Biomedical Signal Processing and Computation

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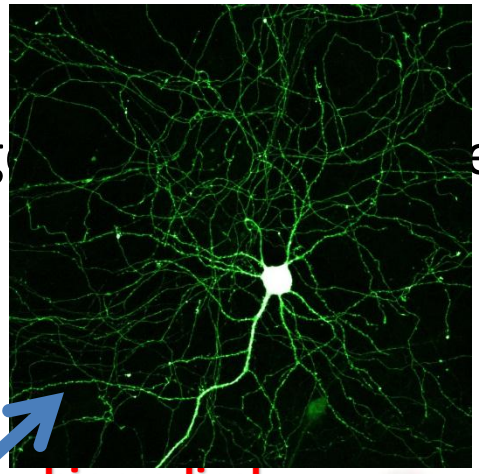
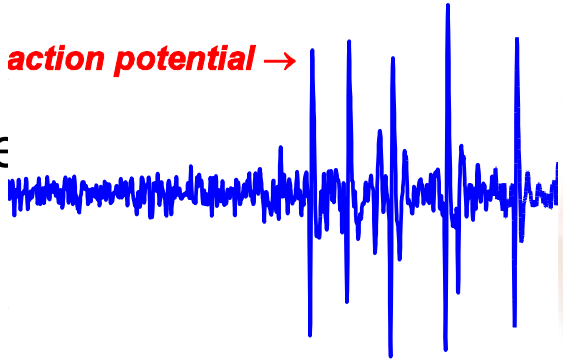
Department of Electrical Engineering and Computer Science (by courtesy)
The Henry Samueli School of Engineering
University of California Irvine

BME1 Guest Lecture
October 13, 2011

Biomedical signals are g e





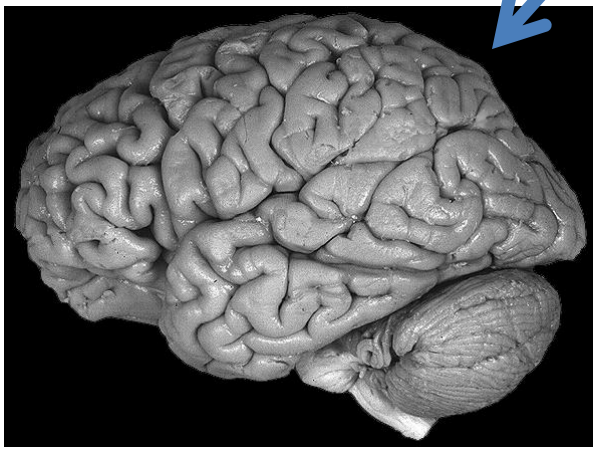
environmental/external variable(s)

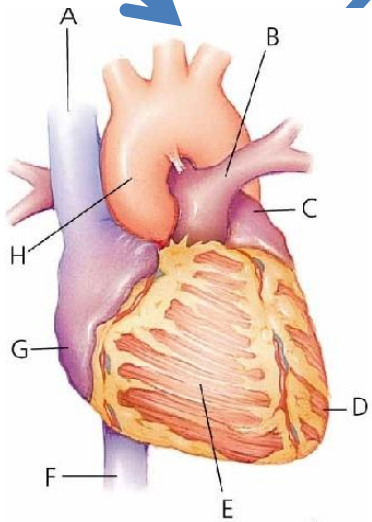
biomedical system

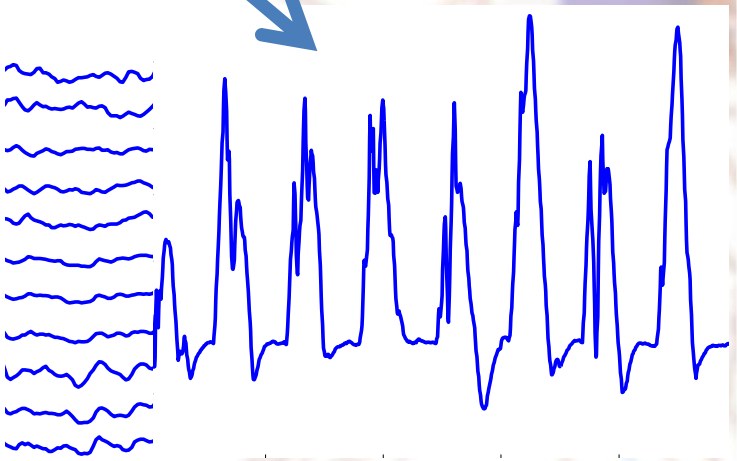
biomedical variable

sensor (measuring device)

biomedical signal







Properties of Biomedical Systems and Signals

Biomedical systems are:

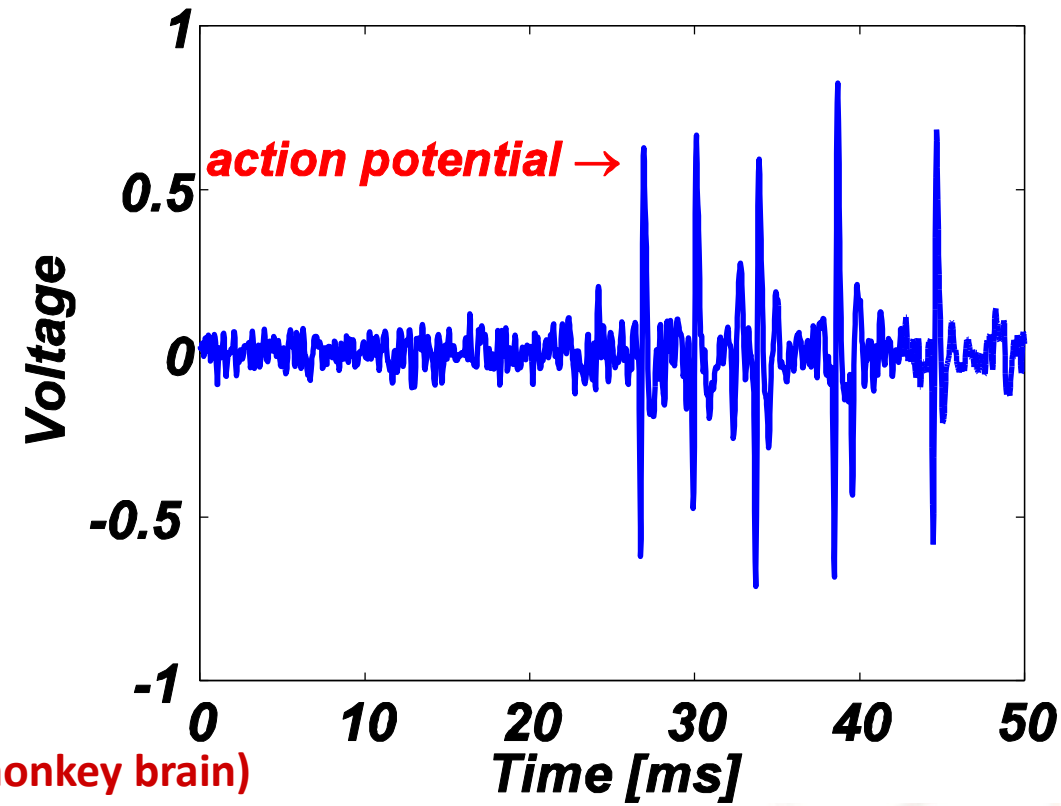
- dynamic
- nonlinear
- stochastic
- non-stationary (time varying)
- spatially distributed
- most have multiple signaling pathways
- some of them are oscillatory

