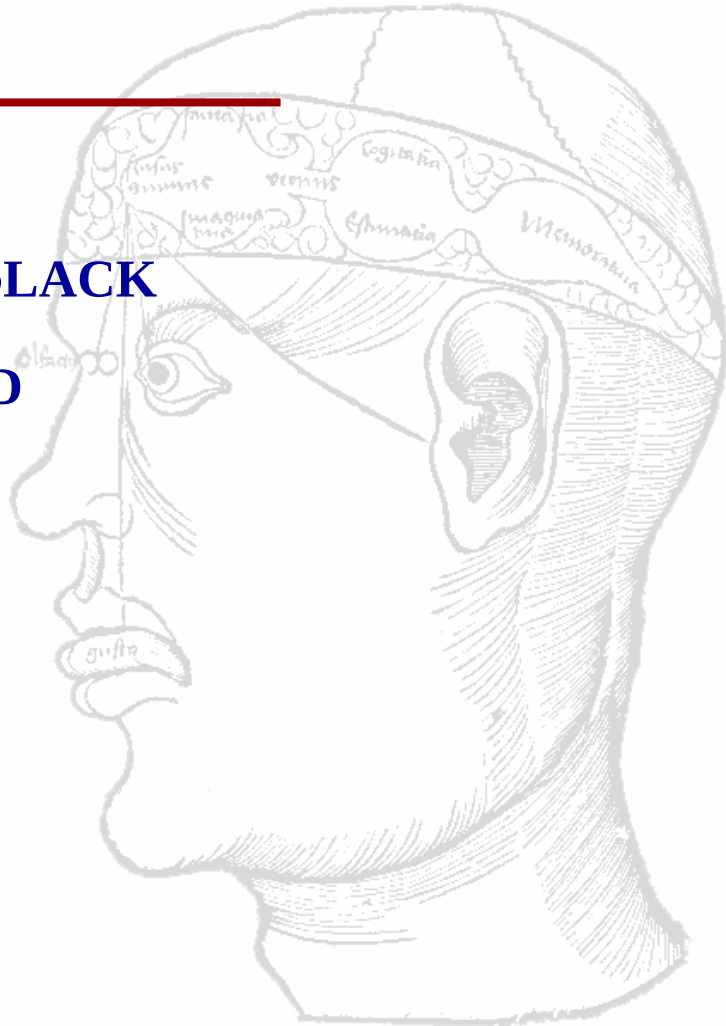
Topics in Brain Computer Interfaces
CS295-7

Professor: **MICHAEL BLACK**

TA: **FRANK WOOD**

Spring 2005



Structure of Course

- Combination of
  - Formal lectures to present basic material
  - Readings from the recent literature
  - Hands-on experience
    - Use real data and decode neural signals.
  - Guest lectures

- Grading
  - Paper reviews and class participation 10%
  - Three homework assignments; total 60%
  - Project 30%

Prerequisites

- Linear algebra (vector spaces, matrices, eigenvalues and eigenvectors)
- Probability (basic laws of probability, normal distribution, sampling,…)
- Calculus (partial derivatives, integration)

This is a graduate seminar and we will move quickly. There will be basic review of mathematical material and links to external resources will be provided.

Course Materials

- There is no textbook.
- All readings will be posted to the web page – this is the main source of information – check it regularly as it will change.

http://www.cs.brown.edu/courses/cs295-7/home.html

- Background reading – see web page.
- Assignments are in Matlab – learn by doing, trying experimenting.
- Data that is at the current state of the art.

Administration

- Michael Black
  - CIT 521
  - Hours:
    - Thursday 2:00-3:00pm
    - Friday 1:00-2:00pm.
- Frank Wood (TA)
  - CIT 357
  - Hours: Monday 4:00-6:00pm

- Do you want a newsgroup or mailing list?

Collaboration Policy

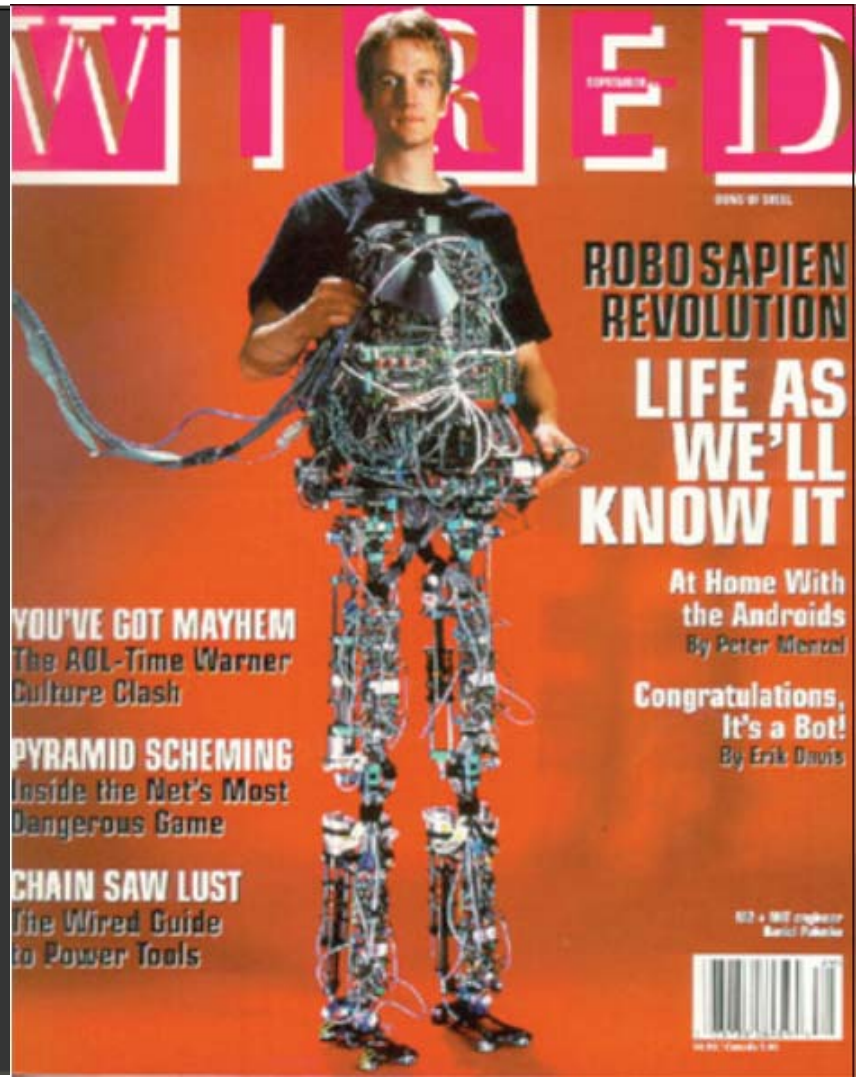
- This is a graduate level seminar class and we will all learn more by interacting inside and outside of class to discuss the material and learn from each other.
- Assignments and the project, however, are to be done on your own. You may ask people for help with general concepts and Matlab programming but your work (including your Matlab code) must be your own.
- If you are ever unsure about what are appropriate interactions, please discuss the situation with me.
- For your reference: Brown's Academic Code.

