Blue Brain - A Survey

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Abstract— Human brain is the most valuable and unique creation of God. The man is intellectual because of the fact that describes well and makes human fall in the category far different and upgraded from other species . "Blue brain" is the name of the world's first virtually created brain. That means a machine that will function as a substitute of human brain. Scientists are consistently looking to create an artificial brain that can think, respond, take decision, and keep everything in its memory. The main aim behind this idea is to map human brain into a highly advance machine. By doing this, man would be able to conserve the thinking and analysing ability of any individual forever and can later utilise that. After the death of the body, the virtually created brain will act as the thinking mechanism. So, even after the death of a person we will not lack the knowledge, intelligence, feelings and memories of that individual l, that can further be used for the development of the human society and many other beneficial acts. As technology is boosting faster than anything. A big software tycoon firm **IBM**(also Big Blues) is now in a way to create a virtual brain, called "Blue brain". If everything goes well, it would be the first virtual brain of the world created by human. IBM, in partnership with some scientists at **Switzerland's Ecole Polytechnique Federale de Lausanne's (EPFL**) Brain and Mind Institute will begin simulating the brain's biological and neurological structure and project the resulting data as a working 3-dimensional model that will recreate the high-speed electro-chemical interactions that take place within the brain's interior. These include cognitive functions such as language, learning, perception and memory in addition to brain malfunction such as psychiatric disorders like depression and autism. From there, the modeling will expand to other regions of the brain and, if successful, shed light on the relationships between genetic, molecular and cognitive functions of the brain.

Index Terms Reverse Engineer, Neuron, Cerebral Cortex, Nano robots , visualization, Modeling Science ,Simulations.

1 Introduction

Drain has always been a great point of attraction for every scientist. Everyone is curious to understand and decode the complexity of human brain. It is complex than any other electronic circuits in the world including very fine and fantastic internal communication system. So, question may arise "Is it really possible to create a human brain?" The answer is "Yes". Because, whatever man has created today, he has always done under the supervision of nature. When man had not invented the device called computer, it was a big question for all if it is really possible to design a device like this with this much of outstanding capacity. But today it is possible due to the vast level approach of human effort.

So the day is not far when the human effort will accomplish this impossible appearing task of uploading human brain inside a computer and simulate over it as a real working model of brain.

The Blue Brain is a technique of "Reverse Engineering" ,the human brain and rebuild 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. Goals of this project are to achieve a complete understanding and access of the brain and to enable better and faster development of brain disease treatments. The research includes observing slices of living brain tissue using highly magnified 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. As of August 2012 the largest simulations are of micro circuits containing around 100 cortical columns such simulations involve approximately 1 million neurons and 1 billion synapses. This is about the same scale as that of a honey bee brain. It is hoped that a rat brain neocortical simulation (~21 million neurons) will be achieved by the end of 2014. A full human brain simulation (86 billion neurons) should be possible by 2023 provided sufficient funding is received. [3]

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2 Artificial Brain Overview

The term Artificial brain is commonly used in the media to describe research that aims to develop software and hardware with cumulative abilities similar to those of the animal or human brain. Research investigating "artificial brains" plays three important roles in science

1. A special study called cognitive neuroscience, which helps neuroscientists to make an ongoing attempt to un-

derstand how human brain works.

2. A thought experiment in the philosophy of artificial intelligence (AI), which demonstrates that it is actually possible to create a machine that has all the capabilities of a human being in theory.
3. A serious long term project to create machines capable of general intelligent action or Artificial General Intelligence. This idea has been popularized by Ray Kurzweil as strong AI (taken to mean a machine as intelligent as a human being).[4]

3 WHAT IS WLUE WRAIN?

IBM is developing a artificial brain known as the Blue brain. It would be the world's first virtual brain. Within 30 years, we will be able to scan ourselves into the computers. It can think like brain, take important and reflex decisions based on the past experience, and respond just as a natural brain. A super computer, with a huge amount of storage capacity, will be used with high speed processing power and will act as a interface between the human brain and artificial one. Through this interface the data stored in the natural brain will be uploaded into the source computer. So brain and its consisting knowledge, intelligence of a person will be kept and used for ever, even after the person is no more. Blue brain is a concept which allows to copy or to transfer all the contents of a human brain into a simulated virtual brain that resides inside a Super computer. The Super computer used in this is Blue Gene as of the current information revealed. It is like uploading a mind in a computer.

