the potential to make VR experiences much more realistic and drastically reduce computation time. However, eye tracking techniques are limited because of the diversity of eye shapes and spatial conditions. For example, it is important to take into account several characteristics of the eye, such as the shape of pupil(s), iris and cornea, the ethnicity of the user, eye color, eye texture, viewing angle, head pose, lighting conditions, the position of iris, and whether the eye is opened or closed [1].

Modern eye tracking works by implementing eye detection and gaze estimation. Eye detection methods use models of the eye to determine where the pupil is. Gaze estimation uses the eye position and image processing techniques to determine where the user is looking. One of the most common methods of determining gaze is by shining an IR light into the eye. This creates a glint in the eye that is consistently located at the same point on the surface of the eye. Thus, the gaze of the user can be calculated using the distance between the pupil and the glint .

Gaze estimation methods rely on accurate calibration to determine a set of parameters used in the model. There are four essential calibration procedures: camera-calibration, geometric-calibration, personal calibration, and gazing mapping calibration [1]. For our project we will focus on personal calibration, where properties of an individual's eyes are estimated. Specifically we will explore personal calibration that utilizes different types of eye movement.

There are three main types of eye movement: fixation, saccades, and smooth pursuits. A fixation is when a user rests their gaze on a small area for at least 80-100 ms. A saccade is a quick eye movement, generally used on objects moving 30 degrees/s or faster. A smooth pursuit is a slower movement where the eye follows a moving target [1]. Eye trackers on the market vary in their use of types of eye movement in calibration methods. For example, the iView X developed by SMI relies solely on static targets [2]. In this method, fixed targets are placed on the screen that the user must look at. The recorded pupil position for each of these points is then used to calibrate the settings of the eye tracker to the user's eye. An alternative method is used by Pupil Labs. The Pupil Labs calibration consists of slowly moving targets that stop in specific locations. When the targets are stopped, the pupil location is recorded. We did not find any side by side comparisons of calibration methods to determine what method works best.

Our Approach

Since we are working with a Pupil Labs eye tracker compatible with the Oculus DK2, we hope to establish which types of eye movement are happening in the current calibration scheme for this device, then attempt changes in the scheme to improve its accuracy. To determine type of eye movement, we will find the speed of the moving target in Pupil Lab's current calibration setup and the amount of time that it stays fixed to determine whether fixation, saccades, and/or smooth pursuits are being used. We will then modify the speed of target movement in order to change the type of eye movement used. If the calibration uses smooth pursuit, we will use smaller target sizes since they have been shown to improve the accuracy of smooth pursuit eye movements [3].

Relevance and Future Work

Besides the potential of obtaining a more accurate initial calibration, this strategy of utilizing different types of eye movement could be leveraged in future work on passive calibration. When using a head mounted display and/or eye tracking interface, any movement of the head or body can dislodge the device and invalidate the calibration. Restarting calibration from the the beginning compromises the immersive feel of the VR experience, so it is desirable to re-calibrate the eye-tracking device during the virtual reality experience. This could be done by using features within the virtual environment that we know the user is looking at. These features would not necessarily be fixed, hence why experimentation with eye movement could prove useful. Another implementation of passive calibration could use a learning algorithm to establish the type of eye movement of the user. It would then infer where the user is looking based on the eye movement type and calibrate based on that data.

Goals and Timeline

1. Set up the Oculus DK2 and Pupil Lab's eye tracker. Collect eye tracking data using the Pupil Labs interface. **Due: 5/25**
2. Establish the type of eye movement used in the current calibration scheme. **Due: 5/29**
    a. If the current method uses smooth pursuit, modify the target size using Unity. **Due: 6/2**
    b. If the current method uses saccades, try a smooth pursuit method using Unity. **Due: 6/2**
3. Develop metrics to compare our calibration algorithm to the standard method. **Due: 6/3**

4. Test the new calibration method on 3-5 subjects. **Due: 6/5**
5. Analyze the results and determine the efficacy of the active calibration. **Due: 6/7**
6. Create our poster. **Due: 6/8**
7. Set up demo for poster session. **Due: 6/8**

References

[1] Hansen, Dan Witzner, and Qiang Ji. "In the eye of the beholder: A survey of models for eyes and gaze." IEEE transactions on pattern analysis and machine intelligence 32.3 (2010): 478-500.
[2] http://twiki.cis.rit.edu/twiki/pub/MVRL/SmiTracker/iViewX_Manual.pdf
[3] Shanidze, Natela, Saeideh Ghahghaei, and Preeti Verghese. "Accuracy of Eye Position for Saccades and Smooth Pursuit." Journal of Vision 16.15 (2016): 23. PMC. Web. 24 May 2017.