念力

Real-world Applications of Brain-Computer Interfaces

Sheng-Hsiou (Shawn) Hsu

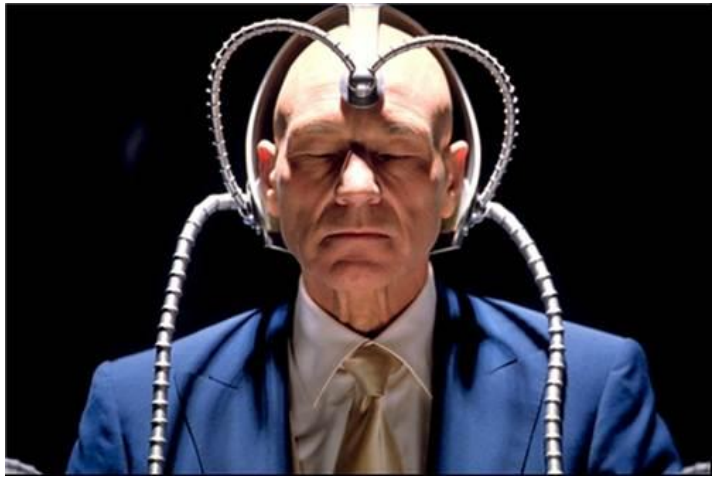
Department of Bioengineering,

Swartz Center for Computational Neuroscience (SCCN),

Institute of Neural Computation (INC),

University of California, San Diego (USCD)

Scientific fiction → Reality?



X-men (2000)



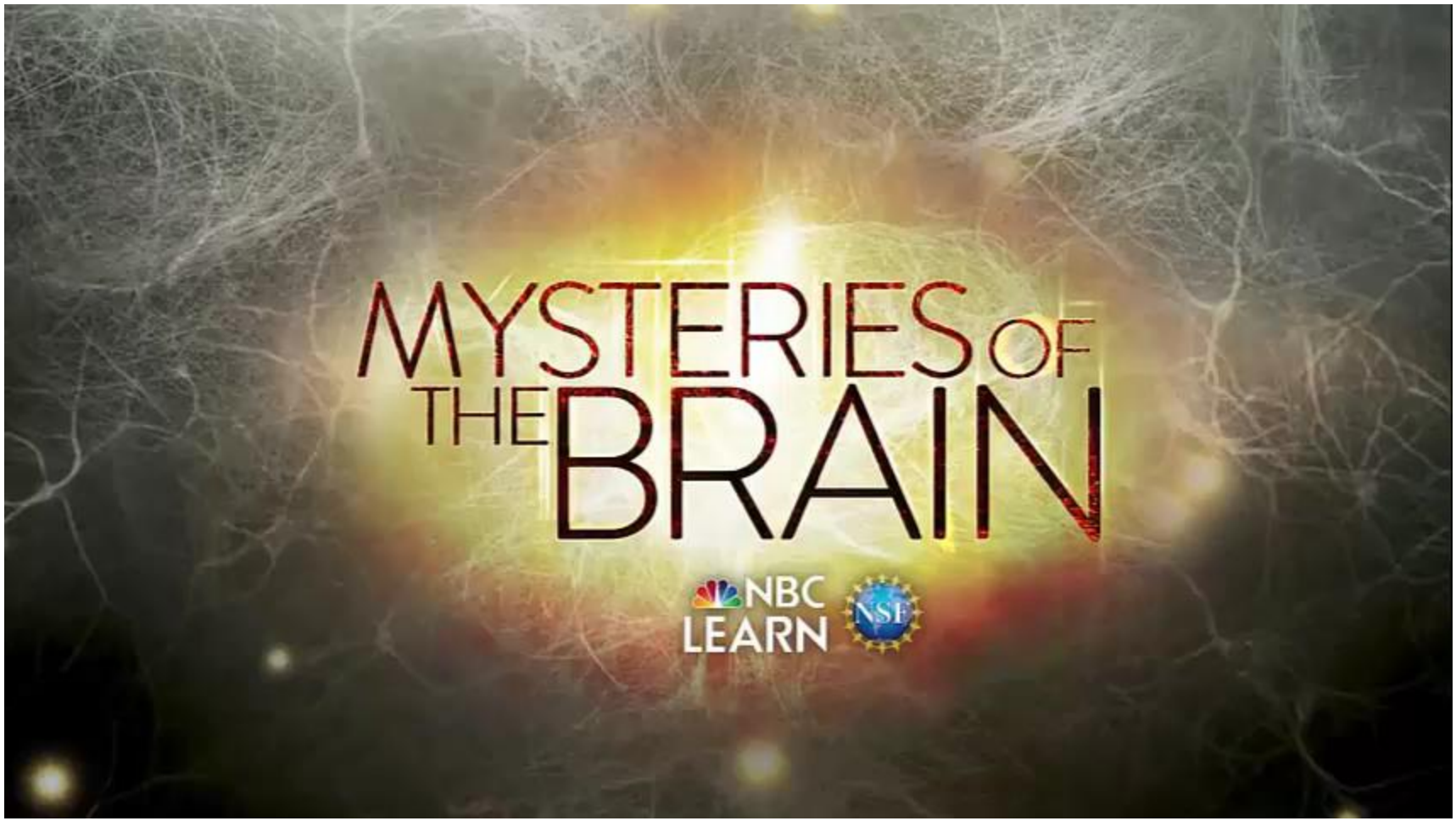
Spider-Man 2 (2004)



