The Big Artificial Brain

Pr. Pierre RABISCHONG[1], Anne MENENDEZ[2], Guy PAILLET[3]

1) Honorary Dean of Montpellier Medicine University, Vice President bio-medical technologies (WABT – UNESCO), 2) Founder of General Vision Inc. and co-inventor of the NeuroMem® technology 3) CEO General Vision, and co-inventor of the ZISC and NeuroMem technology.

Keywords: Artificial brain, neural networks, parallel architecture

Summary:

Important advances in neuroscience make it possible to consider the creation of a Big Artificial Brain (BAB); a brain that attempts to reproduce cerebral functions without copying the natural neuronal components, which have their own technical constraints and biological characteristics far beyond the replication capabilities of the current technologies. The creation of NeuroMem neuronal components by General Vision Inc. has made it possible to construct a BAB of 1 million neurons, interconnected transversely and vertically in a parallel architecture, as the neurons of the human cortex. The applications are numerous and promising.

Introduction:

Given the considerable progress made in our understanding of the brain and the way in which neurons function, it seems possible to develop an artificial brain system. The idea does not consist of copying the biological components which have technical constraints linked to metabolic necessities (anabolic and catabolic) justifying complex circuits for the distribution of nutriments such as oxygen. Their miniaturization is at the nanometer scale level and data transmission and storage is well achieved through neurochemical synaptic gates using activation or inhibition. Modern neurosciences give us increasingly precise images and information about these biological components thanks to the steady improvement of imaging and signal processing tools. At the same time, electronics and modern computer sciences provide us with components that look increasingly closer to the miniaturization of living things, and therefore it seems possible to create an entirely artificial structure capable of mimicking the cerebral functions, without copying them.

One possibility is offered by the neural architecture created and patented jointly in 1994 by Guy Paillet (now president and CEO of General Vision, California) and IBM Corporation, under the name ZISC architecture (Zero Instruction Set Computer). ZISC was deployed into several components such as ZISC36 (1993) and ZISC78 (2001) developed and produced by IBM France, and more recently CM1K (2007) developed and produced by General Vision. General Vision Inc. calls its technology NeuroMem® which stands for Neuromorphic Memories and has integrated it into multiple systems and applications. A NeuroMem chip is a high-performance trainable classifier with an Input layer, a Hidden layer, and an Output layer. One can therefore educate NeuroMem to recognize any form of objects or signals. In other words, NeuroMem behaves like a very good student who understands quickly and forgets nothing. NeuroMem has a unique natively parallel architecture enabling the interconnectivity of neurons intra and inter chips. In other words, multiple chips can be easily connected to one another to expand or partition the student's brain. Arranging these neural networks like the neuronal columns of the human cortex makes it possible to design a Big Artificial Brain.

The Architecture:

The human brain's communication functions receive input from two sources: on the one hand, sensory inputs such as vision, touch, hearing, olfaction-taste, and on the other hand, a central black box where almost unconscious recognition occurs by accessing the brain's memory zones. It processes multimedia information producing expressive responses mainly in the form of spoken and written languages, but also mimicry and gestures, as well as behavioral responses. The back box constitutes the realm of thoughts with its multiple facets which are nowadays better understood such as cognition, memory, intelligence, speculation, conceptualization, consciousness, emotions, mental calculation, artistic creation, and more.

The challenge of the Big Artificial Brain's is therefore to find the technological solutions to create inputs, process them and effectively transmit the appropriate responses in the shortest possible time.

The Entries:

When it comes to communication, vision and hearing are two essential inputs. Today, we have access to very sophisticated two-dimensional or three-dimensional image acquisition systems, capable of capturing shapes, colors, and motion with a resolution and frame rate higher than the human eye. HFR tools (Hyper Fast Reading) can scan and generate text at a speed much greater than the fastest human reader. Similarly, miniaturized radars can measure distances and speed with greater precision than the human eye. On the topic of hearing, we have at our disposal high-performance systems capturing sounds from greater distances and within a broader range of frequencies that can be perceived by the human ear (20 to 20000 Hz). In summary, the BAB can receive extremely large amount of valuable data in a very short time and the NeuroMem chips can learn and recognize this data at high speed. Note that the maximum speed of data transfer in the nervous system is 120 m / sec for the largest nerve fibers of 25µ, when the BAB works at the speed light. In fact, the reaction time of the BAB is independent of the number of neuromorphic memory cells involved in the decision and will be in the order of 10µs.

The Black Box:

This is the equivalent of our biological Black Box, where memory occupies a prominent place. Patients who suffer from Alzheimer's disease live only in the present and loose memory functions while keeping some cognitive remnants of the past. In electronics, memory components have made considerable progress both in term of capacity and performance and we can envision their use for the development of cognitive modules resembling the cortical columns of the human brain. The production of such modules (for text, image, sound recognition) can become pervasive in many domains including scientific, artistic, cultural, sporting, gastronomic, ecological. Unlike the human brain, they waive the risk of loss of information. Another essential attribute of neuromorphic memories must be the comprehension of the unknown which is necessary to trigger learning. This is possible with a topology implementing an RBF network (Radial Basis Function) instead of a k Nearest Neighbors type of classifier (kNN). The neuromorphic memories recall stimuli by comparing their similarity to their own influence fields. This involves a processing unit built into each memory cell and adjusting an acceptable range of similarity dynamically each time a new stimulus is taught.

