Brain-Machine Interfaces

The link between Neurosurgery and Artificial Intelligence

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Present Literature
History

René Descartes

- Founder of “Modern Philosophy" and “Modern Mathematics”
- Bodies are complex machines
- Invented the Cartesian coordinate system
The Beginning

- DBS
  - Pain Disorders
  - Chronic Pain
  - Psychiatric Disorders
Where are we Now?

- DBS/Neuromodulation
  - Parkinson's
  - Epilepsy: Vagus Nerve Stimulator
- Neuroprosthetics
Neuroprosthetics

- Artificial devices used to replace damaged or missing parts of the brain
  - Cochlear Implant
  - Visual prosthesis/retinal implants
Cochlear Implant

- Stimulates nerves
- Need some nerve fibers
- First implanted in 1978
Retinal Implants

- Used in diseases of progressive blindness
- Degradation of photoreceptor cells
  - macular degeneration
  - retinitis pigmentosa
- Two chip System
  - Recognition
  - Transmission
The Idea

Now
- Neuromodulation
- Neuroprosthetics

Future
- Enhancement
- Replacement
Where we are Going

- Neurocontrol
  - Functional Electrical Stimulation
- Brain- Machine Interface
FES

“Cyborg”
- Kevin Warwick/University of Reading
- Implanted electrode array into his forearm

Used recordings for different functions
Controlled an artificial hand
Brain-Machine Interface

- Neural Networks
- Four main Functions
  - Motor
  - Sensory
  - Behavior
  - Intelligence/Cognition
Neural Networks

Backpropagation

1. Present a training sample to the neural network.
2. Compare the network's output to the desired output from that sample. Calculate the error in each output neuron.
3. For each neuron, calculate what the output should have been, and a scaling factor, how much lower or higher the output must be adjusted to match the desired output. This is the local error.
4. Adjust the weights of each neuron to lower the local error.
5. Assign "blame" for the local error to neurons at the previous level, giving greater responsibility to neurons connected by stronger weights.
6. Repeat the steps above on the neurons at the previous level, using each one's "blame" as its error.
Neural Networks

- Based on the Perceptron
- Perceptrons can be added in series or parallel.
- Summation of input and output vectors
- More networks = increase speed
Neural Networks

Axon (Carries signals away)

Nucleus

Dendrites (Carry signals in)

Synapse size changes in response to learning

\[ x = \sum_{j=1}^{N} W_j I_j \]

\[ x > T? \]

OUTPUT
Comparison

Conventional computers
- use an algorithm
- Restricts it to problems with known solutions

Neural Networks
- Learn by trial and error
- Functions by example
Brain Implants

- Biological neural networks: Stimulate one or groups of neurons
- Made of silicon or platinum
- Mimic neurons
- Replace damaged or dead brain cells
Important Considerations

- Complexity of neural connections
- Stable connection
- Plasticity of the human brain
Answers?

- Create bridges for damaged cells
- Compatible brain tissue or molecules that will adhere to brain tissue
- Sensory Substitution
Another Consideration

“Brain in a vat” theory
Can stimulate and train the brain increasing capacity
Brain-Machine Interface

Four main Functions

- Motor
- Sensory
- Behavior
- Intelligence/Cognition
Motor: Transforming Thoughts

- Cyberkinetics developed a system called BrainGate
  - Microchip on the motor cortex
  - Transmission to a digitizer and then computer system for translation
Transforming Thoughts-1

- Neural Signals
  - Uses a device implanted beneath the skull
- Helsinki University
  - Virtual keyboard
- NY Rochester Institute of Technology
  - Computer-brain interface
- Colorado State University
  - EEG recording of various tasks
    - Writing, visualizing numbers
  - Uses a computer interface
Transforming Thoughts-2

- Initial goal is interaction with computers and basic functions
- Future goal is to implant electrical probes directly into muscles
Monkey think, Monkey Do

