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Blue Brain Technology

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ABSTRACT

How great would it be if you never forgot anything or never lost the ability to think and be creative? And just imagine how much more great it would be if your brain can be reconstructed so that it can stay young forever and be used to create wonders even after your death? It would be a great leap in the field of science if the brains of great minds like Steve Jobs or Albert Einstein can be recreated. That is exactly what the blue brain does. The blue brain project is an attempt to reconstruct the brain piece by piece and building a virtual brain in a supercomputer. It began in 2005 with an agreement between the EPFL and IBM, which supplied the Blue Gene/L supercomputer acquired by EPFL to build the virtual brain. The computing power needed is considerable. Each simulated neuron requires the equivalent of a laptop computer. A model of the whole brain would have billions. Supercomputing technology is rapidly approaching a level where simulating the whole brain becomes a concrete possibility. The main aim is to update the brain into a computer. As a first step, the project succeeded in simulating a rat cortical column. Efforts are now being made to simulate the human brain. In five years of work, Henry Mark ram's team has perfected a facility that can create realistic models of one of the brains essential building blocks. This process is entirely data driven and essentially automatically executed on the supercomputer. This modeling will expand to all the areas of the brain and if successful, shed light on the relationships between genetic, molecular and cognitive functions of the brain. These models will be basic building blocks for larger scale models leading towards a complete virtual brain.

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INTRODUCTION

The blue brain project is the brain child of the scientist, Henry Markram at the EPFL in Lausanne, Switzerland. His aim of recreating the brain at cellular level lead to this project in 2005. With a funding of around 1.3 billion dollars, his team is getting closer to success every day. Reverse engineering is used to make this process possible. This will directly lead to better understanding of a brain and its working and, that in turn will help us treat around 600 types of brain diseases. The major goal of the project is to give a better understanding on the functions of the brain The Blue Brain Project is an attempt to recreate the brain and create an artificial counterpart for it. It is nothing but a virtual brain that can think and function like the natural brain with the help of simulations. It should be clear that the BBP is not an artificial intelligence project but rather an attempt to reconstruct the originality of the living organism's brain. It focuses on creating a physiological and biological simulation for various medical and computational applications. As part of the research, slices of the brain tissue are studied using microscopes and patch clamp electrodes. Information about many different kinds of neurons is collected and stored in the database. This information is used to reconstruct the brain and build realistic models of neurons and the network of neurons in the cerebral cortex. The software used for simulating the brain is spread across an array of Blue Gene supercomputers built by IBM, SGI Prism machines, NEURON as well as a few commodities off the shelf PCs. As of January 2015 the simulations contain around 100 cortical columns involving about 1 billion synapses which are about the same amount as that present in a honey bee. The Blue Brain research started with the study of the rat's neocortical column and its simulation is almost completely achieved. It is also hoped that the simulation of the full human brain would be possible by 2023, providing sufficient funding is obtained.

What is blue brain?

The blue brain was a project initiated by neuroscientist Henry Markram and his team of research scientists at the Brain and Mind Institute of École Polytechnique in Lausanne Switzerland in

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2005. The major goal of the project was to build a virtual brain by recreating the brain piece by piece. This became possible by using the blue gene- the world's most powerful super computer and that's why the name Blue Brain. The virtual brain is an artificial brain that can think like a brain and perform the functions of the brain using past experiences and stored data. The research team started off by cutting open the rat's brain, and studying every part of it under powerful microscopes, patch clamps and electrodes. They recreated a virtual rat brain using the research they had done on the rat's cortical column, with the help of supercomputers. The idea behind the project was to reverse engineer the rat's brain by brain simulation. The rat's brain was brought down to molecular level for research involved in this process. Although it is the most powerful supercosmputer it can only perform only about 0.002% of the brains calculation in a second. Thus more studies are done on how to improve the performance of a virtual brain. One such development is the dynamic exascale entry platform (DEEP). The blue brain project paves the way for the human brain project, which is nothing but the recreation of the human brain.

