Machine Learning for Neural Engineering Applications: Current Trends and Future Perspectives

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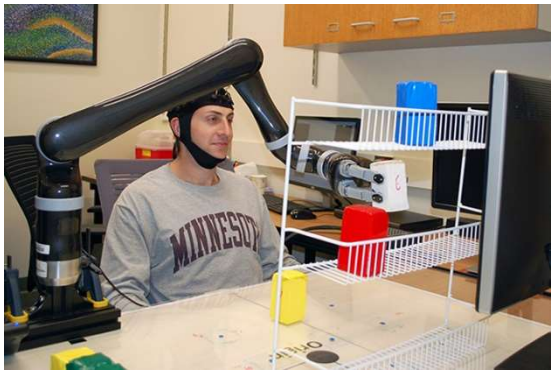
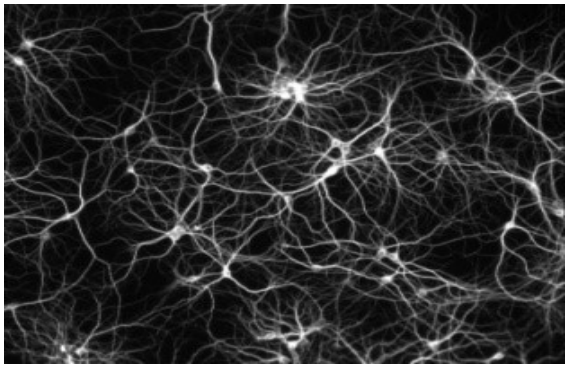
Machine Learning for Healthcare

- Can we use data analytics and machine learning to develop solutions to help people with disabilities?

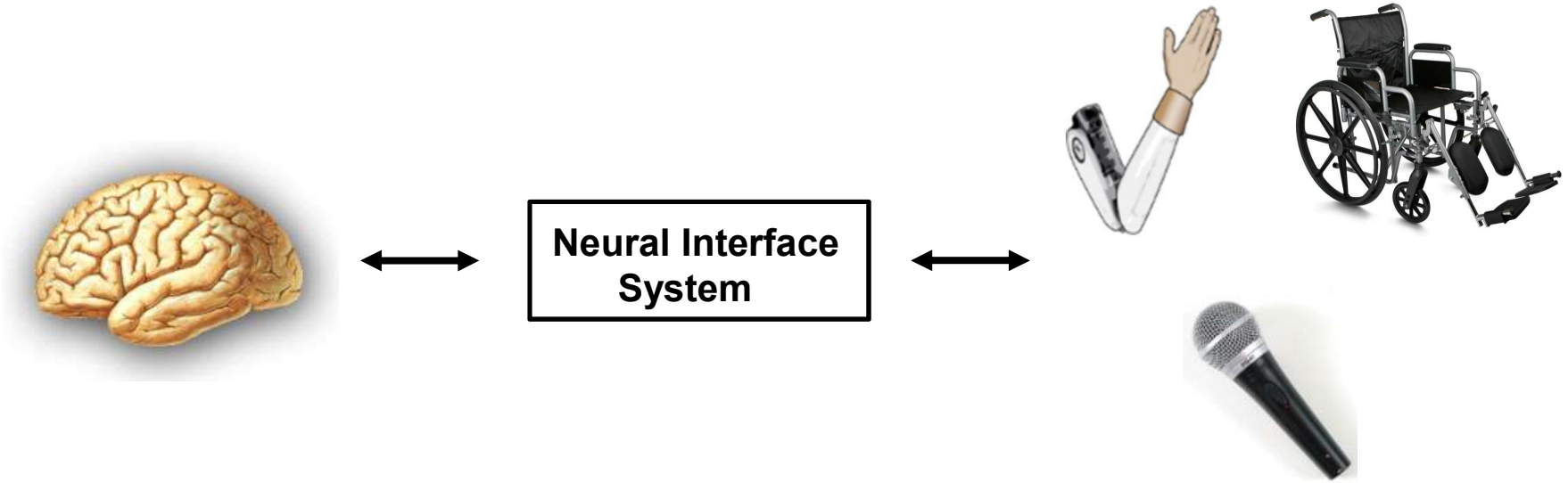


- Can we use data analytics and machine learning to understand how the brain works?



Neural Engineering Systems

- Neural Engineering emerged as a research area in early 2000
- Appears in literature with different names: Brain-Computer Interface (BCI), Neuroengineering, Neural Interface, Neuroprostheses …
- A Neural Interface is a system that interfaces with the brain to restore a lost function caused by a brain-related injury or disorder



Neural Engineering Systems

- Neural interface systems could help patients with physical impairments or lost senses

