

A Survey on Blue Brain Technology: Next Generation Virtual Mind

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Abstract— Could stimulated brain act as a human brain? Could machine feel emotion and thinking like human? These questions seem to be silly and childish but, it's true. Blue brain is the solution which acts as a world's first virtual machine that can feel, understand, act, and perform like human brain. It is good example of artificial intelligence. Currently research is undergoing to implement and achieve this task. First step to identify functionality of neural network and based on that data collected and fitted on virtual machine as our scientist are interested in doing research about brain disfunctioning and its consciousness[1]. Various sources from which data is to be collected as a part of data acquisition, brain simulation model, its implementation techniques, process for uploading human brain into virtual mind are discussed in this survey article. The final objective of this blue brain technology is to achieve all knowledge about brain and enhance potential research area of reverse engineering.

Key words: Neurons, Blue Brain, Artificial Intelligence, Simulated Brain, Nanobots

I. INTRODUCTION

The Blue Brain, a Swiss national brain initiative, aims to create a digital reconstruction of the brain by reverse engineering to identify the fundamental principles of brain structure and function in health and disease. Blue brain is assumed to be world's first subway to genetic engineering and reverse engineering. Main goal is to create synthetic brain[2] that can think, response, take decision without any efforts and difficulties, and keep anything in memory. Future demands machine that can feel, act, process, and comprehend like human by studying slices of human brain. 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. Blue Gene supercomputer built by IBM performs this task and that's why the name "Blue brain" originates. The simulation software is based around Michael Hines's NEURON, which will accompany with Custom built components. The goal of the Blue Brain Project is to build biologically detailed digital reconstructions and simulations of the human brain. The supercomputer-based reconstructions and simulations built by the project offer a radically new approach for understanding the multilevel structure and function of the brain. The project's novel research strategy exploits interdependencies in the experimental data to obtain dense maps of the brain, without measuring every detail of its multiple levels of organization. This strategy allows the project to build digitally reconstructed model of the brain at an unprecedented level of biological detail. Supercomputer-based simulation of their behavior turns understanding the brain into a tractable problem, providing a new tool to study the complex interactions within different levels of brain organization and to investigate the cross-level links leading from genes to cognition. Data acquisition, simulation of brain

model and visualization of virtual brain are the main parts of this project. Blue Brain [3] Project has uncovered a universe of multi-dimensional geometrical structures and spaces within the neural networks that is part of the human brain.

II. NEED FOR BLUE BRAIN

There are several areas which demands successful completion of this project. Society need intelligent ideas and thoughts to be kept with them forever even after death because intelligent is the unborn quality. major areas where we demand blue brain are (1) To upload contents of the natural brain into it (2) To keep the intelligence, knowledge and skill of any person for ever (3) To remember things without any effort (4) 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. (5) A very good example of utilization of blue brain is the case "short term memory". In some movies we might have noticed that a person might be having short term memories. (6) A another situation is that when a person gets older, then he starts forgetting or takes a bit more time to recognize to a person. (7) Short term memory and volatile memory at the old age can be avoided.

III. HUMAN BRAIN VS SIMULATED BRAIN

The brain essentially serves as the body's information processing centre. It receives Signals from sensory neurons (nerve cell bodies and their axons and dendrites) in the central and peripheral nervous system, and in response it generates and sends new signals that instruct the corresponding parts of the body to move or react in some way. It also integrates signals received with signals from adjacent areas of the brain, giving rise perception and consciousness. The human ability to feel, interpret and even see is controlled, in computer like calculations, by the magical nervous system [2]. The three simple functions that it puts into action: Input sensation, Processing, Act output. Sensation is done by sensory cells, also known as neurons send a message straight to your brain. This sensory cell produces electric impulses which are received by neurons. The neurons transfer these electric impulses to the brain. IN processing, the interpretation of things we have felt, tasted, and touched with Our sensory cells, also known as neurons, into responses that the body recognizes. This process is all accomplished in the brain where many neurons work together to understand the environment. Based on the states of the neurons the brain sends the electric impulses representing the responses which are further received by sensory cell of our body to respond neurons in the brain at that time. There are certain neurons in our brain which represent certain states permanently. When required, this state is represented by our brain and we can remember the past things. To remember things we force the neurons to represent certain states of the brain permanently or

for any interesting or serious matter this is happened implicitly. In simulated brain, input response is received through artificial neurons which are single silicon chip. The interpretation of the electric impulses received by the artificial neuron can be done By means of registers. The different values in these register will represent different states of Brain.

Similarly based on the states of the register the output signal can be given to the artificial neurons in the body which will be received by the sensory cell. It is not impossible to store the data permanently by using the secondary memory. In the similar way the required states of the registers can be stored permanently and when required these information can be received and used. Computer by using some stored states and the received input and the performing some arithmetic and logical calculations.

IV. REQUIREMENT

A. Sensory Neurons

The primary software used by the BBP for neural simulations is a package called NEURON. This was developed starting in the 1990s by Michael Hines at Yale University and John Moore at Duke University. The simulation step involves synthesizing virtual cells using the algorithms that were found to describe real neurons. And there are about a billion of these in one cell. First a network skeleton is built from all the different kinds of synthesized neurons. Then the cells are connected together according to the rules that have been found experimentally. Finally the neurons are functionalized and the simulation brought to life. The patterns of emergent behavior are viewed with visualization 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.

