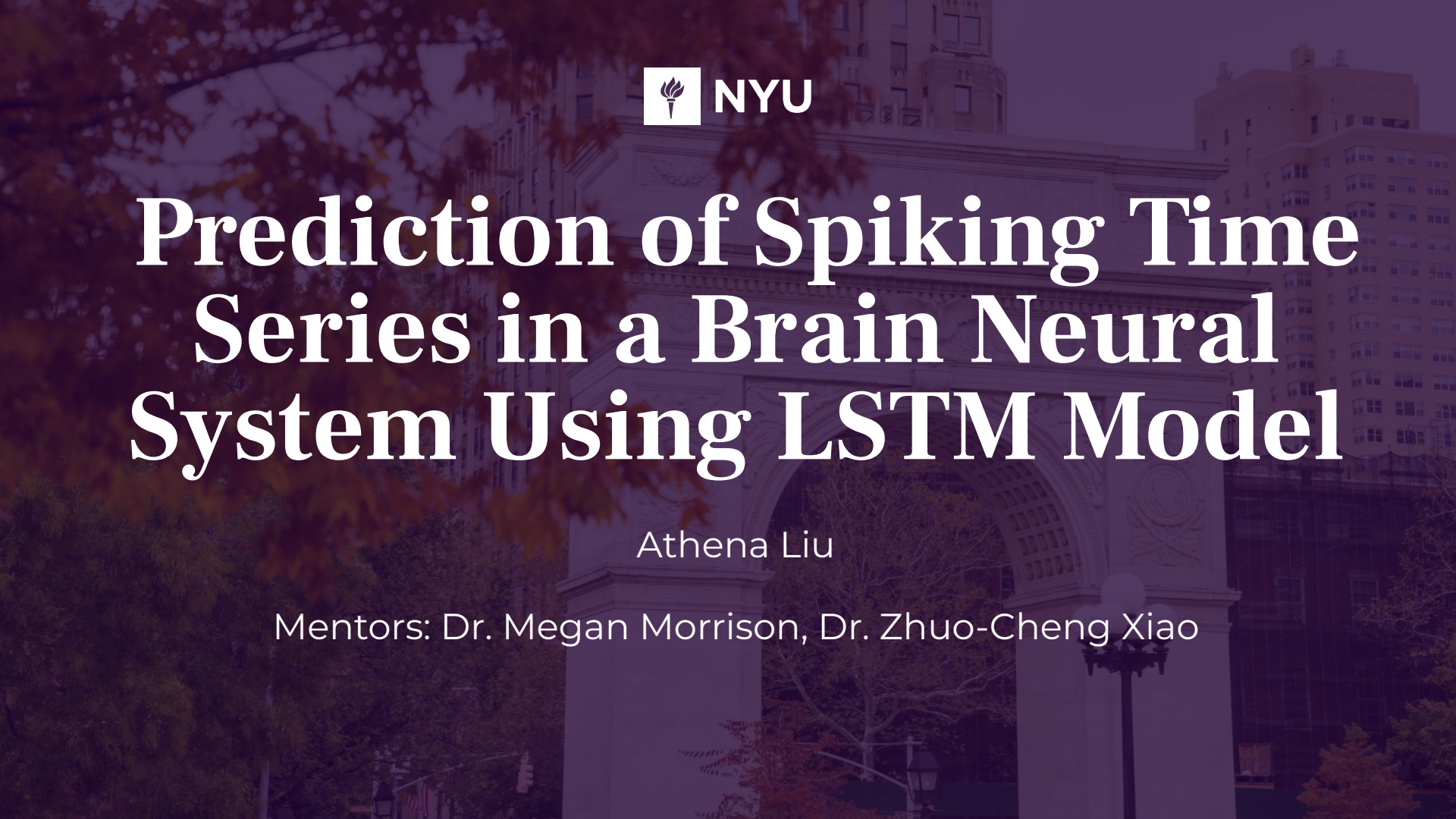


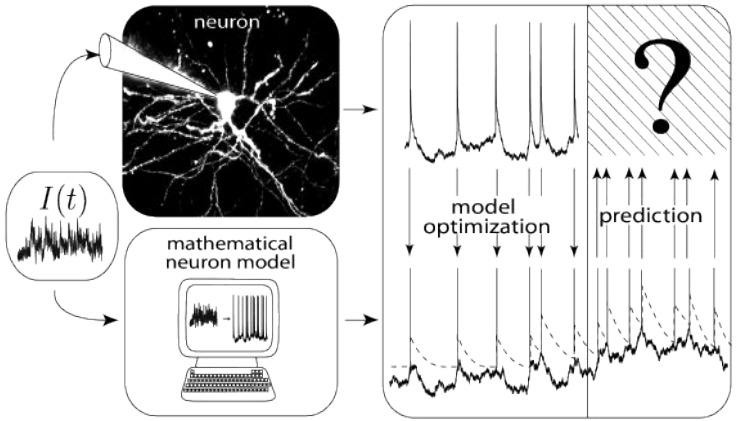
NYU

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

Athena Liu

Mentors: Dr. Megan Morrison, Dr. Zhuo-Cheng Xiao

Goal



Wulfram Gerstner, Werner Kistler, Richard Naud, and Liam Paninski.
1.5 neuronal dynamics online book, Cambridge University Press, 2014.

