



International Journal of Emerging Technologies in Computational and Applied Sciences (IJETCAS)

www.iasir.net

Blue Brain: An approach towards creation of virtual brain

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Abstract: Blue Brain is an attempt to reverse engineer the human brain and recreate it at the cellular level inside a computer simulation. It is used to study the brain's architectural and functional principles and the development of blue brain involves the merging of neural networks, computer simulation and cognitive science. This paper reviews the blue brain's construction. The steps involved in its creation. With the advancement in technology, human, the ultimate source of information and discovery should also be preserved. Human don't live for thousands of years but the information in its mind could be saved and used for several thousands of years. The technology of Blue Brain is of great help in the preservation. This paper discusses about the hardware and supercomputers being used to build a Blue Brain. The merits and demerits involved in creation and implementation of Blue Brain have also been discussed.

Keywords: Virtual Brain, Computer Simulation, Patch clamp electrodes, Neurons, Cerebral cortex, Blue Gene Supercomputer.

I. INTRODUCTION

Human Brain, is the most valuable creation of God. The man is called intelligent because of the brain. Today we are developed because we can think that other animals cannot do. But we lose the knowledge of a brain when the body is destroyed after the death of man. That knowledge might have been used for the development of the human society. So an approach is made to create a virtual brain called the Blue Brain[7][9] which means a machine that can function as human brain and it is possible by clubbing together the aspects of neural networks, computer simulation and cognitive science. The main aim is to upload human brain into a machine. So that man can think, take decision without any effort. After the death of the body, the virtual brain will act as the man. So, even after the death of a person we will not lose the knowledge, intelligence, personalities, feelings, emotions and memories of that man which can be used for the development of the human society. The Blue Brain System[11] is an attempt to reverse engineer the human brain and recreate it at the cellular level inside a computer simulation. The project was founded in May 2005 by Henry Markram at the EPFL in Lausanne, Switzerland[15]. 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 involves studying slices of living brain tissue using microscopes and patch clamp electrodes. Data is collected about all the many different neuron types. This 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 on Michael Hines's NEURON, together with other custom-built components. Figure 1 shows the basic structure of the Blue Brain. The basic principle of Blue Brain is "Determine synapse-scale connectivity by virtually reconstructing a cortical microcircuit and comparing it to a mammalian sample." [2]



Figure 1: Basic structure of Blue Brain

II. NEED FOR VIRTUAL BRAIN

Today we are developed because of our intelligence. Intelligence is the inborn quality that cannot be created. Some people have this quality, so that they can think up to such an extent where other cannot reach. Human society is always in need of such intelligence and such an intelligent brain to have with. But the intelligence is lost along with the body after the death. The virtual brain is a solution to it. The brain and intelligence will be alive even after the death. We often face difficulties in remembering things such as people names, their birthdays, and the spellings of words, proper grammar, important dates, history facts, and etcetera. In the busy life everyone wants to be relaxed [12]. The goal is to gain a complete understanding of the brain and to enable better and faster development of brain disease treatments. With the advancement in technology, human, the ultimate source of information and discovery should also be preserved. Humans don't live for thousands of years but the information in his mind could be saved and used for several thousands of years. The technology helpful in this activity is Blue Brain. The research involves studying slices of living brain tissue using microscopes and patch clamp electrodes. Data is collected about all the many different neuron types. The data is used to build biologically realistic models of neurons and networks of neurons in the cerebral cortex [13].

III. Construction of Blue Brain

There are three main steps to build the virtual brain:

- A. Data Acquisition
- B. Simulation
- C. Visualization of Results.

A. Data Acquisition

Under data acquisition, the brain slices are placed under microscope and the shape as well electrical activity of individual neurons is measured. The neurons are examined by their shape called as morphology, electrophysiological behaviour and their population density[14]. Then these observations are translated into mathematical algorithms which describe the form, functions and position of neurons. The algorithms are then used to generate biologically-realistic virtual neurons ready for simulation. To study the electrophysiological behavior of the neurons, the main tool required is 12 patch clamp[10]. It allows twelve living neurons to be concurrently patched and their electrical activity is recorded.



Figure 2: The 12 patch-clamp

B. Simulation

Simulation refers to the use of a mathematical model to recreate a situation, so that the likelihood of various outcomes can be more accurately estimated. The main focus for the creation of virtual brain is on the neurons and the primary software used for neural simulation is a package called NEURON which was developed in 1990 by Michael Hines and John Morey [6]. It is written in C, C++ and Fortran and is a free, open source software. Neural simulation is basically used for building and using computational models of neurons and network of neurons. For blue brain, the current version of neuron which is being used is 7.2.

