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**INTRODUCTION**

Human brain is the most valuable creation of God. The man is called intelligentbecause of the brain. The brain translates the information delivered by the impulses,which then enables the person to react. But we loss the knowledge of a brain when thebody is destroyed after the death of man. That knowledge might have been used forthe development of the human society. What happen if we create a brain and up loadthe contents of natural brain into it?

**1.1 Blue Brain**

The name of the world’s ﬁrst virtual brain. That means a machine that canfunction as human brain. Today scientists are in research to create an artiﬁcial brainthat can think, response, take decision, and keep anything in memory. The main aimis to upload human brain into machine. So that man can think, take decision withoutany effort. After the death of the body, the virtual brain will act as the man .So, evenafter the death of a person we will not loose the knowledge, intelligence, personalities,feelings and memories of that man that can be used for the development of the humansociety. No one has ever understood the complexity of human brain. It is complexthan any circuitry in the world. So, question may arise “Is it really possible to create ahuman brain?” The answer is “Yes”. Because what ever man has created today alwayshe has followed the nature. When man does not have a device called computer, it wasa big question for all. Technology is growing faster than every thing. IBM is now inresearch to create a virtual brain, called “Blue brain”. If possible, this would be theﬁrst virtual brain of the world. With in 30 years, we will be able to scan ourselves intothe computers. Is this the beginning of eternal life?

1.2 What is Virtual Brain?

Virtual brain is an artiﬁcial brain, which does not actually the natural brain, butcan act as the brain. It can think like brain, take decisions based on the past experience,and response as the natural brain can. It is possible by using a super computer, witha huge amount of storage capacity, processing power and an interface between thehuman brain and this artiﬁcial one. Through this interface the data stored in the naturalbrain can be up loaded into the computer. So the brain and the knowledge, intelligenceof anyone can be kept and used for ever, even after the death of the person.

1.3 Why we need Virtual Brain?

Today we are developed because of our intelligence. Intelligence is the inbornquality that can not be created. Some people have this quality, so that they can think up to such an extent where other can not reach. Human society is always need of suchintelligence and such an intelligent brain to have with. But the intelligence is lost alongwith the body after the death. The virtual brain is a solution to it. The brain and intelli-gence will alive even after the death. We often face difﬁculties in remembering thingssuch as people’s names, their birthdays, and the spellings of words, proper grammar,important dates, history, facts etc... In the busy life every one want to be relaxed. Can’twe use any machine to assist for all these? Virtual brain may be the solution to it. Whatif we upload ourselves into computer, we were simply aware of a computer, or maybe,what if we lived in a computer as a program?

1.4 How it is possible?

First, it is helpful to describe the basic manners in which a person may beuploaded into a computer. Raymond Kurzweil recently provided an interesting paperon this topic. In it, he describes both invasive and noninvasive techniques. The mostpromising is the use of very small robots, or nanobots. These robots will be smallenoughtotravelthroughoutourcirculatorysystems. Travelingintothespineandbrain,they will be able to monitor the activity and structure of our central nervous system

Theywillbeabletoprovideaninterfacewithcomputersthatisascloseasourmindcanbe while we still reside in our biological form. Nanobots could also carefully scan thestructure of our brain, providing a complete readout of the connections between eachneuron. They would also record the current state of the brain. This information, whenentered into a computer, could then continue to function as us. All that is required isa computer with large enough storage space and processing power. Is the pattern andstate of neuron connections in our brain truly all that makes up our conscious selves?Many people believe ﬁrmly those we posses a soul, while some very technical peoplebelieve that quantum forces contribute to our awareness. But we have to now think technically. Note, however, that we need not know how the brain actually functions,to transfer it to a computer. We need only know the media and contents. The actualmystery of how we achieved consciousness in the ﬁrst place, or how we maintain it, isa separate discussion. Really this concept appears to be very difﬁcult and complex tous. For this we have to ﬁrst know how the human brain actually works.

