Quadruped Locomotion

Development of a neuro-inspired control system for quadrupeds to emulate sensorimotor processes in animals

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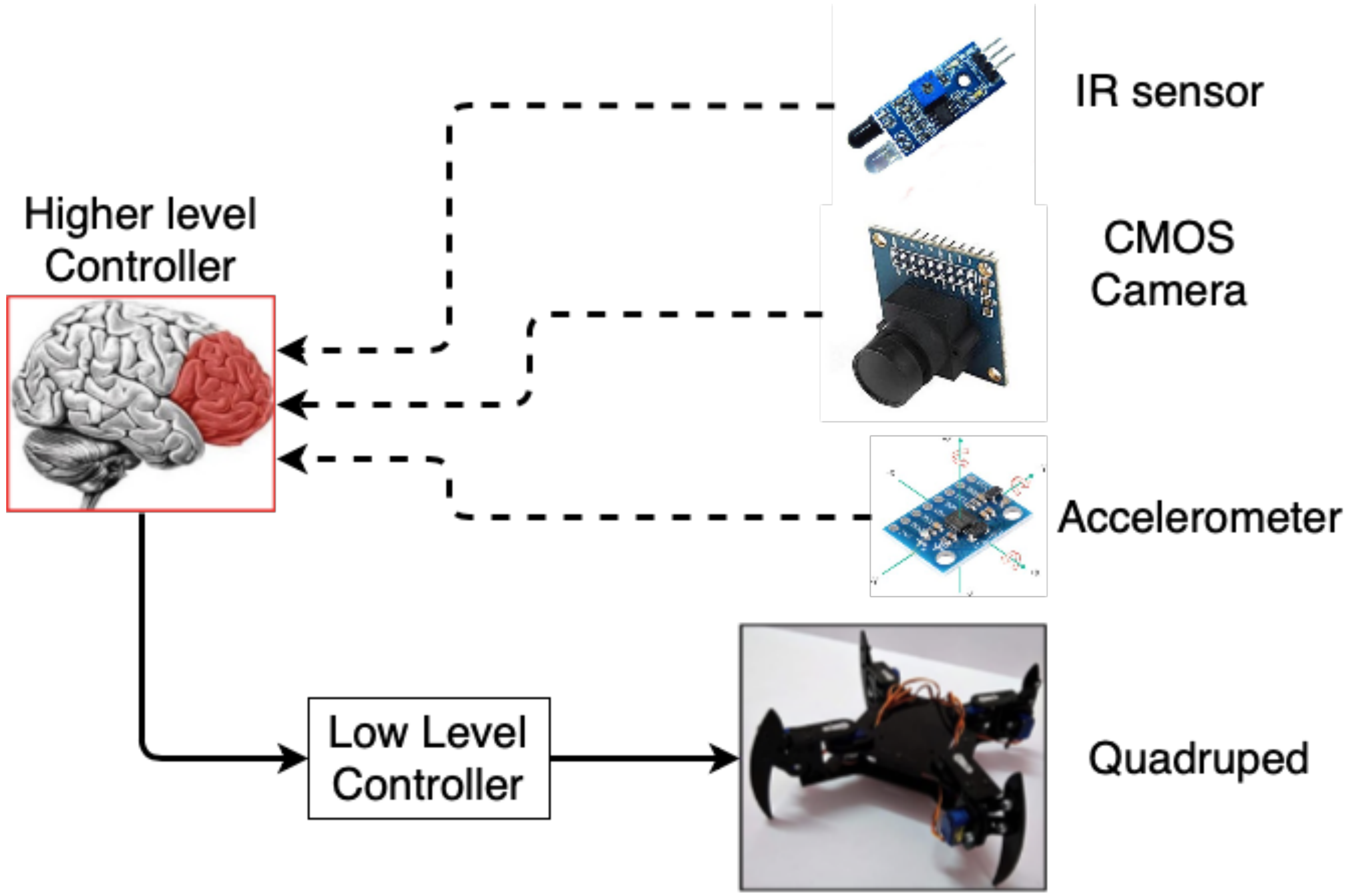
Introduction

