



Brain Data Bank Challenge

- Explorations of Neuroscience for Consumer Neurotechnology

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- IEEE Brain Initiative, CE & Com Society, and Sensors Council

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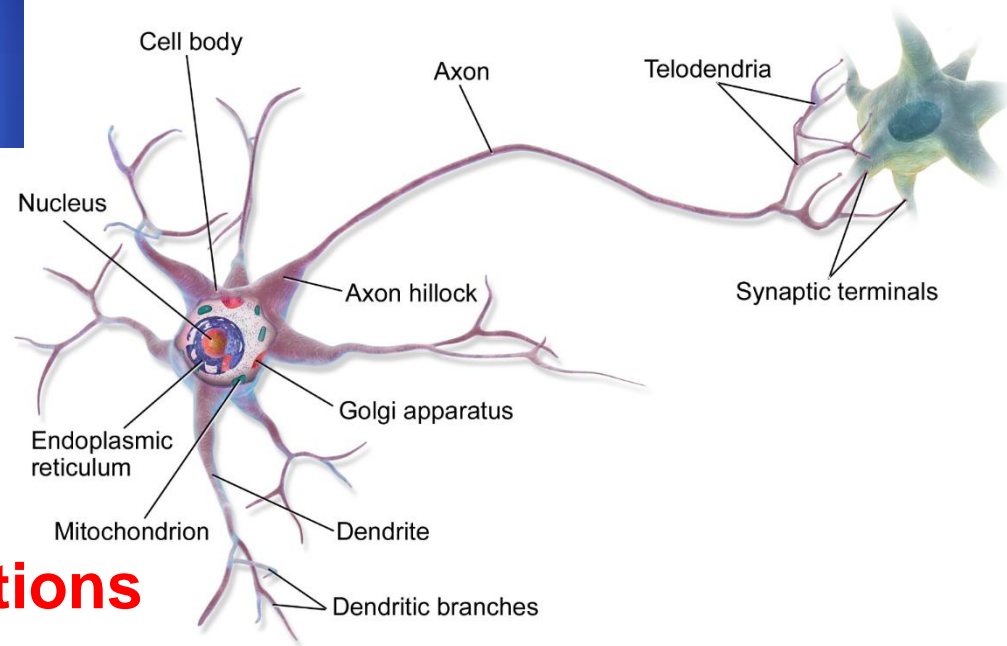
Outline

- **Neuroscience and Neurotechnology**
- **IEEE Brain Exploratory Work**
- **Brain Computer Interface / Brain Data Bank**
- **Case Demonstrations**
- **Summary**
- **Future Directions**

Neurons in the Brain

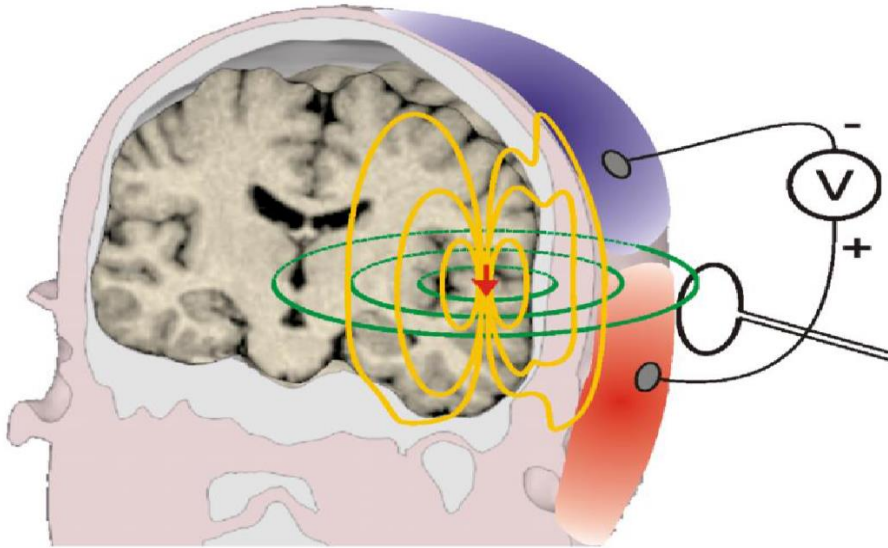


$\sim 10^{11}$ neurons



$10^{14} - 10^{15}$ synaptic connections

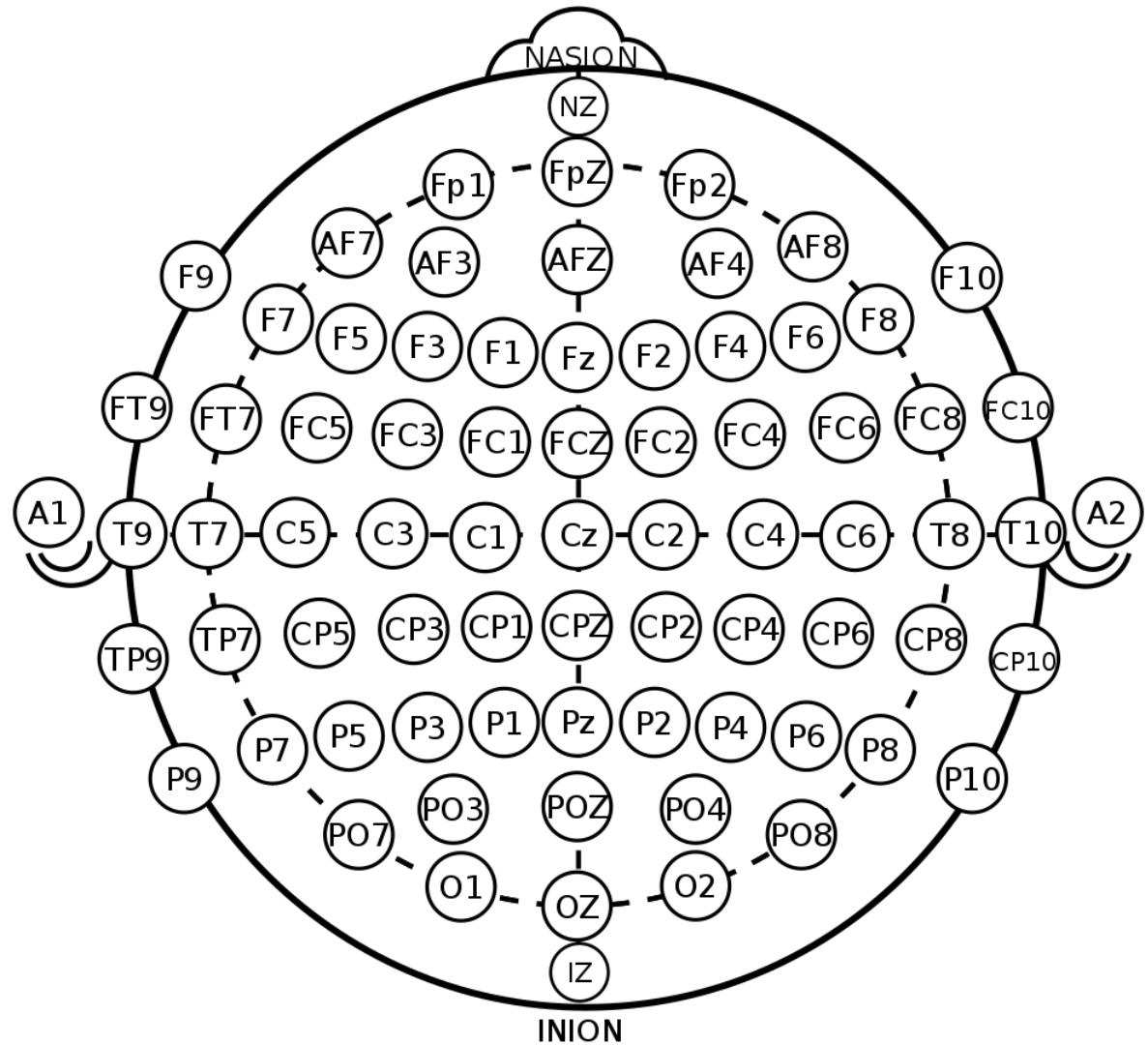
Electroencephalography (EEG)



