From Memristors to Minds

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Propositions accompanying the dissertation

From Memristors to Minds

Enabling End-to-End Neuromorphic Systems with Spiking Neural Networks

By Thomas Tiotto

1. Satisfactory learning is still possible even when spiking network weights are implemented by non-ideal, stochastic items - as are memristors - instead of real-valued, linear, continuous network weights *(Chapter 2)*.

2. The Yakopcic compact model can accurately capture the hysteretic behaviour of Nb-doped $SrTiO_3$ in I-V sweep and pulsed regimes and its parameters can be related to physical characteristics of the device itself, potentially guiding future fabrication *(Chapters 3-4)*.

3. Nb-doped $SrTiO_3$-based synapses require mitigations to address the marked asymmetry in voltage biases, which makes it difficult to learn in a predictable manner, and lack of voltage threshold, which renders reading the device state challenging without disturbing it *(Chapter 4)*.

4. Incorporating biologically-inspired mechanisms into our systems can lead to serendipitous advantages *(Chapter 5)* but within the present-day boundaries of neuromorphic computing it is difficult to know where to draw the line in adherence to biology.

5. To guide research into memristors, it is necessary have a clear end goal in the form of a set of computational desiderata for the systems that will use them. A next necessary step for large-scale, real-world applications would be to reach a consensus on the best materials and techniques to implement these desiderata.

6. A radical understanding of the algorithms and structure underpinning biological intelligence would enable a more flexible use of diverse memristive materials compared to current approaches. A truly brain-like system would not require memristors to try to imitate an idealised weight but their "flaws" could naturally by mitigated or even taken advantage of.

7. The hardware architecture influences the nature of the software that runs upon it, similarly to how the language(s) we speak is thought to shape our umwelt that is, our subjective perception of the world (as posited by the controversial Sapir-Whorf hypothesis).

8. A full-stack non-von Neumann computational framework could transcend the limitations of classical digital computation by completely incorporating analogue computation principles. Such systems could possess the potential to efficiently address complex computational tasks that go beyond what traditional digital computers can achieve and - possibly - unlock true General Artificial Intelligence.

9. Even state of the art AI models like LLMs are limited to a statistical understanding of the world and are consequently brittle and limited in their scope. The ability to store symbolic information and reason upon it in an efficient, flexible, goal-directed manner it is what distinguishes real brains from our pale imitations; from here stems the need for cognitive agents capable of learning, remembering, reasoning, and truly feeling things.

10. When a task or a game is solved by a computer, it automatically stops being considered the litmus test for intelligence.

11. If all goes well, most of us are going to have to find something better to do with our lives than working full-time. If all doesn't go well, we'll be reduced to paperclips (according to Bostrom's Paperclip Maximizer scenario).

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