B. Software

The BBP-SDK (Blue Brain Project - Software Development Kit) is a set of software classes (APIs) that allows researchers to utilize and inspect models and simulations. The SDK is a C++ library wrapped in Java and Python.

C. Super Computer Requirement

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 (Centre for Advanced Modeling Science).

Super computer should have Memory with a very large storing capacity, Processor with a very high processing power, A very wide network, A program to convert the electric impulses from the brain to input signal, which is to be received by the computer and vice versa, very powerful Nanobots to act as the interface between the natural brain and the computer 22.8 TFLOPS peak processing speed.8,096

CPUs at 700 MHz (downgraded to handle massive parallel processing), 256MB to 512MB memory preprocessor. Linux and C++ software, 100 kilowatts power consumption. 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, A 32-processor Silicon Graphics Inc. (SGI) system with 300 GB of shared memory is used for visualization of results

V. IMPLEMENTATION STEPS

Blue brain project is to be implemented in three successive stages. These are data gaining, simulation and visualization.

A. Data Gaining

Data acquisition involves taking brain slices, placing them under a microscope, and measuring the shape and electrical activity of individual neurons. The neurons are typed by morphology (i.e. their shape), electrophysiological behavior, location within the cortex, and their population density. These observations are translated into mathematical algorithms which describe the form, function, and positioning of neurons. One of the methods is to take 300 μm -thick sagittal brain slices from the somato sensory 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 process corrects for this. Slicing also severs 20% to 40% of axonal and dendritic arbors, so these are regrown algorithmically. The electrophysiological behavior of neurons is studied using a 12 patch clamp instrument (pictured below left). 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.

B. Simulation

The primary software used by the BBP for neural simulations [4] is a package called NEURON. This was developed starting in the 1990s by Michael Hines at Yale University and John Moore at Duke University. It is written in C, C++, and FORTRAN. The software continues to be under active development and, as of July 2012, is currently at version 7.2. It is free and open source software. both the code and the binaries are freely available on the website. Michael Hines and the BBP team collaborated in 2005 to port the package to the massively parallel Blue Gene supercomputer. one second of simulated time takes about five minutes to complete. The simulations show approximately linear scaling - that is, doubling the size of the neural network doubles the time it takes to simulate. Currently the primary goal is biological validity rather than performance. Once it's understood which factors are biologically important for a given effect it might

be possible to trim components that don't contribute in order to improve performance.

C. Visualization

RT Neuron is the primary application used by the BBP for visualization 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 propagate through a neuron and between neurons. The animations can be stopped, started and zoomed, thus letting researchers interact with the model. The visualizations are multi-scale that is they can render individual neurons or a whole cortical column.

VI. HOW TO UPLOAD

The uploading is possible by the use of small robots known as the Nanobots[6]. These robots are small enough to travel throughout our circulatory system. Traveling into the spine and brain, they will be able to monitor the activity and structure of our central nervous system. They will be able to provide an interface with computers that is as close as our mind can be while we still reside in our biological form. Nanobots could also carefully scan the structure of our brain, providing a complete readout of the connections. This information, when entered into a computer, could then continue to function as us. Thus the data stored in the entire brain will be uploaded into the computer. Once the microcircuit is built, the exciting work of making the circuit function can begin. All the 8192 processors of the Blue Gene are pressed into service, in a massively parallel computation solving the complex mathematical equations that govern the electrical activity in each neuron when a stimulus is applied. As the electrical impulse travels from neuron to neuron, the results are communicated via inter-processor communication (MPI). Currently, the time required to simulate the circuit is about two orders of magnitude larger than the actual biological time simulated. The Blue Brain team is working to streamline the computation so that the circuit can function in real time - meaning that 1 second of activity can be modeled in one second.

VII. DIGITAL RECONSTRUCTION

With its 100 billion neurons (brain cells) and it's 100 trillion Synapses, the human brain are a complex multi-level system. The connections among the neurons form a hierarchy of circuits, from local micro circuitry up to the level of the whole brain. Meanwhile at a lower level, every neuron and every synapse is a complex molecular machine in its own. The project's current reconstructions reproduce the detailed cellular anatomy, connectivity, and electrical behavior of a small part of the neocortex of young rats (about one third of a cubic millimeter of cortical tissue).

The BBP's[5] reconstruction strategy identifies interdependencies in the Experimental data (e.g. dependencies between the size of neurons and neuron densities, dependencies between the shapes of neurons and

the synapses they form, dependencies between the numbers of "buttons" on axons and synapse numbers) and uses them to "constrain" the reconstruction process. Multiple, intersecting constraints allow the project to build the most faithful reconstructions possible from the sparse available experimental data— avoiding the need to "measure everything". In fact, the BBP's latest reconstruction of the cortical microcircuit connectivity is based on experimental data representing less than 1% of the synaptic connections in the circuit. Lab experiments providing new data and constraints make it possible to test and progressively improve the digital reconstruction.

