Using Active IR for eye detection and tracking

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Introduction

Humans began investigating and developing eye positioning and tracking techniques long before the arrival of computers. But as with most things, our progress in this area has accelerated as the available technology has advanced. With the advancement of artificial intelligence and supercomputers, eye tracking has come a long way in the past few decades.

Overview

Eye tracking is the process of measuring either the motion of a person's eye relative to their head or the point of vector of their gaze [1]. The eye is usually tracked based on an image that is captured and processed. There are three main activities involved in this process; detecting/locating the eye on the image, tracking the eye's position from image to image, and analyzing the region of the eye to determine the point of gaze.

Setup

The tracking system is made up of a camera, IR emitters and a computer for processing the images (we'll refer to the computer as "the system"). Even though passive light can be used in conjunction with a CCD camera (like those in cellphones), it is better to use an active light source and eliminate all ambient light. [5]. CCD cameras are preferred because webcams are too bulky for these purposes and provide more information than

we need [4]. Eye tracking is easier when the environmental conditions in which it's taking place are consistent. This is because it reduces the number of variables the eye tracking algorithm and software must account for. For this reason, it is important to eliminate as much ambient light as possible. IR is the preferred type of active light to use in eye trackers. Unlike visible light, IR is not visible to humans and so it's less distracting. However, exposing the naked eye to IR light for long periods of time can cause damage to the eye. It is recommended that a person uses an IR emitter of wavelength 780 nm. This is below the threshold for human eye safety [1][5]. The IR emitters are arranged in 2 concentric circles with the camera in the center. One ring is small and close to the camera (bright pupil LEDs) while the other one is farther away from the camera (Dark pupil LEDs). This setup is used for both eye detection and tracking
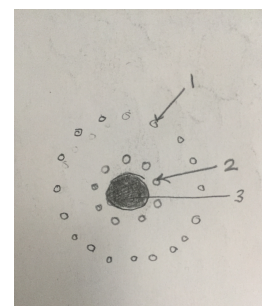

Figure 1. The setup for the tracker. 1 - dark pupil LEDs, 2 – bright pupil LEDs, 3 - camera

Procedure

When IR light falls on a person's cornea, part of it is reflected towards the light source and a glint appears on the person's eye. The distance between the glint and the center of the person's pupil increases as the person looks away from the light source [2]. Bright pupils are formed when the light source is close to the optical axis and dark pupils are formed when it's further away.
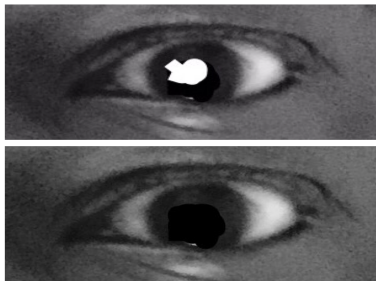

Figure 2. bottom – dark pupil, top – bright pupil

A difference image between the dark and bright pupil images is used to track the eyes. The 2 rings are turned on and off within milliseconds of each other (producing both bright and dark pupil) and the camera captures the eye image. A difference image is then formed by subtracting the image with the dark pupil from the image with the bright pupil.

The user provides the system with models of the eye and these eye models are used both for detecting the eye and tracking it. The system compares all the bright spots from the entire difference image to the eye models to identify possible eye candidates in the difference image. Noise and some of the other textures in the background can also show up but eventually they are filtered out. If the system identifies more than 2 possible eye candidates, it tracks all the candidates and eliminates the inconsistent ones over time.

Usually this works well in a controlled environment but when it is tested in the real world, things like shadows produced by ambient light, glasses and makeup can confuse the system. Movement can also cause the tracker to lose track of the eye after it has begun tracking. Usually when this happens, the tracker must stop tracking and re-initialize the eye detection method again.

While the system is tracking the eye, it is also performing eye region analysis on the eye to determine the person's gaze vector. This is useful if you want to get an idea of what the person is looking at.

Conclusion

Eye tracking is used in medical research, psychology, cognitive science and marketing research. It's used to detect fatigue in workers and drivers, allows merchants to observe what users look at when they are on their website and even what athletes focus on when playing a sport.

We want to adapt this technology for use in our medical device. It can be used to prove that a hands-free solution for recording a patient's responses during the glaucoma eye test is feasible and beneficial because it eliminates patient bias. For our purposes, we wouldn't need all the complex computations involved. What we essentially need is the ability to determine if the eye looks at a certain position. By understanding eye tracking in totality, we can determine what we can do without and what we need to implement to develop our product.

References

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