The Matrix Trilogy (1999, 2003)



Pacific Rim (2013)

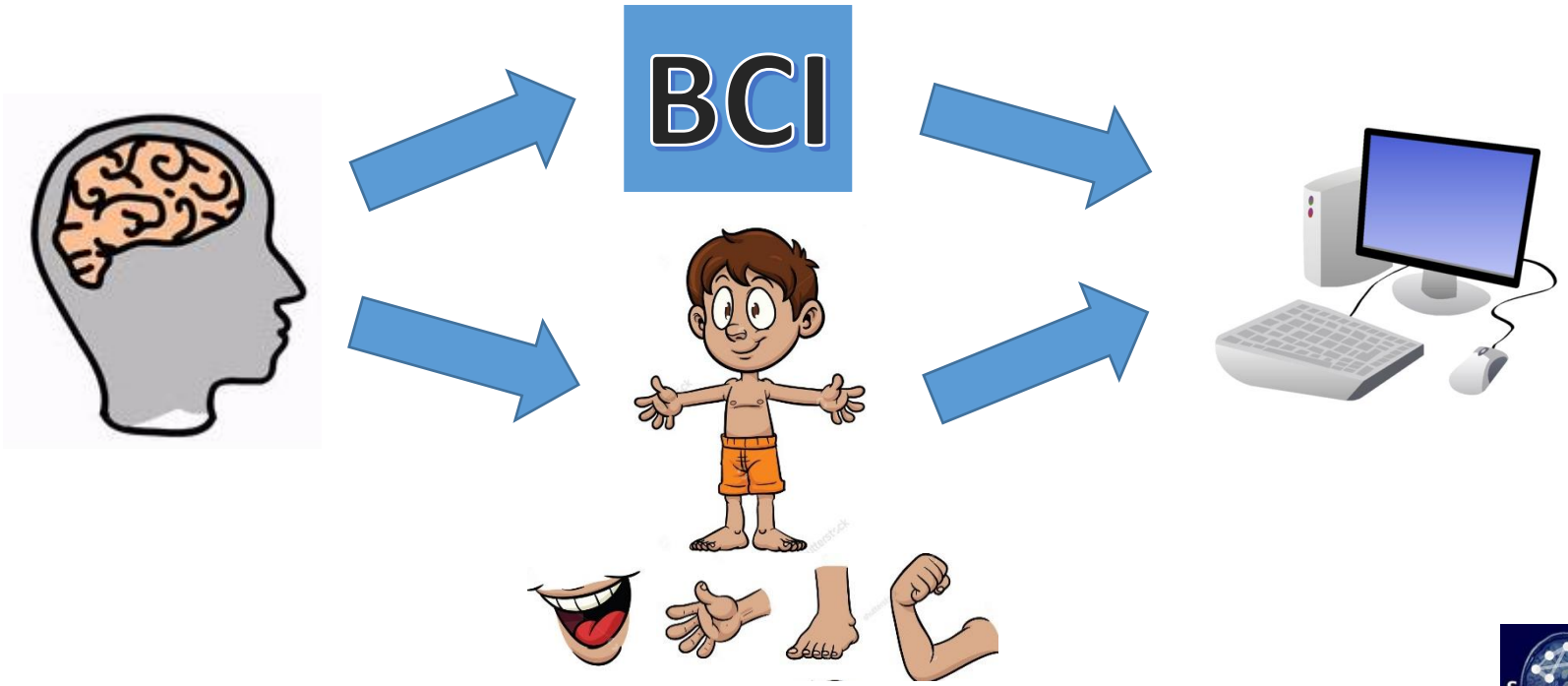

MYSTERIES OF THE BRAIN
NBC LEARN
NSF

Outline

- Introduction to BCI
  - Definition of BCIs
  - Three components of BCIs
  - Types of BCIs
- Challenges and current solutions
- Future directions

Brain–computer interface (BCI)

- A **BCI**, sometimes called a **direct neural interface** or a **brain–machine interface**, is a direct communication pathway between a brain and an external device.



