Fixation Eye Movements

Introduction

In day to day events we perform complex eye movements for various different reasons, such as object recognition and during self motion. These complex motions can be observed by using eye coils [8] or eye trackers. These techniques have been used for many years in neuroscience in optic flow studies [1] and vestibular studies [9]. Eye tracking is also commonly used in nonhuman primate studies to ensure that the monkey fixates and therefore the stimulus is contained within the fovea.

Experimental and theoretical motivation

Participants were instructed to perform long fixations (20 seconds) on a dot on a computer screen. Eye movements were recorded using video-based high-resolution eye tracking systems (EyeLink-II, IView-X 1250). The results of the experiments showed that there is fixation eye movements. The fixation eye movements can be separated into fast jump-like event called microsaccades and slow random walk movements called drift.

Microsaccades are triggered by complex dynamical processes in response to low retinal image slip [3]. The random walk behavior leads us to the approach to apply scaling behavior analysis because of the presence of long-range correlations [4]. When we investigate the scaling behavior, i.e., by applying detrended fluctuation analysis, we find that fixation eye movements show two scaling regions. We observe a short time scale where we get persistent behavior. On a longer time scale where we find anti-persistent behavior. By removing the microsaccades from the data we get changes in the scaling behavior but the persistent short time scale and the anti-persistent long time scale remain.

Up to now we used a minimal model that reproduces the transition from persistence to anti-persistence for the drift based on a delayed feedback mechanism,

\[ x_{t+1} = x_t + v_{t+1} \]
\[ v_{t+1} = (1 - \gamma)v_t + \lambda \tanh(\epsilon v_{t-\tau}) + \sigma \eta_t , \]

where \( \tau \) is the delay parameter that determines the lag of the feedback control mechanism. The other parameters can be adapted to the scaling of the eye movements.

In this project we are interested in what areas of the brain are used during fixation and what areas could induce involuntary microsaccades.
Theoretical Biological Models

Over the past three decades there have been great advances in biologically based model for saccadic eye movements. One of the first models in the field of eye movement was by Robinson [9] and [10]. Theses papers became the cornerstone of eye movement modeling and many papers built upon the models.

In the last two decades research in the control of eye movements has brought some questions to light.

1. Does the brain send position, velocity or acceleration to the muscles [10]?
2. How to implement the rotations using Quaternions or Euler angles [13]?
3. Which areas of the brain are used [12] [2]?
4. Does the eye satisfy Listing’s Law [5]?
5. Are eye movements non-commutative [12]?

A review of some saccadic models can be found in [5].

We are most interested in what area of the brains are used during saccades, therefore we have chosen to use the model by Leferve [2]. The model is nice progression from the original models but it also includes inputs from the cerebellum and the superior colliculus, see Figure 1.

![Figure 1: Overview of the different brain structures included in our model, with their interconnections. The saccadic goal is provided by the frontal eye fields (FEF) in the oculomotor cortex. This structure projects to the superior colliculus (SC) and nucleus reticularis tegmenti pontis (NRTP). The SC also projects to the NRTP which activates the cerebellum (CBLM). Both SC and CBLM participate in the drive to the saccade and activate brain stem medium lead burst neurons (MLBNs) that in turn recruit the extraocular motoneurons of the eye plant (MNs).](image)

Goals of the project

Over the three weeks of the summer school we intend to get a deeper understanding of the classical models for saccadic eye movements. Our goal is to investigate if these models can give insight into the involuntary eye movements during fixation.
Bibliography