VIII. EXPECTED OUTCOMES

A. What Can We Learn from Blue Brain?

Detailed, biologically accurate brain simulations offer the opportunity to answer some fundamental questions about the brain that cannot be addressed with any current experimental or theoretical approaches.

B. Defining Functions of the Basic Elements

Despite a century of experimental and theoretical research, we are unable to provide a comprehensive definition of the computational function of different ion channels, receptors, neurons or synaptic pathways in the brain. A detailed model will allow fine control of any of these elements and allow a systematic investigation of their contribution to the emergent behavior.

C. Understanding Complexity

At present, detailed, accurate brain simulations are the only approach that could allow us to explain why the brain needs to use any different ion channels, neurons and synapses, aspect rum of receptors, and complex dendritic arborizations, rather than the simplified, uniform types found in many models.

D. Exploring the Role of Dendrites

This is the only current approach to explore the dendritic object theory, which proposes that three-dimensional voltage objects are generated continuously across dendritic segments regardless of the origin of the neurons, and that spikes are used to maintain such dendritic objects.

E. Revealing Functional Diversity

Most models engineer a specific function, whereas a spectrum of functions might be possible with a biologically based design. Understanding memory storage and retrieval. This approach offers the possibility of determining the manner in which representations of information are imprinted in the circuit for storage and retrieval, and could reveal the part that different types of neuron play in these functions.

F. Tracking the Emergence of Intelligence

This approach offers the possibility to re-trace the steps taken by a network of neurons in the emergence of electrical states used to embody representations of the organism and its world.

G. Identifying Points of Vulnerability

Although the neocortex confers immense computational power to mammals, defects are common, with catastrophic

cognitive effects. At present, a detailed model is the only approach that could produce a list of the most vulnerable circuit parameters, revealing likely candidates for dysfunction and targets for treatment.

H. Simulating Disease & Developing Treatments

Such simulations could be used to test hypotheses for the pathogenesis of neurological and psychiatric diseases, and to develop and test new treatment strategies.

I. Providing a Circuit Design Platform

Detailed models could reveal powerful circuit designs that could be implemented into silicone chips for use as intelligence devices in industry

IX. FUTURE PERSPECTIVE

The synthesis era in neuroscience started with the launch of human brain project and is inevitable phase triggered by a critical amount of fundamental data. The data set does not need to be complete before such a phase can begin. Detailed models will probably become the final form of databases that are used to organize all knowledge of the brain and allow hypothesis testing, rapid diagnoses of brain malfunction as well as development of treatments for neurological disorders. In short, we can hope to learn a great deal about brain function and dysfunction from accurate models of the brain. A model of the entire human brain at the cellular level will probably take the next decade. As with deep blue, Blue Brain will allow us to challenge the foundations of our understanding of intelligence and generate new theories of consciousness.

X. CONCLUSION

In conclusion, we will be able to transfer ourselves into computers at some point. Most arguments against this outcome are seemingly easy to circumvent. They are either simple minded, or simply require further time for technology to increase. The only serious threats raised are also overcome as we note the combination of biological and digital technologies. While the road ahead is long, already researches have been gaining great insights from their model. Using the Blue Gene supercomputers, up to 100 cortical columns, 1 million neurons, and 1 billion synapses can be simulated at once.

This is roughly equivalent to the brain power of a honey bee. Humans, by contrast, have about 2 million columns in their cortices. Despite the sheer complexity of such an endeavour, it is predicted that the project will be capable of this by the year 2023.

REFERENCES

- [1] Segev, Idan. "ASC 2012: Prof. Idan Segev – “The blue brain”(https://www.youtube.com/watch?v=XBTjIGI44Tk). The Hebrew University of Jerusalem. Retrieved 31 May 2013.
- [2] "Henry Markram: “Simulating the brain; the next decisive years”, video [3/3] 07:00"http://www.kurzweilai.net/henry-markram-simulating-the-brain-next-decisive-years). Retrieved 2011-08-29.

- [3] "Blue Brain Project - IBM has not withdrawn support" (<http://technology-report.com/2009/01/blue-brain-project-ibm-has-not-withdrawn-support/>). Henry Markram, Project Director as quoted by IBM Switzerland to Technology Report on January 19, 2009. Retrieved 2009-04-14
- [4] "Nanotechnology Microscope for Brain Studies" (<http://www.azonano.com/news.asp?newsID=11626>). Retrieved 2011-01-07.
- [5] "Mission to build a simulated brain begins" (<https://www.newscientist.com/article.ns?id=dn7470>), new.
- [6] "Reconstructing the Heart of Mammalian Intelligence" (http://ditwww.epfl.ch/cgiperl/EPFLTV/home.pl?page=start_video&lang=2&connected=0&id=365&video_type=10&win_close=0) Henry Markram's Lecture, March 4, 2008.
- [7] Indian startup to help copy your brain on computers (http://www.siliconindia.com/shownews/Indian_startup_to_help_copy_your_brain_on_computers-nid-65039.html) Silicon India. 1 February 2010.