Consequently, biomedical signals are:

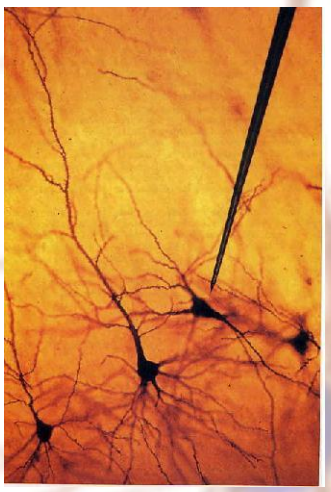
- of limited bandwidth with noise that is colored
- complex (attractors, chaos, fractals)
- noisy
- non-stationary
- high dimensional
- redundant (spatial correlations)
- some of them are periodic

Example 1

Neuronal action potentials



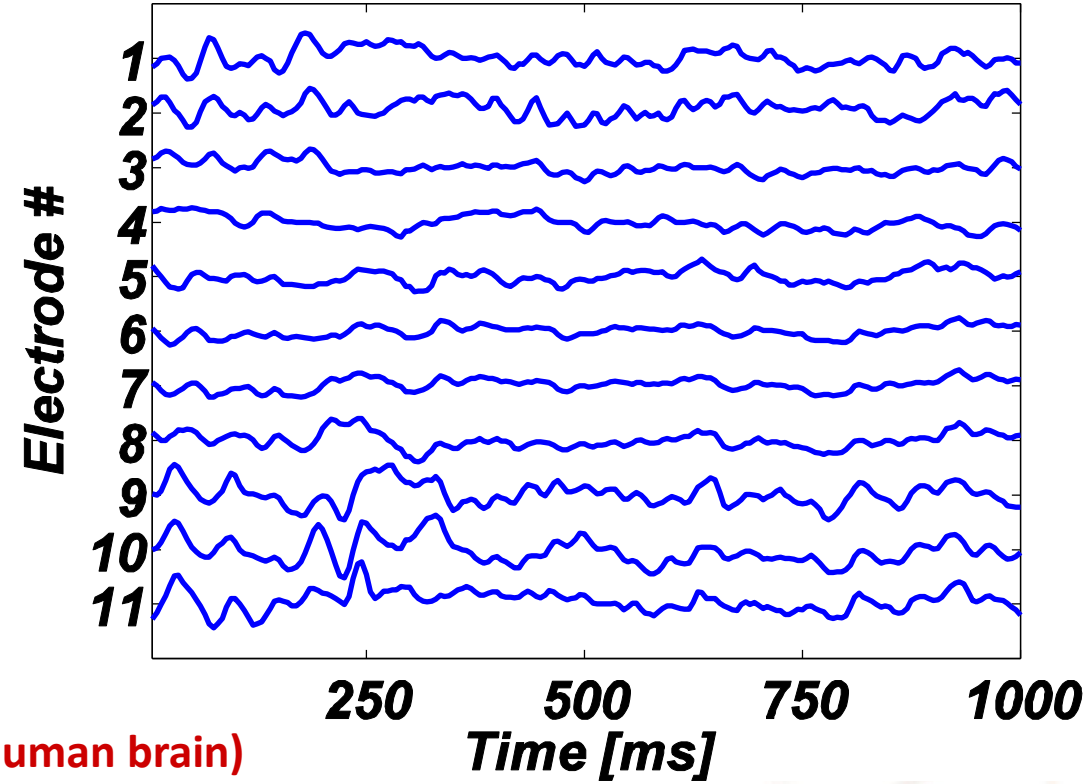
(data from monkey brain)