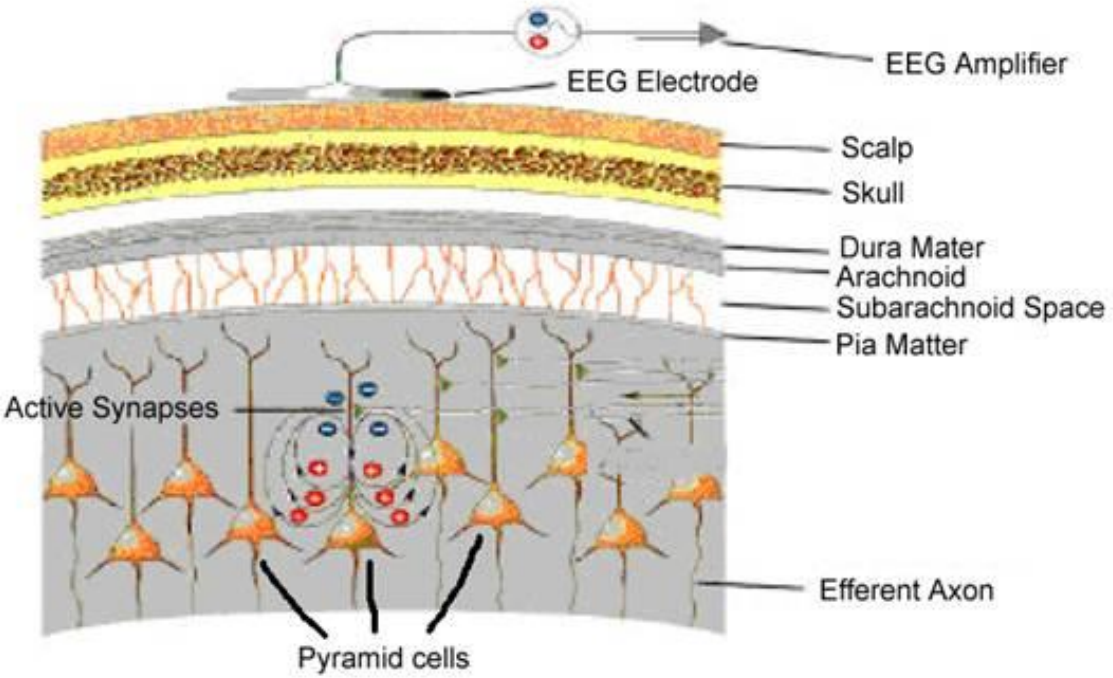
Three components of BCI

Wolpaw, 2002

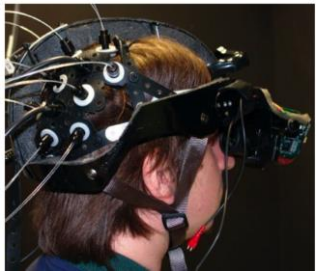


Signal Acquisition → Feature Extraction → Translation Algorithm





NIRS



Seraglia et al., 2011

EEG



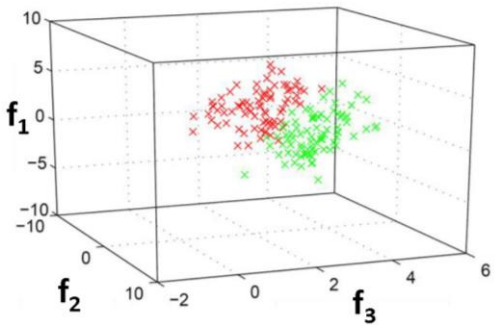
Biosemi

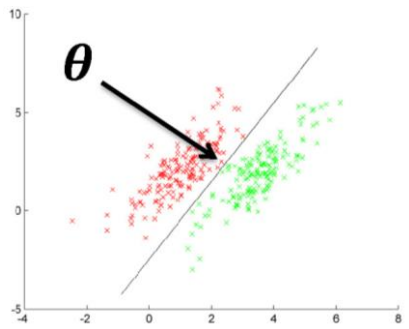
Three components of BCI

Wolpaw, 2002



Frequency Band Name	Frequency Bandwidth	State Associated with Bandwidth	Example of Filtered Bandwidth
Raw EEG	0–45 Hz	Awake	
Delta	0.5–3.5 Hz	Deep Sleep	
Theta	4–7.5 Hz	Drowsy	
Alpha	8–12 Hz	Relaxed	
Beta	13–35 Hz	Engaged	