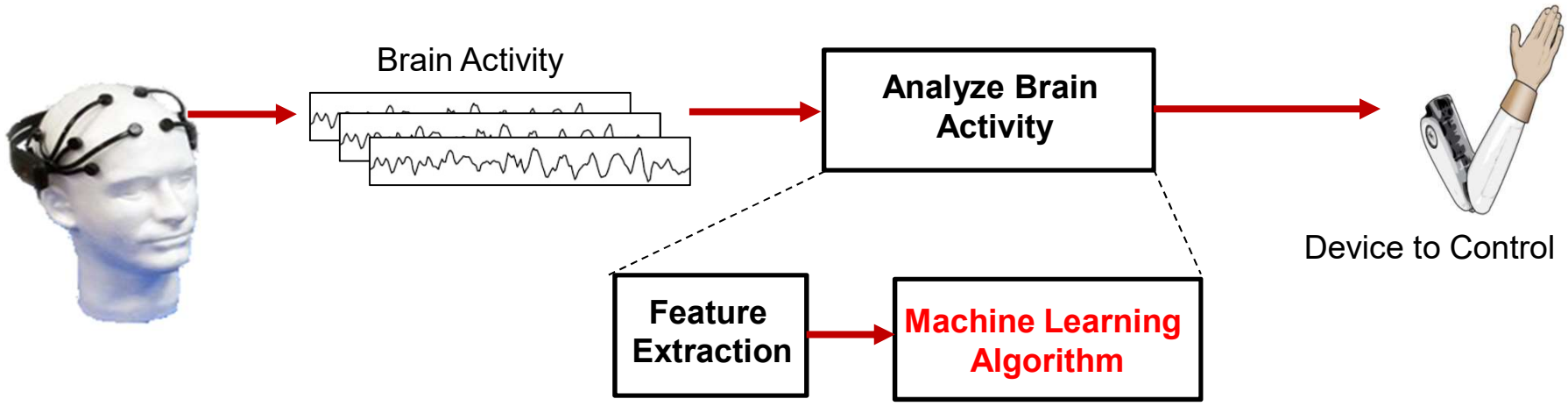
Locked-in Syndrome

Physical Impairments

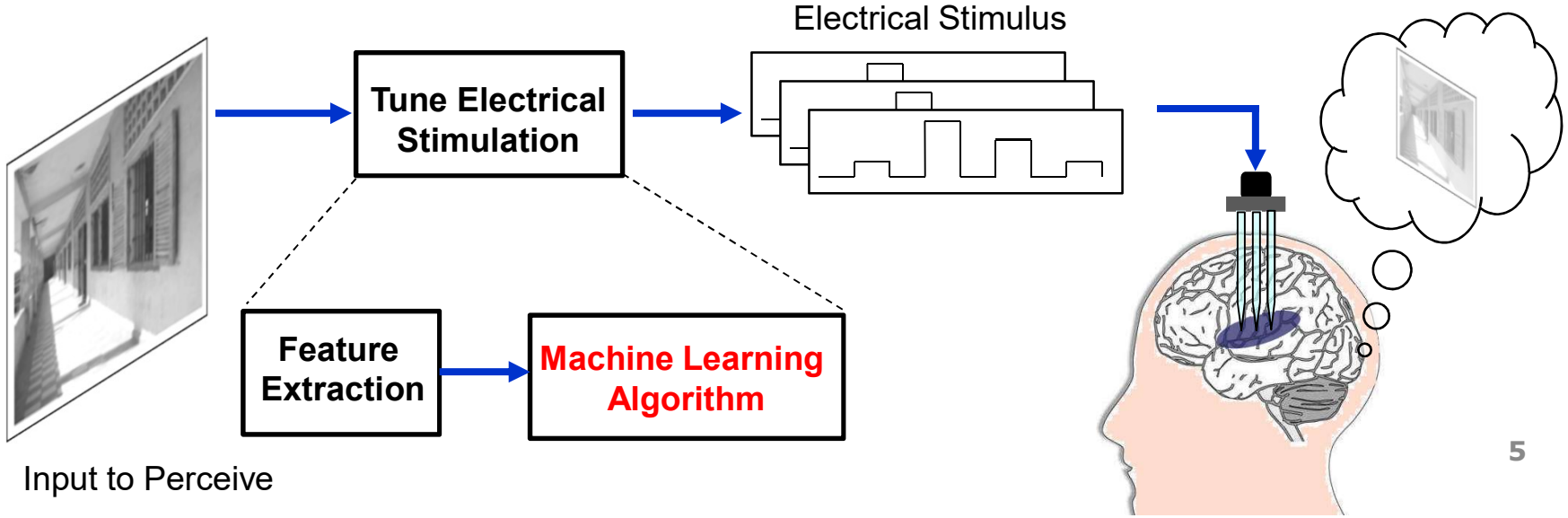
Lost Senses

Neural Interfaces Modes of Operation

- Output Interfaces: Reading from the Brain



- Input Interfaces: Writing to the Brain

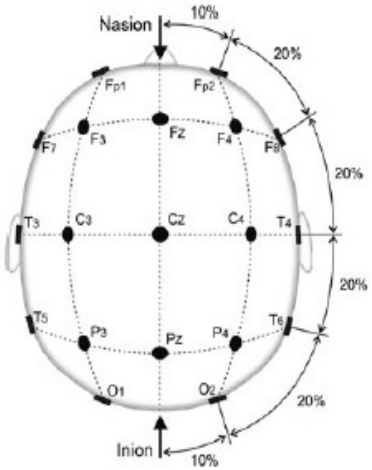


Output Systems: Recording Technology

Recording Devices

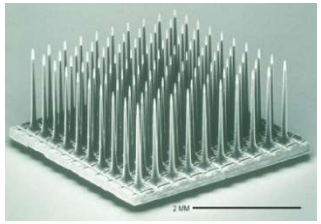
Non-invasive

EEG



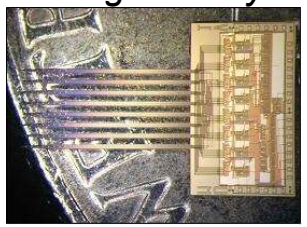
Invasive

Utah Array



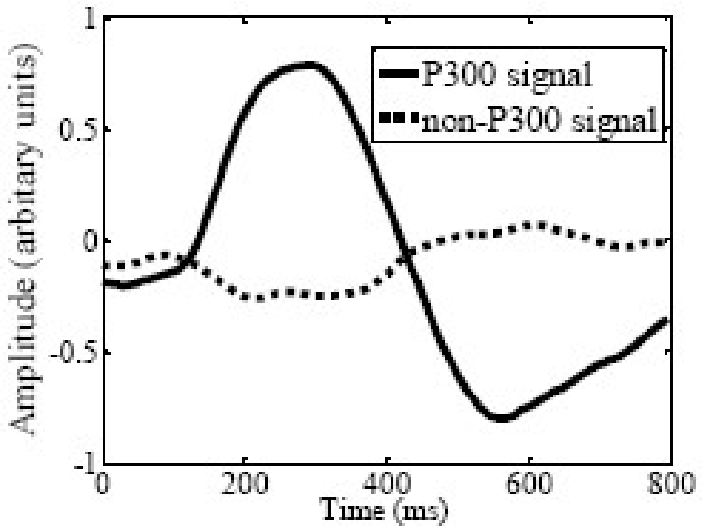
Microwire Array

Michigan Array



P300 Signals

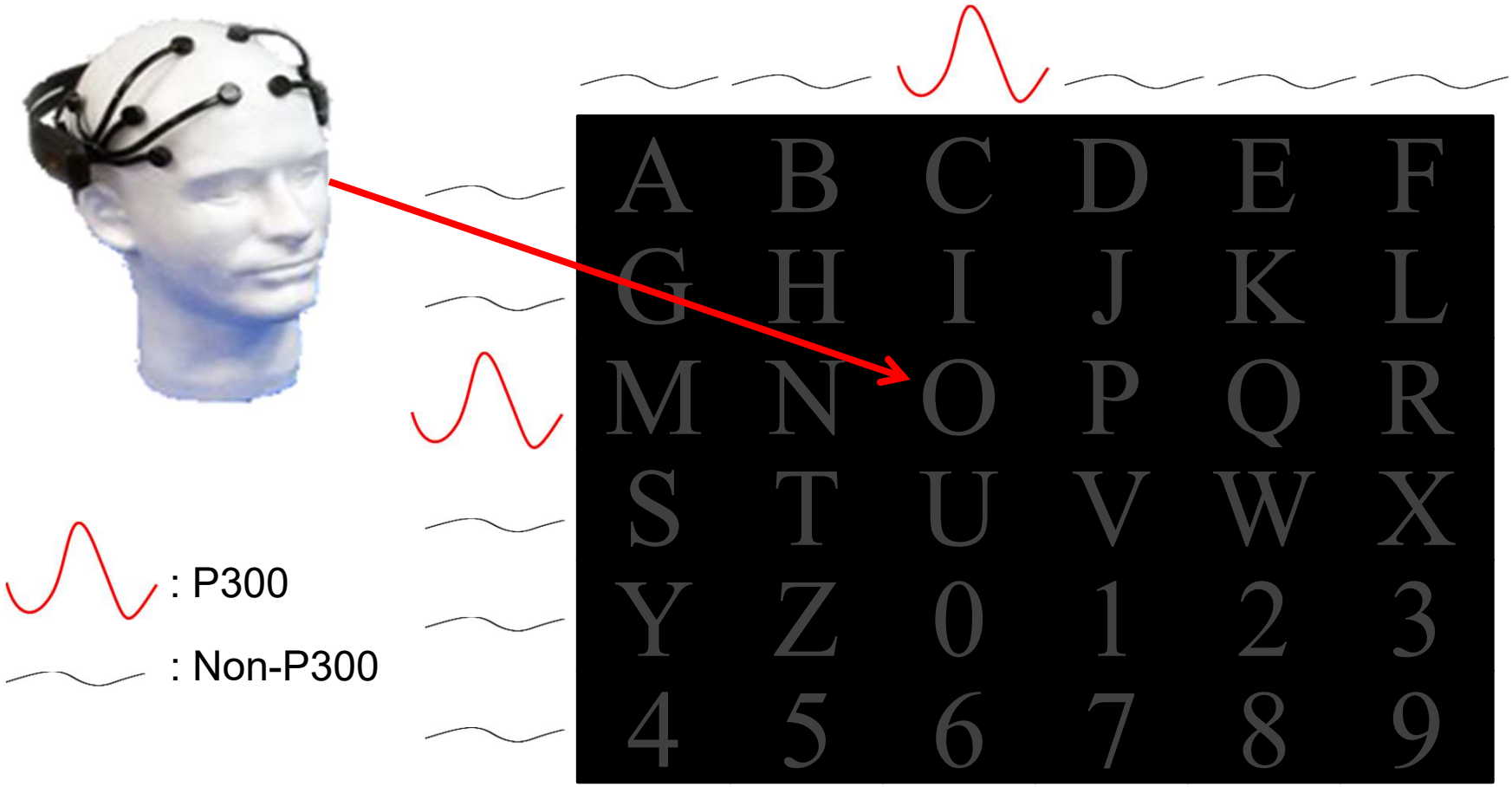
- When a rare event is displayed in front of a subject, a P300 component is recorded on the EEG, which is a large positive wave that occurs approximately 300 ms after event onset



- Using such paradigm, a virtual keyboard system can be developed termed as P300-speller

