Virtual Brain Technology

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Abstract: The human brain has about 100 billion neurons, nerve cells which enable us to adapt quickly to an immense array of stimuli. We use them to respond to anything such as bright sunlight, the smell of chicken frying, a honking horn and anything else our sensors detect. Researchers had launched an ambitious project called Blue Brain, to better understand some of those responses. They are in research to create an artificial brain that can think, response, take decision, and store anything in memory. The main aim is to upload human brain into a machine so that man can think, take decision without much efforts. After the death of the body, the virtual brain will act as the man's brain. Such models will shed light on how memories are stored and retrieved. This could reveal many exciting aspects of the brain, such as the form of memories, memory capacity and how memories are lost. In this paper, we explain the concept and functioning model of blue brain, motivations behind it, limitations and many more.

I. INTRODUCTION

The Blue Brain Project is an attempt to reverse engineer the human brain and recreate it at the cellular level inside a computer simulation. The project was started in May 2005 by Henry Markram at the EPFL in Lausanne, Switzerland. Main goals of the project are to gain a complete understanding of the brain and to enable better and faster development of brain disease treatments. The research involved studying slices of living brain tissue using instruments such as microscopes and patch clamp electrodes. Data is collected about many different neuron types. This collected data is used to build biologically realistic models of neurons and networks of neurons in the cerebral cortex. The simulations are carried out on a Blue Gene supercomputer built by IBM. Hence the name "Blue Brain". The simulation software is based around Michael Hines's NEURON, together with other custom-built components. Human brain is the most valuable creation of God. Man is intelligent because of this valuable creation "brain". “Blue brain” is the name of the world’s first virtual brain. That means a machine that can function as human brain. Today scientists are in research to create an artificial brain that can think, response, take decision, and store anything in memory. The main aim is to upload human brain into a machine so that man can think, take decision without much efforts. After the death of the body, the virtual brain will act as the man's brain .So, even after the death of a person we will not lose the knowledge, personalities, feelings, intelligence and memories of that man that can be used for the development of the human society.

Brain simulation is unbelievably inter-disciplinary research. It involves the domains like brain imaging, neuroscience, computer science, nanotechnology, AI, biotechnology, psychology, philosophy, and many more. A typical human brain usually consists of approximately 85.5 billion nerve cells called neurons. Each neuron is individually linked to other neurons through axons and dendrites. Signals at the biological level of these connections are transmitted by releasing and detecting chemicals known as neurotransmitters. Neuroscientists have stated that important functions that a mind performs such as consciousness, memory, and learning, have been possible due to completely physical and electrochemical processes in the brain.

II. BUILDING VIRTUAL BRAIN

There are three main steps to building the virtual brain: 1) data acquisition, 2) simulation, 3) visualisation of results.

1. Data acquisition:

Data acquisition involves taking brain slices, placing them under a microscope, and measuring the shape and electrical activity of individual neurons. This is how the different types of neuron are studied and catalogued. The neurons are typed by morphology (i.e. their shape), electrophysiological behaviour, location within the cortex, and their population density. These observations are translated into mathematical algorithms which describe the form, function, and positioning of neurons. The algorithms are then used to generate biologically-realistic virtual neurons ready for simulation.

One of the methods is to take 300 µm-thick sagittal brain slices from the somatosensory cortex (SA1) of juvenile Wistar rats (aged 14 to 16 days). The tissue is stained with biocytin and viewed through a bright field microscope. Neuronal 3D morphologies are then reconstructed using the Neurolucida software package (pictured below, far right) which runs on Windows workstations. Staining leads to a shrinkage of 25% in thickness and 10% in length, so the reconstruction

ISSN: 2278 – 1323

process corrects for this. Slicing also severs 20% to 40% of axonal and dendritic arbors, so these are regrown algorithmically.

The electrophysiological behaviour of neurons is studied using a 12 patch clamp instrument. This tool was developed for the Blue Brain Project and it forms a foundation of the research. It enables twelve living neurons to be concurrently patched and their electrical activity recorded. The Nomarski microscope enhances the contrast of the unstained samples of living neural tissue. Carbon nanotube-coated electrodes can be used to improve recording.

Different types of neuron have different mixes of channels - and this contributes to differences in their electrical behaviour. The genes for these channels are cloned at the lab, overexpressed in cultured cells, and their electrical behaviour recorded. Over 270 genes are known to be associated with voltage-gated ion channels in the rat.

2. Simulation:

The simulation step involves synthesising virtual cells using the algorithms that were found to describe real neurons. The algorthims and parameters are adjusted for the age, species, and disease stage of the animal being simulated. Every single protein is simulated, and there are about a billion of these in one cell. First a network skeleton is built from all the different kinds of synthesised neurons. Then the cells are connected together according to the rules that have been found experimentally. Finally the neurons are functionalised and the simulation brought to life. The patterns of emergent behaviour are viewed with visualisation software.

