# Modelling of the Neuronal Responses of Identified Motor Neurons Across Animals

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## Design and application of ANNs to neuronal responses in insects


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## Introduction

**Identified neurons** are neurons with similar or identical dynamical properties [2]. Neurons have been identified so far in small species, including insects, but not all of them have been discovered yet.

Chordotonal organs in insects monitor leg angle and position, velocity and acceleration of leg movements [6]. The **Femoro-tibial Chordotonal Organ (FeCO)** monitors the femur and tibia joint in the locust hind leg (see Fig. 1).

The **reflex control system** corrects the position of the leg when movement is imposed. When a displacement is detected, the FeCO apodeme and flexor strand transmit the movement to the sensory neurons in the FeCO, which excite the motor neurons.

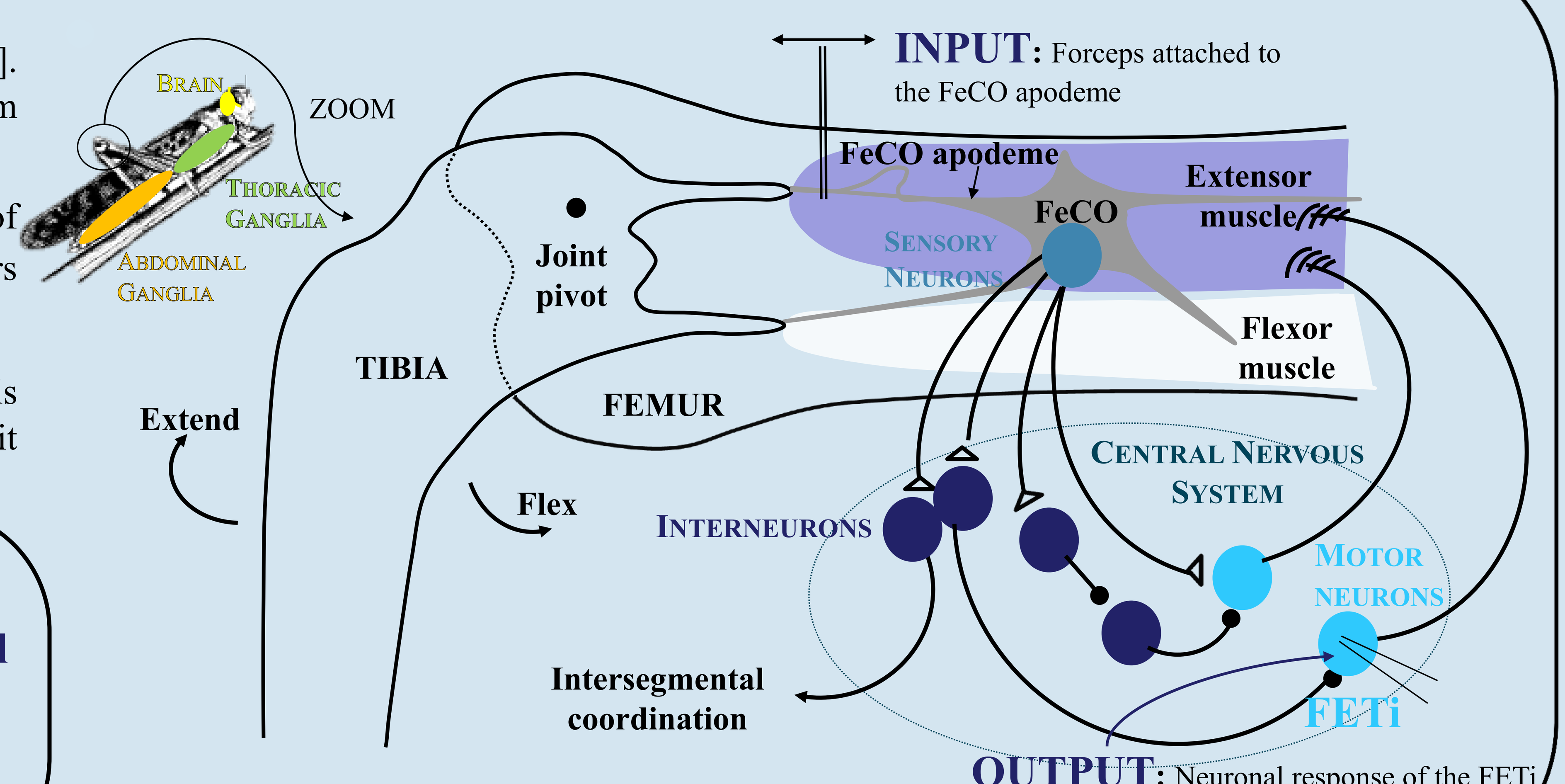


Fig. 1. Central nervous system [3] and zoom to the reflex control system of the hind leg of the locust.