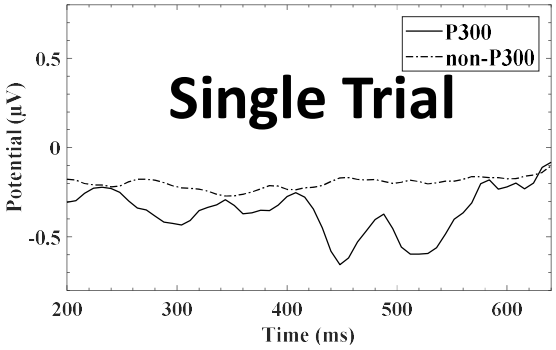
P300-based Spellers

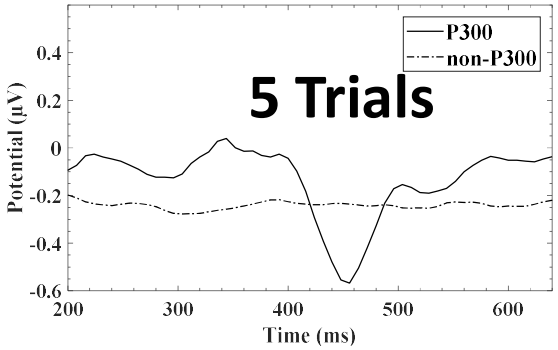
- A brain-controlled speller can be designed using this feature

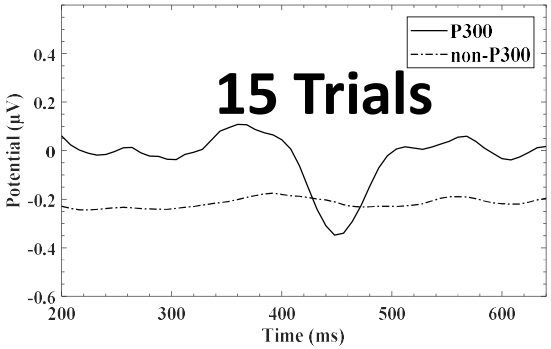


Challenges

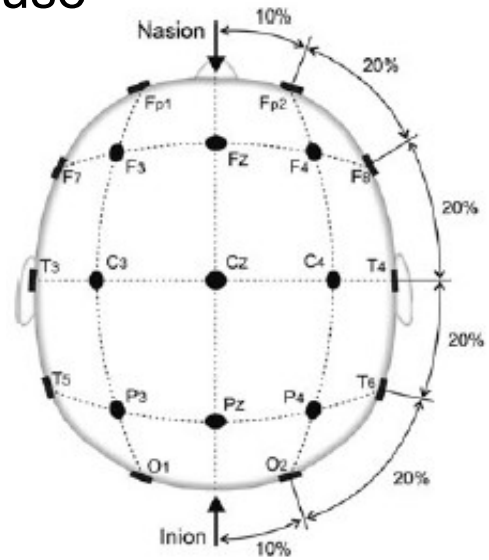
- Data is noisy





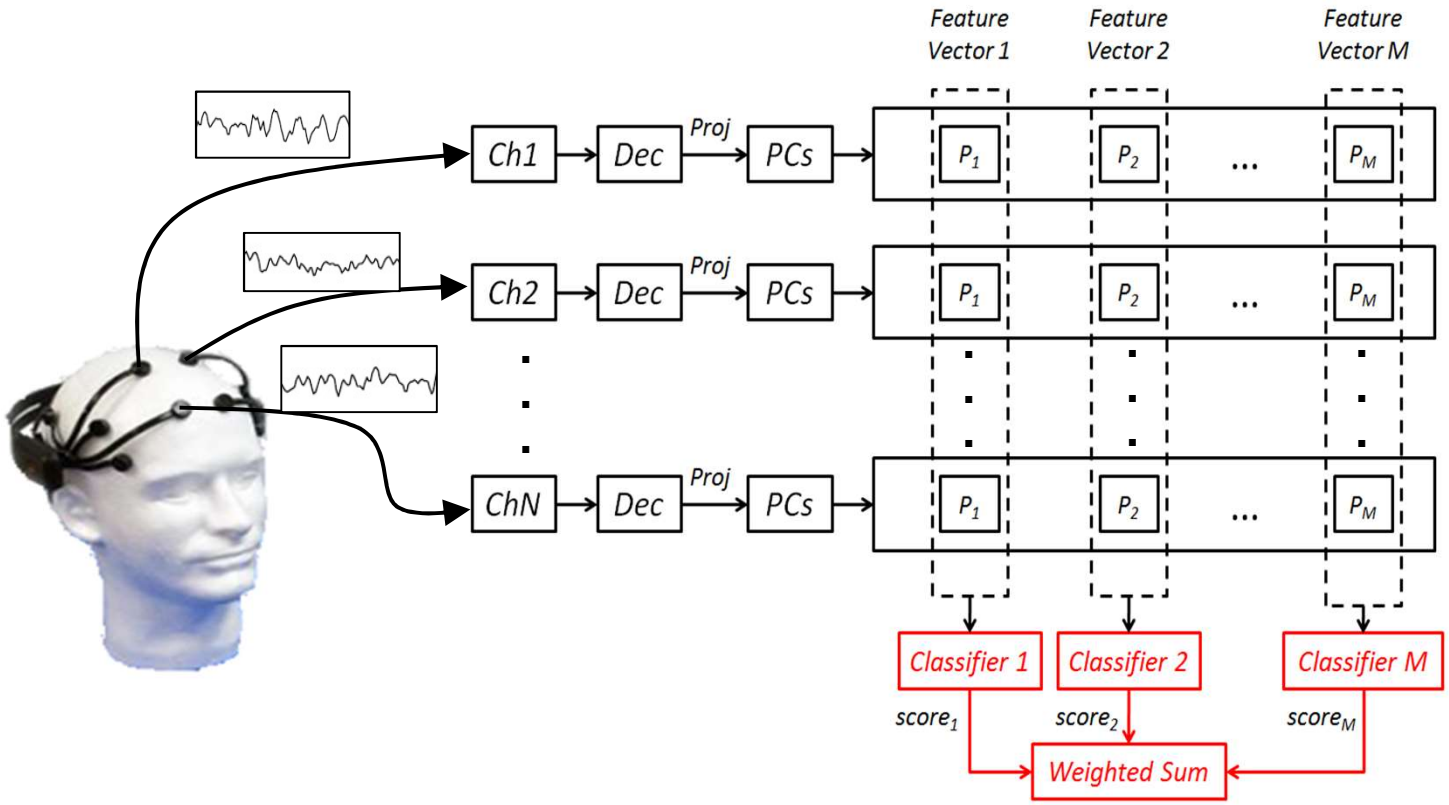


- Multiple signal sources to fuse



PCA Ensemble Classifier for P300 Recognition

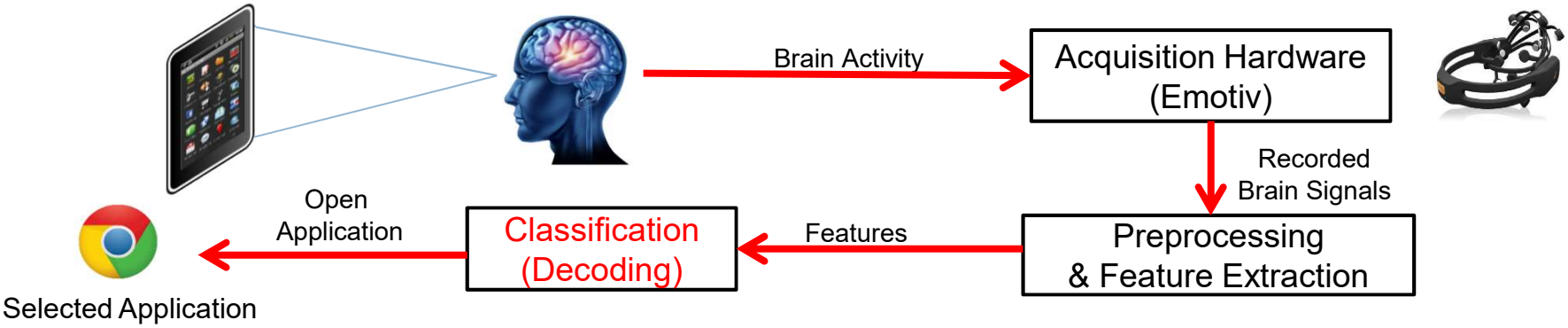
- Ensemble Classifier: Combines the scores of principal component-dependent classifiers