4 NEED OF 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. Can't we use any machine to assist for all these? Virtual brain may be a better solution for it. What will happen if we upload ourselves into computer, we were simply aware of a computer, or maybe, what will happen if we lived in a computer as a program?

5 HOW IT IS POSSIBLE?

First, it is helpful to describe the basic manners in which a person may be uploaded into a computer. Raymond Kurzweil recently provided an interesting paper on this topic. In it, he describes both invasive and noninvasive techniques. The most promising is the use of very small robots, or nanobots. These robots will be small enough to travel throughout our circulatory systems. 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 between each neuron. They would also record the current state of the brain. This information, when entered into a computer, could then continue to function like us. All that is required is a computer with large enough storage space and processing power.

6 WORKING OF NATURAL BRAIN

The working of blue brain can be understand with the help of following concepts-

6.1 Getting to know more about Human Brain

The brain essentially serves as the body's information processing centre. It receivessignalsfromsensoryneurons(nervecellbodiesandtheiraxonsanddendrites) in the central and peripheral nervous systems, 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 from the body with signals from adjacent areas of the brain , giving rise to perception and consciousness. Thebrainweighsabout1,500 grams (3 pounds) and constitutes about 2 % of total body weight. It consists of three major divisions;;

- The massive paired hemispheres of the cerebrum
- The brainstem, consisting of the thalamus, hypothalamus, epitheliums, sub thalamus, midbrain, pons, and medulla oblongata.
- The cerebellum.

The human ability to feel, interpret and even is controlled, in computer like calculations, by the magical nervous system. The nervous system is quite like magic because we can't see it, but its working through electric impulses through your body. One of the world's most "intricately organized" electron mechanisms is the nervous system. Not even engineers have come close to making circuit boards and computers as delicate and precise as the nervous system. To understand this system, one has to know the three simple functions that it puts into action; sensory input, integration & motor output.

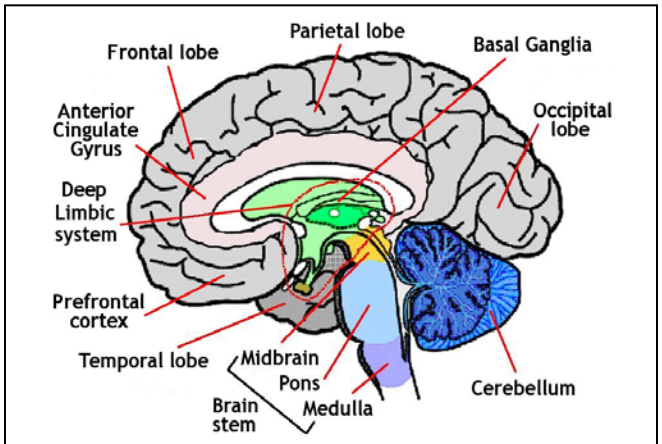

Fig. 1. Model view of left hemisphere of human Brain.

6.2 Sensory Input

When our eyes see something or our hands touch a warm surface, the sensory cells, also known as Neurons, send a message straight to your brain. This action of getting information from your surrounding environment is called sensory input because we are putting things in your brain by way of your senses.

6.3 Integration

Integrationisbestknownastheinterpretationofthingswehavefelt, 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, many neurons work together to understand the environment.

6.4 Motor Output

Once our brain has interpreted all that we have learned, either by touching, tasting, or using any other sense, then our brain sends a message through neurons to effecter cells, muscle or gland cells, which actually work to perform our requests and act upon our environment.

