Motivic analysis of neuronal responses to visual stimuli

A Project Report

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THESIS CERTIFICATE

This is to certify that the thesis entitled **Motivic analysis of neuronal responses to visual stimuli**, submitted by **Athul Vijayan**, to the Indian Institute of Technology, Madras, for the award of the degree of **Master of Technology**, is a bona fide record of the research work carried out by him under my supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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ABSTRACT

KEYWORDS: Markov Decision Processes, Symmetries, Abstraction

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ABBREVIATIONS

RLCS	Rough Longest Common Subsequence
LCSS	Longest Common Segment Set

NOTATION

$\rho(a, b)$	Pearson correlation between a and b
V1	Primary Visual Cortex

CHAPTER 1

Introduction

CHAPTER 2

Background and Previous work

2.1 Visual pathway in brain

2.2 Experiment setup

2.2.1 Sinusoidal grating visual stimuli

2.2.2 Natural videos visual stimuli

2.3 Orientation and Directional selectivity of neurons in V1

CHAPTER 3

Analyzing neuronal properties

Characteristics of neurons in the V1 are discussed in the background section. In this chapter, we use experimental data to demonstrate the claimed properties of neurons in V1. In the experiment, a drifting sinusoidal grating video is shown to awake mice and neuronal responses were recorded. See Section 2.2.1 for detailed experiment setup.

Average response of a neuron is modeled as a function of orientation using a Gaussian function. Similarly, average response to various directions are modeled using a mixture of Gaussian functions. Root mean square of residuals are used as a goodness of fit measure.

Neurons in V1 are classified into simple, complex and unselective cells. Classifying a neuron into either of this class is useful as we can find the population of similar cells in the brain. Rather than thresholding OSI and DSI, We have used a k-means clustering algorithm with more features to classify cells.

3.1 Quantifying Orientation and Directional selectivity

3.2 Modeling neuronal response

Modeling the response of neuron to various orientations and visualizing is a great way to see if in fact there is a orientation selectivity. If the cell seems selective, we can characterize the degree of selectivity and preferred orientation.

Orientation tuning curve is modeled using a Gaussian function with constant offset. The empirical form of the orientation tuning curve is,

$$R_o(\theta) = C + R_p \exp\left\{\frac{-||\theta - \theta_{pref}||^2}{2\sigma^2}\right\}$$

Where $R_o(\theta)$ is the time-averaged response of neuron to angle of orientation θ. Parameter θ_{pref} is the preferred orientation of the neuron. Tuning width σ tell us how much the cell is selective. C is a constant offset.

Similarly, we can model direction tuning curve using a mixture of Gaussian functions with a constant offset.

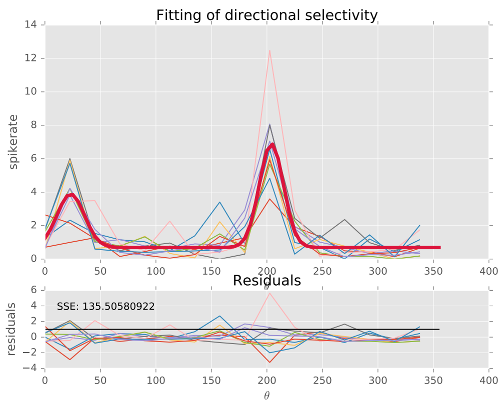
$$R_d(\theta) = C + R_p \exp\left\{\frac{-||\theta - \theta_{pref}||^2}{2\sigma_1^2}\right\} + R_n \exp\left\{\frac{-||\theta - \theta_{null}||^2}{2\sigma_2^2}\right\}$$

Where $R_o(\theta)$ is the time-averaged response of neuron to angle of direction θ. Relative magnitude of tuning widths, σ_1 and σ_2 denote the amount of directional selectivity. C is a constant offset.

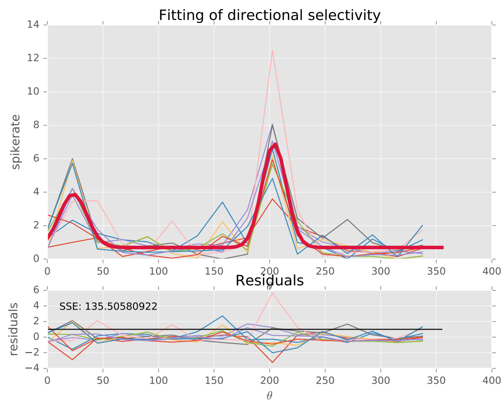
Parameters are estimated by minimizing squared sum of error. Sum of squared error is defined as:

$$SSE = \sum_{i=1}^{N} ||R(\theta_i) - R_o(\theta_i)||^2$$

A gradient descent algorithm finds the optimum parameters by minimizing SSE. In Figure 3.1 , fit of tuning curves of a complex cell is given. The distinct peak in the orientation tuning curve shows selectivity to orientation θ_{pref}. In the direction tuning curve, peaks of different magnitude shows one direction is more preferred than other.



(a) Orientation tuning curve

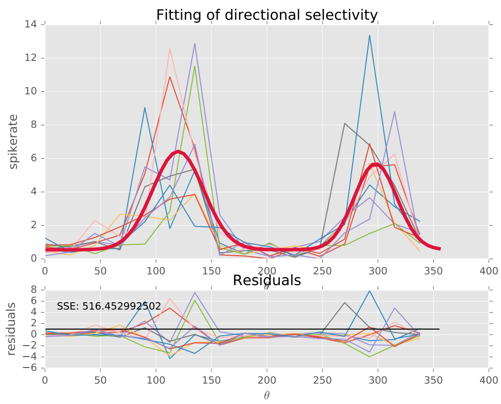


(b) Direction tuning curve

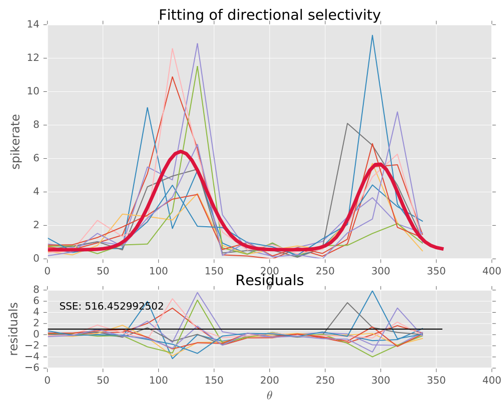
Figure 3.1: Fit of orientation and direction tuning curves of a neuron. The distinct peak in the orientation tuning curve shows selectivity to orientation θ_{pref}. Different σ_1 and σ_2 in direction tuning curve shows direction sensitive cell. - Thus a complex cell

In Figure 3.2 , fit of tuning curves of a complex cell is given. The distinct peak in the orientation tuning curve shows selectivity to orientation θ_{pref}. In the direction tuning curve, peaks of same magnitude shows direction is irrelevant.

3.3 Classification of neurons based on selectivity



(a) Orientation tuning curve



(b) Direction tuning curve

Figure 3.2: Fit of orientation and direction tuning curves of a neuron. The distinct peak in the orientation tuning curve shows selectivity to orientation θ_{pref}. Similar σ_1 and σ_2 in direction tuning curve direction is irrelevant. - Thus a simple cell

CHAPTER 4

Searching for Motifs

CHAPTER 5

Rough Longest Common Subsequence

CHAPTER 6

Inferences and Future work

APPENDIX A

Neural visual pathway

REFERENCES