Temporal resolution: <1ms
Spatial resolution: ~20 µm

Example 2

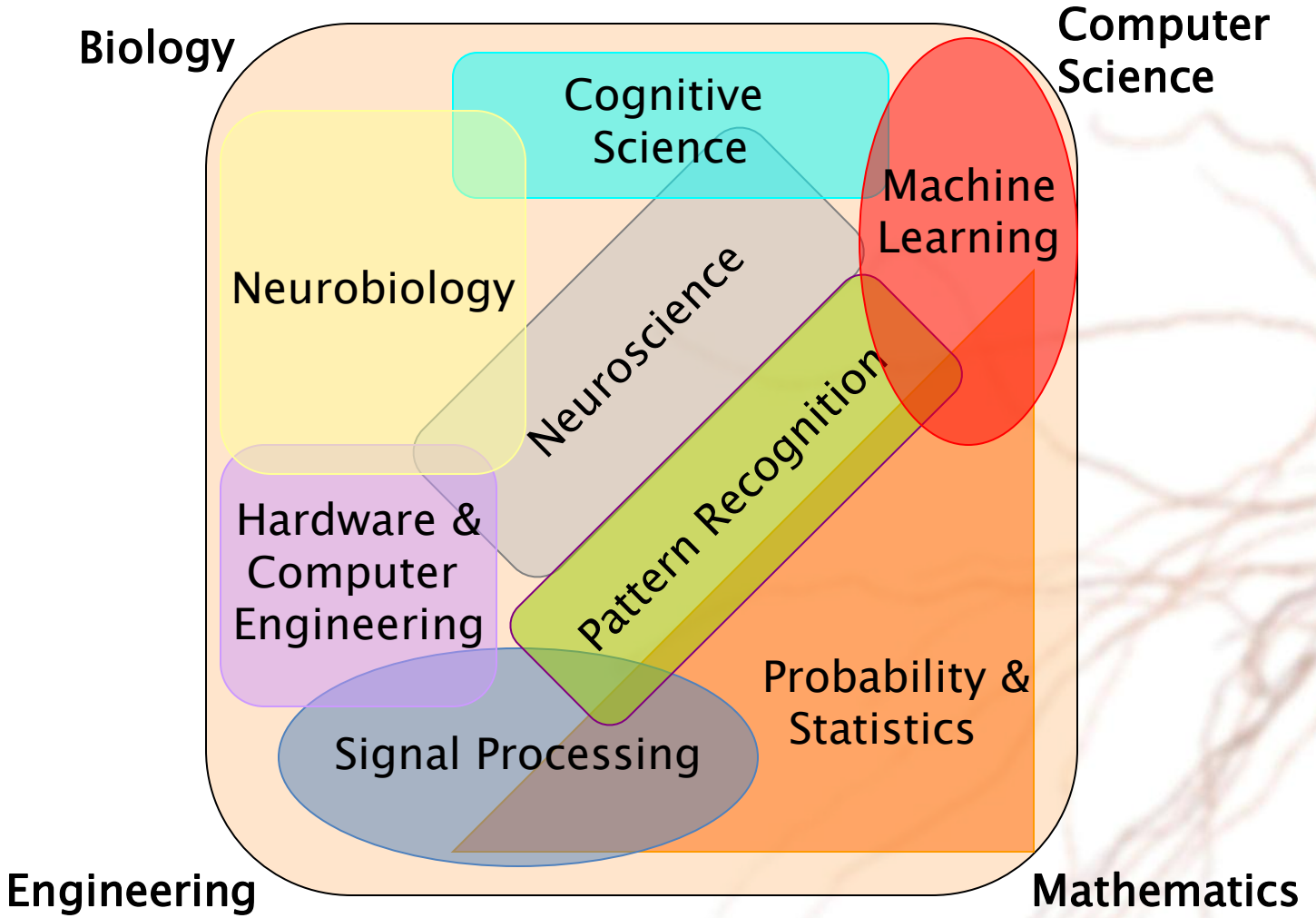
Electroencephalogram (EEG)



(data from human brain)

Temporal resolution: ~10 ms
Spatial resolution: ~2 cm

Research in this area is highly cross-disciplinary!



Investigator and the Lab

Investigator: Zoran Nenadic

- DSc in Systems Science and Mathematics, Washington University, St. Louis, MO
- Postdoctoral Training, California Institute of Technology, Pasadena CA

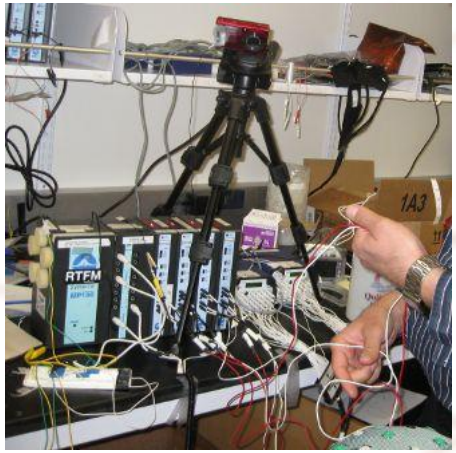
Graduate students (PhD):

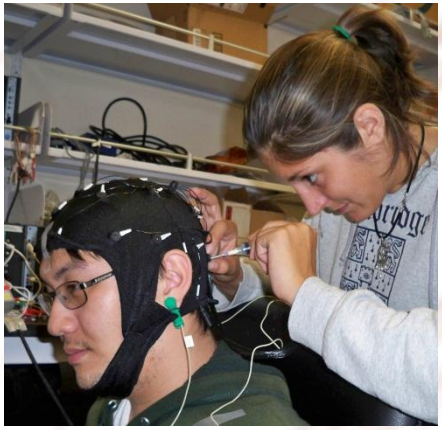
- Christine E. King (BME)
- Chang Won Lee (BME)
- Po T. Wang (BME)
- Victor Quintanar-Zilinskas (MCSB)

Collaborators (UCI):

- An H. Do, MD (Neurology)
- Xiangmin Xu, PhD (Anatomy&Neurobiology)
- A. Lee Swidlehurst, PhD (EECS)
- David J. Reinkensmeyer, PhD (MAE)
- Steven C. Cramer, MD (Neurology)

3474-3476 Natural Sciences II
(~1,100 sq. ft.)





Long-term research question: How does the brain process information?

Short-term research problem(s):

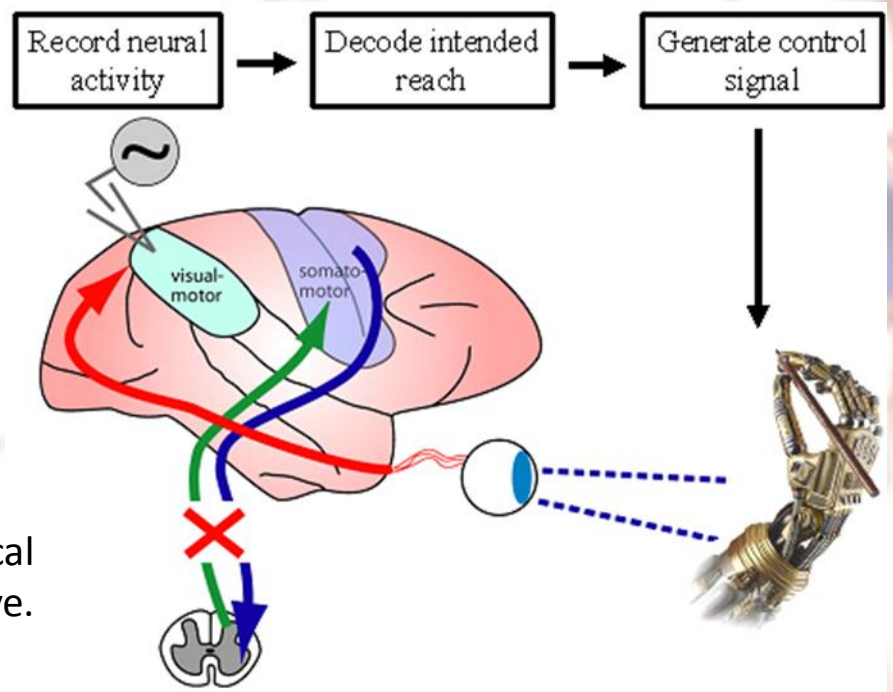
- If we measure brain activity, what inferences can we make about the underlying cognitive processes?
- Can we develop analytical and computational tools to efficiently analyze measurements without making unnecessary or unsupported assumptions? Can this lead to the development of new theories?
- Can we translate this into something useful?