## Objectives

- **Design an ANN able to predict the FETi response of any mechanical input applied in the FeCO apodeme in any animal.**
- **Compare the behaviour of identified motor neurons across animals.**
- **Assess the accuracy of the models.**

## Methods

ANNs have been designed through a **metaheuristic algorithm** [7] combining Evolutionary Programming (**EP**) [4] and Particle Swarm Optimization (**PSO**) [8]. The steps of this algorithm are shown in Fig. 2. The algorithm optimises the architecture of ANNs to that with higher performance and smaller size. This optimisation follows the **fitness function** [1]:

$$f(\eta) = \frac{100}{MSE_\eta\,(\%)} e^{(0.01 \cdot n(\eta))}$$

Where $f(\eta)$ is the fitness for each network $\eta$, $n(\eta)$ the number of nodes and $MSE_\eta$ (%) the % **Mean Square Error**, which describes its performance:

$$MSE_\eta(\%) = 100 \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{\sum_{i=1}^{n}(y_i)^2}$$

Where $y_i$ is the measured output in the FETi and $\hat{y}_i$ the estimated output.

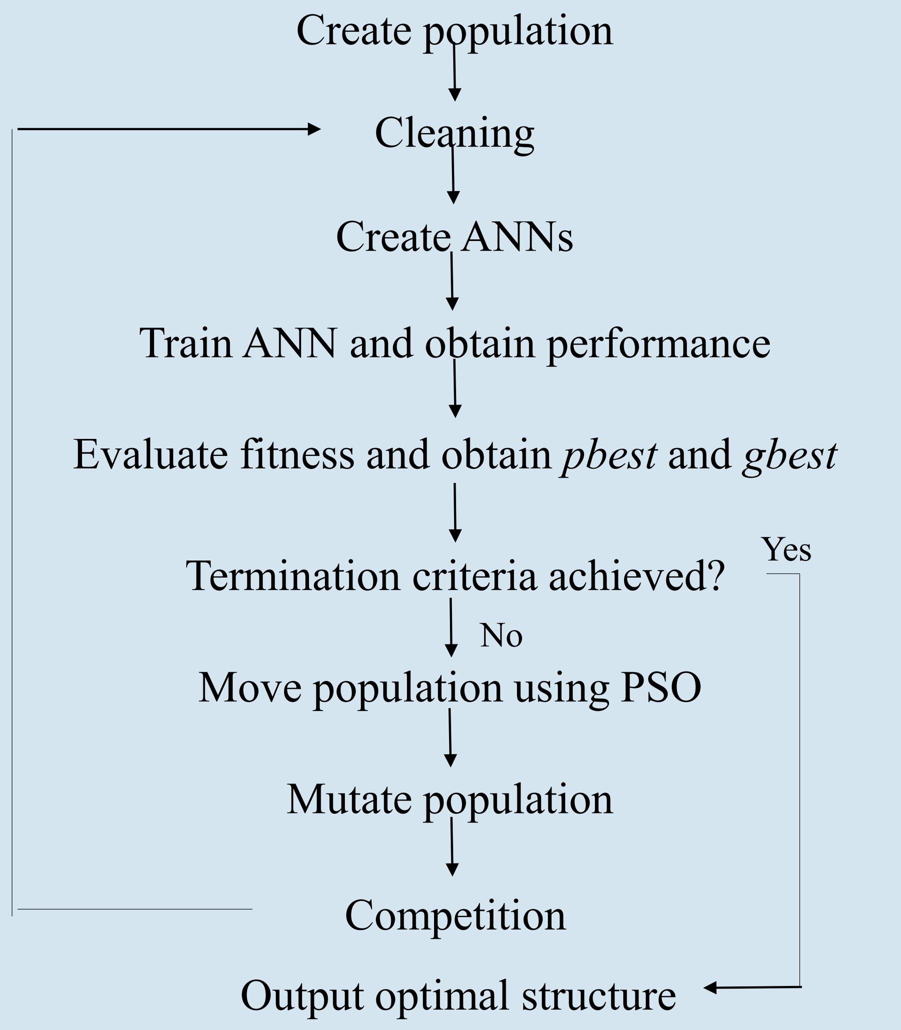


Fig. 2. Flow chart of the metaheuristic algorithm proposed to designed the ANN.

## Results

The algorithm has been applied to three animals so far and has been tested, with six animals and different types of input data (50Hz-band-limited GWN, 1Hz, 2Hz, 4Hz, 5Hz and three different walking inputs obtained from experiments recording locusts walking [4]).