A. S. Elsawy, S. Eldawlatly, M. Taher and G. M. Aly, "MindEdit: A P300-based Text Editor for Mobile Devices," *Computers in Biology and Medicine*, Vol. 80, pp. 97-106, 2017

P300-based Tablet Applications

- Google Funded Research Project at Ain Shams University (2014 – 2015)



- Applications

Speller Application

Accuracy of 3 Subjects: 97.22±3.93%

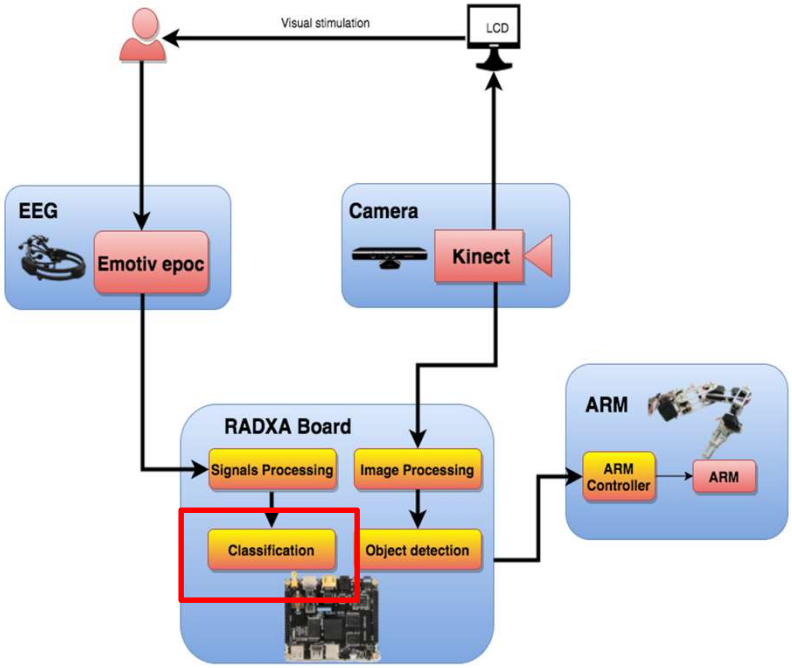
Image Viewer Application

Accuracy of 6 Subjects: 87.5±8.74%

A. S. Elsawy, S. Eldawlatly, M. Taher and G. M. Aly, "Performance Analysis of a Principal Component Analysis Ensemble Classifier for Emotiv Headset P300 Spellers," *Proc. of the 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC 2014)*, pp. 5032 – 5035, Chicago, IL, August 2014

Brain-controlled Robotic Arm

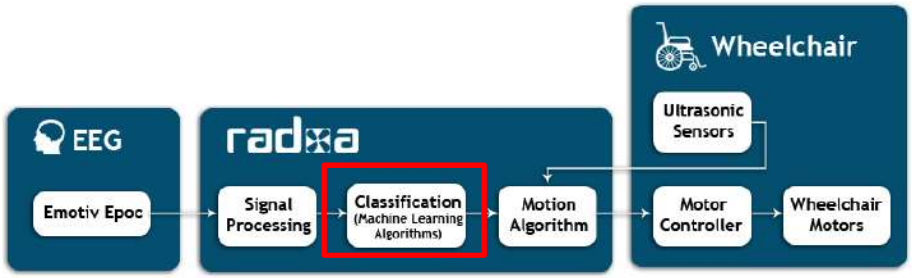
- Graduation Project (2015/2016) at Ain Shams University:
  BC-ARM: Brain-controlled Robotic Arm



- Second Best Biomedical Engineering Project at EED2016

Brain-controlled Wheelchair

- Graduation Project (2013/2014) at Ain Shams University:
  BrainGizer: A Brain-Controlled Wheelchair

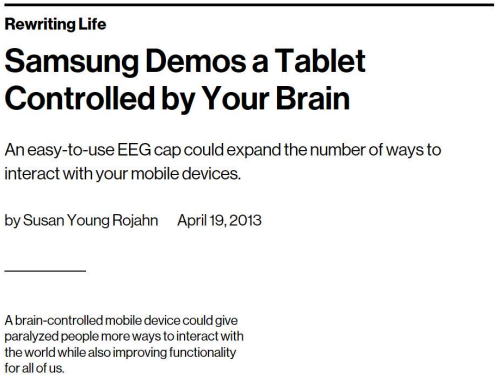


- Best Biomedical Engineering Project at EED2014

- Finalist from Egypt at Netkite Competition

Future Directions: Industrial Interest

- Samsung (April 2013, May 2018)

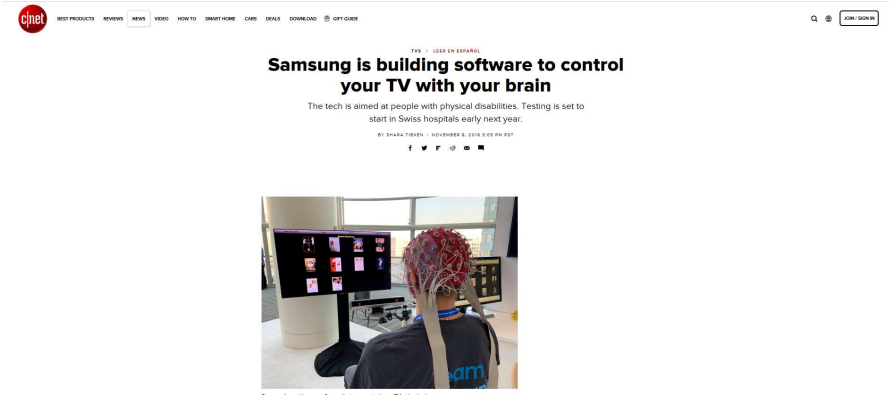

Rewriting Life

Samsung Demos a Tablet Controlled by Your Brain

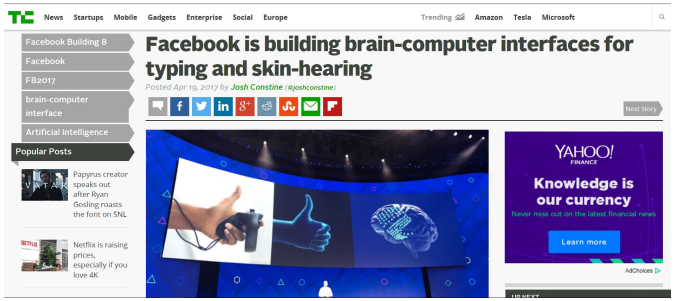
An easy-to-use EEG cap could expand the number of ways to interact with your mobile devices.

by Susan Young Rojahn April 19, 2013

A brain-controlled mobile device could give paralyzed people more ways to interact with the world while also improving functionality for all of us.