Major project: Brain-computer interface (BCI)

Background:

"We will be engaged in the development of principles and techniques by which information from the nervous system can be used to control external devices such as prosthetic devices, communications equipment, teleoperators [· · ·] and ultimately perhaps even computers."

Karl Frank, Founder of the Laboratory of Neural Control at the National Institute of Neurological Disorders and Stroke, [1].



[1] K. Frank. Some approaches to the technical problem of chronic excitation of peripheral nerve. *Ann Otol Rhinol Laryngol*, 77(4):761–771, 1968.

BCI Featured on “60 Minutes”

BCI Research at UC Irvine

P300 Speller

P300 is a brain wave that is generated when a person sees a "rare" event. It is visible roughly 300 milliseconds after seeing the event.

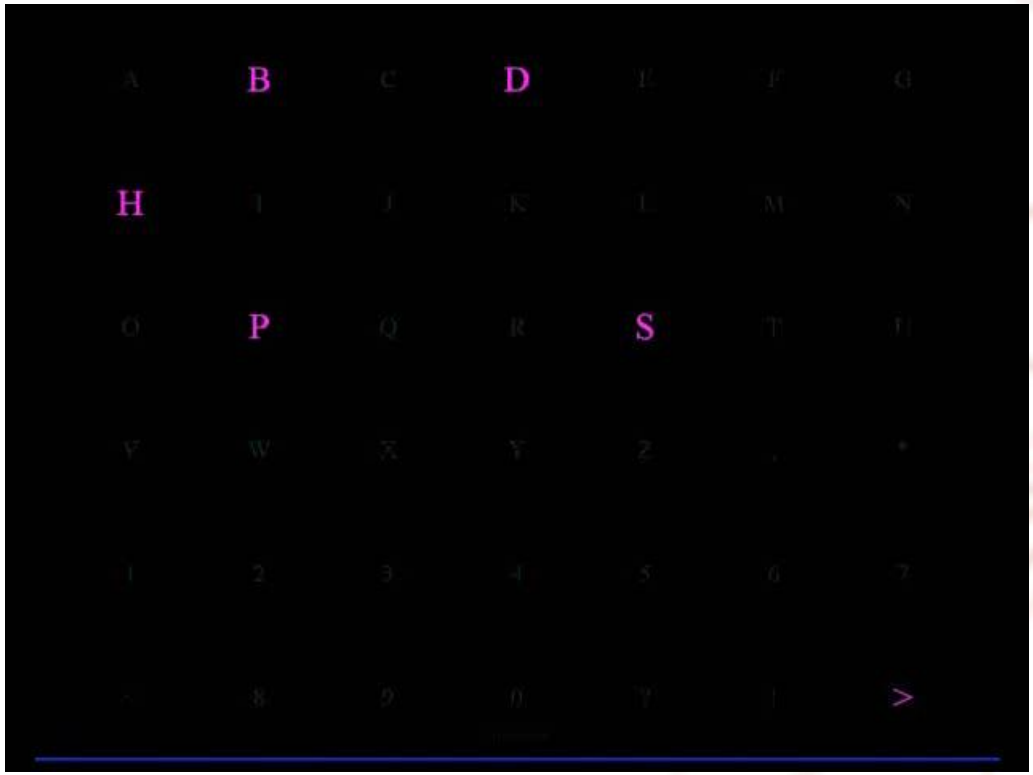
UCIRVINE

CBMSPC

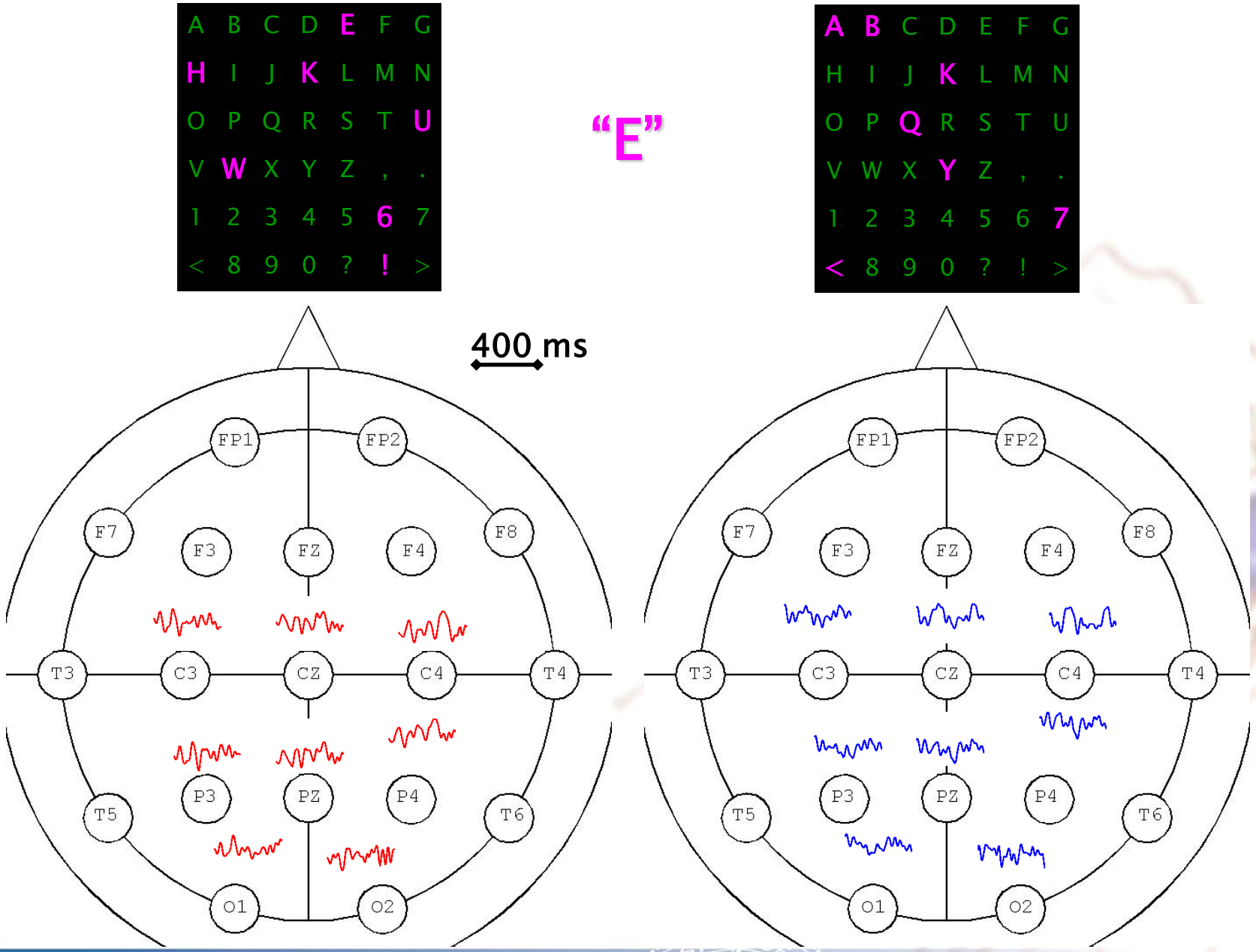
Center for BioMedical Signal Processing and Computation

2nd Generation P300 Speller

- Practical error-free typing rates as high as 12.75 characters/min.
- Error-free information transfer rates >3 bit/sec.
- These are 3 times higher than the performance of similar systems in the field.