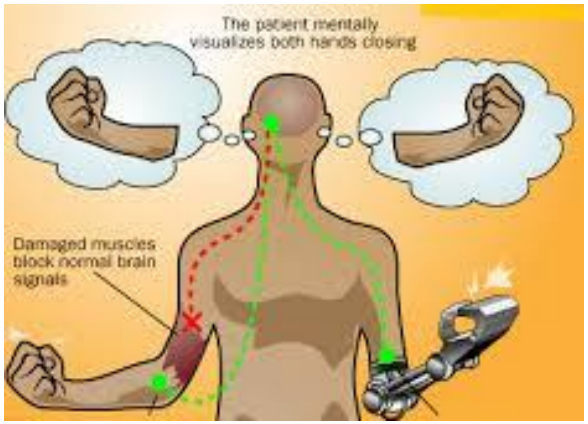


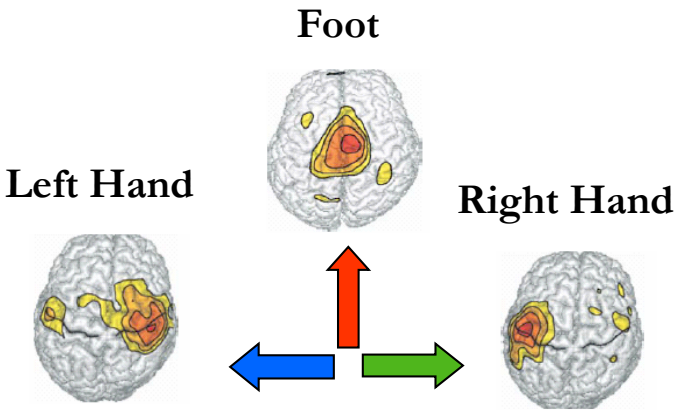


Types of BCI: (1) Active BCI

***Active BCI*:** A user actively, consciously controls the system.

Examples: Motor-imagery BCI





Movement Intention



Bin He, Mind-controlled drone

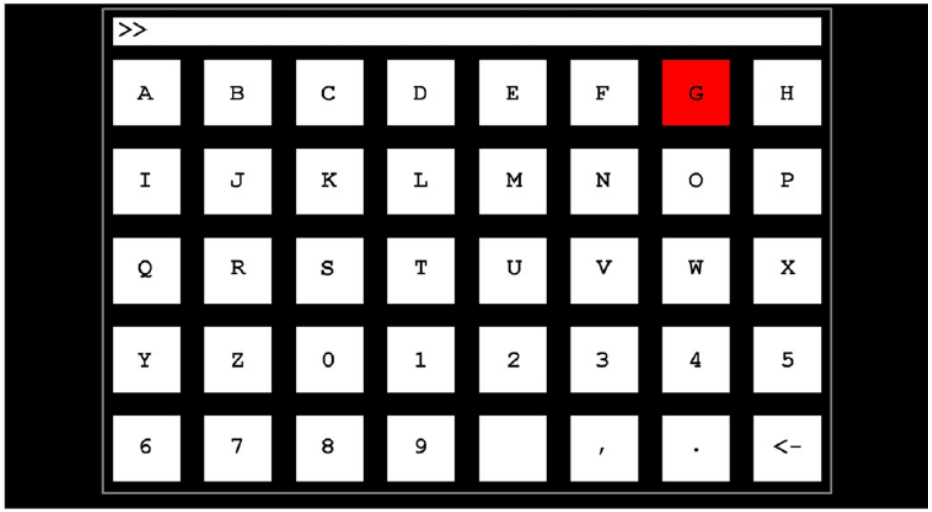


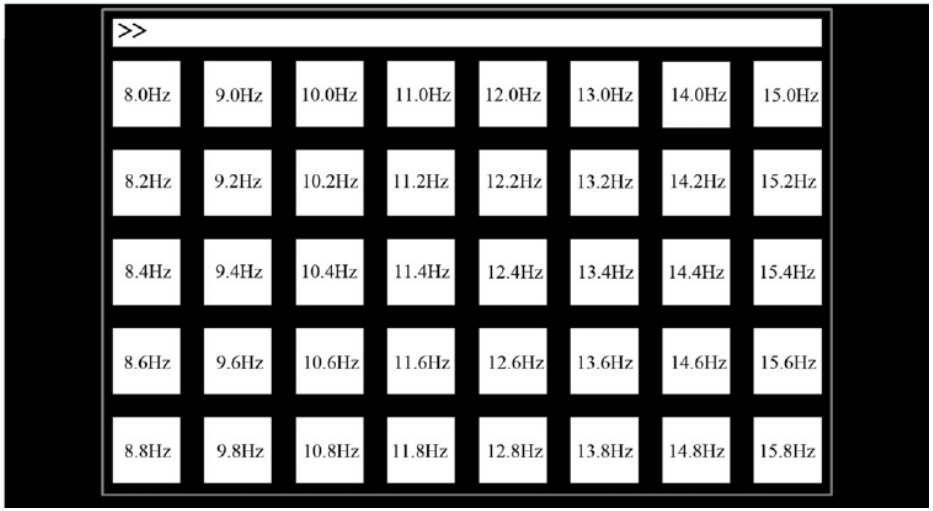
Toyota, Mind-controlled wheelchair

(2) Reactive BCI

***Reactive BCI*:** A user perceives and responses to external stimulation

Examples: steady-state visual-evoked potential (SSVEP) BCI



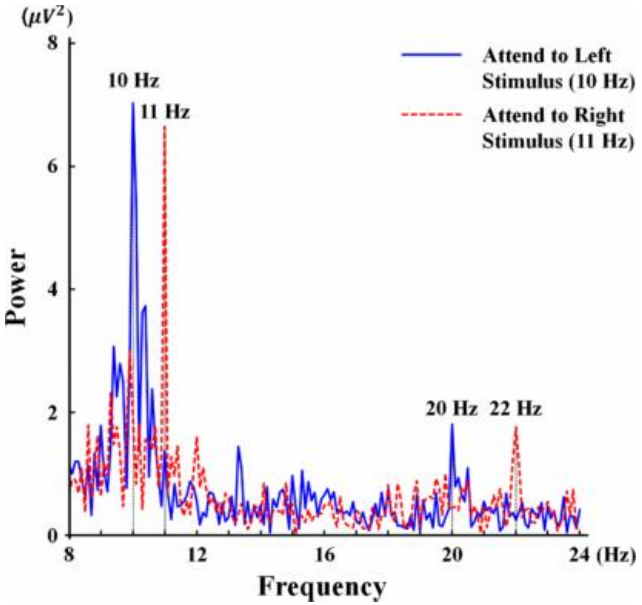


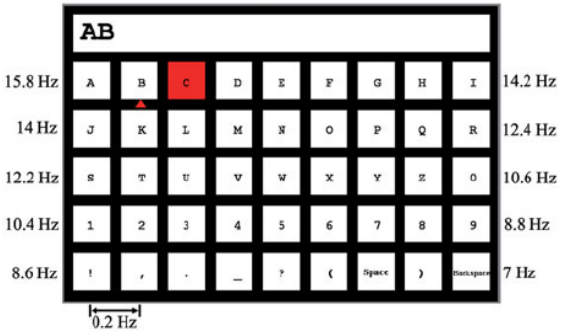
(2) Reactive BCI

***Reactive BCI*:** A user perceives and responses to external stimulation

Examples: steady-state visual-evoked potential (SSVEP) BCI