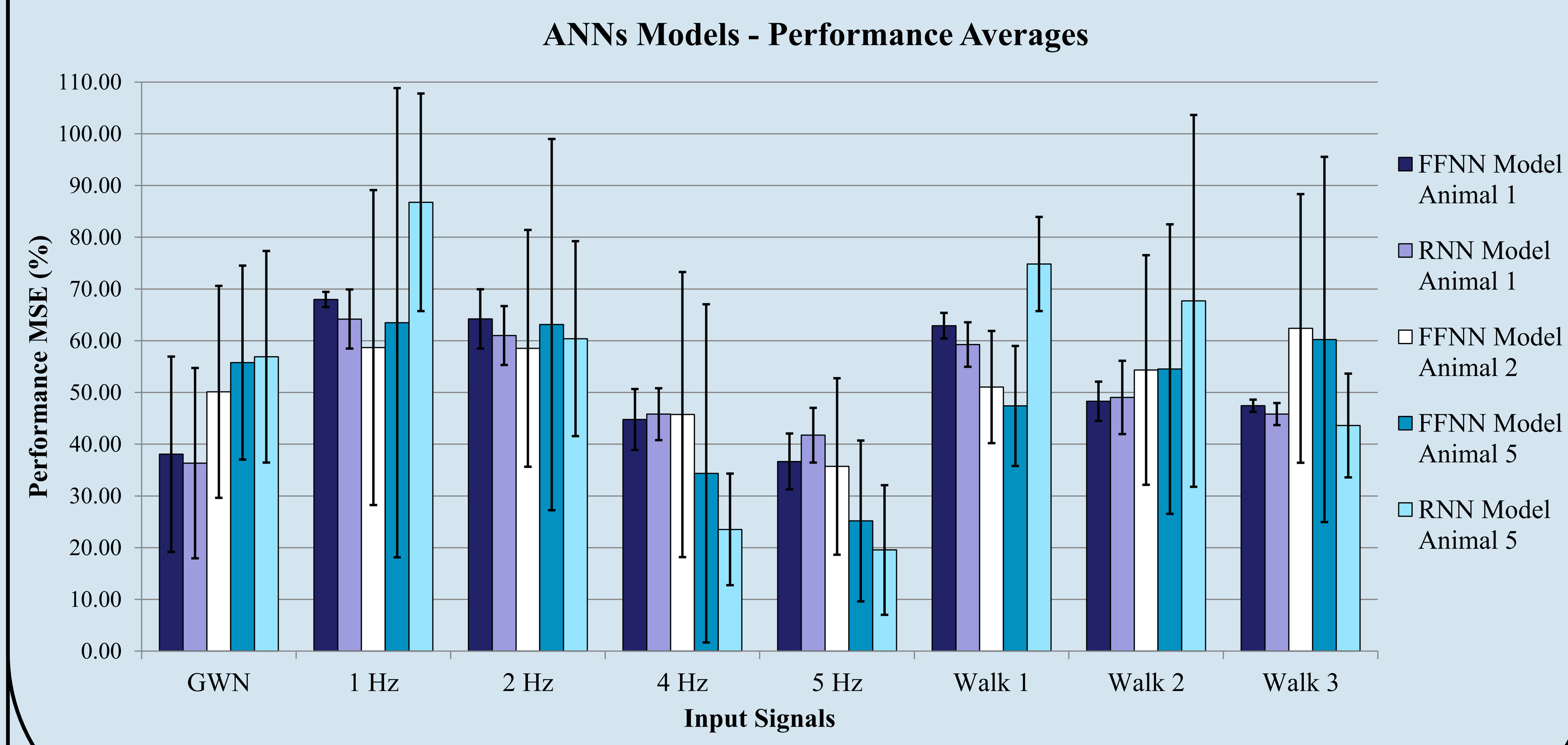


Fig. 3. Averages of the models from animals 1, 2 and 5 when applied to all the available animals.

## Conclusions

The results show that the models are **able to predict the response of the FETi motor neuron across animals** with certain accuracy, implying that there is a common underlying function to all animals. However, the MSE of the predictions show that there are high levels of **spontaneous neuronal activity**, inherent to each individual, which increase the errors in the predictions.

It is suspected that the spectrum of the errors corresponds to these variations in each animal. Since the spontaneous neuronal activity is not correlated with the stimulus applied in the FeCO they are **impossible to predict**. Therefore, the MSE (%) performance test would never reach 0%, and another performance evaluation should be looked at.

The performances of the models are similar between each other. This suggests that any model designed with data from just one animal might over-fit the noise of that particular animal. However, a model designed with a **combination** of data from different animals would be able to detect the **common function**, filtering the spontaneous neuronal activity from each individual.


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