A Biologically Inspired Model of Chromatic Assimilation & Contrast in the Primary Visual Cortex

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Abstract

We present a computational model of the primary visual cortex (V1) inspired by current neurobiological understanding. This understanding treats color and shape as intrinsically connected and, as a consequence, predicts perceptual phenomena such as color induction and assimilation to arise very early in visual processing. We incorporate this understanding into a dynamical model of neuronal activity responding to static or dynamic visual stimuli. Our model confirms the psychophysical predictions on a range of experiments, offering credence to the biological theories.

Index Terms

primary visual cortex, V1, receptive field, single opponent, double opponent, color assimilation, color induction

I. Introduction

COLOR induction and contrast are two related, opposing, perceptual phenomena. The former is a change in perceived color ”toward” a nearby color, while the latter is a change of one color ”away” from the nearby color. Neurophysiological research suggests that these phenomena may arise as early in primate vision as the primary visual cortex (V1). It is proposed that the boundaries between two colored regions drive these effects. Specifically, research in the field describes neurons which fire selectively to boundaries between specific colors, so called double opponent cells, and identifies them as being critically related to the color perceived.

Within, we propose a computational model inspired by the current understanding of this biology. We present two implementations, one more biologically accurate, and another more computationally elegant. We explore the behavior of these models with respect to what they can teach us about the assumed biological theories, as well as their application to the field of computer vision.

II. State of the art

A. *Notes:*

Purpose:

- BIBLIOGRAPHICAL REVIEW ABOUT THE TOPIC OF THE PROBLEM

Biology:

1) What is color?
    - Subjective
    - Correlates to reflectance patterns
2) Historical view → separation of color & shape
3) Parallel/modular/segregated processing [1]
    - Intuitive
        - Black & white movies work fine (Shapley 2011)
        - Full field color can be seen fine
        - LGN research suggested parvicellular & konicellular has color, magnocellular has contrast (edges)
        - Similarly, V5 was ’motion’
4) Current view → integration of color & shape
5) All information is processed as one information stream (too strong??)
    - Color opponency
        - Discuss LMS & opponent color theory
        - Retinal receptive fields & horizontal cells

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- LGN information reflects opponent colors (no spatial opponency)
- SINGLE OPPONENT CELLS RESPOND BEST TO FULL FIELD COLOR

- Spatial opponency
  - LGN information upgraded to include spatial opponency
  - Double opponent cells: color & spatially opponent
  - Spatial frequency sensitivity
  - Orientation sensitivity
  - Shapley shows most V1 cells are double opponent
  - DOUBLE OPPONENT CELLS RESPOND BEST TO COLOR BOUNDARIES
- DO & SO roles
  - If there are SO cells in V1, they aren't just a stepping stone, but encode valuable information. Thus, they likely work in concert with DO cells (more numerous (Shapley))
  - DO cells detect edges → saliency? (Z. Li)
- Interactions (hypercolumns, CO blobs, etc.)
  - Not well understood =(
  - Retinoisotopic
  - Hypercolumns (Z. Li?)
  - What does Shapley think of CO blobs (youtube Q & A)?

Computational Modelling:

1) Prior art: Xavi's PLoS One 2013 paper
   - Avoid detail, save that for *Method*..?
   - Extension of Z. Li's edge detection work
2) Xavi's JoV 2010 paper; differences
   - Weighing Function/Extended CSF vs. Implicit CSF
   - Mathematical vs Dynamical
   - .. this is actually pretty far removed, is it worth mentioning?
3) **What other models contribute points of view here?**

III. Method

A. Image Data Transformation

TODO Introduce the 2 data transformations and their respective meanings

1) Opponent Receptive Fields:

- describe motivation

2) Discrete Wavelet Transform:

- describe motivation

B. Neuro-Dynamical Model

- describe what exactly 'neuro-dynamical' means
- describe how the Z. Li model is used here
- describe how this is agnostic to the initial transformation (data is normalized)

C. NOTES:

We can consider breaking the project down to three distinct problems:

1) What's the data representation input to V1?
   - RGB → receptive fields → LDRGBY
   - RGB → L*a*b* → DWT
2) What's the data representation internal to V1?
   - Neuronal excitation and inhibition
3) How does V1 process the data?
   - Based on Z. Li's dynamic model of neuronal interactions

IV. Experiments

TODO

V. RESULTS

TODO

VI. CONCLUSIONS

TODO

APPENDIX A
APPENDIX TITLE

TODO

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[1] Shapley, Robert, Michael Hawken, and Elizabeth Johnson. *Color in the Primary Visual Cortex*. The Visual Neurosciences. Vol. 2. Cambridge, Mass.: MIT, 2004. 568-86. Print.