

# Mind Uploading with BCI Technology

S. Welikala<sup>1</sup>, A. S. Karunananda<sup>2</sup>

<sup>1,2</sup>Faculty of Information Technology, University of Moratuwa

## Abstract

*Mind uploading has been an emerging field of Artificial Intelligence. This area has been primarily influenced by the research and developments in Brain Computer Interfacing (BCI). This paper presents a research into BCI and its influence on mind uploading. In this context first, a description of the essentials of brain waves, BCI technology, and analysis and processing of brain waves are presented. Secondly, it proceeds to discuss the mind uploading technology with reference to EEG based brain waves analysis through BCI. The research has revealed the recent developments in mind uploading, its applications such as data backup, immortality and uploaded astronauts. More importantly, it has discovered legal and social concerns of mind uploading as a matter, which has not been given adequate attention, despite the numerous developments in the technological landscape of mind uploading research.*

**Keywords:** *Mind Uploading, Brain Waves Analysis, Brain Computer Interfacing, Data Backup*

## 1. Introduction

Mind Uploading is an emerging field, which is commonly misconcepted as a mere scientific fiction, yet the potential of the state of art was hidden for centuries. Mind uploading is the method of copying the organic brain and transferring it to a computer chip [1]. When the copy is being made, the computer can run a simulation model so that the copy can respond the same way as the initial organic brain. People are born to this world had then at the very end, all those who were born, die. When they die their core values and knowledge dies along with them. Only their doings and publications remain. What about the important work they were doing before dying, what about the knowledge areas they contained in their amazing brains, which were not revealed to the world? If we somehow can preserve their knowledge values, the world indeed would be a much more intelligent place. Mind Uploading therefore provides hope to the above-mentioned issue since these amazing minds can indeed be

recorded and preserved for future use with the aid of mind uploading.

This area of knowledge is an interdisciplinary study connecting many areas relating to neuro-science. It involves brain imaging, neuroscience, computer science, AI, psychology philosophy and many more. Earlier this study area was a seemingly science-fictional subject. Later scientists implemented researches about these fictional suggestions to run experimental and theoretical research programs. This paper presents our research into the field of mind uploading, its applications and unattended dimension of mind uploading.

Rest of the paper is organized as follows. Section 2 talks about BCI technology. Section 3 is on Mind uploading. In Section 4, we describe the Blue Brain project as the most cited mind uploading initiative to date. Section 5 describes some major applications of mind uploading. Section 6 presents the challenges or concerns related to mind uploading research. Section 7 is discussion to highlight the key finding of the research. Finally, Section 8 concludes the paper.

## 2. Essentials of BCI

Before moving on to the study of Mind Uploading or Whole Brain emulation, it is necessary to follow up the history, which led from BCI to the development of Whole Brain Emulation. The findings are as follows.

In 1875, the British Physician Richard Caton was the first to record electrical impulses emitted due to brain activity. Hans Berger, German Psychiatrist recorded these signals from the scalp in 1929 [1]. The method of Brain Computer Interfacing was first introduced in the late 70s, but the usage of this technology was limited and set aside due to the costliness of the equipment that are needed and the complex methodology that needed to be followed in the procedure. Today due to the development of technology, there exist low cost BCI devices. Examples for such cost effective equipment are the “NeoruskyMinwave device” and the “Emotive EPOC headset”[2].

### A. BCI ( Brain Computer Interfacing) Definition

BCI is the systematic way that measures and uses the signals of the brain and converts them into actions by using a specially programmed computer systems and equipment [1]. It can be stated that BCI is the accepted method for a brain and a machine to communicate with each other efficiently.

Even though BCI enables interactions with the brain, the brain does not use any of its usual neural systems in order to pass brain information. or its normal output channels[1].In other words humans can control machines or synthetic equipment without and muscular activity. Simply the brain activities are translated into commands and control signals [3].