Background

Animals are highly adept at locomotion and navigation under challenging terrains, capable of responding to a sudden stimulus with extraordinary agility and dexterity. They exhibit behaviour like gait switching, rapid acceleration and deceleration, evasive manoeuvres, climbing, jumping and search. The seamless transition between different behaviours and agile response to an incoming stimulus resulted from the evolution of neural pathways for adaptive locomotion, perception and embodied decision making. A model of such integrated sensorimotor processing can provide greater autonomy and deftness to robotic locomotion and navigation.

System Description



Methods and Materials

A Comparative Study

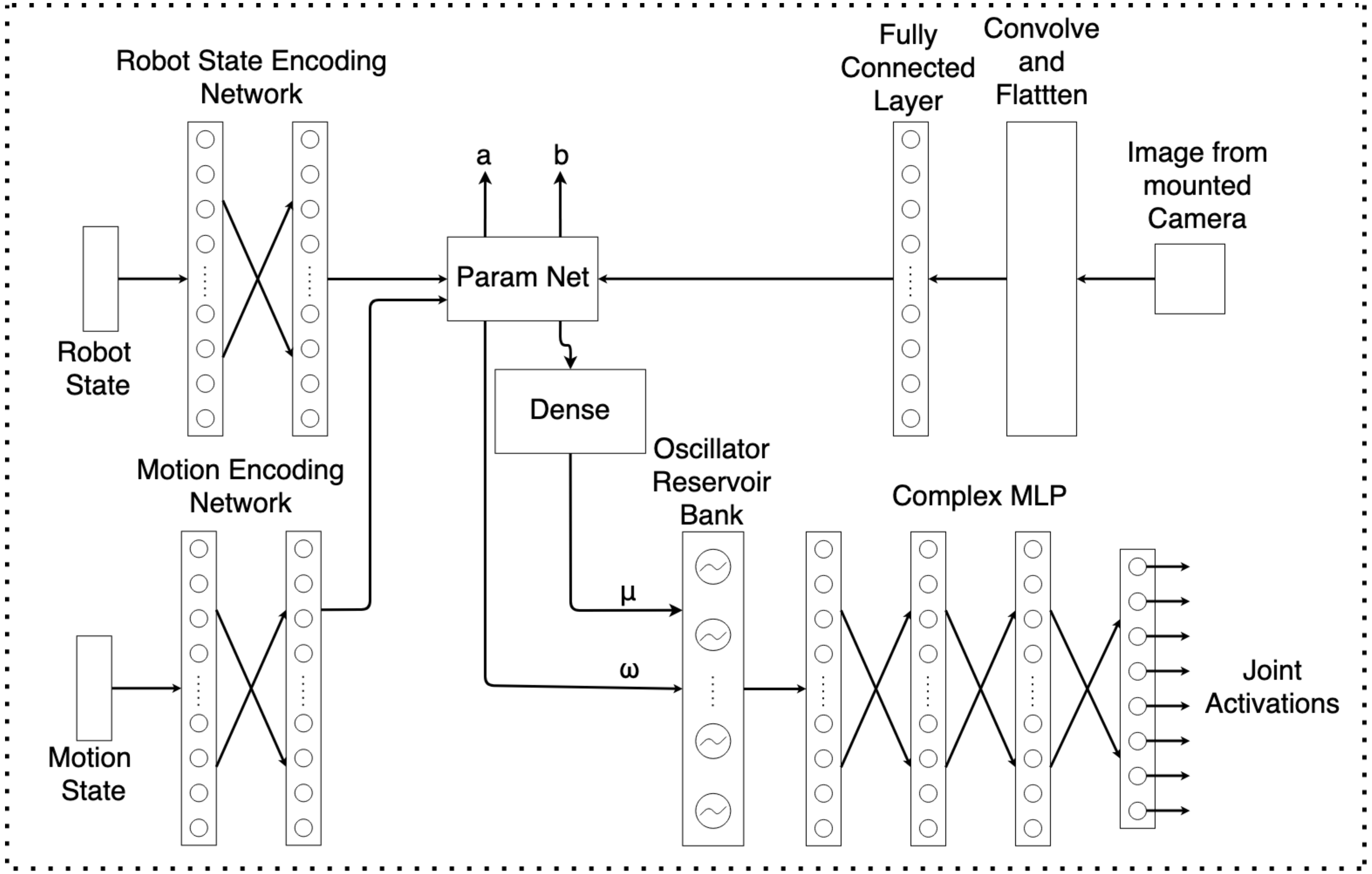
A Comparative Study between three approaches to low level control using neural networks was performed. The three studied architectures were as follows:

1. A feedforward DNN-CPG architecture

2. A fully connected feedforward architecture

3. A CPG architecture using Modified Hopf Oscillator

DNN-CPG Architecture



Methods and Materials

Modified Hopf Oscillator

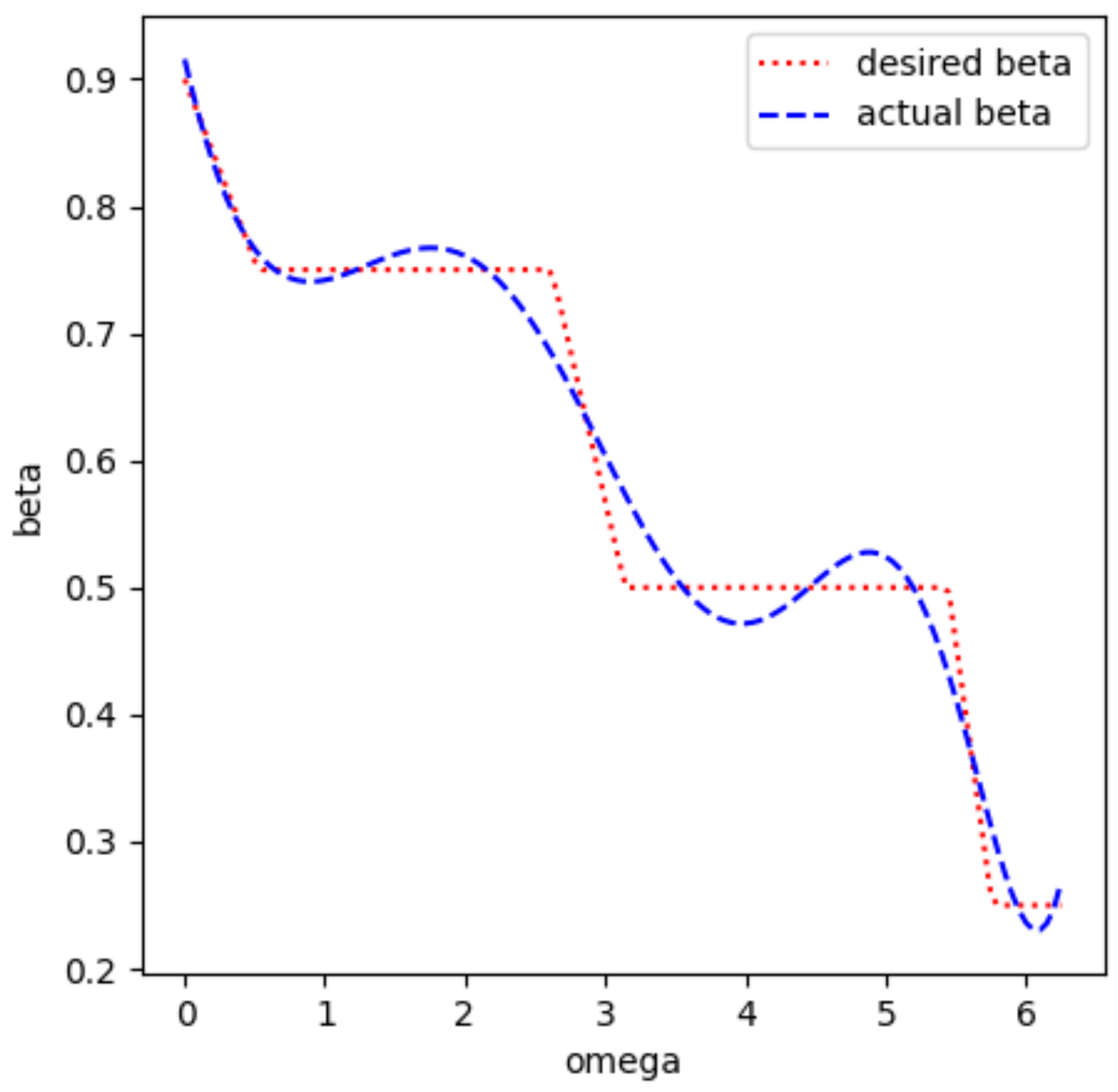
A Hopf Oscillator with a switching frequency was formulated to directly produce joint activations.

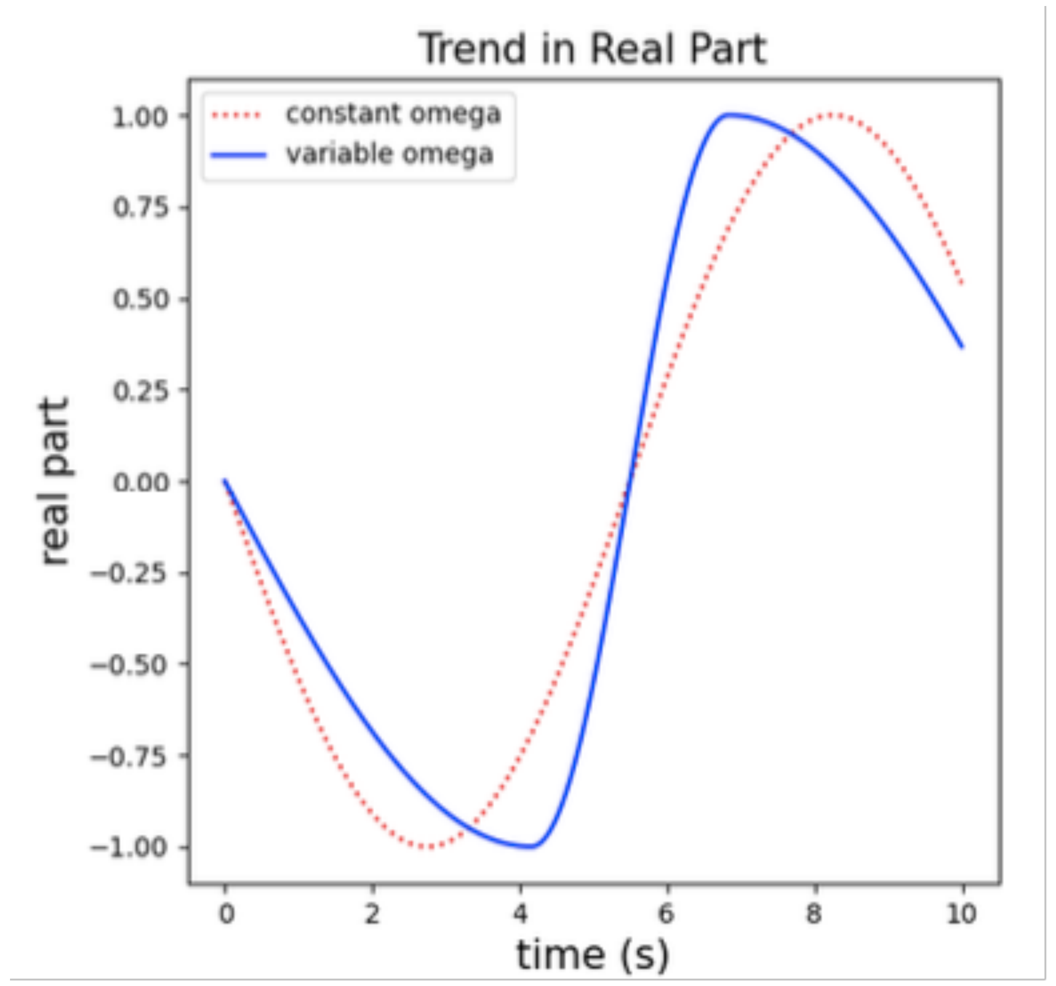
$$\dot{r} = (\mu_\circ - r^2)r$$

$$\dot{\phi} = \omega$$

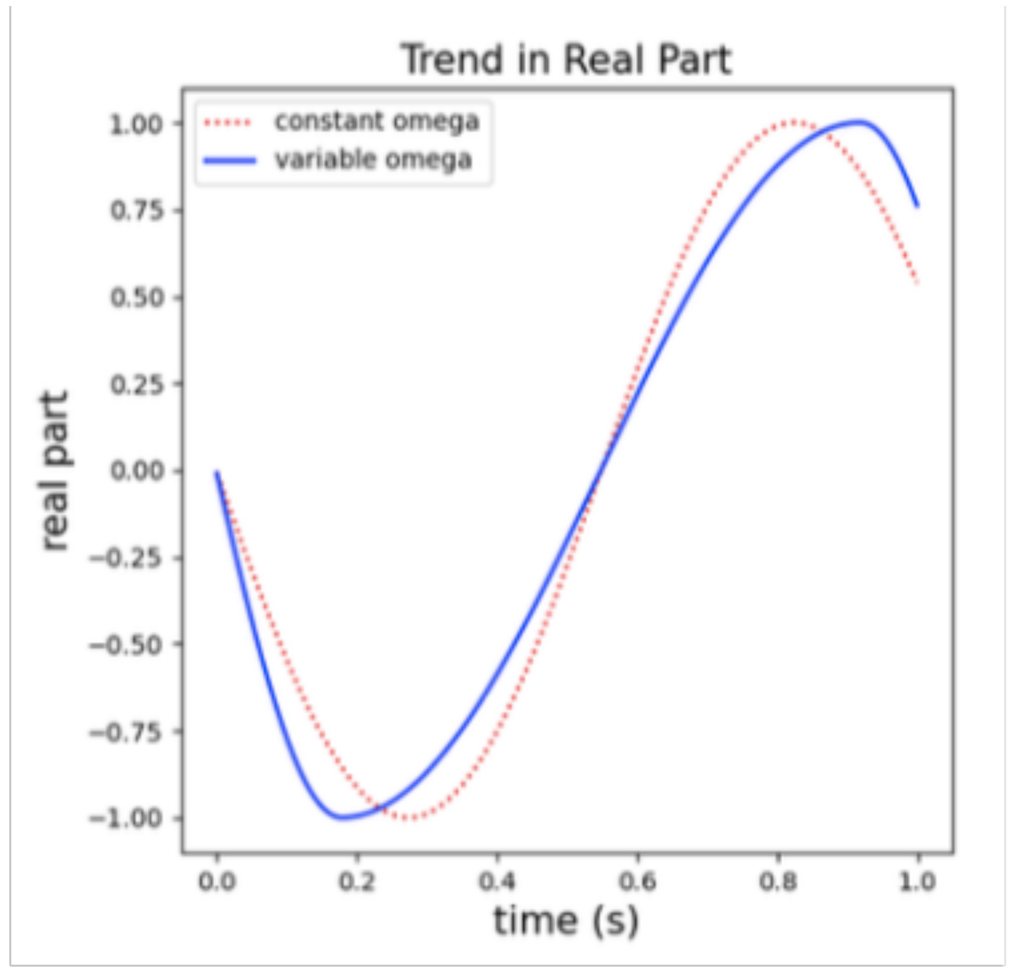
$$\beta = \sum_{i=0}^{i=N} a_i \left|\omega_\circ\right|^i$$

$$\omega = \left|\omega_\circ\right| \times \left(\left| \frac{1}{2\beta(1-\beta)} \right| + \frac{(1-2\beta)}{2\beta(1-\beta)} \times tanh\left(10^3\phi\right) \right)$$

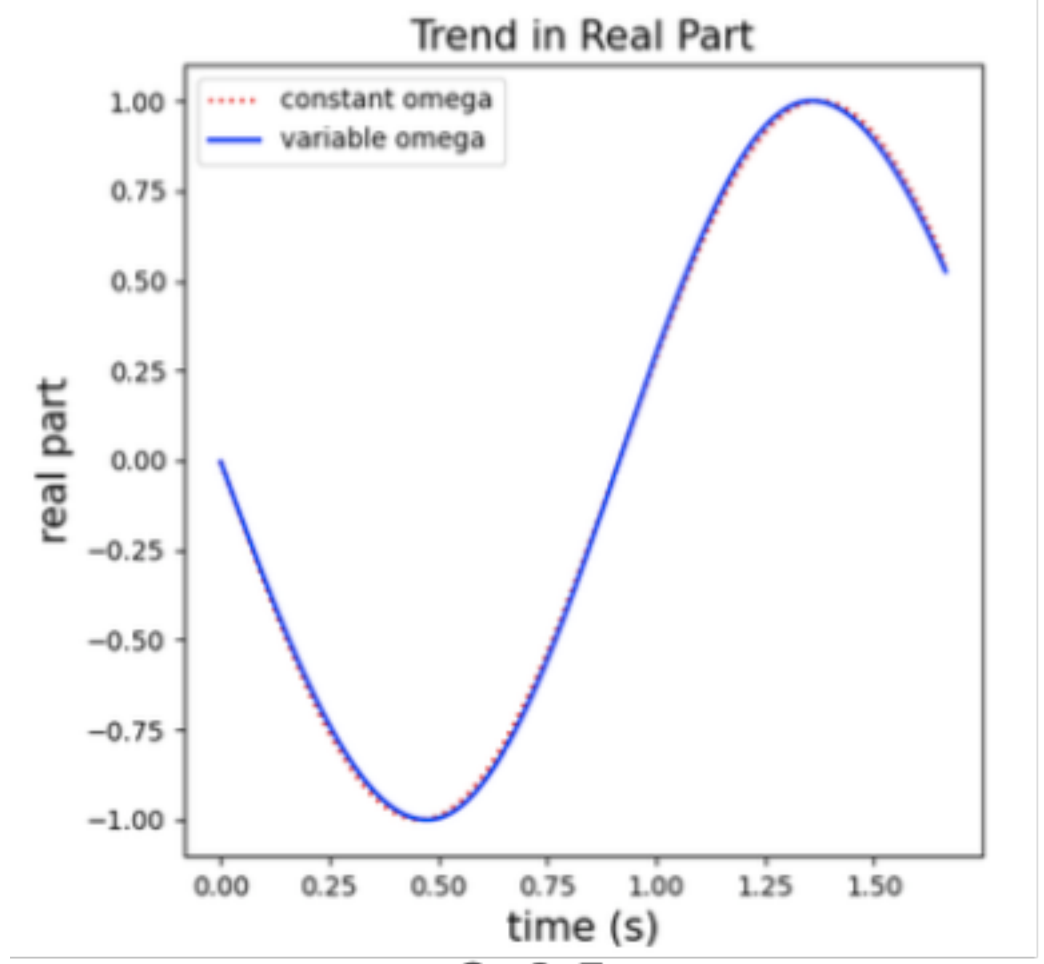




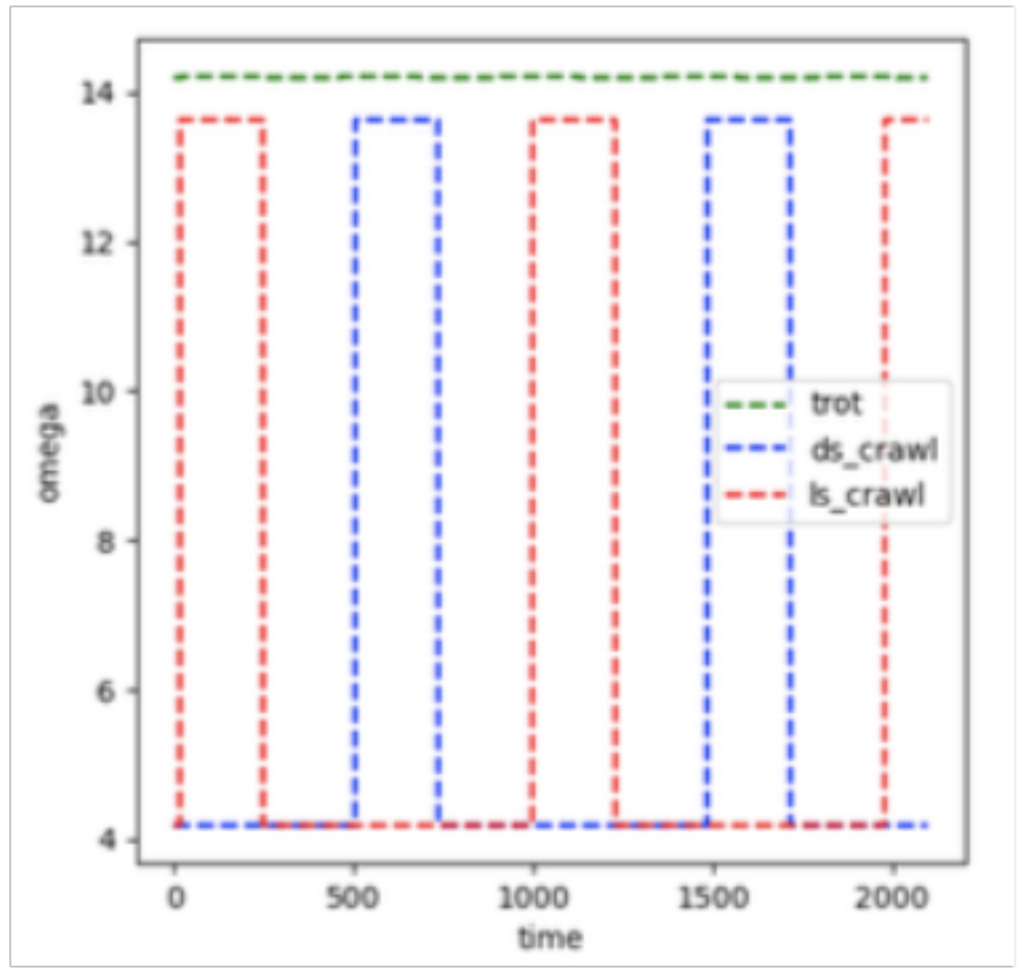
β=0.75



β=0.25



β=0.5



Frequency switching seen in different gaits

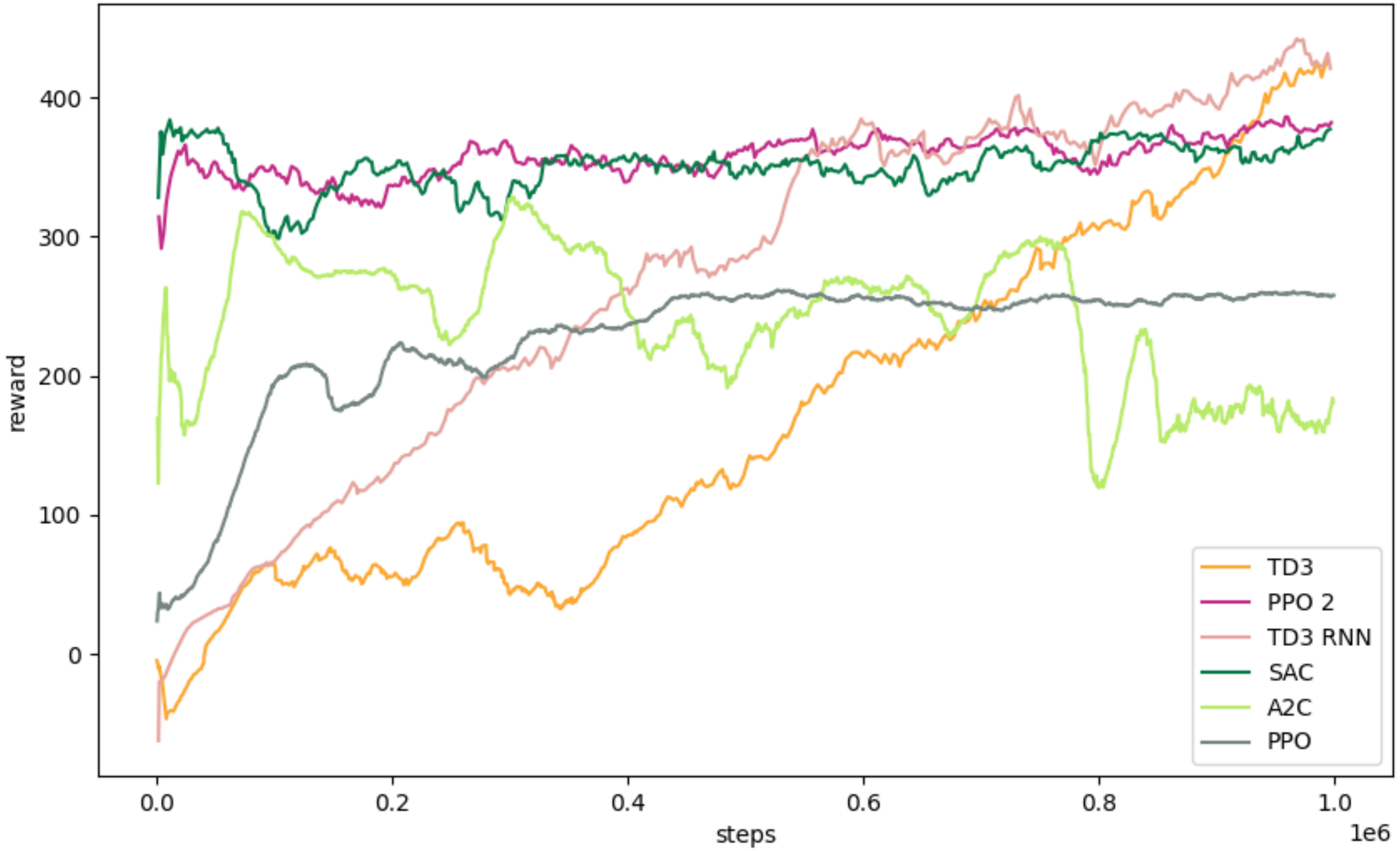
Results

Reinforcement Learning

- Reinforcement Learning Optimisation of Neural Network parameters was performed for the DNN-CPG architecture and the fully connected feedforward architecture

- Models failed to learn a meaningful sequence of actions to make the quadruped move in the desired directions

- Stochastic Algorithms learnt random movement, whereas Deterministic Algorithms found no movement to be the optimum solution.



Conclusion & Future Works

- Failure of the DNN-CPG and the fully connected feedforward architectures using Reinforcement Learning points to the need for restructuring the action space

- The Engineered solution using the CPG architecture exhibits complex behaviours such as variable speeds and gait transition by variation of the CPG parameters

- One to One mapping between the CPG parameters and the motion state of the quadruped can be observed and such a mapping can be easily learnt using Deep Learning/Reinforcement Learning using the shown architecture

DNN-CPG with Modified Hopf Oscillators