Necessity of virtual brain:

Why do we need an artificial brain when our brain works just fine? The answer to this is "intelligence." Intelligence is an innate quality that cannot be created. Intelligence is lost during death of a person. Virtual brain is an attempt to reproduce intelligence using simulated brain waves and past experiences. It can also resolve the problem of forgetfulness. Some of the major factors for building an artificial/virtual brain include, brain disease treatments, better understanding of the working of the human brain, integration of neuroscientific research. It will also provide a great insight for creating thinking devices using a bottom up approach. The living brain is very difficult to understand; the virtual brain will make direct observations simpler and also tries to give a clearer picture of the brain functions. The virtual brain basically involves the process of uploading the living brain into a computer and literally living as a program.

How is it possible?

In the beginning the blue brain was built by the simulation of the living brain using supercomputers. Later the nano-robot technology was put into use. These robots are placed in the central nervous system, spine and the neo-cortical column of a living rat. These nano robots had the ability to travel through every small section of the brain and provide detailed information of the communications between neurons and brains especially in the grey matter. According to research there were both invasive and non invasive techniques to reverse engineer the brain, but the use of nanobots was considered to be the best technique amongst all. The nanobots can keep track of all the brain activities, the current state of the brain and then help the scientists upload all the data into supercomputers with large storage space, processing speed and capacity. IBM is working on creating computers with better storage and performance. It aims to build a microchip that simulates the behavior of one million neurons and ten billion synapses using less power. There are three important steps in the construction of the blue brain, they are: i.Data Acquisition ii.Simulation iii.Visualization.

Data Acquisition:

It is the process of taking the brain slices and studying it under a microscope. Neuronal 3D images of the brain are constructed and studied using the Neurolucida software package. The electrophysiological nature of the neurons is studied using a 12 patch clamp.

Simulation: The primary software used for simulation of the brain is NEURON. The software development kit (SDK) for blue brain project is a set of software classes. More about simulation is discussed in the following paragraph.

Visualization: RTNeuron is the primary application used for the visualization of simulated neurons. It is written in C++ and open GL. Animations of the brain and brain waves can be stopped started and zoomed.

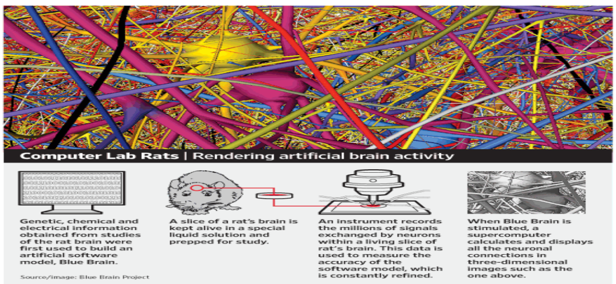

Fig. 1: rendering artificial brain activity.

Brain simulation:

Simulations of the brain started in 2012. Simulations were performed using the best supercomputers in Switzerland. During that period the simulations about 10,000 neurons, which is 1 cortical column was about 300 times slower than the real brain function. Hence increasing the size of the neural network also increased the time. Back then the primary goal was to reconstruct the major areas of the brain rather than performance. The simulations were carried out for every single cell in the CNS. Brain simulation involves cloning of the nerve cells and record synapses that builds up the microcircuits of the brain. Studies were made to find out which areas of the brain were important for a particular function so that the other areas can be ignored. This would also help to reduce the simulation time. It took about 0.025ms to achieve a numerical simulation and about 0.1ms to write the output into a disk. Many research scientists have published papers on how to improve brain simulation. One such paper highlights the importance of ion channels and the flow of electric impulses. It is very difficult to record every nuance of the neuronal network. But it is possible to select a particular network and produce multiple simulated models and then compare these models for best results using optimization algorithm. This approach was first tested with fast spiking and accommodating cortical columns. Both these cases are differentiated according to their electric behavior. In both these neuronal classes, genetic algorithms helped to create models according to the experimental results. The research scientists believe that these models are the basis building blocks for simulating larger neuronal networks. Simulators were setup to make sure that no two neurons had the same features, just like the natural brain. Softwares have been developed to simulate up to 10,000 neurons in the rat brain. These simulations can be viewed using visualization software in the form of 3d images.

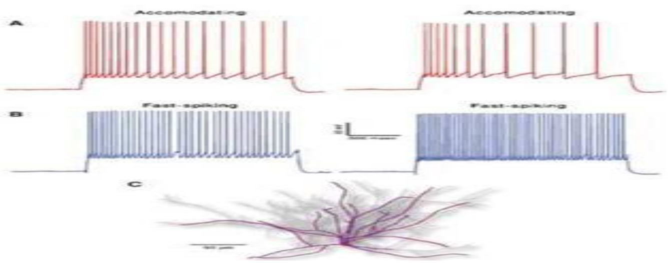

Fig. 2: A Novel Multiple Objective Optimization Framework for Constraining Conductance-based Neuron Models by Experimental Data.

