Brain Computer Interfaces: The Past and Future

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Abstract—Brain Computer Interfaces (BCIs) have evolved significantly over the past century. They have been tried and tested on animals and humans since 1929, when Hans Berger discovered the electrical activity of the brain and EEGs, to monkeys controlling robotic arms and voiceless phone calls, to today, where millions have been invested into BCI research to find a cure for some brain diseases and possibility of enhancing human life.
BCIs range from non-invasive EEGs to invasive ECoGs. Electroencephalography (EEG) is the use of a EEG International 10-20 System skull cap that translates the electrical signal of the brain using the brain into commands and actions that control the external device. Electrocorticography (ECoG) is a procedure that the subject must undertake a craniotomy (surgical procedure), in order to implant the invasive BCI. ECoGs prove to deliver more precise results compared to EEGs. This is due to the electrodes being placed directly onto the cortical surface of the brain.

1 Introduction

We are living in a generation where everything we do is based or influenced around technology. It is very rare to see anyone above the age of 5, not using a technical device at some point throughout their days. With Ipads for kids and all of us with smart phones constantly in our back pockets, who knows what the future of technology holds for us.
Brain computer Interfaces (BCI) have been around for many years now but in my opinion, it will be one of the biggest breakthroughs in technology in the near future. Imagine being able to communicate with others without having to physically speak or control an electronic device with your thoughts. These are future possibilities of BCIs. However, BCIs could not just be used to enhance a Humans Everyday Life, but it opens a world of possibilities to individuals who have a physical or mental disability.
BCIs date back to the 1920s when Hans Berger, a German neuroscientist, discovers the electrical activity of the human brain with EEG [1]. To today, were millions has been invested into the research by various companies, with highly successful entrepreneurs behind them, striving to be the first to make the next big discovery.

1.1 What s a BCI

A direct communication channel between an external device and our brains [2]. A BCI allows the user to control the external device with only the use of their thoughts.

A Brain Computer Interface which is also known as a Brain Machine Interface(BMI) is a device that is controlled by a human brain. A BCI is a device that allows the human to control an electric device only with their thoughts.
BCIs can either be invasive or non invasive. A non invasive example is Electroencephalography (EEG) which is where the user wears an EEG hat that is connected to the external device. Whereas Electrocorticography (ECoG), an invasive procedure, where the BCI is implanted on the Human Brain and communicates with the External device.

1.2 How does a BCI work?

For every little movement in our body, our brain's are constantly at work. In order for our brain to control our bodies, it must send messages throughout our body to the designated muscle/limb. In order for these messages to be passed from our brains to our muscles, neurons are constantly at work.

2 The Brain

Our brains are similarly like computers in how they function. However, our brains are so much more diverse than a computer, as our brains allow us to feel emotions. Our brain consists of a 100 billion neurons constantly at work [3].
A neuron is made up of a cell body, a nucleus, axions and dendrites. Neurons communicate with each other using the axons and dendrites. A Neuron use electrical signals which they pass down through the axon where then the electrical signal in transferred into a chemical signal in which the axon then releases. These releases are known as neurotransmitters. Neurotransmitters are released into the synapse, i.e. the area between the end of the axon and the dendrites. The dendrite of the other neuron is received through the dendrite and is then converted into an electrical signal and the cycle continues [3]. Motor Neurons then carry these signals to the voluntary muscles to carry out tasks such as walking, talking [4] whereas the Sensory neurons carry the signals for the involuntary muscles which carry out our senses like smell, taste, touch [5].
Brain Computer Interfaces then read in these electrical signals from our neurons and translate them into actions and commands that control the external device.

3 Electroencephalography (EEG)

This is one of the most successful examples of Brain Computer Interfaces as it is non-invasive, safe, convenient and inexpensive. [15] EEGs is where the external device is connected to the scalp of a human. Prior to the procedure, the human scalp must be measured using the International 10-20 System. This is where the head is measured from the nasion to the Inion and then from the two pre-auricular points located just inside each ear. From these measurements, the use of 10 percent and 20 percent measurements then locate

where electrodes are to be placed. Each electrode placement is marked with a letter and number. Odd Numbers are placed on the left side of the scalp and even numbers on the Right side. F (Frontal), T(Temporal), C (Central, P(Parietal) and O (Occipital) are the letters used along with the numbers to mark the location of each electrode [2].
EEGs then output the results using montages. There are various montages which display the signals from the various electrode locations.

4 Electrocorticography (ECoG)

Although, it is an invasive procedure, the advancement of ECoGs looks to be on the rise rapidly and will be a massive breakthrough in the technology industry, possibly in the near future. ECoGs is the placement of a BCI electrode directly onto the surface of the brain. In order for this to be done, a craniotomy must take place. A craniotomy is a surgical procedure in which a part of the skull bone is removed to give exposure to the brain. The BCI electrodes are placed on the cortal surface of the brain. ECoGs give higher precision of results compared to EEGs. This is because the electrodes are directly on the surface of the brain, closer to the neurons and therefore the thick bone of the skull is not potentially blocking any electrical waves [15].