### B. BCI System

The Brain Computer Interfacing methodology consists of two major controllers. They are the user and the BCI system. The user who has an organic brain makes the brain signals from their mind activities and the BCI system converts these generated signals into commands or stimulations that can control synthetic systems or machines [4].

There are two basic categories to record brain signals for BCI. They are the noninvasive record methodologies and the invasive record methodologies. These methodologies are the invasive system and the noninvasive system.

The invasive system is the hard and the difficult way. In this method the brain is reached by piercing the human scalp with a needle and sensors are implanted in the brain [5]. Examples for such invasive methods are ElectroCorticoGraphy [ECoG] and MicroElectrodeArrays [MEAs][6].



Figure 1: ECoG Sensor Placements

The noninvasive record methodologies include recording of electroencephalography [EEG], functional magnetic resonance imaging [fMRI], positron emission tomography [PET], infrared imaging [IR], near infrared

spectroscopy [NIRS] , fetal magneto encephalography [fMEG] and single photon emission computed tomography [SPECT] [1].

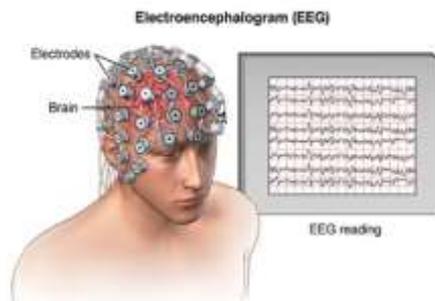


Figure 2: EEG Sensor Placements

One of the efficient devices to acquire such brain signals is the EEG Emotiv EPOC neuron headset. The headset gathers signals from the tissue of the scalp.

### C. The Headset

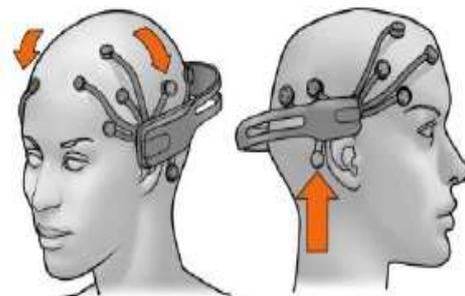


Figure 3: Outlook of the headset

The Emotive EPOC headset is one of the commercially available systems for the general public. It is cost effective and is available for both general consumers as well as researches.

The EPOC Neuron headset consists of 14 electrodes. There exists another 2 extra electrodes that are used as points to mark specific spots on the brain. The other electrodes are placed systematically as per the technology followed [4].

The above electrodes are made out from metal covered in a plastic base. It is wetted with saline water before placing on the scalp for signal acquisition[5].

The number of brain signal samples taken per second is 2048Hz. The resolution that can be obtained from this headset is 14 bits. The bandwidth of the signals that can be handled is 0.2-45HZ [8].

### D. Signal Processing Method

Before any processing is done to the above acquired signals, the noise or the interruptions in the acquired brain waves are duly removed. This

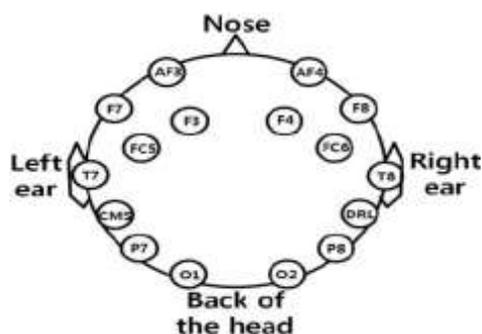


Figure 4: Sensor Placements of the Headset

noise is known as the power line noise. Then features are being extracted and then they are translated into commands by the classifier. The EEG based BCI depends on the thinking pattern of the human it is tested on, but basically the brain pattern tracking depends on the sorting algorithm used that is been used[9].

#### E. P300 BCI

Based on the type of signals BCI can be divided into 2 types. The first is Exogenous BCI and the second type is the Endogenous BCI. Endogenous BCI system consist those based on sensorimotor rhythms and slow cortical potentials (SCPs) which requires a period of intensive training. Exogenous BCI system uses the brain signals that are P300 stimulated. These signals are of two types, there are “related potentials” and “Steady State Visual Evoked Potential” (SSVEP) which does not require any intensive training [10]. Among all the BCI systems, P300 BCI is very popular and famous. There are various techniques to improve accuracy and flexibility of P300 based BCI [7].

### 3. Mind Uploading

With Whole Brain Emulation it is possible to map the exact brain functionality [9]. One-to-one mapping of the brain can be achieved via this method. With the development of Mind Uploading, the researchers are guaranteeing that it would enable software intelligence, copyable human capital, give rise to new ethical problems, immortality and a post human species.

Hans Moravec in 1988 was the first to publish a technical explanation about replacing brain cell to brain cell with software with his publication named *Mind Children: The future of Robot and Human Intelligence* [11].

Ralph Merkle, who is a distinguished computer scientist, was the first person to attempt to analyze the brain emulation. It was

conducted in 1989 where the researcher conducted tests to review the automated analysis and tested on re-establishing methods of the brain. With the success of the tests, he further stated that, “a complete analysis of the cellular connectivity of a structure as large as the human brain is only a few decades away”.

After the concept was introduced, there came several projects those scanned and reconstructed the human brain in a massive scale. An important examples for such a project is the Blue Brain project [9].

#### A. Data for Whole Brain Emulation

What we do in Brain Emulation is to get a one-to-one copy of the functional mind, independent of its organic structure to a biological substrate. Several types of data are obtained to model whole Brain Emulation. They can be described as follows [12].

The first data is the mind state. It is the photograph of the minds activity that depicts the internal awareness and the main factor that gives meaning to the way in which each person behaves [13].

The second data is the Mind Transition Functions. These functions showcase the real time development of the mind state. With this second type of data a person’s future mind state can be predicted when a mind state of a person at a particular instance is given.

The third and the final type of data is the Transition Update Functions. This type of data explains how the second type of data or the above said Mind Transition Function change due to modifications created by the mental activity of the evaluated person. Examples of change in the biological substrate are modified neurotransmitter vesicle concentrations, modified local calcium concentrations, modified axodendritic model, synaptogenesis, neurogenesis structure etc. [14].

#### B. The Methodology

The typical human brain consists of approximately 85.5 billion nerve cells or in other words neurons. Each neuron is linked separately to other such neurons by axons and dendrites, which are also parts of the neuron body. The signals between the neurons are transmitted releasing and detecting biological chemicals known as neurotransmitters.

Mind uploading can be achieved by using any of the following two methods. The first method is the copy and transfer method while

the second method is the slow and steady replacement of neurons. Among the above said two methods, the copy and transfer method is the technique that is used in a larger scale. What is being done is that the basic structure of the neuron system is mapped into a simple artificial neural network. Then, the rest of the simulations and visualizations are carried out.

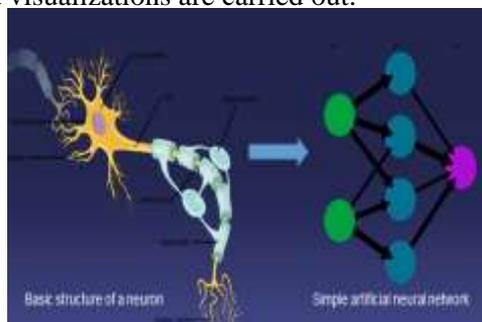


Figure 5: Copy and Transfer

#### 4. The Blue Brain Project

Blue Brain is a project that was initiated to copy and transfer all the contents of the human brain into a virtual brain that resides in a super computer. It is like uploading a mind to a computer.

