[New Brain Computer Interfaces being developed for treating neurological disorders, and controlling military robots with thought]

The brain-computer interface (BCI) allows people to use their thoughts to control not only themselves, but the world around them. Every action our body performs begins with a thought, and with every thought comes an electrical signal. The electrical signals can be received by the brain-computer interface, consisting of an electroencephalograph (EEG) or an implanted electrode, which can then be translated, and then sent to the performing hardware to produce the desired action.

Brain-computer interfaces are being applied in neuroprosthetics, through which paralyzed persons are able to control robotic arms, neurogaming where one can control keyboard, mouse etc using their thoughts and play games, neuroanalysis (psychology), and in defense to control robotic soldiers or fly planes with thoughts.

Current implantable devices are not well matched with body tissues in terms of their mechanical, chemical, and physical properties. The tissues that may be excited or interrogated by implants (e.g., brain, spinal cord, or cardiac muscle) are mechanically compliant, curvilinear, and perform their functions by modulating the flow of ions, Wei-Chen Huang, Haosheng Wu and Christopher J. Bettinger of Carnegie Mellon University (CMU). Conversely, most implantable silicon-based devices are mechanically rigid, and use electrons or holes as their primary information currency.

“These elements of mismatch reduce the overall performance of current implantable technology in three ways. First, the difference in mechanical properties (i.e., the elasticity) can cause local tissue damage that compromises the fidelity of measurements. Second, changing between ionic and electronic transduction decreases the information density and stimulation specificity. Finally, the materials that are typically used in microelectronic implants are susceptible to rapid protein adsorption, which initiates a cascade of local inflammation and scarring. The biological response to the presence of foreign material (such as an implant) can also compromise bidirectional communication.”

Instead of invasive brain surgery, DARPA has developed small brain modem that enters the bloodstream via a catheter and then transmits data. The US military recently successfully implanted and tested its first ‘brain modem’ on an animal subject. Neurologists injected tiny sensors into livestocks’ veins and then recorded the electrical impulses that control the animals’ movements for six months.

The tiny, implanted chip, developed by the Defense Advanced Research Projects Agency (Darpa), uses a tiny sensor that travels through blood vessels, lodges in the brain and records neural activity. The sensor, called a ‘stentrode’, a combination of the words ‘stent’ and ‘electrode’, is the first step in the military’s desire to allow soldiers to control machinery with their minds. The stentrode is the size of a paperclip, flexible and injectable.

BCI are also vulnerable to hacking, they can be used to control soldier's brains and their actions, and they could also be used by criminals to manipulate thoughts or even cause death. According to some Analysts Human Brain is going to become sixth war fighting domain.

Brain Computer Interfaces

There are three fundamental techniques to interface with the brain; non-inasive such as electro-encephalography (EEG), invasive through direct connections and electro-corticography (ECoG), also known as intracranial EEG – a sort of half-way house involving electrodes placed on the brain's exposed surface, rather than hardwired into the brain itself.

Invasive BCI are technologies that provide high resolution but require neurosurgery. They require regulatory approvals, hence manufacturers are less willing to fund clinical trials associated with the approval process.

Non-Invasive BCI have gained popularity in the recent times and are expected to grow at a fast pace in the near future because it provides least discomfort and negligible chance of infection due to electrode use. Progress in non-invasive electroencephalography (EEG)-based brain-computer interface (BCI) research, development and innovation has accelerated in recent years. New brain signal signatures for inferring user intent and more complex control strategies have been the focus of many recent developments. Major advances in recording technology, signal processing techniques and clinical applications, tested with patient cohorts as well as non-clinical applications have been reported, writes Damien Coyle.

Non-invasive BCI has found multiple uses in the areas of medicine such as motor restoration, wheelchair assistance, and treatment of neurological disorders. However noninvasive BCIs suffer from poor efficiency and accuracy, are slow and somewhat uncertain at present, they also tend to make high cognitive demands on the user.

U C Berkeley engineers have built the first dust-sized, wireless sensors that can be implanted in the body without surgery, bringing closer the day when a Fitbit-like device could monitor internal nerves, muscles or organs in real time.Because these batteryless sensors could also be used to stimulate nerves and muscles, the technology also opens the door to “electroceuticals” to treat disorders such as epilepsy or to stimulate the immune system or tamp down inflammation.

“The original goal of the neural dust project was to imagine the next generation of brain-machine interfaces, and to make it a viable clinical technology,” said neuroscience graduate student Ryan Neely. “If a paraplegic wants to control a computer or a robotic arm, you would just implant this electrode in the brain and it would last essentially a lifetime.”

Russian Scientists Create Mind-Reading ‘Neuro-Balalaika’

Researchers from the Immanuel Kant Baltic Federal University’s Institute of Living Systems in Kaliningrad have completed development of a new neural interface device called the

Balalaika, capable of simultaneously recording a variety of electrophysiological signals.

