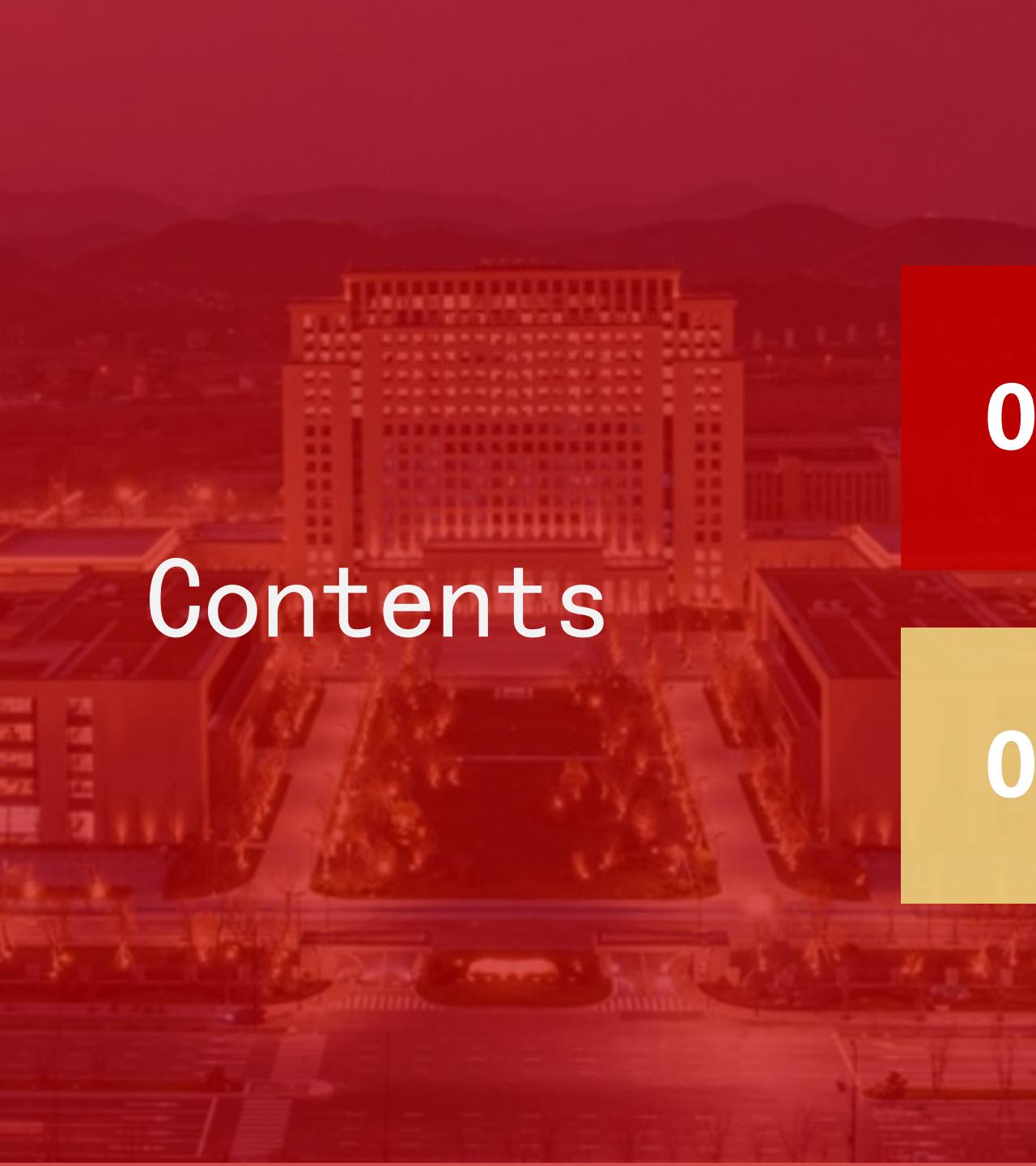


BCI summary

Reporter:
zhengshui13@gmail.com

The background of the slide features a photograph of a modern city skyline at sunset. The sky is a warm orange and red, and the buildings are silhouetted against the light. In the foreground, there's a large, dark building with many windows, possibly a hotel or office building. The overall atmosphere is professional and modern.

Contents

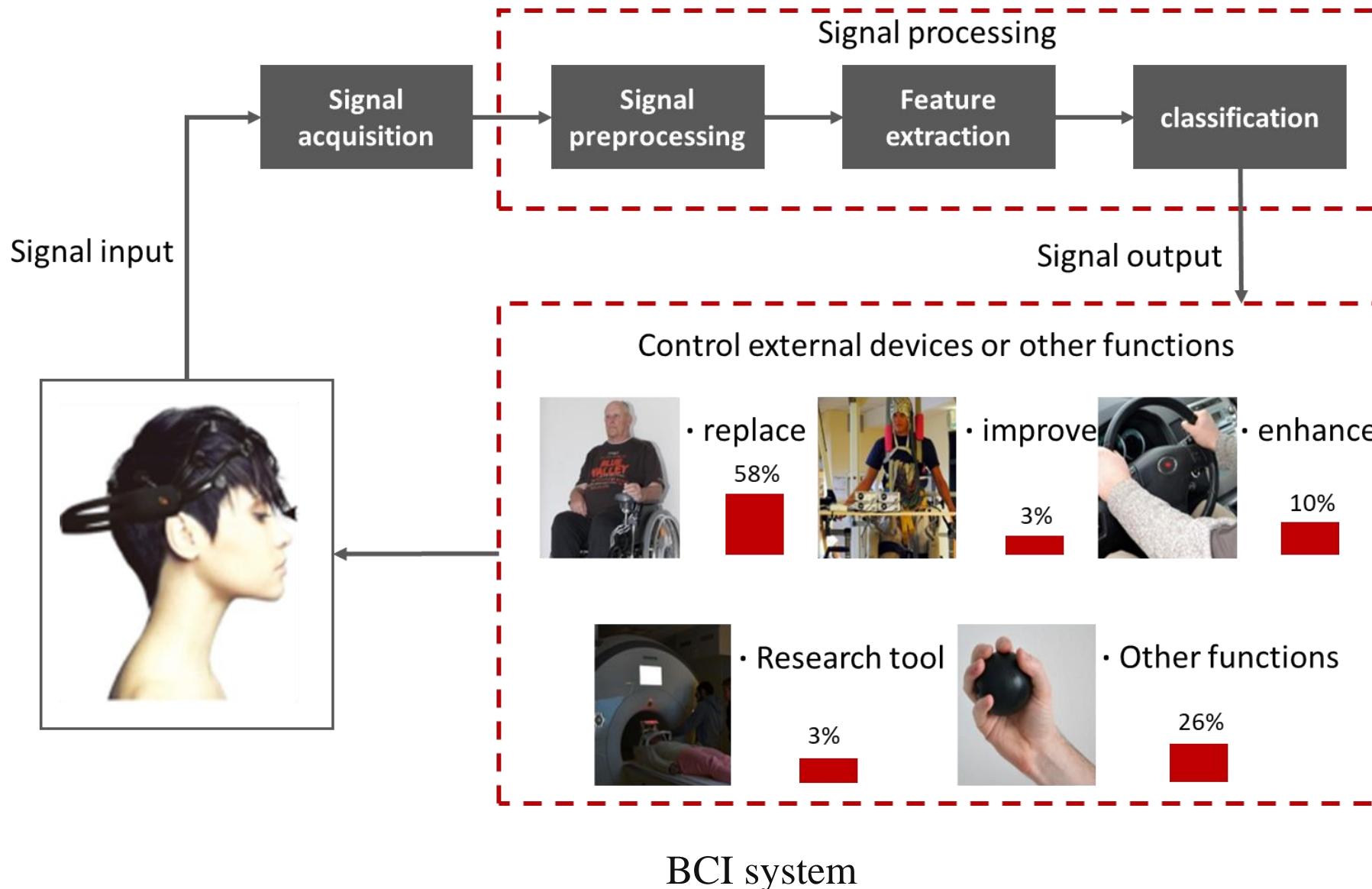
01

Background

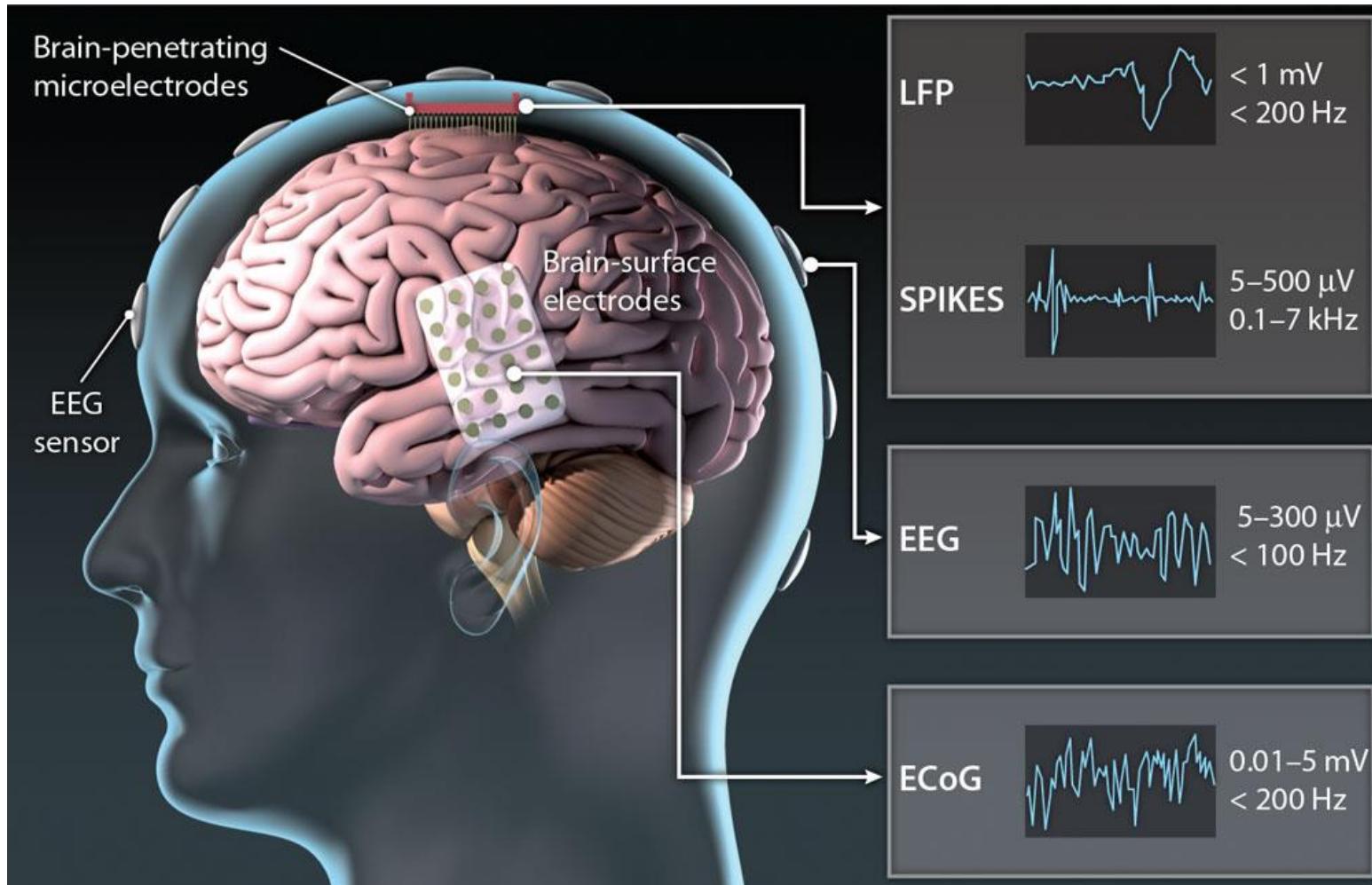
02

Contents

Definition of brain-computer interface (BCI)



Classification of BCI



- **Invasive BCI**
LFP, SPIKE, ECoG
 - **Advantages:**
High signal to noise ratio,
high resolution

- **Non-invasive BCI**
EEG, fMRI, MEG
 - **Advantages:**
Simple operation, no
damage

Thakor et al., Science Translational Medicine, 2013

Case: Invasive BCI

➤ John Donoghue, Brown University

- The paralyzed patient controls the robotic arm to complete the grasping task



Hochberg et al., Nature, 2012

➤ Gregoire Courtine, Lausanne University

- Developed a brain-spinal interface enabling restoration of movement and nerve repair



Lorach et al., Nature, 2023

Case: Invasive BCI

- BCI for language recovery
 - Willett, Stanford University
 - Chang, University of California, San Francisco



Willett et al., Nature, 2023

A high-performance neuroprosthesis for speech decoding and avatar control

Supplementary Video 1:
A demonstration of real-time multimodal decoding from brain activity with simultaneous text decoding, speech synthesis, and avatar animation

Sean L. Metzger*, Kaylo T. Littlejohn*, Alexander B. Silva*, David A. Moses*, Margaret P. Seaton*, Ran Wang, Maximilian E. Dougherty, Jessie R. Liu, Peter Wu, Michael A. Berger, Inga Zhuravleva, Adelyn Tu-Chan, Karunesh Ganguly, Gopala K. Anumanchipalli, Edward F. Chang

Video Editing: Todd Dubnicoff

UCSF Weill Institute for Neurosciences
Department of Neurological Surgery

SPEECH GRAPHICS

Chang Lab

Metzger et al., Nature, 2023

Case: Non-invasive BCI

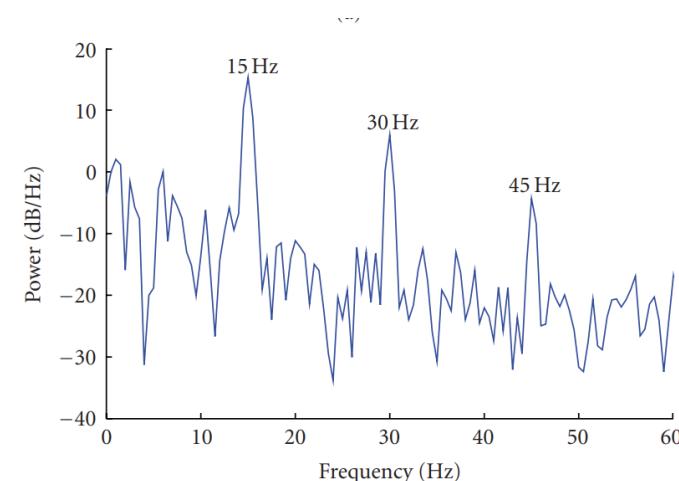
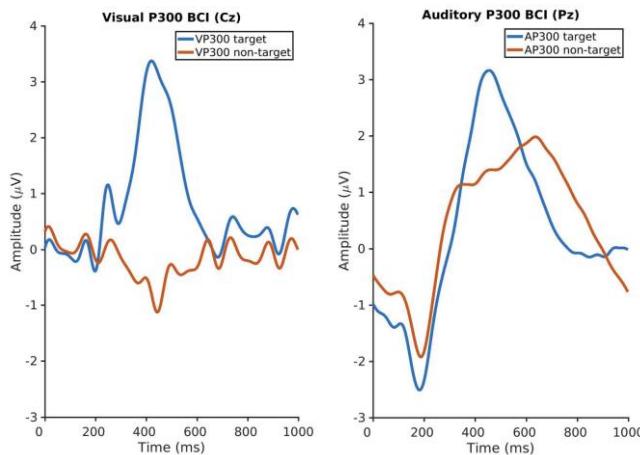
P300