- Primary currents - Cellular currents due to synchronous firing of large populations of neurons - equally spatially co-aligned.
 - Secondary currents - Extracellular return currents measurable as extracranial electric potentials by EEG.
-
- Resulting EEG scalp potential: $\sim 5 - 10 \mu\text{V}$,
due to attenuation, spatial smearing, etc.
 - Artifacts: $\sim 100 \mu\text{V}$

Modified Combinatory Nomenclature (MCN)

EEG P300



A = M, mastoid process

C – central

F – frontal

Fp – pre-frontal

I – Inion

N - Nasion

O – occipital

P - parietal

T – temporal

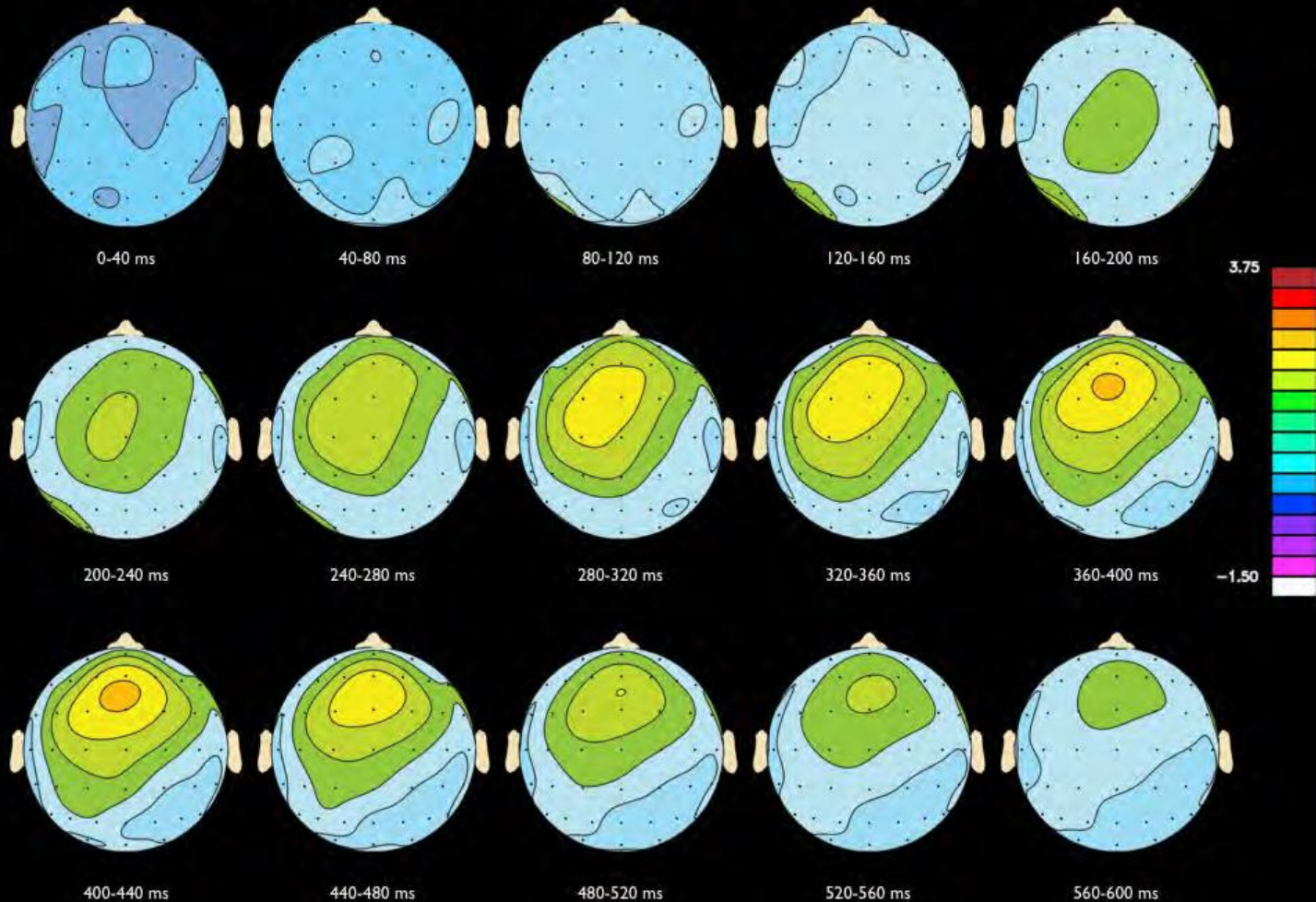
Z – zero, midline

[https://en.wikipedia.org/wiki/10%E2%80%9320_system_\(EEG\)](https://en.wikipedia.org/wiki/10%E2%80%9320_system_(EEG))