Table 1: Comparison between Natural and Simulated Brain.

Natural Brain	Simulated Brain
INPUT In the nervous system in our body the neurons are responsible for the message passing. The body receives the input by sensory cells. This sensory cell produces electric impulses which are received by neurons. The neurons transfer these electric impulses to the brain.	INPUT In a similar way the artificial nervous system can be created. The scientist has created artificial neurons by replacing them with the silicon chip. It has also been tested that these neurons can receive the input from the sensory cells. So, the electric impulses from the sensory cells can be received through these artificial neurons.
INTERPRETATION The electric impulses received by the brain from neurons are interpreted in the brain. The interpretation in the brain is accomplished by means of certain states of many neurons	INTERPRETATION 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.
OUTPUT 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.	OUTPUT 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
MEMORY 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.	MEMORY 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.
PROCESSING When we take decision, think about something, or make any computation, logical and arithmetic computations are done in our neural circuitry. The past experience stored and the current inputs received are used and the states of certain neurons are changed to give the output	PROCESSING In the similar way the decision making can be done by the computer by using some stored states and the received input and the performing some arithmetic and logical calculations.

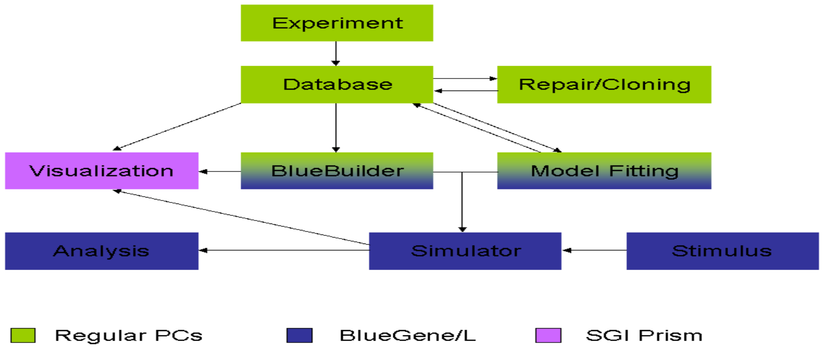

Fig. 3: Tool chain.

The next steps of the project will be performing simulation at the actual molecular level. This is one step ahead of what we have been doing up until now, that is simulation at neuron level. There are also plans to simplify the column simulation to allow for parallel simulation of large numbers of connected columns.

Software used:

NEURON is the first software used by the Blue Brain Project for neural simulations. This was developed in the 1990s by Michael Hines at Yale University and John Moore at Duke University. This software is written in C, C++, and FORTRAN and is still being upgraded. The current version of NEURON being used is 7.3. The operating system used to run this software is linux. NEURON is an open source software and its code is easily available on the web. The BBP team collaborated with Michael Hines in 2005 to port the package to the massively parallel Blue Gene supercomputer. A message passing interface (MPI) called the Neo Cortical Simulator (NCS) and an upgraded version of the software NEURON developed at Yale is used to run the simulations. The NCS was developed at the University of Nevada Reno. The figure below shows the overview of the high level architecture of the software.

Computer hardware/supercomputer:

Hardware/supercomputer:

SUPER COMPUTERS-A project this complex obviously needs a machine with very high computational power, to make the modeling and simulation possible. The scientists used a machined named, BlueGene, for this purpose. This revolutionized the prospects of modeling the brain. The heaps neuroscientific data collected over the past years can be unified under a framework using these biologically accurate models of the brain.

Blue Gene/P

Blue gene is the super computer used by the blue brain project. It was built by IBM. This is where the name "Blue Brain" comes from. In June 2010 this machine was upgraded to a Blue Gene/P. The machine is installed on the EPFL campus in Lausanne and is managed by CADMOS (Center for Advanced Modeling Science). It's not just the blue brain team who used this computer. Various other research teams also make use of this machine for its computational powers. The Blue Brain project uses almost 20% of the operational time. The brain simulations generally run all day. They work generally on Thursdays for this purpose. The rest of the week is used to prepare simulations and to analyze the resulting data. The detailed specification of the computer is available online.