SSVEP

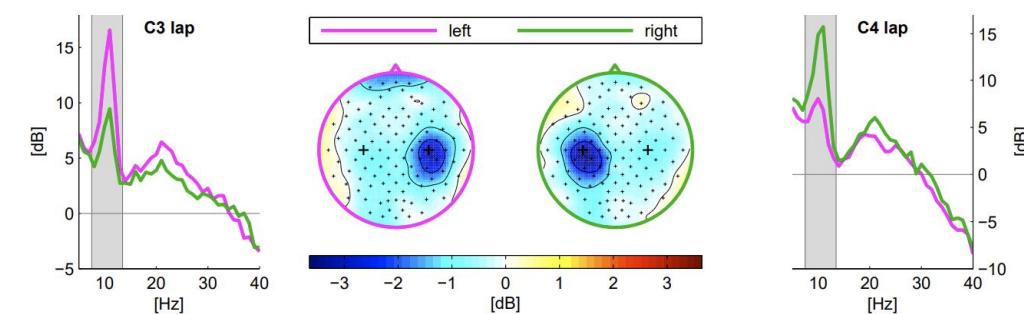


MI



Hammer et al., Neuroscience, 2018

Zhu et al., Neuroscience, 2018



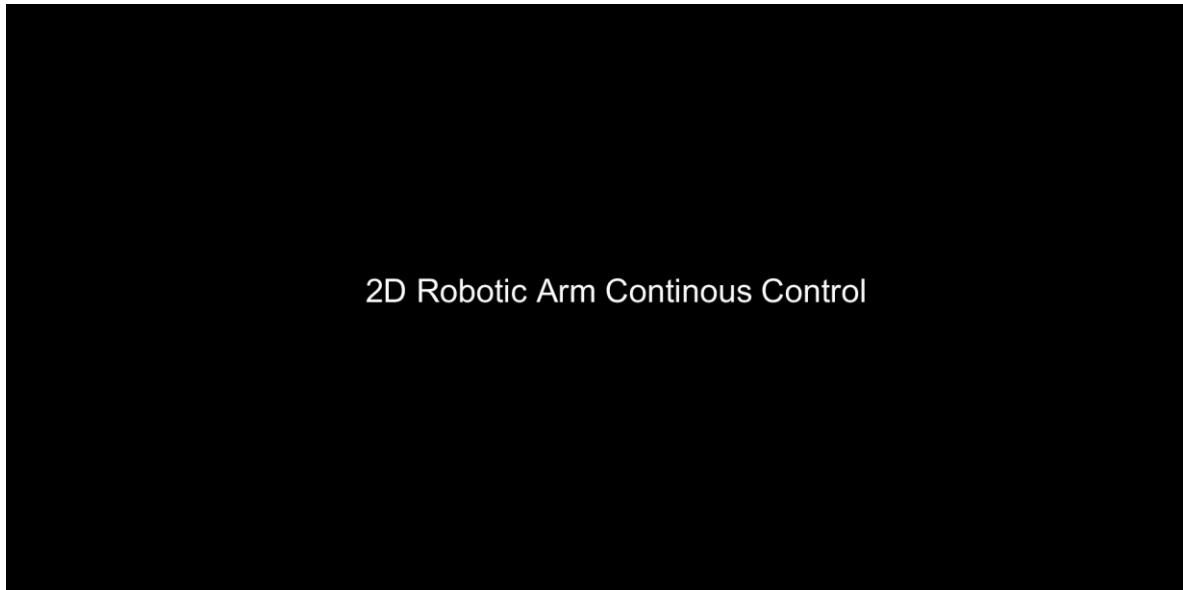
Blankertz et al., NeuroImage, 2010

Case: BCI-MI

➤ External device control

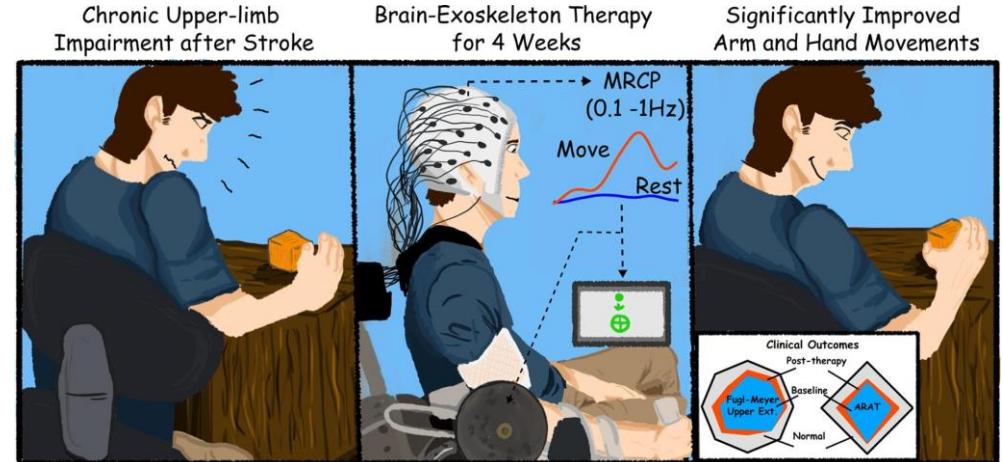
He Bin, Carnegie University

- In 2019, robotic arm controlled by the brain

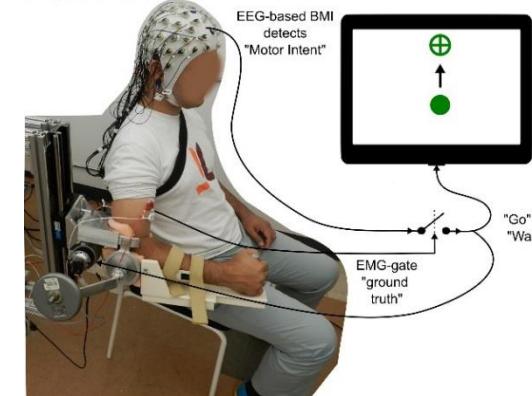


Edelman et al., Science Robotics, 2019

➤ Stroke rehabilitation



B. Experiment Setup

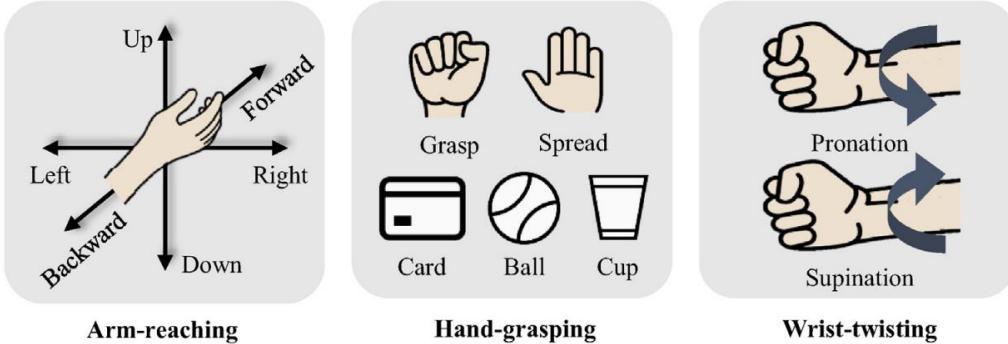


- Neuroplasticity and cortical recombination of BMI

Bhagat et al., NeuroImage: Clinical, 2020

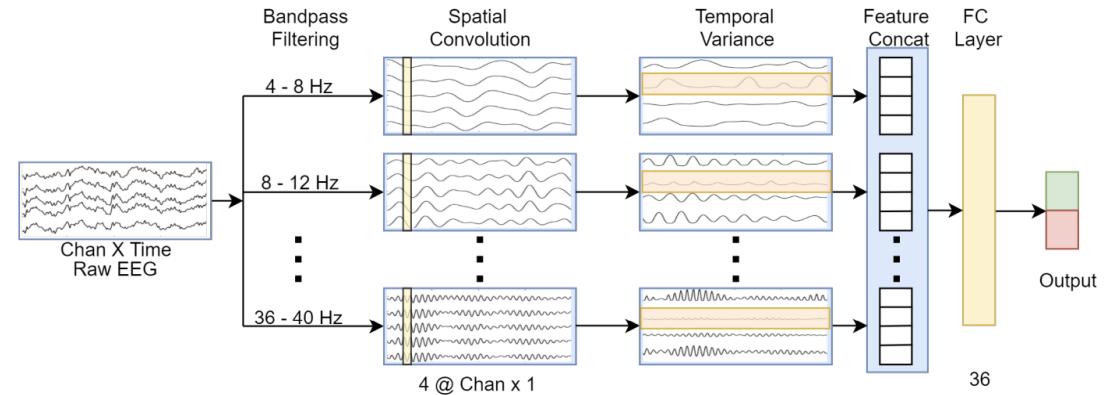
Existing problem and Solutions: BCI-MI

➤ Multi-class

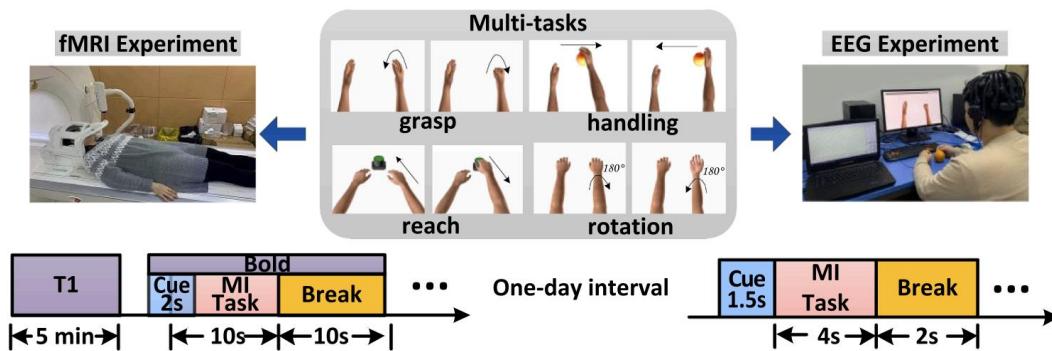


Jeong et al., GigaScience, 2020

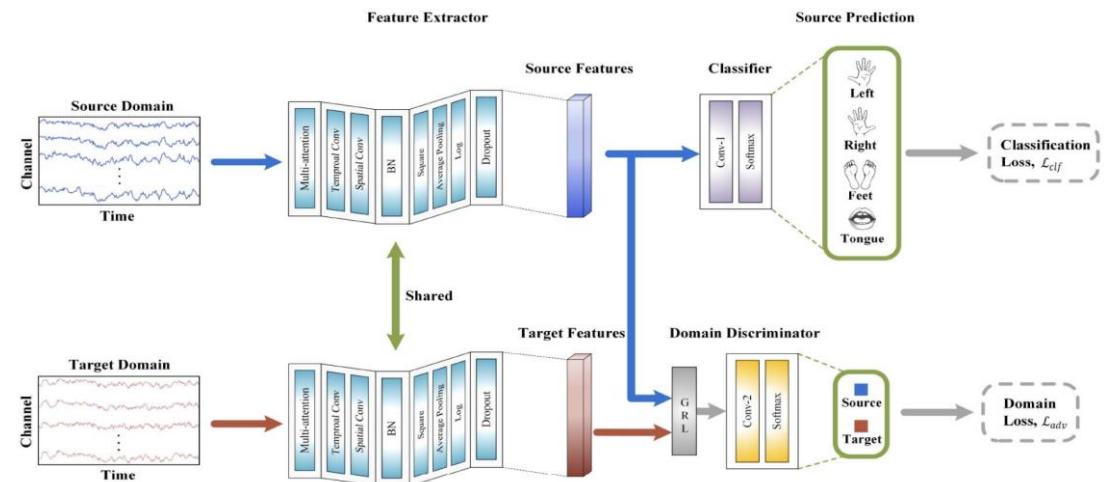
➤ Accuracy rate



Mane et al., EMBC, 2020

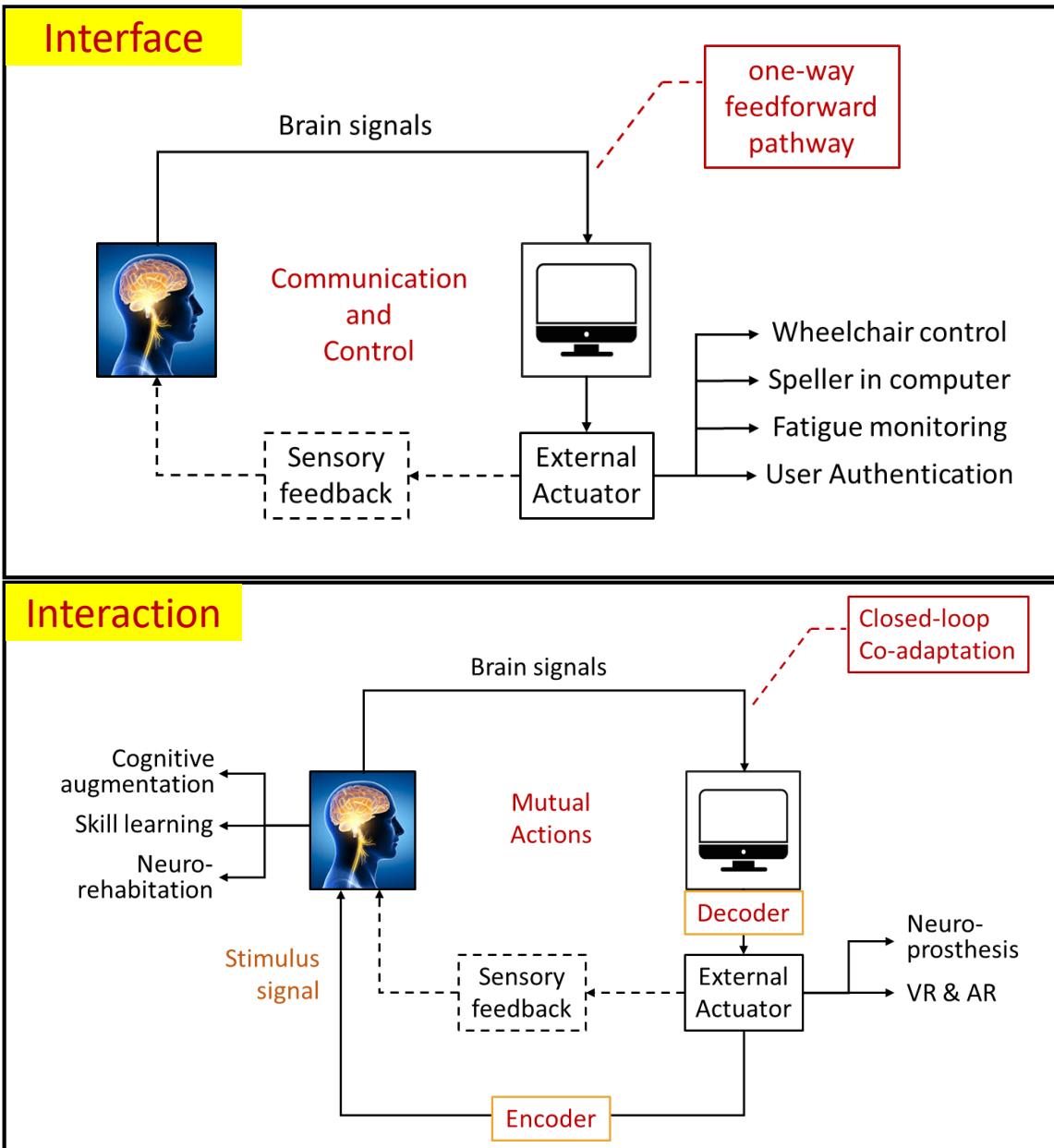


Yang et al., BSPC, 2022

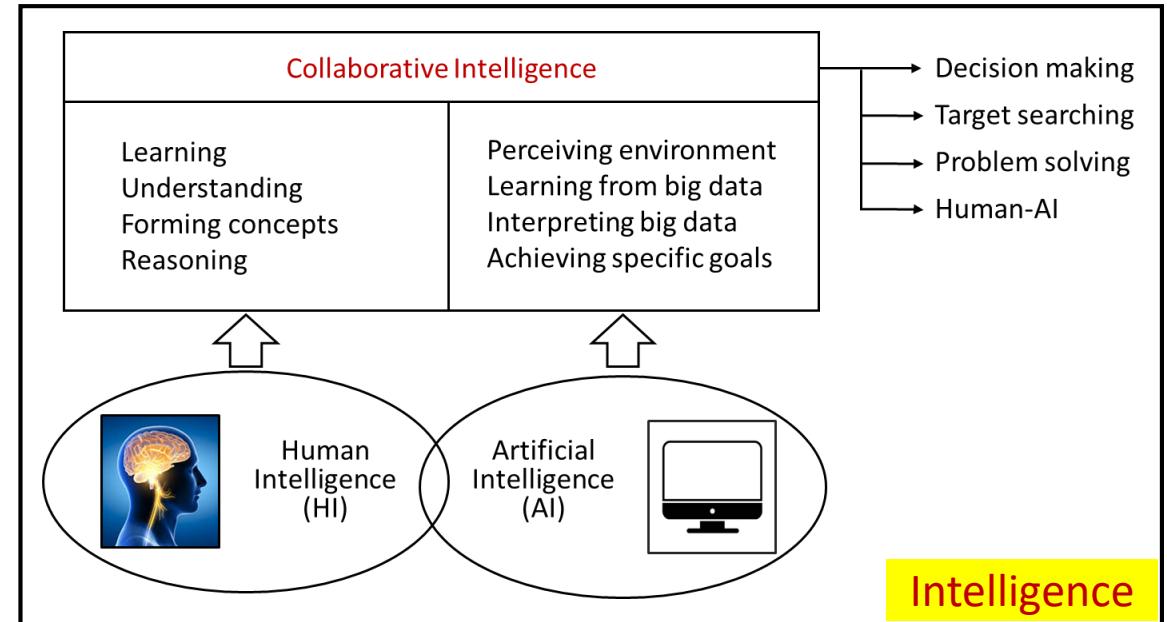


Chen et al., TSMC, 2021