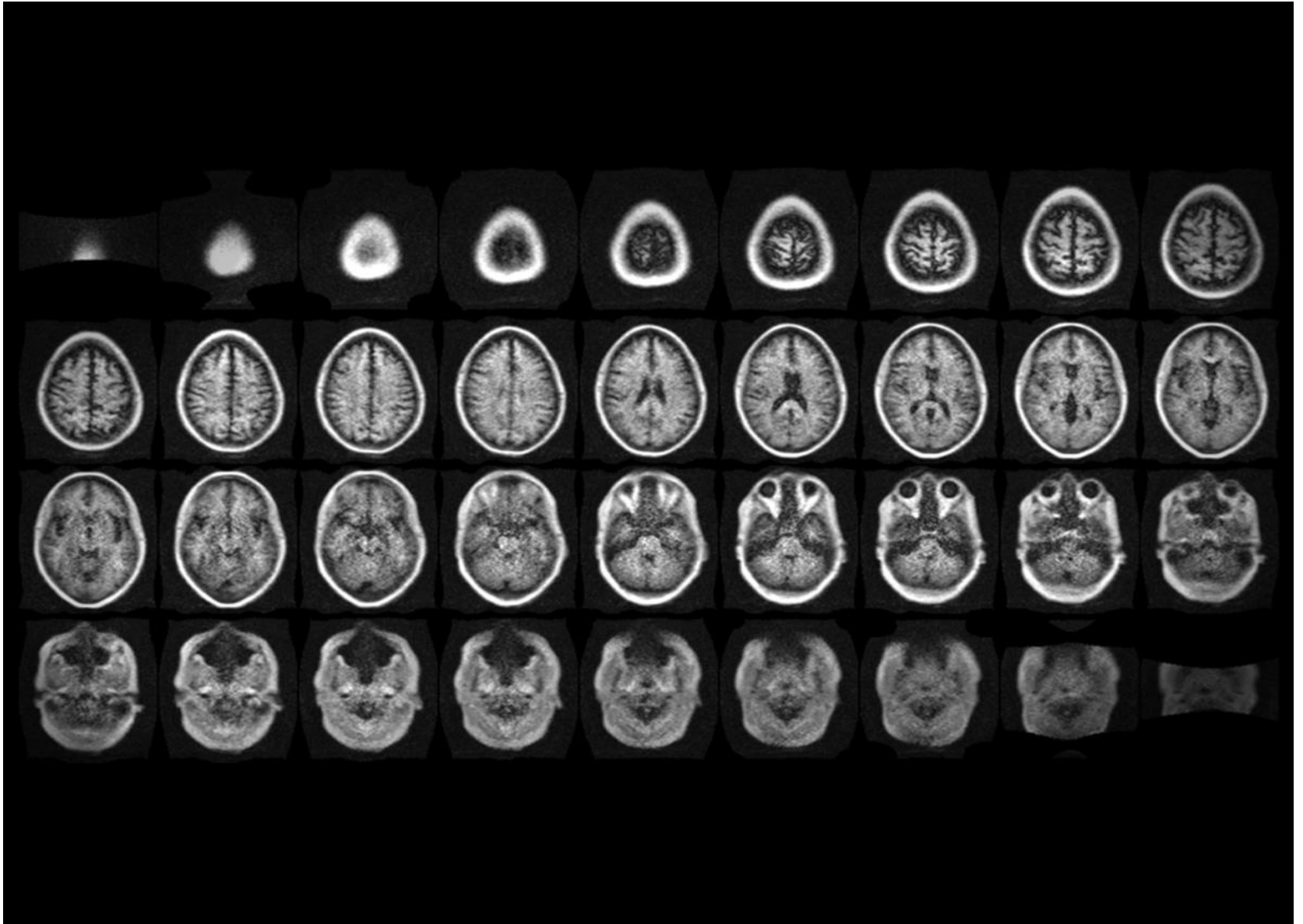
Theta Power Peak at 400 ms

(UCSF dataset, 64 sensors)

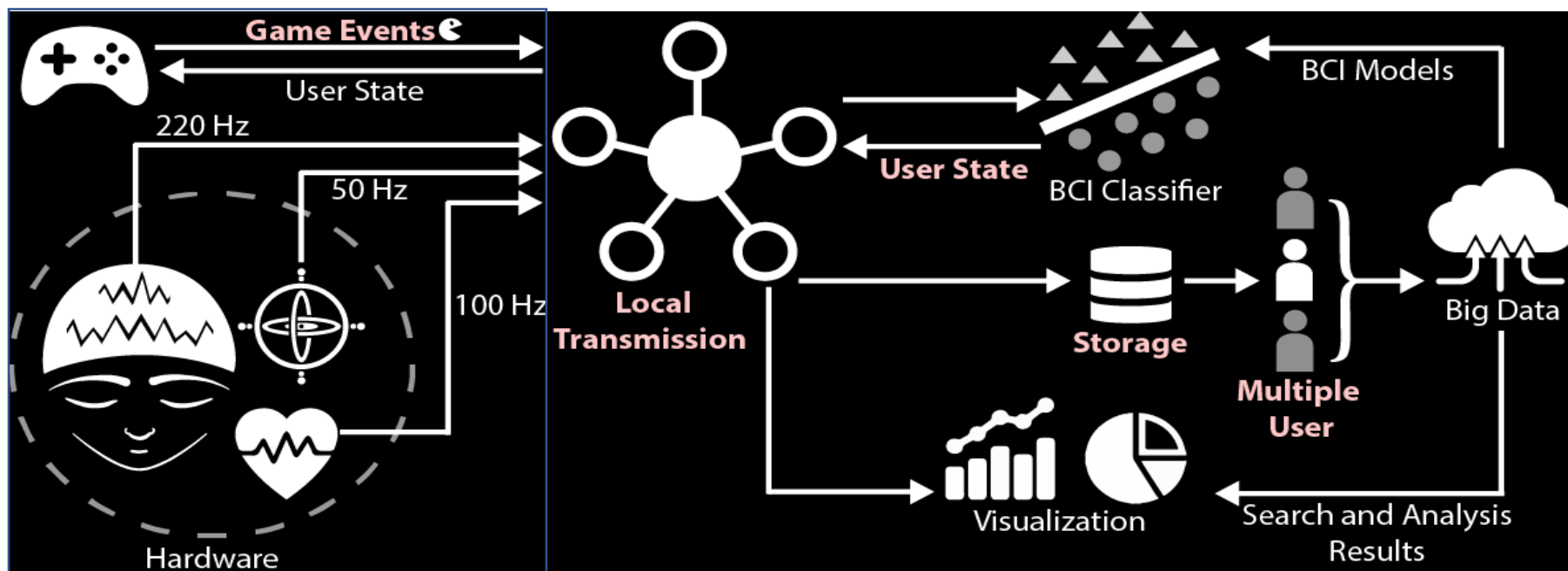
Older Adult Sign & Drive Theta Power



Magnetic Resonance Imaging (MRI)



