Eidgenössische Technische Hochschule Zürich

Non Contact Eye-tracking on Cats

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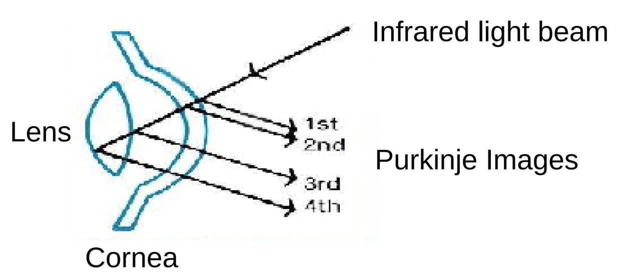
Introduction

The objective of visual neuroscience has shifted over the past years from determining the receptive fields of cells towards the understanding of higher level cognition in awake animals processing natural stimuli. In experiments with awake animals it is important to control the relevant aspects of behavior. Most important for vision science is the control of eye-movements and of the direction of gaze. Here we present Dual Purkinje (DPI) eye-tracking on cats, which is one of the most accurate eye-tracking systems and as a non-contact method does not require any surgery on the subjects.
A common problem with eye-tracking on non-humans is the calibration of the system. We present an objective method, not requiring the collaboration of the subject which allows accurate measurement of gain and offset.
The DPI system, together with the proposed method for calibration results in a highly accurate system for measuring the eye-movements of cats.

The Dual Purkinje (DPI) Eye-tracking System

The Dual Purkinje eye-tracking system is widely used with human subjects because of its high accuracy and the fact that it does not require any surgery on the subjects. We show that the DPI system (manufactured by Fourward Technologies Inc., Buena Vista, VA 24416) can also be used reliably with head fixed cats.

The DPI measures the orientation of the eye using the reflection of an infrared light beam at the cornea and the lens, called Purkinje images.



Infrared light is reflected at the front- and backside of the cornea and the front- and backsize of the lens. These reflections are called Purkinje images.

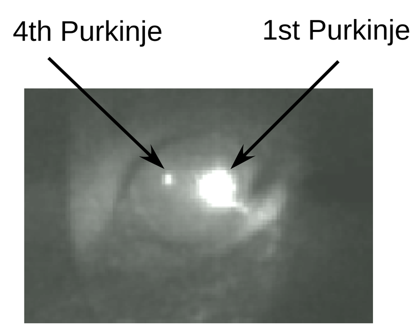
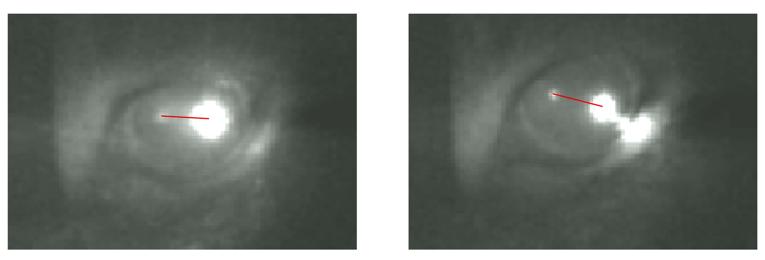
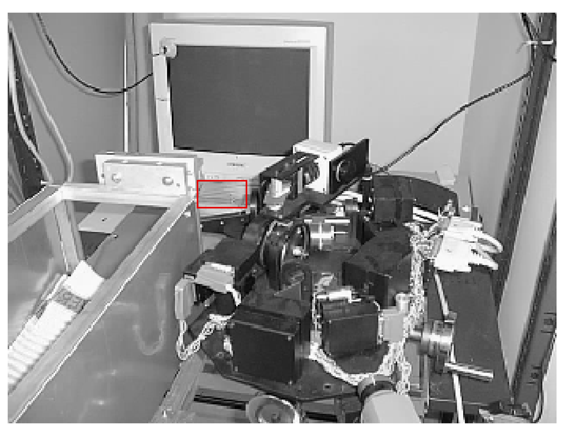


Photo of the 1st and 4th Purkinje image on a cats eye.



The DPI uses the relative position of the 1st and 4th Purkinje to determine the orientation of the eye. This makes the system robust against small displacements of the subject. Proper functionality requires the room to be darkened since the reflections are dim. The operation range furthermore depends on the size of the pupil.



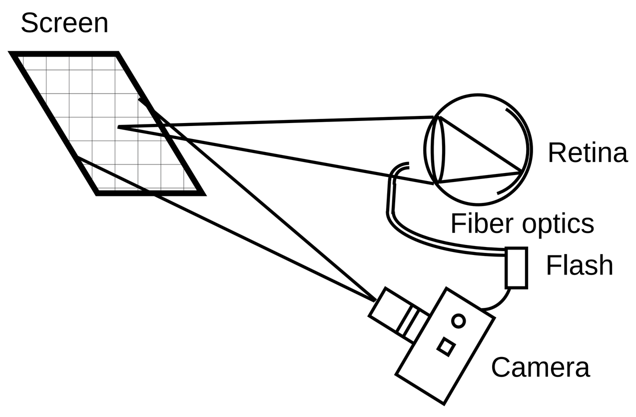
The setup. On the lower right the optical system of the DPI is shown. The red box indicates the oblique mirror placed in front of one eye. It reflects the infrared from and to the eye, but is transparent for normal vision.