- 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.

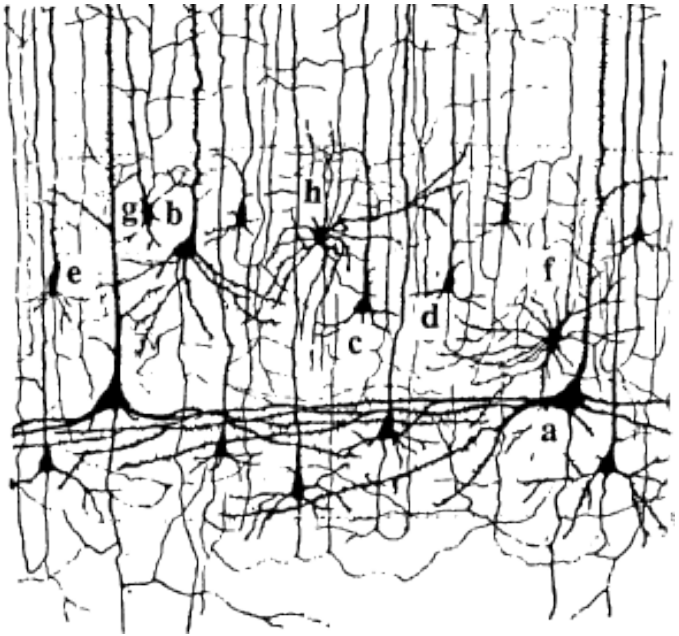
Neural System

- **Neurons**: (Excitatory/Inhibitory)

  elementary processing unit

- **Action potentials (spikes)**:

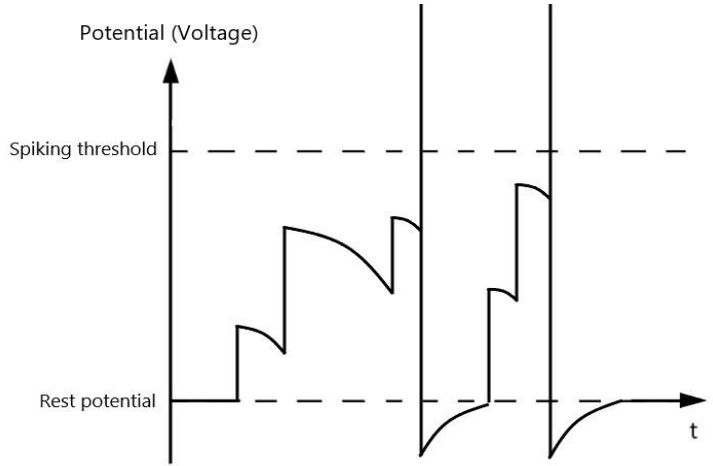
  a short voltage pulse of 1-2 ms duration



