CogniMem™, a paradigm shift in Artificial Intelligence

It is well described in Jeff Hawkins's landmark book "On Intelligence" that an essential difference between the biological approach and the computing approach of intelligence lays in the fact that biology uses active memory cells (neurons) while computers use a procedural activity involving the "fetch, decode and execute" model. The computer model is similar to someone who would need to read both the car user's manual and the vehicle transportation civil code as he drives. Indeed everybody knows that this is not the way to drive! The fact that while initial attempts to drive and obtain a driver's license are a supervised (and somewhat procedural) learning experience, surviving the early days of driving allows us to permanently "memorize" the way of operating the vehicle and behave (more or less) within the driving code. Up to now, no computer has the ability to discard the procedural operation. The fact that computer architecture is based on the segregation of the programs and the data prevents any evolution in this direction. What we are introducing in this paper is a concept that we have matured over the past twenty years and which closely matches a solid-state semiconductor technology with biological model. We call it the CogniMem Technology (i.e. Cognitive Memory).

The CogniMem Technology is to the human brain what the plane of the Wright Brothers was to the bird or what the robot arm is to the human arm. CogniMem is inspired by years of thinking, enlightened discussions with persons such as Prof. Carlo Rubbia and Leon N. Cooper, both Nobel Laureates, and Prof. Bruce Batchelor, a great pioneer in pattern classification. The combination of 30 years of hardware experience and computer anthology, the opportunity to be the lead hardware designer of a huge parallel computing experience in 1984 for the UA1 experiment at CERN and to meet and work with Leon Cooper in 1988 and cooperate with him for 4 years at Nestor Inc. led me to think about the silicon implementation of neural cells working in parallel. Due to these previous developments, it was possible to convince the IBM Semiconductor Labs in Paris to design and manufacture the first issue of the CogniMem technology, the ZISC® chip (Zero Instruction Set Computer). The basic architectural concept was delivered to IBM in February 1993 and the first ZISC36 chip with 36 neurons was powered up successfully in October 1993. A new chip design never went so fast at IBM, thanks to its orthogonal simple architecture as simple as 36 connectable digital neurons. A second version of the ZISC chip was released by IBM in 2001 with 78 neurons and in August 2007 Recognetics proudly released the CogniMem1K chip with 1024 neurons in parallel.

BIOLOGY VERSUS SILICON

- Connectivity: The biology can connect 10,000 or more neurons with billions of connections. The CogniMem silicon neural cells can be daisy-chained indefinitely in parallel, thus designing a brain with unlimited number of connections.
- Memorization: Biology keeps "refreshing" our memory while silicon can keep digital memory as long as it is powered.

- Speed: Transmission between biological neurons is slow (10 milliseconds) while the silicon can pass millions of data bytes on the same wire. Transmission between digital neural cells takes nanoseconds (millions of times faster).
- Portability: The biological brain cannot be cloned but the digital brain can be both educated by one or several human teachers and duplicated in seconds.

WHAT IS "ASSOCIATIVE MEMORY"

In the biological world stimuli are associated with "reaction". Typically an animal will react to a sequence of stimuli with one action or a sequence of actions. A basic difference between the human and the animal behavior is the ability for the human to "classify' for a subsequent purpose. Typically the invention of languages, paintings, hieroglyphs and finally writing is a crucial distinction between humans and animals. These inventions enable the "formal labeling activity" which is unique to mankind. Therefore not only can we react to temporal sequences of stimulus, whether external (sensory) or internal (reflection and emotions), but also can we translate them into literary and artistic masterpieces or simple facts reporting. We are able to integrate previous and current experiences and "associate" them to sequences of letters assembled into words, sentences and chapters or, for the artistic mind, into drawings, sculptures or paintings. This uniqueness of our neo-cortex leads to our natural curiosity (at various levels indeed) and pushes us to want to understand everything. Our evolution started with some primitive languages and drawings on cave walls, and eventually lead to science.

A NEW WAY OF BUILDING AND PROPAGATING KNOWLEDGE

A CogniMem neural network can be trained by one or multiple human beings with different levels of expertise. For example, a combination of good radiology students can teach anomalies seen in simple MRI and CT scan images and expert radiologists can teach unusual and complex cases to recognize cancer tumors, etc. This training can be achieved by simple annotation of pictures without any programming. Typically a MRI scanner can generate thousands of body pictures for one patient, way too much for an MD looking at dozens of patients a day. The knowledge of a CogniMem neural network can be initially built, then enhanced and finally disseminated over the world to spread the combined knowledge of many human experts for the best diagnostic available. This is a new way of building and transferring experience, beyond drawing and writing, regardless of the information support.

DIGITAL NEURAL CELL PHYSIOLOGY

The current CogniMem neural cell has the following specificities:

- Autonomous: reacts by itself to external stimuli (e.g. pattern feeding) with a fully built in combinatory behavior.
- Gregarious: its reaction is inhibited or excited by the reaction of the others cells in the same or a distant neighborhood.
- Auto associative: stores a pattern and recalls it when exposed to a similar stimuli
- Clonable: its knowledge can be propagated to another cell
- Very compact: it can be included into sensors for the visual cortex emulation
- Very high speed: operates at very low frequency (8 MHz), thus very low power consumption, while delivering very high speed recognition (at sensor speed)
- Expandable: Parallel daisy-chaining allows the matching of one digital signature (vector) with millions in a constant few microseconds.

FUTURE OF THE COGNIMEM TECHNOLOGY

- Plasticity: contextual addressing adding the capability to route the response of a neural cell toward one or several specific cells
- Reduced wiring (4 wires or less) for the entire brain.
- Permanent memory
- Three dimensional cascadability
- Asynchronous operation
- Other embodiments, such as nanotechnology or possibly quantum material.

CREDENTIALS AND REFERENCES

- Monolithic image perception device and method (www.uspto.gov, US patent application pending #20070014469)
- Fish Inspection System using a parallel neural network chip and the Image Knowledge Builder application (AI magazine, Spring 2008 issue)
- CogniMem versus DSP (white paper from Recognetics www.recognetics.com)

For more information, www.recognetics.com