**WORKING OF NATURAL BRAIN**

**2.1 Getting to know more about Human Brain**

The brain essentially serves as the body’s information processing centre. Itreceives signals from sensory neurons (nerve cell bodies and their axons and dendrites)in the central and peripheral nervous systems, and in response it generates and sendsnew signals that instruct the corresponding parts of the body to move or react in someway. It also integrates signals received from the body with signals from adjacent areasof the brain, giving rise to perception and consciousness. The brain weighs about 1,500grams (3 pounds) and constitutes about 2 percent of total body weight. It consists of three major divisions;

•

The massive paired hemispheres of the cerebrum

•

The brainstem, consisting of the thalamus, hypothalamus, epithalamus, subtha-lamus, midbrain, pons, and medulla oblongata

•

The cerebellum.The human ability to feel, interpret and even see is controlled, in computer likecalculations, by the magical nervous system.The nervous system is quite like magicbecause we can’t see it, but its working through electric impulses through your body.One of the worlds most “intricately organized” electron mechanisms is the nervoussystem. Not even engineers have come close to making circuit boards and computersas delicate and precise as the nervous system. To understand this system, one has toknow the three simple functions that it puts into action; sensory input, integration &motor output.

**2.1.1 Sensory Input**

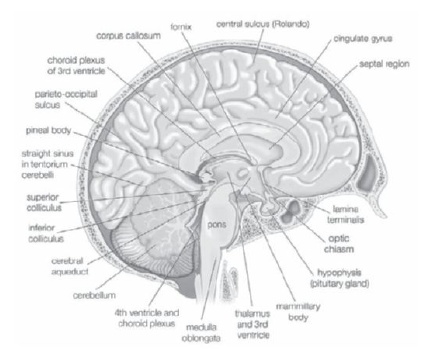
**When our eyes see something or our hands touch a warm surface, the sensorycells, also known as Neurons, send a message straight to your brain. This actionof getting information from your surrounding environment is called sensory inputbecause we are putting things in your brain by way of your senses.**

**2.1.2 Integration**

**Integration is bestknown as theinterpretation ofthings wehavefelt, tasted, andtouched with our sensory cells, also known as neurons, into responses that the bodyrecognizes. This process is all accomplished in the brain where many, many neuronswork together to understand the environment.**

**2.1.3 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 toeffecter cells, muscle or gland cells, which actually work to perform our requests andact upon our environment.5**

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**2.2 How we see, hear, feel, & smell?**

**2.2.1 Nose**

**Once the smell of food has reached your nose, which is lined with hairs, ittravels to an olfactory bulb, a set of sensory nerves. The nerve impulses travel throughthe olfactory tract, around, in a circular way, the thalamus, and ﬁnally to the smellsensory cortex of our brain, located between our eye and ear, where it is interpreted tobe understood and memorized by the body.**

**2.2.2 Eye**

**Seeing is one of the most pleasing senses of the nervous system. This cherishedaction primarily conducted by the lens, which magniﬁes a seen image, vitreous disc,which bends and rotates an image against the retina, which translates the image andlight by a set of cells. The retina is at the back of the eye ball where rods and conesstructure along with other cells and tissues covert the image into nerve impulses whichare transmitted along the optic nerve to the brain where it is kept for memory.**

**2.2.3 Tongue**

**A setofmicroscopicbuds on thetonguedivideeverythingweeatanddrink intofour kinds of taste: bitter, sour, salty, and sweet. These buds have taste pores, whichconvert the taste into a nerve impulse and send the impulse to the brain by a sensorynerve ﬁber. Upon receiving the message, our brain classiﬁes the different kinds of taste. This is how we can refer the taste of one kind of food to another.**

**2.2.4 Ear**

**Once the sound or sound wave has entered the drum, it goes to a large structurecalled the cochlea. In this snail like structure, the sound waves are divided into pitches.The vibrations of the pitches in the cochlea are measured by the Corti. This organtransmits the vibration information to a nerve, which sends it to the brain for interpre-tation and memory.**