Development and prospect: BCI



➤ Generalized Brain-Computer-Interface



Adapted from Gao et al., TICS, 2021

Contents

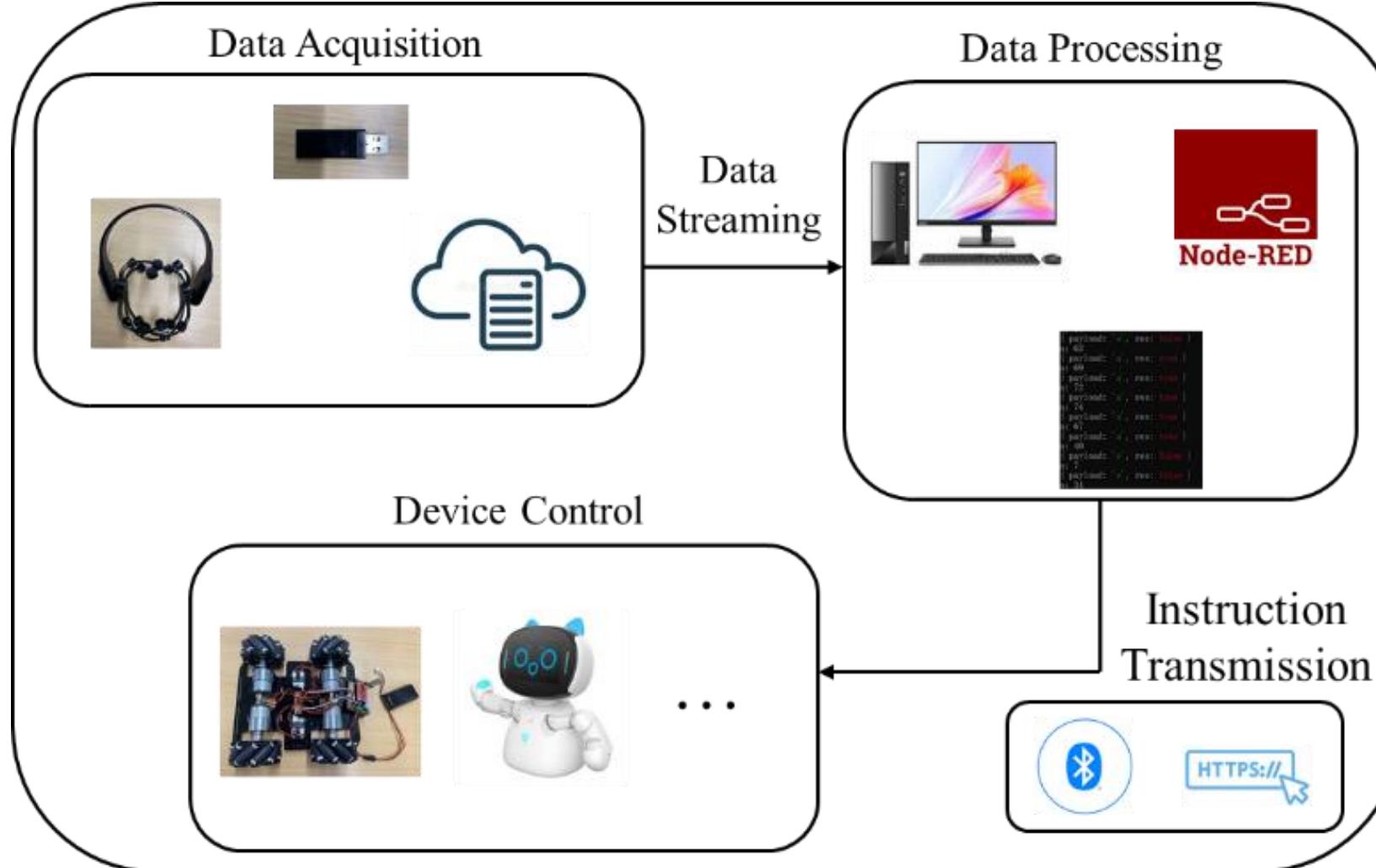
01

Background

02

Contents

BCI information processing platform

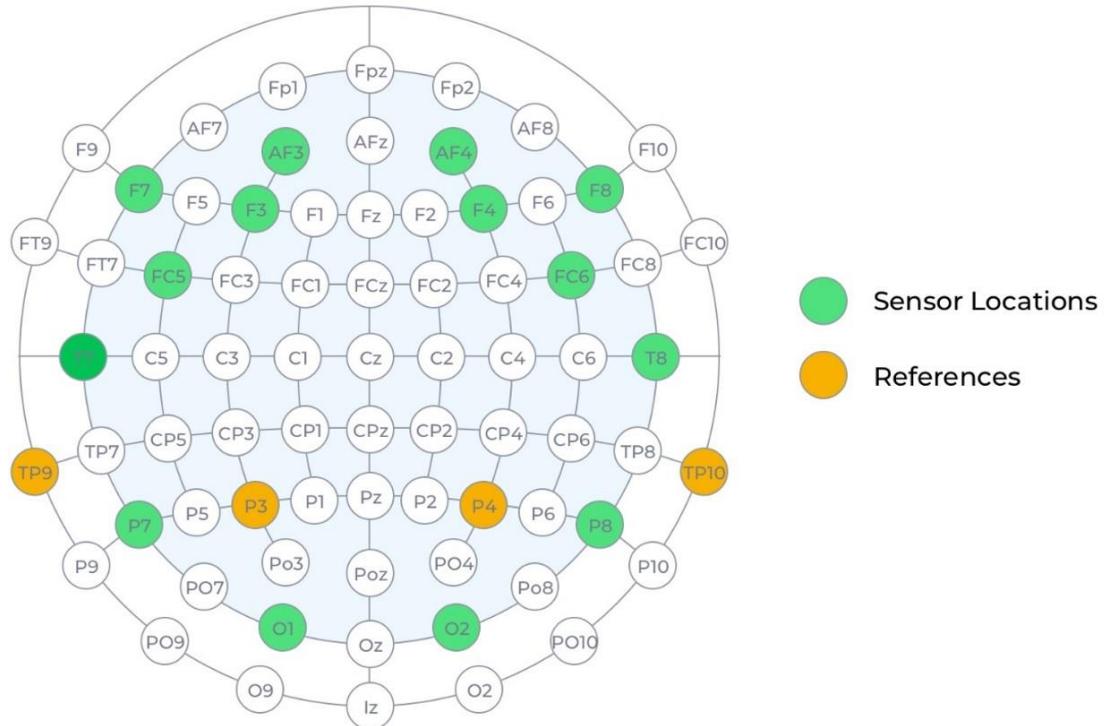


- Developed based on node-red IOT platform
- Simple operation, Robustness and High portability

EEG acquisition

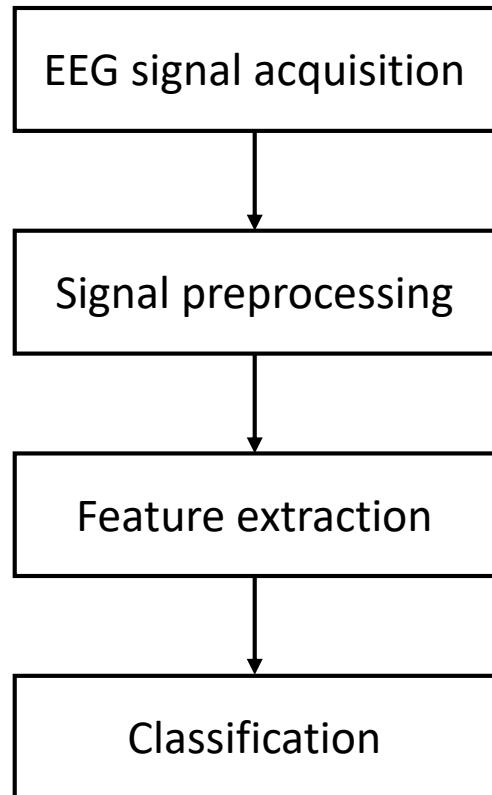


Emotiv headcap

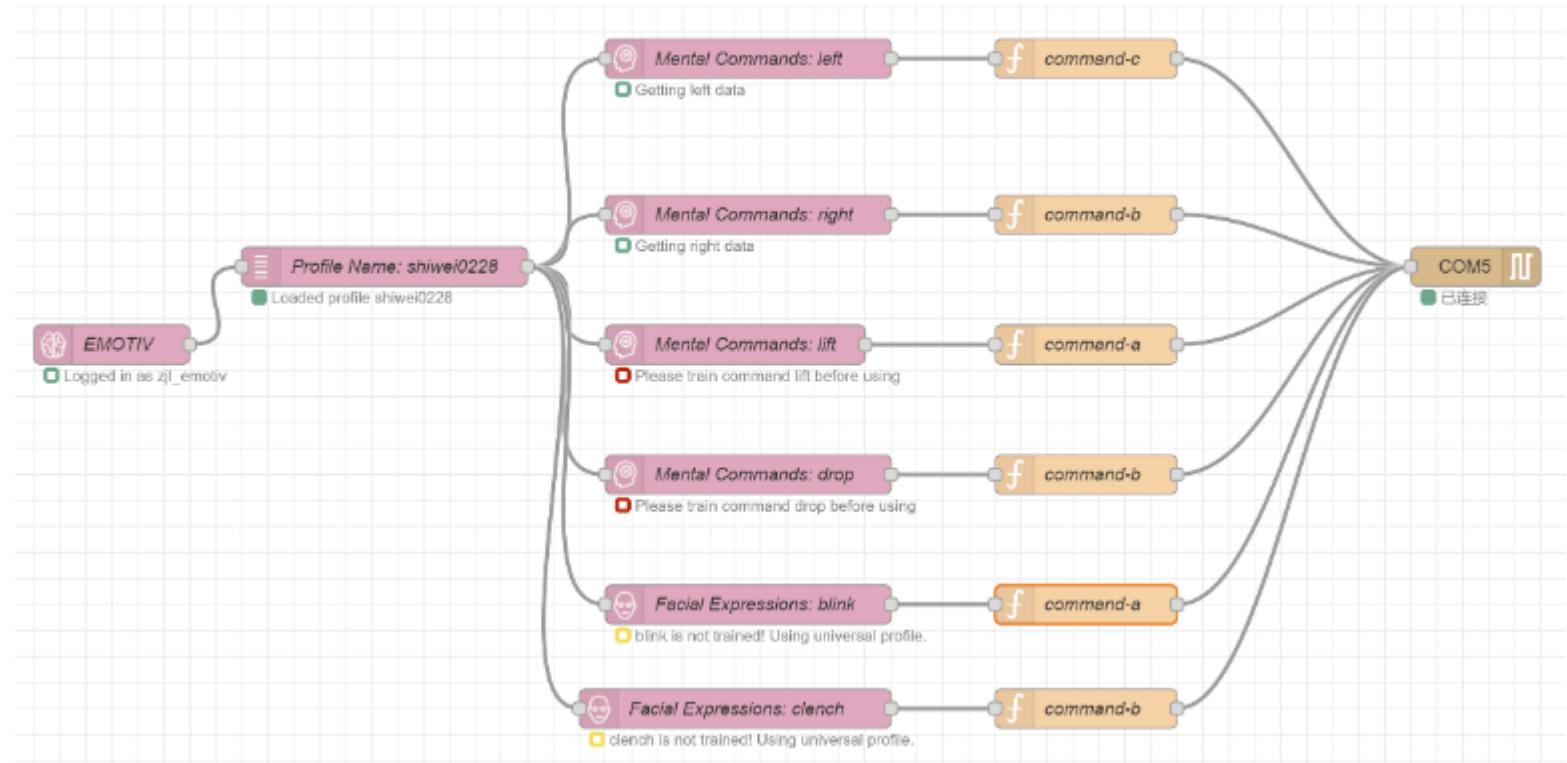


Emotiv EPOC X electrode position
and 10-20 international standard

Signal processing flow and module seal background interface

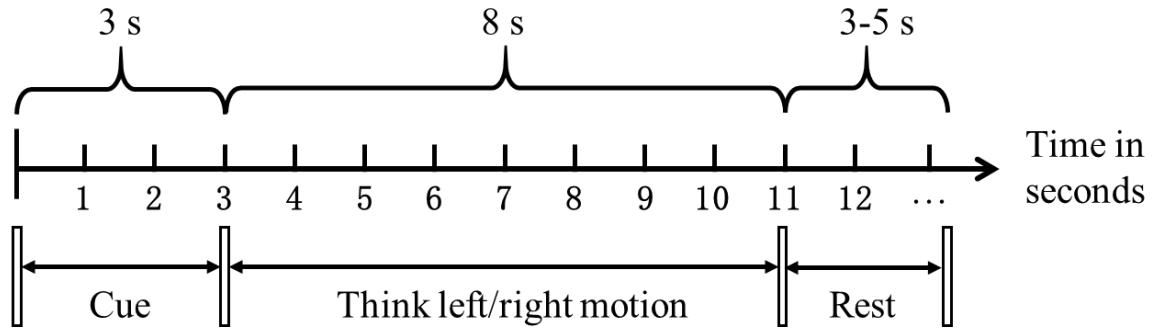


EEG signal processing flow

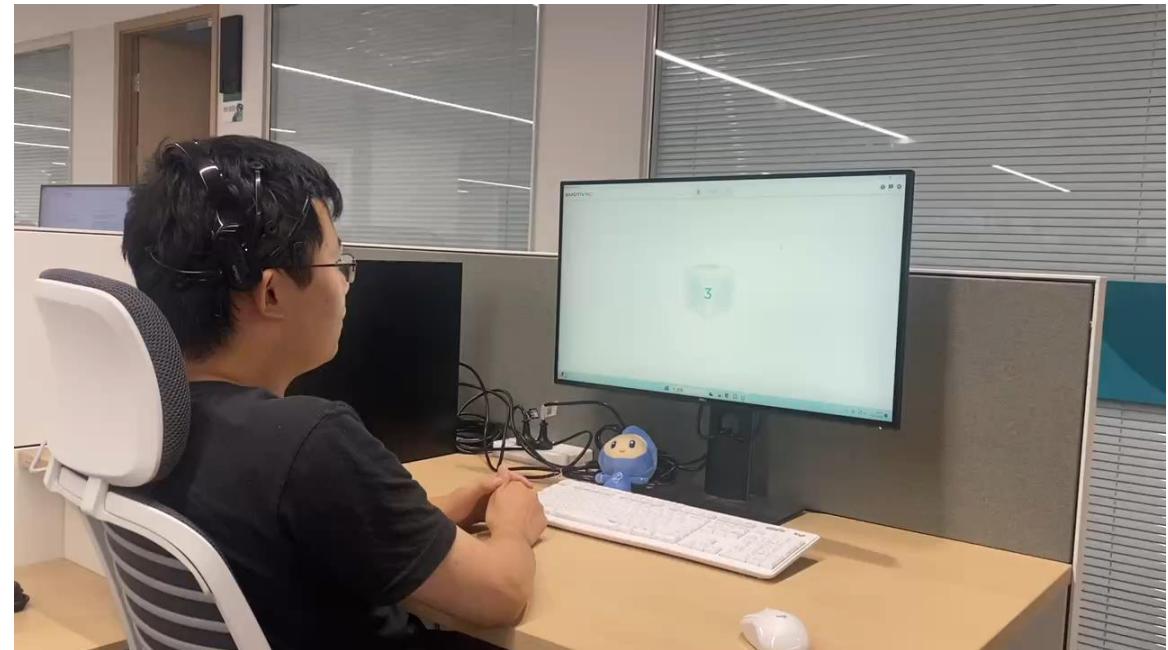


Node-Red background data acquisition and processing

Experimental paradigm

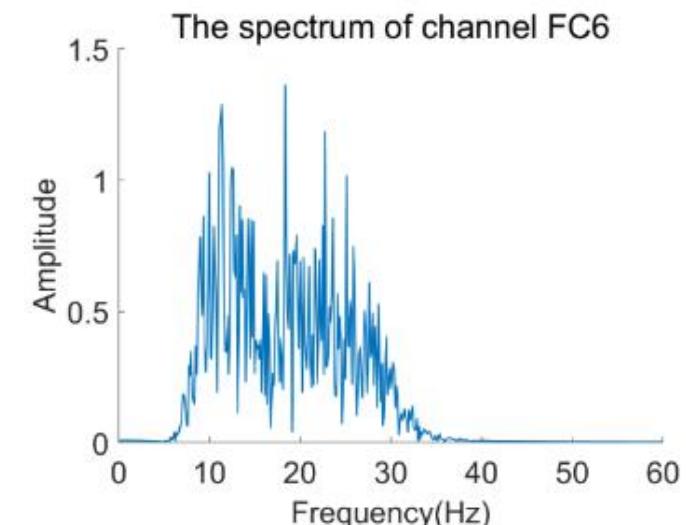
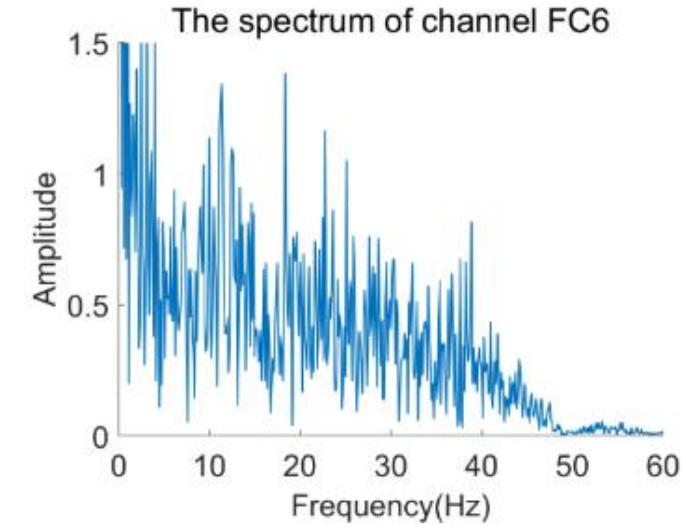
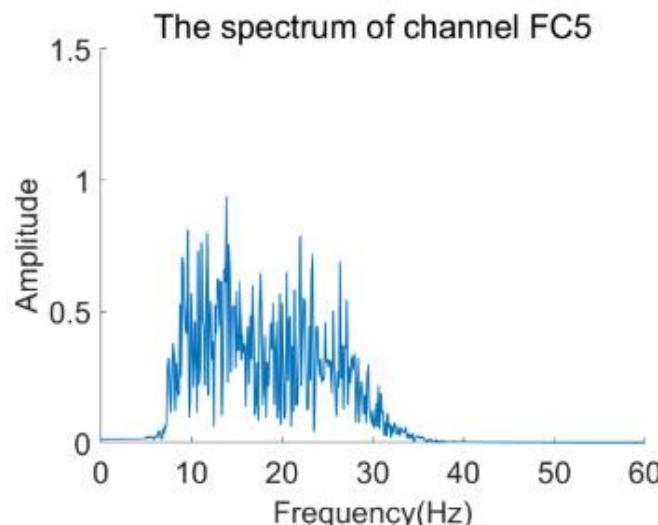
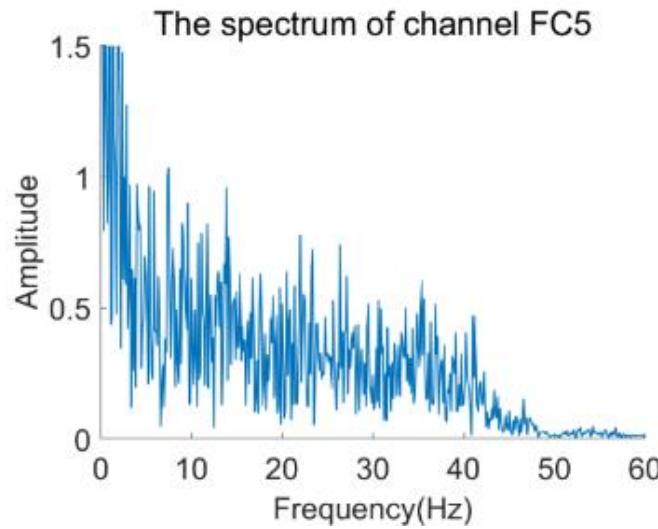
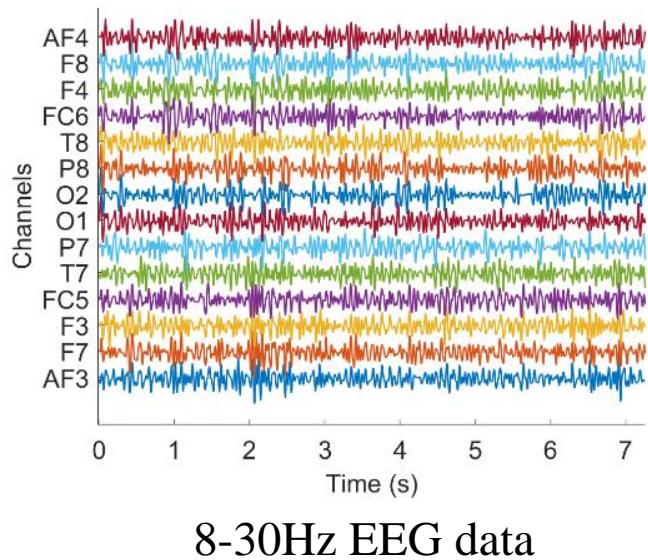
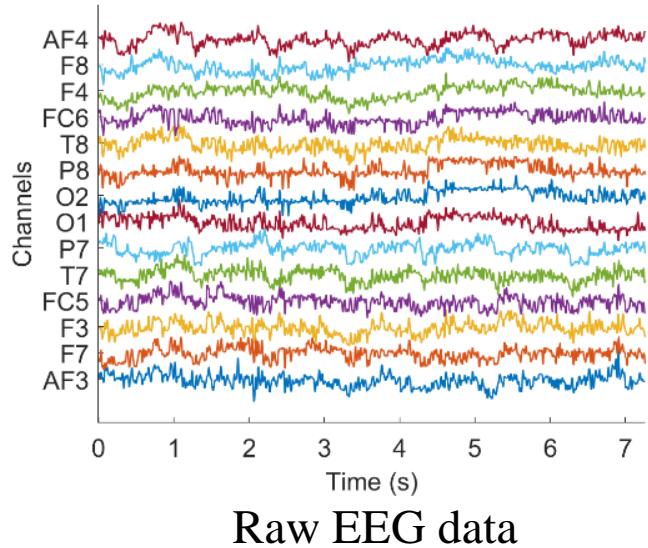