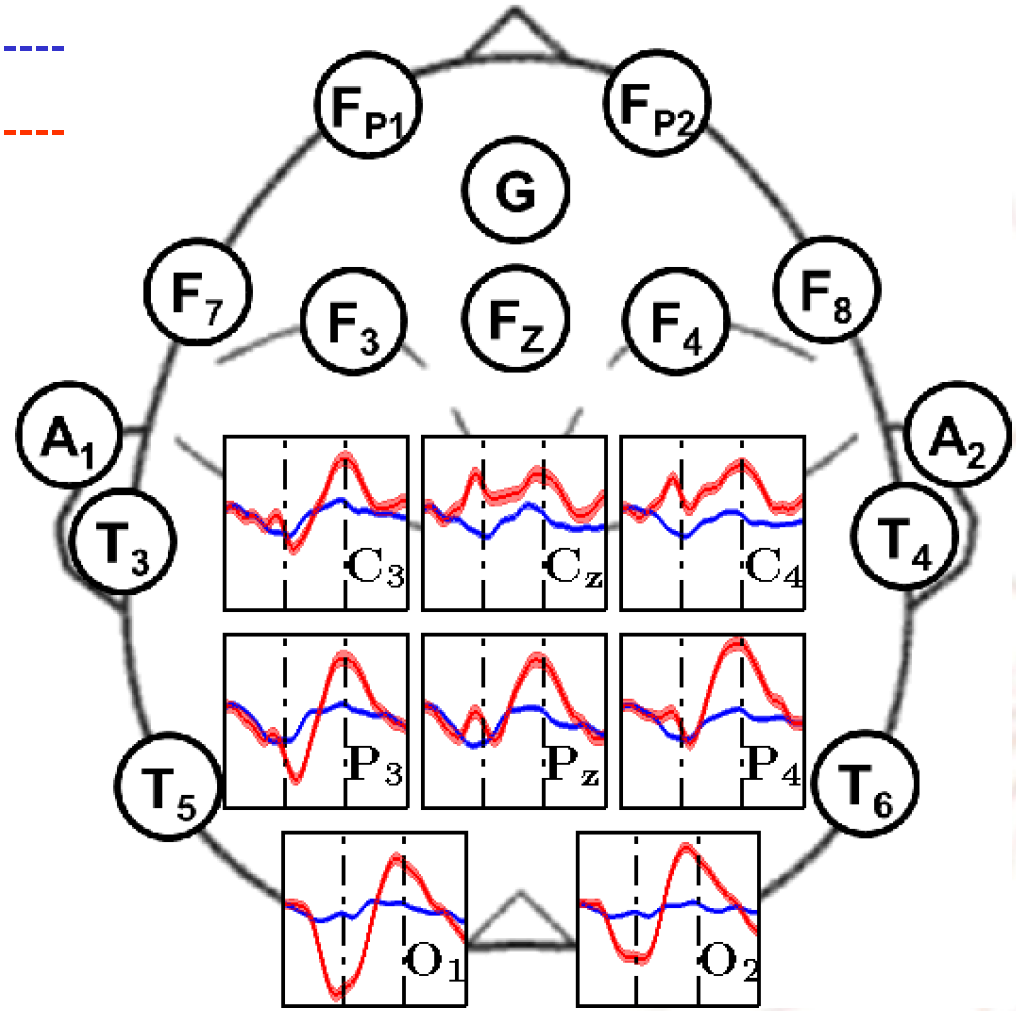


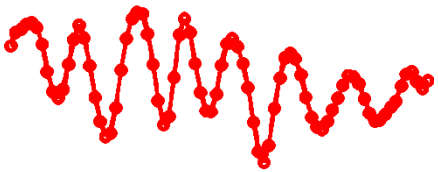
P.T. Wang, C.E. King, A.H. Do and **Z. Nenadic**, Pushing the communication speed limit of a noninvasive BCI speller. (submitted)


A B C D E F G
H I J K L M N
O P Q R S T U
V W X Y Z , .
1 2 3 4 5 6 7
< 8 9 0 ? ! >
"E"
A B C D E F G
H I J K L M N
O P Q R S T U
V W X Y Z , .
1 2 3 4 5 6 7
< 8 9 0 ? ! >
400 ms
FP1
FP2
F7
F3
FZ
F4
F8
T3
C3
CZ
C4
T4
T5
P3
PZ
P4
T6
O1
O2