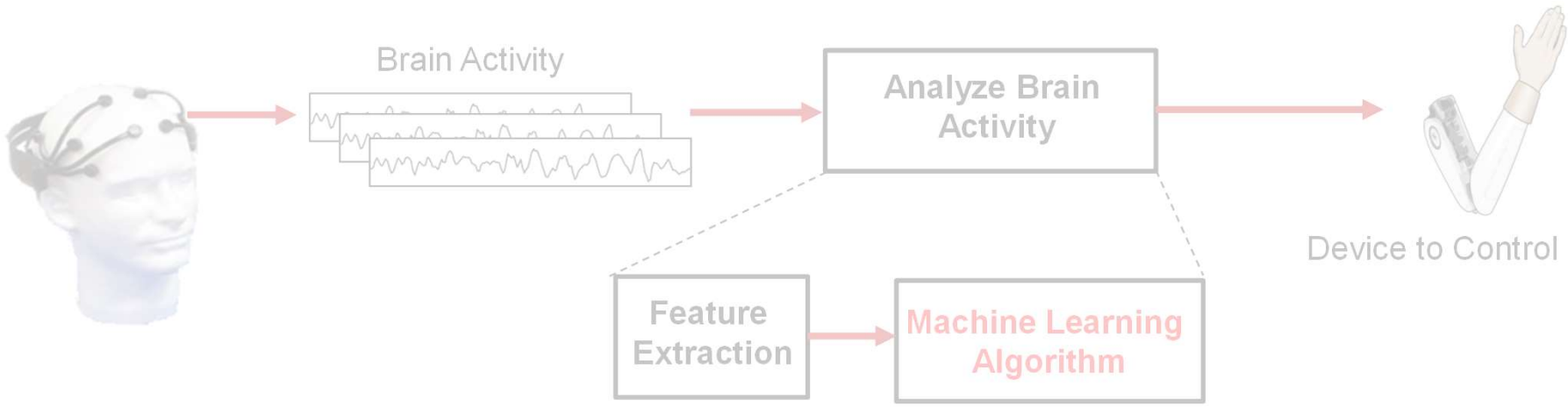
- Facebook (April 2017)



- Elon Musk's Neuralink (August 2017)

Neural Interfaces Modes of Operation

- Output Interfaces: Reading from the Brain



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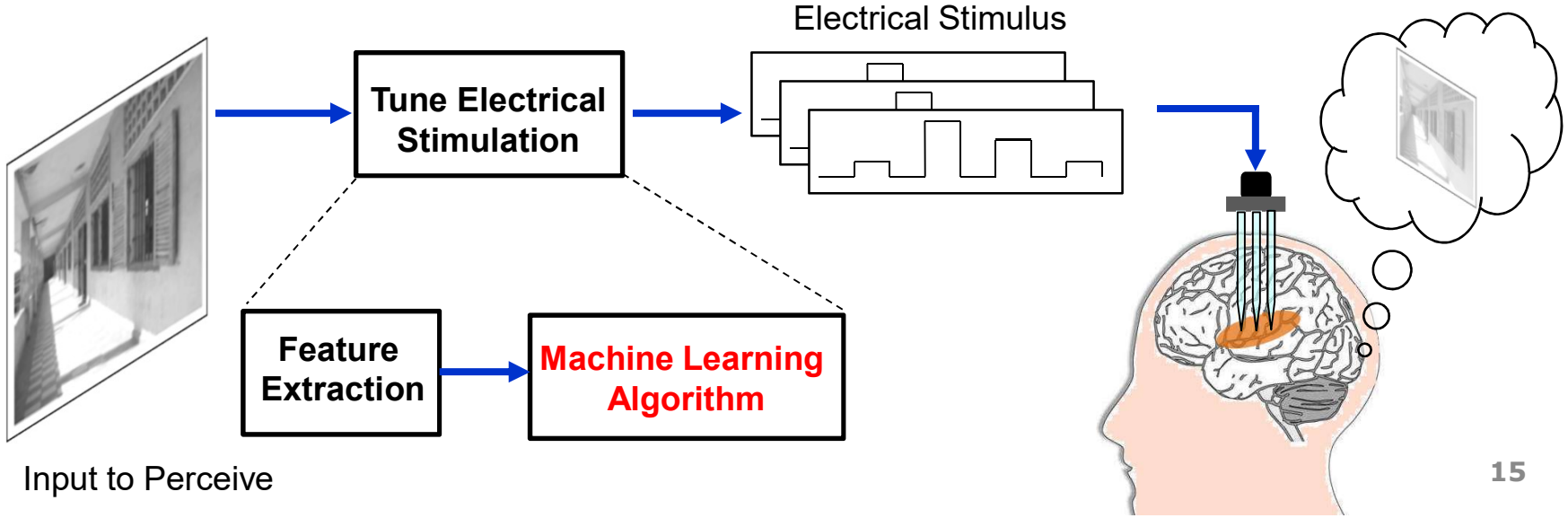
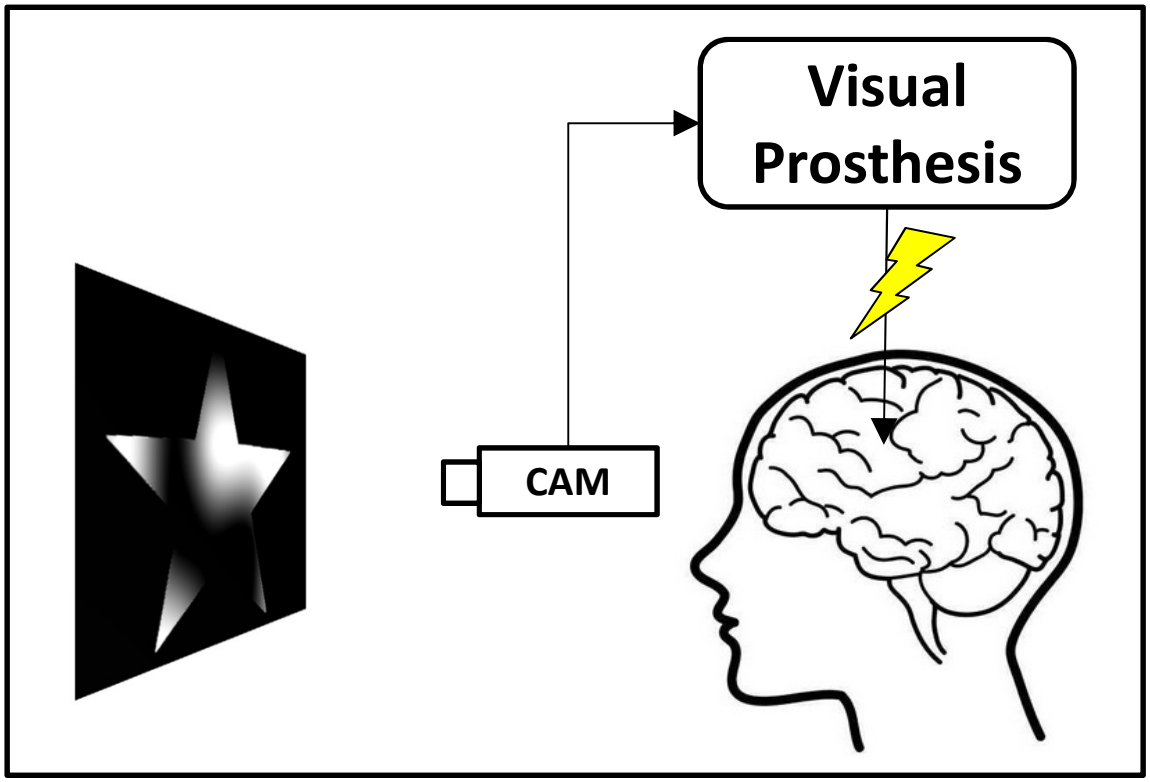