Through, this Blue Brain project researches focused on preserving a person's memory, knowledge and intelligence for forever even after the death of that person. It also focused on solving the issues people face when remembering things in their day-to-day life such as history, names and routes.

The project was led by Henry Markram, Felix Schurmann and Sean Hill and was initiated in year 2005. In 2006, the scientists were able to successfully simulate and upload a neocortex of a rat. The neocortex is the most developed part of the cortex, which is responsible for sight, conscious thinking and hearing of mammals, which is one of the complex parts of the neuron system.

The objective of the project was carried out by implementing a neo-cortical column. It is the smallest functional unit the neocortex and is the brain component, which is responsible for higher functions such as consciousness. In humans, this column is 2mm in height, 0.5 mm in diameter and is composed of about 60,000 neurons.

The researches built the first single cellular model in 2005. The first artificial neocortical column containing 10,000 neurons was built in 2008. A mesocircuit that consist of 100 such columns was developed in 2011.

A rat brain amounts to have about 100 mesocircuits; therefore, such a rat brain was built in 2014. It is believed that a human brain is equal to 1000 times the above-mentioned rat brain and it can be implemented by 2023. Comparing the neo-cortex with regard to the number of neurons, human neocortex consists of 60,000 neurons whereas the rat neocortex consists of 10,000 neurons.

The future goal of the researcher is to stimulate a whole human neo-cortex that consists about 1 million cortical columns[15].

##### A. The Process

The procedure that was followed in the research was data acquisition, simulation, uploading and finally visualizing the results. The organic brain of a human was uploaded into a PC using the invasive method and the noninvasive methods that were previously discussed in this paper[16].

Data Collection is done by collecting brain portions, taking them under a microscope and gauging the shape and electrical behaviour of neurons individually.

The brain model can be extracted in two ways they are the serial sectioning and the brain imaging. In serial sectioning, the brain tissues and the other parts of the nervous system are frozen, scanned and analyzed layer by layer thus capturing the structure of the neurons and their interconnections. While in brain imaging, MRI is used as a technique to map the change in the blood flow around the nervous system and MEG to map the electrical currents. This method captures neurons by their shape, electrical and physiological activity, site within the cerebral cortex, and their population density. This information is then translated into algorithms, which describes the full function of the neurons. Then the generated algorithms are used to generate virtual neurons making them ready for the next step in the process, which is simulation.

Next, the simulation procedure is carried out. It consists of three steps and is controlled by 2 methodologies, which are the simulation speed and the simulation workflow. What happens in simulation is that first, the network skeleton is built from all the different kinds of synthesized neurons. Then, the cells are joined according to the experimentally found rules. Finally, the neurons are functionalized and the simulations are brought to life.

Then the above created neuron blueprints

are analyzed using visualization software. An example for such software is the RT Neuron. It is an ad-hoc software written specifically for neural simulations. This allows programmers and researchers to view the activation potentials propagated through or between neurons.

#### *B. The Nanobots and Software*

Considering both the invasive and the noninvasive methodologies one could say the best practice to obtain brain signals is by using Nanobots. They are small types of Robots that has the capability to record the brain activities. After the robot is later inserted into a computer it could easily simulate the functionality of the organic brain [1].

A software named “Neuron” is used as the special software for the Blue Brain Researchers in order to perform simulation development. This open source software was programmed using C, C++ and FORTRAN languages.

#### *C. The Blue Gene Supercomputer*

As for the hardware necessities, the research need super computers. These computers are called Blue Genes. Many versions of Blue Gene computers were used over the past. Blue Gene/L was used from 2005 to 2009; Blue Gene/P was used until 2011. Blue Gene/Q is the version that is currently used. It is also called JuQEEN. This is known as the world’s 8<sup>th</sup> fastest computer since it has a massive computing speed of 1.6 pitafllops[1].

