Design and Development of Control System

For Quadrupeds using Central Pattern Generator

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Overview

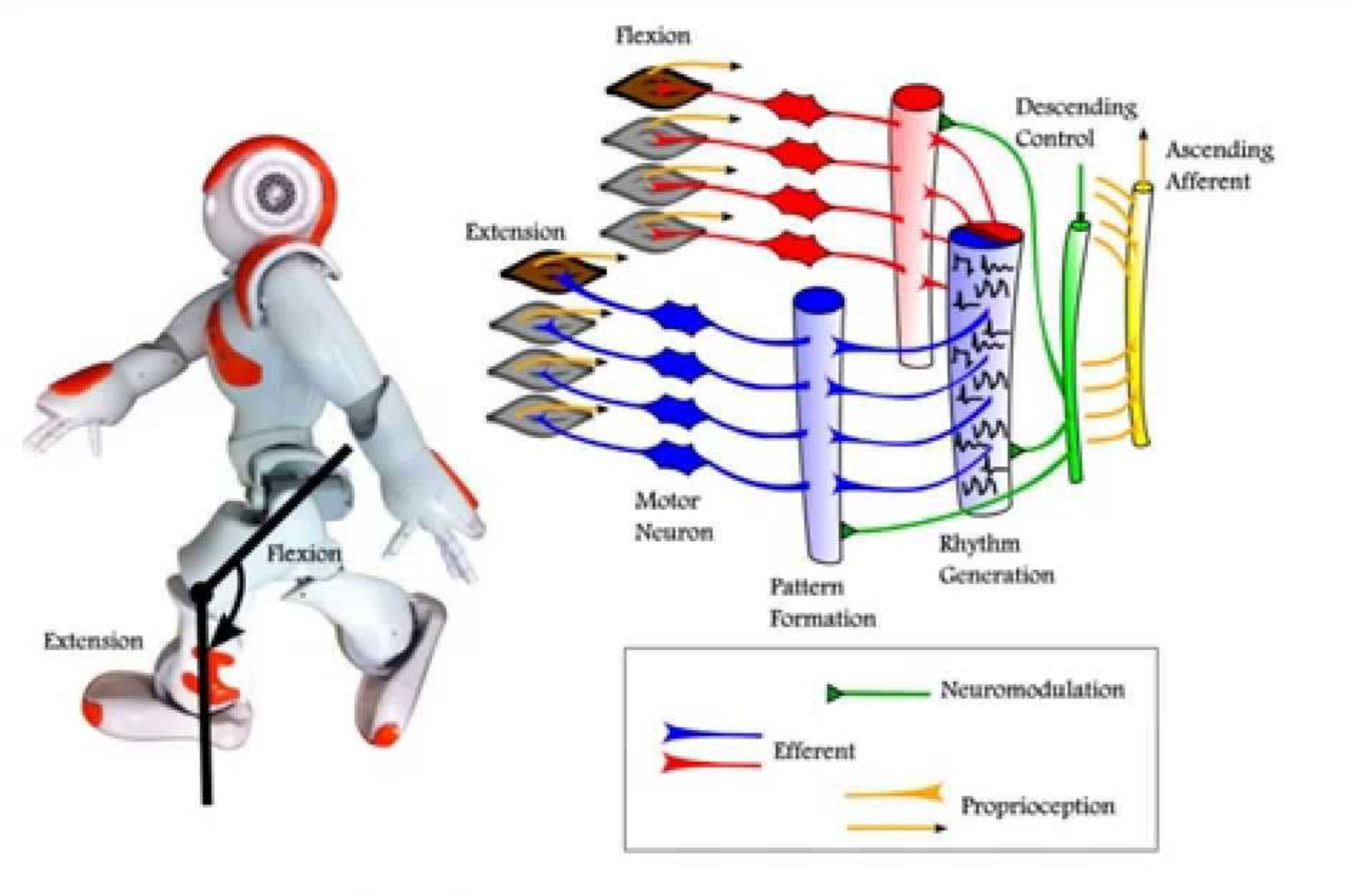
Central Pattern Generators

- A Central Pattern Generator is a neural circuit capable of producing co-ordinated patterns of activity with very simple or no input control signals
- Central Pattern Generators used to model locomotion are often inspired by biological neural circuit as observed in animals
- Central Pattern Generators, present in almost all living organisms are used to modulate rhythmic activities
- Control of activities like generation of gait patterns, beating of the heart etc, which require no to minimum conscious control can be controlled using CPGs

Overview

Advantages of using CPGs over Traditional control methods

- CPGs do not require exact knowledge of Robot Model. Thus CPGs for similar robots can be exchanged with minimal re-tuning
- CPGs show excellent robustness to perturbations
- Same CPG can used for different gait patterns and locomotion parameters (speed, heading etc)
- CPG control strategy is distributed in nature, allowing for better understanding of the employed control strategy



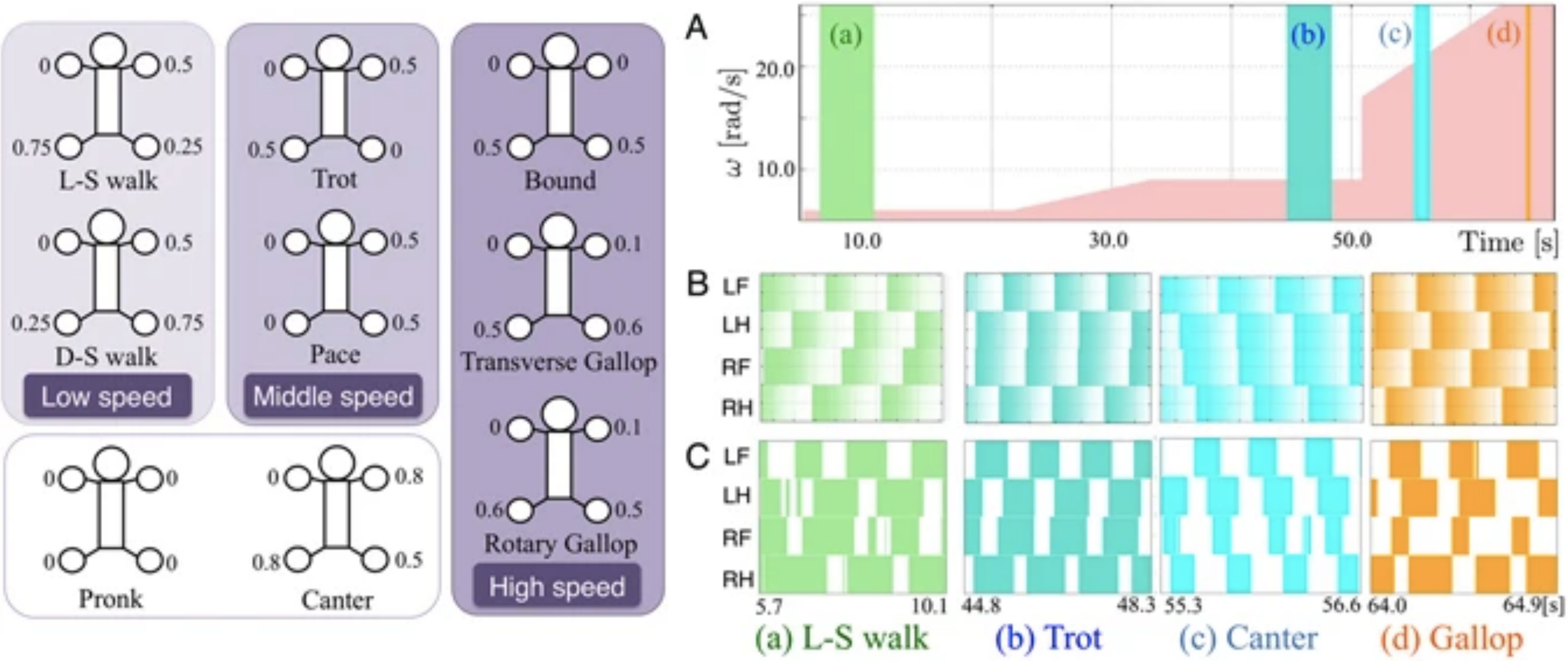
[Nassour et al. 2014]

Example of a Central Pattern Generator for control of gait of a biped robot. The CPG is inspired from how motor patterns are generated in the spinal chord

Problem Statement

The problem statement tackled in this Dual Degree Project can be divided into three sub-problems

- Design of an open loop locomotion controller for a quadruped robot
- Integration of sensory feedback from an image sensor and an ultrasonic sensor into the open-loop controller to provide obstacle avoidance capabilities
- Development and integration of a search algorithm to allow the quadruped to traverse its environment given an objective of searching for a given target, while avoiding any obstacle

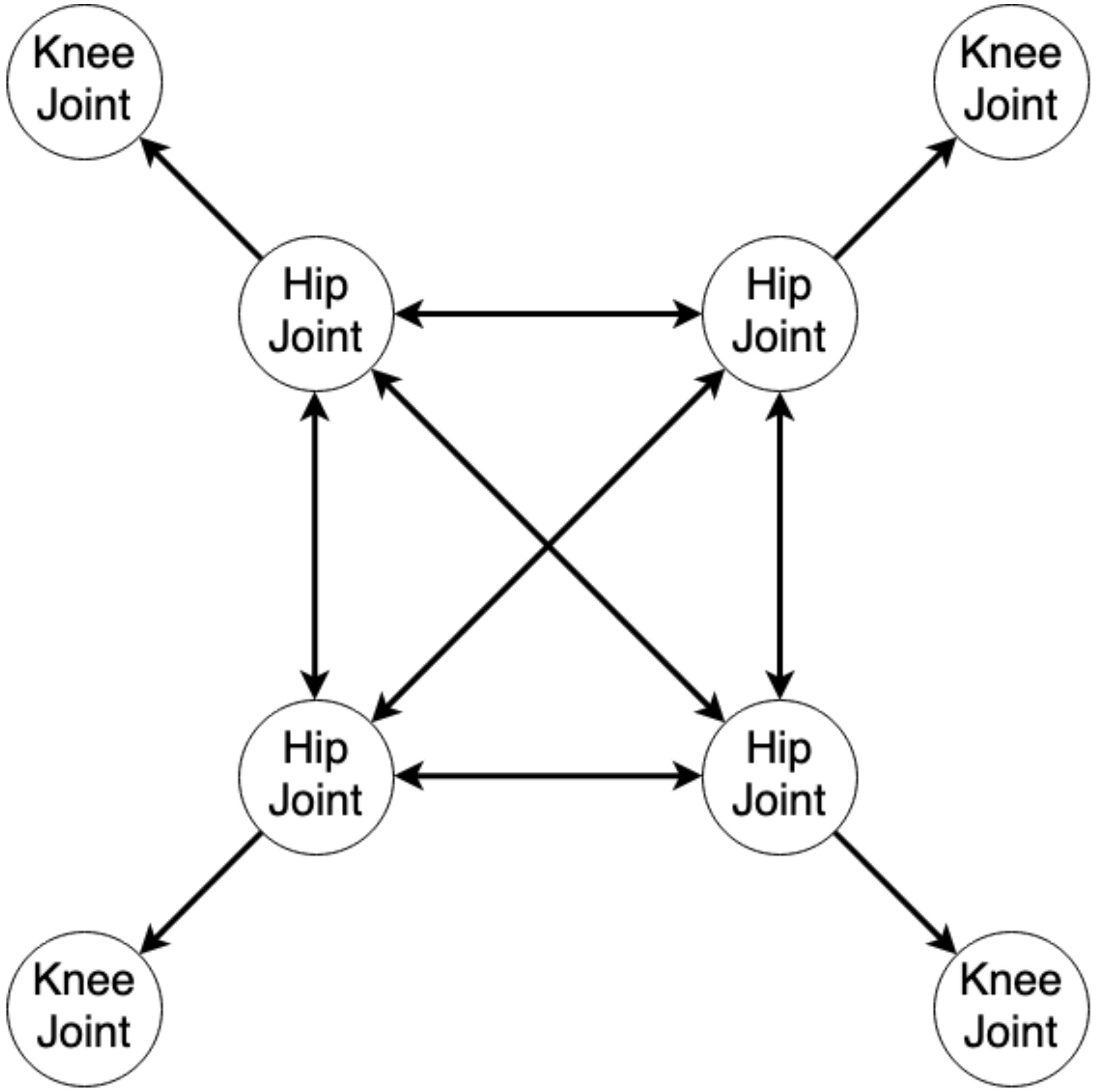


Different Gait Patterns in a Quadruped Robot

Problem Statement

Design of Open Loop Controller

- CPGs using non-linear oscillators can be used to obtain complex gait patterns.
- Modulation of the CPG parameters can also result in gait transition from one gait type to another



Most Common CPG Architecture for motor pattern generation in quadrupeds. This model forms the baseline for comparison of the proposed CPG architecture

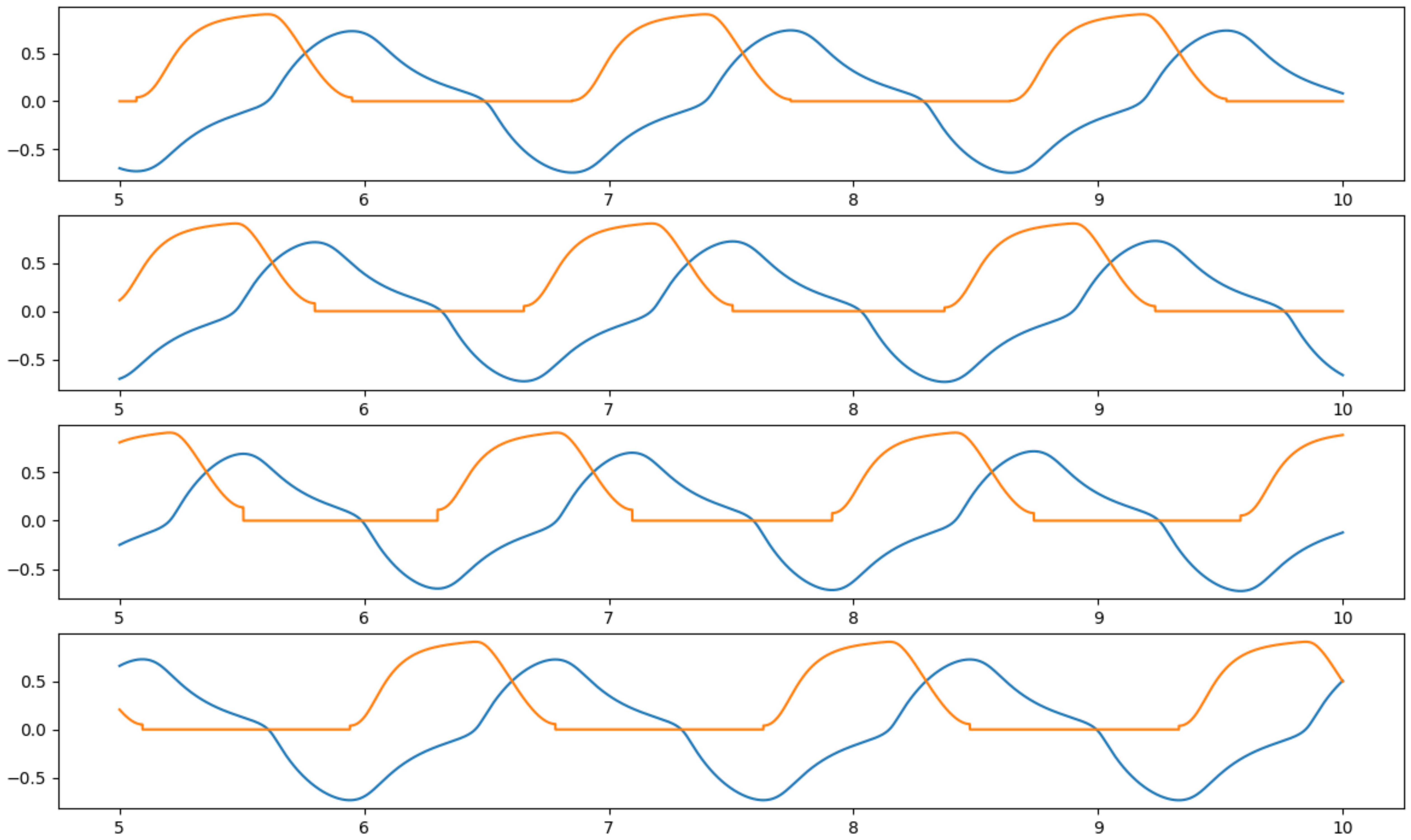
Problem Statement

Design of Open Loop Controller

- CPG models presented by [1], [2] and [3], follow the aforementioned CPG architecture, differing only the use of different Neuron models
- All the Neuron Models have been implemented and simulations performed to understand the effects of parameter modulation on Rhythmogenesis
- Gait patterns obtained for the Wilson Cowan Nervous Oscillator Model were implemented on the Quadruped

Experiment Results

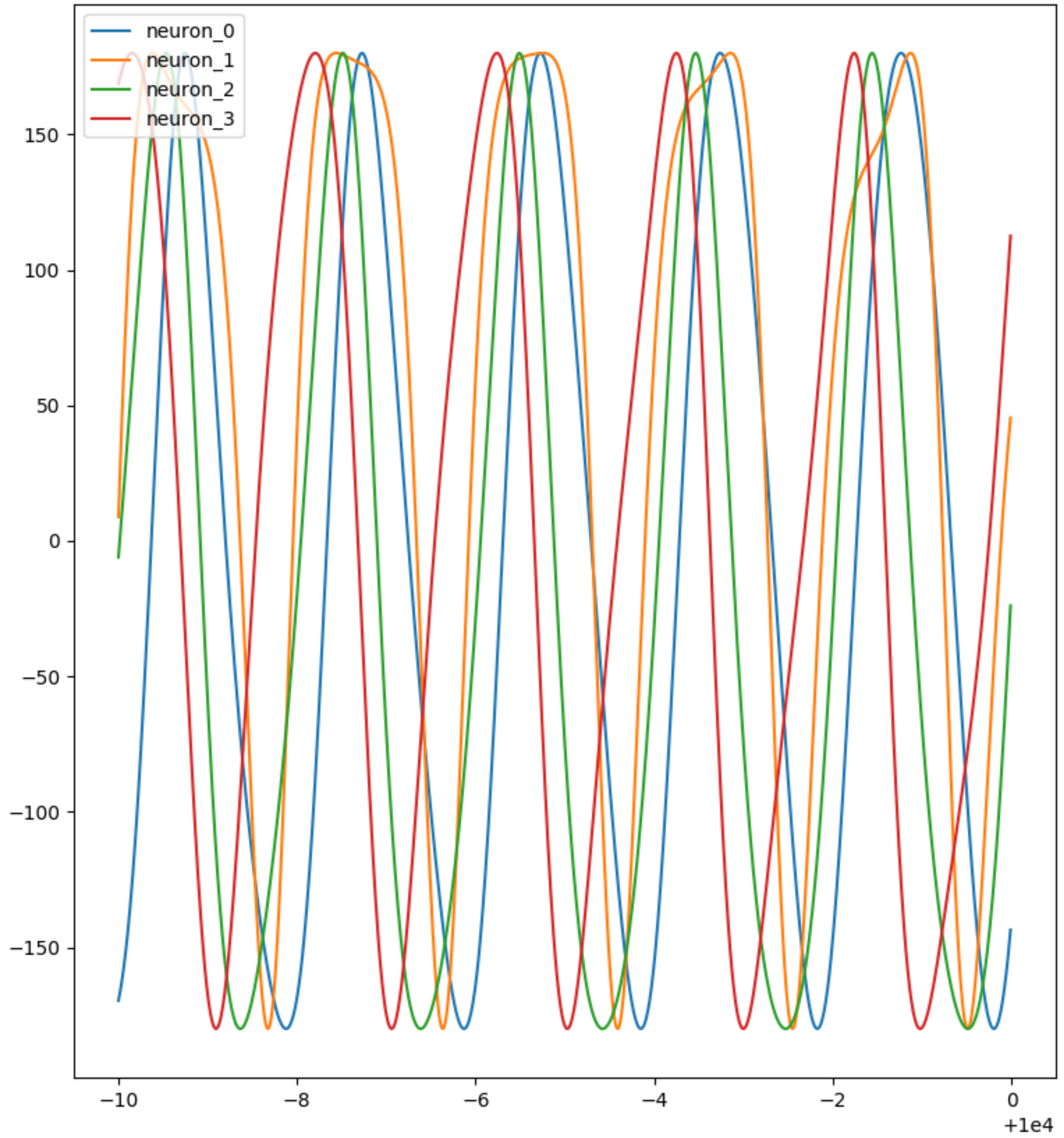
Gait Pattern from Wilson Cowan Nervous Oscillator Model

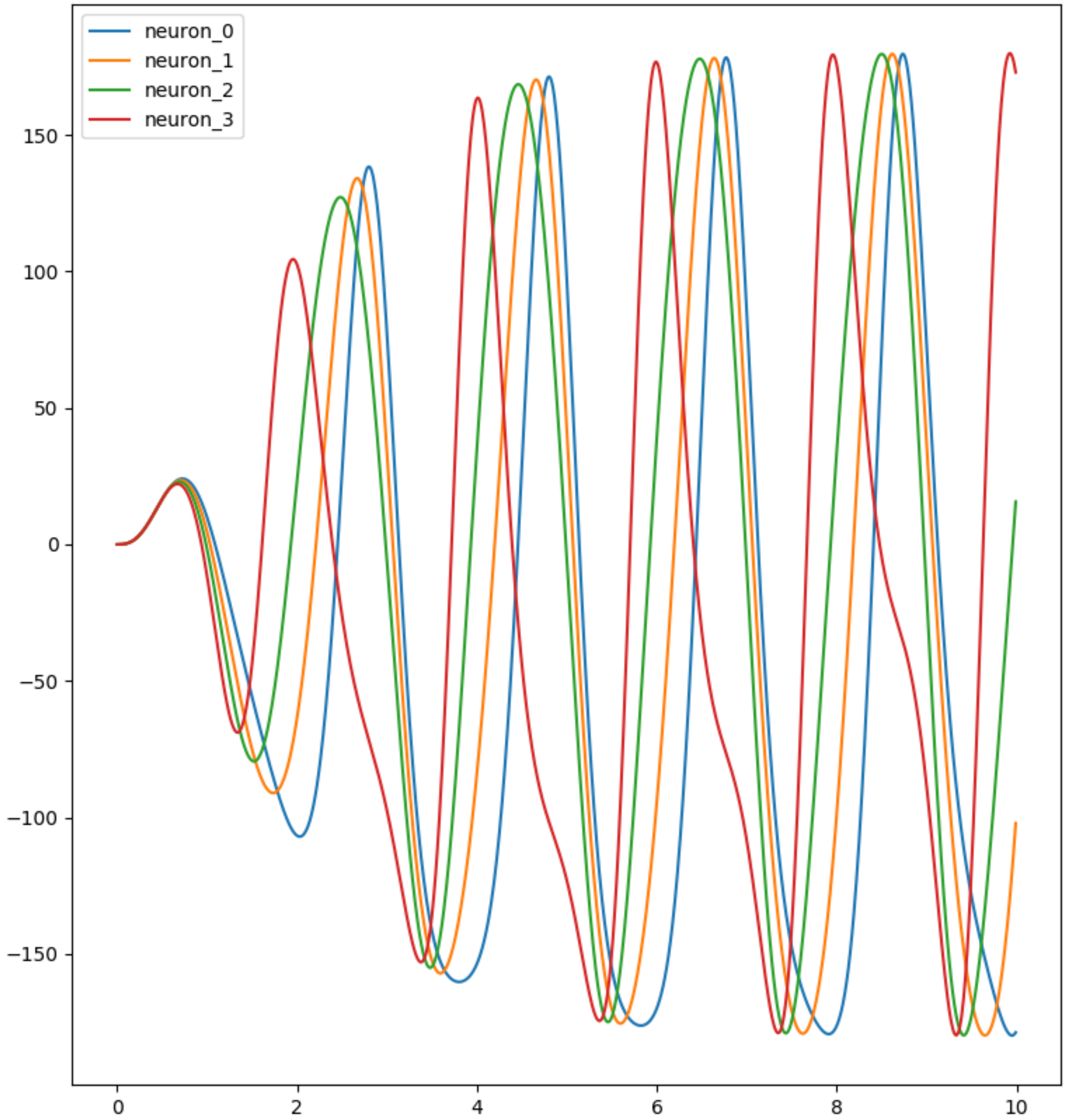


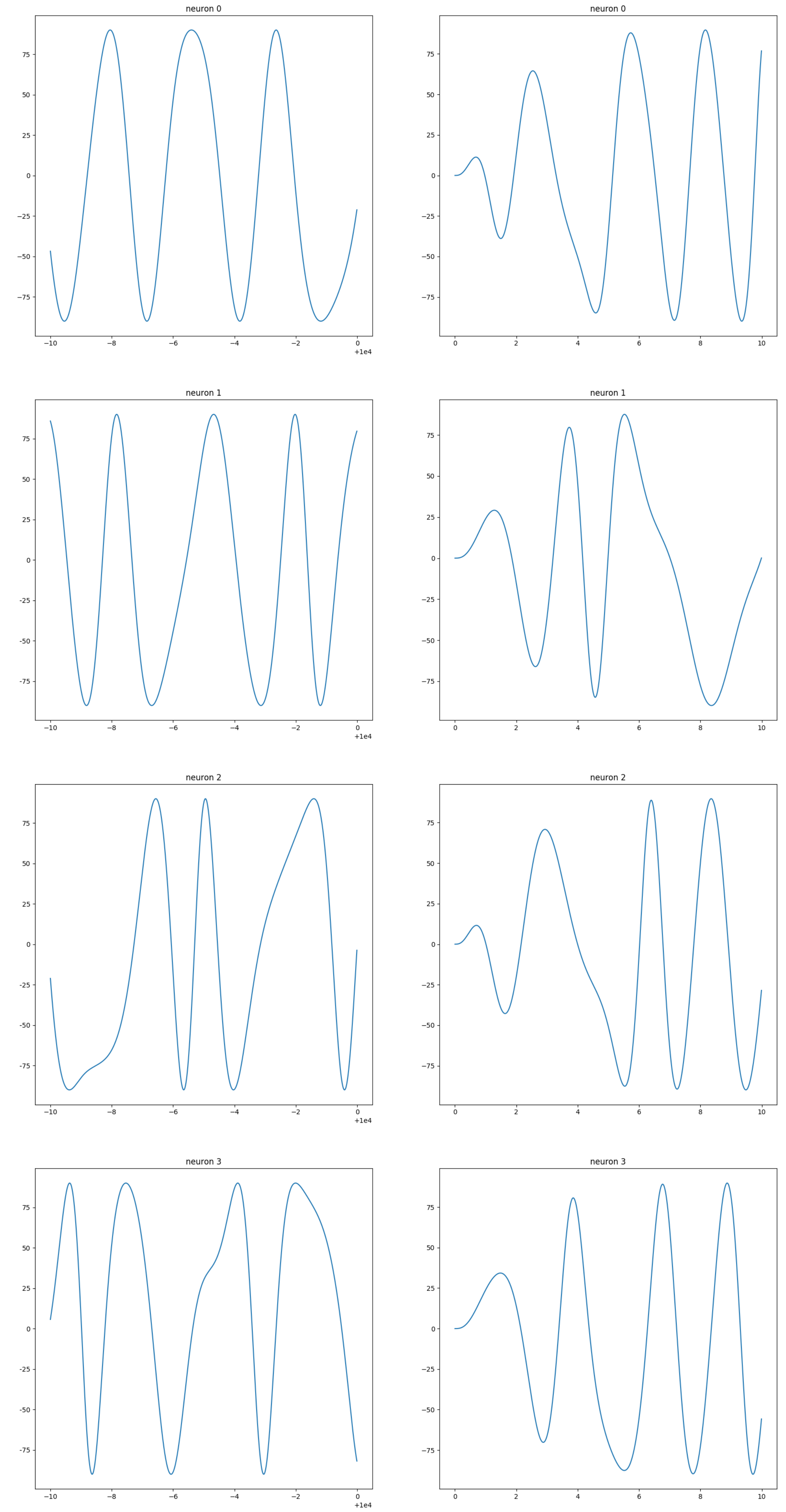
X-axis represents time; Y-axis represents signal

Experiment Results

Simulation of Kuramoto Oscillator

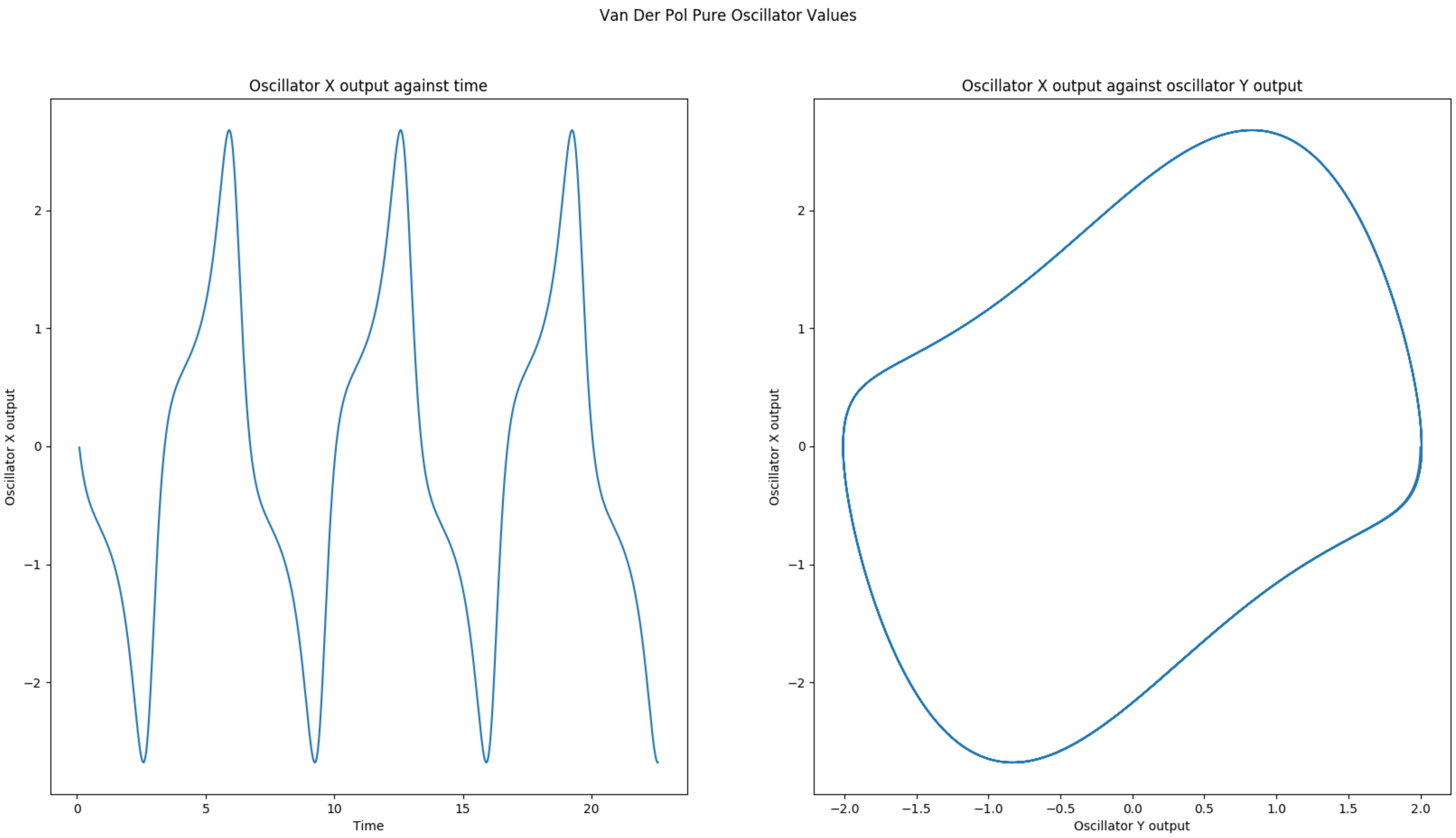






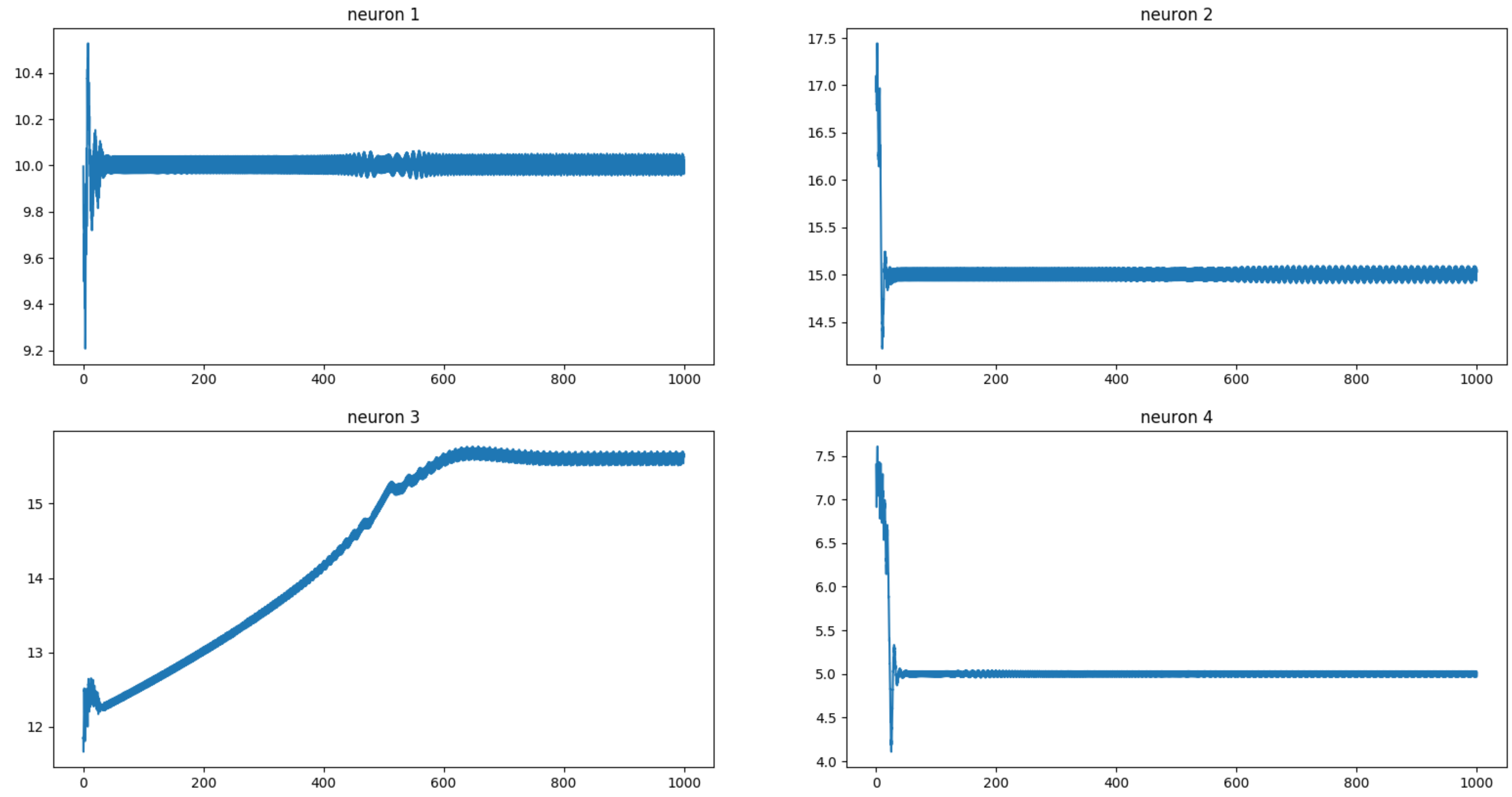
Experiment Results

Simulation of Van der Pol Oscillators



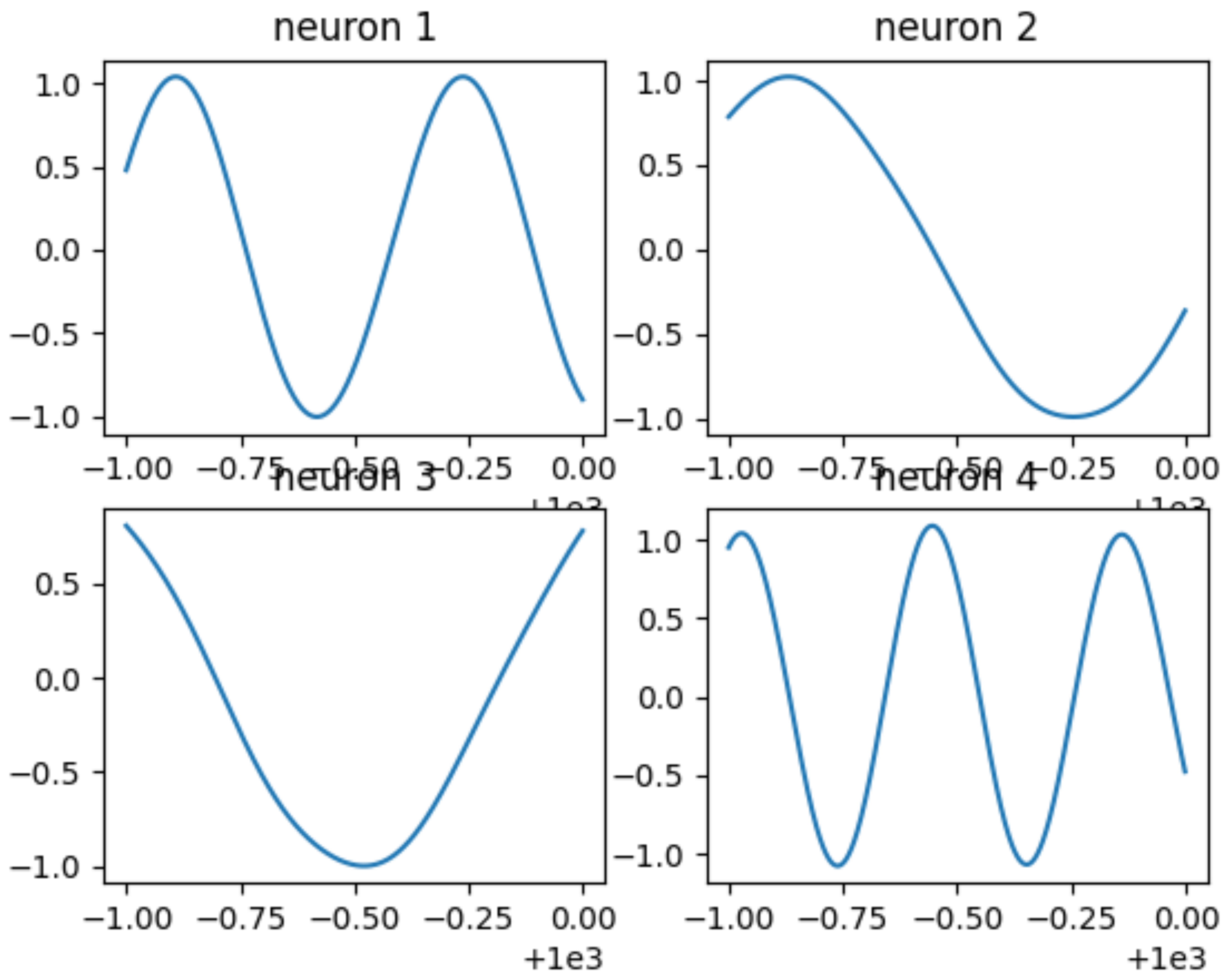
Experiment Results

Simulation of Adaptive Hopf Oscillator



Experiment Results

Simulation of Adaptive Hopf Oscillator



Problem Statement

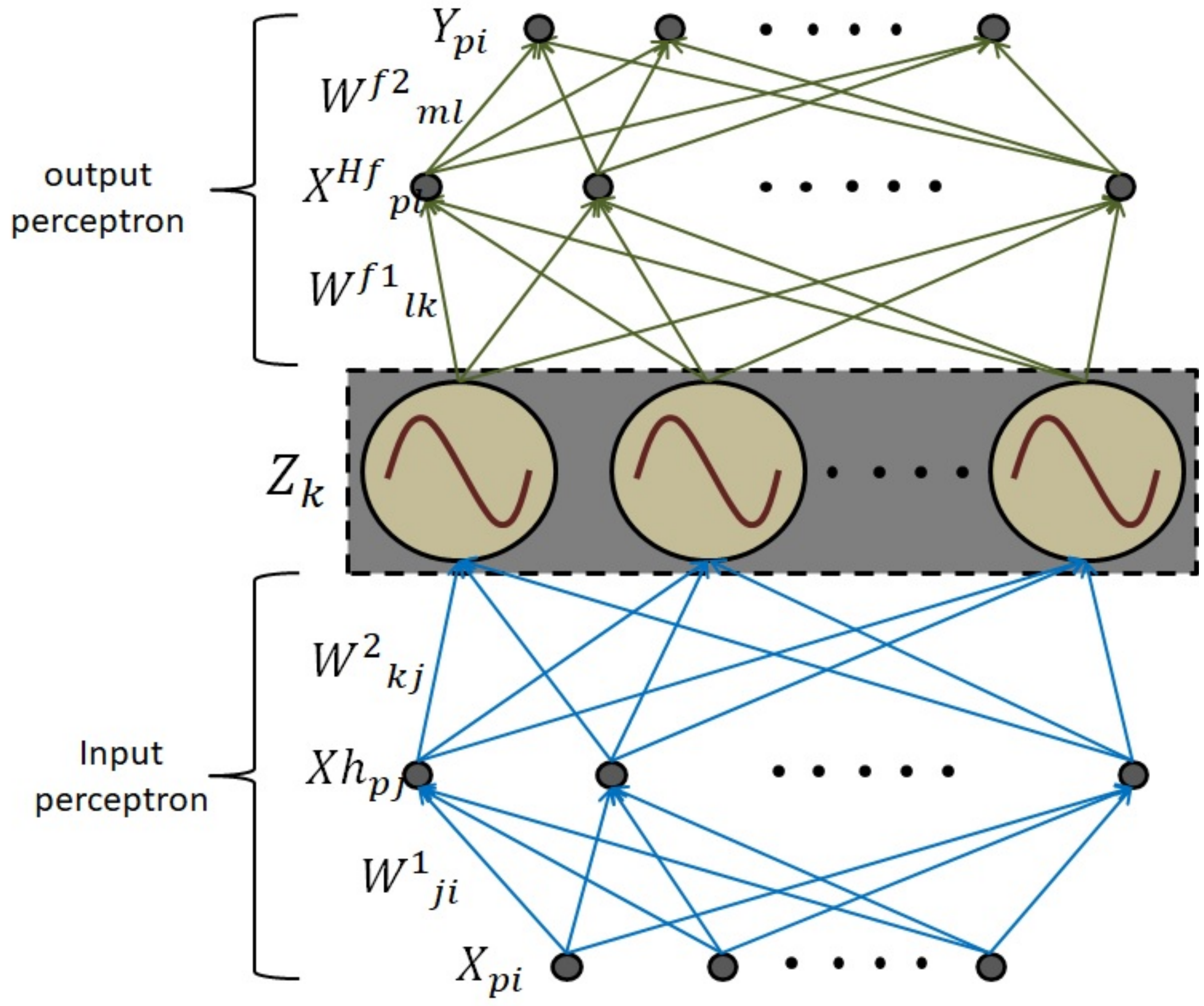
Design of Open Loop Controller

- An Open Loop Controller using the aforementioned CPG architecture requires designing a CPG parameter modulation system for each CPG designed using different neuron models
- The tuning of parameters need to be done for all Motor Programs that are to be implemented onto the quadruped
- Different parameter for a similar architecture with different neuron model would lead to a specific CPG parameter modulation system for each neuron model

Proposed CPG

Design of Open Loop Controller

- The proposed CPG integrates the CPG parameter modulation into the CPG itself
- The same CPG given sufficient training can generate signals for any given input control parameter
- The proposed design based on the ability of neurons to synchronise to a natural frequency
- CPG to be trained in a supervised manner
- Currently synthesising data for different gaits to train this model



Integration of Sensor Feedback

Image Sensor

- Data from Image sensor can be used to implement scene understanding abilities into the robot
- Images can also be used to detect objects and implement obstacle avoiding abilities
- High sensitivity for low-light operation, low operating voltage for embedded application, standard SCCB interface compatible with I2C interface, with AL422 3M-Bits FIFO, raw RGB, RGB (GRB4:2:2, RGB565/555/444),YUV(4:2:2) and YCbCr(4:2:2) output format, support VGA, CIF and from CIF to 40 x 30 format

Integration of Sensor Feedback

Ultrasonic Sensor

- Ultrasonic sensor can help in detecting obstacle, mapping the surrounding etc.
- Most common use is depth perception, can be used to map the immediate ground
- Sensor angle of 15 degrees and can detect objects in a range of 2 cm to 450 cm

Integration of Sensor Feedback

Fusion of two sensor Modalities

- Fusion of the two aforementioned sensor modalities can be used to improve the perceptive abilities of the robot
- Need for a design of a sensor data fusion system
- The proposed fusion system would, given the information from sensors output the modified control parameters to be input the proposed CPG
- Image data to be passed through a Deep CNN to extract relevant features for the fusion system
- Need to design a similar feature extraction system for ultrasonic sensor

Search and Path Planning Algorithm

- Search and Path Planning to be done using Reinforcement Learning algorithms
- More detailed Literature survey to be performed for development of this module

References

1. Pattern generators with sensory feedback for the control of quadruped locomotion; Ludovic Righetti and Auke Jan Ijspeert
2. CPG modulation for navigation and omnidirectional quadruped locomotion; Cristina P. Santos, Vítor Matos
3. CPG Driven Locomotion Control of Quadruped Robot; Chengju Liu, Yifei Chen, Jiaqi Zhang and Qijun Chen