Report

On

Blue Brain

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1. INTRODUCTION

The Blue Brain Project is an attempt to create a synthetic brain by reverse-engineering mammalian brain circuitry. Today scientists are in research to create an artificial brain that can think, response, take decision, and keep anything in memory. The main aim is to upload human brain into machine. So that man can think, take decision without any effort.

The research involves studying slices of living brain tissue using microscopes and patch clamp electrodes. Data is collected about all the many different neuron types. This data is used to build biologically realistic models of neurons and networks of neurons in the cerebral cortex. The simulations are carried out on a Blue Gene supercomputer built by IBM. Hence the name "Blue Brain". The simulation software is based around Michael Hines's NEURON, together with other custom-built components.

The goal of the Blue Brain Project is to build biologically detailed digital reconstructions and simulations of the rodent, and ultimately the human brain. The supercomputer-based reconstructions and simulations built by the project offer a radically new approach for understanding the multilevel structure and function of the brain. The project's novel research strategy exploits interdependencies in the experimental data to obtain dense maps of the brain, without measuring every detail of its multiple levels of organization (molecules, cells, micro-circuits, brain regions, and the whole brain). This strategy allows the project to build digital reconstructions (computer models) of the brain at an unprecedented level of biological detail. Supercomputer-based simulation of their behavior turns understanding the brain into a tractable problem, providing a new tool to study the complex interactions within different levels of brain organization and to investigate the cross-level links leading from genes to cognition.

2. HISTORY

The aim of the project, founded in May 2005 by the Brain and Mind Institute of the École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland, is to study the brain's architectural and functional principles. The project is headed by the founding director Henry Markram and co-directed by Felix Schürmann and Sean Hill. Using a Blue Gene supercomputer running Michael Hines's NEURON software, the simulation does not consist simply of an artificial neural network, but involves a biologically realistic model of neurons. It is hoped that it will eventually shed light on the nature of consciousness. [1]

The initial goal of the project, completed in December 2006, was the simulation of a rat neocortical column, which is considered by some researchers to be the smallest functional unit of the neocortex (the part of the brain thought to be responsible for higher functions such as conscious thought). In humans, each column is about 2 mm in length, has a diameter of 0.5 mm and contains about 60,000[contradictory] neurons; rat neocortical columns are very similar in structure but contain only 10,000 neurons (and 108 synapses). Between 1995 and 2005, Markram mapped the types of neurons and their connections in such a column.

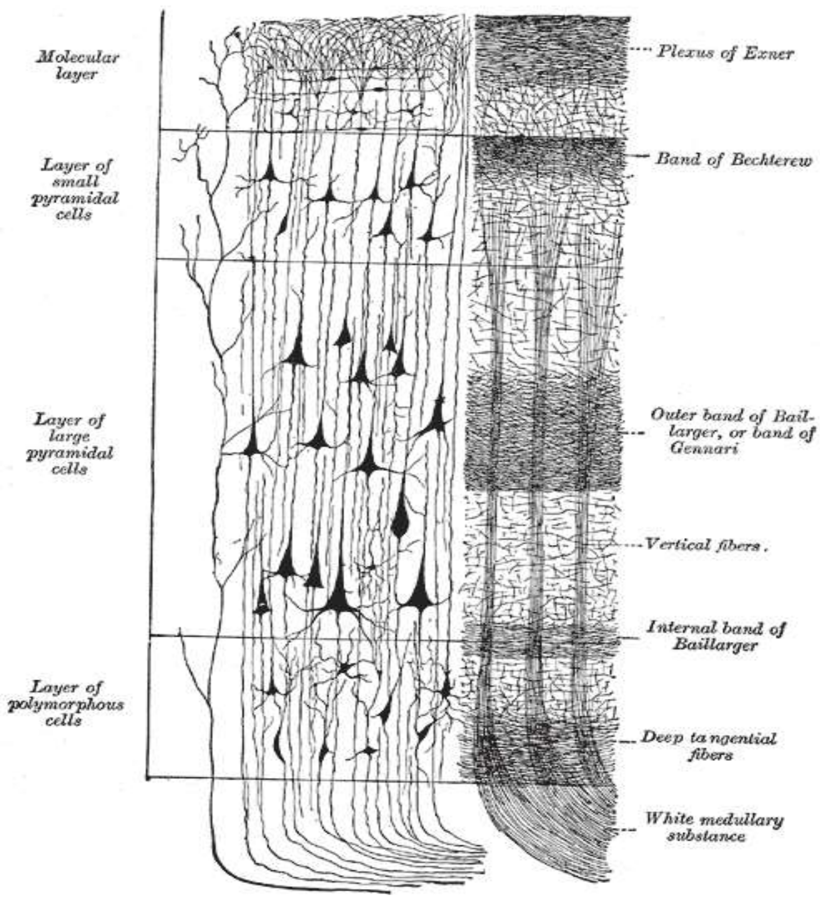

Fig.1. Representative Column of neocortex.