Experimental paradigm



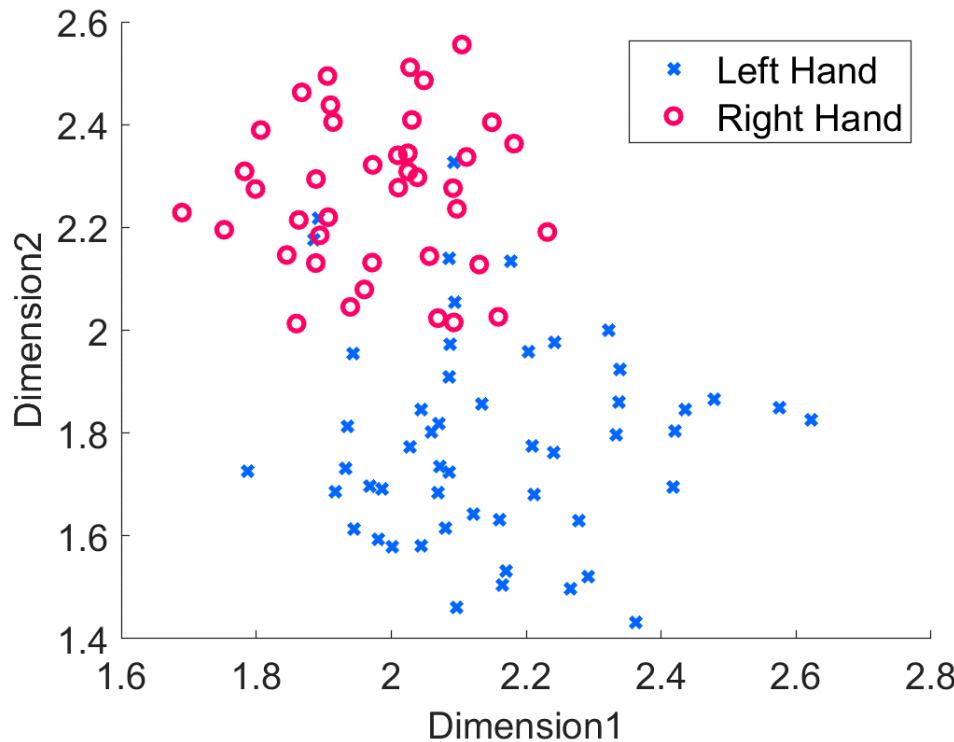
Emotiv BCI training

Data preprocessing

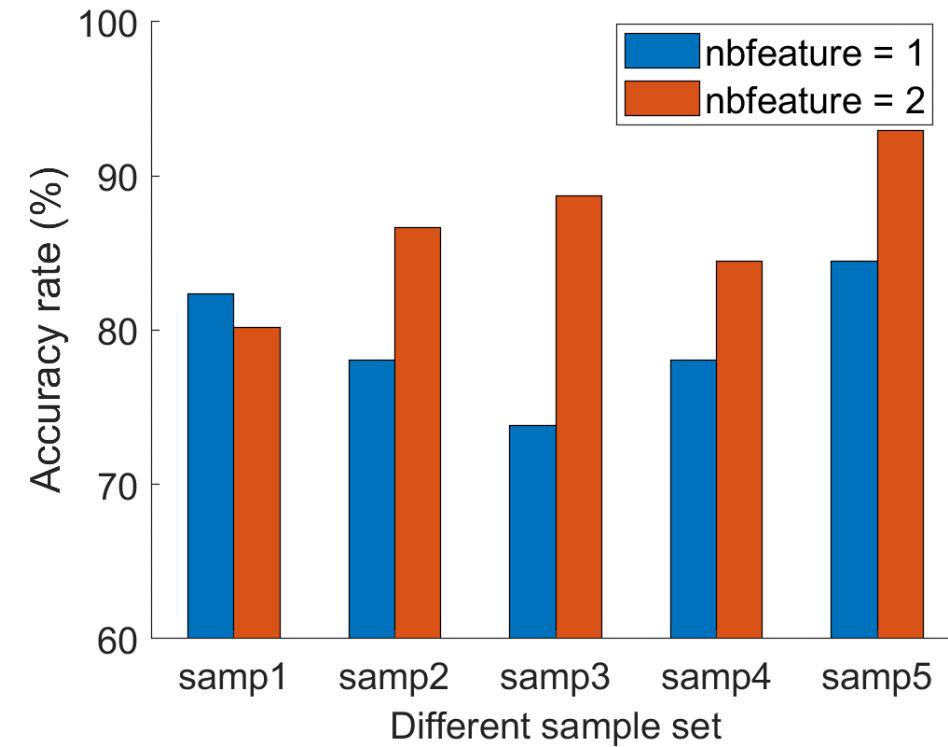


Feature extraction and classification

CSP feature extraction

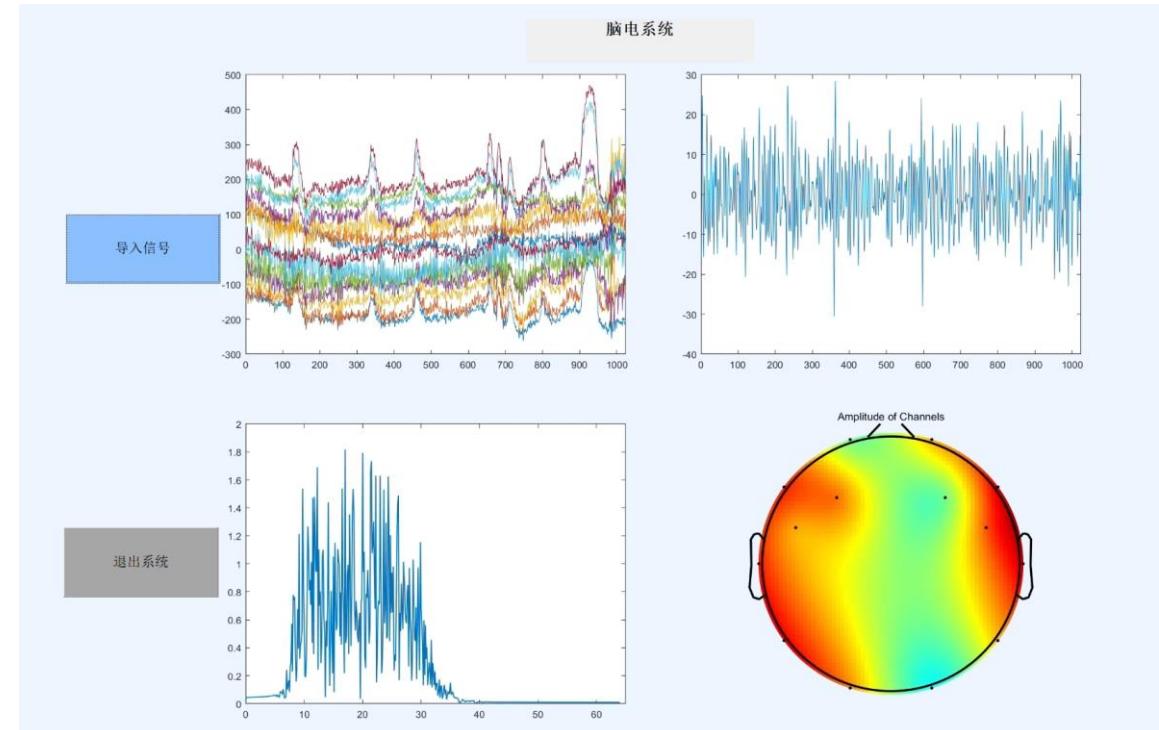


SVM classification



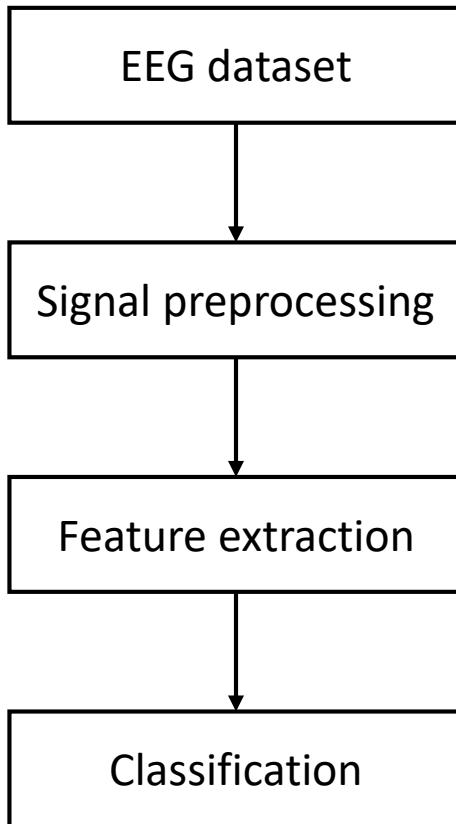
Brain-controlled smart car

- The intelligent car has five states: stationary, forward, backward, left and right;

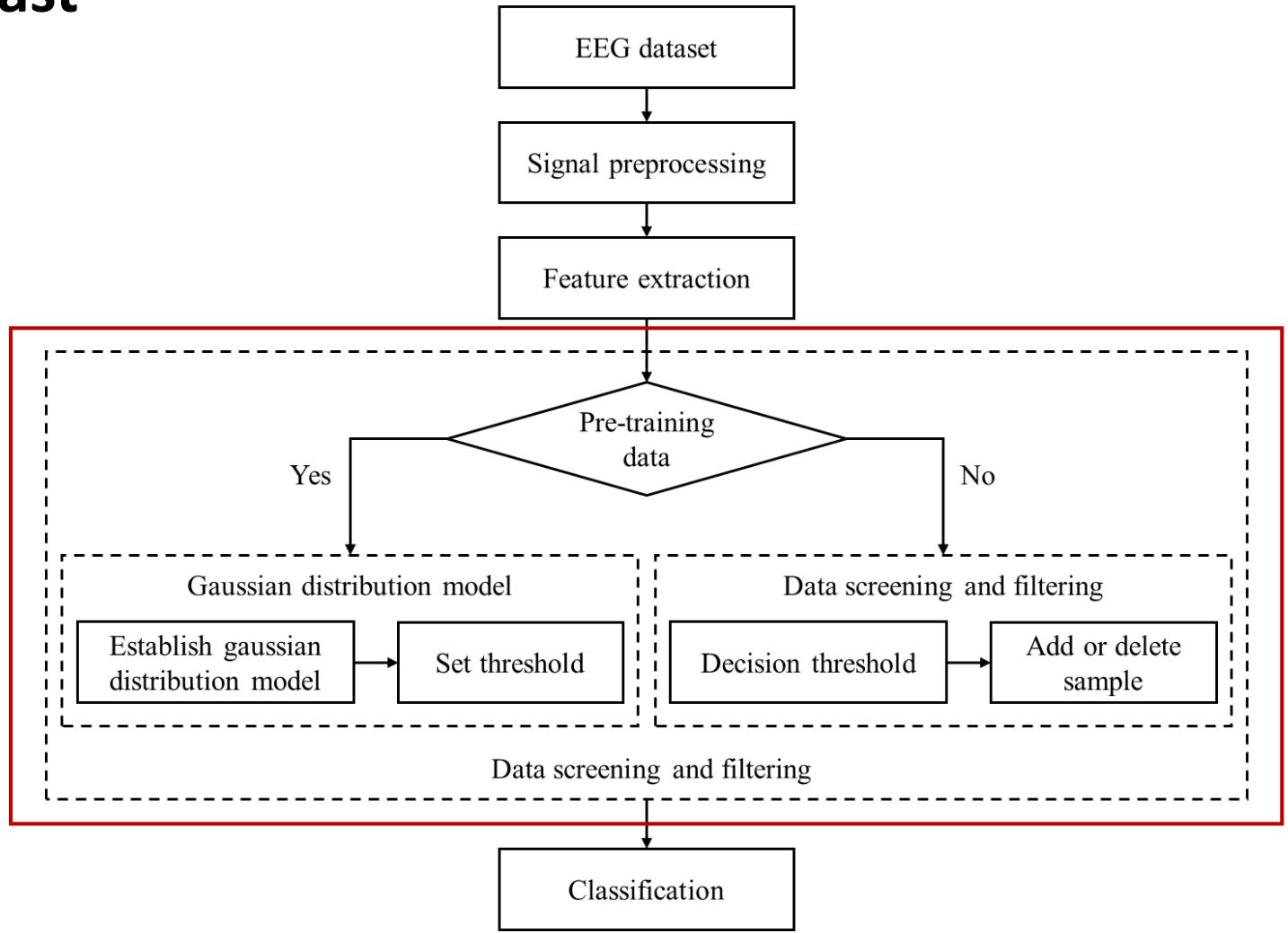


GMM model data screening to improve BCI accuracy

➤ Signal processing flow contrast



Traditional processing flow



GMM-based processing flow

NSW data sets and public data sets

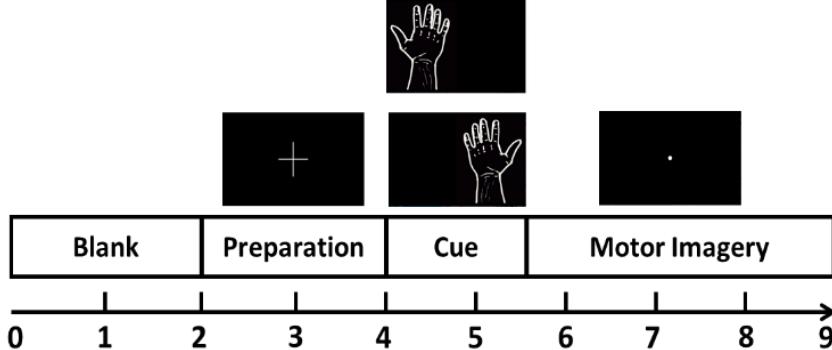
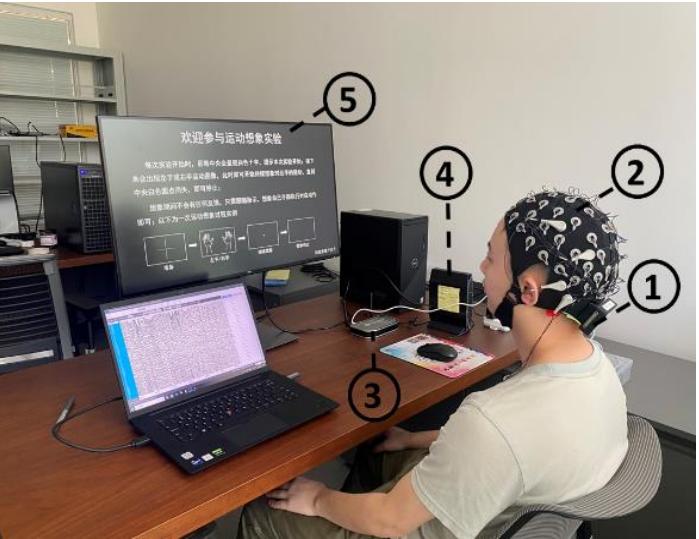
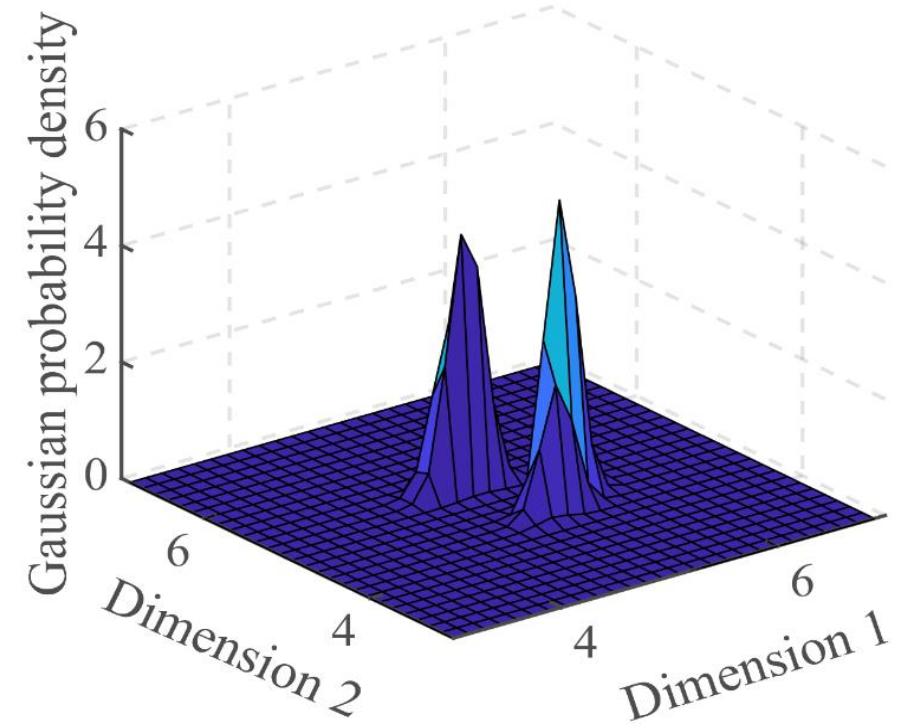
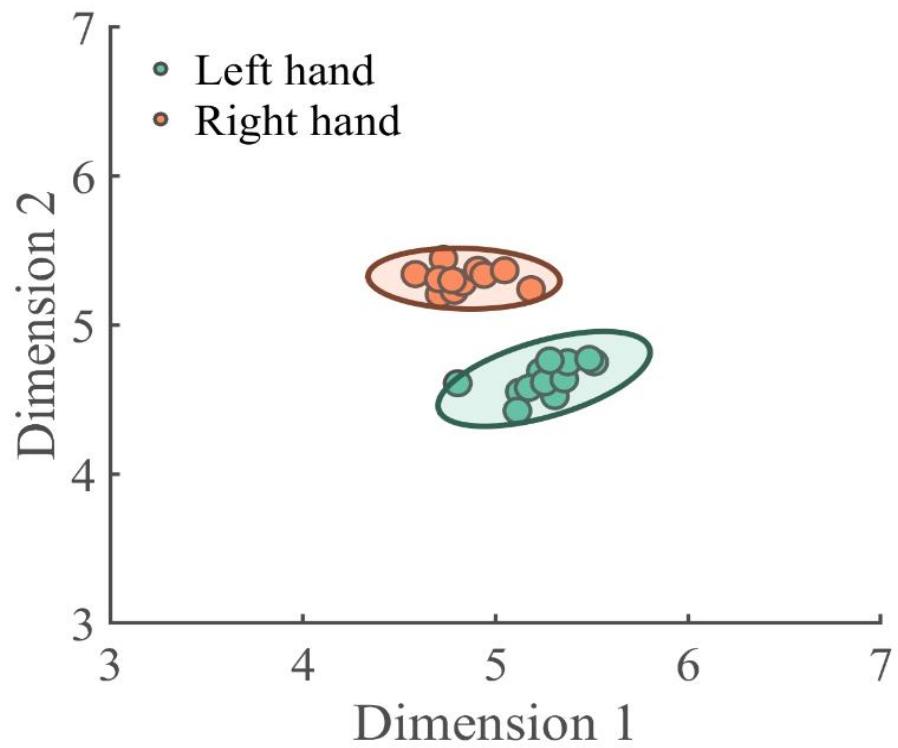