7 BRAIN SIMULATION

The simulation of blue brain is similar to the following-

7.1 Natural Brain

1. **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.
2. **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.
3. **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.
4. **Memory** - There are certain neurons in our brain which represent certain states permanently. When required these state is interpreted by our brain and we can remember the past things. To remember thing we force the neurons to represent certain states of the brain permanently or for any interesting or serious matter this is happened implicitly.
5. **Processing** - When we take decision, think about something, or make any computation, Logical and arithmetic calculations are done in our neural circuitry. The past experience stored and the current input received are used and the states of certain neurons are changed to give the output.

8 NEURON

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. 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.

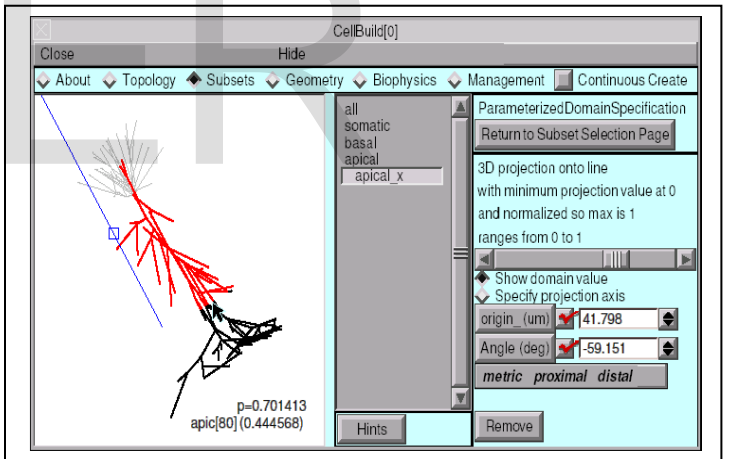

Fig.2. NEURON cell builder window

8.1 Working Flow of Neuron

The simulation step involves synthesizing virtual cells using the algorithms that were found to describe real neurons. The algorithms 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 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. 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 they require larger and larger networks. The plan is to build a generalized 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.

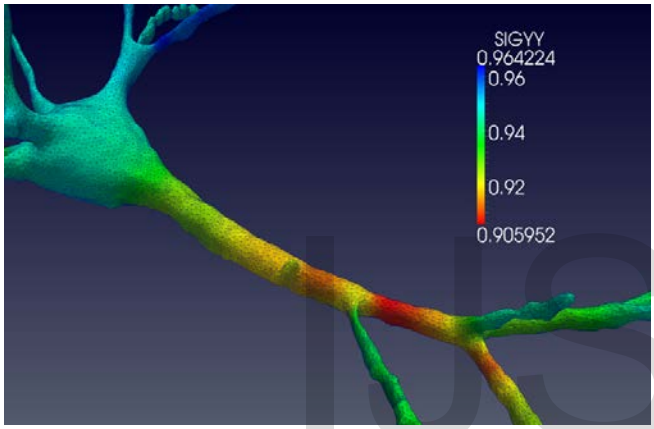

Fig.3. RTNeuron visualization of a neuron

8.2 RT Neuron

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. RT Neuron is ad-hoc software written specifically for neural simulations, i.e. it is not generalise able to other types of simulation. RT Neuron takes the output from Hodgkin-Huxley simulations in NEURON and render 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. The image right was rendered in RT Neuron.

9 How the Blue Brain project will work?

The followings are the concepts related to the working of blue brain-

9.1 Goals and Objectives

The Blue Brain Project is the First comprehensive attempt to reverse-engineer the mammalian brain, in order to understand brain function and dysfunction through detailed simulations. The mission in undertaking The Blue Brain Project is to gather all existing knowledge of the brain, accelerate the global research effort of reverse engineering the structure and function of the components of the brain, and to build a complete theoretical framework that can orchestrate the reconstruction of the brain of mammals and man from the genetic to the whole brain levels, into computer models for simulation, visualization and automatic knowledge archiving by 2015. Biologicallyaccuratecomputermodelsofmammalianandhumanbrainscouldprovideanew foundation for understanding functions and malfunctions of the brain and for a new generation of information-based, customized medicine.