S. Ramòn y Cajal (1909) *Histologie du système nerveux de l'homme et des vertébré*. A. Maloine, Paris.

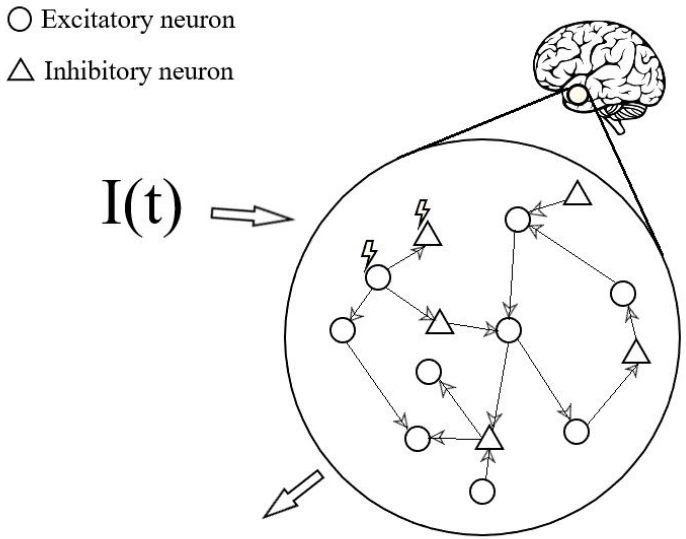
Integrate-and-Firing Model

Only care about the time of events



A neuron receives spikes from:

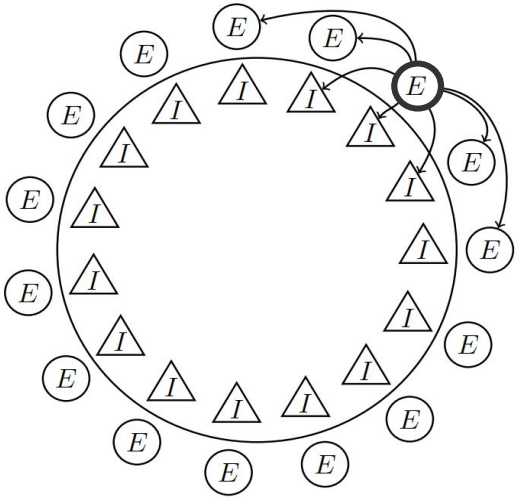
- Other neurons that project to it
- External current input