In November 2007, the project reported the end of the first phase, delivering a data-driven process for creating, validating, and researching the neocortical column.

By 2005, the first single cellular model was completed. The first artificial cellular neocortical column of 10,000 cells was built by 2008. By July 2011, a cellular mesocircuits of 100 neocortical columns with a million cells in total was built. A cellular rat brain is planned [dated info] for 2014 with 100 mesocircuits totaling a hundred million cells. Finally a cellular human brain is predicted possible by 2023 equivalent to 1000 rat brains with a total of a hundred billion cells.

Now that the column is finished, the project is currently busying itself with the publishing of initial results in scientific literature, and pursuing two separate goals: construction of a simulation on the molecular level, which is desirable since it allows studying the effects of gene expression; simplification of the column simulation to allow for parallel simulation of large numbers of connected columns, with the ultimate goal of simulating a whole neocortex (which in humans consists of about 1 million cortical columns).[contradictory]

In 2015, scientists at École Polytechnique Fédérale de Lausanne (EPFL) developed a quantitative model of the previously unknown relationship between the glial cell astrocytes and neurons. This model describes the energy management of the brain through the function of the neuro-glial vascular unit (NGV). The additional layer of neuron-glial cells is being added to Blue Brain Project models to improve functionality of the system.

3. NEED OF VIRTUAL BRAIN

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. Virtual brain may be a better solution for it.

4. POSSIBILITY

Many people believe firmly those we possess a soul, while some very technical people believe that quantum forces contribute to our awareness. But we have to now think technically. Really this concept appears to be very difficult and complex. 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 non-invasive techniques. The most promising is the use of very small robots, or Nanobot. 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. Nanobot 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.

5. Natural Brain

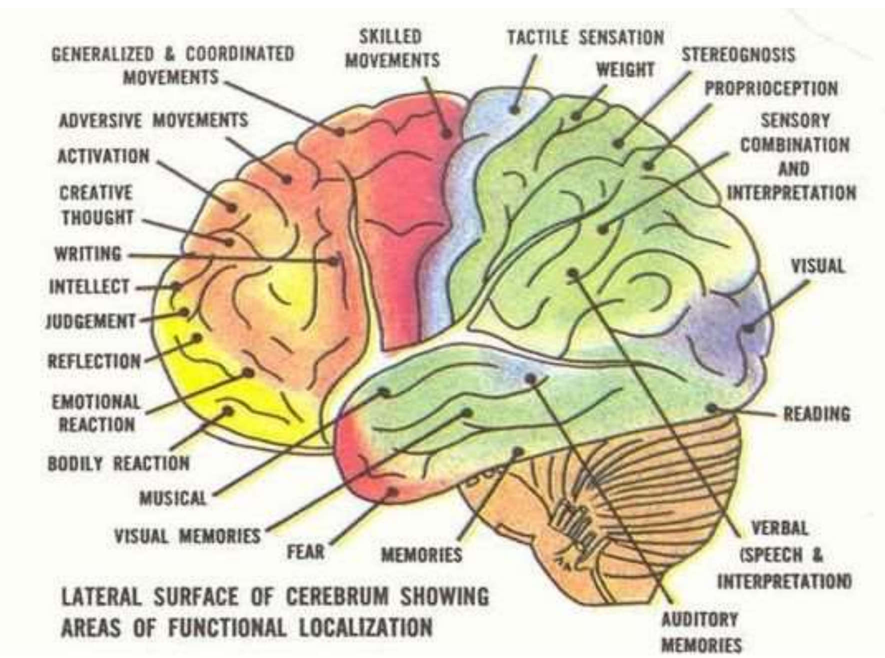

Fig.2. Natural Human Brain. [9]

The brain essentially serves as the body's information processing centre. It receives Signals from sensory neurons (nerve cell bodies and their axons and dendrites) in the central and peripheral nervous system, and in response it generates and sends new signals that instruct the corresponding parts of the body to move or react in some way. It also integrates signals received with signals from adjacent areas of the brain, giving rise perception and consciousness. The brain weighs about 1500 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, epithalamus, subthalamus,
Midbrain, pons and medulla oblongata.
- The cerebellum.

5.1 Functioning Of Natural Human Brain

The human ability to feel, interpret and even see 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 the body. One of the world's most "intricately organized" electron mechanisms is the nervous system. Not even engineers have come close for making circuit boards and computers as delicate and precise as the nervous system.[10]

The three simple functions that it puts into action: sensory input, integration, motor output.

5.1.1 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.

5.1.2 Integration

Integration is best known as the interpretation of things we have felt, tasted, and touched with

Our sensory cells, also known as neurons, into responses that the body recognizes. This process is all accomplished in the brain where many neurons work together to understand the environment.

5.1.3 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 to effecter cells, muscle or gland cells, which actually work to perform our requests and act upon the environment.

5.2 How Sensory Organs Work

5.2.1 Nose

The smell reaches and travels to an olfactory bulb – a set of sensory nerves. The nerve impulses travel through the olfactory tract, around, in a circular way, the thalamus and finally to the sensory cortex of brain located between our eye and ear.

5.2.1 Eye

Seeing action is conducted by the lens, which magnifies the image; vitreous disc, which bends and rotates the image against the retina, which translates the image and light by a set of cells. The retina with rods, cones and other cells and tissues at the back of the eyeball convert the image into nerve impulses which is transmitted along the optic nerve to the brain.

5.2.2 Tongue

The microscopic buds with taste pore on the tongue convert the taste into a nerve impulse and the impulse is sent to the brain by a sensory nerve fiber.

5.2.3 Ear

The sound waves reach the cochlea. Here the sound is divided into pitches. This organ transmits the vibration information to a nerve, which sends it to the brain.

5.3 Comparison between Natural Brain 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	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.

brain permanently or for any interesting or serious matter this is happened implicitly.	
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.

6. STEPS TO BUILD THE VIRTUAL BRAIN

There are three main steps to building the virtual brain: 1) data acquisition, 2) simulation, 3) visualization of results.

6.1 Data acquisition

Data acquisition involves taking brain slices, placing them under a microscope, and measuring the shape and electrical activity of individual neurons. This is how the different types of neuron are studied and catalogued. The neurons are typed by morphology (i.e. their shape), electrophysiological behaviour, location within the cortex, and their population density. These observations are translated into mathematical algorithms which describe the form, function, and positioning of neurons. The algorithms are then used to generate biologically-realistic virtual neurons ready for simulation. [2]

One of the methods is to take 300 µm-thick sagittal brain slices from the somatosensory cortex (SA1) of juvenile Wistar rats (aged 14 to 16 days). The tissue is stained with biocytin and viewed through a bright field microscope. Neuronal 3D morphologies are then reconstructed using the Neurolucida software package (pictured below, far right) which runs on Windows workstations. Staining leads to a shrinkage of 25% in thickness and 10% in length, so the reconstruction process corrects for this. Slicing also severs 20% to 40% of axonal and dendritic arbors, so these are regrown algorithmically.

The electrophysiological behaviour of neurons is studied using a 12 patch clamp instrument (pictured below left). This tool was developed for the Blue Brain Project and it forms a foundation of the research. It enables twelve living neurons to be concurrently patched and their electrical activity recorded. The Nomarski microscope enhances the contrast of the unstained samples of living neural tissue. Carbon nanotube-coated electrodes can be used to improve recording.

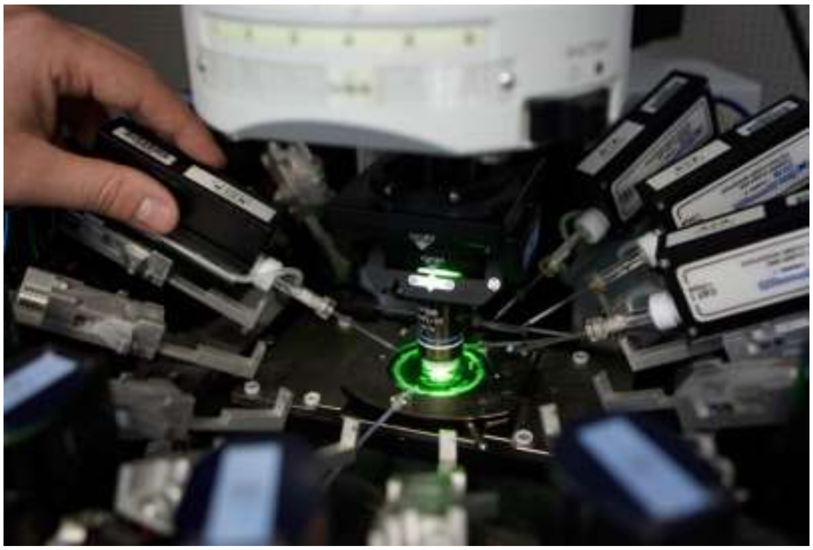

Fig.3. The 12 patch-clamp close view

Around 200 different types of ion channel (Ion channels are pore-forming membrane proteins whose functions include establishing a resting membrane potential, shaping action potentials and other electrical signals by gating the flow of ions across the cell membrane, controlling the flow of ions across secretory and epithelial cells, and regulating cell volume. Ion channels are present in the membranes of all cells.) are found in the cell membranes of cortical neurons. Different types of neuron have different mixes of channels - and this contributes to differences in their electrical behaviour. The genes for these channels are cloned at the lab, overexpressed in cultured cells, and their electrical behaviour recorded. Over 270 genes are known to be associated with voltage-gated ion channels in the rat. The results of this work are publicly available online at Channelpedia. [2]

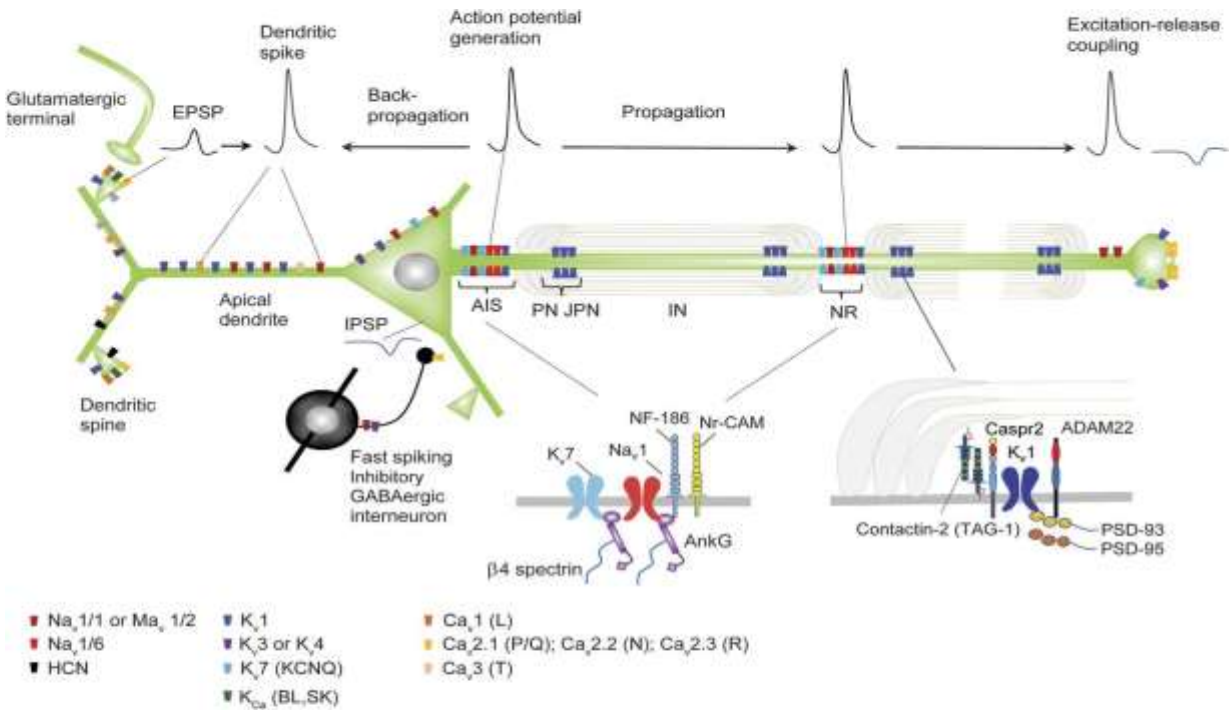

Fig.4. ion-channel

6.2 Simulation

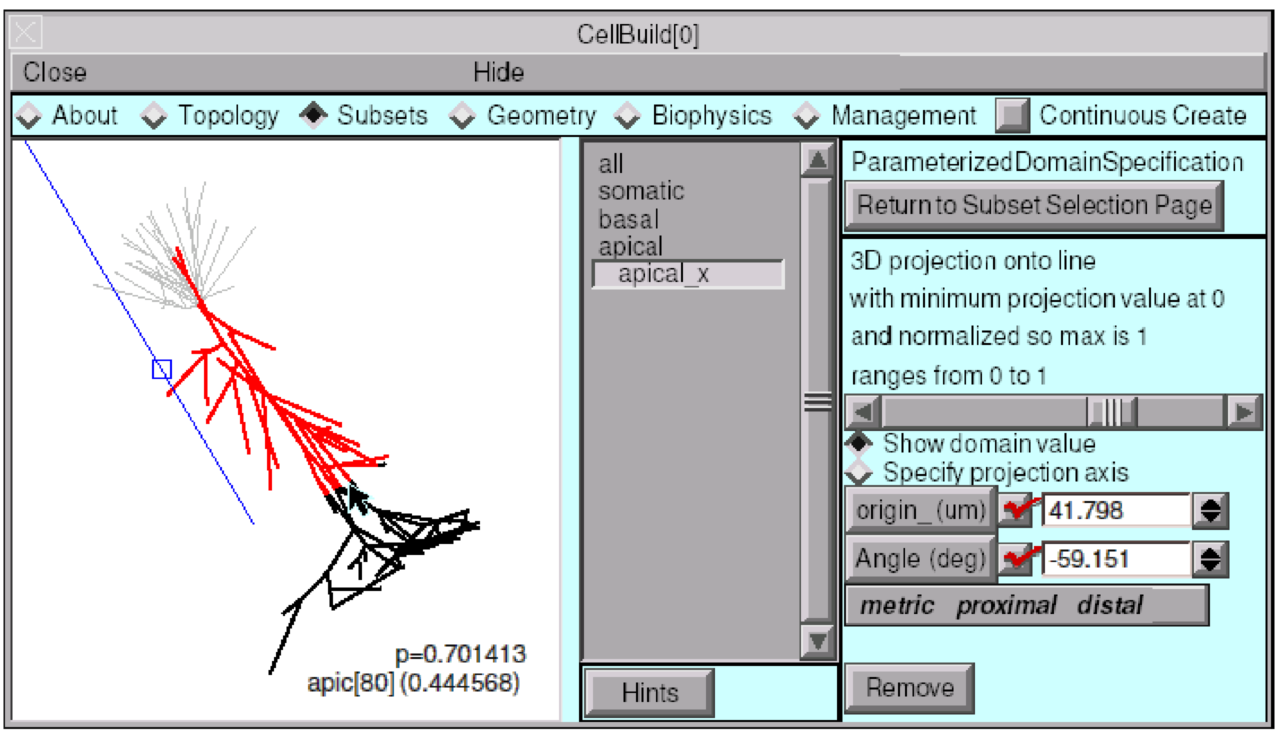

Fig.5. Example NEURON cell builder window

6.2.1 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.

6.2.2 Simulation speed

In 2012 simulations of one cortical column (~10,000 neurons) run at approximately 300 x slower than real time. So one second of simulated time takes about five minutes to complete. The simulations show approximately linear scaling - that is, doubling the size of the neural network doubles the time it takes to simulate. Currently the primary goal is biological validity rather than performance. Once it's understood which factors are biologically important for a given effect it might be possible to trim components that don't contribute in order to improve performance.

The simulation time step for the numerical integrations is 0.025 ms and the time step for writing the output to disk is 0.1 ms.

6.2.3 Workflow

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 behaviour 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 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.

6.2.4 BBP-SDK

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

6.3 Visualization of results

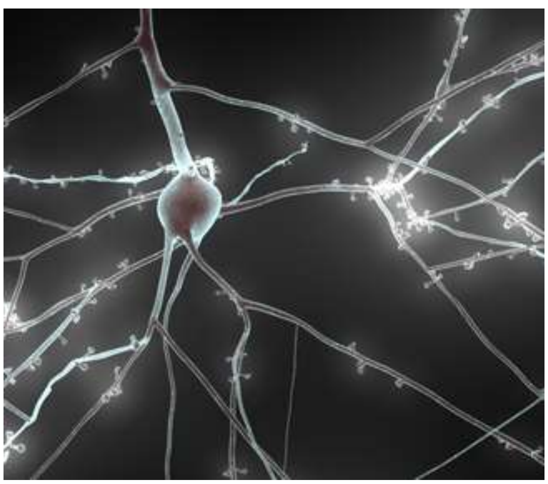

Fig.6. RTNeuron visualisation of a neuron

RTNeuron

RTNeuron is the primary application used by the BBP for visualisation of neural simulations. The software was developed internally by the BBP team. It is written in C++ and OpenGL. RTNeuron is ad-hoc software written specifically for neural simulations, i.e. it is not generalizable to other types of simulation. RTNeuron takes the output from Hodgkin-Huxley simulations in NEURON and renders them in 3D. This allows researchers to watch as activation potentials propagate through a neuron and between neurons. The animations can be stopped, started and zoomed, thus letting researchers interact with the model. The visualizations are multi-scale that is they can render individual neurons or a whole cortical column.

7. Computer hardware / Supercomputers

7.1 Blue Gene/P

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 and is managed by CADMOS (Center for Advanced Modelling 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 "C-BPP".

Blue Gene/P technical specifications:

- 4,096 quad-core nodes (16,384 cores in total)

- Each core is a PowerPC 450, 850 MHz
- Total: 56 teraflops, 16 terabytes of memory
- 4 racks, one row, wired as a 16x16x16 3D torus
- 1 PB of disk space, GPFS parallel file system
- Operating system: Linux SuSE SLES 10
- Public front end: bluegene.epfl.ch and processing log

This machine peaked at 99th fastest supercomputer in the world in November 2009. By June 2011 it had dropped to 343th in the world. It has since dropped out of the top 500. See the Blue Gene/P ranking on the TOP500 list. More details and photos: CADMOS Blue Gene/P presentation (PDF).

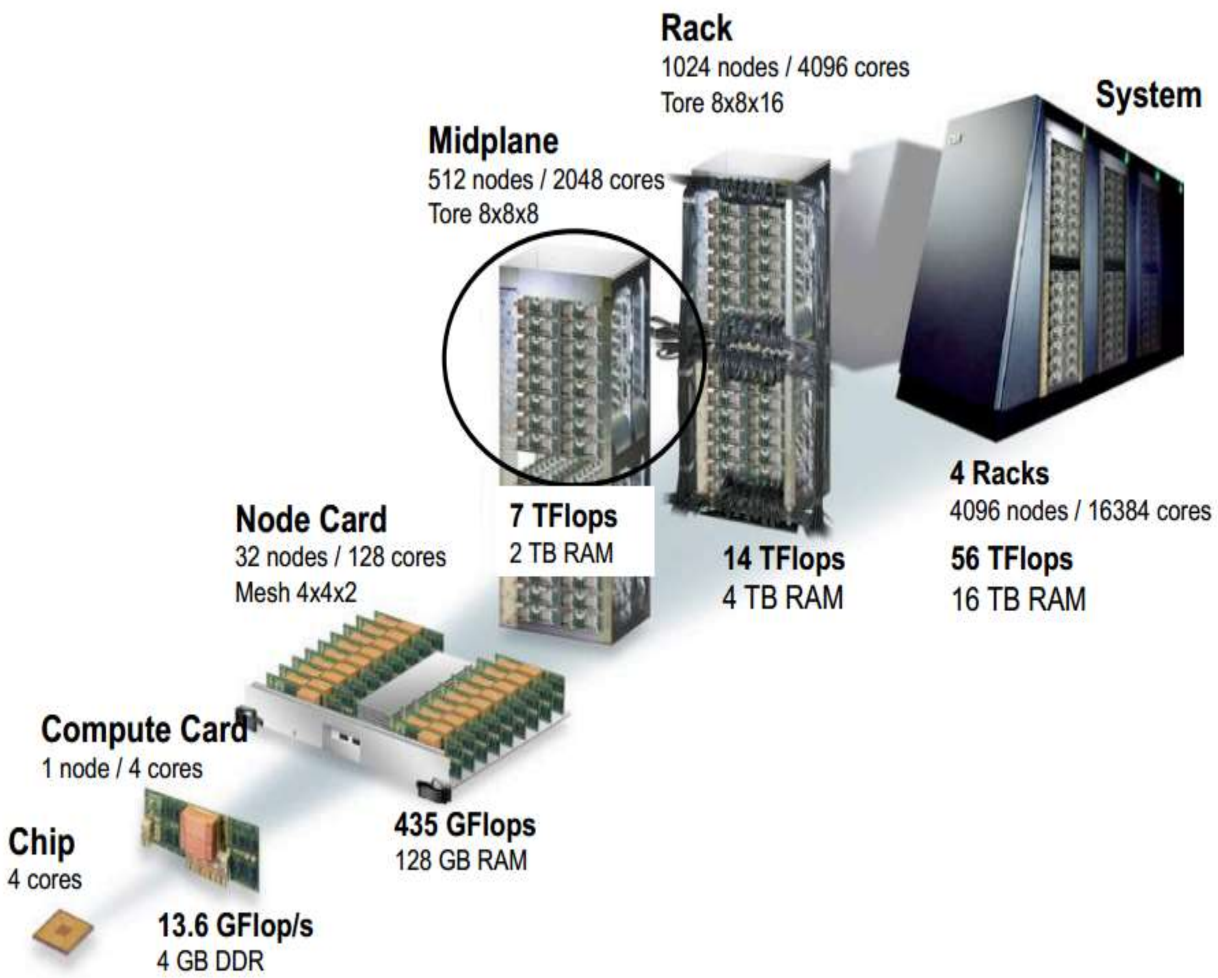

Fig.7. Hierarchy of Blue gene processing units [2]

Fig.8. Blue Gene/P Supercomputer

7.2 Silicon Graphics

A 32-processor Silicon Graphics Inc. (SGI) system with 300 GB of shared memory is used for visualisation of results.

7.3 Commodity PC clusters

Clusters of commodity PCs have been used for visualisation tasks with the RTNeuron software. A research paper published by the BBP team in 2012 describes the following setup:

- 11 node cluster, 3.47 GHz processors (Intel Xeon X5690)

- 24 GB RAM, 3 NVidia GeForce GTX 580 GPUs
- Full-HD passive stereo display connected to two GPUs on head node
- 1 Gbit/s, 10 Gbit/s Ethernet, 40 Gbit/s QDR InfiniBand

It's not known where this cluster is physically located - either in the BBP lab itself, in an EPFL data center, or elsewhere.

7.4 JuQUEEN

Fig.9.JuQUEEN supercomputer in Germany

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 petaflops 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 JuBrain (Jülich Brain Model) research initiative. This aims to develop a three-dimensional, realistic model of the human brain. This is currently separate from the Blue Brain Project but it will become part of the Human Brain Project if the latter is chosen for EU funding in late 2012.

7.5 DEEP - Dynamical Exascale Entry Platform

DEEP (deep-project.eu) is an exascale supercomputer to be built at the Jülich Research Center in Germany. The project started in December 2011 and is funded by the European Union's 7th framework programme. The three-year prototype phase of the project has received €8.5 million. A prototype supercomputer that will perform at 100 petaflops is hoped to be built by the end of 2014.

The Blue Brain Project simulations will be ported to the DEEP prototype to help test the system's performance. If successful, a future exascale version of this machine could provide the 1 exaflops of performance required for a complete human brain simulation by the 2020s.

The DEEP prototype will be built using Intel MIC (Many Integrated Cores) processors, each of which contains over 50 cores fabricated with a 22 nmprocess. These processors were codenamed *Knights Corner* during development and subsequently rebranded as *Xeon Phi* in June 2012. The processors will be publicly available in late 2012 or early 2013 and will offer just over 1 teraflop of performance each.

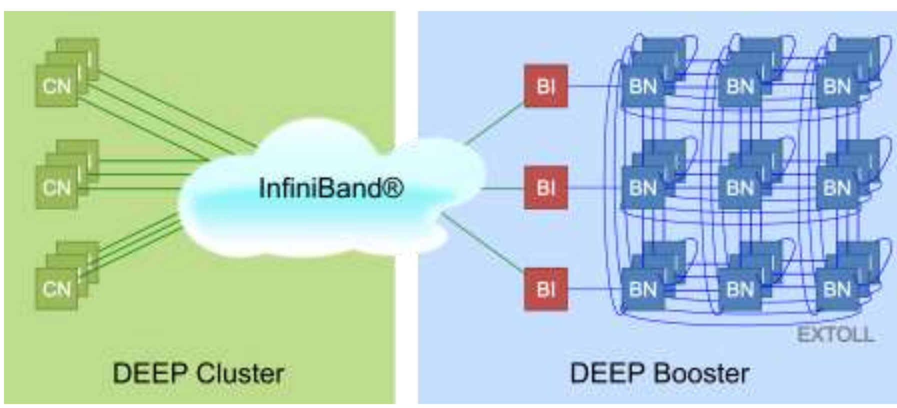

Fig.10. DEEP cluster-booster architecture[2]

8. UPLOADING THE BRAIN

The uploading is possible by the use of small robots known as the Nanobots .These robots are small enough to travel throughout our circulatory system. Traveling into the spine and brain, they will be able to monitor the activity and structure of our central nervous system. [2]

