WHOSE ELECTRIC BRAIN?

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Memristors are collapsing the boundaries between humans and machines and ushering in an age where humanistic discourse must reach beyond its conventional boundaries. The distinctions between life/nonlife, courtesy of the memristor which confers the ability of remember and learn on machines, are blurring into undecidability. This paper traces the scientific developments and speculates about the possibility of cognitive entanglement.

Introducing the memristor

We still don't know much about brains, our own or any other species' and yet work on artificial brains (or forms of consciousness) continues at a furious pace aided by discoveries such as the memristor, which offers tantalizing possibilities for scientists and engineers and speculative material for artists, philosophers, and writers.

A new circuit element in electrical engineering, the memristor, is a contraction of the words memory and resistor. In other words, it acts like a resistor (a standard circuit element along with the capacitor and the inductor) and it has memory.

"Think of the resistor as a pipe through which water flows. The water is electric charge. The resistor's obstruction of the flow of charge is comparable to the diameter of the pipe: the narrower the pipe, the greater the resistance. For the history of circuit design, resistors have had a fixed pipe diameter. But a memristor is a pipe that changes diameter with the amount and direction of water that flows through it. If water flows through the pipe in one direction, it expands (becoming less resistive). But send the water in the opposite direction and the pipe shrinks (becoming more resistive). Further, the memristor remembers its diameter when water last went through. Turn off the flow and the diameter of the pipe 'freezes' until the water is turned back on." (Williams, 2008, p. 2)

Up until the Spring of 2008 the memristor was an obscure, almost forgotten theory in electrical engineering. Posited by Dr. Leon Chua, professor of Electrical Engineering at the University of California, Berkeley, the presence of a memristor as a potential addition to the classic circuit elements (the resistor, the capacitor, and the inductor) was theorized in 1971. (Note: In fact, there was an earlier scientist, George Widrow who posited a very similar new circuit element that he termed the memistor. Chua came to his theory independently. [Moutet, 2010, p. 211])

A team led by R. Stanley Williams at the HP Laboratories in Palo Alto, CA, published a study in the May 2008 issue of the journal Nature describing how they proved the new circuit element's existence experimentally.

It might not have happened,

" … the hypothetical device was mostly written off as a mathematical dalliance. Thirty years later, HP senior fellow Stanley Williams and his group were working on molecular electronics when they started to notice strange behavior in their devices. ‘They were doing really funky things, and we couldn't figure out what [was going on]’, Williams says. Then his HP collaborator Greg Snider rediscovered Chua's work from 1971. ‘He said, Hey guys, I don't know what we've got, but this is what we want, Williams remembers’.” Williams spent several years reading and rereading Chua's papers. ‘It was several years of scratching my head and thinking about it’. Then Williams realized their molecular devices were really memristors. ‘It just hit me between the eyes’.” (Adee, 2008)

In fact, ‘being hit between the eyes’ is a strange metaphor for Williams to use since memristors and other such phenomena at the nanoscale cannot be observed with the eye. The microscopes are haptic, i. e., the tip or probe is dragged across a surface during which time minute variations are recorded via software then the information assembled into an image on a computer screen that is viewable by scientists. Nonetheless, Williams has created visual representations of memristors such as this one.

A few months after Williams and his HP Labs team offered experimental proof of the memristor’s, existence the team published research (in Nature again) with a description of achieving engineering control of the new circuit element both in its digital and analogue forms. In its digital form, the memristor would allow instant operation. For example, your computer or laptop or phone or other electronic device would start instantaneously as it would no longer need to reboot. In its analog form, the memristor could allow hardware to learn.

Undecdability and boundary collapse

The memristor’s capacity to be either digital or analog calls to mind Jacques Derrida’s notion of undecidability. This notion of undecidability does not lend itself to the memristor proper as it is a theory which explains a collection of anomalies in electrical engineering at the micro and nano scales and as such is not dependent on the binary system which makes undecidability possible for such constructs as zombies, for example.

“Between life and death – it’s an uncertain space. The zombie might be EITHER alive OR dead. But it cuts across these categories; it is BOTH alive AND dead. Equally it is NEITHER alive NOR dead, since it cannot take on the ‘full’ senses of these terms. True life must preclude true death. The zombie short-circuits the usual logic of distinction. Having both states, it has neither. It belongs to a different order of things: in the terms of life and death, it cannot be decided.” (Collins & Mayblin, 2000, p. 19)

Where the notion of undecidability does lend itself, if not to the memristor proper, is to the proposed machinic functions made possible by the analogue/digital memristor.