9.2 Architecture of Blue Gene

Blue Gene/L is built using system-on-a-chip technology in which all functions of a node (except for main memory) are integrated onto a single application-specific integrated circuit (ASIC). This ASIC includes 2 PowerPC 440 cores running at 700 MHz. Associated with each core is a 64-bit "double" floating point unit (FPU) that can operate in single instruction, multiple data (SIMD) mode. Each (single) FPU can execute up to 2 "multiply-adds" per cycle, which means that the peak performance of the chip is 8 floating point operations per cycle (4 under normal conditions, with no use of SIMD mode). This leads to a peak performance of 5.6 billion floating point operations per second (giga FLOPS or GFLOPS) per chip or node, or 2.8 GFLOPS 9 in non- SIMD mode. The two CPUs (central processing units) can be used in "coprocessor" mode (resulting in one CPU and 512 MB RAM (random access memory) forcomputaion,the other CPU being used for processingthe I/O (input/output) of the main CPU) or in "virtual node" mode (in which both CPUs with 256 MB each are used for computation). So, the aggregate performance of a processor card in virtual node mode is: 2 x node = 2 x 2.8 GFLOPS = 5.6 GFLOPS, and its peak performance (optimal use of double FPU)is: 2x5.6GFLOPS=11.2GFLOPS.Arack(1,024nodes = 2,048 CPUs) therefore has 2.8 tera FLOPS or TFLOPS, and a peak of 5.6 TFLOPS. The Blue Brain Projects Blue Gene is a 4-rack system that has 4,096 nodes, equal to 8,192 CPUs, with a peak performance of 22.4 TFLOPS. A 64-rack machine should provide 180 TFLOPS, or 360 TFLOPS at peak performance.

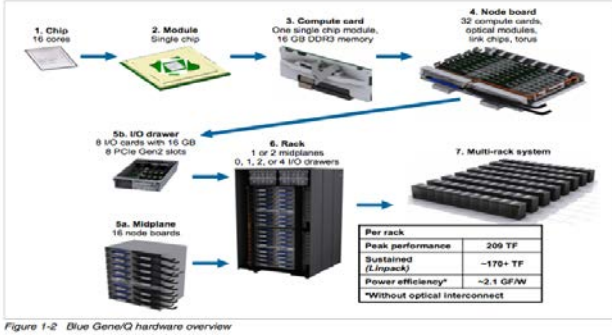

Fig.4. Blue Gene/O hardware overview

10 INTERPRETING THE RESULTS

Running the Blue Brain simulation generates huge amounts of data. Analyses Of individual neurons must be repeated thousand sof times. And analyses dealing with the network activity must deal with data that easily reaches hundreds of gigabytes per second of simulation. Using massively parallel computers the data can be analyzed where it is created (server-side analysis for experimental data, online analysis during simulation). Given the geometric complexity of the column, a visual exploration of the circuit is an important part of the analysis. Mapping the simulation data onto the morphology is invaluable for an immediate verification of single cell activity as well as network phenomena. Architects at EPFL have worked with the Blue Brain developers to design a visualization interface that translates the Blue Gene data into a 3D visual representation of the column. A different upper computers used for this computationally intensive task. The visualization of the neurons' shapes is a challenging task given the fact that a column of 10,000 neurons rendered in high quality mesh accounts for essentially 1 billion triangles for which about 100GB of management data is required. Simulation data with a resolution of electrical compartments for each neuron accounts for another 150GB. As the electrical impulse travels through the column, neurons light up and change color as they become electrically active. A visual interface makes it possible to quickly identify areas of interest that can then be studied more extensively using further simulations. A visual representation can also be used to compare the simulation results with experiments that show electrical activity in the brain.