The concept of intelligence which can be expressed as speculative and / or praxis, is the ability to solve a problem once stimuli and contextual information are comprehended and understood. Artificial inputs can be recognized and converted to keywords in any language describing the nature of the problem and activating the corresponding cognitive module to get an answer. Decision-making algorithms can also be stored in the BAB, allowing it to recognize a situation and take a decision. At this stage, we are describing a highly non-linear classifier simply trained by examples as opposed to complex conventional analytical tools which must solve problems, considering numerous variables.

There is also the problem of consciousness, whose emergence does not coincide with the arrival of mankind as some still believe. Indeed, any animal with a nervous system has some form of consciousness: The fly being chased quickly goes away; The dog recognizing his master wags its tail; The carnivore awaiting its prey and preparing his attack has a strategy. On the other hand, the chimpanzee throwing a stick to catch a banana out of his reach uses it as a tool, and unlike the human, does not seek to improve it or keep it with him. Indeed, consciousness features many levels and the most complex level, only granted to humans, is abstraction. In the brain, there is not a central location for consciousness, but the need for many activated neuronal columns. One can wonder what level of consciousness can the BAB have through the instantiation of numerous interactive components. It is likely that it could free itself from the tutelage of its authors and go on with its life. This is certainly an interesting aspect of our research as well as its artistic creativity which is expressed with brushes, scissors, paint, and other tools very easy to simulate by software installed in the BAB.

Note that in a specific operating mode of the BAB called RBF mode, the network can learn, recognize, and generalize. It can recognize even if the stimulus is different than the examples used during training. Such ability of the BAB is like our own biology which can adapt and match elements that have evolved. The difficulty for the BAB machine will be to find the best set of parameters describing the event to help its identification and proper discrimination from other elements (feature extraction process). For example, we can all recognize, even after several years, a friend or loved one because we are able to generalize.

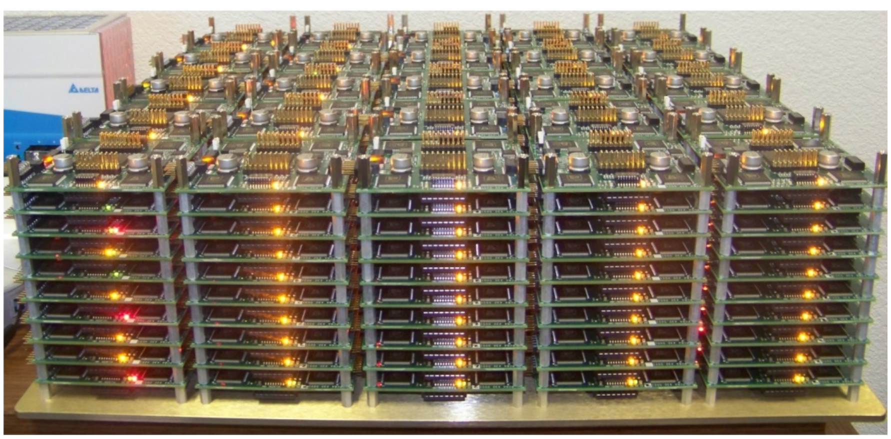
Finally, come the subject of emotions. They play a considerable role in human and animal behavior. We know quite well the circuit of emotions in the brain which is in fact largely linked to the memory as demonstrated by Papez. We also know that all kinds of visual, auditory, or tactile emotions are experienced by the body in its entirety through the connections of the limbic system to the hypothalamus, which manage the always present vegetative reactions (palms, sweating, acceleration of heart rate, intestinal tract, etc.) and neuroendocrine (adrenal system). Of course, the BAB, which does not have a physical body and especially no sympathetic or parasympathetic neuro-vegetative system, will not have any emotions. This becomes an advantage when it comes to solving a complex intellectual problem, but a disadvantage when it comes to appreciating a painting or experiencing an emotional situation. The great director Stephen Spielberg has remarkably explored this problem in his film A.I. (Artificial Intelligence, 2001).

Expressive Exits:

Synthetic spoken languages are now commonly accepted in most industrialized countries. They have considerably improved and feature rich intonations resembling human voices. The BAB will be able to speak and even sing if necessary.

With regards to writing, multiple technologies are available, including our modern printers, speech to text translators, FMW (Fast Multilingual Writing) software, etc. So, the answer to a question could easily appear in a form we are familiar with. It is a technical aspect related to the human-machine interface which does not present any major difficulties.

Status of Project:



In 2012, Guy Paillet and Anne Menendez have built at their Petaluma office (California) a BAB of 1 million neurons (beside) composed of 25 columns of 10 stackable NeuroStack boards with each four CM1K chip, totaling 4096 neurons per board. The CM1K chip is a neuronal component which has 1,024 neurons corresponding to 256 inputs and 16,392 outputs with 262,144 interconnects (synapses), which allow 26 billion connections per second. A NeuroStack board populated with 4 CM1K chips can process 1000 patterns in tens of a microsecond with an energy expenditure of 250 Milliwatts. The human cortex has six layers of neurons, which are interconnected vertically and horizontally, representing a very powerful storage and processing matrix. Similarly, the BAB features transversal and horizontal interconnections in a parallel architecture. Another 100,000-neurons version was presented at the Academy of Medicine on October 1, 2013. Pierre Raymond in his Saint-Louis laboratory has worked with his team for practical applications of NeuroMem by developing novelty products. Today a NeuroMem chip of 100,000 neurons (28 nm. geometry) could be manufactured with a footprint of less than 8x8 mm2, so a 1 Million neurons BAB could occupy about the surface of a credit card.

The Applications:

NeuroMem has already made it possible to create fast and reliable recognition systems for still and moving objects such as the faces of people in a crowd, fingerprints, terrestrial, aerial, or marine vehicles, plants. In the medical field, it can be used for genome sequencing, microscopic tumor identification, dermatology and all that is related to normal or pathological morphology. It can thus become a reliable diagnostic tool for all kinds of practitioners. In other areas, it can be used for reading texts written in pictograms such as Japanese or Chinese kanji, which makes it much easier for those unfamiliar with the characters to read signs. Any form of physical signal can be recognized and analyzed by this system.

As far as the current BAB project is concerned, the objective is to scientifically analyze the possibilities and limits of mimicking the cerebral functions and determine if within an artificial system a form of "personality" can emerge, capable of making decisions and creating artistic structures, concepts, or objects without having first to establish a transfer function. Additionally, one of the applications of the BAB in medicine, would be to provide libraries with a system capable of responding to a qualitative request for documents in a field of pathology. Modern search engines give a list of works and often a rich bibliography but without providing an "expert" opinion that could be provided by the BAB. As a result, the construction of specific cognitive modules could be the subject of thesis for students. It could also be used as an instrument for learning to diagnose symptoms and clinical signs, especially since it has enough memory to store all the rare pathological forms that teachers cannot always present to the students. One can also consider the analysis of an experimental design with the aim of isolating and identifying the input data which are correlated.

Conclusion:

Artificial Intelligence on Silicon is a very young science, with half a century of existence at most. It certainly challenges the common realm of thought. The highly parallel, bio-inspired operating mechanisms have been implemented on computers but have remained sequential with the same bottleneck: access to memory. Today's commercially-available technologies combine parallelism of function with structural parallelism, making it possible to achieve unequaled performance with a conventional computer. The information is now processed in parallel by decision cells incorporating multiple parallel processors. The NeuroMem chips are unique in the sense that they integrate neuromorphic memories working in parallel with a constant intrinsic reaction time. This research on the theme of "thinking and the machine" can therefore in the future be easily integrated into those carried out by many teams in robotics, experimental psychology, and neuroscience.

Bibliography:

[1] MICHELAT T., HUEBER N., RAYMOND P., PICHLER A., SCHALL P., DUGARET B.- Automatic pedestrian detection and counting applied to urban planning,

AmI'10 Proceedings of the First international joint conference on Ambient intelligence, 2010 Springer-Verlag Berlin, Heidelberg. 285-289, ISBN: 3-642-16916-3 978-3-642-16916-8†

[2] MOUKADEM A., DIETERLEN A., HUEBER N., BRANDT C., RAYMOND P. Localization of Heart Sounds Based on S-Transform and Radial Basis Function Neural Network, IFMBE Proceedings, 15th Nordic-Baltic Conference on Biomedical Engineering and Medical Physics, Prague, CZ, 2011, Vol. 34,. 168-171

[3] MOUKADEM A., DIETERLEN A., HUEBER N., BRANDT C., RAYMOND P. Comparative study of heart sound localization algorithms, Bioelectronics, Biomedical, and Bioinspired Systems V, Copenhagen, DK, 2011, Proceedings Vol. 8068

[4] EICHHORN M., A. PICHLER A., P. RAYMOND P. Novel all-hardware closed-loop adaptive optics system using massively-parallel neural processing. Proc. SPIE 7912, Solid State Lasers XX: Technology and Devices, 791217 2011.

[5] PICHLER A., RAYMOND P., MARC EICHHORN M. Fast wavefront sensing using a kNN hardware classifier chi. Applied Physics B 2013, Lasers and Optics, ISSN 0946-2171, DOI 10.1007/s00340-013-5607-y

[6] RABISCHONG P. Le Programme Homme. PUF 2003.