Advantages:
High accuracy
No surgery
Insensitive to small displacements of the subject
High temporal resolution
Use with animals and humans

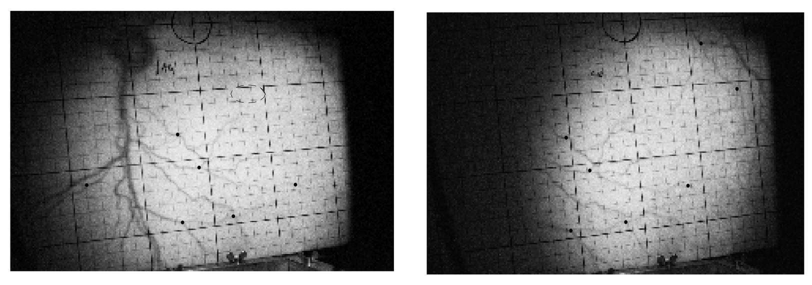
Disadvantages:
Expensive
Setup changes before use on cats
Technically complicated

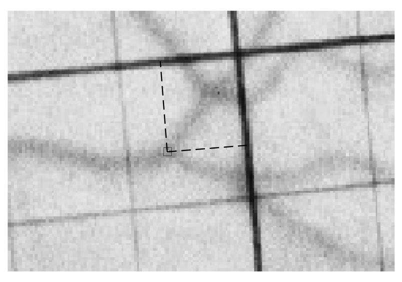
Accurate and Objective Calibration

Every system for eye-tracking needs calibration. In contrary to humans, which can be told to fixate given spots, calibration with animals is more difficult. For cats we propose the following objective method for measuring gain and offset. It has the advantage to rely entirely on objective criteria and not to involve the cooperation of the subject.

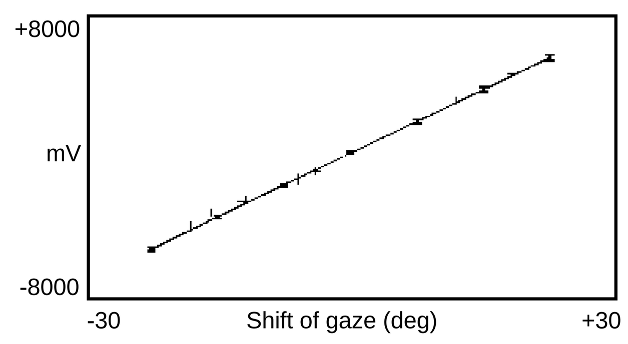


While recording the position indicated by the eye-tracking system the orientation of the eye is also documented by taking photos of a retinal reflection.
The retina is illuminated by a flash coupled to a camera. The light of the flash is guided through a fiber optics cable placed right in front of the eye. The light is reflected at the tapetum and illuminates a tangent screen. There a photo of the reflection is taken.





Two photos of a retinal reflection. The visible structures include the blind spot and several blood vessels. Points common to several photos are selected (black dots) and their position relative to a grid is measured (right). From this the shift of the eye between two photos can be computed.

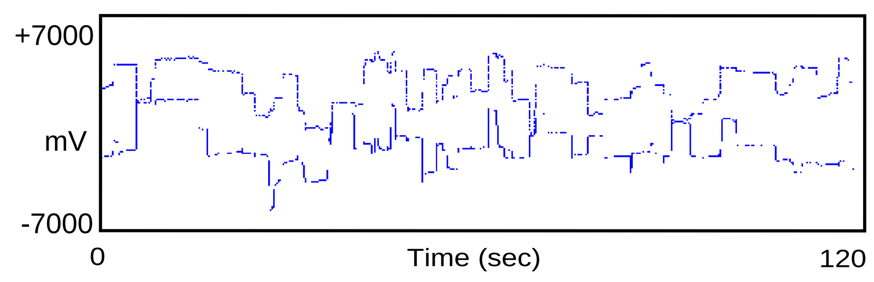


The shift computed from the photos is compared with the eye-tracker output and allows accurate calibration of the system (mean regression error of 0.28deg at zero degrees and 0.56deg at +15 degrees). If one is only interested in the gain, then the error is reduced to 0.18 deg on average. The absolute direction of gaze, as well as it is defined, can be determined from the position of the area centralis in the photos and the gain and offset.

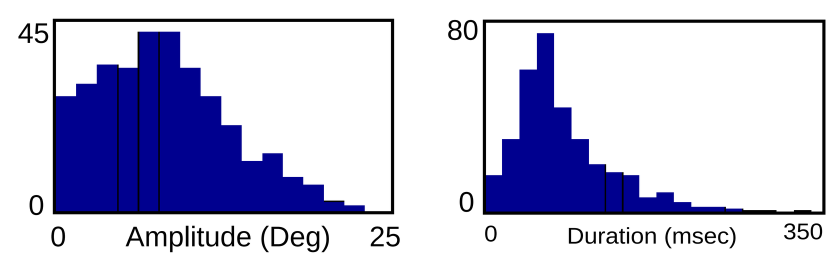
An Example

We are interested in how cats perceive their natural environment and how they process natural (visual) stimuli. We recorded a set of video sequences from a camera mounted to a cats head. These videos are played back to the animals under controlled conditions in the lab.

Example of two frames of a natural movie. The black circle indicates the estimated direction of gaze.



Horizontal (solid) and vertical (dashed) orientation of the eye as signalled by the eye-tracker (output in mV).



Examples of amplitude and duration histograms for a total of 15 minutes of video.

Conclusion

We showed how the DPI system, which was previously used only with primates, can be used reliably with cats. Together with the proposed method for calibration it results in a convenient system for controlling the eye-movements of cats with a precision required for the electrophysiological study of early visual areas.