The “Bionic Man”

Fun fact:

The “Six Million Dollar Man” would cost $22,727,272.72 in 2004 US dollars.


Science
8 February 2002
Vol. 295 No. 5557
Pages 917–1180 $9
BODYBUILDING:
The Bionic Human
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE


WIRED
ROBO SAPIEN REVOLUTION
LIFE AS WE'LL KNOW IT
At Home With the Androids
By Peter Merzel
Congratulations, It's a Bot!
By Erik Davis
YOU'VE GOT MAYHEM
The AOL-Time Warner Culture Clash
PYRAMID SCHEMING
Inside the Net's Most Dangerous Game
CHAIN SAW LUST
The Wired Guide to Power Tools

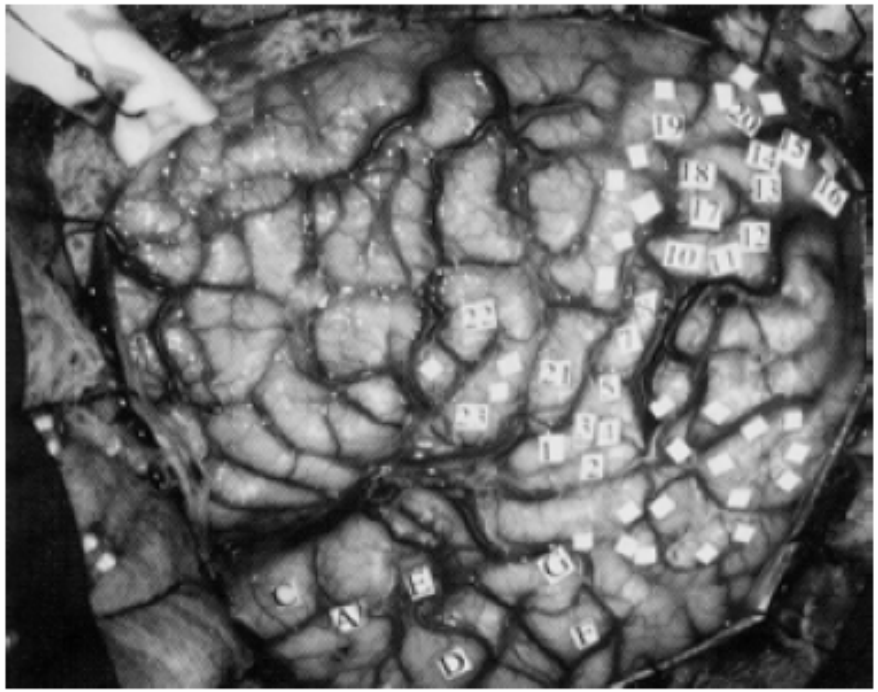
Jose Delgado 1965

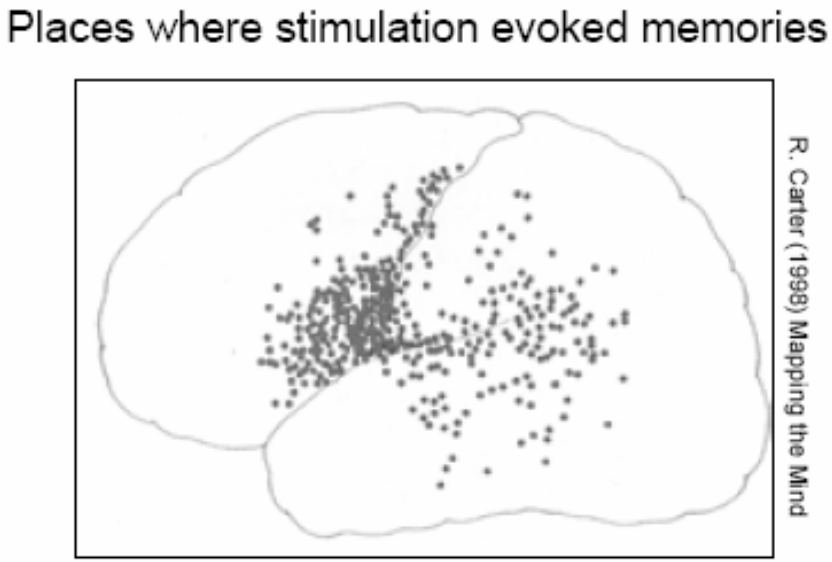
Afternoon sunlight poured over the high wooden barriers into the ring, as the brave bull bore down on the unarmed "matador" – a scientist who had never before faced a fighting bull. But the charging animals horns never reached the man behind the red cape. Moments before that could happen, Dr Jose **Delgado, the scientist, pressed a button on a small radio transmitter in his hand and the bull braked to a halt**. Then he pressed another button on the transmitter, and the bull obediently turned to the right and trotted away.

