Prediction of Spiking Time Series in a Brain Neural System Using LSTM Model

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PART 01

Goal

- Brain is a complex system
- Mathematical models for neural system are high-dim and nonlinear
- We want to know the properties of these models with machine learning

➢ With an initial condition of a brain neural system, we want to predict its spiking patterns using machine learning.

Neural System

- **Neurons**: (Excitatory/Inhibitory) elementary processing unit

- **Action potentials (spikes)**: a short voltage pulse of 1-2 ms duration

Integrate-and-Firing Model

Only care about the time of events

A neuron receives spikes from:
- Other neurons that project to it
- External current input

- Excitatory neuron
- Inhibitory neuron

Time series of spikes
600 neurons on a ring model:
- 300 Inhibitory
- 300 Excitatory

Each E projects to 5 neurons and each I projects to 5 neurons

Each E projects to 55 neurons and each I projects to 5 neurons
Methodology

Inputs:

- **Spiking counts** of all neurons in the neural system over 3000 ms
- **External inputs** injecting to all neurons respectively over 3000 ms

Output:

- Prediction of testing data's spiking counts

Training process:

- Cut the input into overlapping time intervals of length 10 ms
- Use the input at time intervals $t = n$-steps, ..., $n-1$ to predict the spiking count at $t = n$
- Minimize the loss function for training data:

$$MSE = \frac{1}{n_t} \sum_{i=1}^{n_t} \| X_i - \hat{X}_i \|^2$$
**Result:** LSTM model

1 E & 1 I
Project to each other

15 E & 15 I
E projects to 1
I projects to 1

30 E & 30 I
E projects to 1
I projects to 1

LSTM: deal with gradient vanishing

Plots: all are spiking counts of one single neuron randomly chosen from its neural system (one line of the output)
Result: LSTM model

LSTM: deal with gradient vanishing

Plots: all are spiking counts of one single neuron randomly chosen from its neural system (one line of the output)
Summary

- Develop an LSTM model to predict the spiking time series of lower dimensional neural systems.

**Future work:** Improve the performance for the prediction

- Neural systems with more connected neurons
- High dimensional neural system with more than 60 neurons

Reference: