Presentation On Brain-Computer Interfacing

(Mike Gruenfeld - 7/4/18)

Reference: "The Economist" January 6, 2018 (Technology Quarterly Review Section)

https://www.economist.com/technology-quarterly/2018-01-06/thought-experiments

Human Brain - Regions and Functions

- Refer to graph (last page).
- Contains 85 billion neurons.
- Typical neuron has 10,000 connections to other neurons.

Long-term Needs for Interfacing Capability

- Rise of artificial intelligence (AI) demands a concomitant upgrade of human capabilities.
- Need for humans to co-exist with AI, rather than being subjugated to it.
- Need for humans to communicate much more quickly with each other, and with computers.
- Need for humans to be able to access and absorb knowledge instantly from the cloud.
- Need to be able to pump images from one person's retina straight into the visual cortex of another.
- Need to create entirely new sensory abilities from infrared eye sight, to high frequency hearing.
- Need to ultimately meld together humans and AI.

Sources for Listed Long-Term Goals

- Bryan Johnson founded a new firm called "Kernel" to develop read and write neural code.
- Elon Musk founded a new firm called "Neuralink" to create new kinds of brain implants.
- Military's Defense Advanced Research Projects Agency

(DARPA) funding universities and research institutions to create new and advanced high-resolution brain implants.

Objective

- To extract and decode neural signals from the brain in order to mitigate physical disabilities, and control external devices.

Example

- Signals from macaque monkey brains were recorded when viewing pictures of 50 different aspects of people's faces, skin color, eye spacing, etc. Enabled the prediction of faces the monkeys were shown from signals emanating from their brains.

Ailments

- Paralysis of stroke victims.
- Lou Gehrig's disease.
- Epilepsy
- Deafness.
- Blindness.
- Parkinson's disease.
- Severe depression.
- Locked-in syndrome
- Dysphagia: impaired swallowing.
- Aphasia (inability to understand or produce speech).
- Alzheimer's disease.

Treatments

- Since 2004 13 paralyzed people have been implanted with a system called "BrainGate".
- BrainGate uses an array of small electrodes (Utah array) implanted onto the motor cortex.
- Utah array electrodes detect 200 neurons that fire when

someone intends to move his hands and arms. The signals are sent through wires that poke out of the person's skull to a decoder, where they are translated into a variety of outputs, from moving a cursor to controlling a limb.

- Requires a brain-computer interface (BC), for interactions between brains and machines.
- Decoding neural activity and using the code to control external devices.
- The BrainGate System has allowed a woman paralyzed by a stroke to use a robotic arm to take her first sip of coffee without help from a caregiver. Also, used by a paralyzed person to type at the rate of 8 words per minute. It has even reanimated useless human limbs.
- A newly developed system adds a skin-like layer to prosthetic limbs. Pressure applied to the skin-like layer is transmitted to the user's brain via an electric nerve stimulator implanted in the arm, above the prosthesis, giving the user the perception of touch and pain.

(Source: https://gizmodo.com/electronic-skin-allows-user-of-prosthetic-hand-to-fee-1826965132)

- Cochlear implants convert sound into electrical signals, and sent to an electrode in the inner ear, stimulating the cochlear nerve so that the sound is heard in the brain. "Like playing Chopin with a fist", but the brain works out the signals. 300,000 people already have these.
- More than 150,000 people have had electrodes implanted for deep-brain stimulation to help them control Parkinson's disease.
- In people who suffer from movement disorders, such as Parkinson's Disease, spaghetti-like wires, and big electrodes, are used to carry out deep-brain stimulation.
- Patient control of deep brain stimulation through conscious thought, being pursued. Deep brain stimulation used to control a constant tremor, but can

cause a slurring of words. For presentations, patient may want to eliminated slurring of words, while temporarily accepting return of tremor.

- More than 50 million people worldwide have epilepsy, with half not responding to medication; 300 million suffer depression, with many could be helped with BCI, and the quality of life for many oldsters who suffer from dysphagia could also greatly benefit.
- Brain implants monitor brain activity for signs of imminent epileptic seizures, and deliver electrical stimulation to stop them.
- A device for stimulating the visual cortex of blind people in order to project images into their mind's eye.
- To allow blind people to see, by producing images inside their brains. This project is funded by DARPA with the objective of inputting signals directly into the visual cortex. A chip that contains 65,000 electrodes is placed on top of the visual cortex, but under the membrane that surround the brain. The next generation chip will house one million electrodes/sensors.
- Some methods beam infrared light into the brain (near infrared spectroscopy), to put simple yes/no questions, and to identify yes/no answers, to locked-in patients who had been completely immobilized by Lou Gehrig's disease. Success rate is about 70%.
- A deep brain stimulation device, using electrodes inserted into decision-making and problem-solving regions of the brain, successfully slowed down the progress of Alzheimer's disease.

