Computational Neurodynamics Coursework 1

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Overview

This document provides a Python simulation of small-world modular networks using **Izhikevich neuron models**. The myNetwork class simulates complex neuron dynamics with excitatory and inhibitory connections, with functions for network setup, connectivity, simulation, and visualisation.

Code Structure

- init (self, num ex, num in, num ex module, Dmax)
 - Purpose: Initialises the network, setting the number of excitatory and inhibitory neurons and configuring initial parameters.
 - Parameters:
 - num_ex: Total excitatory neurons.
 - num_in : Total inhibitory neurons.
 - num_ex_module : Number of excitatory neuron modules.
 - Dmax: Maximum delay (ms) for synaptic transmission.
- set_Ex_to_Ex(self)
 - Purpose: Defines excitatory-to-excitatory connectivity within each module.
 - Return: Returns a connectivity matrix, ex_to_ex , specifying the excitatory neuron connections.
- set_Ex_to_In(self)
 - Purpose: Establishes connections from excitatory neurons to inhibitory neurons, with each inhibitory neuron connecting to four excitatory neurons.
 - Return: Returns a connectivity matrix, ex_to_in , indicating excitatory-to-inhibitory connections.
- set_weights(self)
 - Purpose: Constructs a synaptic weight matrix for the network by combining connectivity matrices for excitatory and inhibitory neurons.
 - **Dependencies**: Uses set_Ex_to_Ex() and set_Ex_to_In() for partial matrices, which are combined and scaled to create the full weight matrix.
- set_parameters(self)
 - Purpose: Sets the neuron model parameters (a , b , c , d) for excitatory and inhibitory neurons with slight variation for realism.
- set_delays(self)
 - Purpose: Configures synaptic delays for all neuron-to-neuron connections, with specific delays assigned based on neuron types.
- rewire(self, p)
 - **Purpose**: Rewires excitatory-to-excitatory connections within each module with a probability p , implementing small-world network characteristics.
 - Parameters: p : Probability of rewiring each excitatory connection.
- plot_connectivity(self)
 - Purpose: Plots the network's connectivity matrix, showing the structure of all connections.
- set_all(self)
 - $\bullet \ \ \, \textbf{Purpose} \hbox{: High-level initialiser that sets up the network by calling } \ \ \, \text{set_weights} \ \, , \ \ \, \text{set_delays} \ \, , \ \ \, \text{and} \ \ \, \text{set_parameters} \ \, . \\$
- plot_raster(self, T)
 - Purpose: Runs the simulation for T ms and generates a raster plot of neuron firing events over time.
 - Parameters: T : Simulation time (ms).
- plot_mean_fire_rate(self, window_size, step_size)
 - Purpose: Computes and plots the mean firing rate of neurons in each module over a 1000 ms simulation using a sliding window approach.
 - Parameters:
 - window_size : Size of each window (ms).
 - step_size : Time shift between windows (ms).

Dependencies

- Python Libraries:
 - numpy: For numerical operations.
 - random: For random sampling and shuffling.
 - matplotlib: For plotting connectivity and simulation results.
- Custom Module:
 - iznetwork : Custom module to manage neuron network simulation, used for creating the IzNetwork object and setting neuron parameters, weights, and delays.