**BRAIN SIMULATION**

**A comparative discussion of Natural Brain and Simulated Brain is given below.NATURAL BRAIN SIMULATED BRAIN1. INPUTIn the nervous system in our body theneurons are responsible for the messagepassing. The body receives the inputby the sensory cells. These sensorycellsproduceselectricimpulseswhicharereceived by the neurons. The neuronstransfer these electric impulses to thebrain.1. INPUTIn a similar way the artiﬁcial nervoussystem can be created. The scientisthas already created artiﬁcial neurons byreplacing them with the silicon chip. Ithas also been tested that these neuronscan receive the input from the sensorycells. So, the electric impulses fromthe sensory cells can be received throughtheseartiﬁcialneuronsandsendtoasupercomputer for the interpretation.2. INTERPRETATIONThe electric impulses received by thebrain from the neurons are interpreted inthe brain. The interpretation in the brainis accomplished by the means of certainstates of many neurons.2. INTERPRETATIONThe interpretation of the electric impulsesreceived by the artiﬁcial neuron can bedone by means of a set of register. Thedifferent values in these register willrepresent different states of the brain.3. OUTPUTBased on the states of the neurons thebrain sends the electric impulses repre-senting the responses which are furtherreceived by the sensory cell of our bodyto respond. The sensory cells of whichpart of our body is going to receive that, itdepends upon the state o f the neurons inthe brain at that time.3. OUTPUTSimilarly based on the states of theregister the output signal can be given tothe artiﬁcial neurons in the body whichwill be received by the sensory cell.7**

**NATURAL BRAIN SIMULATED BRAIN4. MEMORY.There are certain neurons in our brainwhich represent certain states perma-nently. When required these state is inter-preted by our brain and we can rememberthe past things. To remember thing weforce the neurons to represent certainstates of the brain permanently or forany interesting or serious matter this ishappened implicitly.4. MEMORYIt is not impossible to store the datapermanently by using the secondarymemory. In the similar way the requiredstatesoftheregisterscanbestoredperma-nently. And when required these infor-mation can be retrieved and used.5. PROCESSINGWhen we take decision, think aboutsomething, or make any computation,Logical and arithmetic calculations aredone in our neural circuitry. The pastexperience stored and the current inputreceived are used and the states of certainneurons are changed to give the output.5. PROCESSINGIn a similar way the decision making canbe done by the computer by using somestored states and the received input & byperforming some arithmetic and logicalcalculations.8**

**HOW THE BLUE BRAIN PROJECT WILL WORK?**

**4.1 Goals & Objectives**

**The Blue Brain Project is the ﬁrst comprehensive attempt to reverse-engineerthe mammalian brain, in order to understand brain function and dysfunction throughdetailed simulations. The mission in undertaking The Blue Brain Project is to gatherall existing knowledge of the brain, accelerate the global research effort of reverseengineering the structure and function of the components of the brain, and to build acomplete theoretical framework that can orchestrate the reconstruction of the brain of mammals and man from the genetic to the whole brain levels, into computer modelsfor simulation, visualization and automatic knowledge archiving by 2015. Biologi-cally accurate computer models of mammalian and human brains could provide a newfoundation for understanding functions and malfunctions of the brain and for a newgeneration of information-based, customized medicine.**

**4.2 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 700MHz. 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 nouse of SIMD mode). This leads to a peak performance of 5.6 billion ﬂoating pointoperations per second (gigaFLOPS or GFLOPS) per chip or node, or 2.8 GFLOPS9**

**in non- SIMD mode. The two CPUs (central processing units) can be used in “co-processor” mode (resulting in one CPU and 512 MB RAM (random access memory)for computation, the other CPU being used for processing the I/O (input/output) of themain CPU) or in “virtual node” mode (in which both CPUs with 256 MB each areused 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: 2 x 5.6 GFLOPS = 11.2 GFLOPS. A rack (1,024 nodes= 2,048 CPUs) therefore has 2.8 teraFLOPS 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 to8,192 CPUs, with a peak performance of 22.4 TFLOPS. A 64-rack machine should provide 180 TFLOPS, or 360 TFLOPS at peak performance.**

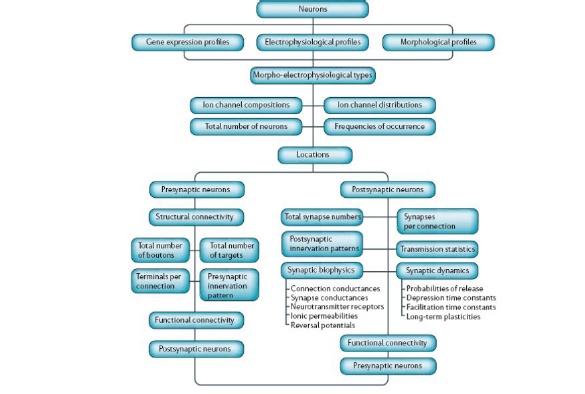
**Fig. 4.1. The Blue Gene/L supercomputer architecture**