The device, designed and built from scratch in Russia, is simultaneously able to conduct electroencephalographic monitoring (recording electrical activity of the brain), electroencephalographic monitoring (measuring electrical activity of muscle fibers), electrooculographic monitoring (measurement of bioelectric potential during eye movement), photoplethysmographic monitoring (measuring blood flow), and measurement of skin temperature.

Using the Balalaika, users can play computer games hands-free, operate a wheelchair or even an exoskeleton. If a disabled person does not feel well enough to go to a clinic for testing and monitoring, he or she can do so from home, sending the results remotely to their doctor.

Researchers are now busy at work on an ‘avatar’, a program capable of matching human and robot activity via remote control. “Figuratively speaking, when a person raises his hand, a robot standing in the distance also raises his hand,” institute director Maxim Patrushev explained.

The multi-measurement features of the Balalaika’s instrumentation have allowed researchers to confirm that the simultaneous use of electroencephalographic, electrooculographic and photoplethysmographic signals significantly improves accuracy in the interpretation of planned physical activity on the basis of brain signals. It is assumed that the use of multiple signals helps to bring the probability of error-free remote control of external devices using brain power comes close to 100%, making it a major technical breakthrough for robotics and the development of technology to assist people with motor system diseases.

BCI in form of Artificial Skin

John Rogers at the University of Illinois at Urbana-Champaign and his team have built a Brain Computer Interface, in the form of flexible electronic skin that conforms to the body. The interface comprising just of small patch of gold electrodes sticks to the skin through van der Waals forces like a digital tattoo. The patch applied behind the ear, falls off when the build-up of dead skin beneath it loosens its grip.

Their solution does away with the cumbersome electrodes, annoying gels and wires of conventional EEGs described by Rogers as a “rat’s nest of wires attached to devices that interface to the skin with tape and gels and bulky metallic objects”. The team is now working on wireless transmission of data and power, allowing it to work even if the wearer is moving.

Invasive BCI

Invasive BCI have greater application in neuroprosthetics compared to non-invasive BCI since in order to understand/regulate the neural connectivity of specific brain areas, it becomes necessary to introduce neural implants (electrodes). One of the critical technologies is material used to make electrodes used to make Brain Computer Interfaces.

Lund University’s Breakthrough for

electrode implants

“There are several elements that must go hand in hand for us to be able to record neuronal signals from the brain with decisive results. First, the electrode must be bio-friendly, that is, we have to be confident that it does not cause any significant damage to the brain tissue. Second, the electrode must be flexible in relation to the brain tissue. Remember that the brain floats in fluid inside the skull and moves around when we, for instance, breathe or turn our heads.”

The Lund researchers’ Professor Jens Schouenborg and Dr Lina Pettersson have developed tailored electrodes, which they call 3-D electrodes, are unique in that they are extremely soft and flexible in all three dimensions, in a way that enables stable recordings from the neurons over a long time.

In order to implant such electrodes, the researchers have developed a technique for encapsulating the electrodes in a hard but dissolvable gelatine material that is also very gentle on the brain. The electrodes are made of 4 mm gold leads and individually insulated with 4 mm parylene. The array of electrodes consists of eight flexible channels, designed to follow the movement of the brain. Both the electrode and implantation technology, which have been tested on rats, are patented by NRC researchers, in Europe and the US, among other places.

“This technology retains the electrodes in their original form inside the brain and can monitor what happens inside virtually undisturbed and normally functioning brain tissue”, says Johan Agorelius, a doctoral student in the project.

Until now, developed flexible electrodes have not been able to maintain their shape when implanted, which is why they have been fixated on a solid chip that limits their flexibility, among other things. Other types of electrodes that are used are much stiffer. The result in both cases is that they rub against and irritate the brain tissue, and the nerve cells around the electrodes die.

“The signals then become misleading or completely non-existent. Our new technology enables us to implant as flexible electrodes as we want, and retain the exact shape of the electrode within the brain”, says Johan Agorelius.

“This creates entirely new conditions for our understanding of what happens inside the brain and for the development of more effective treatments for diseases such as Parkinson’s disease and chronic pain conditions than can be achieved using today’s techniques”, concludes Jens Schouenborg.

Electronic dura mater for long-term multimodal neural interfaces

Team of researchers at a Swiss technology institute , Pavel Musienko and others have developed a new ultra flexible electrodes modeled on dura matter, the protective membrane of the brain and spinal cord, that can both stimulate and record from neurons.

Most of current electrode implants—even thin, plastic interfaces—present high elastic moduli in the gigapascal range, thus are rigid compared to neural tissues. "The mechanical mismatch between soft neural tissues and stiff neural implants hinders the long-term performance of implantable neuroprostheses. Here, we designed and fabricated soft neural implants with the shape and elasticity of dura mater, the protective membrane of the brain and spinal cord."