The bull was obeying commands in his brain that were being called forth by electrical stimulation – by the radio signals – of certain regions in which the fine wires had been painlessly implanted the day before.

Modified Behaviour in Animals the Subject of Brain Study: By John A. Osmundsen New York Times May 17, 1965.

Stimulating Humans



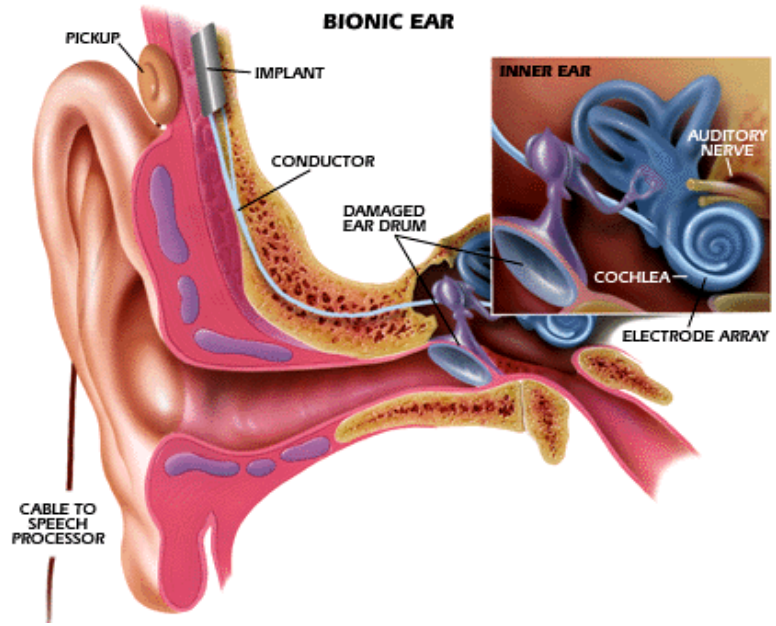


Wilder Penfield, 1950's.

"It was like standing in the doorway at [my] high school. I heard my mother talking on the phone, telling my aunt to come over that night." – 21 year old male.