#### *D. Advantages and Disadvantages of Blue Brain*

The blue brain was mainly implemented for the preservation of human mind after death. The next main idea was to promote decision making all by the computer itself. The blue brain has the ability to interact with other humans and animals. This application was tested using a rat brain and had been a success. Another such advantage is to use it to help deaf people by using direct nerve signal acquisition and simulation.

The main disadvantage is humans becoming slaves of the system they themselves created. It raises a chance for the computer-modeled brains to be hacked. This can also lead to a third party controlling of the brain that can be used to create destructions or to cause harm to other human beings or systems. This might eventually lead to cause a war against humans and machines [15].

## **5. The Applications of Mind Uploading**

The application of Mind Uploading can be used for many fields of science and non-science activities. Basically, it can be used to solve brain related problems.

Researches have released that the method can be applied for the treatment of Neuron science related disorders such as Autism, Asperger syndrome, Alzheimer’s disease, Parkinson’s disease, Bipolar disorder, chronic diseases, dementia, epilepsy, etc. When treating above ailments the problem is to try best practices using real patients, but using mind uploading the practitioners can simulate any of the above ailments in a synthetic platform in order to test mind treatments and activities to solve the problem. Thereby the treatment can be applied to real humans without creating greater harm or difficulties to test subjects [17].

Another interesting usage of WBE is the ability to test the continuous functioning of the brain of a person even after the person has died. This can be mainly used in the case of brain donations where the brain can be analyzed to test and study signs of depression, hallucination, anxiety, stress, brain malfunction, mental retardation and other such cognitive or even genetic disorders.

Among all the applications, the most tested and the most interesting usage of this is the ability to use this technology to help people who are complete or partially paralyzed people will be able use this technology. A similar application for the above is the ability to use this technology to simulate the brain signals of deaf people who are unable to talk and t read their minds.

The discussion about Uploaded Astronauts can also be brought forward as an application of Mind Uploading. In a human spaceflight, space stations or NASA can use uploaded astronauts where the computers with the uploaded minds of the real astronauts are sent to space to eliminate harm caused by zero gravity, vacuum of space and cosmic radiation. This way we can reduce the size of the spacecraft and will be able to increase the Return on Investment in such space projects.

The issues unanswered with current engineering or scientific experimental or theoretical approaches can be sought easily with the usage of this study[18].

Another such application is for the usage of study. Students will be able to study and

practically experience the complexity of the brain, its contents such as the ion channels, receptors, neurons, synapses, role of dendrites, etc. can be well comprehended and explored.

This can also be applied to solve major social problems such as drug abuse, addicted people to intoxicants and people who have done various types of grave crimes. The technology could find as to what mental stimulants resulted the people to do crimes etc.

For the scientists and philosophers who is interested in knowing about the conscious and subconscious mind can also get advantage from this application.

In case of memory loss due to ailments or accidents, with this technology people might be able to recover their lost memories[2].

In simple terms, we will no longer forget anything that is in our mind and we need not fear about it happening. This point can also be explained as the memory backup. Preservation of the memory can be ensured. Since, this data preservation is done in a supercomputer this rise to other advantages as well. It is that computer based intelligence has much faster processing power relative to the human processing power. As a fact, the electromagnetic signals of the brain travel 150 meters per second. While the electronic signals of the brain can travel 2/3 of the speed of the light. This implies that the virtual brain model can think thousands to million times faster than the organic human brain.

With WBI, we can recreate a model of a person's brain, which paves the way to take decisions even when the actual person is present. This is more advanced than any clone since the brain is re-created in a computer and the model can itself act as a high performance super computer that has a high processing speed and a large memory capacity.

Last but not the least among all the above said applications the optimal application is that death, which is the limiting factor of all human existence would no longer effects the knowledge or the core values of a human being. The intelligence of mankind would survive death with the usage of this emerging technology.

When considering the above it is apparent that Mind Uploading can indeed be for the betterment of the society, but just as anything else in the world BCI and mind uploading have its own limitations or challenges.