- Dr. Nicolelis/Duke University
- Implant allowing monkey to control a game using thoughts
- Monkey could play using only visual feedback
How it works

- Microelectrodes along the frontal and parietal lobes
- Computer system recognizes patterns of signals when monkey moves
Relevance

- Transmitted to a robotic arm
  - Can control another device to move objects
  - Can then use artificial limbs in paralyzed people
Brain- Machine Interface

Four main Functions

- Motor
- **Sensory**
- Behavior
- Intelligence/Cognition
Research involves using either sensory substitution versus direct cortical stimulation.
Brain- Machine Interface

Four main Functions
- Motor
- Sensory
- Behavior
- Intelligence/Cognition
Behavior

- OCD (ventral striatum and midline thalamus)
- Depression
Depression

- Constant, weak electrical stimulus to area 25

- Study of six patients
  - 4 improved
Brain-Machine Interface

Four main Functions

- Motor
- Sensory
- Behavior
- Intelligence/Cognition
Artificial Hippocampus

- Studied at the University of Southern California
- Hippocampus is very ordered and structured
- Strictly involved in formation of new memories
Artificial Hippocampus

2003 Devised a mathematical model of hippocampus
- Slices of rat hippocampus were stimulated with electrical signals
- Each electrical input produces a corresponding output.
- Programmed onto a chip
Artificial Hippocampus

2004 Used a grid of miniature electrodes to feed signals in and out of the microchip

- Compared rat hippocampus slices to the chip
- Signals matched in shape, timing and statistics

Next Step: implant in rats and then in Monkeys
Chip takes over the processing of nervous signals normally performed by the hippocampus.

Multiple electrodes are placed on each array. They are positioned to mimic the structure of nerve tissue within a slice of the hippocampus, and make contact with other parts of the brain.

Recording electrode array "listens" to neuron activity coming into the hippocampus and feeds it to the chip.

Stimulating electrode array delivers the appropriate electrical output to the rest of the brain.
Problems

- Making long-range connections to other parts of the brain
- Bypassing healthy tissue
- Development of scar tissue as well as cell death of previous neurons
  - electrodes coated with proteins that should mimic healthy tissue
Artificial Intelligence (AI)

- Intelligence exhibited by an artificial entity.
  - Behavior
  - Learning
  - Adaptation
Artificial Intelligence (AI)

Research in AI is concerned with producing machines to automate tasks requiring intelligent behavior.

- Planning
- Scheduling
- Problem solving
Schools of Thought

Conventional AI
- AKA: Machine Learning
- Demonstrates applied reasoning
- Example: Clippy

Computational Intelligence
- Interactive
- Learning
- Example: Consumer product control systems
Present Uses

- Government uses AI computers to schedule units
- Gaming
  - Virtual reality
  - Image Processing
- Robotics
- Automation
Where AI is heading..

- Space Exploration
- Deep Ocean Exploration
- Virtual Reality
- “Android Robots”
- Douglas Lenat-A
  common sense knowledge base
Steven Levy

- Based on Biological behaviors
- “Natural” rules
Life “in silico”

Computer viruses are close to becoming “life”

Artificial organisms that meet criteria of living creatures
Artificial Intelligence in Medicine (AIM)

- More evidence based medicine = more information = more reliance on computers
- Can the medical profession rely on the computer to make the right clinical assessment?
- Diagnosis is a process, not an event and fortunately, human cognition is still superior to machine intelligence
Ethical Issues

- There is little or no reason to create mechanical laborers (that can think independently)
- What is considered the type of human being to design as an “Android”
- Inability to understand complex interactions
Ethical Considerations

- Can you give consent?
- Could implants force some people to remember things they would rather forget?
Conclusions

- Still in its infancy
- Very little animal or human models
- Designing software to mimic reasoning and deductive ability is no easy task.
Final Thoughts

- Materialists: world is objective matter
- Idealists: world is acquired from mind
- Kant: The Metaphysical