1 Dynamics of Model Neuronal Networks.

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Description: The brain performs its tasks through the activity of coupled assemblages of brain cells, or neurons. I will discuss mathematical models of the dynamics of such assemblages, focusing on coupling architectures that arise in the mammalian visual cortex. There, the primary visual cortex operates to extract information crucial for interpreting visual scenes. I will discuss large-scale network models, composed of many model neurons, intended to model such brain areas, methods by which to mathematically reduce the complexity of such systems, and how to analyze their behavior.

Prerequisites: ODEs, Linear Algebra, knowledge of Fourier transforms and series, some knowledge of numerical analysis.

1.1 Topics (not necessarily ordered, not necessarily covered)

1.1.1 Introduction to Primary Visual Cortex

Basic response properties
- orientation selectivity
- spatial phase selectivity
- simple cells
- complex cells

Architecture
- The numbers
- population ratios
- Laminar structure
- Connectivity distances
- Long-range connectivity
- inter-laminar connections
- The input layer 4C

Feature maps
- retinotopy
- orientation
- spatial frequency
- direction selectivity
- spatial phase

The nature of geniculate excitation

1.1.2 Modeling of Neuronal Dynamics

The Integrate-and-Fire neuron
- Networks of I&F neurons
Numerical Methods for time-stepping and spike summation
Mean-Field modelling
  High-conductance derivation
  Ordered vs. disordered maps
Orientation Tuning
  The Feed-Forward model
  The role of inhibition
  The ring model and the marginal phase state of
    Ben-Yishai, Bar-Or, and Sompolinsky
Models of large-scale activity patterns
  Ermentrout & Cowan, Bressloff
  Kang, Shelley, Sompolinsky
The Simple cell
  Feed-forward model
  WSMS model
  Troyer & Miller model
  Chance, Nelson, Abbott
The Complex cell
  The hierarchical model of Hubel and Wiesel
  Chance, Nelson, Abbott and the role of excitation
  TSSM egalitarian model
Population density models
  Derivation
  g/v independence and firing rate models
  The role of population fluctuations and higher-order moment conditions

1.2 Syllabus (tentative)

Lecture 1 – Sept. 3, Introduction and Organization
  Introduction to V1.
Lecture 2 – Sept. 10, The integrate-and-fire neuron and networks
Lecture 3 – Sept. 17, Some numerical methods for I & F networks
Lecture 4 – Sept. 24, Bob Shapley, What the data says I
Lecture 5 – Oct. 1, Bob Shapley, What the data says II
Lecture 6 – Oct. 8, Mean-field models and high-conductance asymptotics
Lecture 7 – Oct. 15, Models of orientation tuning
Lecture 8 – Oct. 22, Models of simple and complex cells
Lecture 9 – Oct. 29, Large-scale activity patterns I
Lecture 10 – Nov. 5, Kukjin Kang, Large-scale activity patterns II
Lecture 11 – Nov. 12, Society for Neuroscience Nat’l Mtg.
Lecture 12 – Nov. 19, David Cai, Kinetic theory I (?)
Lecture 13 – Nov. 26, David Cai, Kinetic theory II (?)
Lecture 14 – Dec. 3, Last class
1.3 Bibliography

1.3.1 Useful Books

R. De Valois and K. De Valois, *Spatial Vision*
D. Hubel, *Eye, Brain, and Vision*
K. Koch, *Biophysics of Computation*

1.3.2 Response Maps of V1

- [3, 1, 2] – Early work on intrinsic imaging of orientation selectivity patterns.
- [5, 6] – Controversial works on spatial frequency in V1.

1.3.3 Large-scale I&F Network Models of V1


References