(Source:https://www.express.co.uk/news/science/911685/Alzheimer-s-disease-dementia-science-breakthrough-brain-pacemaker-slows-progression)

Invasive Methods - Penetrating Brain

- Existing implants record only a tiny selection of the brain's

signals. The Utah Array of BrainGate picks up the firing of just 200 neurons out of the 85 billion total.

- The ideal implant would be safe, small, wireless, and long-lasting. It would be able to transmit huge amounts of data at high speed. And, would be able to interact with many more neurons than current technology allows. The DARPA requirements are to target one million neurons (a one million wire device), and to accomplish this by 2021, including a pilot trial using humans.
- Output of data from a one million wire device presents a massive problem. Such a device will produce 24 gigabits of data every second (a streaming ultra-high-definition movie on Netflix uses up to 7 GB per hour).
- Researchers are researching a wide range of implants for sending and receiving signals from the brain, with outfits like Kernel, Neutralink, and DARPA pursuing a four-year time-frame for pilot studies with humans.
- Using brain-computer interfaces (BCI) studied electrical activity in the temporal lobe when someone is listening to conversation. Can be used to predict what word the person heard. Similar signals also produced when person imagines hearing words. Potentially useful for a speech processing device for conditions like aphasia.
- The most ambitious visions of BCIs, in which thoughts, images, and movements are seamlessly encoded and decoded, will require high-resolution implantable interfaces. This is the approach of companies like Neuralink and Kernel, and is also supported with tens of millions of dollars distributed by the military's Defense Advanced Research Projects Agency (DARPA) to various research organizations.
- Development of whole brain interfaces is the eventual long-term goal for getting data out of the brain, or into it.
- Progress in invasive technologies will initially depend on

therapeutic applications. But, ensuring an adequate supply of patients for experimentation is a major problem. Epilepsy patients whose sole remaining option is surgery, are the major source.

Invasive Methods - Not Penetrating Brain

- One invasive method places electrodes solely on the surface of the brain, instead of inserting electrodes into the tissue of the brain, using a grid of microelectrodes, like BrainGate's Utah array.
- Some techniques try to communicate with the brain through the peripheral nervous system. One effort is to use the vagus nerve, which runs from the brain into the abdomen. This connects to the "locus coeruleus", which is deep in the brain stem, and modulates anxiety and stress.

Non-Invasive Methods

- Lots of work being done to read neural code outside the skull. But, tradeoff between the degree of invasiveness, and the fidelity of brain signals measured.
- Easiest way to read electrical activity outside is with an electroencephalogram (EEG), using a cap with lots of electrodes pressed against the scalp. Unresolved signals from thousands of neurons beneath the electrodes, neurons deep in the brain not detected, and signals distorted by layers of bone, and tissues.
- One promising non-invasive technique uses infrared light sent through the skull that's either absorbed or reflected back to detectors, providing a picture of what's going on in the brain. Being evaluated for allowing locked-in patients to communicate.
- Measuring changes in blood oxygenation in the brain enables reconstruction of fuzzily film clips of what people were watching.

- Facebook plans to create a "silent speech" interface for typing 100 wpm straight from the brain.
- New startup "Openwater" developing a non-invasive neural-imaging system that will eventually allow minds to be read.

Futuristic Methods

- Powering such devices will be by inductive coupling.
- "Neurograins" (the size of sugar grains) which can be sprinkled on top of the cortex, or implanted within it, comprise another approach. Each grain, would have a built-in amplifier, the ability to transmit data to an external processor, and to be powered inductively.
- Use of magnetic nanoparticles is also planned. They can penetrated deeply into the brain, and heated by induced external magnetic fields, causing nearby neurons to fire.
- Use of ultrasound to cause tiny particles ("neural dust") to vibrate, and nearby neural activity will alter the vibration, which can be recorded and analyzed.
- An ultra-thin membrane like porous net made of flexible polymer, studded with sensors. This BCI simulates the flexibility and softness of neural tissue, and allows inserting this BCI into the brains of epilepsy is now planned.
- An invasive technique that does not require drilling through the skull. A stent-like device, that's studded with electrodes, is positioned through blood vessels to blood vessels that overlie the brain. And, then opens within the blood vessel. Human trials are scheduled to begin.

Medication for Brain Enhancement

- Human trials are underway to determine whether a protein called CREB works as an on-switch to promote new connections among neurons, to help build long-term

memories. Current trials with CREB-boosting drugs only address stroke victims, and other cases of brain trauma. But, trials for enhancing brain function of healthy individuals are also planned. Simply swallowing a little pill may someday produce speedier learners who can memorize a Shakespearean play after one reading, or quickly learn another language.
(Source:http://discovermagazine.com/2018/jun/wheres-that-viagra-for-memory)

Growing Brains and Merging with Robots

- Tiny Neanderthal and Human brains, that are being grown in petri dishes, will be installed in crab-like robots in order to determine why we and our cousins developed so differently.
(Sources:https://nypost.com/2018/06/28/scientists-growing-neanderthal-brains-to-battle-humans/
and
http://www.sciencemag.org/news/2018/06/exclusive-neanderthal-minibrains-grown-dish)