NERVOUS ROBOT

Biologically Inspired Spiking Neural Network for Autonomous Robot Control

What?

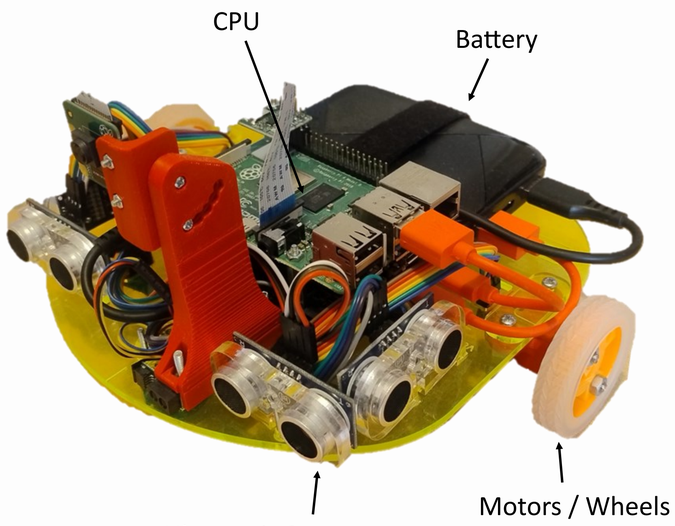
A project to develop a central control system utilising spiking neural networks, experimenting with exploration and obstacle avoidance behaviours for use on a robot.

Why?

This robot project has been carried out to explore the possibilities of designing a system which replaces the need for traditional control algorithms and use biologically inspired spiking neural networks to achieve event driven behaviours allowing a robot to explore its environment whilst employing obstacle avoidance.

How?

Design of a set of spiking neural microcircuits will enable a range of reactive behaviours based upon the sensors onboard the robot.



About the Robot:

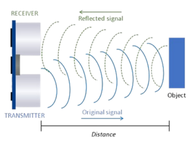
The robots simple hardware design enables easy decisions to be made when choosing the desired behaviours.

- Two independent motors/wheels with a castor wheel to balance the robot
- Onboard battery power supply
- Ultrasonic sensors facing varying directions are used which provide long distance reliable measurements

CPU

Low level Arduino running a RTOS for efficient communication with peripherals

Raspberry Pi for SNN and more functionality



Sensors

Ultrasonic sensors for long range accurate distance measurements

Motors

Differential drive robot Variable speed and independent control on each motor

CPU:

- Arduino Nano running RTOS
- Raspberry Pi providing computing power for SNN
- Connected via serial UART connection

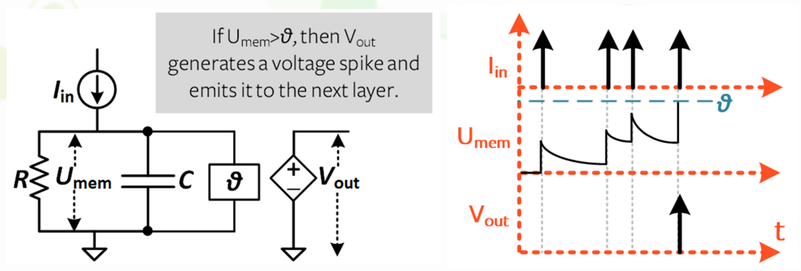
Software:

- C++, fast and efficient on the Nano
- Python, flexibility and wide range of libraries

Spiking Neural Networks

Spiking neural networks (SNN) are a type of artificial neural network which aim to more naturally represent a biological nervous system and allow for more unique event driven autonomous behaviours over traditional algorithms.

The Leaky integrate & fire model (LIF) shown below, is the most basic model of a neuron and synapse, and has been used in this project



A state machine was designed to aid with the thought process of the robot's behaviours.

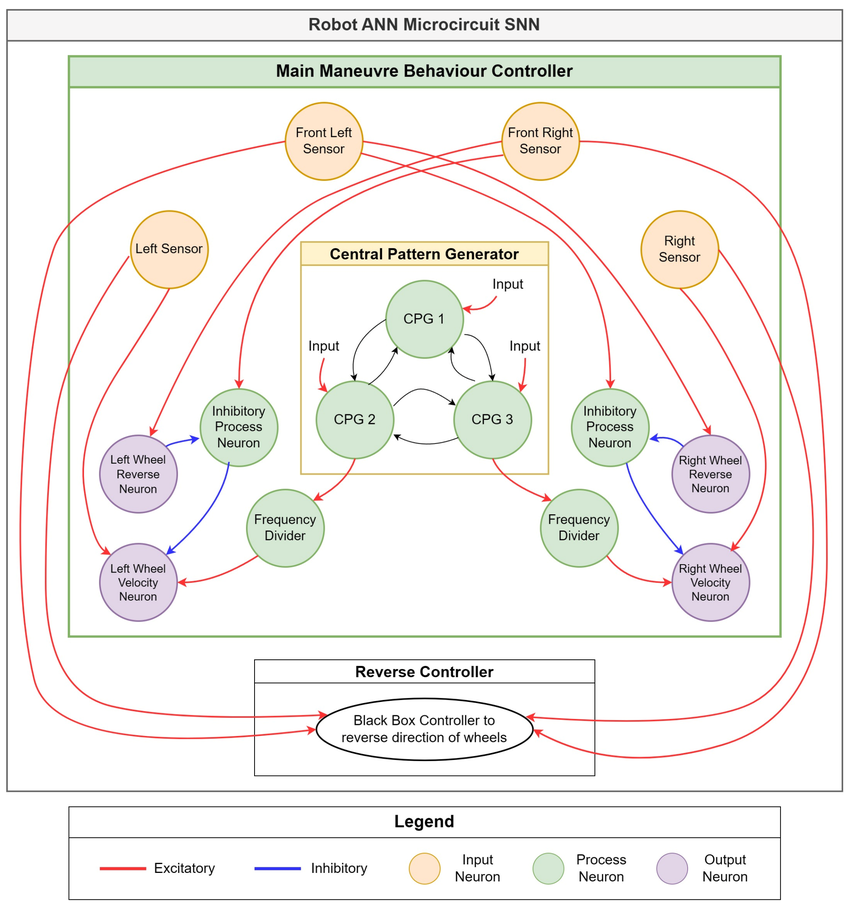
A summary of the states is as follows:

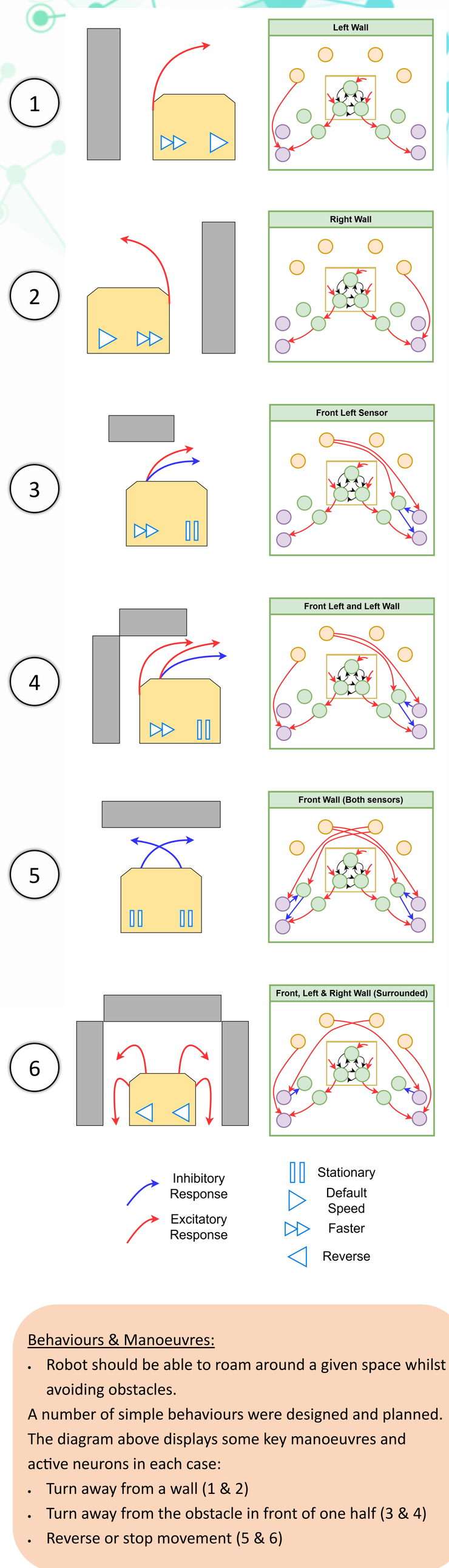
- Setup the SNN
- Read the sensor measurements
- Set neuron characteristics from measurements
- Run SNN
- Determine direction and speed to move
- Move direction and set speed

Later on this state machine was reduced in complexity to allow for a more event driven operation of the robot.

Spiking Neural Network Diagram:

- Visualisation of the neurons and synapses connected together
- Defines the structure of the network and it's connections that are present on the robot





Behaviours & Manoeuvres:

- Robot should be able to roam around a given space whilst avoiding obstacles.

A number of simple behaviours were designed and planned. The diagram above displays some key manoeuvres and active neurons in each case:

- Turn away from a wall (1 & 2)
- Turn away from the obstacle in front of one half (3 & 4)
- Reverse or stop movement (5 & 6)

Summary:

From experimenting and testing the robot after implementing the code, it has been shown that the use of SNNs has been successful in providing a control system for exploration and obstacle avoidance on an autonomous robot.

- A simple but modular network design allowed for ease of development with plenty of customisability.
- Expansion to provide extra functionality is possible.
- The majority of the implementation utilising the Raspberry Pi provided a suitable level of control.
- Delays between the sensors and the robots decision/movement have been experienced. A number of possibilities for improvement could be explored.

UNIVERSITY of York

William Betteridge, Andy M. Tyrrell, Andrew Walter, Martin Trefzer, Shimeng Wu

School of Physics, Engineering & Technology University of York

Contact: wab513@york.ac.uk