Brain Data Interoperability : CTA-2060



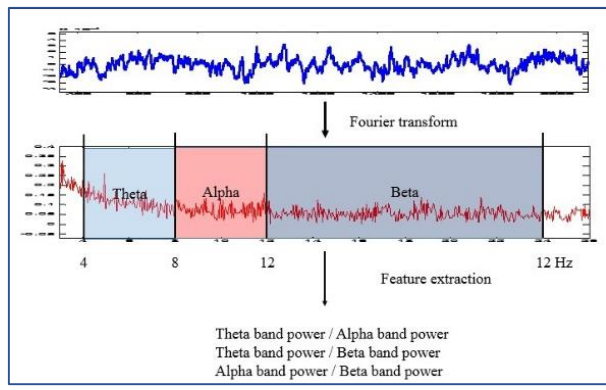
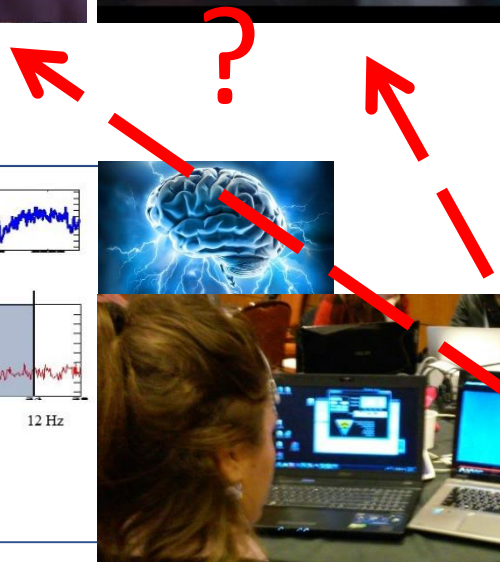
Source: N. Bigdelys-Shamlo, T. Mullen, C. Kothe, N. N. Chu, & K. A. Robbins, 2015

Brain Initiative in Action: Hackathons/Challenges/Competitions

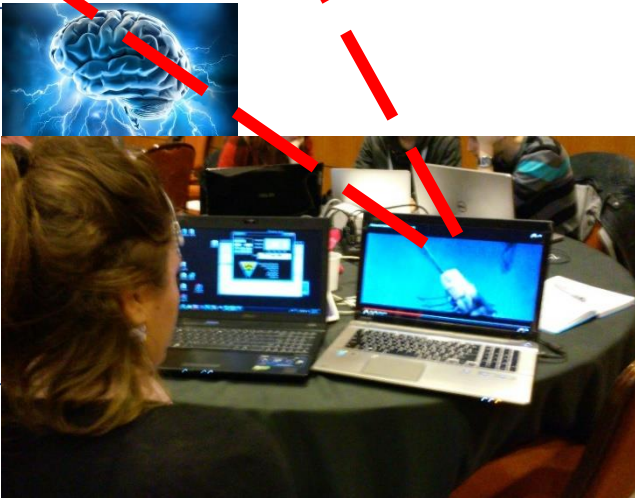
- 2016 – > BCI : Brain Computer Interface
- 2017 – > BDB : Brain Data Bank - Analytics & Usability
- 2018 – > AI/ Machine Learning/Neural Network
- Participants at 8 BDBC include:
 - Graduate students/faculty from UCSD, CSU-SD, NCU, UC-Berkeley, Drexell, UPenn, Columbia, Strathclyde, Glasgow, Jadavpur, MIT, Harvard Medical, Georgia Tech, UMKC, St Petersburg State, Pavlov-Physiology-RAS, HSE-RAS, NWPU, TJU, SUNY-Buffalo, Colorado, North Texas, Polytech Montreal, CHUM, Kiel, UNO, SUND, Chapman ...
 - Some start-ups / entrepreneurs from: San Diego, Taiwan, Boston, India, Singapore, Hungary, Slovenia ...

Cloud Analysis of Frontal EEG for Online “Like/Dislike” Mood Detection - NCU, Taiwan, 2016