11 COMPUTER HARDWARE/SUPERCOMPUTERS

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). 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 (usually Thursdays). 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".

1. Blue Gene/P technical specifications
2. 4,096 quad-core nodes
3. Each core is a PowerPC 450, 850 MHz
4. Total: 56 teraflops, 16 terabytes of memory
5. 4 racks, one row, wired as a 16x16x16 3D torus
6. 1 PB of disk space, GPFS parallel file system
7. Operating system: Linux SuSE SLES 10

12 COMPUTER HARDWARE/SUPERCOMPUTERS

The following hardware & supercomputers are required fro blue brain-

12.1 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. These include-

1. **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 system at ic investigation of their contribution to the emergent behaviour.
2. **Understanding complexity -** At present, detailed, accurate brain simulations are the only approach that could allow us to explain why the brain needs to use many different ion channels, neurons and synapses,a spectrum of receptors , and complex dendriti candaxon a larborizations, rather than the simplified, uniform types found in many models.
3. **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.
4. **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 representationsofinformationareimprintedinthecircuitforstorageandretrieval,and could reveal the part that different types of neuron play in these crucial functions.
5. **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.
6. **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 istheonlyapproachthatcouldproducealistofthemostvulnerablecircuitparameters, revealing likely candidates for dysfunction and targets for treatment.
7. **Simulating disease and 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.
8. **Providing a circuit design platform -** Detailed models could reveal powerful circuit designs that could be im-

plemented into silicone chips for use as intelligence devices in industry.

13 APPLICATION OF BLUE BRAIN

These are the applications of blue brain-

1. **Gathering and Testing 100 Years of Data -** The most immediate benet is to provide a working model into which the past 100yearsknowledgeaboutthemicrostructureandworkingsoftheneocorticalcolumn can be gathered and tested. The Blue Column will therefore also produce a virtual library to explore in 3D the microarchitecture of the neo cortex and access all key research relating to its structure and function.
2. **Cracking the Neural Code -** The Neural Code refers to how the brain builds objects using electrical patterns. In the same way that the neuron is the elementary cell for computing in the brain, the NCC is the elementary network for computing in the neo cortex. Creating an accurate replicaoftheNCCwhichfaithfullyreproducestheemergentelectricaldynamicsofthe real micro circuit, isan absolute requirement revealing how the neo cortex processes, stores and retrieves information.
3. **Understanding Neocortical Information Processing -** The power of an accurate simulation lies in the predictions that can be generated about the neo cortex. Indeed, iterations between simulations and experiments are essential to build an accurate copy of the NCC. These iterations are therefore expected to reveal the function of individual elements (neurons, synapses, ion channels, receptors), pathways (mono-synaptic, disynaptic, multi synaptic loops) and physiological processes (functional properties, learning, reward, goal-oreinted behavior).
4. **A Novel Tool for Drug Discovery for Brain Disorders -** Understanding the functions of different elements and pathways of the NCC will provide a concrete foundation to explore the cellular and synaptic bases of a wide spectrum of neurological and psychiatric diseases. The impact of receptor, ion channel, cellular and synaptic deficits could be tested in simulations and the optimal experimental tests can be determined.
5. **A Global Facility -** A software replica of a NCC will allow researchers to explore hypotheses of brain function and dys function accelerating research. Simulation runs could determine which parameters should be used and measured in the experiments. An advanced 2D, 3D and 3D immersive visualization system will allow "imaging" of many aspects of neural dynamics during processing, storage and retrieval of information. Such imaging experiments may be impossible in reality or may be prohibitively expensive to perform.
6. **A Foundation for Whole Brain Simulations -** With current and env is ageable future computer technology it seems unlikely that a mammalian brain can be simulated with full cellular and synaptic complexity (above the molecular level). An accurate replica of an NCC is therefore required in ordertogeneratereducedmodelsthatretaincriticalfunctionsandcomputationalcapabilities, which can be duplicated and interconnected to form neocortical brain regions. Knowledge of the NCC architecture can be transferred to facilitate reconstruction of subcortical brain regions.
7. **A Foundation for Molecular Modeling of Brain Function -** Anaccuratecellularreplicaoftheneocorticalcolumnwillprovidethefirstand essential step to a gradual increase in model complexity moving towards a molecular level description of the neocortex with biochemical pathways being simulated. A molecular level model of the NCC will provide the substrate for interfacing gene expression with the network structure and function. The NCC lies at the interface between the genes and complex cognitive functions. Establishing this link will allow predictions of the cognitive consequences of genetic disorders and allow reverse engineering of cognitive deficits to determine the genetic and molecular causes. This level ofsimulationwillbecomearealitywiththemostadvanced-phaseofBlueGenedevelopment.