• Blue Gene/P technical specifications
• 4,096 quad-core nodes
• 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 10This machine peaked at 99th fastest supercomputer in the world in November 2009.

Fig. 4: Blue gene .

Fig. 5: supercomputer rack.

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.

Uploading human brain:

Simulations can be performed only after the human brain is uploaded into a computer. This process is called mind uploading. It can be made possible by the use of small robots called Nanobots. These robots and minute and hence, they can travel through our central nervous system, spine and the small areas in our brain. They monitor the functions of the brain and the nervous system. Once this is complete they will be able to provide the structure of our brain to the user interface while we still reside in our biological form. The nano-bots also helps us to identify the connection between every neuron in the brain. All the synapses are recorded into a computer with the help of nanobots. Research work is done to improve this process by finding the particular nerves in which the nanobots can be placed. This will increase both speed and performance. Scientific visualization is the key for brain simulation. The uploaded data is viewed with softwares like RTNeuron and the important details are remodeled into an artificial brain. The basic idea is to recreate a virtual brain which performs all the functions of the natural brain.

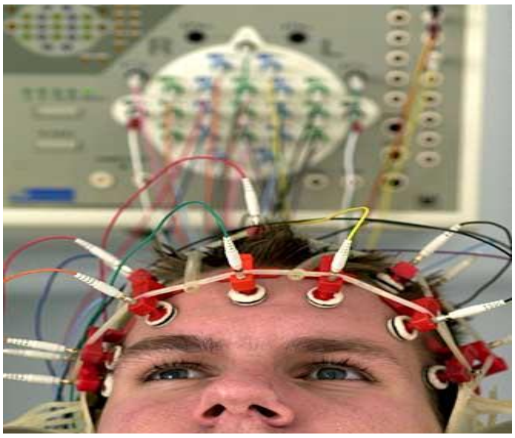

Fig. 6: Scanning the brain.

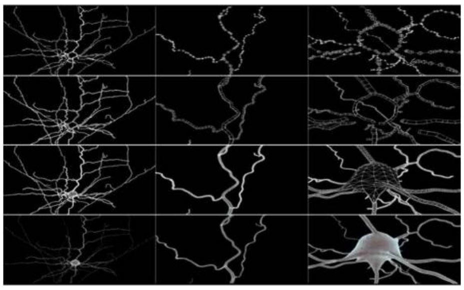

Fig. 7: Simulated Neuron Activity in 3D.

Merits and demerits:

The major advantage of the blue brain project is that it enables the reconstruction of the brain such that the persons intelligence can be used even after his/her death. With the blue brain things can be easily remembered and decisions can be made with the help of past experiences. It would allow people with Parkinson's to think and perform actions via direct nerve stimulation. It helps to understand the activity and thinking capabilities of different animals by interpreting the electric impulses from their brain. It would also help to induce hearing capabilities in the deaf through direct nerve stimulation and also help for many psychological diseases.

Human beings will start to depend more on computers for their livelihood. Technical knowledge may be misused by hackers. Computer viruses will increase and pose a critical threat leading to loss of data or malfunction of the system. The real threat, however, is the fear that people will have of new technologies. That fear may culminate in a large resistance. Clear evidence of this type of fear is found today with respect to human cloning. People will start to depend more on computers for their activities.

What can we learn from Blue Brain?

The blue brain provides an almost detailed description of the brain function. It might resolve the doubts on some fundamental concepts of the brain that cannot be addressed with any current experimental or theoretical approaches. It will help us to understand the complexity of the brain and will allow us to explain the need for many different ion channels, neurons, synapses, receptors complex dendritic and axomal arborations, gyri, sulci etcetera.

