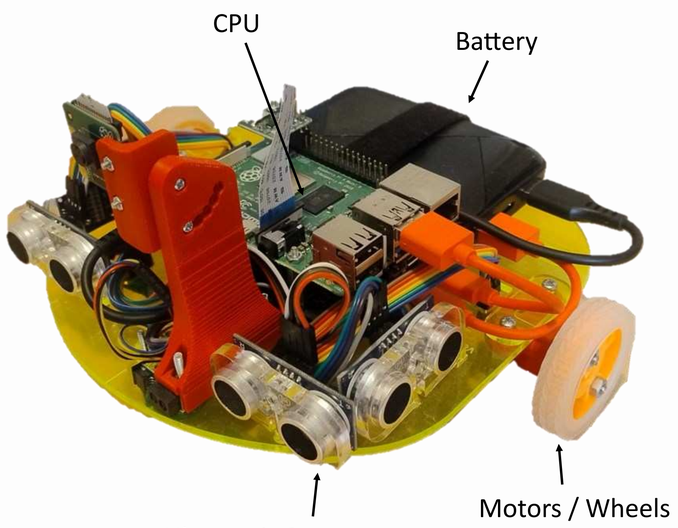
Biologically Inspired Spiking Neural Network for Autonomous Robot Control

What?
This work reports on the development of a central control system utilising spiking neural networks, experimenting with exploration and obstacle avoidance behaviours.

Why?
This work explores 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 neural microcircuit [1] inspired controller that will enable a range of reactive behaviours based upon the sensors onboard the robot.



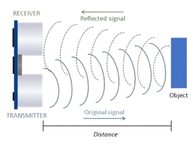
About the Robot:
The robot's simple hardware design enables easy decisions to be made when choosing the desired behaviours.

- 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

UNIVERSITY of York

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

School of Physics, Engineering & Technology
University of York

Contact:
andrew.walter@york.ac.uk

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 work

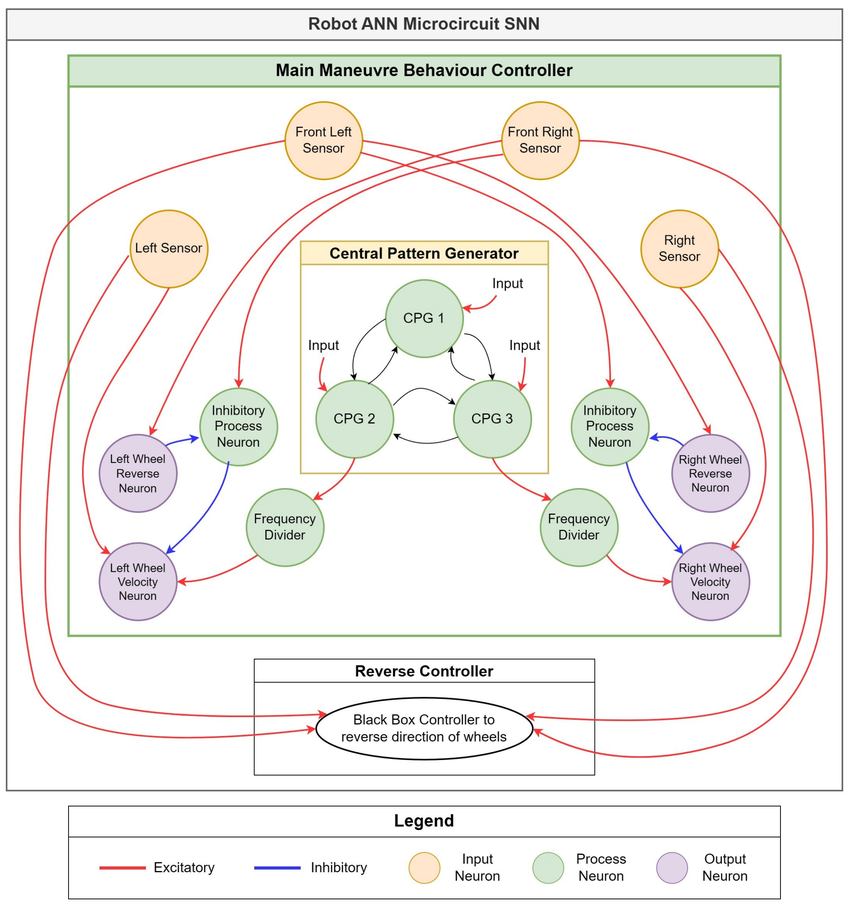
A state machine was designed to aid with the thought process of the robot's behaviours.
A summary of the states is as follows:

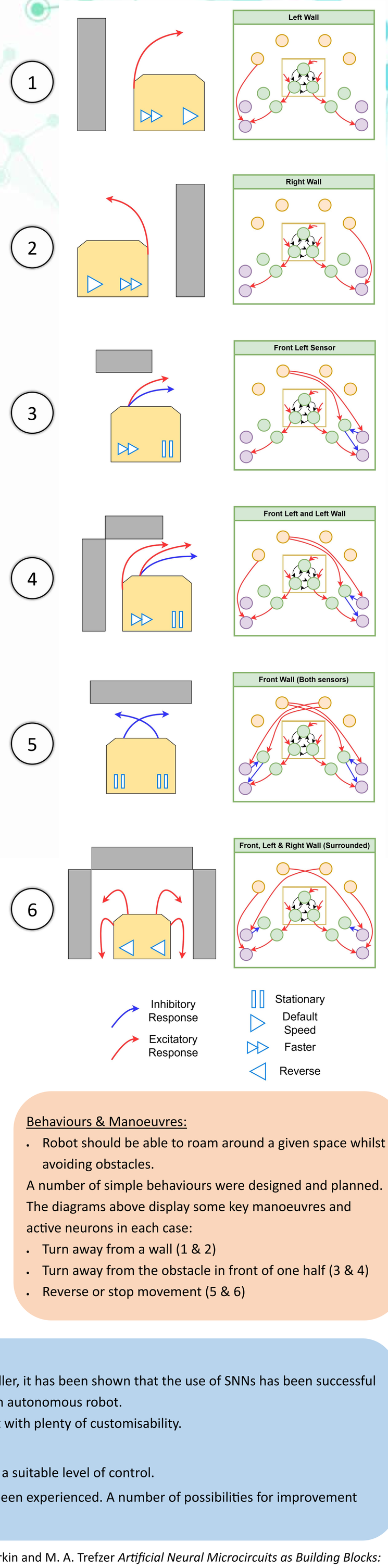
- Setup the SNN
- Read the sensor measurements
- Set neuron characteristics from measurements
- Run SNN
- Determine direction and speed to move
- Move direction and set speed

A second version of the state machine was designed that reduced in complexity to allow for a more event driven operation

Spiking Neural Network Structure (below):

- 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 diagrams above display 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 designing the SNN controller, 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.

[1] A. Walter, S. Wu, A. M. Tyrrell, L. McDaid, M. McElholm, N. T. Sumithran, J. Harkin and M. A. Trefzer *Artificial Neural Microcircuits as Building Blocks: Concept and Challenges* 2024 https://arxiv.org/abs/2403.16327