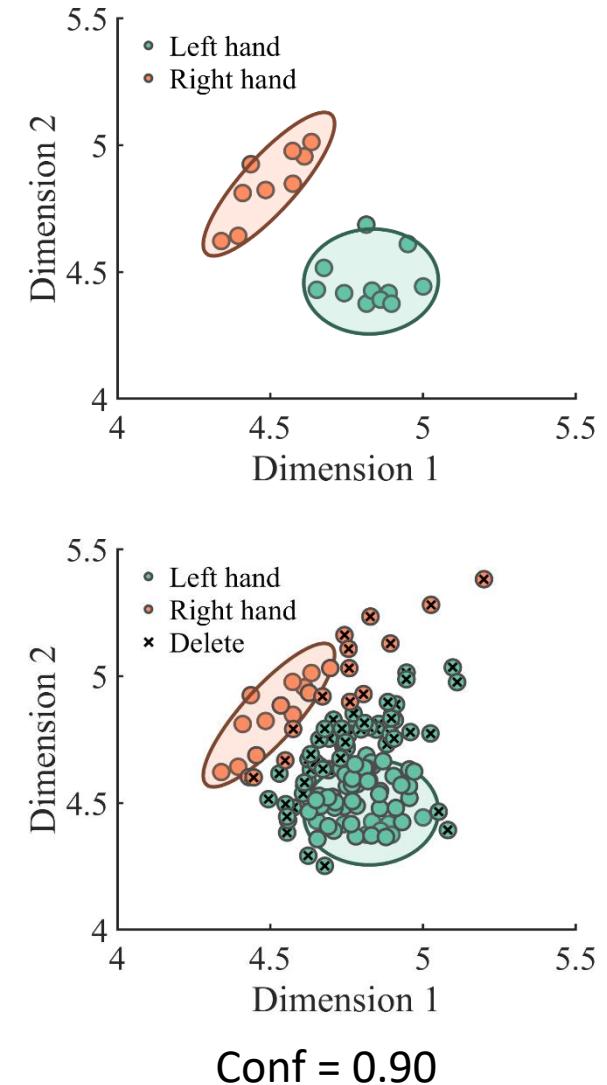
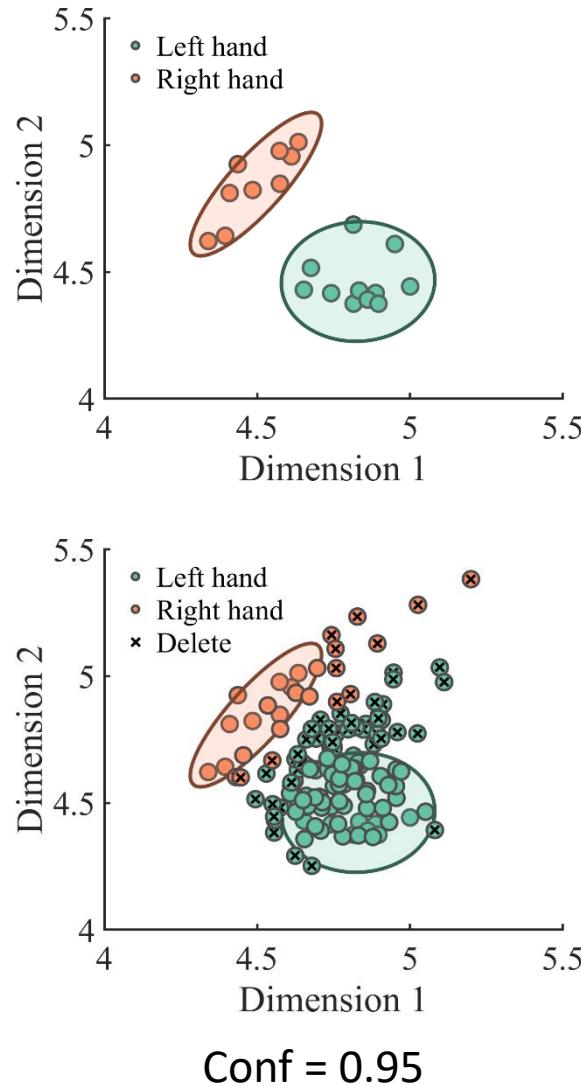
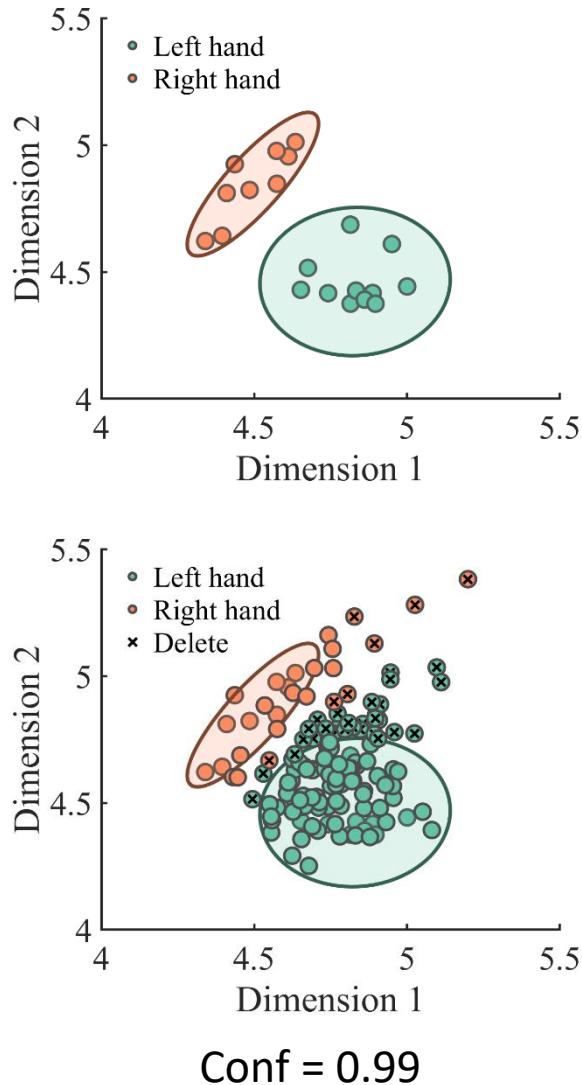
Table 1. Public datasets and NSW364 experiment datasets.

Dataset	No. of subjects	No. of trials	Data length(s)	Sample rate (Hz)	No. of channels
BNCI2014[20]	6	144	4	250	22
Cho2017[21]	6	200	3	512	64
NSW364	3	100	3	1000	64

| Small sample pre-training based on GMM



Results of filtering using different confidence levels



Classification accuracy on different data sets

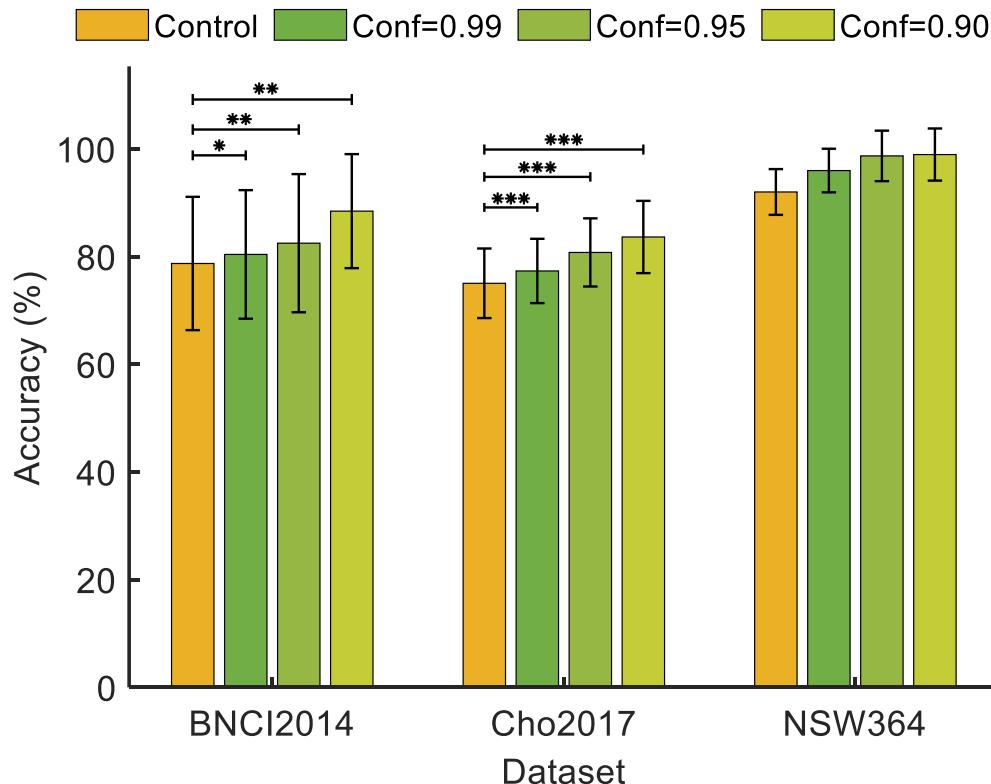
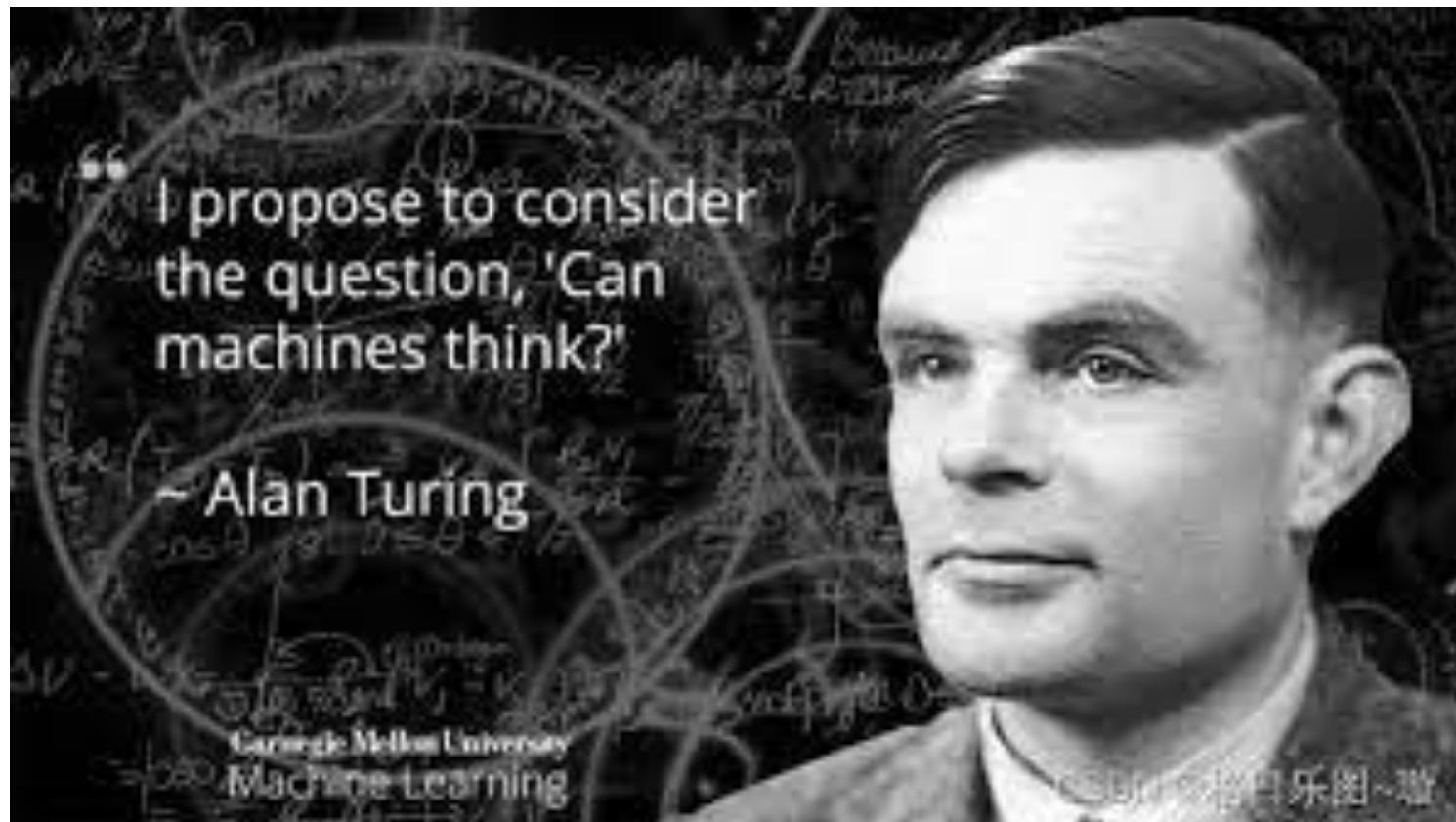


Table. Classification accuracy (%) at different confidence levels in different data sets

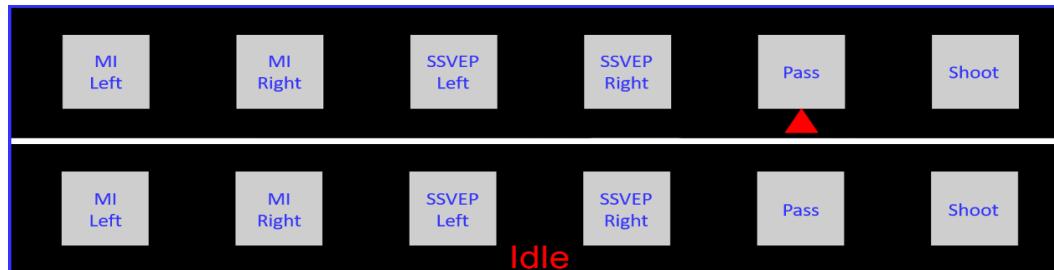
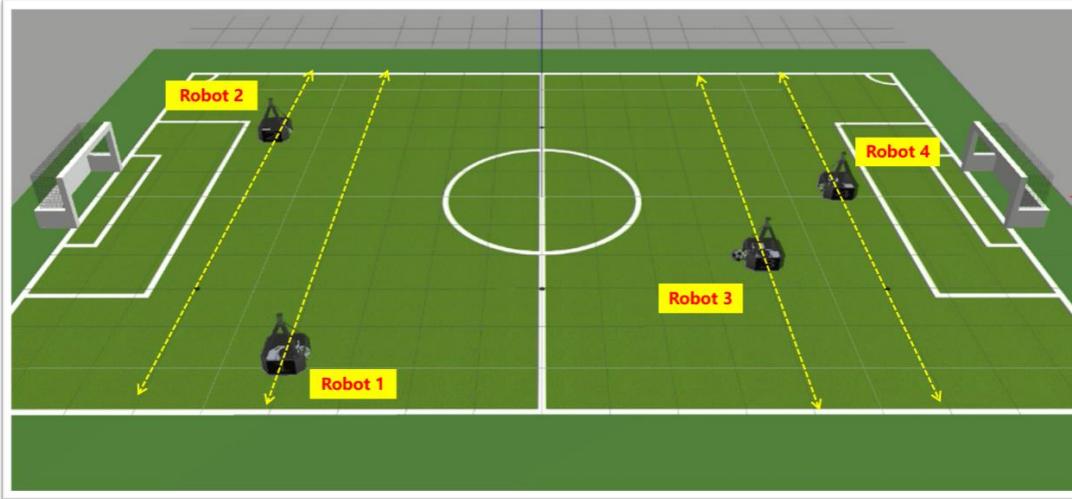
Methods \ Datasets	BNCI2014	Cho2017	NSW364
Conf=1 (Control)	78.72 ± 12.38	75.04 ± 6.46	92.00 ± 4.25
Conf = 0.99	80.40 ± 11.93	77.33 ± 5.97	95.98 ± 4.05
Conf = 0.95	82.49 ± 12.83	80.77 ± 6.34	98.70 ± 4.69
Conf = 0.90	88.44 ± 10.59	83.64 ± 6.71	98.94 ± 4.84