**4.3 Modelling the Microcircuit**

**The scheme shows the minimal essential building blocks required to recon-struct a neural microcircuit. Microcircuits are composed of neurons and synapticconnections. To model neurons, the three-dimensional morphology, ion channelcomposition, and distributions and electrical properties of the different types of neuronare required, as well as the total numbers of neurons in the microcircuit and the relativeproportions of the different types of neuron. To model synaptic connections, thephysiological and pharmacological properties of the different types of synapse that10**

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**connect any two types of neuron are required, in addition to statistics on which partof the axonal arborization is used (presynaptic innervation pattern) to contact whichregions of the target neuron (postsynaptic innervations pattern), how many synapsesare involved in forming connections, and the connectivity statistics between any twotypes of neuron. Neurons receive inputs from thousands of other neurons, whichare intricately mapped onto different branches of highly complex dendritic trees andrequire tens of thousands of compartments to accurately represent them. There istherefore a minimal size of a microcircuit and a minimal complexity of a neuron’smorphology that can fully sustain a neuron. A massive increase in computationalpower is required to make this quantum leap - an increase that is provided by IBM’sBlue Gene supercomputer. By exploiting the computing power of Blue Gene, theBlue Brain Project1 aims to build accurate models of the mammalian brain from ﬁrst principles. The ﬁrst phase of the project is to build a cellular-level (as opposed toa genetic- or molecular-level) model of a 2-week-old rat somatosensory neocortexcorresponding to the dimensions of a neocortical column (NCC) as deﬁned by thedendritic arborizations of the layer 5 pyramidal neurons. The combination of infrareddifferential interference microscopy in brain slices and the use of multi-neuron patch-11**

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**clamping allowed the systematic quantiﬁcation of the molecular, morphological andelectrical properties of the different neurons and their synaptic pathways in a mannerthat would allow an accurate reconstruction of the column. Over the past 10 years, thelaboratory has prepared for this reconstruction by developing the multi-neuron patch-clamp approach, recording from thousands of neocortical neurons and their synapticconnections, and developing quantitative approaches to allow a complete numericalbreakdown of the elementary building blocks of the NCC. The recordings have mainlybeen in the 14-16-day-old rat somatosensory cortex, which is a highly accessibleregion on which many researchers have converged following a series of pioneeringstudies driven by Bert Sakmann. Much of the raw data is located in our databases,but a major initiative is underway to make all these data freely available in a publiclyaccessible database. The so-called ’blue print’ of the circuit, although not entirelycomplete, has reached a sufﬁcient level of reﬁnement to begin the reconstruction at thecellular level. Highly quantitative data are available for rats of this age, mainly becausevisualization of the tissue is optimal from a technical point of view. This age alsoprovides an ideal template because it can serve as a starting point from which to studymaturation and ageing of the NCC. As NCCs show a high degree of stereotypy, theregion from which the template is built is not crucial, but a sensory region is preferredbecause these areas contain a prominent layer 4 with cells specialized to receive inputto the neocortex from the thalamus; this will also be required for later calibration within vivo experiments. The NCC should not be overly specialized, because this couldmake generalization to other neocortical regions difﬁcult, but areas such as the barrelcortex do offer the advantage of highly controlled in vivo data for comparison. Themouse might have been the best species to begin with, because it offers a spectrum of molecular approaches with which to explore the circuit, but mouse neurons are small,which prevents the detailed dendritic recordings that are important for modelling thenonlinear properties of the complex dendritic trees of pyramidal cells (75-80% of theneurons). The image shows the Microcircuit in various stages of reconstruction. Onlya small fraction of reconstructed, three dimensional neurons is shown. Red indicatesthe dendritic and blue the axonal arborizations. The columnar structure illustrates the layer deﬁnition of the NCC.**