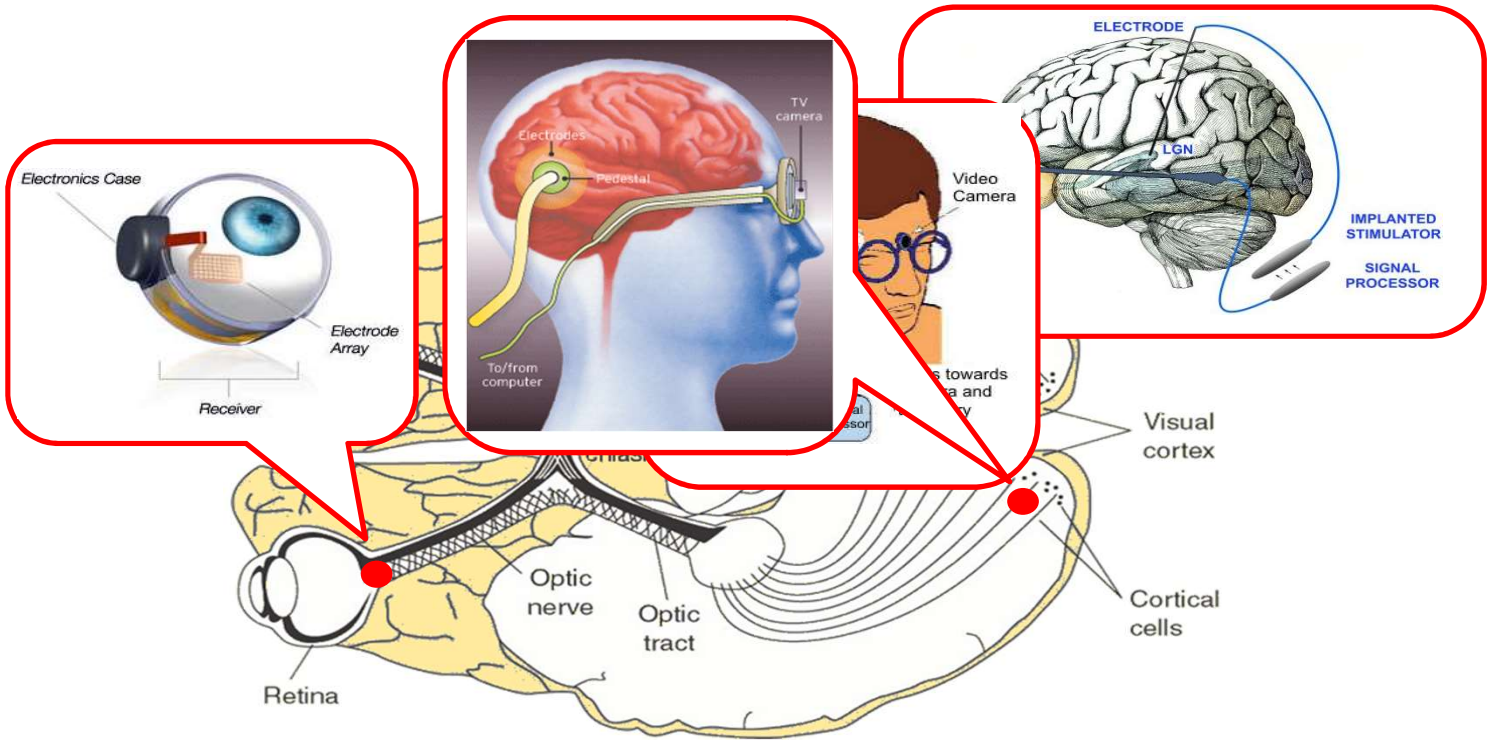
Vision Restoration

- Can the blind restore their vision through brain stimulation?



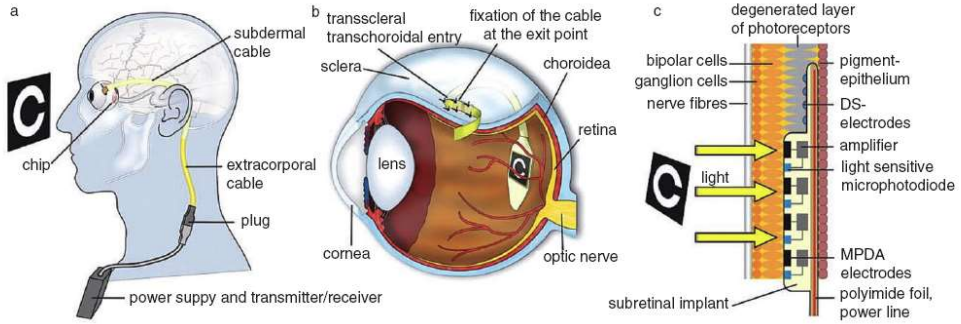
Vision Restoration

- There are multiple candidate sites for visual prostheses



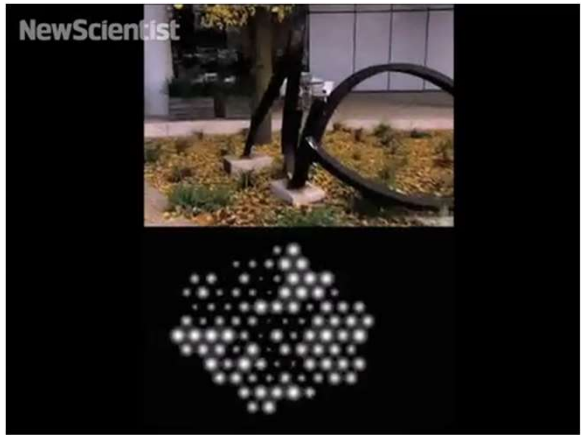
Retinal Implants

- Retinal implants (Argus II) have recently demonstrated success



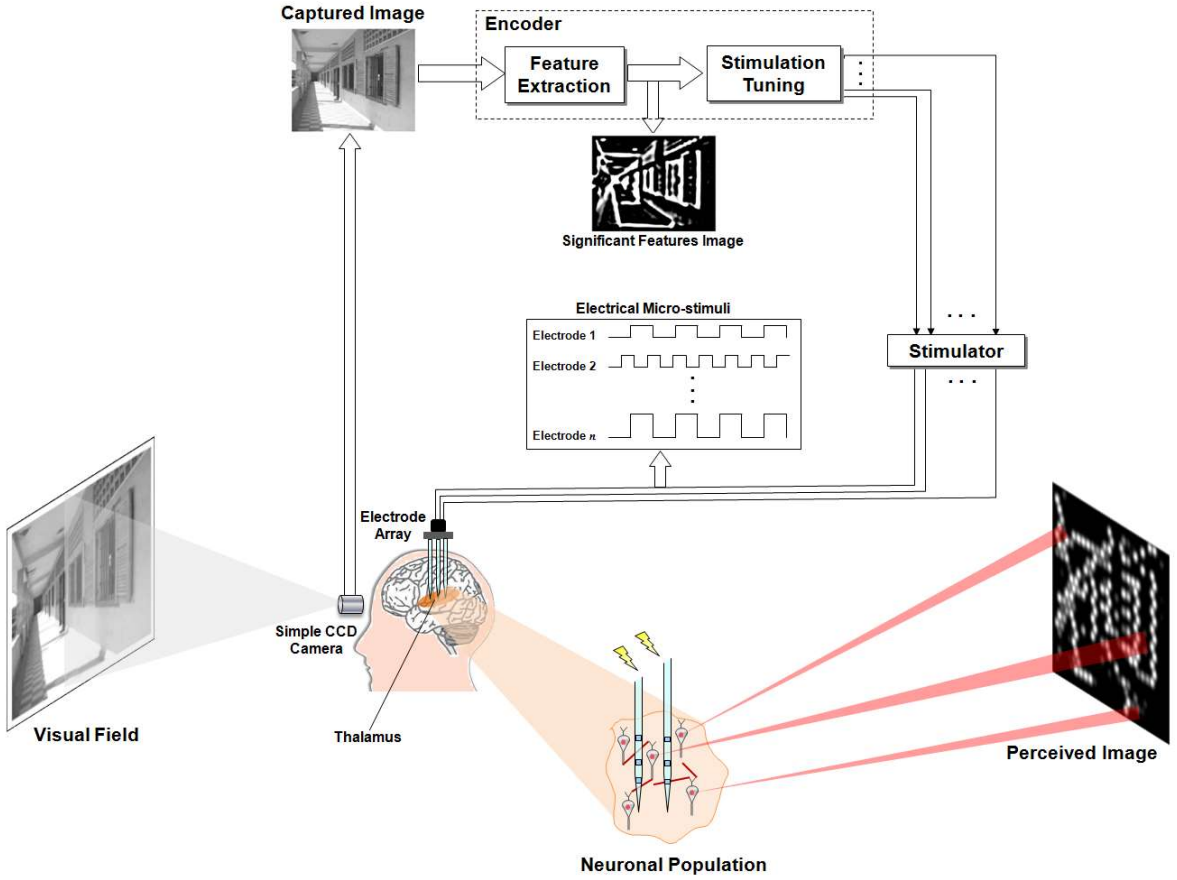
(Ong and da Cruz, 2012)

- First approved by FDA in February 2013. As of mid 2018, ~300 patients have been implanted with the Argus II system