Zheng et al, ICRA. 2023

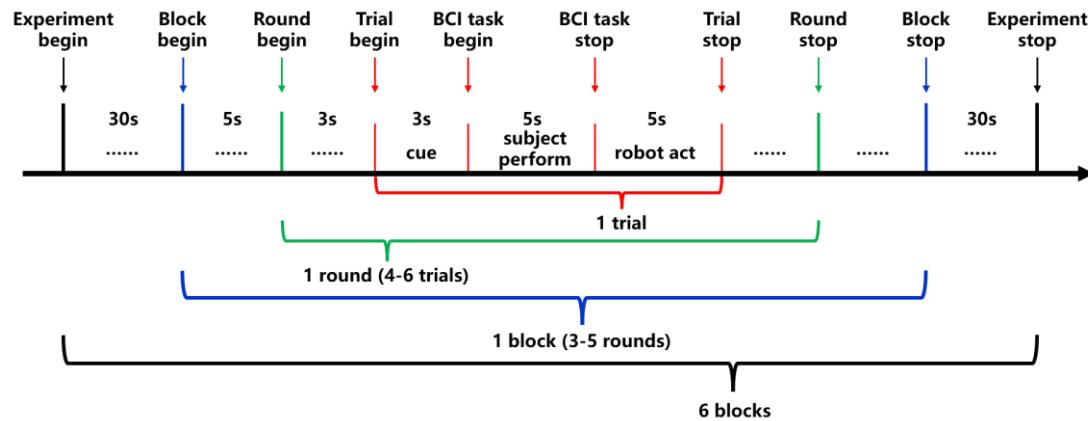
| World Robot Competition-Turing



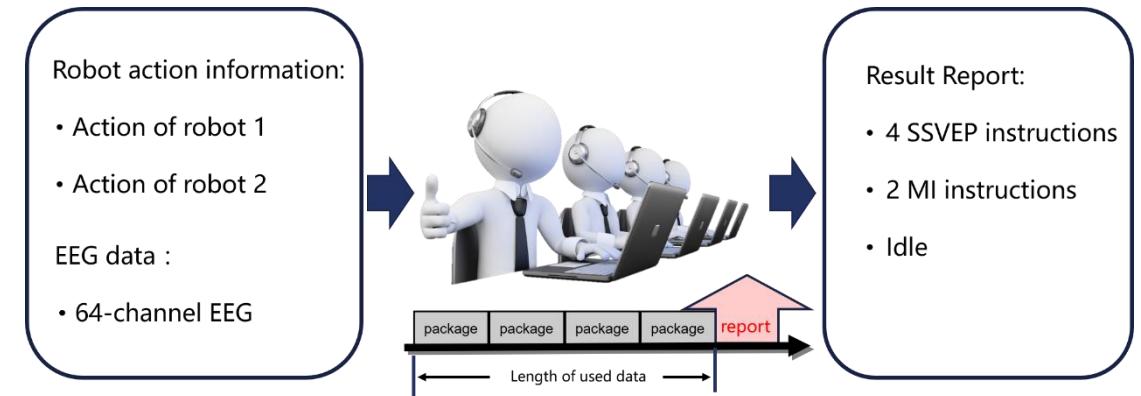
Introduction to the Turing problem



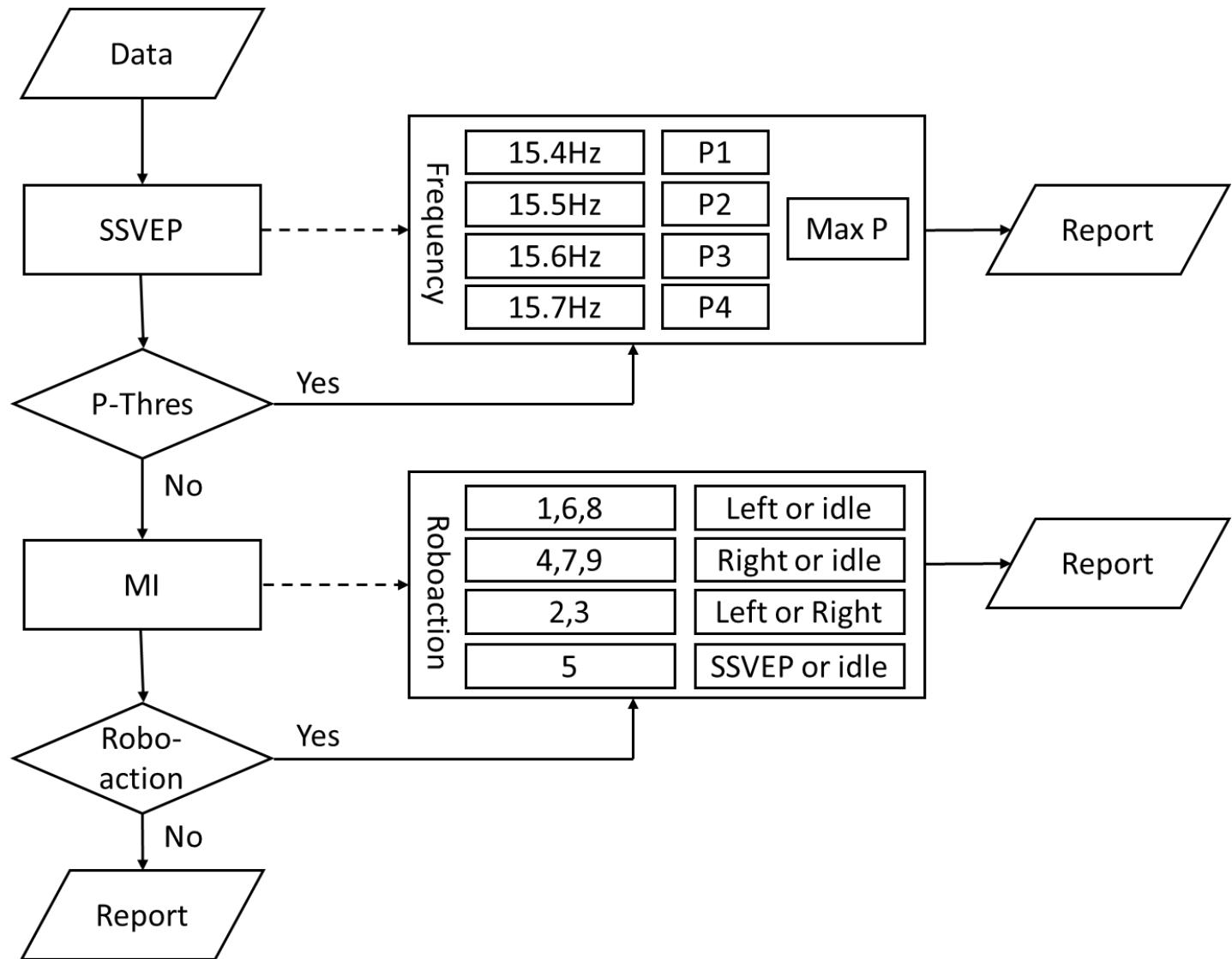
Introduction to the Turing problem



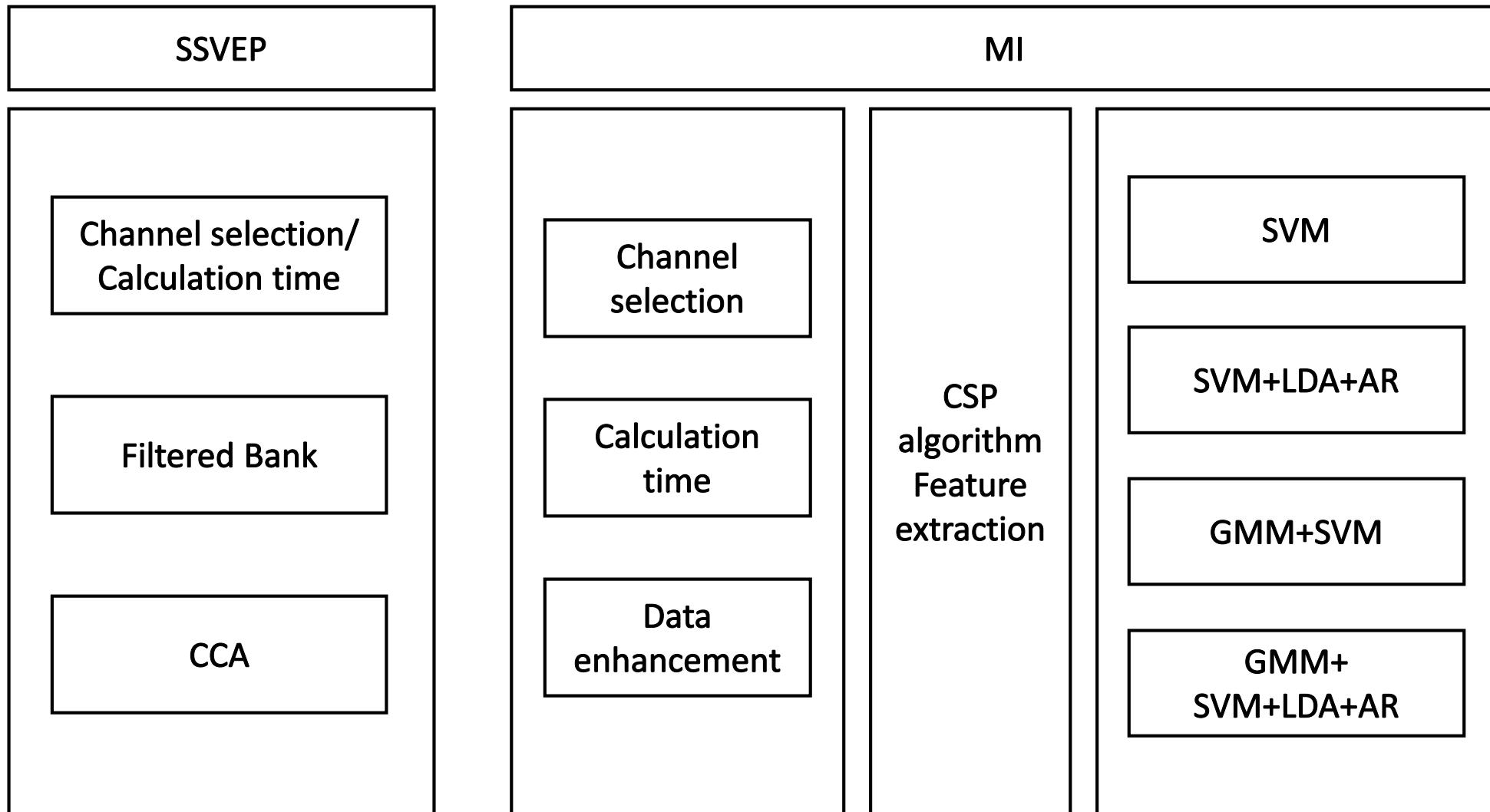
SSVEP-BCI			
left	right	pass	shoot
15.4 Hz	15.5 Hz	15.6 Hz	15.7 Hz



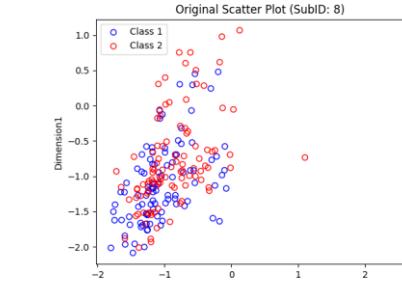
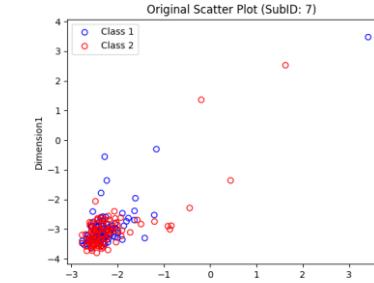
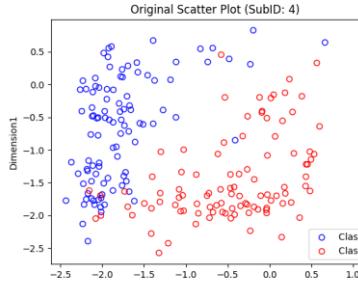
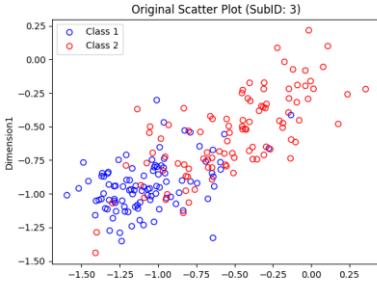
Algorithm framework



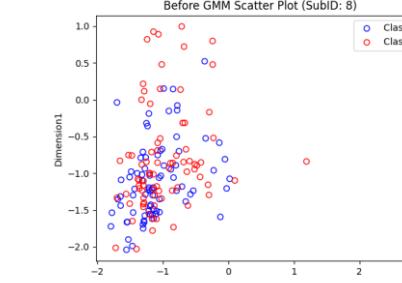
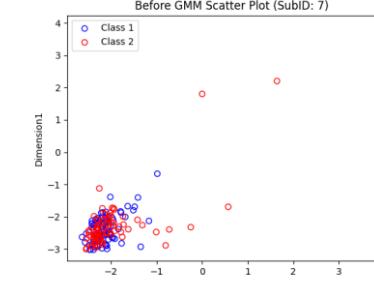
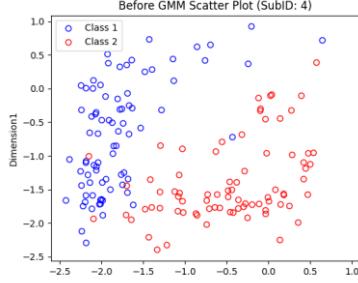
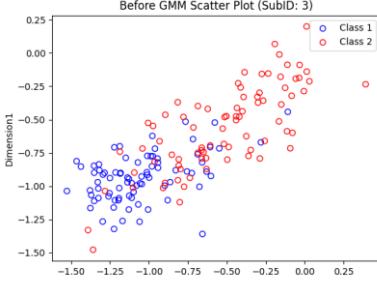
Algorithm framework



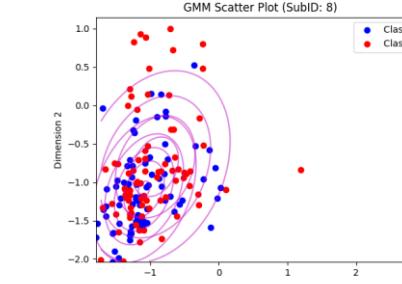
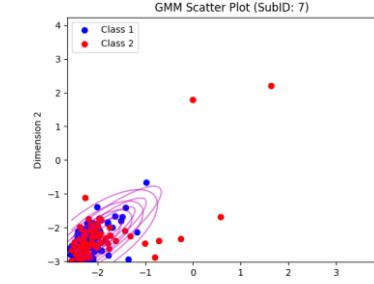
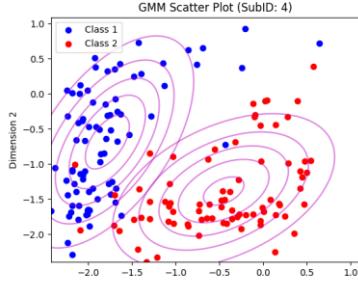
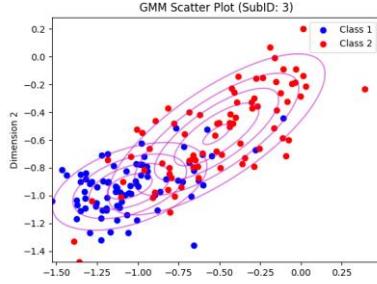
Case: GMM model used to improve MI classification accuracy



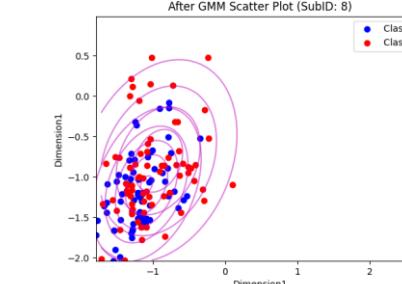
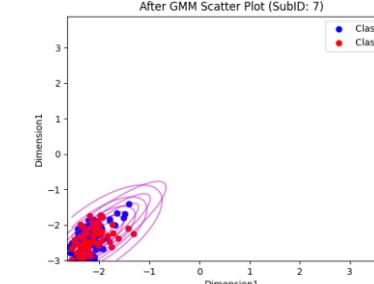
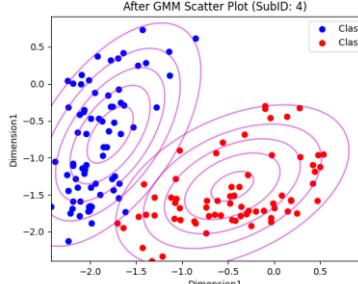
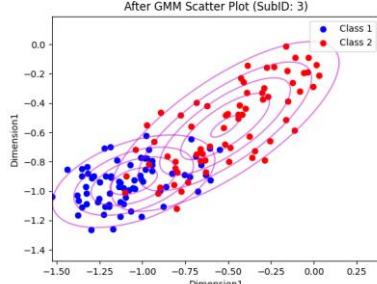
Sample set



Training set



Gaussian distribution curve

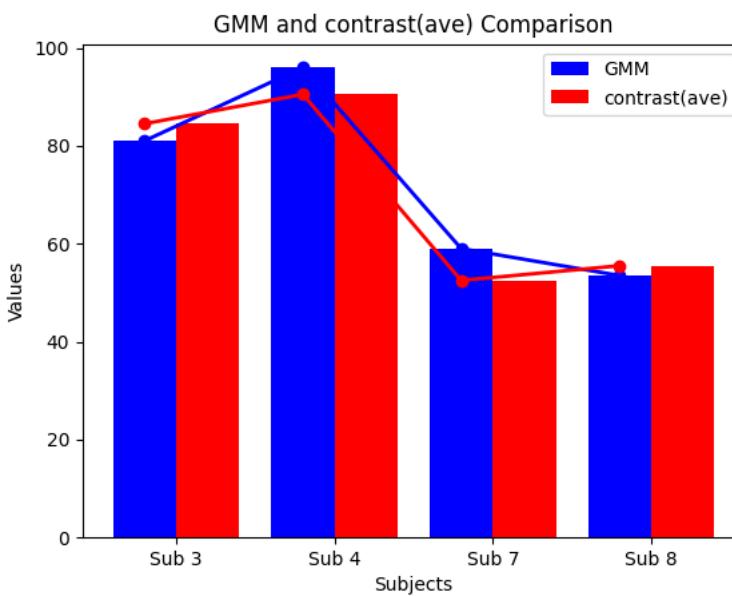


Filtered data set

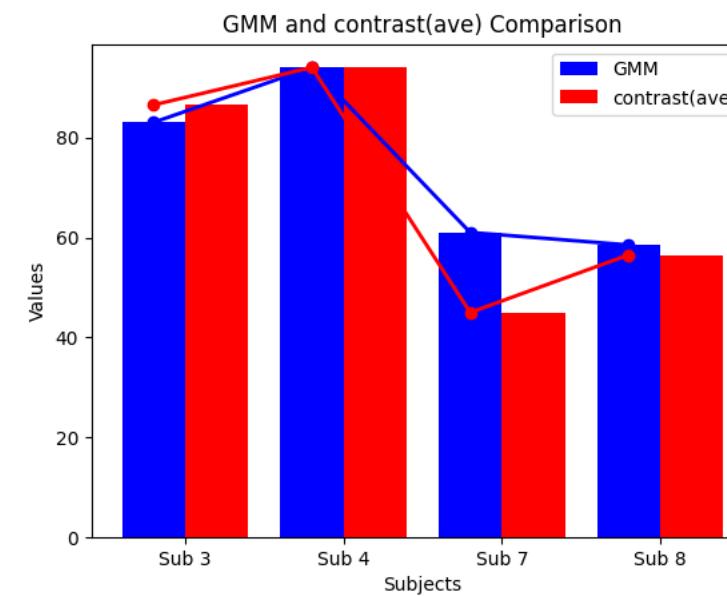
Case: GMM model used to improve MI classification accuracy