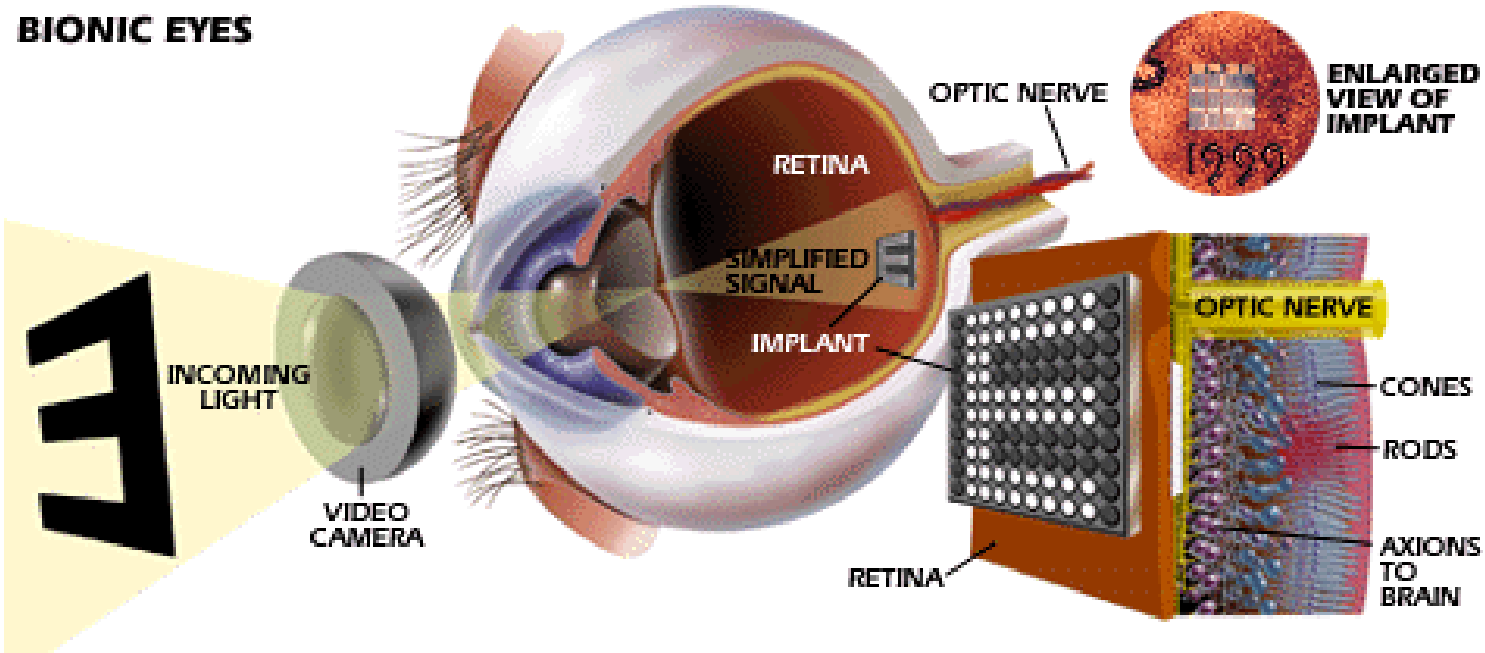
Penfield and Perot, Brain 86:595, 1963

Auditory Prostheses

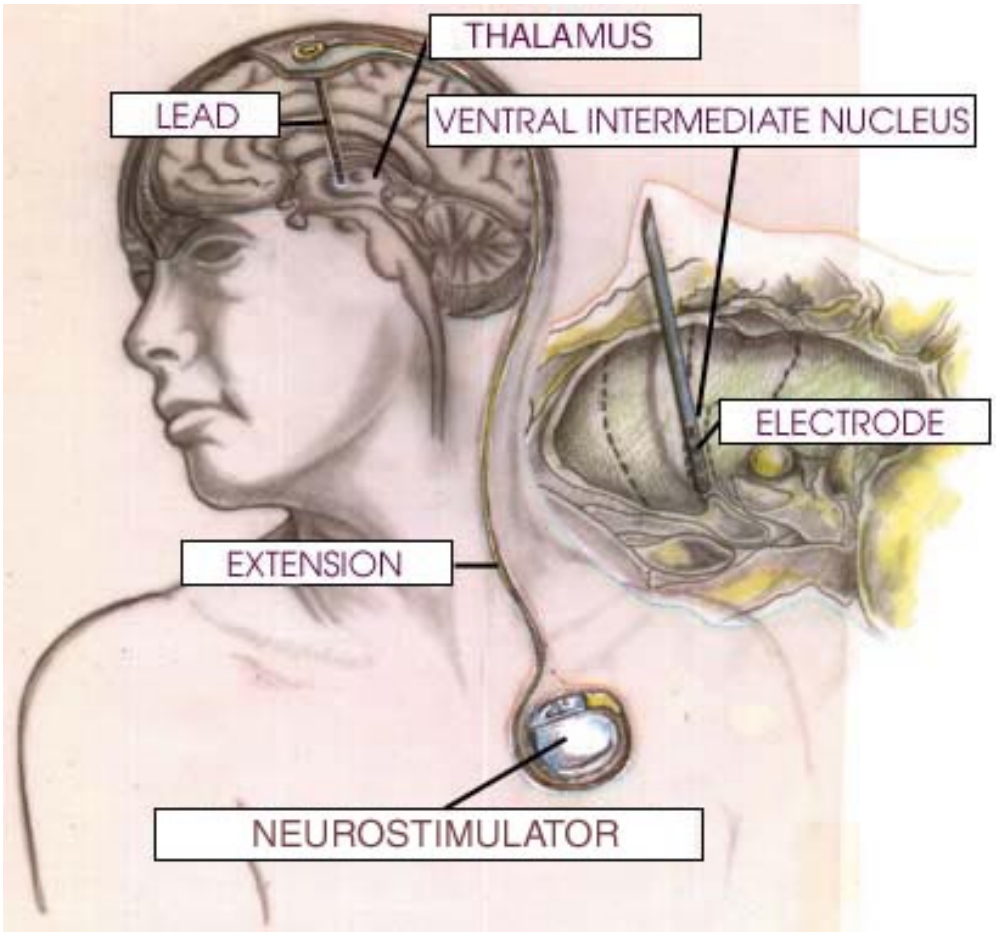


Cochlear implants.

Visual Prostheses



Deep Brain Stimulation



Neurostimulator
Control Magnet
Model 7452

Parkinson's

Epilepsy

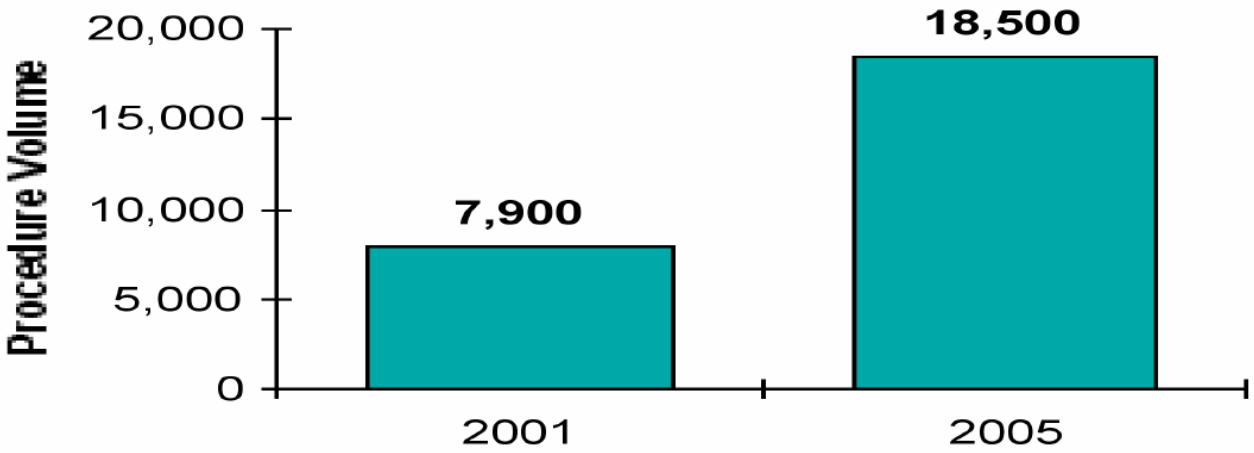
Obsessive-Compulsive Disorder.

...

Medtronic Inc.