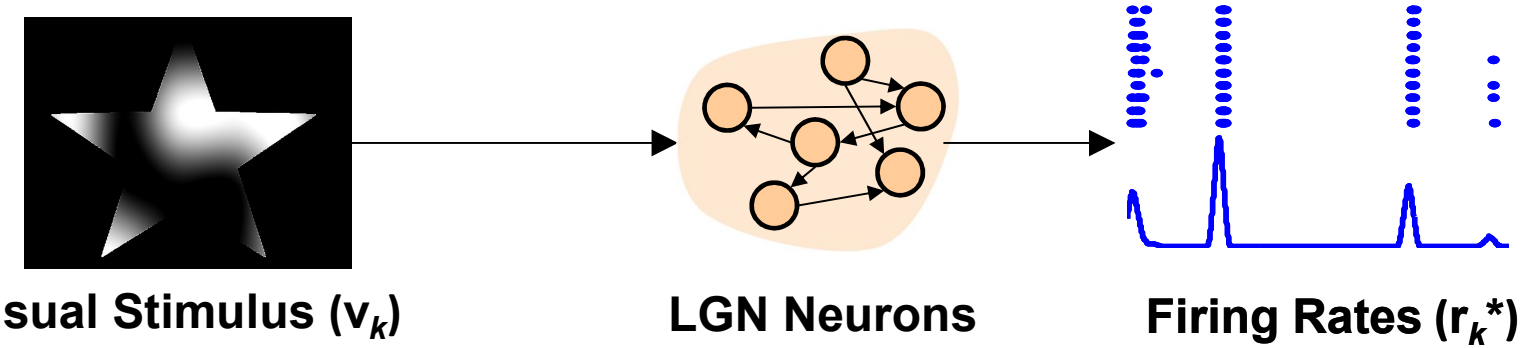
Thalamic Visual Prostheses

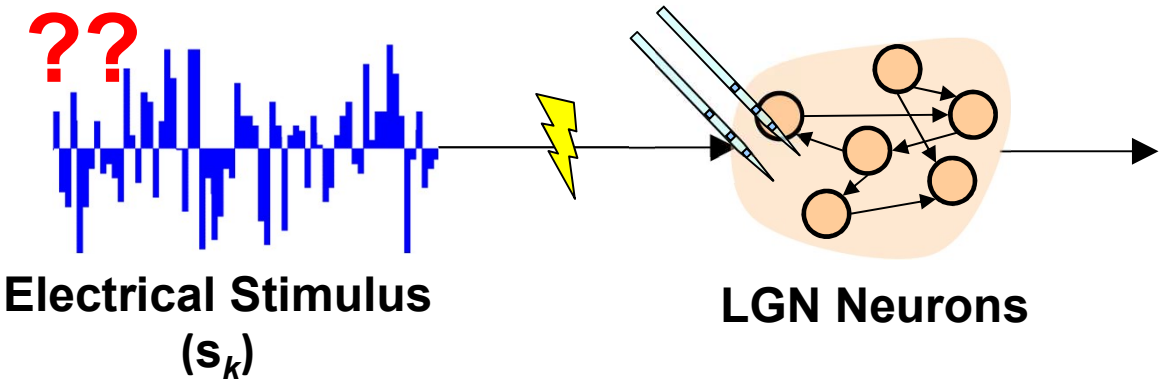
- STDF Funded Project at Ain Shams University (2014 – 2017)
- COMSTECH-TWAS Joint Research Grants Programme (2017 – 2019)
- Objective: Developing an invasive neural interface system to restore vision for the blind



Thalamic Visual Prostheses

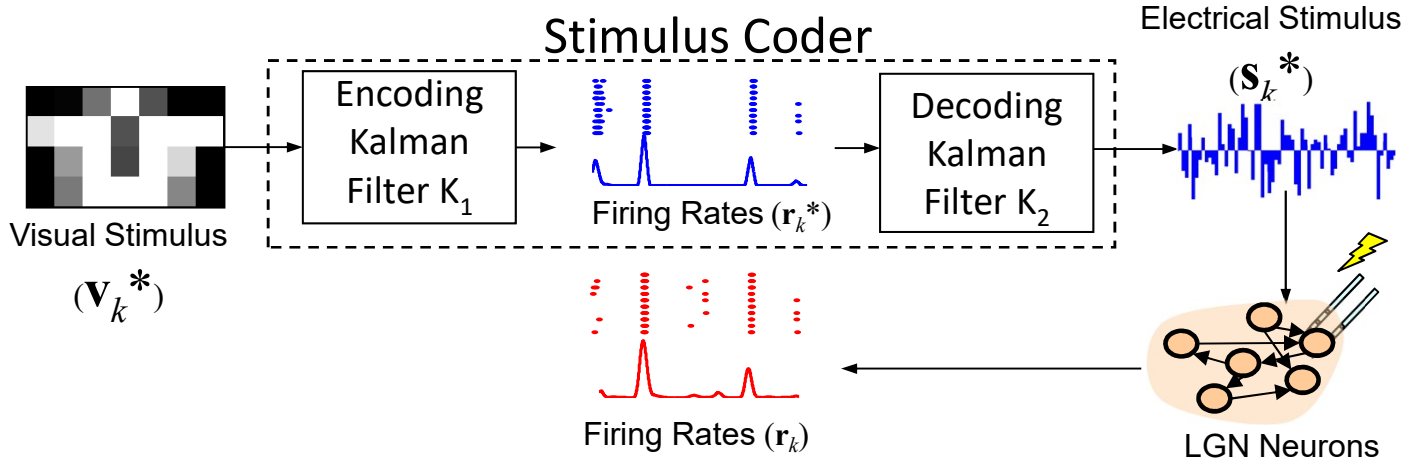
- Algorithms that could be used to elicit responses using electrical stimulation similar to that elicited using visual stimulation



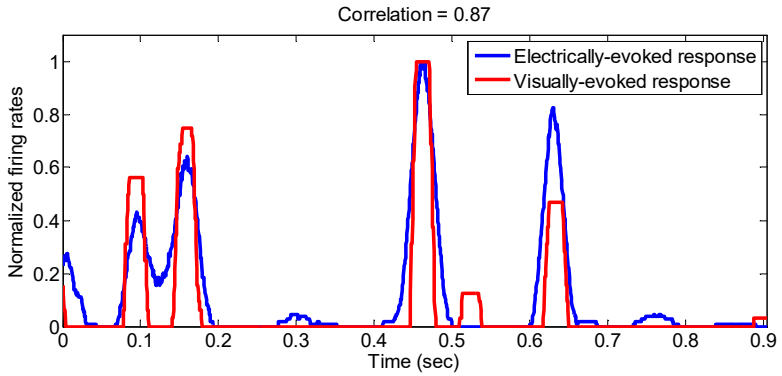


Thalamic Visual Prostheses

- Kalman Filter-based Approach



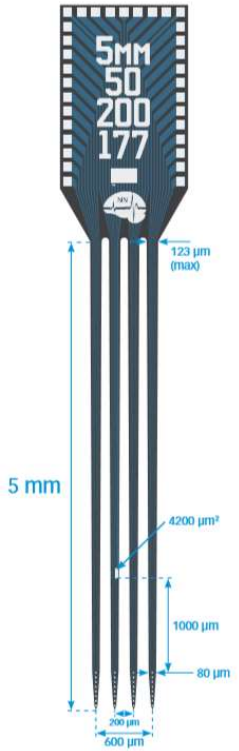
- Results: High similarity between firing rates with correlation of 0.69



A. Jawwad, H. H. Abolfotuh, B. Abdullah, H. M. K. Mahdi and S. Eldawlatly, "Modulating Lateral Geniculate Nucleus Neuronal Firing for Visual Prostheses: A Kalman Filter-based Strategy," *IEEE Transactions on Neural Systems and Rehabilitation Engineering, Vol. 25, No. 10, pp. 1917-1927, 2017*

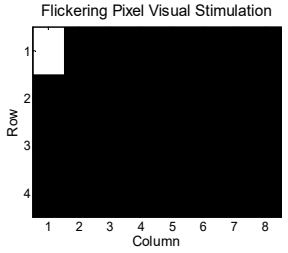
Rat LGN Recordings

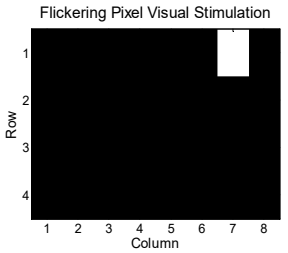
- Albino female rats
- Urethane anesthesia
- Dilated left eye pupil
- In vivo extracellular recordings using 32-channel microelectrode arrays
- Recording at depth of 3.5mm–4mm (Right LGN)