A basic unit of the cerebral cortex is the cortical column. Each column can be mapped to one function, e.g. in rats one column is devoted to each whisker. A rat cortical column has about 10,000 neurons and is about the size of a pinhead. The latest simulations, as of November 2011, contain about 100 columns, 1 million neurons, and 1 billion synapses. A real life rat has about 100,000 columns in total, and humans have around 2 million. Techniques are being developed for multiscale simulation whereby active parts of the brain are simulated in great detail while quiescent parts are not so detailed.

Every two weeks a column model is run. The simulations reproduce observations that are seen in living neurons. Emergent properties are seen that require larger and larger networks. The plan is to build a generalised simulation tool, one that makes it easy to build circuits. There are also plans to couple the brain simulations to avatars living in a virtual environment, and eventually also to robots interacting with the real world. The ultimate aim is to be able to understand and reproduce human consciousness.

3. Visualisation of results:

RTNeuron: RTNeuron is the primary application used by the BBP for visualisation of neural simulations. The software was developed internally by the BBP team. It is written in C++ and OpenGL. RTNeuron is ad-hoc software written specifically for neural simulations, i.e. it is not generalisable to other types of simulation. RTNeuron takes the output from Hodgkin-Huxley simulations in NEURON and renders them in 3D. This allows researchers to watch as activation potentials propogate through a neuron and between neurons. The animations can be stopped, started and zoomed, thus letting researchers interact with the model. The visualisations are multi-scale, that is they can render individual neurons or a whole cortical column

III. SUPERCOMPUTERS USED

Blue Gene/P:

The primary machine used by the Blue Brain Project is a Blue Gene supercomputer built by IBM. This is where the name "Blue Brain" originates from. IBM agreed in June 2005 to supply EPFL with a Blue Gene/L as a "technology demonstrator". The IBM press release did not disclose the terms of the deal. In June 2010 this machine was upgraded to a Blue Gene/P. The machine is installed on the EPFL campus in Lausanne (Google map) and is managed by CADMOS (Center for Advanced Modelling Science).

Blue Gene/P technical specifications:

- 4,096 quad-core nodes (16,384 cores in total)
- Each core is a PowerPC 450, 850 MHz
- Total: 56 teraflops, 16 terabytes of memory
- 4 racks, one row, wired as a 16x16x16 3D torus
- 1 PB of disk space, GPFS parallel file system
- Operating system: Linux SuSE SLES 10
- Public front end: bluegene.epfl.ch and processing log

DEEP - Dynamical Exascale Entry Platform:

DEEP (deep-project.eu) is an exascale supercomputer to be built at the Jülich Research Center in Germany. The project started in December 2011 and is funded by

ISSN: 2278 – 1323

the European Union's 7th framework programme. The three-year protoype phase of the project has received €8.5 million. A prototype supercomputer that will perform at 100 petaflops is hoped to be built by the end of 2014.

The Blue Brain Project simulations will be ported to the DEEP prototype to help test the system's performance. If successful, a future exascale version of this machine could provide the 1 exaflops of performance required for a complete human brain simulation by the 2020s.

IV. MOTIVATIONS BEHIND BLUE BRAIN

Four broad motivations behind the Blue Brain Project are:

- Brain disease treatments
- Scientific curiosity about consciousness and the human mind
- Integration of all neuroscientific research results worldwide
- Progress towards building thinking machines (bottom up approach)

One in four people will suffer from one of around 560 brain diseases during their lifetime. Therefore it is important to have a good strategy for understanding these diseases and finding suitable treatments. The living brain is very difficult to study. Both from a technical perspective, and a moral one. A virtual model, however, makes direct observations possible. Experiments on models are also more efficient and limit the need for laboratory animals. The Blue Brain Project, by including molecular-level simulations, could be used to study the effect of new pharmaceutical compounds on virtual brains of any species, age, and stage of disease.

Another aim of the Blue Brain Project is to provide a centrally coordinated resource for the 200,000 active neuroscientists in the world. Previously each researcher has focused on their own specialist field without the results being shared and easily available to all.

Advantages

- We can remember things without any effort.
- Making decision without the presence of a person is possible.
- We can Use the intelligence of a person after his/her death.
- Understanding the activities of animals is possible.
- Allowing the deaf to hear via direct nerve stimulation is achievable.

Disadvantages of Blue Brain

- It increases the risk of human dependency on Blue Brain every time.
- Once a Blue Brain related to a particular person's neural schema is hacked, the brain could be used against the very person.
- Since it an approach to make machines intelligent and thoughtful it increases the risk of machines conducting war against human (like we have been watching in the movies like Terminator, Universal soldier, etc.)

V. CONCLUSION

The Blue Brain Project is the first made comprehensive attempt to reverse-engineer the brain of mammalian, so that through detailed simulations the function of brain can be understood properly. With the advancements in technology, human who is the ultimate source of information and discovery should also be preserved. A human does not live for thousands of years but the information in their mind could be saved and used for several thousands of years. The whole idea is that memory, mental illness and perception triggered by neurons and electric signals could be soon treated with a supercomputer that models nearly all the 1,000,000 million synapses of the brain.

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ISSN: 2278 – 1323