Chen et al., High-speed Speller



Patient assistant /
Smart home control

(3) Passive BCI

Passive BCI: spontaneous brain activity without voluntary control.

Example: Muse meditation



(3) Passive BCI

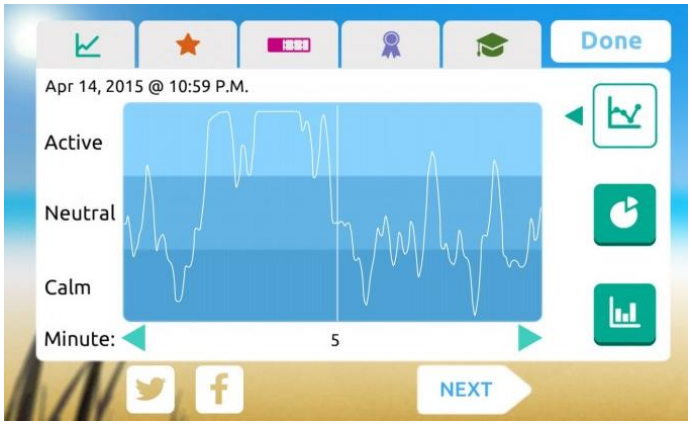
Passive BCI: spontaneous brain activity without voluntary control.

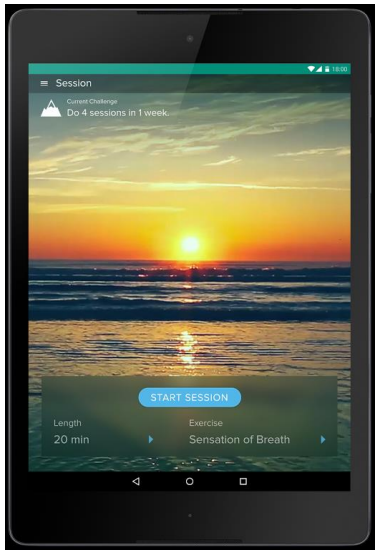
Example: Muse meditation





Frequency Band Name	Frequency Bandwidth	State Associated with Bandwidth	Example of Filtered Bandwidth
Raw EEG	0–45 Hz	Awake	
Alpha	8–12 Hz	Relaxed	





Outline

- Introduction to BCI
- **Challenges and current solutions**
  - Signal acquisition
  - Feature extraction
  - Translation algorithm
- Future directions