14 ADVANTAGES AND LIMITATIONS

There are some advantages & limitations of blue brain-

14.1 Advantages

1. We can remember things without any effort.
2. Decision can be made without the presence of a person.
3. Even after the death of a man his intelligence can be used.
4. The activity of different animals can be understood. That means by interpretation of the electric impulses from the brain of the animals, their thinking can be understood easily.
5. It would allow the deaf to hear via direct nerve stimulation, and also be helpful form any psychological diseases. By downloading the contents of the brain that was uploaded into the computer, the man can get rid from the madness.

14.2 Limitations

Further, there are many new dangers these technologies will open. We will be susceptible to new forms of harm.

1. We become dependent upon the computer systems.
2. Others may use technical knowledge against us.
3. Computer viruses will pose an increasingly critical threat.
4. 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.

15 FUTURE SCOPE OF ADVANCE AI

Blue Brain is a futuristic technology. For doing it we will first have to upload human brain to the targeted super computer. We can do it easily with help of small robots called Nano robots. These robots can travel through inner parts of our body

(circular system) without damaging them. They can monitor and analyse human's central nervous system and with this detail we can easily create and function a blue brain (from a super computer).

Blue Brain can make us excel in each and every field of human kind. Be it engineering, medical or artistic, we can easily get guidance (proper one) with master blue brains of respective fields (and the best thing is their forever nature means blue brains will be there forever and future generation can also get benefited from them). Blue brains will be able to treat mental disorders related to human brains also. With this technology we can use someone's brain even after his/her death. So Blue Brain is a futuristic technology which will let us proceed with real pace and quality. Please share your views about this upcoming technology.

16 MERITS AND DEMERITS

With the blue brain project the things can be recalled without any struggle, conclusions can be made without the attendance of a person. Even after the death of a man his brainpower can be used. The activity of different animals can be assumed. That means by clarification of the electric impulses from the brain of the animals, their thinking can be assumed easily. It would allow the deaf to hear via direct nerve stimulation, and also be helpful for many psychological diseases. Due to blue brain system human beings will become reliant on the computer systems. Technical information may be abused by hackers; Computer viruses will pose an gradually critical threat. The real threat, however, is the fear that people will have of new technologies. That fear may terminate in a large confrontation. Clear sign of this type of fear is found today with respect to human cloning. What can we learn from Blue Brain? Full, biologically correct brain simulations offer the chance to answer some fundamental questions about the brain that cannot be talked with any current experimental or theoretical tactics.

17 CONCLUSION

In conclusion, we will be capable of transferring ourselves into computers system at some point of time. Most influences against this result are seemingly easy to avoid. They are either simple minded, or simply require more time for technology to increase. The only serious hazard raised are also overcome as we note the permutation of biological and digital technologies. While the way ahead is so long and complex, already researches have been gaining great visions 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 approximately equivalent to the brain power of a honey bee. Humans, by difference, have about 2 million columns in their cortices. In spite of the sheer complexity of such an undertaking, it is projected that the project will be capable of this by the year 2023.

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