Cloud Computation

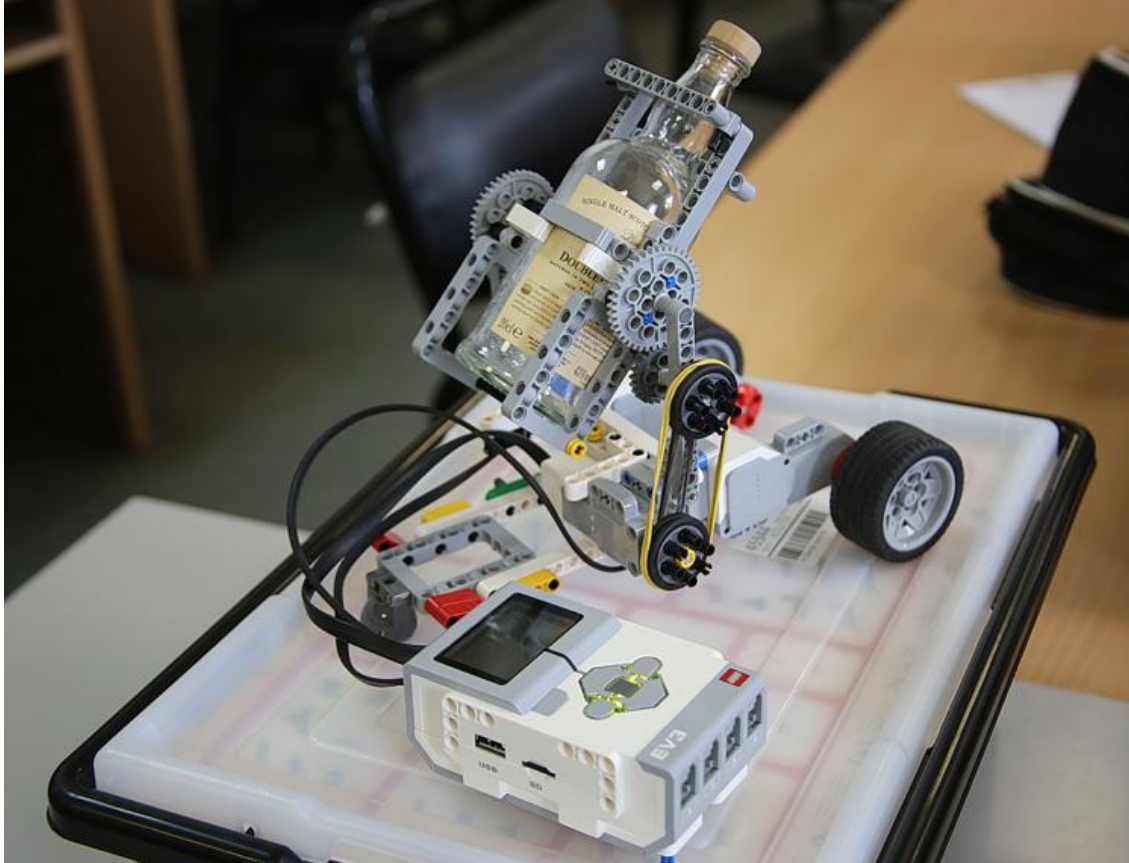


EEG – Eye Blinking + PPG/ECG



The result of emotion detections:
16/20 = 80 %, from Budapest

BDBC-SP Champion – HSE, RAS, St. Petersburg “Multi-user Motor Imagery BCI for Cooperative & Competitive Interaction” - 2017



<https://yadi.sk/i/x1t-i5BP3KUkPf>

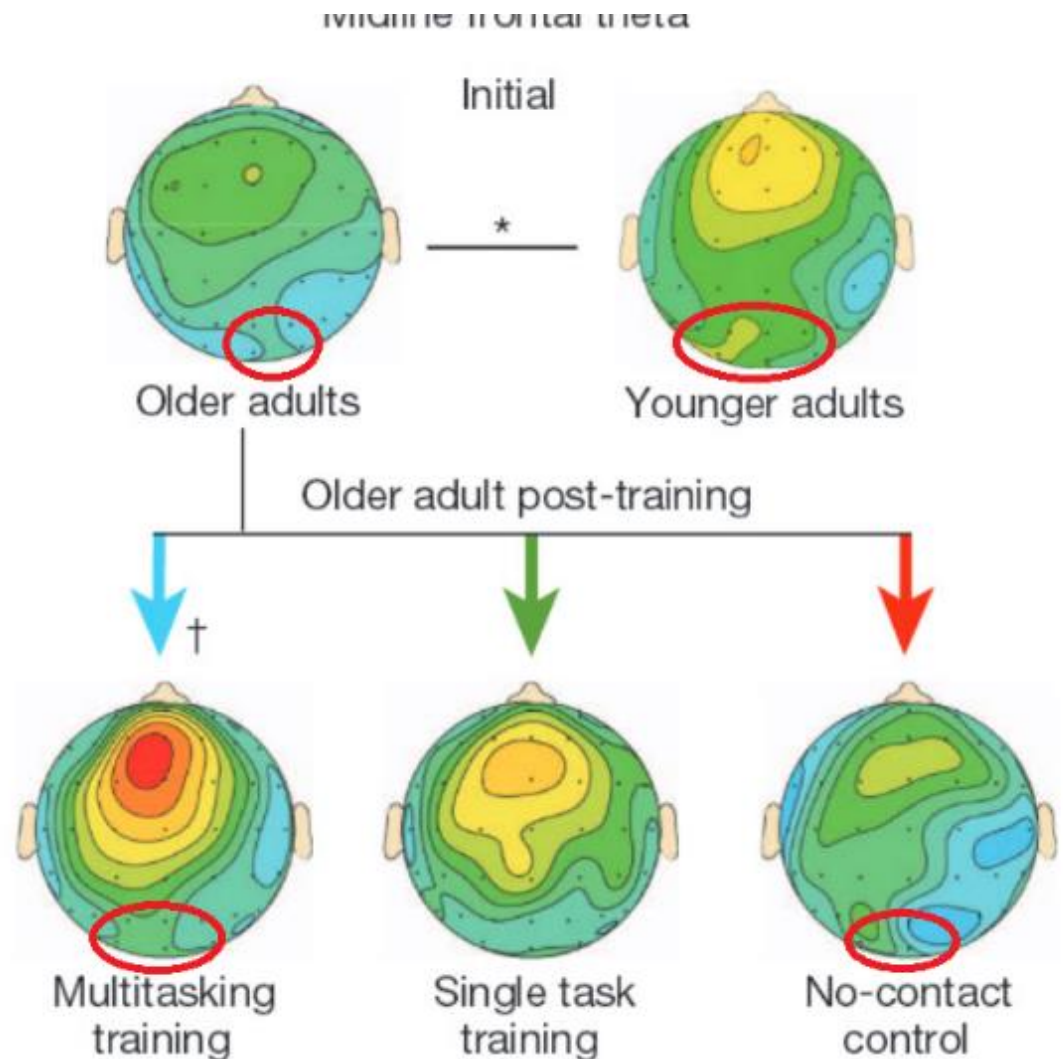
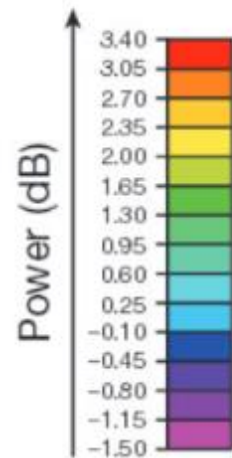
BDBC-Seattle Champion-UMKC: “Brain Insight” Using UCSF Original Datasets (> 350 GB)