Human Brain Impants

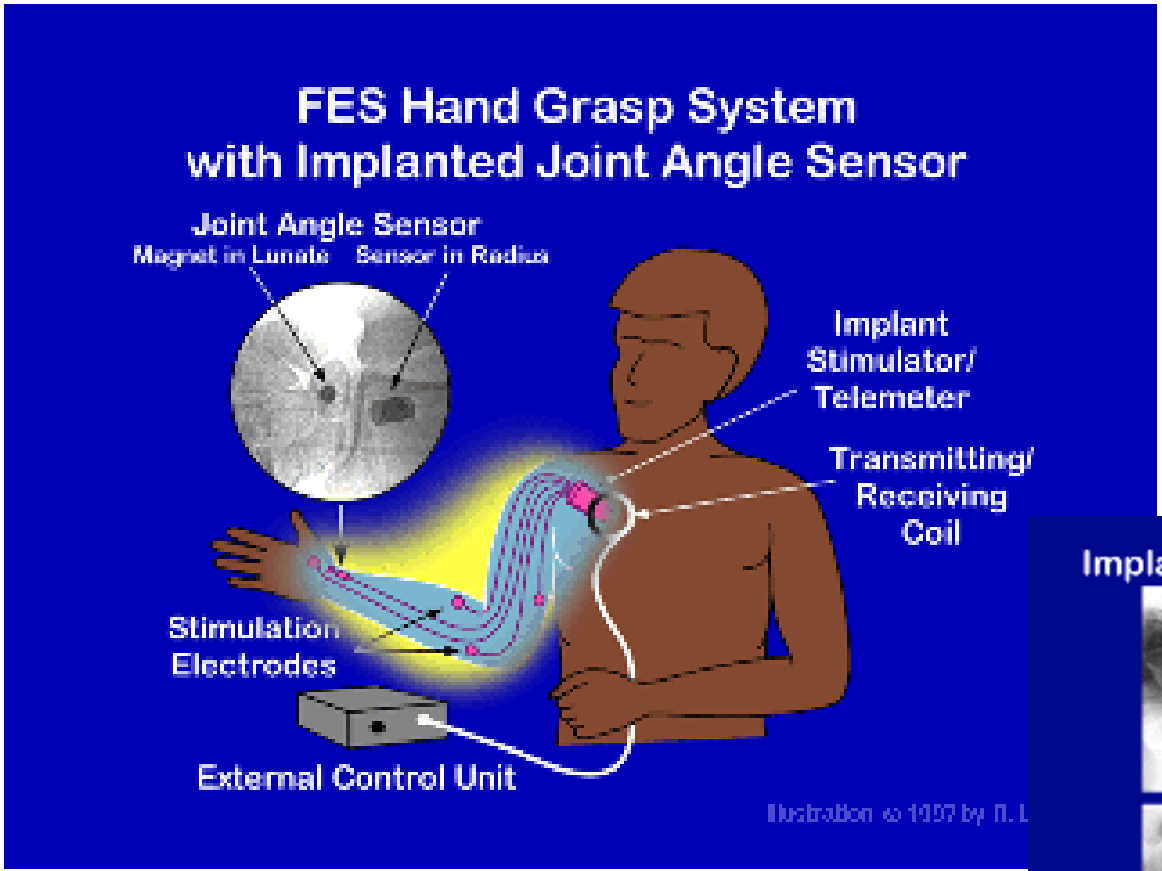
Worldwide DBS Implants[1]

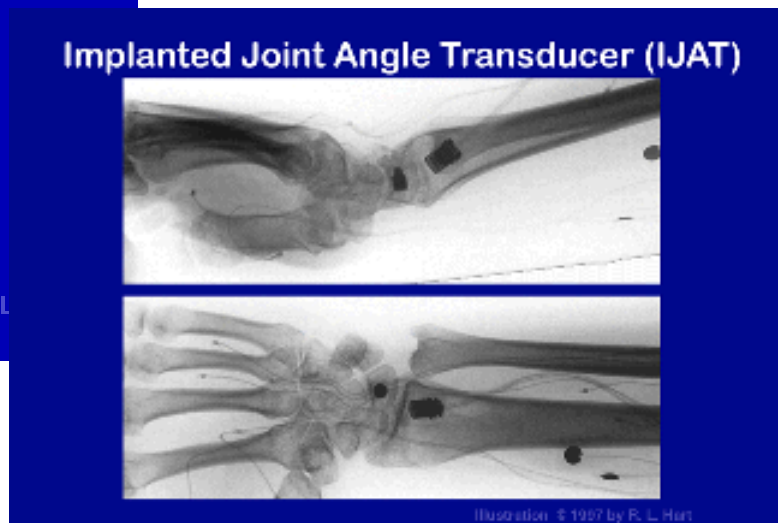


- Analysts estimate a 24% growth rate in the DBS market over the next four years.[2]
- Medtronic's Activa® DBS implant was originally approved in 2000 for essential tremor, and most recently in January 2002 for Parkinson's Disease.
- Sales of Activa® for DBS have more than doubled between Q1Y01 and Q1Y02.[3]