Virtual mind states cannot die. At least they

cannot die due to old age or sicknesses since they are not organic. Virtual beings can make themselves old or young according to their preference and can live as long as it wants until the hardware and software supports the system[13].

## 6. Challenges of Mind Uploading

This section discusses the challenges/concerns in the mind uploading research. In this sense, we have highlighted ethical, legal and social concerns.

### A. Ethical concerns

There is no doubt that the human brain is an impressive creation that is both powerful and unique. The usage of anything in this world can be applied to create both positive and negative impacts to the world. Therefore, the human brain being the most powerful asset, people can misuse it. Therefore, people can cause massive destructions buy using it.

The core values of the human were the only thing that was safe from the adverse impacts of the machine era today. However, one can say that application of BCI is like giving the control of human core values to the hands of technology. Our brains would become dependent on computer systems.

As the next challenge, it is important to consider the impact that is created from technological malware. When you give your brain control over to computer systems, there is high chance for your brain to get effected by different types of malware.

As we all know, man is prone to be adducted to new technologies very quickly as quickly as it grasps technologies. What if people becomes addicted to BCI and become slaves of the technology. This can also be a challenge.

People can also use this ingenious technology for illegal purposes. This will do harm for the other people living in this world and then people would have fear about this subject area. Earlier, when human cloning was introduced, people started to fear the science and brought oppositions to it. BCI and mind uploading is something more strong and powerful than cloning therefore it is clear that people would scare this technology more than there feared cloning [2].

Brain emulations should be done one-nerve materials to be tested. Animals are the option used in such situations. Animal and wild life

enthusiastic brings forwards the theory that it is immoral to use animals for such testing purposes since they do not have the ability to say forth their unwillingness. In the case of using humans as testing materials, none brings out the same concept since humans do have the ability to say their objections, but if the person used for testing is a paralyzed or a so-called locked in person then the morality rule applies.

Next, the question arises about volunteering for providing human brains for testing and laboratory practices. They say that such volunteering would amount to the ending of the biological life of the volunteer. Furthermore such volunteering while alive is likely to be equivalent to assisted suicide since the outcome of such testing is unknown and there is a high probability of risk of failure [19].

Apart from the above the identity of the willing parties to be tested and the global issues such as the extinction of species of animals, which can also arise with such testing should also be taken into account before the application of mind uploading.

### *B. The Legal Concerns*

When this technology is opened to the public, there arises a problem with regard to the legal implications. It is clear that we can program a virtual brain to have cognatic power but does it mean that having cognatic powers like humans can categorize it as human beings with rights.

Are they human replicas or are they separate individuals? That raises a question whether the synthetic brain copies should be called citizens of the country. Do they have immigration rights? Do they take the nationality of the person who was volunteered to provide the brain or do they fall into a different nationality?

Since a virtual personality can be scattered all around the world in different server computers in the globe is it possible to restrict such a person to a particular nationality considering the above stated fact. As it can be clearly seen this discussion regarding the legal implications is itself a book full of questions, people in general need to find answers for it [20].

### *C. Social Concerns*

The virtual personnel's were created as a copy of a true and an existing human being. In other words, the mind was reproduced from a

real man's mind. The problems arises from the fact that whether the virtual persons should be given the right or the opportunity to reproduce or re-generate copies of them. Due to the high processing capabilities that the machine embedded copies have, they undoubtedly exceed the powers of the human beings. Therefore, they can easily generate multiple copies of them to reproduce several copies. If that's the case the world will have multiple same personalities [20].

Mind uploading or whole brain emulation creates a one to one copy of the brain in a computer system. When it is done, one can say that the copy acts as same as the organic brain[11]. Therefore, can state that the disorder that can affect the organic brain can also affect the computerized brain. Therefore, the effect should be catered. In order to correct theses errors we need to treat it. This treatment can also be programmed solution[21].

