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Some Thoughts about Artificial Consciousness

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Introduction

The problem of consciousness is, probably, one of the most difficult problems in the whole philosophy. Most philosophers believe that it is a mystery that cannot be explained yet. Others believe that this mystery will never be explained. They claim that our sensations, or qualia, are indefinable, so they cannot be described using a computer algorithm. Therefore, consciousness is not computable and human brain cannot be build using the hardware of a traditional computer.

Other scientists, like Roger Penrose and Stuart Hameroff developed a theory that consciousness arises by quantum effects in physical components of the cells, called microtubules. But in fact, this theory is very close to panpsychism, a pseudo-scientific view in science, like Ben Goertzel wrote in his book [1]. In panpsychism, “it is admitted that everything in universe has a little bit of proto-consciousness which manifests as full consciousness only in certain entities”. So, even a cluster of living cells may have a certain level of consciousness in some cases.

But there are other philosophers, like Daniel Dennett, which believe that machines could be conscious in the same way as humans if they are constructed and programmed correctly. Other scientists, like Marvin Minski, Igor Alexander, Drew McDermott or Scott Aaronson believe that consciousness machines can be built. All of them are agree that these machines should have a great level of complexity and should learn in a long process of evolution, like us. Igor Alexander wrote in [2]: “I shall argue that for a machine to begin its climb to consciousness, the possession of a cellular learning system is crucial. Could an individual be said to have any form of consciousness were he or she to rely solely on the instincts available at birth? Everything I think about has something to do with a mass of images, sounds and feelings that seem to happen in my head. Such sensations could not have been there at birth as they are reflections of events that have happened since birth. So the neural network is a special kind of string and sealing wax in which learning of sensations and visions can be explained.” And Scott Aaronson in [3] shows a similar idea: “This is that, in trying to write programs to simulate human intelligence, we’re competing against a billion years of evolution. And that’s damn hard. One counterintuitive consequence is that it’s much easier to program a computer to beat Garry Kasparov at chess than to program a computer to recognize faces under varied lighting conditions. Often the hardest tasks for AI are the ones that are trivial for a five-year-old – since those are the ones that are so hardwired by evolution that we don’t even think about them.”

Hardware

If a consciousness machine could be ever built, the first question might be about the complexity of the hardware. Probably, the structure of this machine should contain some distributed neural networks, and some associative memories which will be programmed in the process of learning through evolution. So, the question is how many neurons are necessary for a first level of consciousness? And how many FPGAs are required to implement this network?

Well, if we look in animal world, we can see that the brain of an ant contain about 250,000 neurons and a honeybee brain has about 1,000,000 neurons. A dog has a brain which contains 150,000,000 neurons, and a cat has a brain which contains 300,000,000 neurons. Which one is more conscious? Our brains have about 100,000,000,000 neurons while an elephant brain may have 200,000,000,000. We consider, and this is a truism, that our consciousness is higher than eventually other consciousness among other animals. Although human intelligence evolved in the last couple of million years, while elephantine intelligence has been evolving for over 100 million years [4, 5].

The computational cost of simulating one neuron depends on the level of detail that one includes in the simulation. Extremely simple neuron models use about 1,000 floating-point operations per second (FLOPS) to simulate one neuron (in real-time). But oversimplified models do not match always experimental results [6]. The electro physiologically realistic Hodgkin–Huxley model uses 1,200,000 FLOPS [4]. Kurzweil and Moravec offer other estimation. They consider for human brains, that 10^{11} neurons, each of them with about 1000 synapses and a speed of 100 pulses each second need a computation speed of about $10^{11}\times10^{3}\times10^{2}=10^{16}$ FLOPS, a value that differ only with a single order from the previous estimation. For comparison, China’s Sunway TaihuLight, the world’s most powerful supercomputer as of June 2017, provides about 9.3×10^{16} FLOPS [7]. So, at least theoretically, it would be possible an evolution rate multiplied by nine, in comparison with evolution rate of humans in our history.

But how many ICs are necessary to deploy a human brain? A direct estimation is not possible as there are a lot of neuron models with different characteristics. Even operands can use Fixed Point or Floating Point Arithmetic. It’s clear that ICs should be programmable, because synapses change their values in evolution. If we use a simplified model, then each neuron can be implemented using one LUT for output nonlinear function, one multiplier, one adder and a number of registers equal with the weights, or synapses, in the real neuron. One of the best technologies of the present moment in FPGA building is the 16nm FinFET+ process technology used by Xilinx in the new Zynq UltraScale+ MPSoCs. Highest density device from this family contains more than one million logic cells, one million flip-flops and half million LUTs [8]. In a single FPGA of this type we can model, probably, more than 1000 neurons, each of them with 1000 synapses [9, 10]. Subsequently we need probably more than 100,000,000 FPGAs for building an artificial brain comparable with the human brain, and this goal seems to be impossible in our days. Even if we were able to implement one million neurons in an IC, then we need 100,000

FPGAs, while the largest cluster of FPGAs in the world, built in Hong Kong, contains only 6048 Spartan-6 LX150 FPGA chips from Xilinx.

Software

Software is the most difficult problem in a practical implementation of the human brain. Because in FPGAs, software is the tool which establishes the configuration of hardware and this must be done in an evolutionary process. The plasticity of the brain should be modeled with the plasticity of FPGA circuits, by their reprogramming during the evolution. How can be interconnected all these programmable cells to initiate a function of this brain and how the conscience emerge in such a huge network? Perhaps a process similar to percolation in physics is necessary for the emergence of a first level of consciousness, but the main question is how we recognize such an event. How we can prove that a network is conscious? It seems that, even if we have a functional hardware, we simply don't know how to write the software.

Conclusion

Probably, a conscious machine will be built in the future. When? It depends on existing technology and the conception of software. It is not sure that current hardware technology is feasible for the development of an artificial brain. Using the best programmable circuits like FPGAs raises a lot of problems. Maybe a new revolution in Evolvable Hardware technology is necessary. In this case, perhaps a new software concept must be developed. But I think that learning of a conscious machine through evolution remains the most important thing. The need for evolution is a certainty. How fast should this evolutionary process be? That depends on our goals and the environment. And if we want to compete with humans, then this learning process is likely to be lasting, maybe comparable to our lives.

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