Source: Cyberkinetics

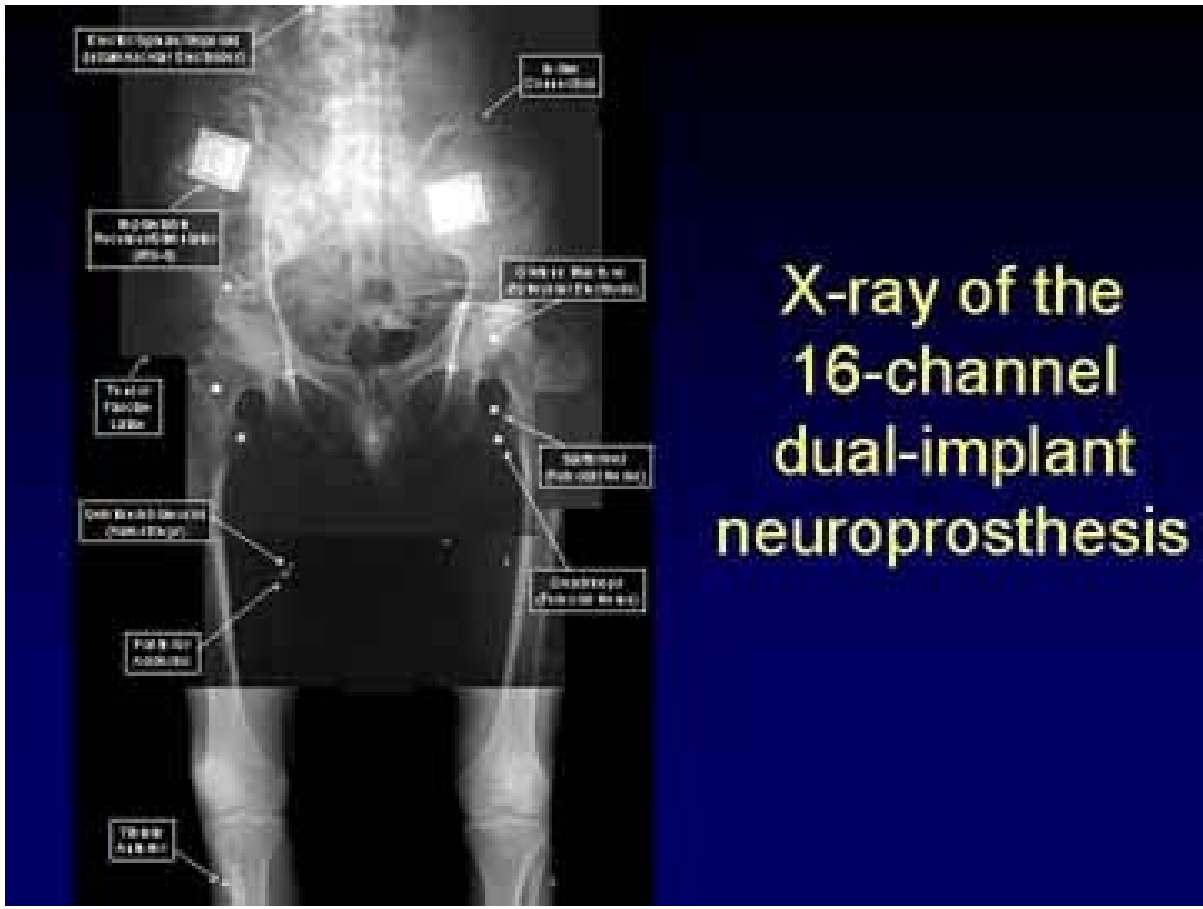
Functional Electrical Stimulation





Case Western, Biomedical Engineering

FES Implanted Electrodes



Case Western, Biomedical Engineering

Human Neural Prostheses

Simple test interfaces:

* Paint program
* TV controls
* Pong
* Dummy mail program.
* robot arm and gripper control.

Cyberkinetics INC.

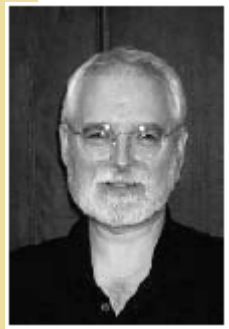
Neurotechnology at Brown

Engineering/Physics

Arto Nurmikko

Neuroscience

Donoghue Lab

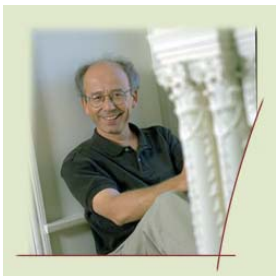


Spinoff company:

Cyberkinetics INC.

Applied Mathematics

Elie Bienenstock



Computer Science

Michael Black

Neurosurgery

Gerhard Friehs

Neural Motor Prosthesis

cerebral palsy

cerebellar disorders

locked-in syndrome

other stroke

spinal cord injury

spinal muscular atrophies

ALS

muscular dystrophy

limb loss

multiple sclerosis

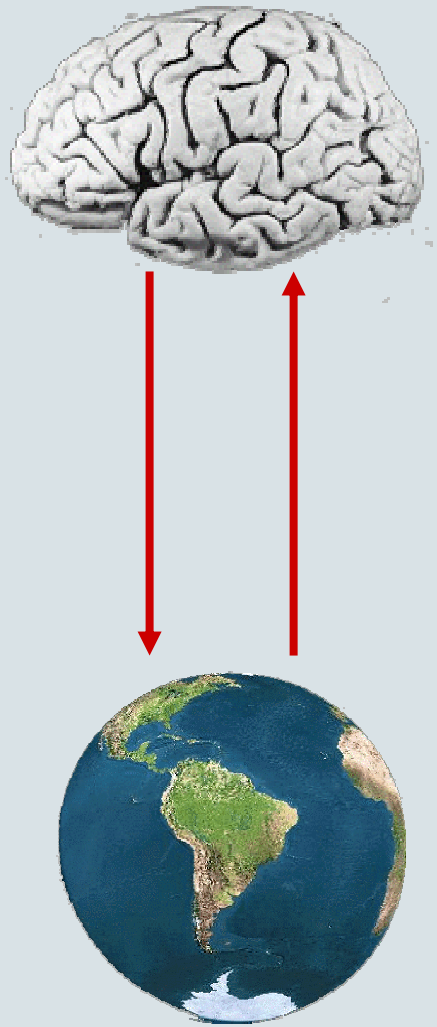
veterans

* Many neurological disorders disrupt the ability to *move* or *communicate*, but leave *cognition* intact.

* Spinal cord injury:
  ~ 200,000 cases in the USA
  11,000 new cases/year
  mostly young

* Amyotrophic Lateral Sclerosis (ALS or Lou Gehrig's disease)
  20,000 cases
  5,000 new cases/year