Humans are created with the organic body and the phycology. The culture has a relatively high impact. The thought of death usually motivates as well as scares them to take actions quickly and efficiently [22].As a result of this overwhelming nature they create an anxiety in their minds. This anxiety gives meaningfulness to life as the person tries to work hard during their lifetime. Since WBE abolishes death this anxiety issue becomes erased from the minds of the people[23]. Since death anxiety enriches life it becomes as question as to the fact that WBE is disadvantages to the fruitful lifestyle of human beings[24].

If all the thoughts and mind states can be mapped to computer simulations, that implies that the brain states can be represented by bit streams in computers, which also known as digital data. This Digital data can be changed, copied as well as disrupted due to noise in various instances. Therefore, WBI is open to dangers [25].

## **7. Discussion**

When analyzing the above details we can specifically see that Mind Uploading carries a vast scope of positive outcomes to the society at large. In the same manner, after evaluating the ethical challenges and the implications, a person can also argue that Mind Uploading is indeed a dangerous technology to adhere to. In such situations, it is the general belief to weigh both the sides in a balance to see the impact it can

make. People should realize that all, things in the society has both pros and cons, therefore it should be the responsibility of the humans to use the technology wisely for the development of the society but not to make a negative impact on the world.

When looking back at the researches and developments achieved in the past few decades it is clear that this subject area has much potential to grow and flourish for the betterment of the world. According to the above, among all animals in the world the rat was used as a test subject. It brings forward a hope that his technology therefore can also be used for other animals. As examples, ants, termites and bees are special types of insects that are known to be the most efficient and the most architectural insects of all. Therefore, if researches can find a way to control the brains of these species, the service of these important animals can also be used for the betterment of the world.

If the technology were used to create disaster to humans the species would itself extinct from the universe or else it can be used for the betterment of the society. Therefore, it is evident that the steering wheel of this technology like any other knowledge area is in the hands of its user.

## 8. Conclusion

Mind uploading is a challenging and a long-term prospect. It has been developed from the mere idea of being a myth into current high-end projects in just about 30 years. Today the study field is developing in a tremendous speed. Along with the daily developments, the study area of Mind Uploading has come across challenges both globally and ethically. The ethical issue of the inability to obtain the consent of the paralyzed people before using as test subjects is now on legal debate in the US. It is believed that the laws would be enforced to govern this situation in the near future. Therefore it is clear that there should be a bridge between both the aspects (Positive and negative) in order to provide a favorable outcome for the society and the world at large. Therefore, it is clear that a scale or measurement should be introduced to acknowledge the feasibility of this study field of Mind Uploading using BCI. Apart from all the technological advancements in the field of Mind Uploading using BCI technology it is apparent that the impact of law and ethics

with regard to Mind Uploading is not yet been addressed sufficiently.