The main factors on which the simulation depends are:

i. Simulation Speed

The simulations show approximately linear scaling - that is, doubling the size of the neural network doubles the time it takes to simulate. The simulation time step for the numerical integrations is 0.025ms and the time step for writing the output to disk is 0.1ms [16].

ii. Workflow

The simulation step involves synthesizing virtual cells using the algorithms that are used to describe real neurons. The algorithms and parameters are adjusted for the age, species and disease stage of the species being simulated. First network skeleton is built, then the cells are connected together to the rules that have been found experimentally. Finally the neurons are functionalized and the simulation is brought to life. Further the patterns are viewed with the help of visualization software. The ultimate aim is to be able to understand and human consciousness.

iii. BBP-SDK

The BBP-SDK (Blue Brain Project-Software Development Kit) is a set of software classes which are used to utilize and inspect models and simulations. The SDK is a C++ library wrapped in Java and Python [1]. The Blue Brain simulation uses one microprocessor for each of the 10,000 neurons in the cortical column of a cerebral cortex [17]. It helps to build a brain microcircuit, in order to scale it in human brain. The neocortical column represents the basic functional unit of the cerebral cortex in mammals that underlies nearly all sensory and cognitive processing. These units are repeated millions of times across the cortex. Reverse-engineering [4] a portion of the neocortex involves capturing many levels of detail about microscopic cells and fibers- living, dynamic entities that are invisible to the naked eye. Figure 3 shows the Cell Builder Window of NEURON software.

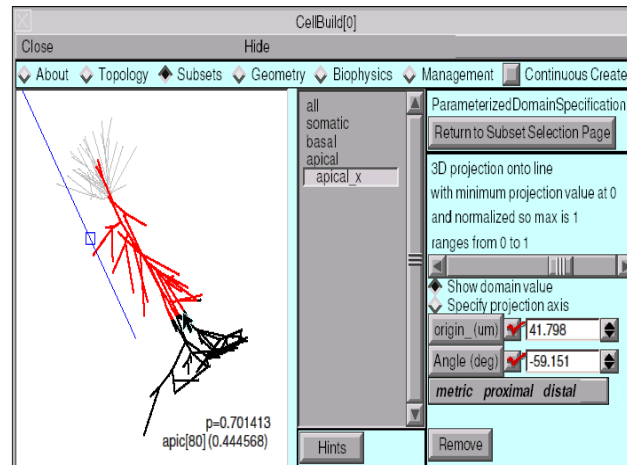


Figure 3: NEURON Cell Builder Window

C. Visualization of Results

RT NEURON is a primary application used for visualization of emergent behaviour of neural simulation. RTNeuron is ad-hoc software written in C++ especially for neural simulations. RTNeuron takes the output from Hodgkin-Huxley simulations in NEURON[8] and renders them in 3D and visualization are multi-scale as well 3D animation can be stopped, started and zoomed at any stage of process. For visualization of result, 32 processors silicon graphics inc.(SGI) system with 32GB of shared memory is being used. Below figure signifies rendered in RTNeuron[20].



Figure 4: RTNeuron visualization of a neuron

III. Computers for Building Blue Brain

A. Blue Gene Supercomputer

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 Modeling Science) [18]. The computer is used by a number of different research groups, not exclusively by the Blue Brain Project. In mid-2012 the BBP was consuming about 20% of the compute time. The brain simulations generally run all day, and one day per week.

The rest of the week is used to prepare simulations and to analyze the resulting data. The supercomputer usage statistics and job history are publicly available online - look for the jobs labeled as "C-BPP"[19]. A Blue Brain aims to unlock the secrets of brain by using the brute power of a supercomputer. Primary machine used by the blue brain is a Blue Gene Supercomputer built by IBM[5]. This machine is upgraded as Blue Gene/P in June 2010 and is installed on the EPFL campus and managed by CADMOS (Center For Advanced Modeling Science)[3]. Basically the brain simulation run all day once in a week otherwise the resulting data of simulation made on supercomputers is being analyzed.

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



Figure 5: Blue Gene/P Supercomputer

B. JuQUEEN

JuQUEEN is an IBM Blue Gene/Q supercomputer that was installed at the Jülich Research Center in Germany in May 2012. It currently performs at 1.6 peta flops and was ranked the world's 8th fastest supercomputer in June 2012. It's likely that this machine will be used for BBP simulations starting in 2013, provided funding is granted via the Human Brain Project. In October 2012 the supercomputer is due to be expanded with additional racks. It is not known exactly how many racks or what the final processing speed will be. The JuQUEEN machine is also to be used by the research initiative. This aims to develop a three-dimensional, realistic model of the human brain[15].

IV. MERITS AND DEMERITS OF BLUE BRAIN

Merits of Blue Brain

1. Blue brain is an approach to store and utilize human intelligence and information present in the mind even after human demise.
2. It is an important move towards self-decision making by the computer or machine that holds a Blue brain.
3. Business analysis, attending conferences, reporting, etc. are very significant functions that an intelligent machine can do consistently.
4. It can be used as an interface between human and animal minds. The BBP has become successful in rat and some other animals which is a sign of success.
5. It a good remedy towards human disability like a deaf can get the information via direct nerve stimulation.

Demerits of Blue Brain

1. It increases the risk of human dependency on Blue Brain every time.
2. Once a Blue Brain related to a particular person's neural schema is hacked, the brain could be used against the very person.
3. 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

With the creation of a blue brain we will be able to transfer ourselves into the computer at some time in future. Blue Brain can be used for the treatment of brain diseases. A large number of people suffer from brain diseases

in their lifetime. Therefore it is important to have a good strategy for understanding these diseases and finding suitable treatments. Blue Brain will search for insights into how human beings think and remember. Blue Brain offers a better understanding of human consciousness. It is a progress towards building thinking machines.

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