**•**

**The microcircuits (from left to right) for layers 2, 3, 4 and 5.**

**•**

**A single thick tufted layer 5 pyramidal neuron located within the column.**

**•**

**One pyramidal neuron in layer 2, a small pyramidal neuron in layer 5 and thelarge thick tufted pyramidal neuron in layer**

**•**

**An image of the NCC, with neurons located in layers 2 to 5.**

**4.4 Simulating the Microcircuit**

**Once the microcircuit is built, the exciting work of making the circuit functioncan begin. All the 8192 processors of the Blue Gene are pressed into service, ina massively parallel computation solving the complex mathematical equations thatgovern the electrical activity in each neuron when a stimulus is applied. As the elec-trical impulse travels from neuron to neuron, the results are communicated via inter-13**

**processor communication (MPI). Currently, the time required to simulate the circuitis 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 canfunction in real time - meaning that 1 second of activity can be modeled in one second.**

**4.5 Interpreting the Results**

**Running the Blue Brain simulation generates huge amounts of data. Analysesof individual neurons must be repeated thousands of times. And analyses dealing withthe network activity must deal with data that easily reaches hundreds of gigabytes persecond of simulation. Using massively parallel computers the data can be analyzedwhere it is created (server-side analysis for experimental data, online analysis duringsimulation).Given the geometric complexity of the column, a visual exploration of thecircuit is an important part of the analysis. Mapping the simulation data onto themorphology is invaluable for an immediate veriﬁcation of single cell activity as wellas network phenomena. Architects at EPFL have worked with the Blue Brain devel-opers to design a visualization interface that translates the Blue Gene data into a 3Dvisual representation of the column. A different supercomputer is used for this compu-tationally intensive task. The visualization of the neurons’ shapes is a challengingtask given the fact that a column of 10,000 neurons rendered in high quality meshaccounts for essentially 1 billion triangles for which about 100GB of managementdata is required. Simulation data with a resolution of electrical compartments foreach neuron accounts for another 150GB. As the electrical impulse travels throughthe column, neurons light up and change color as they become electrically active. Avisual interface makes it possible to quickly identify areas of interest that can then bestudied more extensively using further simulations. A visual representation can also beused to compare the simulation results with experiments that show electrical activityin the brain14**

**4.6 Data Manipulation Cascade**

**Building the Blue Column requires a series of data manipulations .The ﬁrststep is to parse each three-dimensional morphology and correct errors due to the invitro preparation and reconstruction. The repaired neurons are placed in a databasefrom which statistics for the different anatomical classes of neurons are obtained.These statistics are used to clone an indeﬁnite number of neurons in each class tocapture the full morphological diversity. The next step is to take each neuron andinsert ion channel models in order to produce the array of electrical types. The ﬁeldhas reached a sufﬁcient stage of convergence to generate efforts to classify neurons,such as the Petilla Convention - a conference held in October 2005 on anatomical andelectrical types of neocortical interneuron, established by the community. Single-cellgene expression studies of neocortical interneurons now provide detailed predictionsof the speciﬁc combinations of more than 20 ion channel genes that underlie electricaldiversity. A database of biologically accurate Hodgkin-Huxley ion channel models isbeing produced. The simulator NEURON is used with automated ﬁtting algorithmsrunning on Blue Gene to insert ion channels and adjust their parameters to capture thespeciﬁc electrical properties of the different electrical types found in each anatomicalclass. The statistical variations within each electrical class are also used to generatesubtle variations in discharge behaviour in each neuron. So, each neuron is morpho-logically and electrically unique. Rather than taking 10,000 days to ﬁt each neuron’selectrical behaviour with a unique proﬁle, density and distribution of ion channels,applications are being prepared to use Blue Gene to carry out such a ﬁt in a day. Thesefunctionalized neurons are stored in a database. The three-dimensional neurons arethen imported into Blue Builder, a circuit builder that loads neurons into their layersaccording to a “recipe” of neuron numbers and proportions. A collision detectionalgorithm is run to determine the structural positioning of all axo-dendritic touches,and neurons are jittered and spun until the structural touches match experimentallyderived statistics. Probabilities of connectivity between different types of neuron areused to determine which neurons are connected, and all axo-dendritic touches areconverted into synaptic connections. The manner in which the axons map onto the15**