Challenges of BCI in real-world applications



- Uncomfortable and inconvenient
- Poor signal quality – EEG signals are noisy

- EEG-channel signals are highly correlated
- Lack of effective pattern recognition algorithms

- Doesn't work for a long time
  - Brain activities are constantly changing

Current solution 1: Signal Acquisition

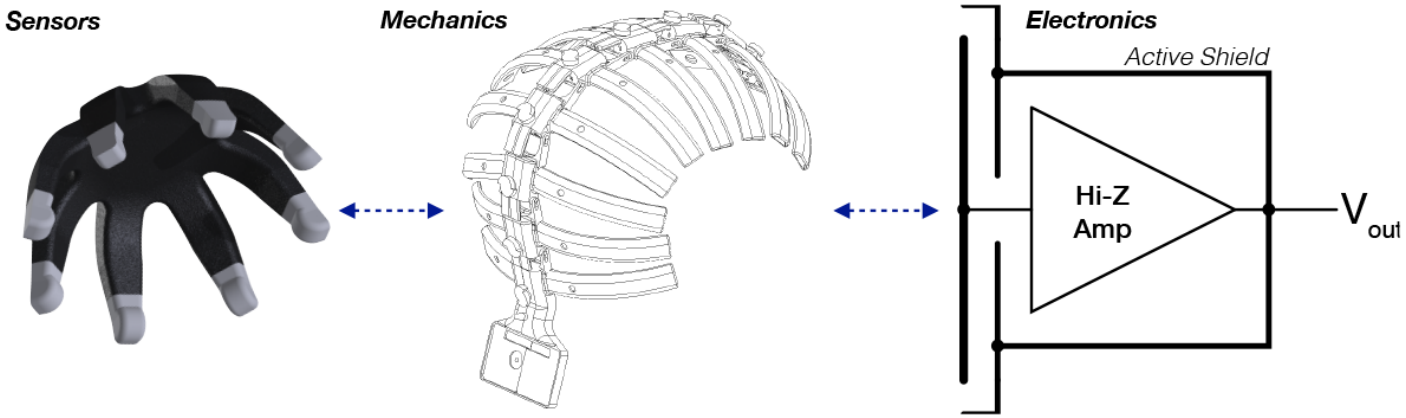


Mike Chi

Cognionics, Inc.

- Uncomfortable and inconvenient
- EEG signals are noisy

- Portable, Dry Electrodes
- Active circuit for noise reduction





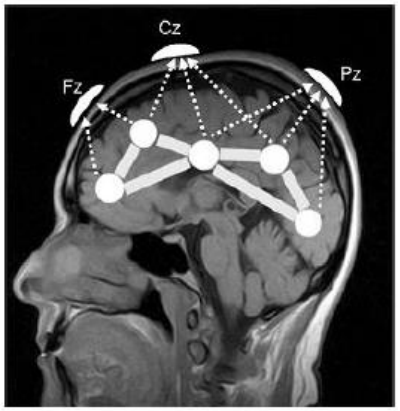
Current solution 2: Feature Extraction

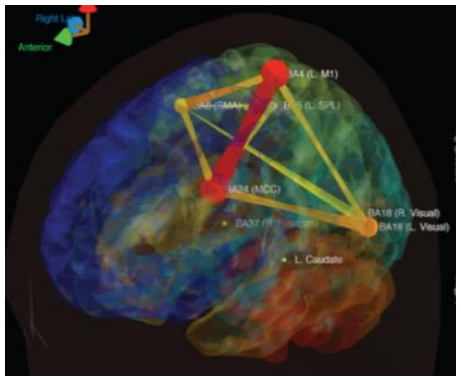
- EEG-channel signals are highly correlated
- Lack of effective pattern recognition algorithms

Signal processing and **machine learning** techniques:

1. Blind source separation
2. Source localization
3. Connectivity analysis
4. Artificial neural network

Source-level analysis





Makeig et al. “Evolving Signal Processing for Brain–Computer Interfaces”, 2012

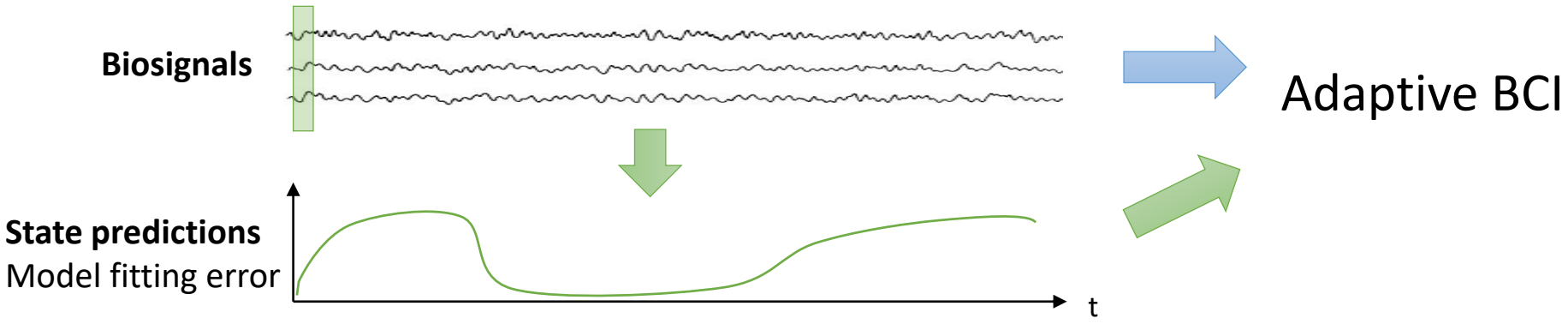
Current solution 3: Translation algorithm

