HACETTEPE UNIVERSITY
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

GRADUATION PROJECT
Cracking the Neural Code for Sensory Perception and Locomotion

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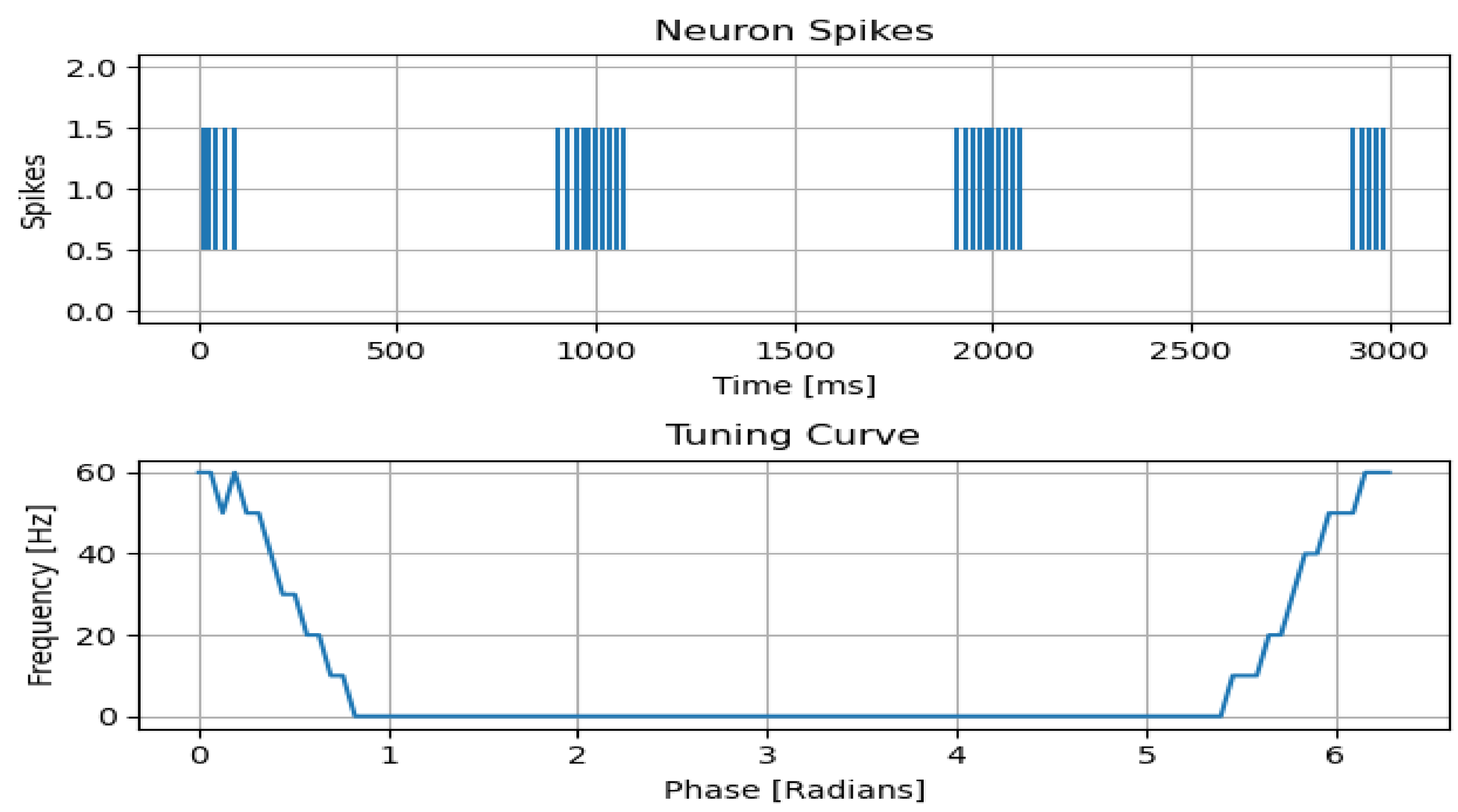
INTRODUCTION

The neurons in animal bodies communicate with each other through chemical signals at synapses. This data, the neural activity in the brain circuits, is an encrypted version of the sensory signals perceived from the environment and the motor commands transmitted to the muscles. This project aims to crack the neural code to understand the encoding mechanisms adopted in the midbrain circuits. We will try to understand how the sensory and motor signals are encoded in the midbrain circuits. This will be a kind of reverse engineering project, we will try to crack the neural code used to encode sensory and motor processes.



