Spiking Neural Networks: Population Dynamics and Synchronization

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Abstract

This report presents a comprehensive analysis of spiking neural network dynamics. We implement leaky integrate-and-fire neurons, analyze population synchronization, compute spike train statistics, examine balanced excitation-inhibition, and investigate network oscillations. All simulations use PythonTeX for reproducibility.

Contents

Chapter 1

Introduction

The leaky integrate-and-fire (LIF) neuron model:

$$\tau_m \frac{dV}{dt} = -(V - V_{rest}) + R_m I_{syn} \tag{1.1}$$

When $V \geq V_{th}$: emit spike and reset to V_{reset}.

1.1 Network Connectivity

Synaptic current:

$$I_{syn}(t) = \sum_j w_j \sum_k \delta(t - t_j^k - d) \tag{1.2}$$

Chapter 2

Network Activity

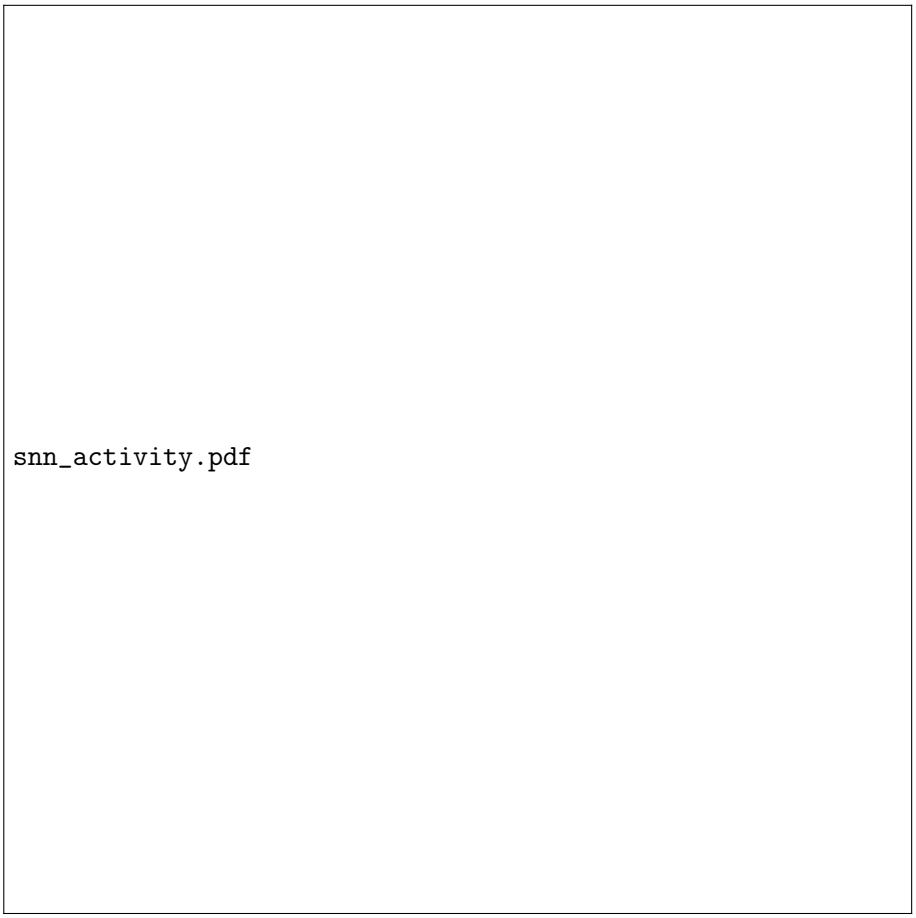

Figure 2.1: Network activity: (a) raster, (b) population rate, (c) rate distribution, (d) ISI, (e) cross-correlogram, (f) power spectrum.

Chapter 3

Synchronization Analysis

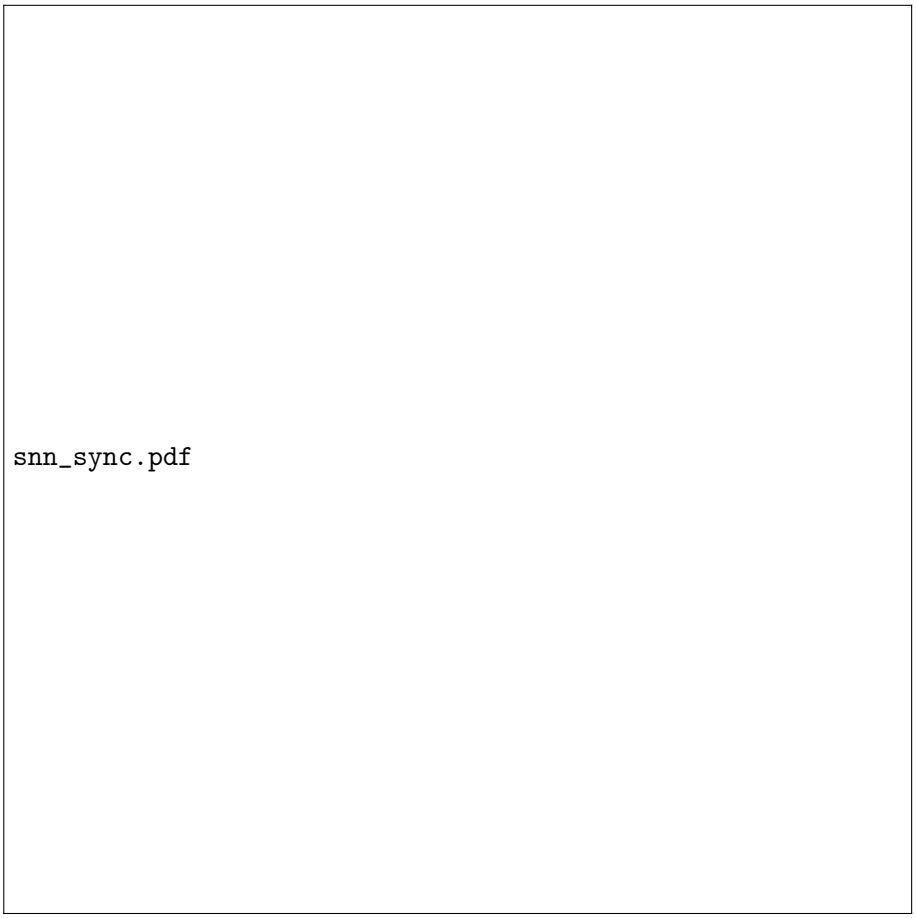

Figure 3.1: Synchronization: (a) spike counts, (b) membrane traces, (c) E/I balance, (d) F-I curve, (e) correlations, (f) connectivity.

Chapter 4

Numerical Results

Table 4.1: Spiking network results

Parameter	Value	Units
??	??	??
??	??	??
??	??	??
??	??	??
??	??	??
??	??	??

Chapter 5

Conclusions

1. Balanced E/I maintains stable asynchronous activity
2. ISI CV near 1 indicates irregular Poisson-like firing
3. Sparse connectivity produces weak correlations
4. Population oscillations emerge from network interactions
5. Inhibition shapes temporal precision of excitation
6. LIF networks capture essential cortical dynamics