* Current assistive technology is limited



Neural Motor Prosthesis

cerebral palsy

cerebellar disorders

locked-in syndrome

other stroke

spinal cord injury

spinal muscular atrophies

ALS

muscular dystrophy

limb loss

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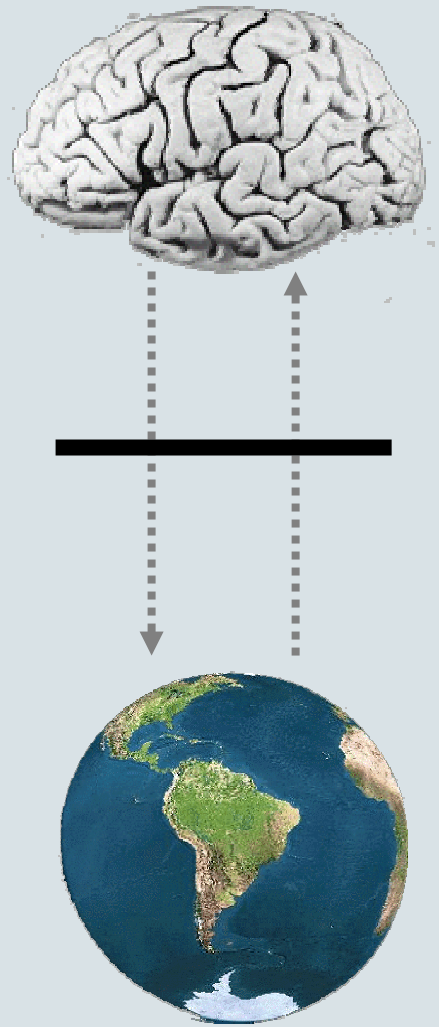

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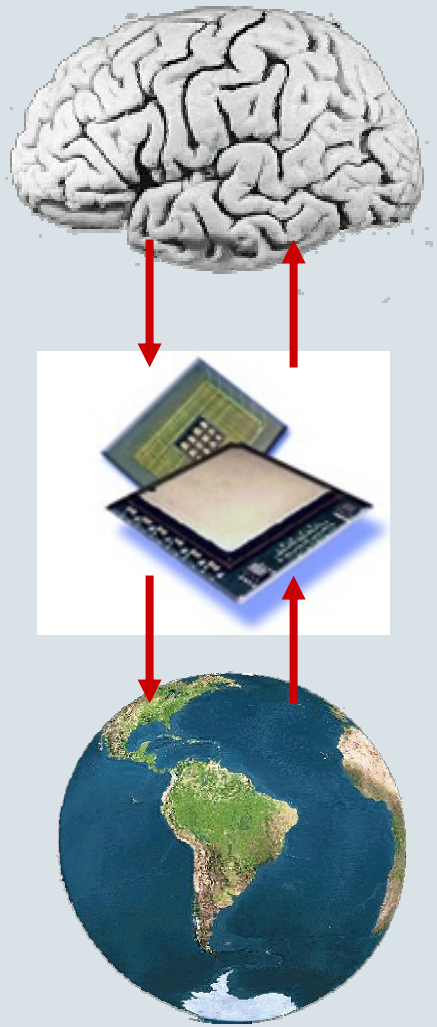
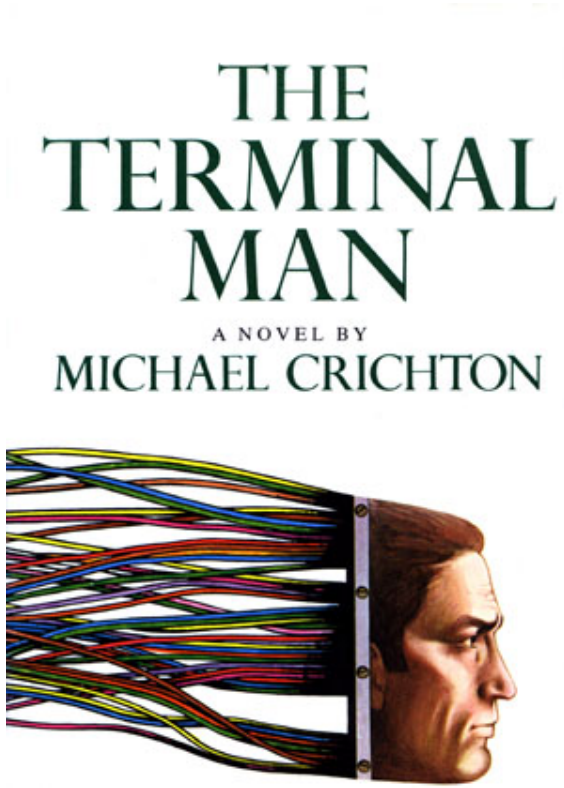


Human Neural Prostheses

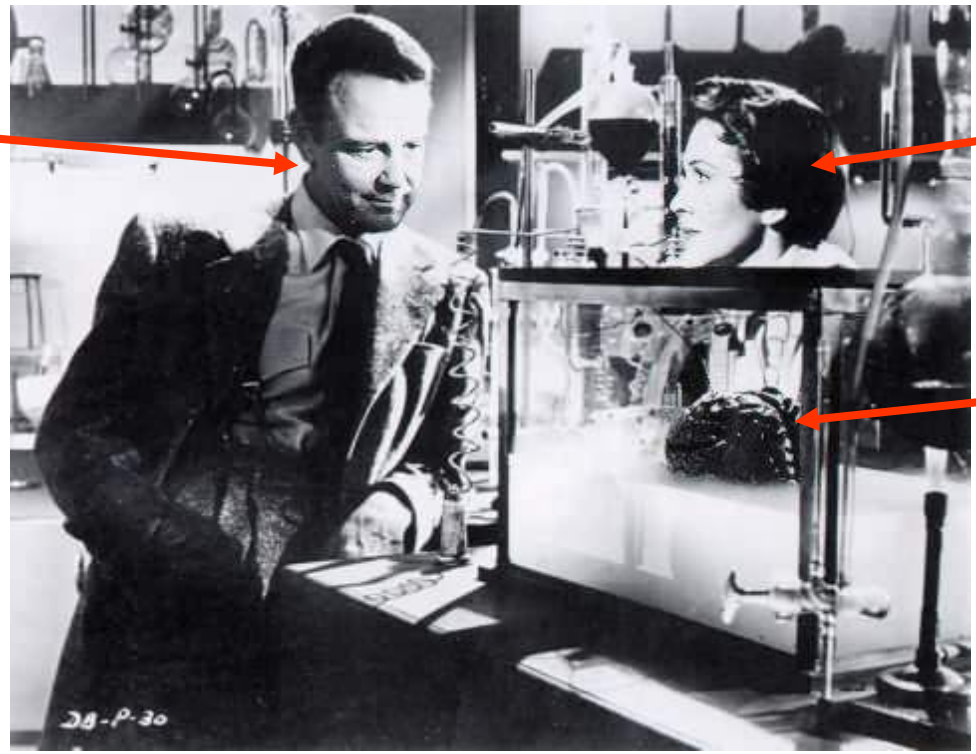
"One might think of the computer in this case as a prosthetic device. Just as a man who has his arm amputated can receive a mechanical equivalent of the lost arm, so a brain-damaged man can receive a mechanical aid to overcome the effects of brain damage. … It makes the computer a high-class wooden leg."