MATHEMATICAL OVERVIEW

We used the LIF (Leaky Integrate and Fire) neuron model in this project. This is a mathematical model that establishes the neuron input output relationship.

$$\tau_m \frac{dV}{dt} = V_L - V + \frac{I}{g_L}$$

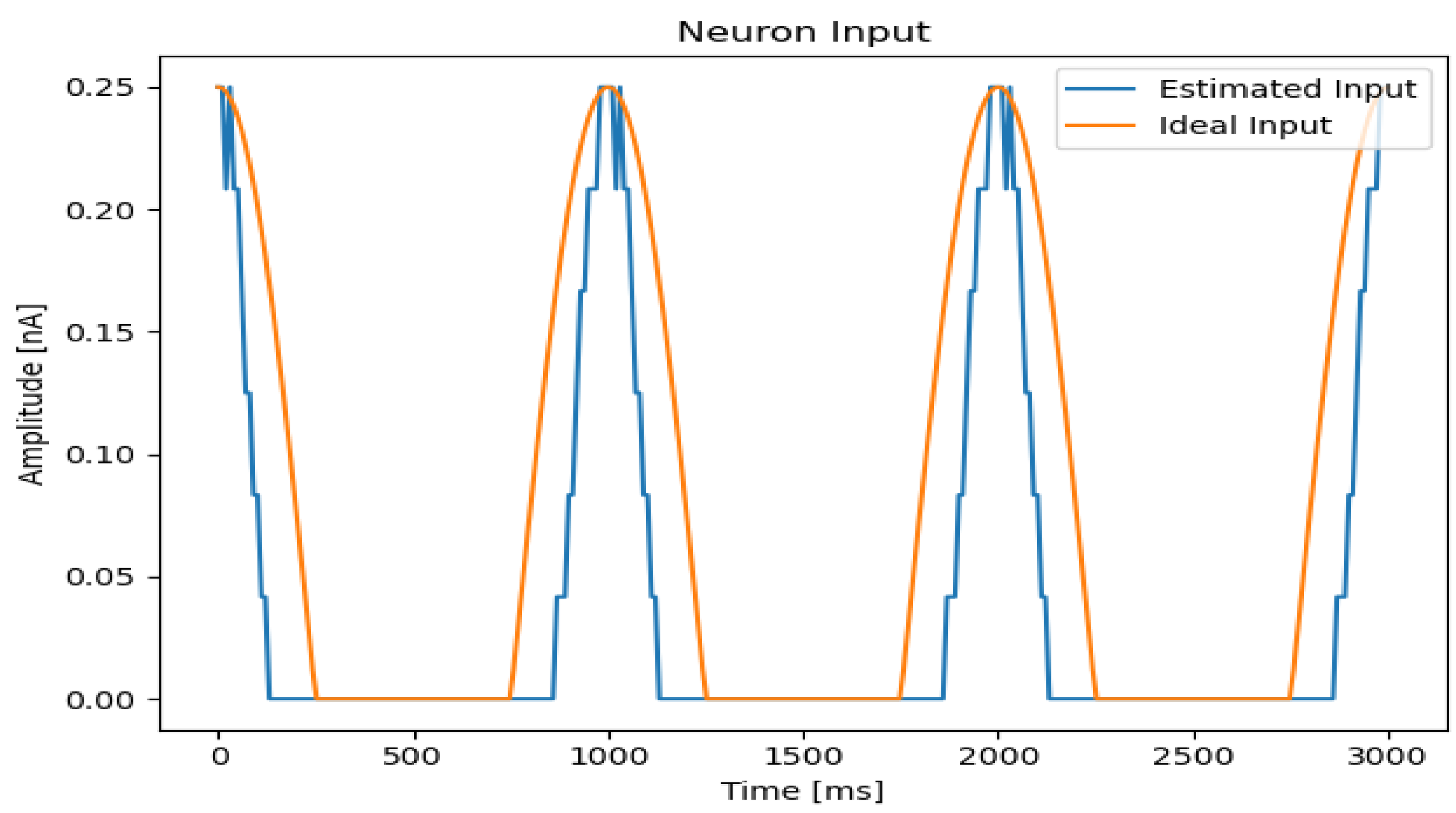
τ_m: *membrane time constant* [ms]

V_L: *leak reversal potential* [mV]

V: *membrane potential* [mV]

g_L: *leak conductance* [nS]

I: *external input current* [pA]

