End to end reconstruction of ImageNet images from primate retinal ganglion cell spike trains

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Introduction

In this project, we plan on building a deep learning model that can reconstruct natural images from the spiking activity of hundreds of retinal ganglion cells (RGCs) from the macaque monkey retina. In ex vivo experiments, natural images from the ImageNet database, either flashed, or jittered to simulate eye movements, were presented to several preparations of macaque monkey retina while the responses of hundreds of RGCs were recorded, simultaneously. We will build an end-to-end model that will map from RGC response space to stimulus space. The goals of this project are twofold: (1) to build a general purpose tool that can reconstruct high dimensional images from a lower dimensional embedding and (2) to use the developments of this tool to gather concrete insights as to how the primate visual system functions in natural viewing conditions.

Related work

Prior work in visual and computational neuroscience has addressed problems of retinal encoding and decoding through a variety of methods. Classically, retinal encoding has been addressed through the use of simple linear-nonlinear models in which individual RGCs are assumed to perform linear filtering on an incoming visual scene, the output of which is subject to either a learned [3] or general [6] nonlinearity to influence neural firing. More recently, modern machine learning methods have addressed the problem of neural encoding. Deep convolutional neural networks (CNNs) were applied to salamander retina to predict responses to natural stimuli and the performance is in general much higher compared to classical linear-nonlinear methods [4].

Although neural encoding, i.e. mapping from stimulus to response, is an important aspect of understanding brain function, inverting a model and attempting to decode an image can provide insights as to how the brain actually interprets signals from the retina. Classically, this has been accomplished again using primarily linear methods in both temporal white noise [7] and naturalistic stimuli [2] and provides a baseline for how much stimulus content is contained in the spike trains of RGCs.

Recent work, either in simulation [5] or with RGCs of different model organisms [1, 8] have applied nonlinear methods to the reconstruction problem, including deep learning and CNNs. However, no groups have yet attempted applying deep learning methods to reconstruction in the primate retina, which is most relevant to human vision. Thus, we plan on applying similarly described methods to natural image reconstruction to the primate retina to afford the best understanding of how the human brain extracts meaningful visual information from the early visual system.

Deliverables

The data are already acquired as part of the PhD research of ARG, AL and other past students in the Chichilnisky Lab. The first major deliverable is identifying quality data sets in the massive database and pre-processing the data so as to be suitable for use in a modern machine learning framework/environment.

We will try out several ideas. Similar to [5], we will first apply a linear reconstruction of the static images (similar to [2]) and then use a CNN to enhance the reconstruction. With the tools in place...
for this relatively simple/straightforward approach, we will next develop an end-to-end reconstruction from responses to jittered natural stimuli. We will first learn filters for each cell in image space and then apply a CNN to reconstruct the original image from the responses to a jittered stimulus.

We will have the preprocessing done by next week and start on the simple model, which will take around 4 days total. With this simple model in place, we will then iterate on the more complicated end-to-end model, which will take around a week or so. We hope at the end of the quarter to have an end-to-end system for reconstructing static images from responses to jittered stimuli, using linear reconstruction as a baseline comparison.

References


