In-Depth Analysis of the Izhikevich Model and Network Dynamics

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Web Application – Colab Notebook

Introduction

This project presents an in-depth analysis of the Izhikevich neuron model, a widely used spiking neuron model that efficiently captures biologically realistic firing patterns while maintaining computational efficiency. Our goal was to explore different neuronal behaviors, analyze their dynamics, and simulate network activity in a structured manner.

Single Neuron Analysis

We investigated the effects of different parameter configurations on neuron firing patterns, enabling us to classify neurons based on their excitability and response to external stimuli. The phase plane analysis was conducted to visualize the dynamics of the neuron's membrane potential and recovery variable.

Interactive Web Application

To enhance understanding and allow further experimentation, we developed a web-based interactive tool. This tool enables users to manipulate Izhikevich model parameters and observe real-time changes in neuron behavior, facilitating deeper insight into how different configurations influence spiking dynamics.

Network Simulations

We first simulated a **fully connected network**, which exhibited strong synchronization among neurons, leading to bursts of highly correlated activity. To contrast this, we implemented a **small-world network topology**. This configuration resulted in a more balanced and biologically plausible firing pattern, reducing excessive synchronization while maintaining efficient communication.

We analyzed network activity using histograms of firing rates and **power spectral density (PSD)** plots. The small-world network showed more heterogeneous and less synchronized spiking activity compared to the fully connected network, which demonstrated strong global oscillations.

Conclusion

This project provided valuable insights into the Izhikevich model, both at the single-neuron and network levels. By developing an interactive web tool and implementing various network structures in a Jupyter notebook, we gained a deeper understanding of the role of connectivity in shaping neural dynamics.