BLUE BRAIN - Synergy between Artificial Intelligence, Reverse Engineering and Nanotechnology

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ABSTRACT
The Blue Brain creativity, headed by IBM, is a revolutionary effort to develop the first-ever artificial brain, also known as a virtual brain. Main objective of this project is to create a machine capable of uploading and preserving person's knowledge, personality, memories, and intelligence. In this research work, reverse engineering and artificial intelligence which are considered as sophisticated technologies are employed. The BB project utilizes supercomputers and nanobots for its execution. The BBP-SDK (Blue Brain project-software development kit) is precisely designed to support this aspiring mission. The project aims to achieve a comprehensive understanding of the brain which will be helpful for the development of advanced treatments for brain diseases. Researchers are currently exploring the creation of an artificial brain capable of thinking, responding, making decisions, and retaining information. This paper explores this cooperative and collaborative approach of fields of computer science (Artificial intelligence and reverse engineering) and nanotechnology in developing the independent thinking machine and paving the way for extraordinary advancements in neuroscience, and understanding of the human brain.

Keywords
Human Brain; Artificial brain; Artificial intelligence; Blue Brain; Reverse Engineering; Neuron; Nanotechnology.

1. INTRODUCTION
Reverse engineering, artificial intelligence and nanotechnology are the major fields of modern science and technology [1-11]. Reverse engineering is a dynamic analysis or static analysis method in which deconstructing architectural structures are done to extract the design information from them. It is a process of analysing a technology to understand its design, functionality, and components. This can be obtained by taking an existing product or system and examining its inner workings, its behaviour and outputs. So, this magnificent approach of studying and analysing a thing to learn what it is made of and how it is constructed.

On the other hand, artificial intelligence is the science and engineering of making smart computer programs. It is basically simulation of human intelligence in machines and empowering them to perform tasks. It typically requires human intelligence such as learning, problem solving, understanding natural language and recognizing pattern. We all are also aware about the development and revolutionary contribution of nanotechnology in every field of science and technology. The Synergy between these three fields (Artificial Intelligence, Reverse Engineering and Nanotechnology) results in remarkable outcomes of developing an artificial brain what we call it as blue brain [12-15]. In this article we will present an overview regarding the technology behind blue brain project and its possible outcomes.

2. HISTORY OF INITIATIVE TAKEN
Blue brain project is an initiative taken by Swiss brain research led by Henry Markram to recreate the artificial brain by performing a reverse engineering on Brain circuitry. This project was initially founded in 2005 at Brain and Mind Institute of EPFL (Ecole Polytechnique Federale de Lausanne, Switzerland) that specializes in natural Sciences and Engineering. Artificial Intelligence incorporates a range of methods such as machine learning, deep learning, computer vision and robotics. With the goal of modelling the neocortical column (basic functional unit of a mammal's brain), IBM (International Business Machines) and professor Henry Markram collaborated to launch the brain project in July 2005. In 2006, this project accomplished a Landmark by simulating a rat neocortical column. With subsequent efforts, it started simulating more complex brain regions and adopted ultimate aim of developing artificial brain.

3. GOAL OF THE PROJECT
The basic goal of this project is to create first physiologically accurate digital reconstructions and simulations of mouse brain by establishing experimental, theoretical and clinical neuroscience. The major goal of project is to build a cellular level model of two-week-old rat's somatosensory cortex with dimensions equivalent to neocortical column. This knowledge is now used to process emotions and thoughts which give deeper understanding into decision making power of human brain.

4. HOW THIS SYNERGY ACHIEVED
Reverse Engineering is the act of dismantling an object to see how it works. The main purpose is to study and understand how something functions, which is then frequently employed to replicate and creating an equivalent item with improvements. On the other hand, AI is a branch of computer science concerned with building smart and intelligent machines or systems capable of performing tasks that ordinarily requires human knowledge. AI is interdisciplinary science with various methodologies and approaches in machine learning and deep learning which serves as the foundation of computer learning and is used in almost every field. Nanotechnology is the science and engineering of material at the nanoscale to create materials, devices, and systems with unique and outstanding properties. Nanotechnology enables the design of tiny robots (Nanobots) capable of performing specific tasks at the cellular or molecular level.

In BBP, the Synergy between these three fields was achieved as all these focus on the similar goals and everything which is to be accomplished was related and interconnected. Objectives of these fields were to establish a link between human brain and artificial brain so that smart machine can reconstruct and work like human brain. This combined effort can give us effective

results as compared to any other. This collective effort proved to be fruitful in the development of artificial brain which can think, respond and act as the natural brain. These fields work together effectively to turn this possibility into realization using supercomputer, an interface between natural brain and the virtual brain. Collaborative work of these fields was necessity to initiate working of the human brain into our computers. Reverse engineering works to understand the concept of how information processing occurs in biological neural network of our brain which was used to develop various algorithms. Hence together they accelerate the innovation of developing artificial brain.

5. ANATOMY OF HUMAN BRAIN USED IN BLUE BRAIN

The brain is totally like a smart computer that processes the information received from our senses and send messages back to the body. Human brain consists of billions of brain cells called neurons (Figure 1) [16]. A neuron (neurone or nerve cell) is an electrical impulsive cell found in our nervous system that fires electric signals/action potentials throughout the neural network. Neurons communicate with other cells with the help of specialized connections called synapses. These specialized connections use minute number of chemical neuro-transmitters to pass the electric signals from presynaptic neuron to the target cell through the synaptic gap. The information collected by receptors is called sensory input. The nervous system processes and interprets sensory input and then decides what actions should be taken. The nervous system stimulates effector organs (such as muscles and glands) to cause a response (motor output).

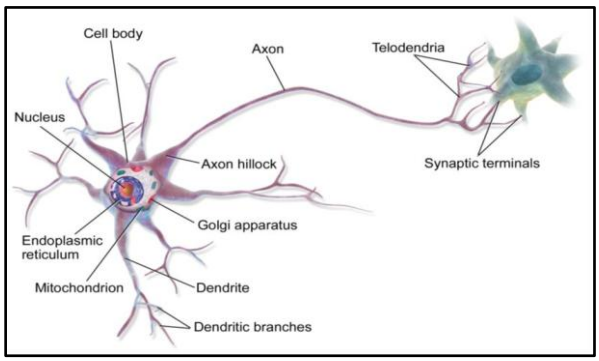

Fig 1: Brain Neuron. [16]

6. ABOUT BLUE BRAIN TECHNOLOGY

The blue brain project at EPFL (Ecole Polytechnique Federale de Lausanne, Switzerland) is a Swiss brain research initiative taken by founder and director professor Henry Markram. The goal of this project is to build biologically detailed digital reconstructions and simulation of the mouse brain. The aim of the blue brain is to create simulation neuroscience as a complementary approach along with experimental, theoretical and clinical neuroscience to understand the brain. BBP technology is new approach for recognizing the multi-level structure and function of brain. Blue brain technology uses Blue Gene supercomputer developed by IBM to work with the brain simulation process. Blue Gene is an IBM project to design supercomputers that can reach operating speed in the petaFLOPS (PFLOPS) range with lower power consumption. The project used three generations of supercomputers Blue Gene/L, Blue Gene/P and Blue Gene/Q. Blue Gene systems have also consistently scored top positions in rating of super-computer systems focused on data intensive loads. This Blue Gene supercomputer uses Michael Hien's NEURON, which is a simulation environment for modelling individual neurons and network of neurons.

7. UTILIZED SOFTWARE FOR NEURAL SIMULATIONS

NEURON is pioneering software used for modelling and simulating the electrical behavior of neurons and neural network. NEURON was developed by Michael Hins (Yale University) and John Moore (Duke University) in 1990's. It is written in C, C++ and Fortran and compatible with Linux. The current available version 8.2 was released in July 2022. As an open-source platform, NEURON code is readily assessable online. In collaboration with Michael Hines in 2005, the BBP team adapted NEURON for Blue Gene supercomputer enabling parallel processing. For simulations, the team used a message passing interface (MPI) known as the neocortical simulator (NCS), and NEURON software. NEURON allows the researchers to create computational representation of neurons and also simulate the electrical behavior and synaptic connections through simulation.

8. UTILISED HARDWARE

Blue brain originates from Blue Genes supercomputers which is primary machine used by BBP. In June 2005, IBM agreed to supply Blue Gene/L supercomputers [1], and finally in June 2010, the machine was upgraded to Blue Gene/P. Each Blue Gene/P computes chip has four power PC450 processor cores that run at 850 MHz. The chip's memory subsystem is made up of two DDR2 memory controllers, tiny private L2 caches as well as central shared 8MBL3 cache. Blue Gene/P comprised of big number of compute nodes each having processor, memory along with communication interface with peak performance of single node is approx. 13.6 G Flops. Blue Gene/Q (installed in 2012) is third supercomputer design in Blue Gene series which has peak performance of 20 petaFLOPS. It consists of chip containing various 64-bit A2 processor cores. Each Core processor code is 4 way multithreaded that runs at 1.6 GHz and has SIMD quad vector double precision floating point unit. Each chip has 18 cores and 16 processor cores. Core number 17 handles operating system and one core is meant for redundant manufacturing spare to enhance the yield. The supercomputers give peak performance of 204.8 G flops and draws 55 watts approximately.

9. WHY SUPERCOMPUTERS

Supercomputers play a vital role in BBP project due to its advanced computation. These computers easily deal with massive data and complex datasets. Parallelism is essential for simulating the neurons which are in billions in count, so an advanced simulation techniques are employed along with parallel computing using supercomputers. In 2012, Blue Gene/Q installation took top position in the list of TOP 500 project ranks and considered as powerful non distributed computer system in the World (According to Graph 500 rating and Green 500 ranking).

10. INSIGHT INTO VIRTUAL BRAIN

An artificial brain is the virtual brain that can act like a natural brain by taking decisions and respond on the basis of that decision. This concept of virtual brain is only possible using supercomputers due to their huge amount of storage capacity, processing power. The major necessity for this development is preservation of Intelligence which is otherwise lost with the person after death. The virtual brain also gives solutions to the problem of remembering the things and solutions for other brain related diseases like short term memory, unconsciousness etc. The process of developing the artificial/virtual brain

consists of following three steps (Figure 2).

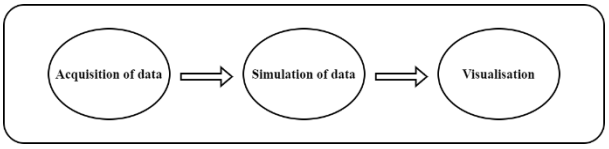

Fig 2: Process of developing virtual brain.

10.1 Acquisition of data

Data can be acquired by studying the activity and connectivity of individual neurons in the brain. This helps to gain a better understanding of how brain processes information and communicate with other parts of the body. Once the information is collected, it needs to be processed and analyzed using step by step instructions, known as algorithms which are used to generate virtual neurons that can closely resemble real neurons both in structure and functions.

10.2 Simulation of data

Using Blue Gene super computer and Michael Hine's NEURON software, the Simulation creates biologically realistic models of neurons. This software is a simulation environment for modelling individual and neurons networks. Primarily hoc is used as scripting language and Python interface is also available.

10.3 Visualization

This phase generally expresses the behavior and patterns of simulated neurons. RT Neuron is an interactive visualization tool for detailed neural simulations developed by blue brain project team. It is written in C++ and open GL. RT Neuron provide the output of Hodgkin-Huxley simulations in a three-dimensional environment. Hodgkin-Huxley simulations are based on mathematical model used to describe the action potentials in neuron. This helps the researchers to interact with the model by pausing, stopping, zooming at any desired part to get proper visualization.

11. UPLOADING HUMAN BRAIN

The tiny robots (known as nanobots) make uploading possible and these robots move throughout our circulatory system due to their microscopic size. These robots track the activity and structure of nervous systems, and penetrate easily through spine and brain. Nanobots also be used to carefully scan the connections throughout our brain structure. The information so obtained is then uploaded into the computer. It helps to repair the damaged tissues, enhance cognitive functions and even enables direct brain computer interfaces.

12. MERITS AND DEMERITS OF BLUE BRAIN PROJECT

The Blue Brain Project significantly advances our understanding of brain functions, structures, and dynamics by creating digital reconstructions of the brain and has proven a major milestone in neuroscience. Another notable merit of the project lies in its ability to shed light on various neurological disorders and diseases like Parkinson's disease, thereby facilitating the development of treatments and therapies. Moreover, the project drives significant technological innovation, particularly in supercomputing and computational neuroscience. Additionally, it serves as an educational platform, attracting researchers, students, and professionals in the field. By fostering collaboration among researchers and institutions, the project promotes interdisciplinary research in neuroscience, artificial intelligence and nanotechnology, resulting in ground-breaking innovations. The Blue Brain Project, while a pioneering endeavor in neuroscience, artificial intelligence and nanotechnology, is not without its challenges and drawbacks. One of the most significant hurdles it faces is the substantial demand for computing resources, which can prove to be both costly and resource-intensive. The complexity in simulating the human brain presents a formidable computational challenge. Furthermore, questions surrounding the accuracy and validity of the brain simulations generated by the project persist, which is on-going challenge of achieving complete precision in such a vast field. The creation of detailed digital reconstructions of the brain also raises ethical concerns, particularly regarding the potential misuse of brain simulation technology. The Blue Brain Project is heavily reliant on technological advancements, particularly in the fields of supercomputing and computational neuroscience, highlighting the project's dependency on the rapid evolution of technology. Another notable drawback is the allocation of resources, both financial and human, to the project, which may divert attention and funding from other important areas of neuroscience research. This project also requires global research, collaboration, and careful consideration of ethical implications to ensure that the Blue Brain Project remains a valuable and ethical endeavor in the pursuit of knowledge. Further information, regarding the science, progress and future perspectives in this blue brain project can be accessed from the website/portal of the project [17].

13. CONCLUSION

The Blue Brain Project exemplifies the powerful synergy between artificial intelligence (AI), reverse engineering and nanotechnology in advancing our understanding of the brain. By employing AI techniques, sophisticated computational algorithms and nanobots, researchers are able to reverse engineer the complex neural networks of the brain, leading to detailed digital reconstructions. This collaboration enables scientists to unravel the mysteries of brain function, structure, and dynamics in ways previously unimaginable. The project's innovative approach not only sheds light on fundamental questions in neuroscience but also holds immense potential for practical applications of technology adopted and beyond. Through the convergence of all these technologies, the Blue Brain Project paves the way for groundbreaking discoveries, offering new insights into neurological disorders, developing novel therapies, and driving technological innovation. As the project continues to evolve and expand, it serves as evidence for the transformative power of interdisciplinary collaboration to unlock the secrets of the most complex organ in the human body.

14. REFERENCES

[1] Malik, S., Muhammad, K. and Waheed, Y., 2023. Nanotechnology: a revolution in modern industry. Molecules, 28(2), p.661.

[2] Taha, T.B., Barzinjy, A.A., Hussain, F.H.S. and Nurtayeva, T., 2022. Nanotechnology and computer science: Trends and advances. Memories-Materials, Devices, Circuits and Systems, 2, p.100011.

[3] Bayda, S., Adeel, M., Tuccinardi, T., Cordani, M. and Rizzolio, F., 2019. The history of nanoscience and nanotechnology: from chemical–physical applications to nanomedicine. Molecules, 25(1), p.112.

[4] Emerich, D.F. and Thanos, C.G., 2003. Nanotechnology and medicine. Expert opinion on biological therapy, 3(4), pp.655-663.

[5] Surendiran, A., Sandhiya, S., Pradhan, S.C. and Adithan, C., 2009. Novel applications of nanotechnology in medicine. Indian Journal of Medical Research, 130(6), pp.689-701.

[6] Ahmed, A.A., Alegret, N., Almeida, B., Alvarez-Puebla, R., Andrews, A.M., Ballerini, L., Barrios-Capuchino, J.J., Becker, C., Blick, R.H., Bonakdar, S. and Chakraborty, I., 2025. Interfacing with the Brain: How Nanotechnology Can Contribute. ACS nano.

[7] Yoo, J., Tang, S. and Gao, W., 2023. Micro-and nanorobots for biomedical applications in the brain. Nature Reviews Bioengineering, 1(5), pp.308-310.

[8] Li, J., Esteban-Fernández de Ávila, B., Gao, W., Zhang, L. and Wang, J., 2017. Micro/nanorobots for biomedicine: Delivery, surgery, sensing, and detoxification. Science robotics, 2(4), p.eaam6431.

[9] Sacha, G.M. and Varona, P., 2013. Artificial intelligence in nanotechnology. Nanotechnology, 24(45), p.452002.

[10] Hamet, P. and Tremblay, J., 2017. Artificial intelligence in medicine. metabolism, 69, pp. S36-S40.

[11] Csete, M.E. and Doyle, J.C., 2002. Reverse engineering of biological complexity. science, 295(5560), pp.1664-1669.

[12] Markram, H. (2006). The blue brain project. Nature Reviews Neuroscience, 7(2), 153-160.

[13] Shanthi, D., Kuncha, P., Dhar, M. M., Jamshed, A., Pallathadka, H., & JE, A. L. K. (2021, July). The Blue Brain Technology using Machine Learning. In 2021 6th International Conference on Communication and Electronics Systems (ICCES) (pp. 1370-1375). IEEE.

[14] Sharma, S., Payal, N., Kaushik, A., &Goel, N. (2014, April). Blue brain technology: A subway to artificial intelligence. In 2014 Fourth International Conference on Communication Systems and Network Technologies (pp. 1106-1109). IEEE.SWETHA M, PRIYANKA N, VIKRAM P. The Blue Brain Technology.

[15] Eilemann, S., Abdellah, M., Antille, N., Bilgili, A., Chevtchenko, G., Dumusc, R., ... &Schürmann, F. (2017). From big data to big displays high-performance visualization at blue brain. In High Performance Computing: ISC High Performance 2017 International Workshops, DRBSD, ExaComm, HCPM, HPC-IODC, IWOPH, IXPUG, P^ 3MA, VHPC, Visualization at Scale, WOPSSS, Frankfurt, Germany, June 18-22, 2017, Revised Selected Papers 32 (pp. 662-675). Springer International Publishing.

[16] Zhang, J. (2019). Basic neural units of the brain: neurons, synapses and action potential. arXiv preprint arXiv:1906.01703.

[17] https://portal.bluebrain.epfl.ch/.