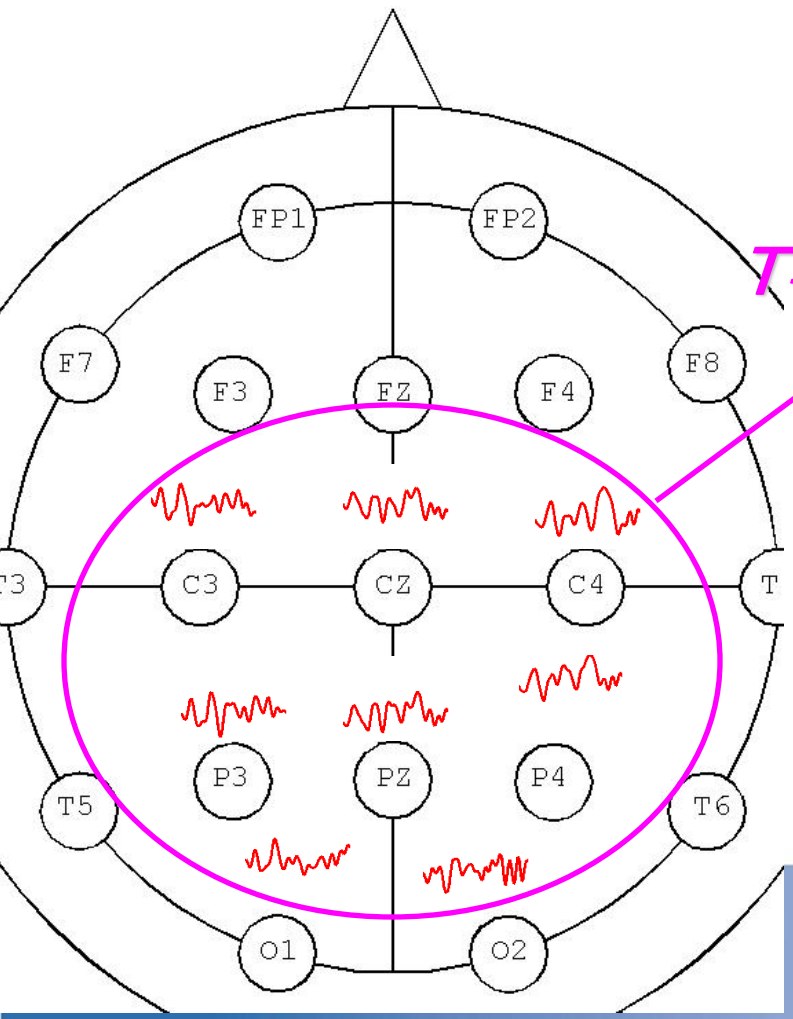
Non-oddball ----

Oddball ----

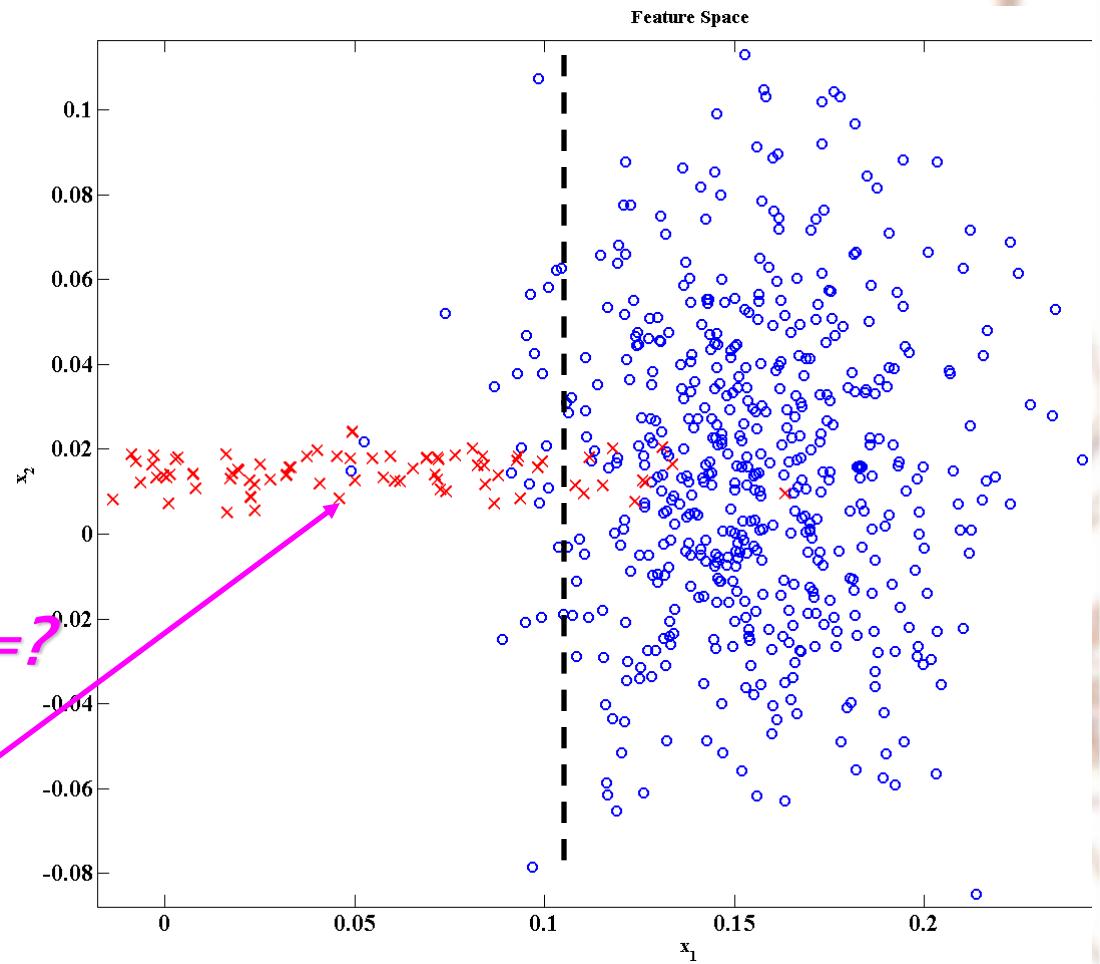




80 points
(numbers)



T=?



2 numbers

640 numbers

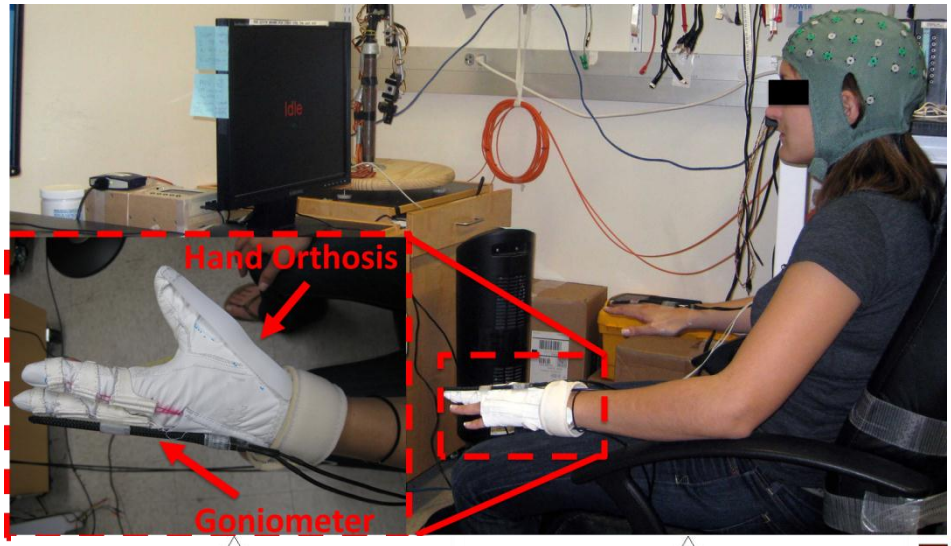
BCI as a Prosthetic Technology for Spinal Cord Injured (SCI)