**dendrites between speciﬁc anatomical classes and the distribution of synapses receivedby a class of neurons are used to verify and ﬁne-tune the biological accuracy of thesynaptic mapping between neurons. It is therefore possible to place 10-50 millionsynapses in accurate three-dimensional space, distributed on the detailed threedimen-sional morphology of each neuron. The synapses are functionalized according to thesynaptic parameters for different classes of synaptic connection within statistical vari-ations of each class, dynamic synaptic models are used to simulate transmission, andsynaptic learning algorithms are introduced to allow plasticity. The distance fromthe cell body to each synapse is used to compute the axonal delay, and the circuitconﬁguration is exported. The conﬁguration ﬁle is read by a NEURON subroutinethat calls up each neuron and effectively inserts the location and functional propertiesof every synapse on the axon, soma and dendrites. One neuron is then mapped ontoeach processor and the axonal delays are used to manage communication betweenneurons and processors. Effectively, processors are converted into neurons, and MPI(message-passing interface)- based communication cables are converted into axonsinterconnecting the neurons - so the entire Blue Gene is essentially converted into aneocortical microcircuit. We developed two software programs for simulating suchlarge-scale networks with morphologically complex neurons. A new MPI version of NEURON has been adapted by Michael Hines to run on Blue Gene. The secondsimulator uses the MPI messaging component of the large-scale NeoCortical Simu-lator (NCS), which was developed by Philip Goodman, to manage the communicationbetween NEURON-simulated neurons distributed on different processors. The lattersimulator will allow embedding of a detailed NCC model into a simpliﬁed large-scalemodel of the whole brain. Both of these softwares have already been tested, produceidentical results and can simulate tens of thousands of morphologically and electri-cally complex neurons (as many as 10,000 compartments per neuron with more thana dozen Hodgkin-Huxley ion channels per compartment). Up to 10 neurons can bemapped onto each processor to allow simulations of the NCC with as many as 100,000neurons. Optimization of these algorithms could allow simulations to run at close toreal time. The circuit conﬁguration is also read by a graphic application, which renders16**

**the entire circuit in various levels of textured graphic formats. Real-time stereo visu-alization applications are programmed to run on the terabyte SMP (shared memoryprocessor) Extreme series from SGI (Silicon Graphics, Inc.). The output from BlueGene (any parameter of the model) can be fed directly into the SGI system to performin silico imaging of the activity of the inner workings of the NCC. Eventually, thesimulation of the NCC will also include the vasculature, as well as the glial network,to allow capture of neuron-glia interactions. Simulations of extracellular currents andﬁeld potentials, and the emergent electroencephalogram (EEG) activity will also bemodelled.**

**4.7 Whole Brain Simulations**

**The main limitations for digital computers in the simulation of biologicalprocesses are the extreme temporal and spatial resolution demanded by somebiological processes, and the limitations of the algorithms that are used to modelbiological processes. If each atomic collision is simulated, the most powerful super-computers still take days to simulate a microsecond of protein folding, so it is, of course, not possible to simulate complex biological systems at the atomic scale.However, models at higher levels, such as the molecular or cellular levels, cancapture lower-level processes and allow complex large-scale simulations of biologicalprocesses. The Blue Brain Project’s Blue Gene can simulate a NCC of up to 100,000highlycomplexneuronsatthecellularorasmanyas100millionsimpleneurons(aboutthe same number of neurons found in a mouse brain). However, simulating neuronsembedded in microcircuits, microcircuits embedded in brain regions, and brain regionsembedded in the whole brain as part of the process of understanding the emergenceof complex behaviors of animals is an inevitable progression in understanding brainfunction and dysfunction, and the question is whether whole-brain simulations areat all possible. Computational power needs to increase about 1-million-fold beforewe will be able to simulate the human brain, with 100 billion neurons, at the samelevel of detail as the Blue Column. Algorithmic and simulation efﬁciency (whichensure that all possible FLOPS are exploited) could reduce this requirement by two to17**