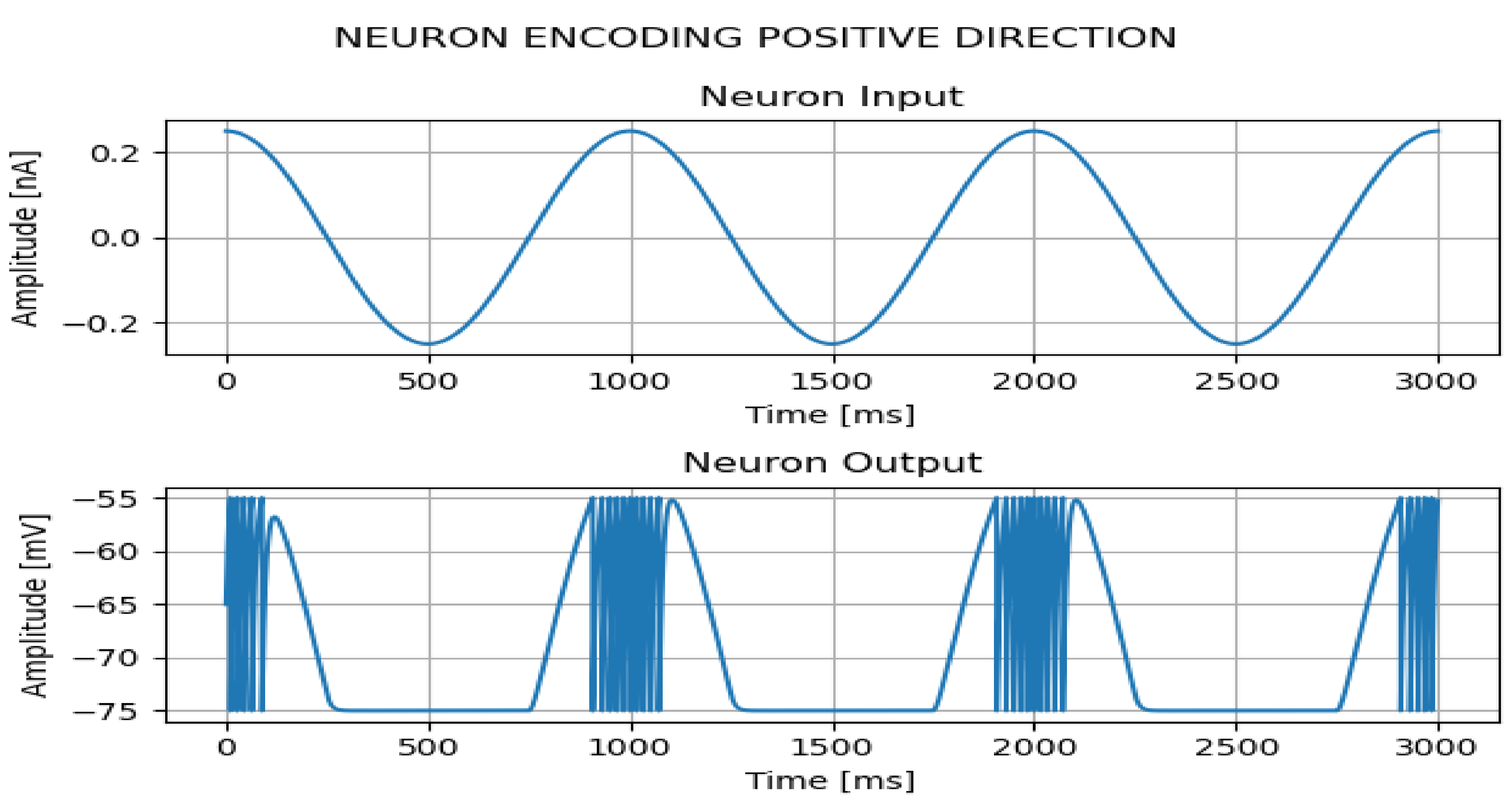


METHODOLOGY

- We implemented the LIF model in Python using Euler's method.
- The created neurons encoded features such as movement, speed, and acceleration.
- The tuning curve of each neuron was extracted.
- From the extracted tuning curves, the inputs to the neurons were predicted.

CONCLUSION

In this project, we simulated how neurons in the brain encode information and how to decode it. By inserting electrodes into extracellular medium, we can record the electric field induced by action potentials. Tuning curves can be obtained experimentally, allowing us to measure signals from the brain and predict the input. In the future, using these encoding and decoding techniques, it may be possible for many paralyzed patients to regain control of their muscles. The margin of error in the simulation is due to the low resolution of the tuning curve.



ADDITIONAL RESOURCES

- If you want to read more about the theory of the project, see Laurence F. Abbott and Peter Dayan, "Theoretical Neuroscience," MIT Press, 2001.
- If you want to get information about the implementation of the project, see Christopher R. Fetsch, Alexandre Pouget, Gregory C. DeAngelis, Dora E. Angelaki, "Neural correlates of reliability -based cue weighting during multisensory integration", Nature Neuroscience, 2013.