Applications:

1. Cracking the Neural Code
2. Gathering and Testing 100 Years of Data.
3. Understanding Neocortical Information Processing
4. A Novel Tool for Drug Discovery for Brain Disorders
5. A Global Facility
6. A Foundation for Whole Brain Simulations
7. A Foundation for Molecular Modeling of Brain Function

Human brain project overview:

Blue brain is an initiative that paves the road towards the development of the human brain project. The human brain project aims to simulate the human brain using extremely powerful supercomputers and simulators. One of the key goals of the human brain project is to serve as a cure for diseases like Alzheimers, Parkinsons, blindness etc.. The human brain is an extremely fast, highly powerful, immensely energy efficient, self learning and self repairing computer. It could perform as many as 38 thousand trillion operations per second. Latest research has proved that the simulation of brain can help blind people to create images etc in color since the visual part is still being triggered even if a person is unable to see. Nanobots are used to record the activity of every single neuron and nerve in the central nervous system. . To achieve this goal the Blue Brain team has come together with more 80 international partners to propose the Human Brain Project (HBP). There are more neurons in the brain than the stars in a galaxy; hence huge databases are required to store all the data about these neurons. The most important details are then fed into computers and then built into a virtual brain. The success of this project which is believed to be achieved in 2020 will be a big leap in neuroscience, medicine and computer engineering. It will also try to solve mysteries about the brain function and provide better means of treatment for brain diseases. Parallel simulations are performed using NEURON to understand pre-synaptic clefts and post synapses. The increased number of neurons in the human brain has led to integration of simulators for analysis and neuronal research. A human brain is so powerful that it can perform trillions of calculations simultaneously and to achieve this, neural computers will have to depend on optical technology. Computers unlike the parallel functioning neuronal network of the brain perform calculations in a linear method. Neuromorphic chips are being manipulated to perform parallel calculation and increase performance. The human brain project is funded by the European Union, Swiss government and IBM. The human brain project plays an important role in the development of artificial general intelligence which is nothing but an AI that can perform intellectual tasks just like every human being. Recreation of the brain is a tedious process, but with the advance in technology this can be achieved in the near future.

Annexure:

Working of the human brain- the working of the brain is split into 3 units: 1. Sensory input 2. Integration and 3. Motor input. Stimulus is perceived by the sense organs and sent to the brain for integration. This input is converted to human body readable form or motor input and sent to the muscles or other organs so that they can respond to the stimulus. There are many brain lobes involved in this process. Each lobe performs a different function as per the stimulus received. Electric impulses are passed between synaptic clefts to achieve neuronal communication so that it can process the sensory input and produce an equivalent motor input.

Neural computation- neural systems are created to understand working of different areas of the brain like the optical area, respiratory area etc. All the functions of the brain are interlinked but some of them can be idealized and recreated by computational technology. Neural computation involves algorithms that help to record the activity and communication among neurons. Artificial neural networks are an interconnection of neurons which can process input and enable pattern recognition and reproduction of knowledge and learning through machines. In an artificial neural network neurons are in the form of nodes that are interconnected to form a biological neural network. These networks consist of adaptive weights and that are used during training and prediction. Just like the brain these networks consists of different layers for responding to sensory inputs, integration of these inputs and providing motor inputs. This is the basic concept used in the blue brain technology.

Conclusion:

There are two sides to every coin. Likewise the blue brain project has its own positives and negatives. It would be a great milestone in the field of neuroscience and computer engineering if the brain can be replicated. While there is a long journey ahead to reach this goal, simulated models have and are providing a great deal of information to build a working model of the human brain. Given the sheer complexity of the human brain developments are made in both software and hardware technology to achieve simulation of the human neocortex that contains about 2 million columns. Every person wants to be free and relaxed in their busy life. The human does just this. It will reduce the stress and increase the memory capacity. After all what could be better than recreating intelligence? Using the Blue Gene supercomputers, up to 100 cortical columns, 1 million neurons, and 1 billion synapses can be simulated at once. But like Einstein feared will technology start to reduce the importance of direct human communications?

REFERENCES

Henry Markram, "The Blue Brain Project", Nature Reviews Neuroscience

Henry Markram, 2004. Maria Toledo-Rodriguez, Yun Wang, Anirudh Gupta, Gilad Silberberg, Caizhi Wu, Nat Rev Neurosci, 5(10): 793-807.

Henry Markram, J. HFSP, 2008, 2(3): 132–135.

http://bluebrainproject.epfl.ch.

http://boingboing.net/2011/05/11/blue-brain-project-b.html

http://en.wikipedia.org/wiki/Artificial_neural_network

http://en.wikipedia.org/wiki/Mind_uploading

http://people.hss.caltech.edu/~steve/markham

http://research.ibm.com/bluebrain

http://www.eecs.berkeley.edu/~klueska/

https://www.afhu.org

The Blue brain project, 2008. Markram Henry, International conference of IEEE.

www.artificialbrains.com