**three orders of magnitude. Simulating the NCC could also act as a test-bed to reﬁnealgorithms required to simulate brain function, which can be used to produce ﬁeldprogrammable gate array (FPGA)-based chips. FPGAs could increase computationalspeeds by as much as two orders of magnitude. The FPGAs could, in turn, providethe testing ground for the production of specialized NEURON solver application-speciﬁc integrated circuits (ASICs) that could further increase computational speedby another one to two orders of magnitude. It could therefore be possible, in principle,to simulate the human brain even with current technology. The computer industry isfacing what is known as a discontinuity, with increasing processor speed leading tounacceptably high power consumption and heat production. This is pushing a qualita-tively new transition in the types of processor to be used in future computers. Theseadvances in computing should begin to make genetic- and molecular-level simulationspossible. Software applications and data manipulation required to model the brain with**

**Fig. 4.4. The data manipulation cascade**

**biological accuracy. Experimental results that provide the elementary building blocksof the microcircuit are stored in a database. Before three-dimensional neurons aremodelled electrically, the morphology is parsed for errors, and for repair of arboriza-tions damaged during slice preparation. The morphological statistics for a class of neurons are used to clone multiple copies of neurons to generate the full morpho-logical diversity and the thousands of neurons required in the simulation. A spectrum18**

**of ion channels is inserted, and conductances and distributions are altered to ﬁt theneurons electrical properties according to known statistical distributions, to capturethe range of electrical classes and the uniqueness of each neurons behaviour (modelﬁtting/electrical capture). A circuit builder is used to place neurons within a three-dimensional column, to perform axo-dendritic collisions and, using structural andfunctional statistics of synaptic connectivity, to convert a fraction of axo-dendritictouches into synapses. The circuit conﬁguration is read by NEURON, which callsup each modelled neuron and inserts the several thousand synapses onto appropriatecellular locations. The circuit can be inserted into a brain region using the brainbuilder. Anenvironmentbuilderisusedtosetupthestimulusandrecordingconditions.Neurons are mapped onto processors, with integer numbers of neurons per processor.The output is visualized, analysed and/or fed into real-time algorithms for feedback stimulation.19**

**APPLICATIONS OF BLUE BRAIN PROJECT**

**5.1 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,**

**5.1.1 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 ionchannels, 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 behaviour.**

**5.1.2 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, neuronsandsynapses, aspectrumofreceptors, andcomplexdendriticandaxonalarborizations,rather than the simpliﬁed, uniform types found in many models.**

**5.1.3 Exploring the role of dendrites.**

**This is the only current approach to explore the dendritic object theory, whichproposes that three-dimensional voltage objects are generated continuously acrossdendritic segments regardless of the origin of the neurons, and that spikes are usedto maintain such dendritic objects.20**

**5.1.4 Revealing functional diversity**

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

**5.1.5 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 theorganism and its world.**

**5.1.6 Identifying points of vulnerability**

**Although the neocortex confers immense computational power to mammals,defects are common, with catastrophic cognitive effects. At present, a detailed modelis the only approach that could produce a list of the most vulnerable circuit parameters,revealing likely candidates for dysfunction and targets for treatment.**

**5.1.7 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.**

**5.1.8 Providing a circuit design platform**

**Detailed models could reveal powerful circuit designs that could be imple-mented into silicone chips for use as intelligence devices in industry.21**

**5.2 Applications of Blue Brain**

**5.2.1 Gathering and Testing 100 Years of Data**

**The most immediate beneﬁt is to provide a working model into which the past100 years knowledge about the microstructure and workings of the neocortical columncan be gathered and tested. The Blue Column will therefore also produce a virtuallibrary to explore in 3D the microarchitecture of the neocortex and access all keyresearch relating to its structure and function.**

**5.2.2 Cracking the Neural Code**

**TheNeuralCoderefers tohow thebrainbuilds objects usingelectricalpatterns.In the same way that the neuron is the elementary cell for computing in the brain, theNCC is the elementary network for computing in the neocortex. Creating an accuratereplica of the NCC which faithfully reproduces the emergent electrical dynamics of thereal microcircuit, is an absolute requirement to revealing how the neocortex processes,stores and retrieves information.**

