Purkinje Images

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As the uses and implementations of eye tracking grow, a common method still used to track eyes are Purkinje images. Understanding how Purkinje images work and the role they play with current eye tracking methods is important for the innovation of these technologies.

Introduction

The eye is made up of several working parts of which the most relevant to Purkinje images are the cornea and lens.

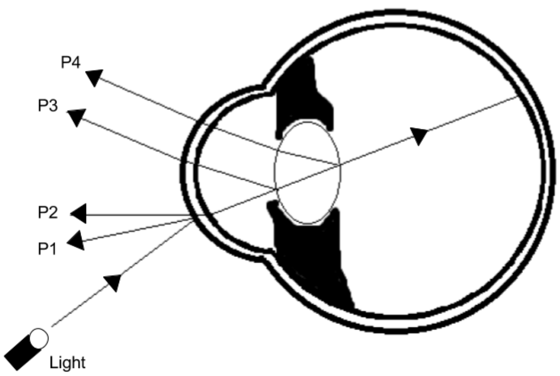

Figure 1. Diagram depicting the four Purkinje image reflections.

Purkinje images are reflections from light, particularly infrared (IR) light, off the eye. There typically exist four visible Purkinje images labeled P1 through P4 which can be seen in Figure 1. P1 is also known as the corneal reflection or glint, and it reflects from the outer surface of the cornea. P2 reflects off the inner surface of the cornea, and P3 reflects off the outer surface of the lens. P4 reflects off the inner surface of the lens and is also referred as the lens posterior reflection. Of the four images, P4 is the only inverted image while the others are erect images due to how it reflects from the inner surface of the lens. The first and second Purkinje images are almost completely superimposed thus only the first Purkinje image is typically used to detect eye fixation since it is brighter (i.e. procedure in which the optometrist asks you to follow a light). P3 is larger than the other images while P4 is smaller but with a brighter intensity than P3. The differences in sizes is because the curve of the lens is bigger on the front of the lens versus the back of it. For eye tracking, P1 and P4 are commonly used to determine eye position.

Purkinje Images and Eye Tracking

As stated before, many eye tracking technologies have made use of Purkinje images to detect eye position, particularly using the first and fourth images though the third may be used occasionally. The way in which the first and fourth images were used in older tracking methods was by calculating the space between the two images (Lewis, 1977). This is because the spacing between the images does not change when the eye is looking at the same plane of the optical axis (i.e. the plane at which the center of the eye would lie). When the relative distance does change, it means that the eye has shifted from the optical axis.

This type of tracking works relatively well in 2D since you're able to distinguish when the eye is focused on a certain plane by the distance of the Purkinje images. This does not however provide as reliable or useful a solution for current eye tracking as the implementation is large and difficult.

Although some implementations of current eye tracking do still depend on detecting Purkinje images, many have moved on to used video tracking with dark and bright pupil detection. These take photos where the pupil either appears bright or dark and uses the changes in location of the detected eye to determine the path it is taking. This also has its limitations in that if the pupil is lost, which can happen often, the whole system must reset and attempt to detect the pupil again.

Relevance to Glaucoma Testing

Current methods of testing for glaucoma are very subjective. Although current Humphrey machines do contain some sort of eye tracking, it is used only to detect how much a patient blinks to get more accurate data on the testing experience.

To make the test more objective, we would have to eliminate the patient's conscious manual input. Since the test consists of determining whether the patient has seen a light or not, eye detection would be useful in eliminating the patient bias. Because IR is not visible to the human eye under normal circumstances, it could be used to determine whether the pupil is looking at the point of light being examined. This could be accomplished by examining the Purkinje images that are reflected when the IR enters the eye. It is important then to understand how Purkinje images work and how they can be used to determine eye fixation.

Conclusion

Purkinje images are very useful in not only determining eye fixation but also in measuring a host of other information of the eye. Many successful tracking methods where made using Purkinje images. Although newer, more robust methods for eye tracking exist, the IR method would be usable and easier for us to implement. This means that we must understand more clearly how Purkinje images work to be able to potentially implement a pupil detection system based on IR light for our modified glaucoma test.

References

1. Mauser, W., Michael (1 Jan. 2011). "Exploring the Anatomy of Your Own Eye | The American Biology Teacher." *Exploring the Anatomy of Your Own Eye | The American Biology Teacher*. <http://abt.ucpress.edu/content/73/1/28>

2. Tabernero, Juan (1 Jun. 2007). Biomedical Optics: Surface reflections reveal hidden eye misalignments. <http://www.laserfocusworld.com/articles/print/volume-43/issue-6/features/biomedical-optics-surface-reflections-reveal-hidden-eye-misalignments.html>

3. Horner, G., Douglas (2004). Oculomotor Functions and Neurology CD-ROM*. Chapter 4. <http://www.opt.indiana.edu/v665/CD/CD_Version/CH4/CH4.HTM>

4. Tobii AB (2017) <http://www.tobiipro.com/learn-and-support/learn/eye-tracking-essentials/what-is-dark-and-bright-pupil-tracking>

5. Lewis, B., Edgar (7 Jun. 1977). High-resolution vision system. <https://www.google.com/patents/US4028725>