5 History of BCIs

The first recording of a BCI dates to as early as the 1920s. In 1929, Hans Berger, who was a German psychiatrist, recorded electrical activity of the brain using an EEG. Before Berger made his discovery, he assessed brain blood of humans who had skull fractures. After many years of assessing the blood he went on observe the electrical activity of the brain. Later, when the recording of the electrical activity improved, he then attached electrodes to the scalp like the way it is done today [6].
Subsequently, in the 1950s, Jos Delgado, who was a Spanish physiology professor was the first to study implanted electrodes on the brains of animals which then progressed to human brains. Delgado used stimoceivers, which received radio waves into the skulls of cats, monkeys, bulls and even humans. He could then control these animals behaviours with the click of a button [7]. One of Delgados most famous experiments in 1969, is where a bull is charging at Delgagdo in a ring and with a click of a button the bulls behaviour changes completely and walks off in the opposite direction.

As stated in [6], Delgado also carried out several tests on humans. He could generate lust, fear, anger, humour along with many other emotions on the subjects. For example, one particular test he carried out on a human, was on a nineteen-year-old girl with epilepsy. While she calmly played the guitar, he then introduced rage in her, which she reacted by breaking her guitar against a wall.
Continuing to 1970s, when the Bionic Ear was born. The Bionic Ear is a Cochlear Implant (CI) which is a surgically implanted electronic device according to [8], that gives the sense of sound to those who are deaf or hard of hearing. Robin Michelson M.D. was the first to have carried out successful tests of implanted CIs. In 1972, the Bionic Ear was released on the market. In 1976, University of California, Los Angeles (UCLA) BCI lab team found indication of possible communication of controlling a cursor through a two-dimensional maze [2].
Dr William Dobelle in 1978 was the first to give a blind man the ability to see again with a BCI. Dr Dobelle implanted electrodes on the subjects visible cortex and then fitted him with a pair of glasses that contained a mini camera. The images caught by the camera were then translated into electrical signals for the brain to interpret and then transferred to the implant in the brain giving the subject the ability of sight again [9].
The first High quality signals produced from an invasive BCI was in 1998. Then in 1999, Jim Jatich who was a quadriplegic, was the first to be aided by a EEG to give him restricted mobility in his hands [2].
Back in 2002, electrocorticography was carried out on monkeys in Brown University. This resulted in the monkeys being able to control a cursor on a computer. According to [10], the movement of the cursor was instant and nearly as rapid and accurate as being done physically.
A Monkey then controlled a robotic arm in 2005. Prior to the experiment, the monkey was thought to reach out for objects. During the experiment, the monkey had the electrodes implanted on its brain and its arms restrained, while hooked to a robotic arm. The test involved placing food in front of the monkey at different locations. Successfully, the monkey could then control the robotic arm to reach out and pick up the food using just its mind [11].
2008 was the year of voiceless phone calls. A neckband translated thoughts into dialogue. After special training, the subject could send signals to their voice vocals without speaking. The neckband would then convert these signals from the voice box into speech in which the user at the other end of the phone call could hear [12].

6 Present and Future of BCIs

In the past year or two, a lot of money has been invested into companies that plan to make the huge breakthrough in BCI technology in the coming years. Such companies are Facebook, Kernal and Neuralink.
In 2015, Mark Zucherberg, the creator of Facebook social media site, revealed that he and the facebook team are working on a secret project that will one day allow us to share full sensory and emotional experiences [13].
Last year, Bryan Johnson, an entrepreneur, invested 100 million dollars into the company Kernal. Kernal is a start-up business he founded in order to link human brains to computers [13].
In March of this year, it was published that a new and upcoming company 'Neuralink' is being founded by Elon Musk long with eight others. Neuralink specialises in implanted brain computer interfaces. The short-term goal for Neuralink is to be able to treat brain diseases using implanted BCIs and then further into the future, give the ability to enhance human life using these BCIs. These enhancements could lead to possible communication with thoughts, have all the information of the world wide web with just a thought or even entertainment purposes by controlling

games with our minds [14].
With millions being funded into the study of BCIs, the future and possibility of BCIs aiding people with disabilities and giving them, a whole new life is a strong one.

7 Conclusion

Brain Computer Interfaces have significantly evolved from when they were first discovered back in 1929 by Hans Berger to now in 2017, in which the future is looking bright in this particular field of research, due to millions being funded along with competition between some of the worlds biggest entrepreneurs, fighting it out, to see who will make what would be one of the biggest discoveries in technology, first.
EEGs prove to be the most successful and most used form of BCI due to it being safe and inexpensive. However, ECoGs look to be the future of BCIs, with the companies like Neuralink specialising in the invasive procedure.
The possible future uses of BCIs is so vast, from the possibility of communicating with each other with just our thoughts to life changing opportunities for those who are paralysed, have a brain disease like epilepsy, or even giving a blind or deaf person, the sense of sight or hear again.
But will it be worth it? Will many be willing to go under the knife and a chip implanted on their brain. Nevertheless, even if they did, what is the guarantee that our bodies will not reject the implanted BCI and try fight it? So many questions, that we will just have to wait patiently for the answers.

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