➤ Results:

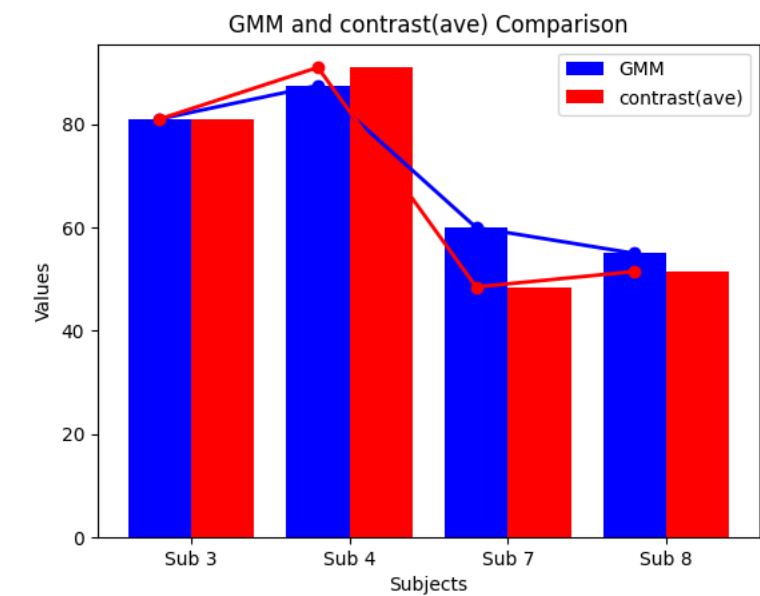
- The accuracy of data sets with more outliers is significantly improved
- The accuracy can be improved by adjusting the confidence of sample screening



Conf = 85%



Conf = 90%

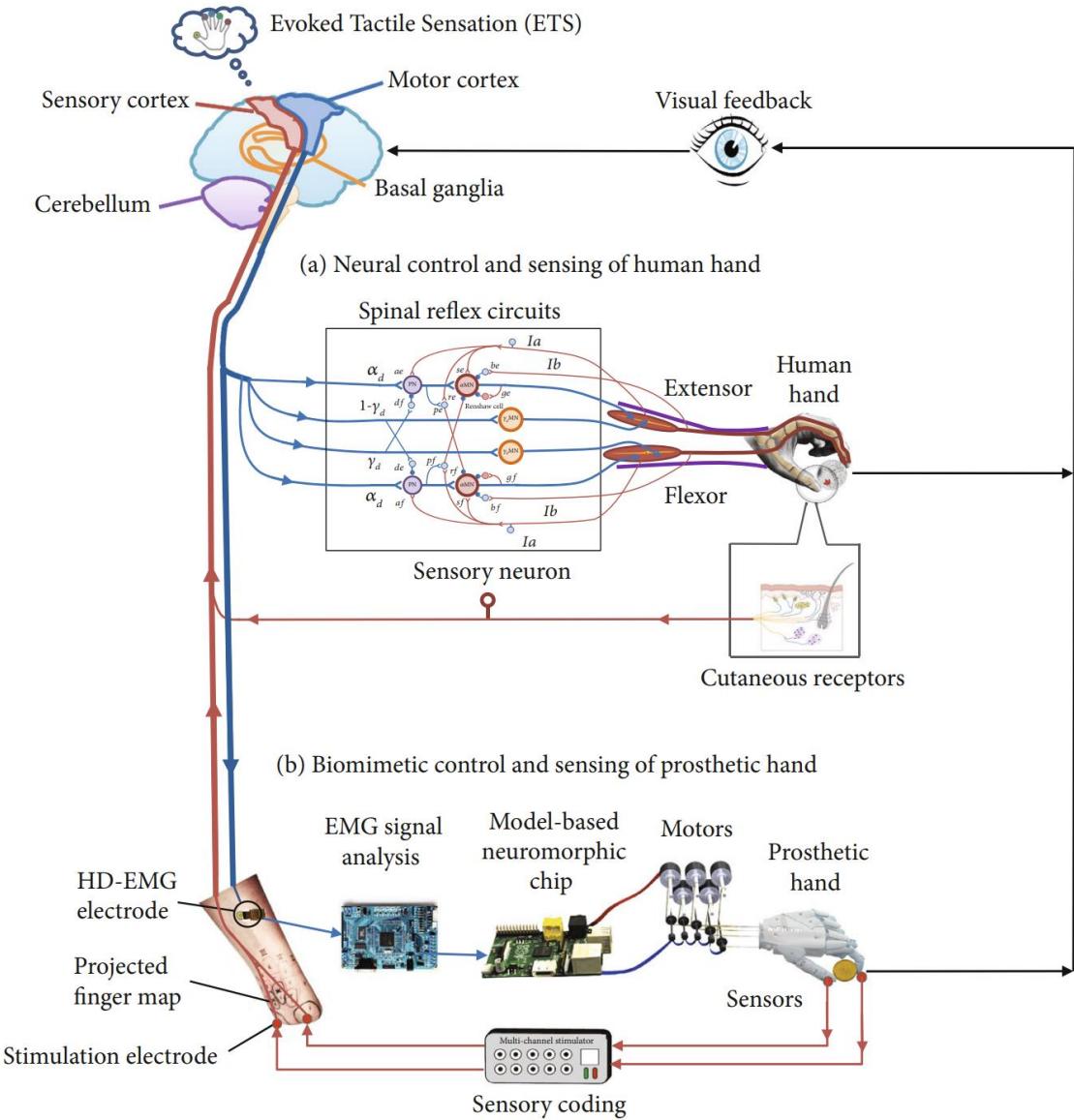


Conf = 95%

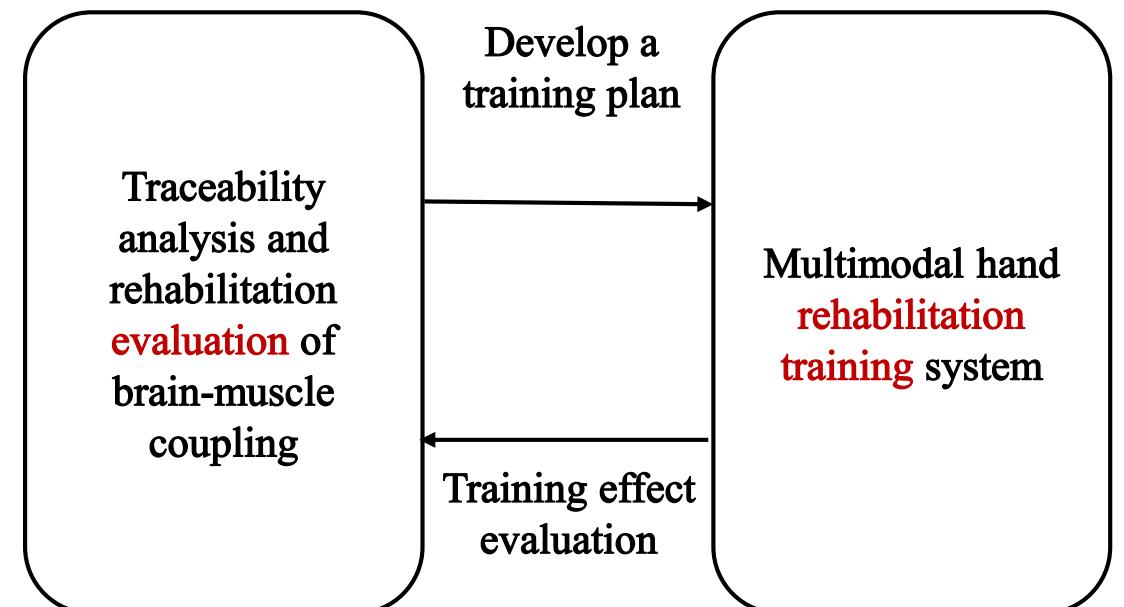
Turing-Competition Result



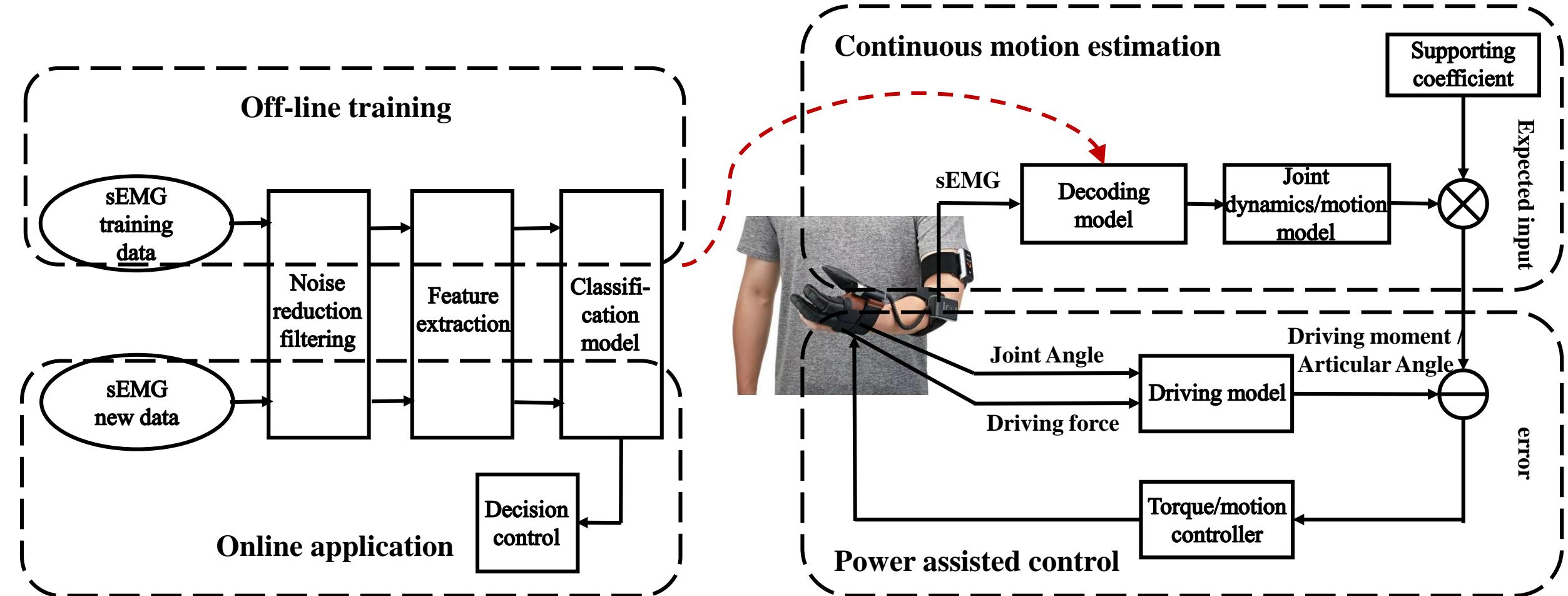
Multi-modal rehabilitation training system



Patient assessment and rehabilitation training system



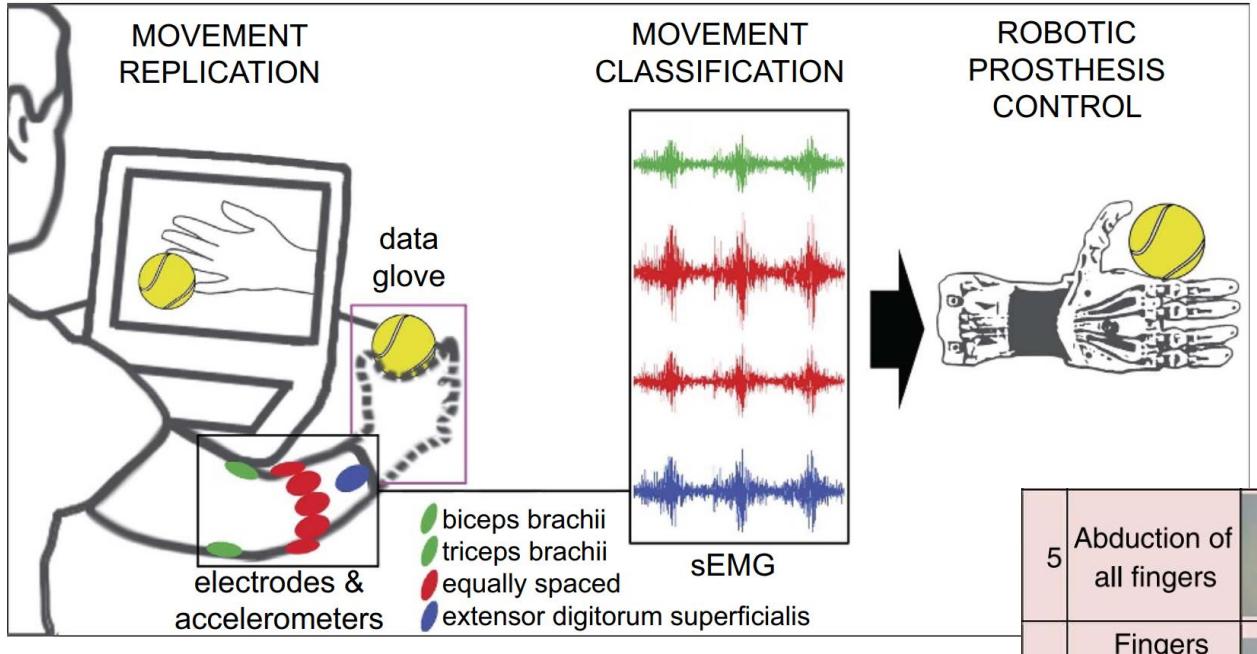
sEMG signal process



Discrete action classification based on sEMG

Continuous motion estimation and manipulator control based on sEMG

Ninapro database



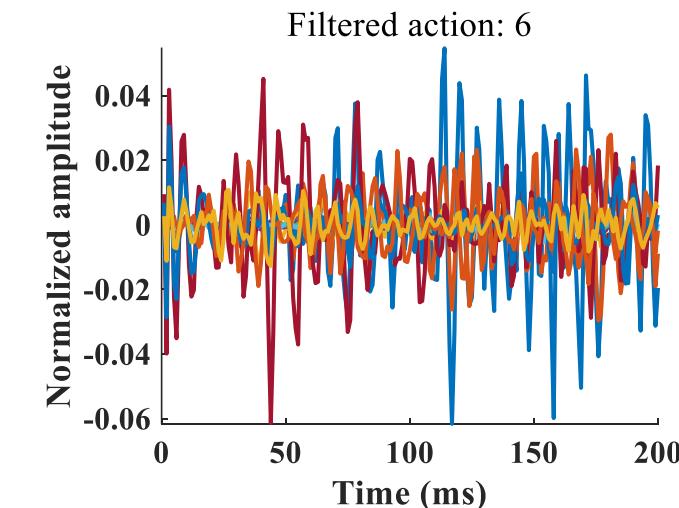
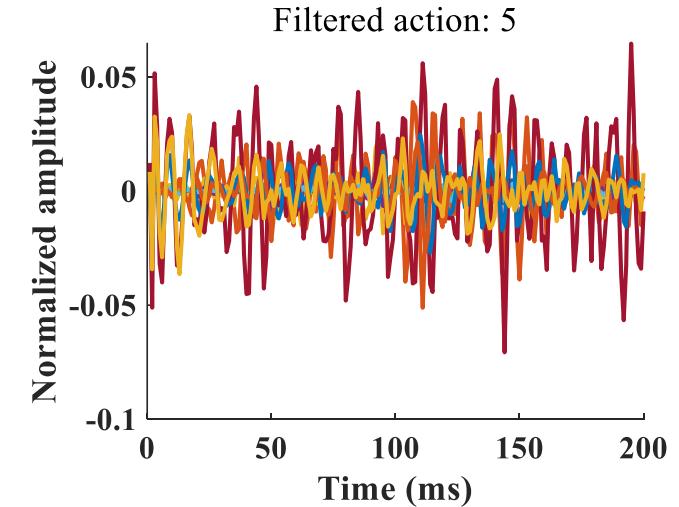
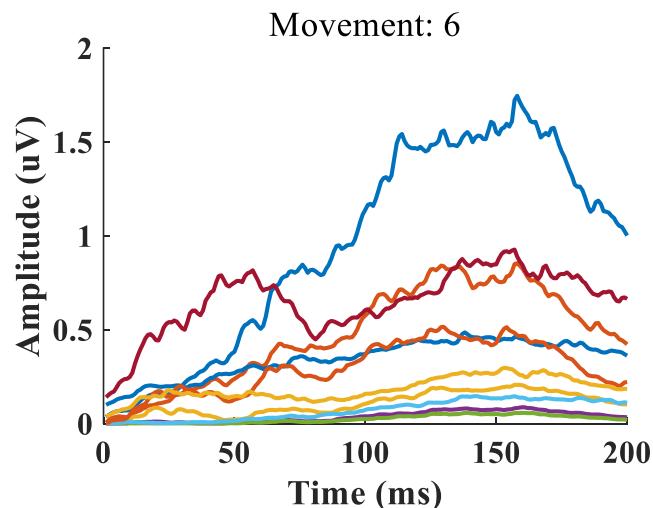
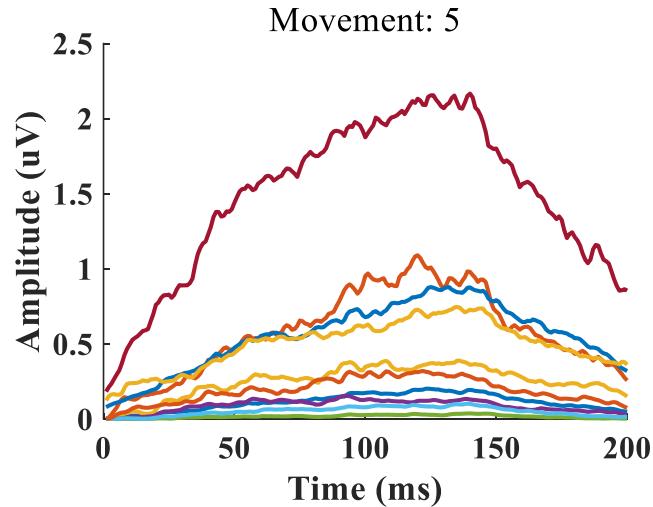
- EMG and joint angle data acquisition
 - 53 movements, and repeated 10.
 - Healthy people and amputees.
- Our experimental:
healthy people, stretching and clenching.

