Memristive WTA Synapses

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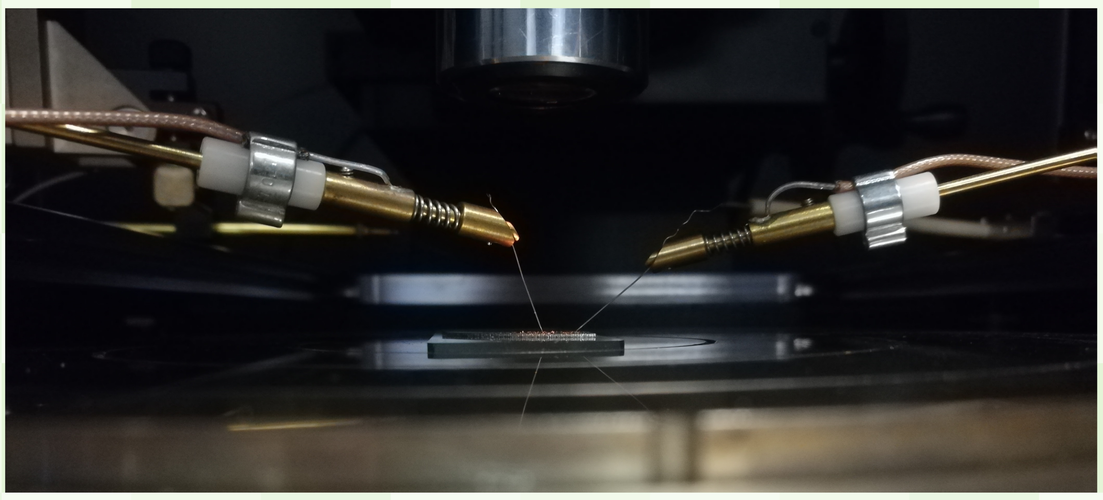
1. Overview

- In this work we demonstrate how analogue behaviours observed in memristive SiOx devices can be used to produce Winner Takes All (WTA) like computations.

- The proposed schematic is verified experimentally and then approximated with a simulation model.

- Finally, a large network of the WTA devices are simulated to demonstrate edge detection on a high contrast image.



2. Device Behaviour

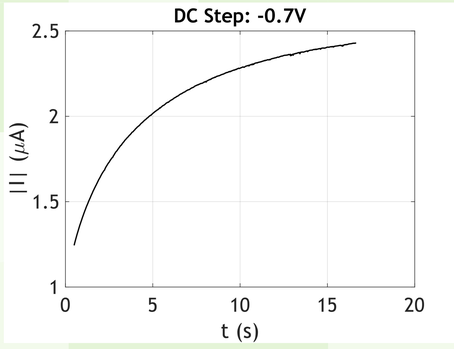
- Our devices are operated in a high resistive state with traditional switching being avoided.

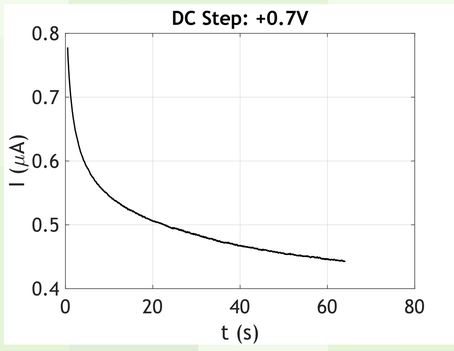
- They are formed in such a way that low level DC voltages modulate the conductance over time.

- This change is dependent on both polarity and magnitude as well as being volatile.

- Negative voltages increase the conductance whereas positive voltages reduce the conductance as shown in the graphs adjacent.

- The mechanism behind this operation is not yet understood and is currently being investigated. Initial work suggests Poole-Frenkel conduction is dominant for positive potentials whereas Schottky emission may dominate during negative potentials.





3. Schematic

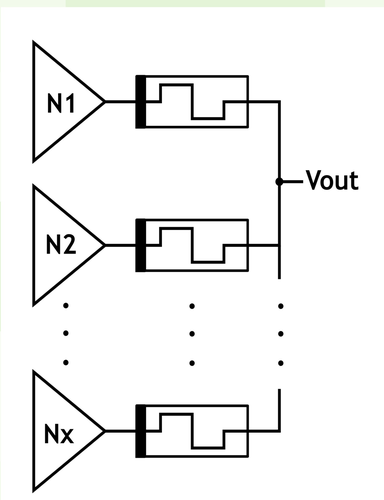
- Inputs take the form of voltage sources outputting fixed amplitude spikes with a frequency proportional to the input value.

- When a voltage source is not spiking it should pull its output to 0V.

- Each memristor associated with an input neuron is attached to a common node as shown in the adjacent figure. This node is the layer's output.

- This circuit results in a potential divider setup. When a neuron spikes the output is pulled high with a voltage proportional to the input memristor's resistance and the parallel combination of the remaining devices pulled to 0V.

- The memristors are orientated so that a firing neuron reduces its associated resistance while increasing that of the neurons that have been pulled to 0V.



4. Experimental

- The setup was tested experimentally with a Keithley 4200 characterisation unit.

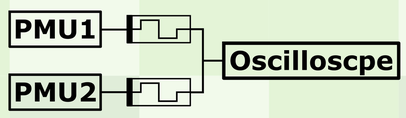
- The Keithley's Pulse Module Units (PMUs) sourced input spikes while an oscilloscope monitored the output voltage.

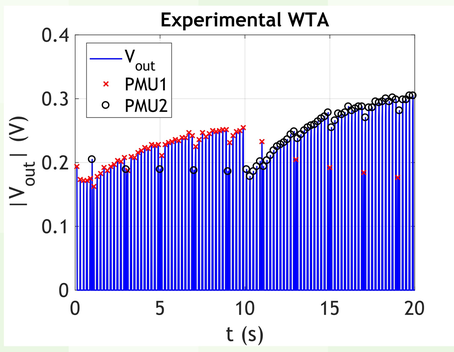
- The input frequencies of the neurons were set so that the frequency of one was much greater than the other. Halfway through, these frequencies were switched.

- The output spikes caused by the more active neuron grow over time while the output spikes caused by the lesser active are attenuated.

- When the activities of the two neurons are switched we can see the behaviour of the output reverses, as intended.

- The more active neuron's outputs are transmitted with a higher efficiency than those of the less active.



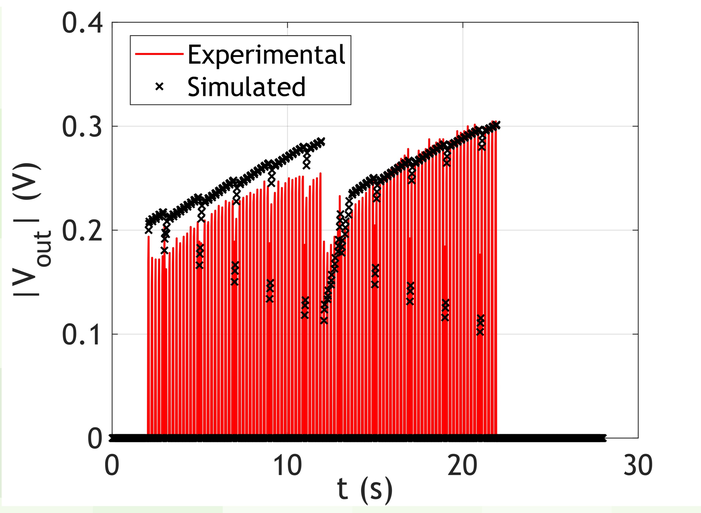


4. Simulation Model

- Testing edge detection required the simulation of many devices.

- These simulations used a linear approximation of the device to trade-off between accuracy and simulation time.

- To verify the model, we simulated the previous experimental work and compared the results.

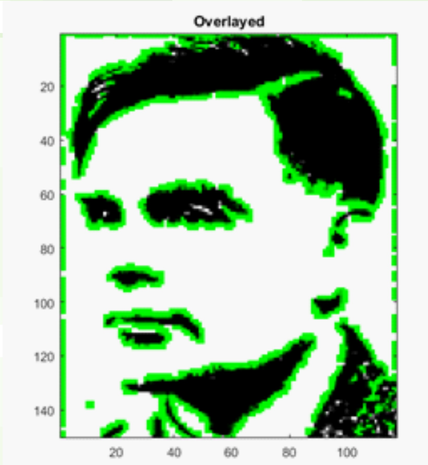
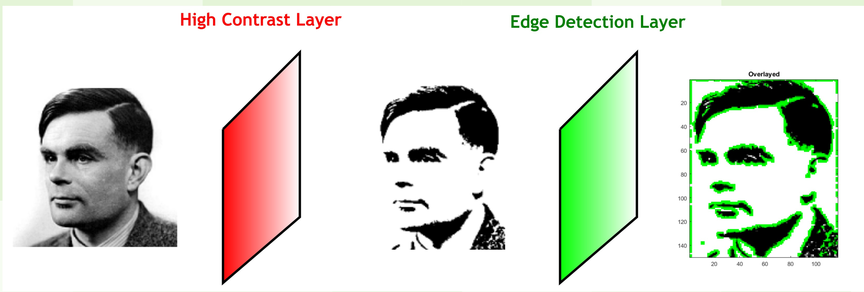


5. Application: Edge Detection

- We then used the concept of the WTA-like layers to tackle the problem of edge detection.

- The system is spike based and limited to high contrast images.

- This work was fully simulated and has yet to be physically implemented.

- The result of this work is shown in the image below, green pixels indicate the predication of an edge.

- Performance is good for high contrast images whereas images with smoother gradients do not perform well. We are looking into designing a preceding layer to push the image to a high contrast version.