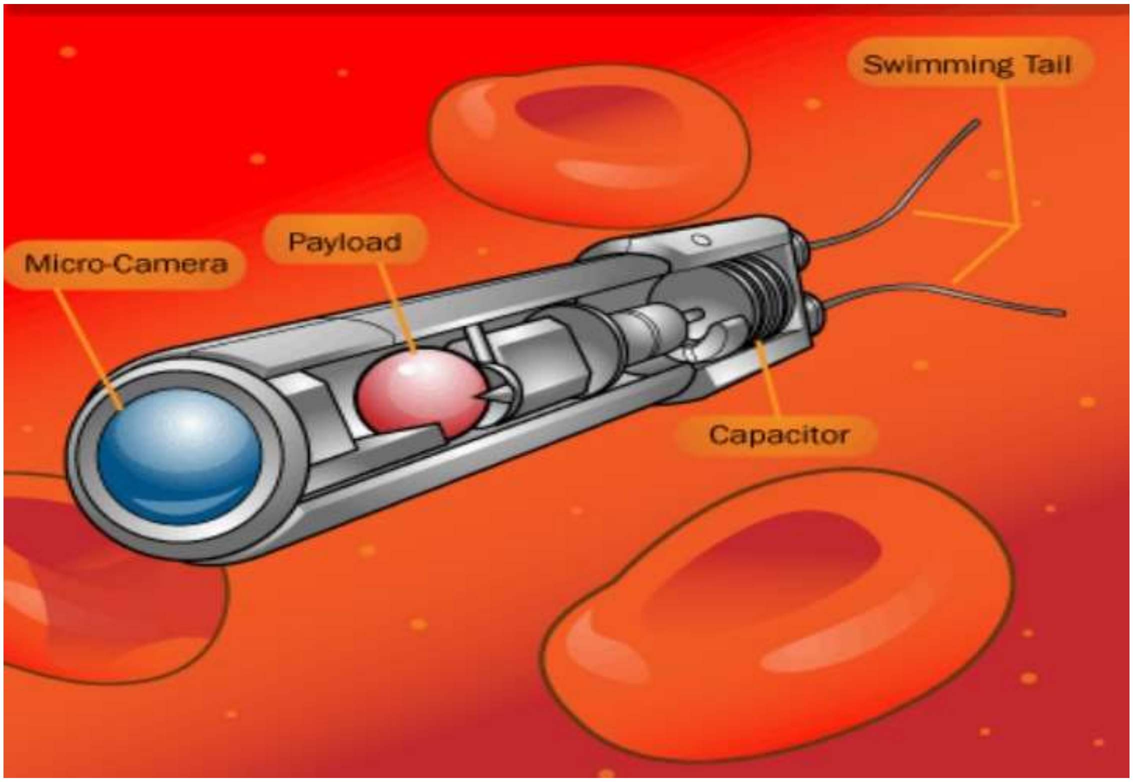

Fig.11. Uploading the brain by Nanobots

They will be able to provide an interface with computers that is as close as our mind can be while we still reside in our biological form. Nanobots could also carefully scan the structure of our brain, providing a complete readout of the connections. This information, when entered into a computer, could then continue to function as us. Thus the data stored in the entire brain will be uploaded into the computer.

9. Applications of Blue Brain:

1. Gathering and testing of 100 years data.

2. Cracking the neural code.

3. Understanding the 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 modelling of brain function.

10. 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 i.e. by interpretation of the electric impulses from the brain of animals, their thinking can be understood easily.

5. It would allow the deaf to hear via direct nerve stimulation, and also be helpful for many psychological diseases. By downloading the contents of the brain that was uploaded into the computer, the man can get rid of from the madness.

11. Limitations

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.

12. Future Perspective:

The BBPs current digital reconstructions are first drafts, to be refined in future releases. The fact that they are detailed means they are "data ready" – it is easy to incorporate data from new experiments as they become available. The BBP will dedicate significant effort to this task. Current BBP reconstructions omit many features of neural anatomy and physiology that are known to play an important role in brain function. Future BBP work will enrich the reconstructions with models of the neuro-vascular glia system, neuromodulator, different forms of plasticity, gap-junctions, and couple them to neurorobotics systems, enabling in silicon studies of perception, cognition and behaviour.

A second major effort will be dedicated to reconstructions and simulations on a larger scale than neural micro circuitry. The Blue Brain team is already working with communities in the Human Brain Project and beyond, to build digital reconstructions of whole brain regions (somatosensory cortex, hippocampus, cerebellum, basal ganglia) and eventually the whole mouse brain. This work will prepare the way for reconstructions of the human brain, on different scales and with different levels of detail.

Finally, a very large part of BBP activity is dedicated to engineering: developing and operating the software tools, the workflows and the supercomputing capabilities required to digitally reconstruct and simulate the brain and to analyses and visualize the results.

13. CONCLUSION

In conclusion, we will be able to transfer ourselves into computers at some point. Most arguments against this outcome are seemingly easy to circumvent. They are either simple minded, or simply require further time for technology to increase. The only serious threats raised are also overcome as we note the combination of biological and digital technologies. While the road ahead is long, already researches have been gaining great insights from their model. Using the Blue Gene supercomputers, up to 100 cortical columns, 1 million neurons, and 1 billion synapses can be simulated at once. This is roughly equivalent to the brain power of a honey bee. Humans, by contrast, have about 2 million columns in their cortices. Despite the sheer complexity of such an endeavor, it is predicted that the project will be capable of this by the year 2023.

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