## References

- [1] M. Gidwani, A. Bhagwani, and N. Rohra, "Blue Brain - The Magic of Man," 2015, pp. 607–611.
- [2] K. Amarasinghe, D. Wijayasekara, and M. Manic, "EEG based brain activity monitoring using Artificial Neural Networks," in *Human System Interactions (HSI), 2014 7th International Conference on*, 2014, pp. 61–66.
- [3] S. Q. Xie, C. Gao, Z. L. Yang, and R. Y. Wang, "Computer-brain interface," in *Neural Interface and Control, 2005. Proceedings. 2005 First International Conference on*, 2005, pp. 32–36.
- [4] R.-B. NAGY, F. POPENTIU, and C. Tarca, *Survey of Brain Computer Interface Systems*. Jan, 2014.
- [5] D. Prince, M. Edmonds, A. Sutter, M. Cusumano, W. Lu, and V. Asari, "Brain machine interface using Emotiv EPOC to control robai cyton robotic arm," in *Aerospace and Electronics Conference (NAECON), 2015 National*, 2015, pp. 263–266.
- [6] C. B. Matlack, H. J. Chizeck, and C. T. Moritz, "Empirical Movement Models for Brain Computer Interfaces," *IEEE Trans. Neural Syst. Rehabil. Eng.*, vol. 25, no. 6, pp. 694–703, Jun. 2017.
- [7] K. Holewa and A. Nawrocka, "Emotiv EPOC neuroheadset in brain-computer interface," in *Control Conference (ICCC), 2014 15th International Carpathian*, 2014, pp. 149–152.
- [8] D. S. Benitez, S. Toscano, and A. Silva, "On the use of the Emotiv EPOC neuroheadset as a low cost alternative for EEG signal acquisition," in *Communications and Computing (COLCOM), 2016 IEEE Colombian Conference on*, 2016, pp. 1–6.
- [9] D. Wijayasekara and M. Manic, "Human machine interaction via brain activity monitoring," in *Human System Interaction (HSI), 2013 The 6th International Conference on*, 2013, pp. 103–109.
- [10] G. S. Taylor and C. Schmidt, "Empirical Evaluation of the Emotiv EPOC BCI Headset for the Detection of Mental Actions," *Proc. Hum. Factors Ergon. Soc. Annu. Meet.*, vol. 56, no. 1, pp. 193–197, Sep. 2012.
- [11] A. Sandberg, "Feasibility of whole brain emulation," in *Philosophy and Theory of Artificial Intelligence*, Springer, 2013, pp. 251–264.
- [12] R. Koene and D. Deca, "Editorial: Whole Brain Emulation seeks to Implement a Mind and its General Intelligence through System Identification," *J. Artif. Gen. Intell.*, vol. 4, no. 3, pp. 1–9, Jan. 2013.
- [13] R. A. Koene, "Fundamentals of whole brain emulation: State, transition and update representations," *Int. J. Mach. Conscious.*, vol. 4, no. 01, pp. 5–21, 2012.
- [14] R. A. Wasu and D. Kapgate, "Improving Accuracy in Brain Computer Interface using P300 Potential," 2015.
- [15] N. Ghimire and M. F. Iqbal, "Blue Brain."
- [16] R. Vinayakumar, A. P. D. Varghese, and V. Paul, "The Blue Brain Technology Using Wetware Technology and Fuzzy Logic."
- [17] R. A. Koene, "Experimental research in whole brain emulation: the need for innovative in vivo measurement techniques," *Int. J. Mach. Conscious.*, vol. 4, no. 01, pp. 35–65, 2012.

- [18] A. Sandberg, "Ethics of brain emulations," *J. Exp. Theor. Artif. Intell.*, vol. 26, no. 3, pp. 439–457, 2014.
- [19] A. Sandberg, "Monte Carlo model of brain emulation development," Working Paper 2014–1 (version 1.2), Future of Humanity Institute. <http://www.aleph.se/papers/Monte%20Carlo%20model%20of%20brain%20emulation%20development.pdf>, 2014.
- [20] B. Tonn, "Will Psychological Disorders Afflict Uploaded Personalities?," *World Future Rev.*, vol. 3, no. 4, pp. 25–34, 2011.
- [21] *Singularity hypotheses*. New York: Springer, 2012.
- [22] C. A. P. Linssen and P. C. Lemmens, "Embodiment in Whole-Brain Emulation and its Implications for Death Anxiety," 2016.
- [23] C. Eliasmith and O. Trujillo, "The use and abuse of large-scale brain models," *Curr. Opin. Neurobiol.*, vol. 25, pp. 1–6, Apr. 2014.
- [24] R. Cattell and A. Parker, "Challenges for brain emulation: why is building a brain so difficult," *Nat. Intell.*, vol. 1, no. 3, pp. 17–31, 2012.
- [25] P. Eckersley and A. Sandberg, "Is Brain Emulation Dangerous?," *J. Artif. Gen. Intell.*, vol. 4, no. 3, Jan. 2013.