**5.2.3 Understanding Neocortical Information Processing**

**The power of an accurate simulation lies in the predictions that can begenerated about the neocortex. Indeed, iterations between simulations and exper-iments are essential to build an accurate copy of the NCC. These iterations aretherfore expected to reveal the function of individual elements (neurons, synapses,ion channels, receptors), pathways (mono-synaptic, disynaptic, multisynaptic loops)and physiological processes (functional properties, learning, reward, goal-oreintedbehavior).**

**5.2.4 A Novel Tool for Drug Discovery for Brain Disorders**

**Understanding the functions of different elements and pathways of the NCCwill provide a concrete foundation to explore the cellular and synaptic bases of a widespectrumofneurologicalandpsychiatricdiseases. Theimpactofreceptor, ionchannel,cellular and synaptic deﬁcits could be tested in simulations and the optimal experi-22**

**mental tests can be determined.**

**5.2.5 A Global Facility**

**A software replica of a NCC will allow researchers to explore hypotheses of brain function and dysfunction accelerating research. Simulation runs could determinewhich 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 imagingexperimentsmaybeimpossibleinrealityormaybeprohibitivelyexpensivetoperform.**

**5.2.6 A Foundation for Whole Brain Simulations**

**With current and envisageable future computer technology it seems unlikelythat 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 inorder to generate reduced models that retain critical functions and computational capa-bilities, 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.**

**5.2.7 A Foundation for Molecular Modeling of Brain Function**

**An accurate cellular replica of the neocortical column will provide the ﬁrst andessential step to a gradual increase in model complexity moving towards a molecularlevel description of the neocortex with biochemical pathways being simulated. Amolecular level model of the NCC will provide the substrate for interfacing geneexpression with the network structure and function. The NCC lies at the interfacebetween the genes and complex cognitive functions. Establishing this link will allowpredictions of the cognitive consequences of genetic disorders and allow reverse engi-neering of cognitive deﬁcits to determine the genetic and molecular causes. This levelof simulation will become a reality with the most advanced phase of Blue Gene devel-opment.23**

**ADVANTAGES AND LIMITATIONS**

**6.1 Advantages**

**•**

**We can remember things without any effort.**

**•**

**Decision can be made without the presence of a person.**

**•**

**Even after the death of a man his intelligence can be used.**

**•**

**The activity of different animals can be understood. That means by interpre-tation of the electric impulses from the brain of the animals, their thinking can be understood easily.**

**•**

**It would allow the deaf to hear via direct nerve stimulation, and also be helpfulfor many psychological diseases. By down loading the contents of the brain thatwas uploaded into the computer, the man can get rid from the madness.**

**6.2 Limitations**

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

**•**

**We become dependent upon the computer systems.**

**•**

**Others may use technical knowledge against us.**

**•**

**Computer viruses will pose an increasingly critical threat.**

**•**

**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 fearis found today with respect to human cloning.24**

**FUTURE PERSPECTIVE**

**The synthesis era in neuroscience started with the launch of the Human BrainProject and is an 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. Indeed, itis essential to guide reductionist research into the deeper facets of brain structure andfunction. As a complement to experimental research, it offers rapid assessment of theprobable effect of a new ﬁnding on preexisting knowledge, which can no longer bemanaged completely by any one researcher. Detailed models will probably becomethe ﬁnal form of databases that are used to organize all knowledge of the brain andallow hypothesis testing, rapid diagnoses of brain malfunction, as well as developmentof treatments for neurological disorders. In short, we can hope to learn a great dealabout brain function and disfunction from accurate models of the brain .The time takento build detailed models of the brain depends on the level of detail that is captured.Indeed, the ﬁrst version of the Blue Column, which has 10,000 neurons, has alreadybeen built and simulated; it is the reﬁnement of the detailed properties and calibrationof the circuit that takes time. A model of the entire brain at the cellular level willprobably take the next decade. There is no fundamental obstacle to modeling thebrain and it is therefore likely that we will have detailed models of mammalian brains,including that of man, in the near future. Even if overestimated by a decade or two, thisis still just a ’blink of an eye’ in relation to the evolution of human civilization. As withDeep Blue, Blue Brain will allow us to challenge the foundations of our understandingof intelligence and generate new theories of consciousness.25**

**CONCLUSION**

**In conclusion, we will be able to transfer ourselves into computers at somepoint. Most arguments against this outcome are seemingly easy to circumvent. Theyare 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.26**

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