174 Subjects, age 20–80

47/41 qualified Subjects; age 60-79

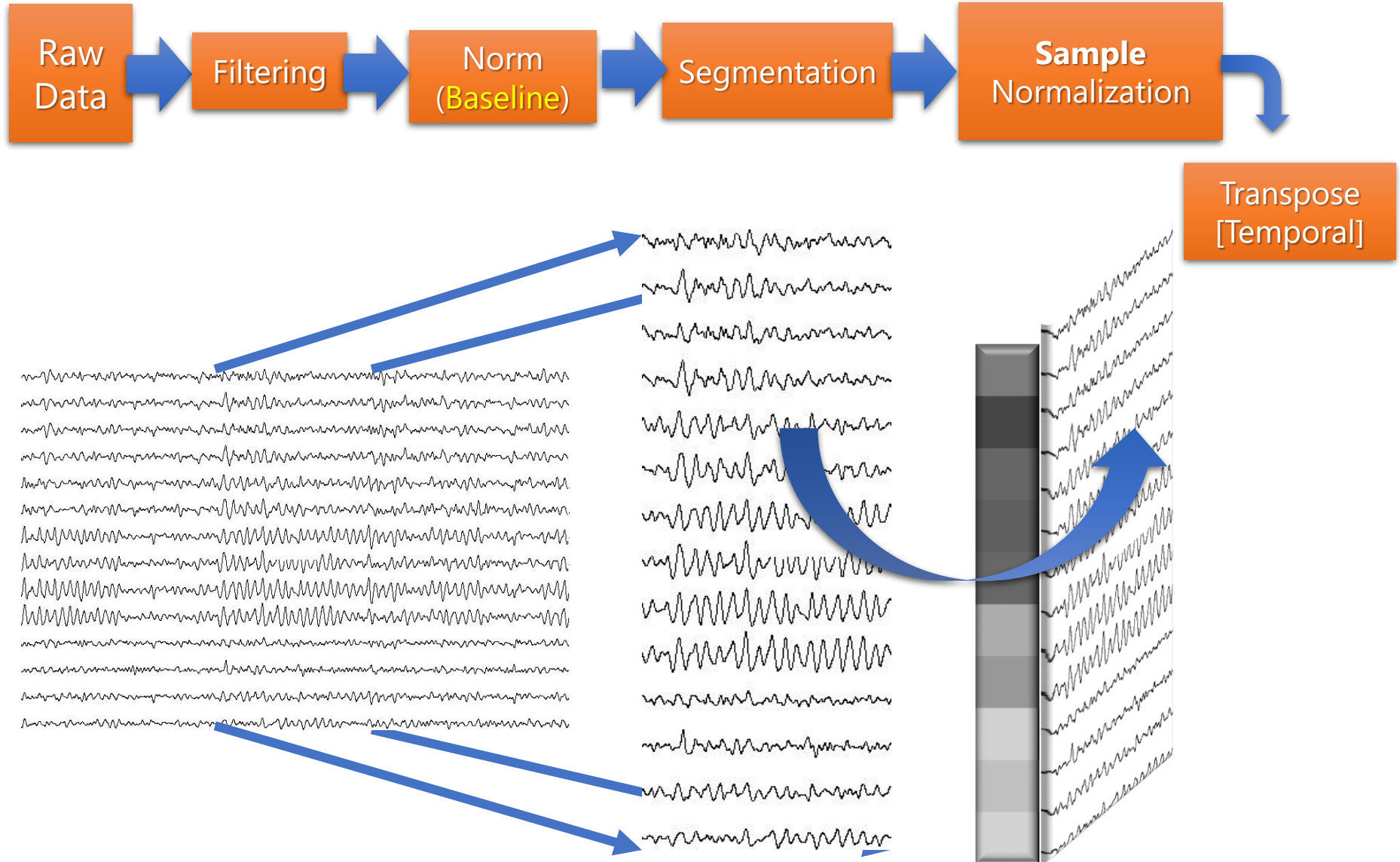
3 groups : each ~14 subjects

EEG taken in 2013 & 2018



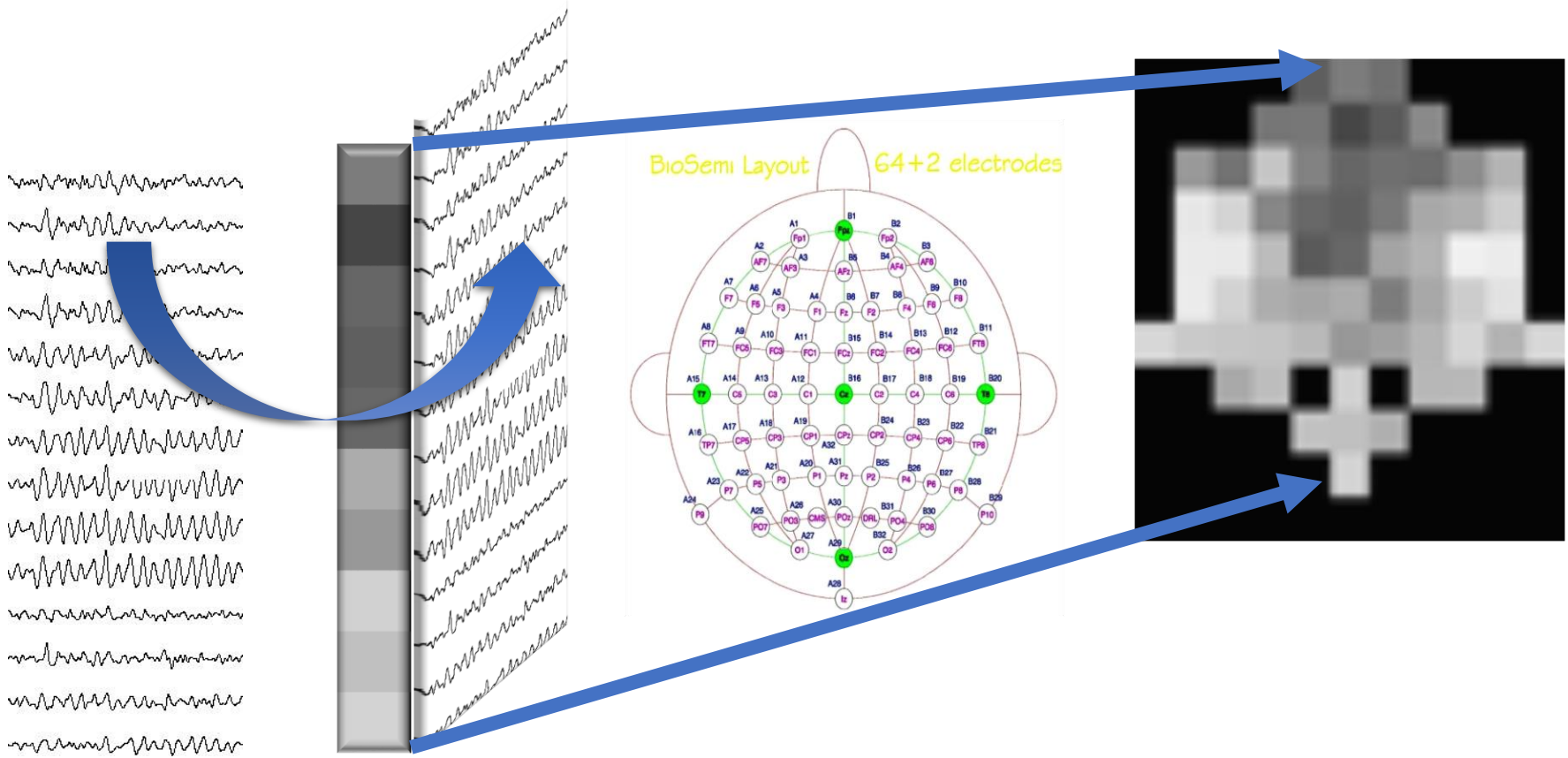
Conventional Pipe Line: Data Transformation