It’s by rendering possible that dual digital/analogue space that the memristor can be described as an agent of undecidablility since it performs a transformative function for machinery/hardware which until now was decidably nonlife. With the advent of the memristor, machinery/hardware, formerly unable to remember and learn, has the possibility of both, a trait that defines biological systems (life). The advent of the memristor as a new circuit element leads to the same questions one asks about zombies, is the machine alive or dead, or both, or neither? Unlike the zombie (life/nonlife) which hungers for brains thereby destroying that which is decidably life, the memristor (via the field of neuromorphic engineering) could lead to the creation of an artificial brain thereby making machinic life/nonlife possible.

Neuromorphic engineering is an interdisciplinary field,

"… whose goal is to design artificial neural systems with physical architectures similar to biological nervous systems. One of the key components of any neuromorphic effort is the design of artificial synapses. The human brain contains vastly more synapses than neurons – by a factor of about 10,000 – and therefore it is necessary to develop a nanoscale, low power, synapse-like device if scientists want to scale neuromorphic circuits towards the human brain level. … 'A memristor by definition is a resistive device with inherent memory. It is in fact very similar to a synapse – they are both two-terminal devices whose conductance can be modulated by external stimuli with the ability to store (memorize) the new information.' [Dr. Wei Lu, assistant professor at the University of Michigan, Dept of Electrical Engineering and Computer Science]." (Berger, April 23, 2010)

This description of the memristor as being "… very similar to a synapse" followed by details that make the two seem identical is fascinating in light of Williams' 2008 comments "'We won't claim that we're going to build a brain, but we want something that will compute like a brain', Williams says. They think they can abstract 'the whole synapse idea' to do essentially analog computation in an efficient manner." (Adee, 2008) In two years, they went from 'abstracting the whole synapse idea' to acknowledging its similarity. While scientists drift closer to publicly acknowledging the memristor's possibilities (and its position as a transformative agent conferring undecidability on that which was previously decidable), they do not appear willing to publicly commit to the notion.

The notion of undecidability allows us to view a collapse of boundaries that first occurred theoretically in quantum physics. That theoretical work is now being made manifest at the nanoscale and we can expect it to lead to the collapse of several boundaries at the macroscale that would once have been unthinkable. For an example of a boundary collapse at the nanoscale, until recently biologists and physicists would have told you that biological molecules do not follow the principles of quantum mechanics.

"Until now, says Prof. Ron Naaman of the Institute's Chemical Physics Department (Faculty of Chemistry), both biologists and physicists have considered quantum systems and biological molecules to be like apples and oranges. But research he conducted together with scientists in Germany, which appeared recently in *Science* …, definitively shows that a biological molecule – DNA – can discern between quantum states known as spin." (Nanowerk, March 2011)

The conclusion based on this research seems to have been prefigured by Alfred North Whitehead. A well known mathematician who wrote on philosophy, physics, logic, and more. He suggested some 80 years ago, "… there is no absolute gap between living and nonliving societies." (Sherburne, 1981, p. 88) This also seems to prefigure Derrida's undecidability and zombies as living and/or dead. (In Whitehead's terminology, atoms and molecules are considered societies.)

Here's another example of a nanoscale boundary collapse,

"Air and water meet over most of [the] Earth's surface, but exactly where one ends and the other begins turns out to be a surprisingly subtle question.

"A new study in *Nature* narrows the boundary to just one quarter of water molecules in the uppermost layer -- those that happen to have one hydrogen atom in water and the other vibrating freely above." (Science Daily, June 19, 2011)

The boundary between water (liquid) and air (gas) collapses; is the molecule water or air, both or neither? It's too early to tell if this undecidability will have any consequences at the macroscale but this 'haptic' boundary collapse (water is touchable while air is not) echoes something which takes place amongst scientists working at the nanoscale.

Entanglements

Colin Milburn (2008) documents another kind of boundary collapse, one, between researchers and atoms/molecules, taking place at the tip of a scanning tunneling microsocope (STM).

"The media ecology of the STM—nanoscale haptic image, machinic symbolic, and the real interchange of electronic particles tunneling across the quantum 'vacuum gap' or 'forbidden space' between the molecular world and the STM's tip, outside processed data—comes to instantiate, to materialize, the human subject's perceptual ratios differently, such that the encounter with the world is apprehended now not as a division of perception (for example, into visual or auditory ratios) but rather as quantum connectivity or engtanglement, where 'real space' is touched across the symbolic translations of data ... (p. 90) data

Milburn's version of quantum entanglement could be called a manifestation of cognitive entanglement, while the memristor as an enabling agent could be described as facilitating yet another kind of cognitive entanglement.

At its heart, entanglement, whether it's quantum or cognitive, is about connectivity. In Milburn's stated case, the entanglement at the sensory and cognitive levels is such that it seems as if humans are in direct contact with a nano world, comprised of atoms and molecules.

"It's not, of course, that the operator is 'actually' touching individual atoms (however that would differ from our everyday encounter with gross matter), but rather that the medial translations and remediations of electronic convergence have produced sensations of connectivity at a radically different scale: tunneling all the way down, with no uncrossable or 'forbidden' gaps between our world and the world of the quantum." (Milburn, p. 91)

This nano world which can be touched is being extended beyond the research community and scientists to the general public in exhibitions like Nanooze at Walt Disney World's Epcot Center where visitors (mostly families) are encouraged to 'touch a molecule' as one of the exhibits is titled. In fact, visitors are touching an animation of a molecule. (de la Giroday, Sept. 6, 2011) This is an invitation to treat the nano world as if we have direct contact with it or, in this case, as if an animation of a molecule transforms, in the same way Milburn suggests that the STM has done for scientists, perceptual ratios so that the boundary between visual and haptic perceptions collapse and leave an interstitial space where cognitive entanglement occurs.

Milburn's following description of the impact that this shift creates for scientists can also be applied to the visitors at Walt Disney World's Nanooze exhibition,

"It is an affective moment, an unconscious, as-if-unmediated experience of direct 'connection' with molecularity. In the same way that new media work to make it seem that no mediation is involved in presenting an immersive immediacy … viewing the images produced by the STM while operating the machine makes it seems as if the human is in direct confrontation with the molecular nanoworld. … Thus the real local properties of the nanoworld become interdigitated with the exploded fingertips of the posthuman colonist.” pp.90/91

Or when you’re at Walt Disney World, these are the exploded fingertips of a visitor, usually a child.

Where is this going?

The memristor as a transformative agent enables the possibility of an entanglement unthinkable even 30 years ago, a cognitive entanglement between life and nonlife. By enabling the creation of artificial synapses and, ultimately, artificial brains for machines that can learn and remember in a fashion similar to biological systems, the memristor facilitates another boundary collapse courtesy of research at the nanoscale. This collapse leads to undecidability with regard to the distinctions between life and nonlife. Combined with the boundary collapse (which we can expect will extend into the general population as STM’s and other microscopes of that ilk become commonplace in educational institutions at all grade levels (and/or the proliferation of more exhibitions like Nanooze) which Milburn documents, the stage is set for a number of scenarios.

One of the first to occur comes from popular culture which has framed and dominated the public discussion there has been about life/nonlife. The popular culture discussions on life/nonlife are longstanding reaching back to 1818 at least and the publication of Mary Shelley’s Frankenstein. More recent entertainments such as True Blood, a series of books and now US television programmes, feature vampires (the living dead) who want acceptance and ‘human’ rights from the living. Another example can be seen in the debates on the Star Trek: The Next Generation and Star Trek: Voyager US television programmes. Including such characters as an android, Data, and a holographic doctor, respectively, seem deliberate attempts to introduce discussions about life/nonlife and acceptance and human rights into the DNA of the series themselves. In contrast to Star Trek where nonlife (except for the Borg which outside the Star Trek universe is known as a cyborg, an entity integrating biological life with machinic life) strives to be accepted by humans, Battlestar Galactica (the new and old versions), which also introduced life/nonlife into the DNA of its stories, featured androids and robots determined to exterminate humankind.

All these discussions are for the most part binary. The two categories in recent entertainments are (1) they (e.g. machines/holographic constructs) are like us, i.e., life, or they (e.g. cyborg which are part machine and part biological organism) are not like us, i.e., nonlife. But Milburn’s observation that scientists experience a direct experience of molecularlty with a concomitant shift in perceptions and extension of connectivity across the gap which exists between the macro and nanoscale suggests the possibility that the binary model for this discussion will collapse in much the same way that the visual/haptic boundary collapses for both scientists working with STMs and visitors playing with an animation at the Nanooze exhibition.

As these boundaries collapse yet another chain of cognitive entanglement scenarios is made possible in the life/nonlife discussion. Technically, the memristor makes possible not just an artificial brain but the integration of artificially derived synapses with biologically derived synapses. For example, it can be expected that future patients (already experiencing a cognitive entanglement with the nano world) will want to have their brains repaired or possibly have their intelligence augmented with an artificial synapse leading to a type of cognitive entanglement that is intimate. It is possible to envision a future where the distinctions between humans and machines will be difficult, if not impossible, to maintain.

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