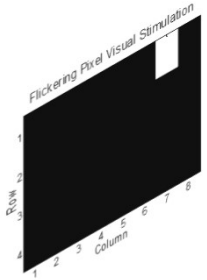


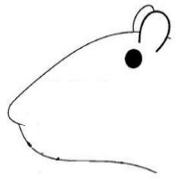
LGN Neurons Response to Visual Stimulation

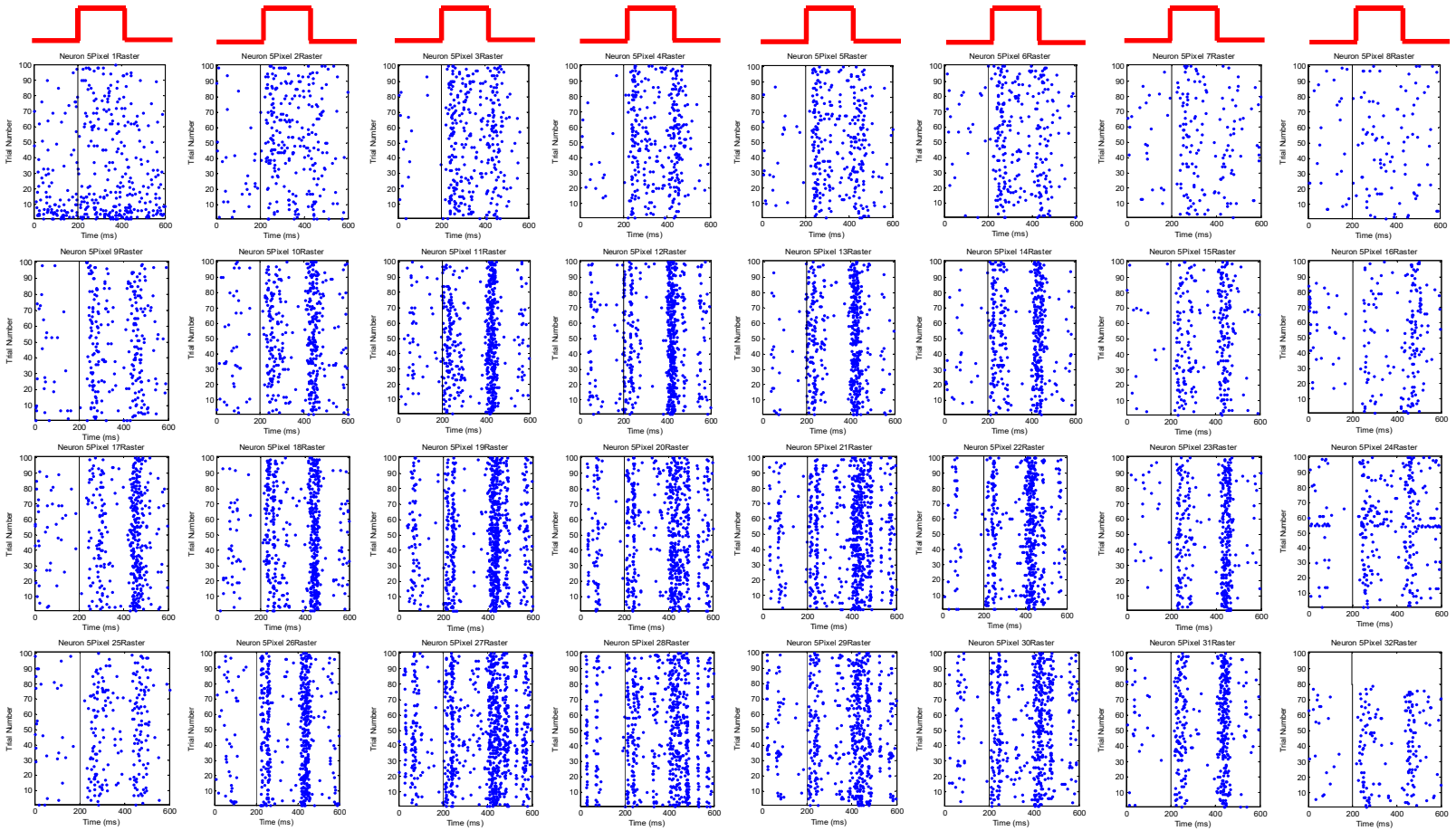
- Visual Stimulus and Response





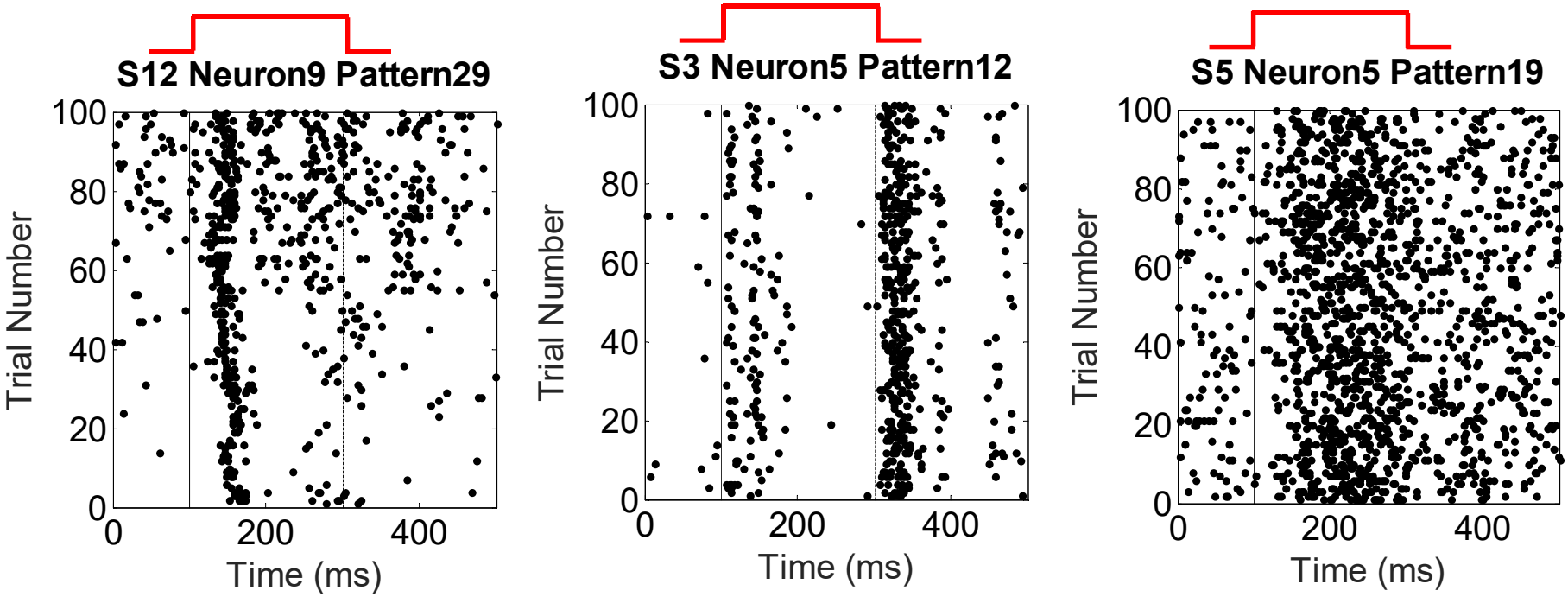






LGN Neurons Response to Visual Stimulation

- Variations in Response Properties



Summary

- We demonstrated how machine learning lies at the heart of neural engineering applications
- Using machine learning algorithms, neural interfaces can read from and write to the brain
- Neural interfaces provide systems that can help disabled people
- Using thoughts to move things and bionic men are no longer science-fiction!

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Ahmed Ossama, BSc
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ITAC
برنامج دعم التعاون بين الشركات والجهات العلمية
Information Technology Academia Collaboration

Information Technology Industry Development Agency (ITIDA)

Thank you