Data Preprocessing:

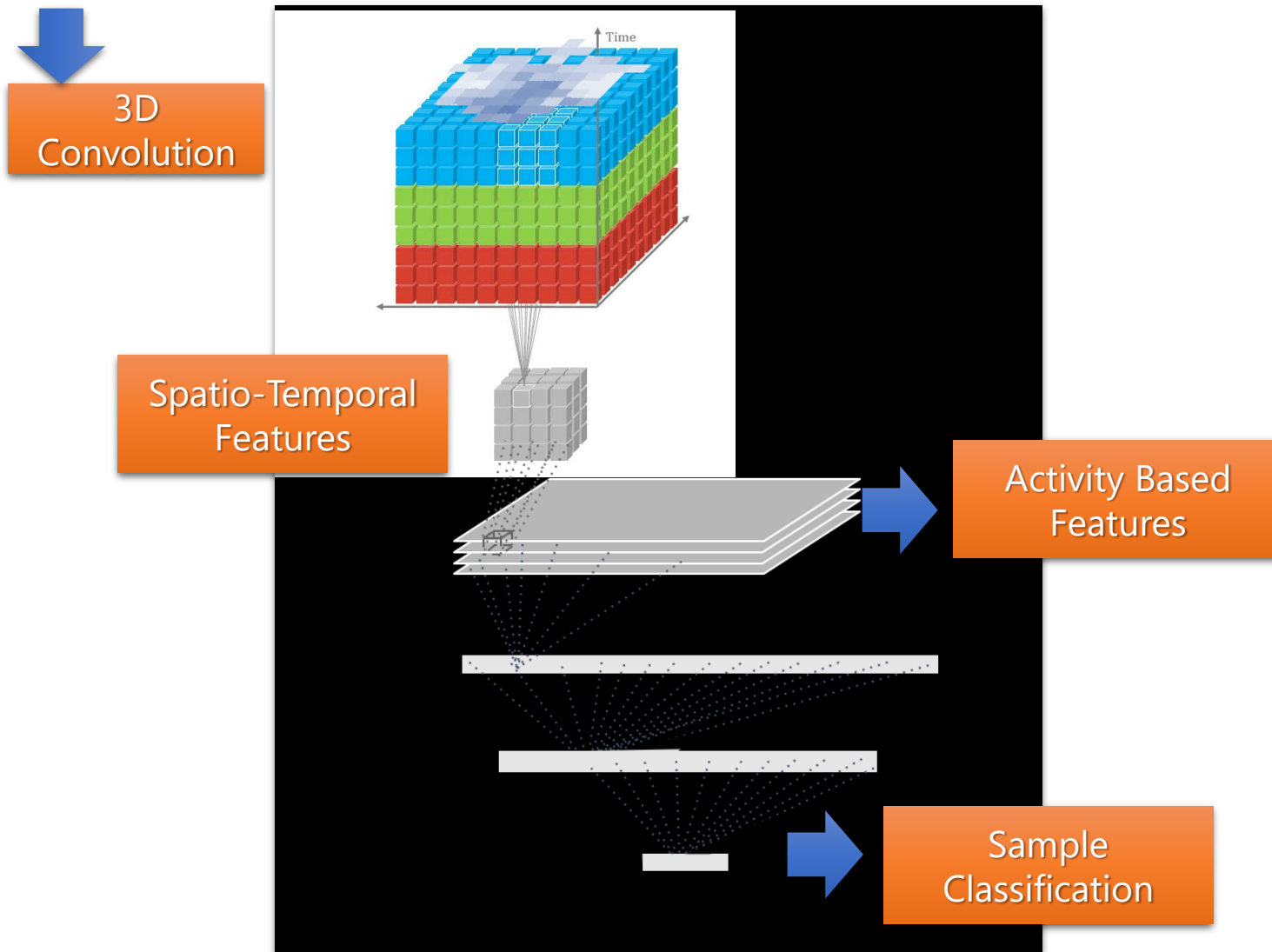


Alternative Pipe Line: Data Transformation

Data Preprocessing:

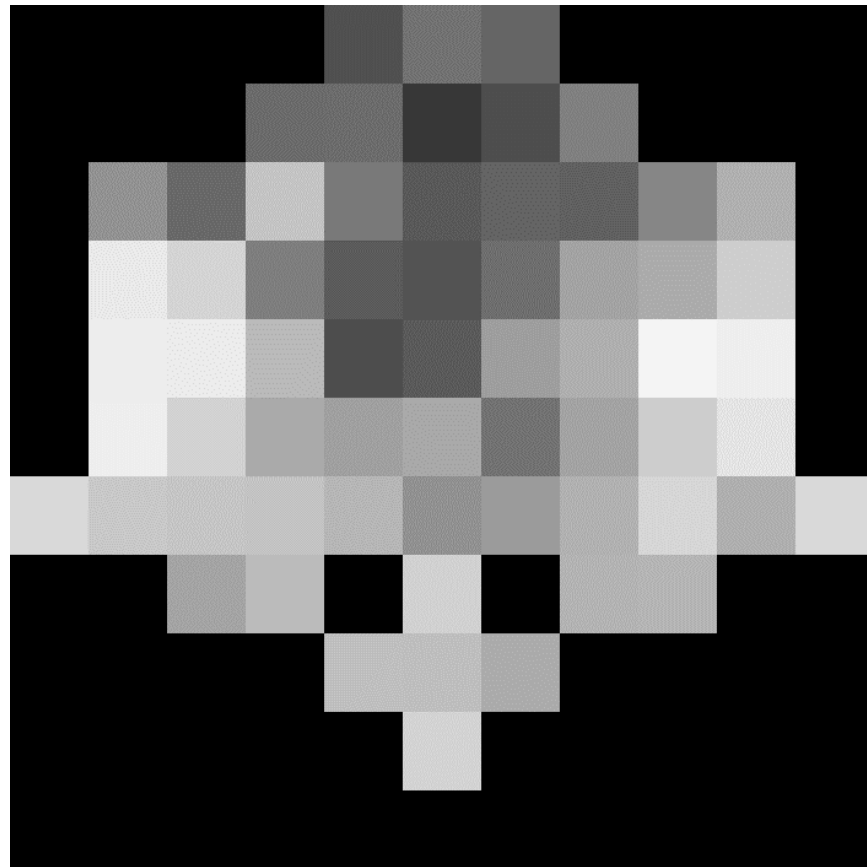


New Pipe Line: 3D Convolutional Neural Network



Data Visualization

Average combined response:
(40-sample, single subject)



Datasets used in BDBC Presentations

Presentation Title in brief	BDBC Year	Authors' Affiliation	Dataset Name	Dataset Year
Cloud Analysis-detect mood	2016	NCU & CWI , Taiwan	NCU "Mood"	2016
Brain wrestling	2017	HSE, RAS, Russia	NFB Lab	2017
BCI data labeling	2017	Pavlov Inst. RAS, Russia	Tender's "Attention"	2011
Reading; easy/difficult	2017	TCS & Jadavpur U., India	Jadavpur Univ.	2017
Stress - bias, frustration	2017	TCS , India	AffPAC	2009
Intelligence Training	2017	GIT & CRA , USA	INSIGHT	2016
Dimensionality	2018	UKMC, USA	NeuroRacer	2013 & 2018
3D CNN	2018	UKMC, USA	NeuroRacer	2013 & 2018
Deep Learning	2018	SUNY-B, UCB & UNT, USA	NeuroRacer	2013 & 2018
AI - to predict epilepsy	2019	Polytech Montreal / CHUM, Canada	Melborne	2013
CNN- to predict epilepsy	2019	U-Kiel, Germany	CHB-MIT	2009
Graphics-Brain Network	2019	UNO & SUND, USA	SPANLab	2017-2019

Characteristics of Datasets & Analytics

Dataset Name	Size (GB)	No. of Channels	No. of Subjects	Physiological Signals	AI/ML	Accuracy, Sensitivity
NeuroRacer	350	64	47/41	EEG	√	87%
CHB-MIT	43	4	22	EEG	√	90%
Melborne	31	16	12	iEEG	√	86%
NCU“Mood”	<1	8	20	EEG,ECG, PPG	√	80%
INSIGHT	12	BOLD	25	fMRI/ DTI	√	77%
“Attention”	<1	62	8	EEG, EOG	√	76%
AffPAC	<1	37	10	EEG,GSR,PPG,EOG,EMG		76%
NFB Lab	<1	32	2	EEG,MEG		by demo.
Jadavpur U.	.337	4	9	EEG, Eye- track		by entropy
SPANLab	WiP	10	35	sMRI-DTI		WiP

Summary

- Single-subject EEG -> Multi-subject EEG correlation.
- The number of subjects for brain signal measurements : 8 ~ 174.
- Qualified subjects for dataset assessment < 50.
- NeuroRacer datasets ~ 350 GB - Data compression via ML -> 1/ 280.
- Using AI increases brain image dataset usability by 15% in accuracy (overall topped at 90%.)
- Aiming for consumer applications: e.g.,
 - 3D CNN enhancement suggests comparable performance by **reducing EEG channels** from 64 to 31 (-> 12 for 10% compromise in accuracy.)
 - **Ultra-low power** IoT application - GAPuino board prototype (with optimized HWCE convolutional engine.)

BDBC-2020 and Future Directions

- Brain Image Processing – to contemplate and complement schemes for more **intelligent** feature selection and classification states
- **AI** algorithms to overcome brain dataset idiosyncrasy
- 3D Visual Display showing brain image **dimensionality**
- **Graphic-centric** neural network analysis
- Brain dataset **fusion and reliability**
- BDBC-2020 plans to focus on **Aging Brain** and Integration of **East-West** Electronics & Physiology
 - 1st round in Taiwan – Russia – Boston and Webcast
 - Final round in Sunnyvale and Webcast

Thank you!

(Full content: <https://brain.ieee.org/2019-competitions-and-challenges/>)

Q & A ...

Acronym

AI	Artificial Intelligence	HSE	Higher School of Economics
BCI	Brain Computer Interface	ICCE	International Conference on Consumer Electronics
BDB	Brain Data Bank		
BDBC	Brain Data Bank Challenge / Competition	iEEG	intracranial EEG signals
BOLD	Blood Oxygenation Level Dependent	IoT	Internet of Things
CE	Consumer Electronics	MCN	Modified Combinatory Nomenclature
CHB-MIT	Children's Hospital Boston – Massachusetts Institute of Technology	MEG	MagnetoEEG
CHUM	University of Montreal Hospital Center	ML	Machine Learning
CNN	Convolutional Neural Network	MRI	Magnetic Resonance Imaging
CRA	Charles River Analytics, Inc.	NCU	National Central University
CTA	Consumer Technology Association	PPG	Photoplethysmogram
DL	Deep Learning	RAS	Russian Academy of Science
DS	Data Set	sMRI	structural MRI
DTI	Diffusion Tensor Imaging	SPCN	Signal Processing in the Context of Neurotechnology
ECG	ElectroCardioGram	SUNY-B	State University of New York at Buffalo
EEG	ElectroEncephaloGram	SVM	Support Vector Machine
EMG	ElectroMyoGram	TCS	Tata Consultancy Service and Technology
EOG	ElectroOculoGram	UCB	University of Colorado at Boulder
ERP	Event Related Potential	UCSF	University of California at San Francisco
FA	Fractional Anisotropy	UIUC	University of Illinois at Urbana-Champaign
FS	Figure Series	UMKC	University of Missouri at Kansas City
fMRI	functional MRI	UNO	University of New Orleans
GIT	Georgia Institute of Technology	UNT	University of North Texas
GSR	Galvanic Skin Response	WiP	Work in Progress