Michael Crichton,
The Terminal Man, 1972



From Science Fiction to Practice

"Mad" scientist



Fun fact:
Nancy Davis
(Reagan)

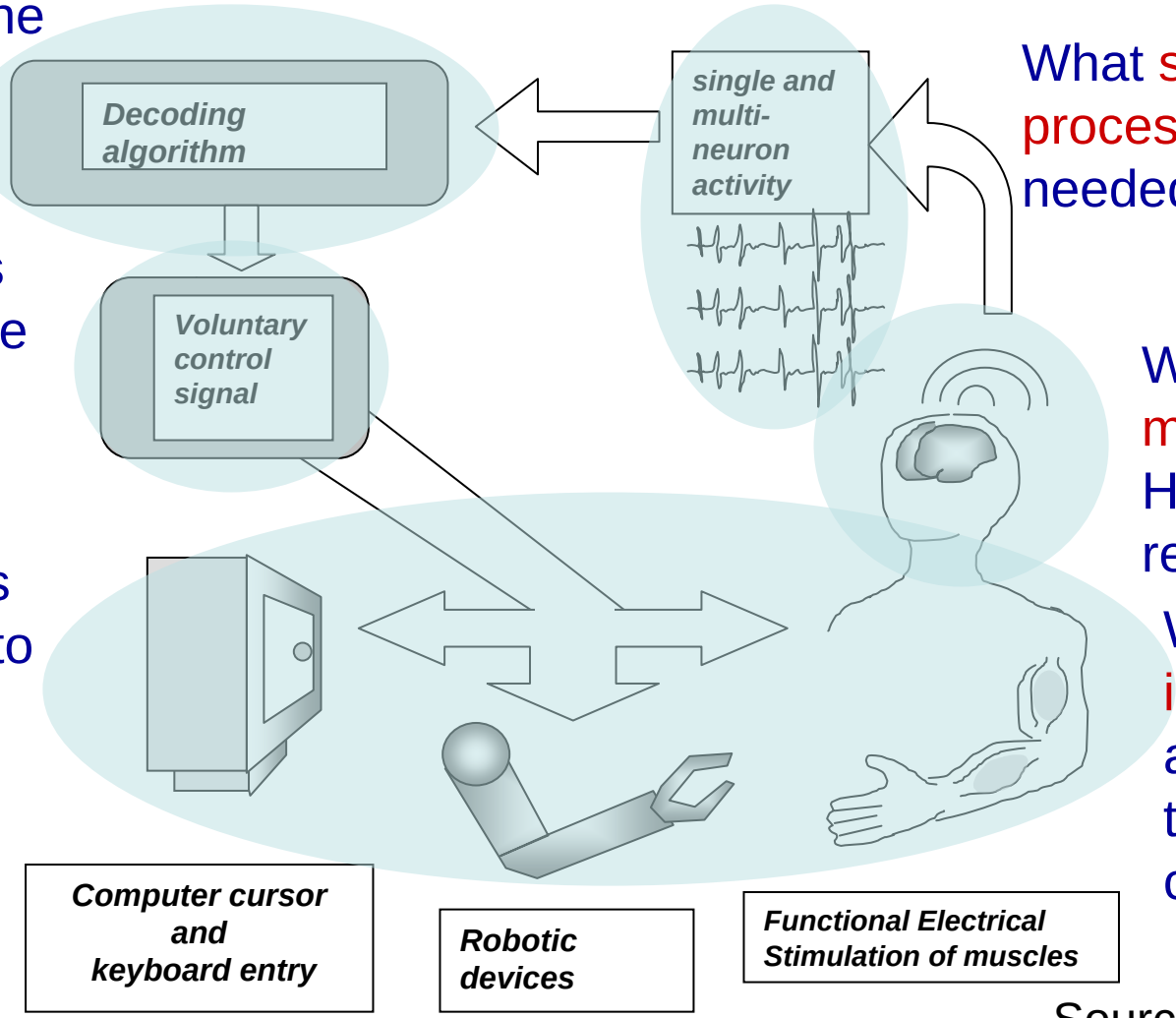
Brain

*"If I could find … a **code** which **translates** the relation between the reading of the encephalograph and the mental image …the brain could **communicate** with me."*

"Donovan's Brain", Curt Siodmak, 1942

What this Course Covers

What do the signals encode?
What algorithms can we use to decode them?
Can we exploit this decoding to control devices?



What signal processing is needed?

What can we measure?
How do we record it?

What kinds of interfaces and assistive technologies can we build?

Source: Mijail Serruya

Building Bionic Humans

To get there we will cover

- Basics of neurons
- Models of neural coding
- Decoding methods using
  - Linear regression
  - Bayesian inference
  - Artificial neural networks
- Machine learning methods
  - Dimensionality reduction (PCA/SVD)
  - Support vector machines
- Inference methods
  - Particle filtering, Monte Carlo methods.
  - Hidden Markov models (maybe)
- Ethical considerations and technology directions