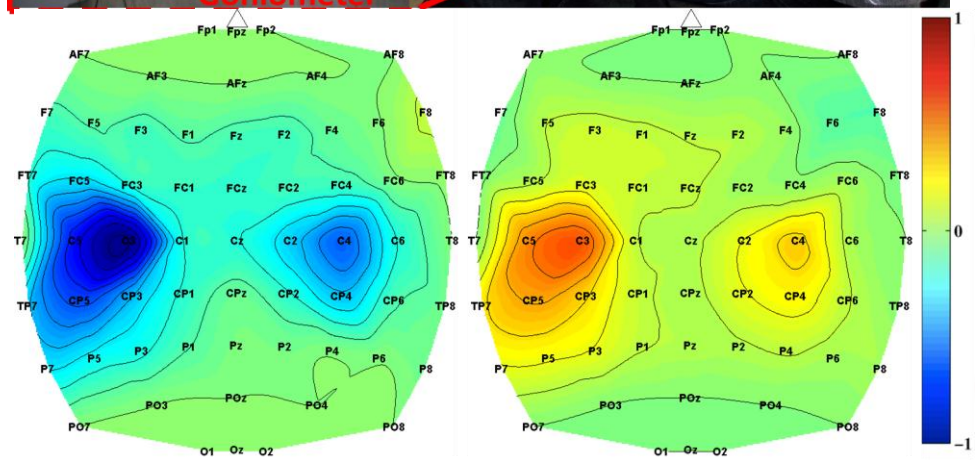
Subject with paraplegia (T8, ASIA B), 11 years post-injury uses BCI to control the linear ambulation of a virtual reality avatar.

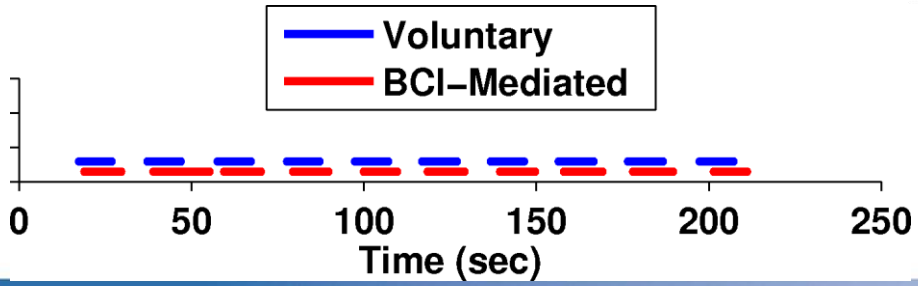
P.T. Wang, C. King, L.A. Chui, **Z. Nenadic**, A. Do, BCI controlled walking simulator for a BCI driven FES device, *In Proc. of RESNA Annual Conference*, Las Vegas, Nevada, June 26-30, 2010.

BCI Hand Orthosis for Neurorehabilitation after Stroke

C.E. King, P.T. Wang, M. Mizuta, D. Reinkensmeyer, A.H. Do, S. Moromugi, and **Z. Nenadic**, Noninvasive brain-computer interface driven hand orthosis, *in Proc. of the 33rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, 5786-5789, 2011.







Summary of Experiment:

- Subject instructed by visual cues
- Upon the cue, the subject clenches the right fist
- EEG measured by the EEG cap
- EEG data analyzed by BCI computer
- BCI computer drives the orthosis mounted on the left hand
- Hand movements measured by custom-made goniometers [2]

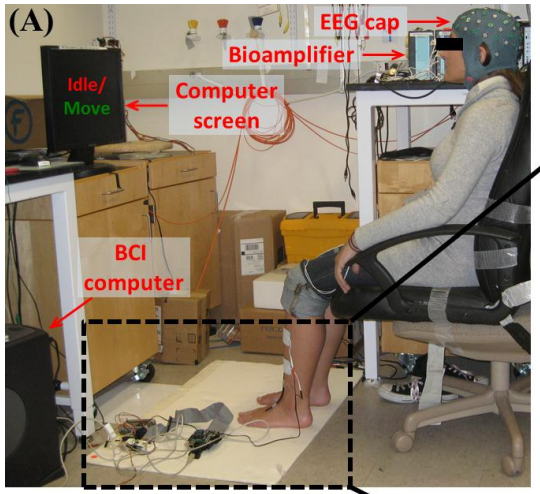
Lag (sec) (n=5)	ρ	Omission	False Alarm
2.24 (0.20)	0.78 (0.06)	0.40 (0.89)	1.8 (1.10)

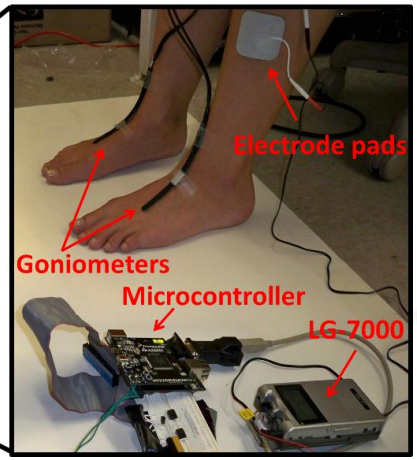
[2] P.T. Wang, C.E. King, A.H. Do, and **Z. Nenadic**, A durable, low-cost electrogoniometer for dynamic measurement of joint trajectories, *Med. Eng. Phys.*, vol. 33(5), 546-552, 2011.