- Doesn't work for a long time: nonstationary brain activities

Cognitive or Mental states monitoring:

- Attention, drowsiness, mental fatigue, mental workload

Initial reference state (alert)



Hsu et al., 2016

Outline

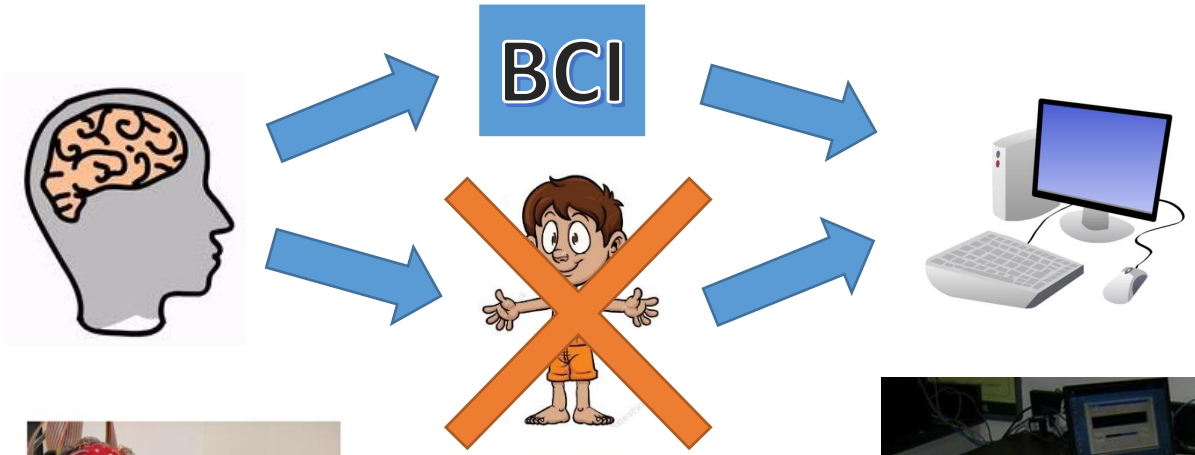
- Introduction to BCI
- Challenges and current solutions
- **Future directions**





Current focus – replace, restore functions

- Rehabilitation/communication for patients with motor impairment





KU Leuven



Brain2Robot
(Fraunhofer FIRST)



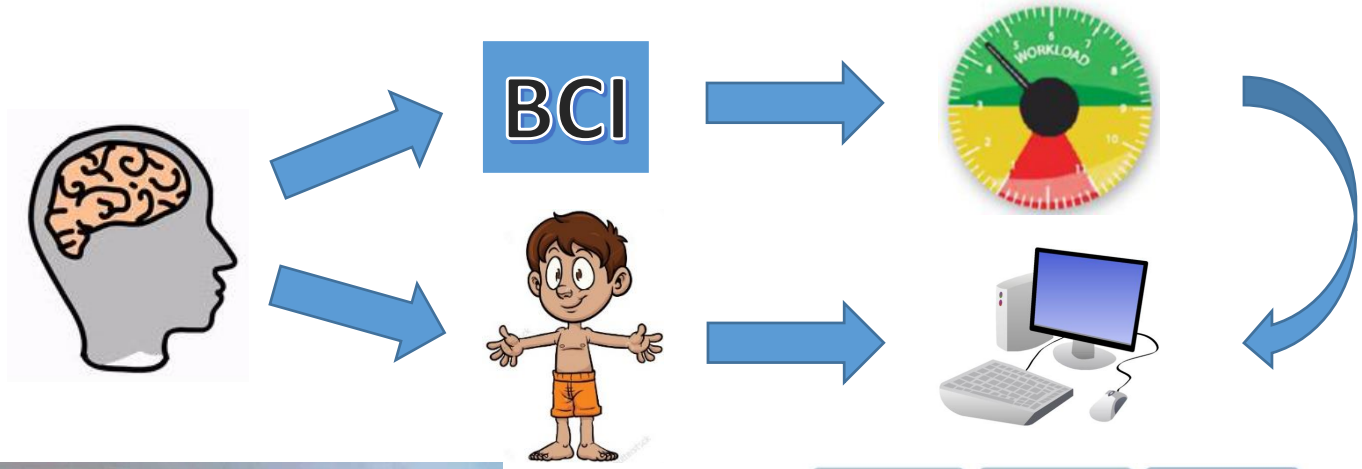
P300 Speller



Gao, Wang et al.