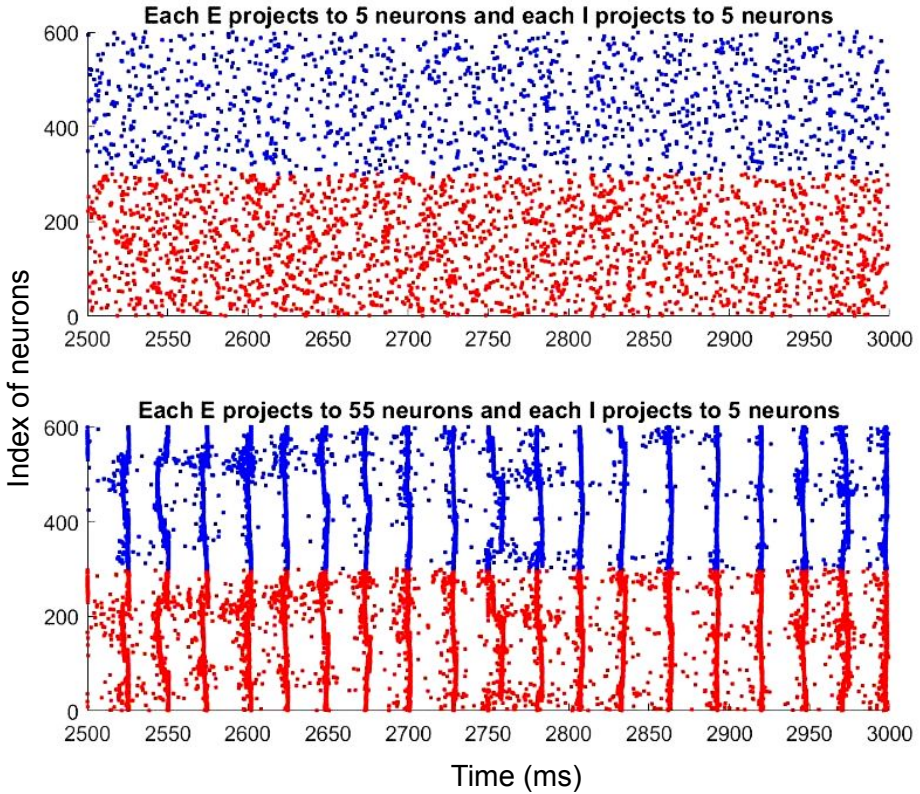


Time series of spikes

Spiking Pattern

600 neurons on a ring model:
- 300 Inhibitory - 300 Excitatory





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

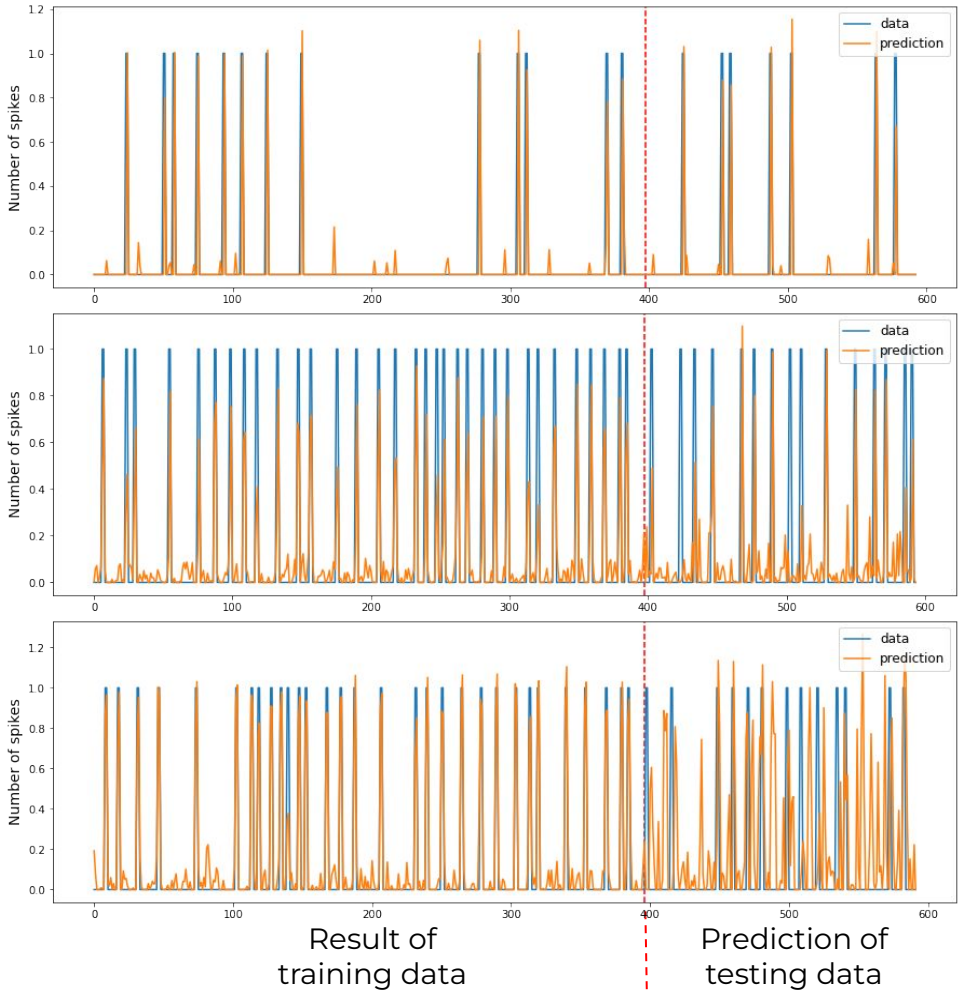
LSTM: deal with **gradient vanishing**

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

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



Result: LSTM model

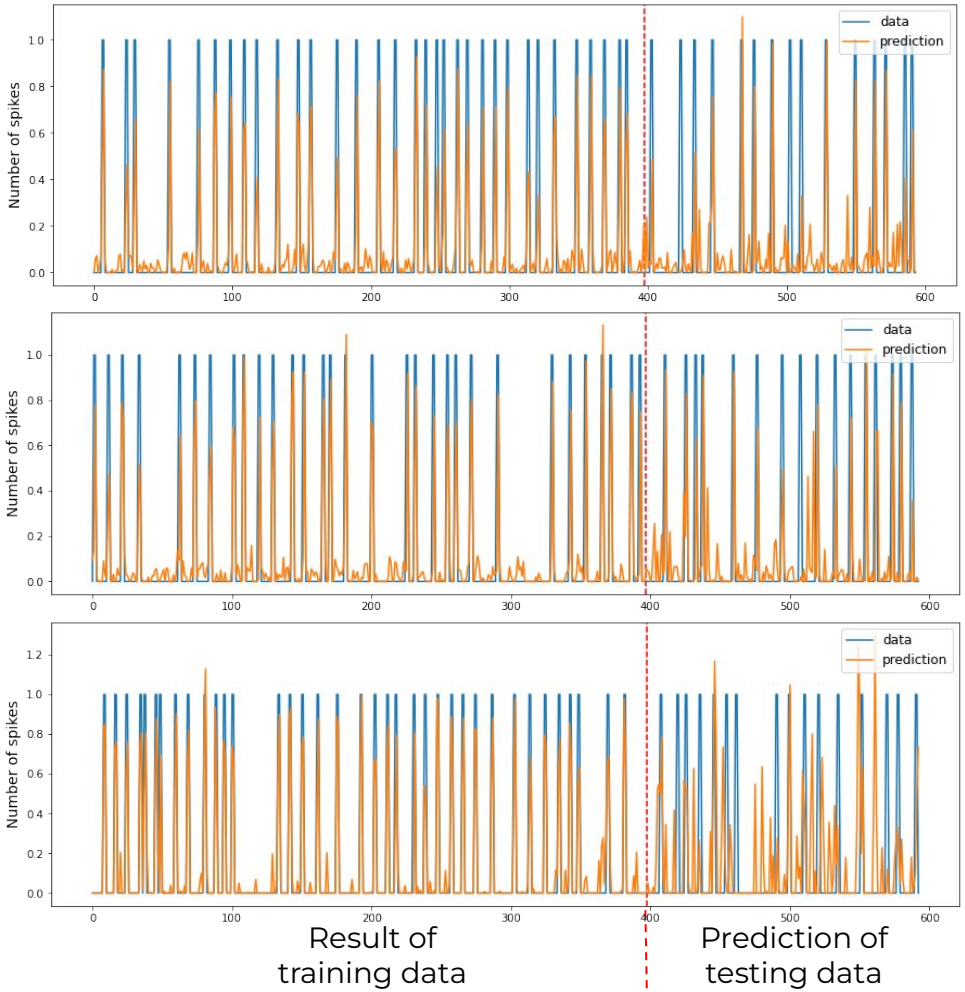
LSTM: deal with **gradient vanishing**

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

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

15 E & 15 I
E projects to 3
I projects to 6

15 E & 15 I
E projects to 5
I projects to 10



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*:

1. S. Ramòn y Cajal (1909) *Histologie du système nerveux de l'homme et des vertébré*. A. Maloine, Paris.
2. Wulfram Gerstner, Werner Kistler, Richard Naud, and Liam Paninski. *1.5 neuronal dynamics online book*, Cambridge University Press, 2014.
3. Xiao, Zhuo-Cheng, and Kevin K. Lin. "Multilevel Monte Carlo for Cortical Circuit Models." *Journal of Computational Neuroscience*, vol. 50, no. 1, Feb. 2022, pp. 9–15. Springer Link, https://doi.org/10.1007/s10827-021-00807-3.