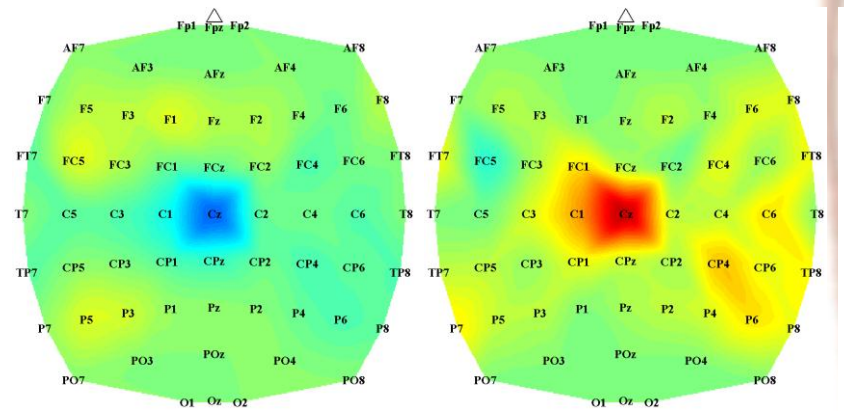
BCI-FES System for Neurorehabilitation after Stroke

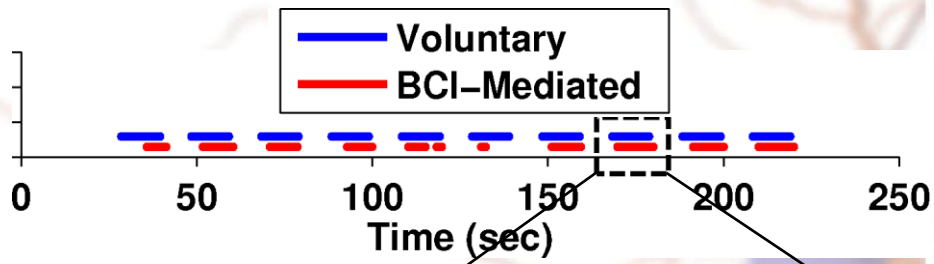
A.H. Do, P.T. Wang, C.E. King, A. Abiri, and **Z. Nenadic**, Brain-computer interface controlled functional electrical stimulation system for ankle movement, *J. NeuroEng. Rehabil.*, vol. 8(49), 2011.

How does it work?

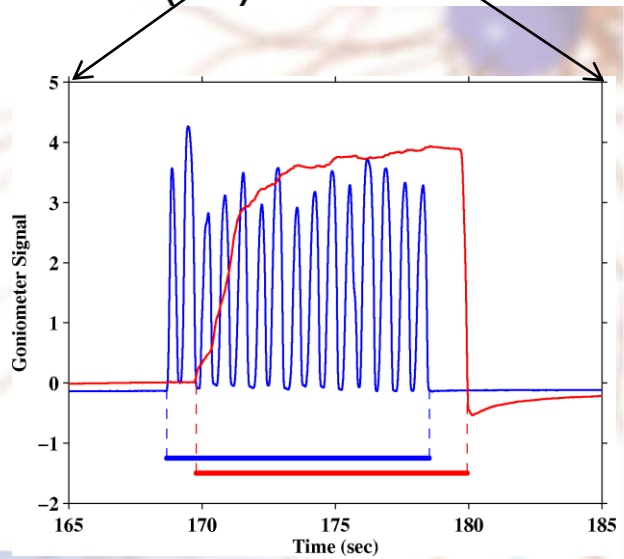








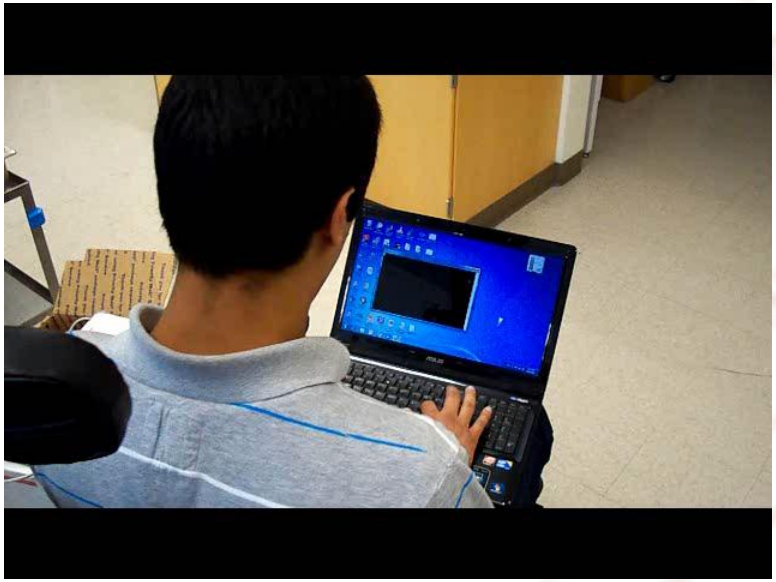
Subject	Lag (sec)	ρ	Omission	False Alarm
1	3.1	0.67	0	0
2	1.4	0.72	0	0
3	2.7	0.59	0	1
4	3.0	0.62	0	0
5	2.9	0.77	0	0



Will it work on stroke subjects?

Future Work:

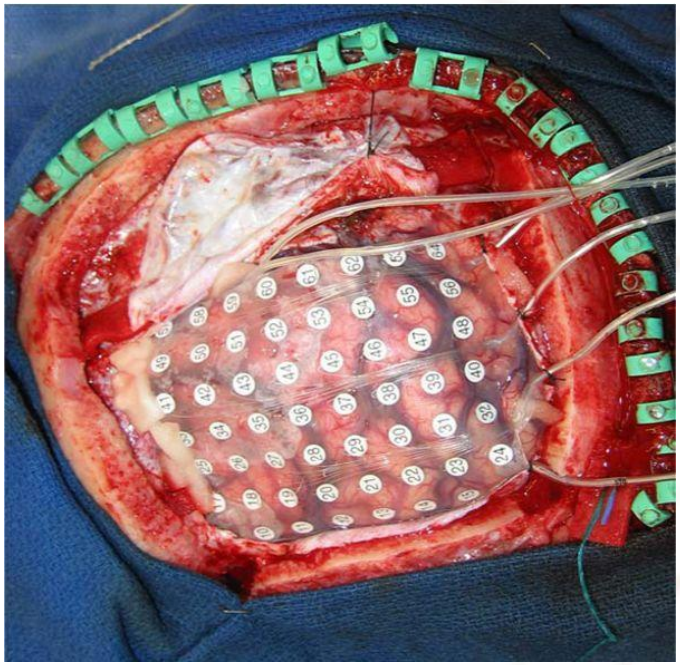
- BCI-driven wheelchair
- BCI-driven functional electrical stimulation device for restoring ambulation in subjects with paraplegia due to SCI
- Invasive BCI control of upper extremity prosthesis



BCI Control of Upper Extremity Prosthesis

6 DOF robotic arm

Electrocorticogram (ECOG) grid



x-ray of ECOG grid

More videos can be found at:

http://cbmspc.eng.uci.edu/
http://www.youtube.com/user/UCIBCI

Funding sources:

Roman Reed Foundation
hope for spinal cord research

ALS Association
Fighting Lou Gehrig's Disease
1985 · 25th Anniversary · 2010

NSF

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DARPA