Future directions – augment, enhance functions

- Cognitive state monitoring and gaming
  - Monitor mental workload, mental fatigue, alertness in pilots, air traffic controllers, plant operators



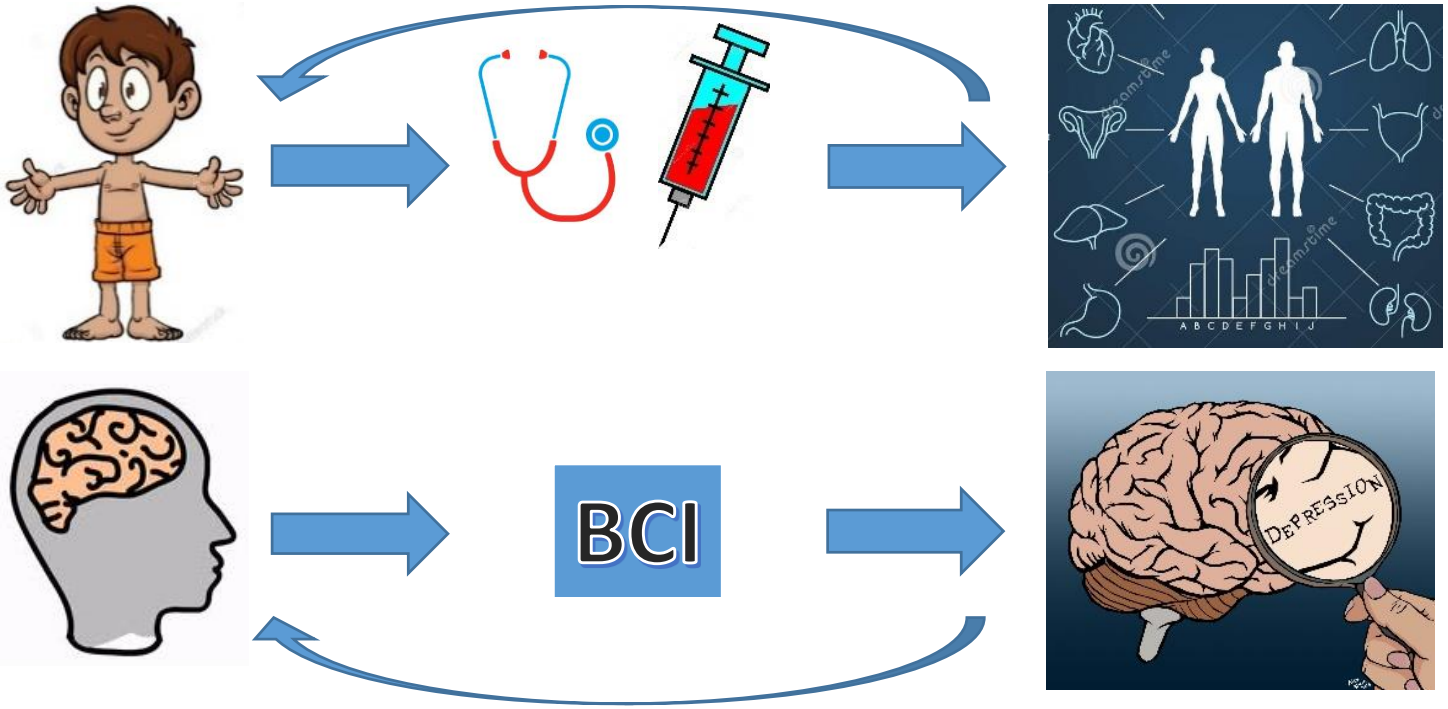


Haufe et al., 2011



Future directions – assess, monitor mental health

- Mental health or Mental Hygiene
  - Sleep, emotions, anxiety, stress, depression, happiness



Conclusion

- BCI provides a direct communication pathway between a brain and an external device.
- Three components: (1) signal acquisition, (2) feature extraction, (3) translation algorithm
- Challenges: (1) poor signal quality, (2) lack of effective methods, (3) doesn't work for a long time
- Current solutions: (1) active circuit, dry electrodes, (2) source-level analysis, machine learning, (3) state monitoring
- BCI is not only for patients to restore or replace their body functions, but also for general public to enhance their capability and to assess mental health.





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Cognionics

Mike Chi