"The implant, which we called electronic dura mater or e-dura, integrates a transparent silicone from substrate (120 mm in thickness), stretchable gold interconnects (35 nm in thickness), soft electrodes coated with a platinum-silicone composite (300 mm in diameter), and a compliant fluidic microchannel (100 mm by 50 mm in cross section)." The interconnects and electrodes transmit electrical excitation and transfer electrophysiological signals. The microfluidic channel, termed chemotrode , delivers drugs locally .

They next tested the long-term biointegration of soft implants compared to stiff, plastic implants (6 weeks of implantation). Both types of implants were inserted into the subdural space of lumbosacral segments in healthy rats. They found that rats with the stiff implant began to have trouble walking within just a few weeks, and later examination showed both inflammation and deformation of their spinal cords. The rats with the e-dura implant displayed no such motor problems or physiological degradation. The electrodes also proved to be effective in accurately recorded from and stimulated neurons in the brain and spinal cord.

Carbon Micro thread electrodes

In 2014, Scientists at University of Michigan have come up with micro thread electrode which is delicate enough not to damage nerve tissue and still resilient enough to last decades. This seven micrometer carbon fiber thread is 100 times thinner than common metal electrodes. It has its tip coated with polymer to pick of signals even from a single neuron.

The electrodes may lead to development of long lasting brain machine interfaces through which paralytic persons could control robotic limbs or computer mouse. However there is still many challenges to overcome like finding ways to insert such fine electrodes.

Carbon nanotube fibers make superior brain electrodes

Carbon nanotube fibers invented at Rice University may provide the best way to communicate directly with the brain. “They’re like extension cords,” said Mehdi Razavi, the director of electrophysiology clinical research at the Texas Heart Institute and the project’s lead investigator. “They allow us to pick up charge from one side of the scar and deliver it to the other side. Essentially, we’re short-circuiting the short circuit.”

The fibers have proven superior to metal electrodes for deep brain stimulation and to read signals from a neuronal network. Because they provide a two-way connection, they show promise for treating patients with neurological disorders while monitoring the real-time response of neural circuits in areas that control movement, mood and bodily functions.

“The brain is basically the consistency of pudding and doesn’t interact well with stiff metal electrodes,” Caleb Kemere, a Rice assistant professor said. “The dream is to have electrodes with the same consistency, and that’s why we’re really excited about these flexible carbon nanotube fibers and their long-term biocompatibility.”

The fibers were created by the Rice lab of chemist and chemical engineer Matteo Pasquali.” We developed these fibers as high-strength, high-conductivity materials,” Pasquali said. “Yet, once we had them in our hand, we realized that they had an unexpected property: They are really soft, much like a thread of silk. Their unique combination of strength, conductivity and softness makes them ideal for interfacing with the electrical function of the human body.” The working end of the fiber is the exposed tip, which is about the width of a neuron. The rest is encased with a three-micron layer of a flexible, biocompatible polymer with excellent insulating properties.

The challenge is in placing the tips. “That’s really just a matter of having a brain atlas, and during the experiment adjusting the electrodes very delicately and putting them into the right place,” said Kemere, whose lab studies ways to connect signal-processing systems and the brain’s memory and cognitive centers.

Kemere foresees a closed-loop system that can read neuronal signals and adapt stimulation therapy in real time. He anticipates building a device with many electrodes that can be addressed individually to gain fine control over stimulation and monitoring from a small, implantable device. The Welch Foundation, the National Science Foundation and the Air Force

Office of Scientific Research supported the research.

University of Melbourne scientists develop BCI which gets implanted in the brain without surgery

Australian scientists funded by the US Defense Advanced Research Projects Agency (Darpa) have developed a tiny, matchstick-sized Brain Computer interface called a stentrode. This stentrode is flexible enough to be able to pass through the blood vessels and get implanted into the motor cortex, the brain’s control centre – bypassing the need for complex invasive brain surgery.

The device would capture and decode the brain signals and then wirelessly transmit appropriate commands through the skin to enable control of an exoskeleton attached to their limbs simply by thinking about it.

The stentrode could also benefit people with Parkinson’s disease, motor neurone disease, obsessive compulsive disorder and depression and could even predict and manage seizures in epileptic patients. The work is the result of close collaboration between the University of Melbourne, the Royal Melbourne Hospital and the Florey Institute of Neuroscience and Mental Health.

In late 2017, a select group of paralysed patients from the Royal Melbourne and Austin Hospitals in Australia will be chosen for the trial, where they will be implanted with the stentrode. If the trial succeeds, the technology could become commercially available in as little as six years.

References and Resources also include:

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