	Database 1	Database 2	Database 3
Intact Subjects	27	40	0
Trans-radial Amputated Subjects	0	0	11
sEMG Electrodes	10 Otto Bock	12 Delsys	12 Delsys
Total Number of Movements (rest included)	53	50	50
Number of Movement Repetitions	10	6	6
Exercise 1			
Reference in Fig. 2	Exercise A	Exercise B	Exercise B
Number of Movements	12	17	17
Ground Truth Parameter	Hand Kinematics	Hand Kinematics	Hand Kinematics (<i>when available</i>)
Hand Kinematics/Dynamics Sensors	Cyberglove II	Cyberglove II	Cyberglove II (<i>when available</i>)
Exercise 2			
Reference in Fig. 2	Exercise B	Exercise C	Exercise C
Number of Movements	17	23	23
Truth Parameter	Hand Kinematics	Hand Kinematics	Hand Kinematics (<i>when available</i>)
Hand Kinematics/Dynamics Sensors	Cyberglove II	Cyberglove II	Cyberglove II (<i>when available</i>)
Exercise 3			
Reference in Fig. 2	Exercise C	Exercise D	Exercise D
Number of Movements	23	9	9
Ground Truth Parameter	Hand Kinematics	Hand Dynamics	Hand Dynamics (<i>when available</i>)
Hand Kinematics/Dynamics Sensors	Cyberglove II	FFLS	FFLS (<i>when available</i>)

Atzori et al., Sci Data, 2014

| sEMG signal analysis

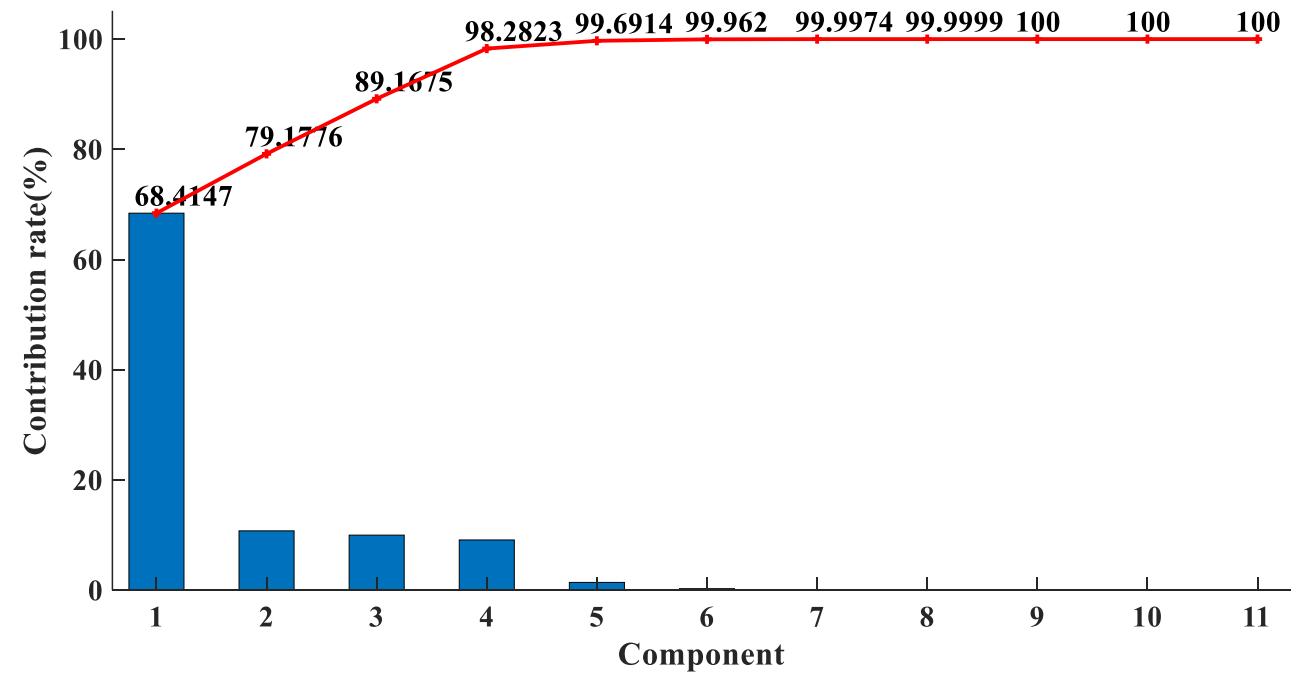
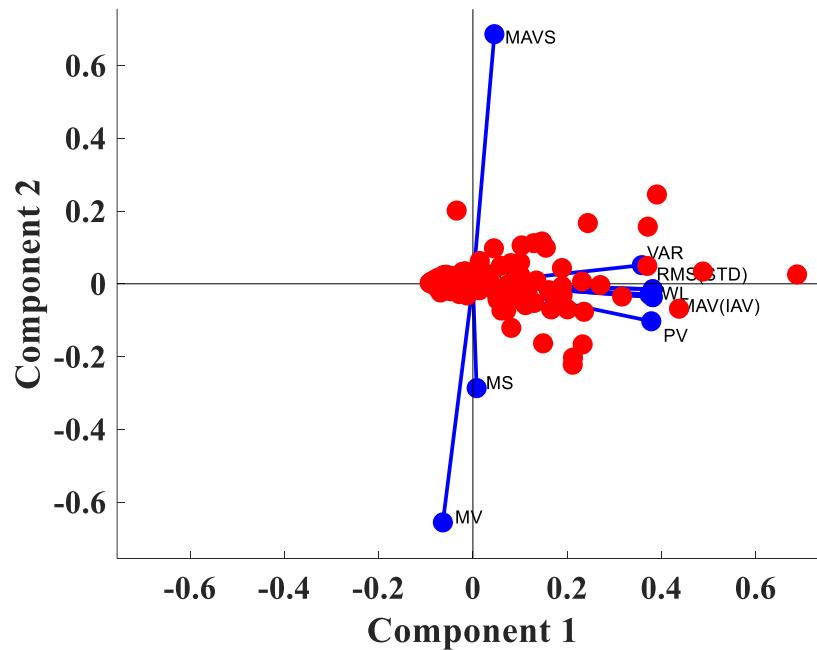
➤ sEMG signal segmentation, alignment and filtering



sEMG signal analysis

➤ Feature extraction and principal component analysis

- TDfeature = [IAV;MAV;MAVS;WL;MV;VAR;STD;RMS;WAMP;PV;MS];



```
命令行窗口

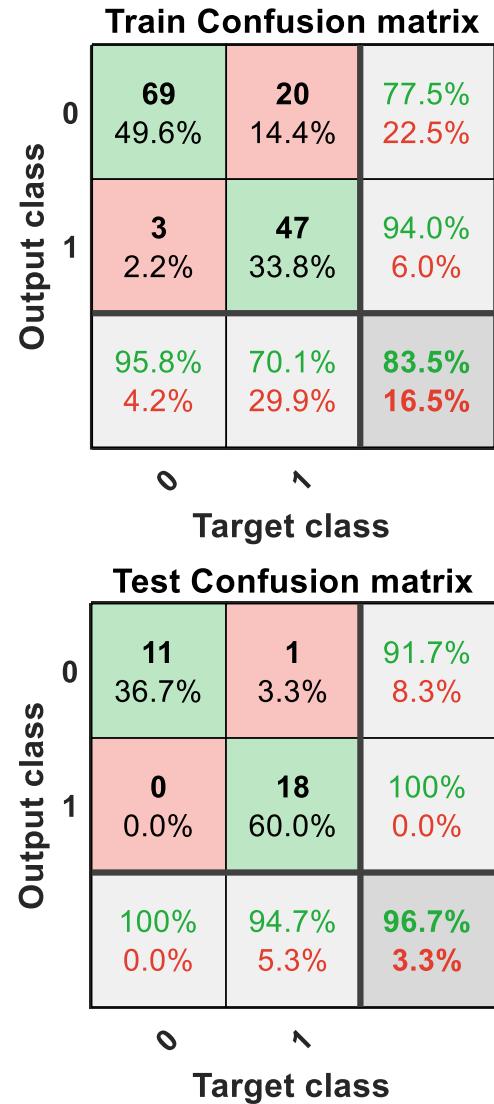
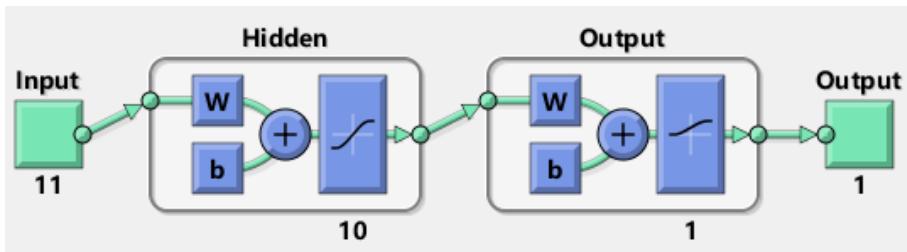
title_str =
'filtered action: 6'

准确率: 85.00%
jx>>
```

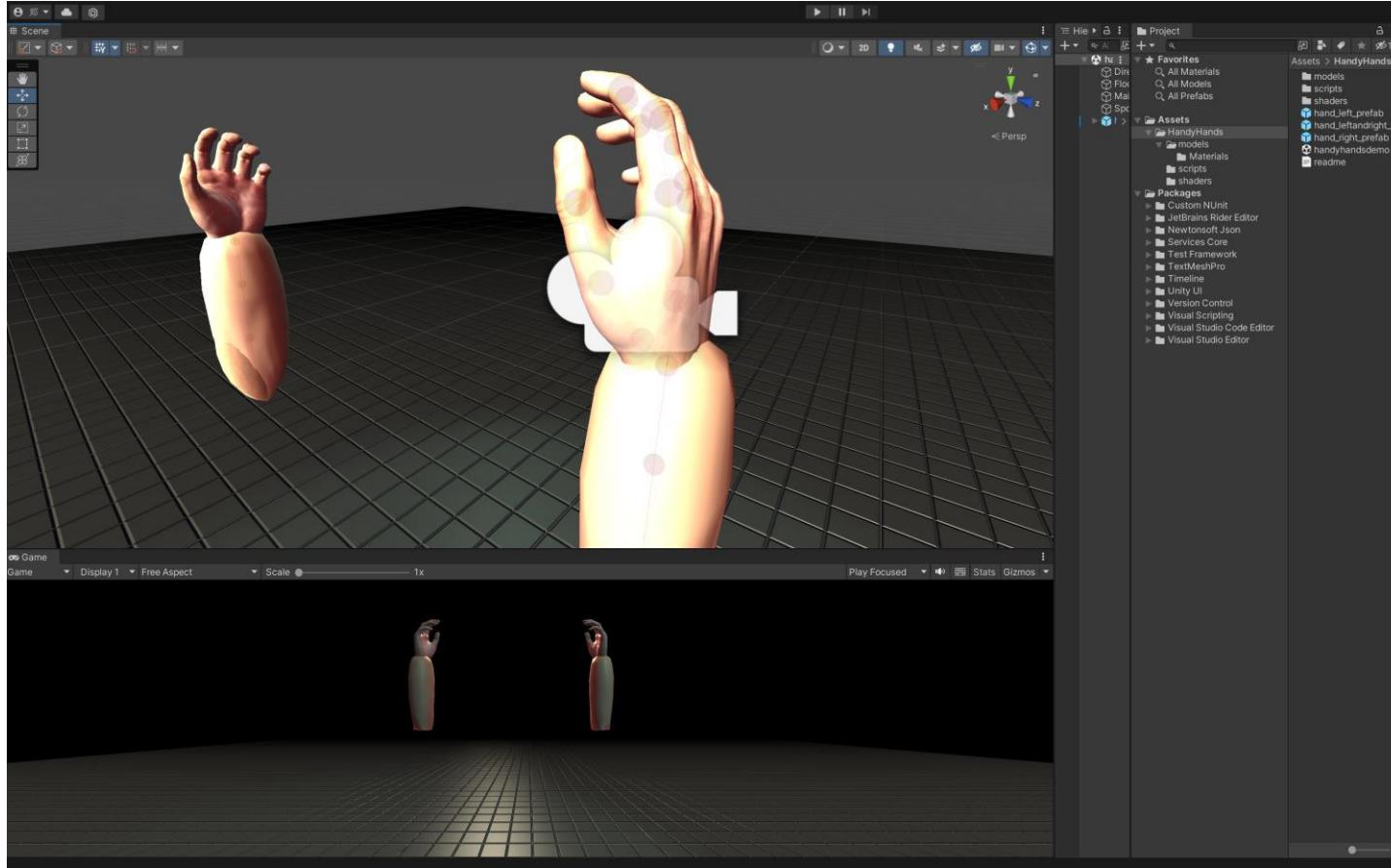
sEMG signal analysis

➤ 10-layer neural network

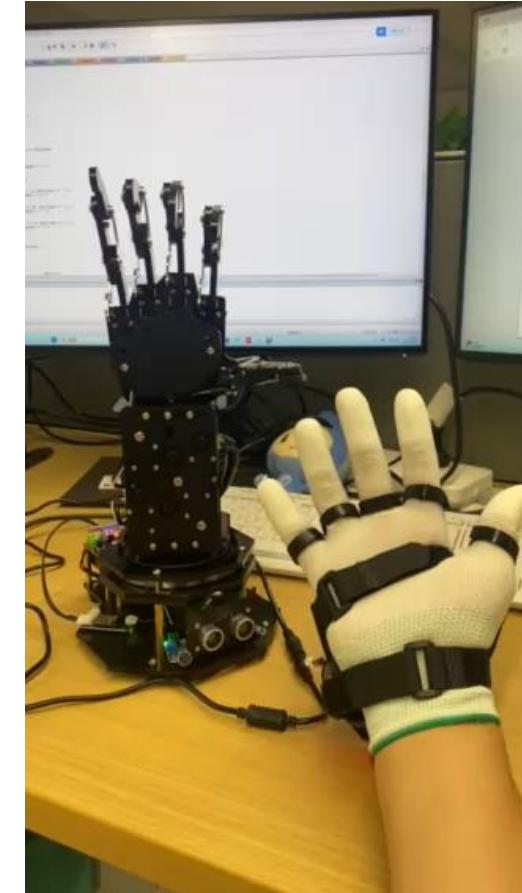
- 139:30:30



Bionic manipulator



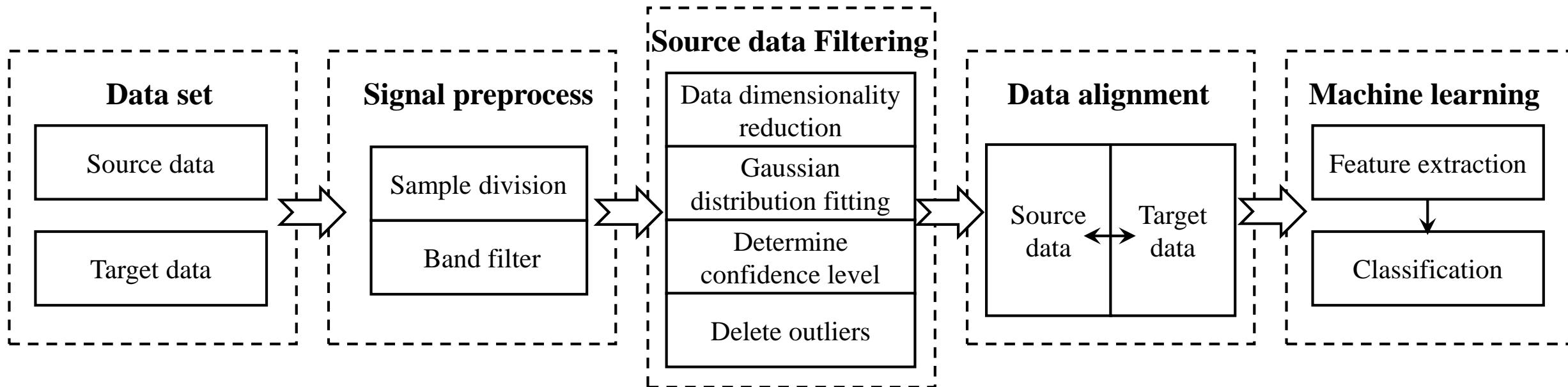
Unity3D simulates hand model



Manipulator hardware

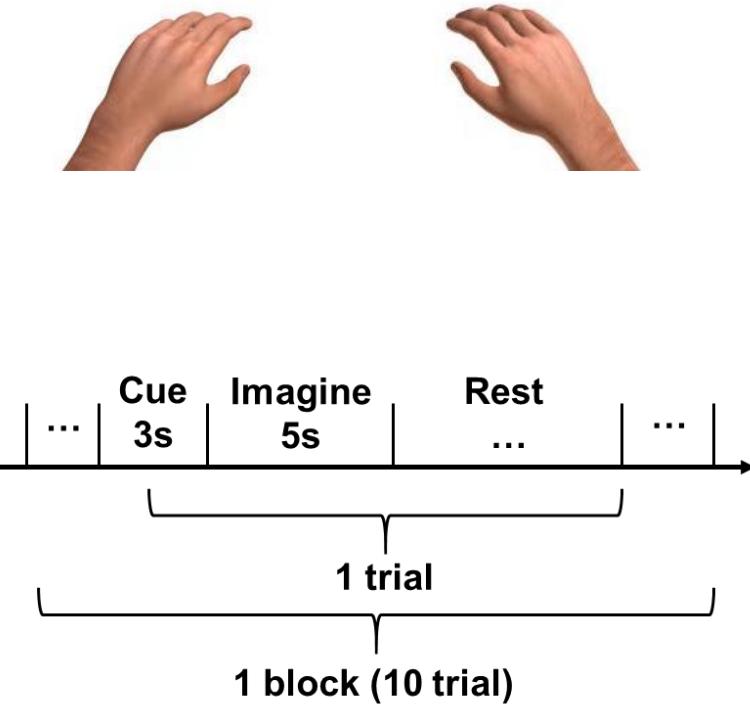
Others

➤ Transfer learning: GMM-EA-CSP-LDA

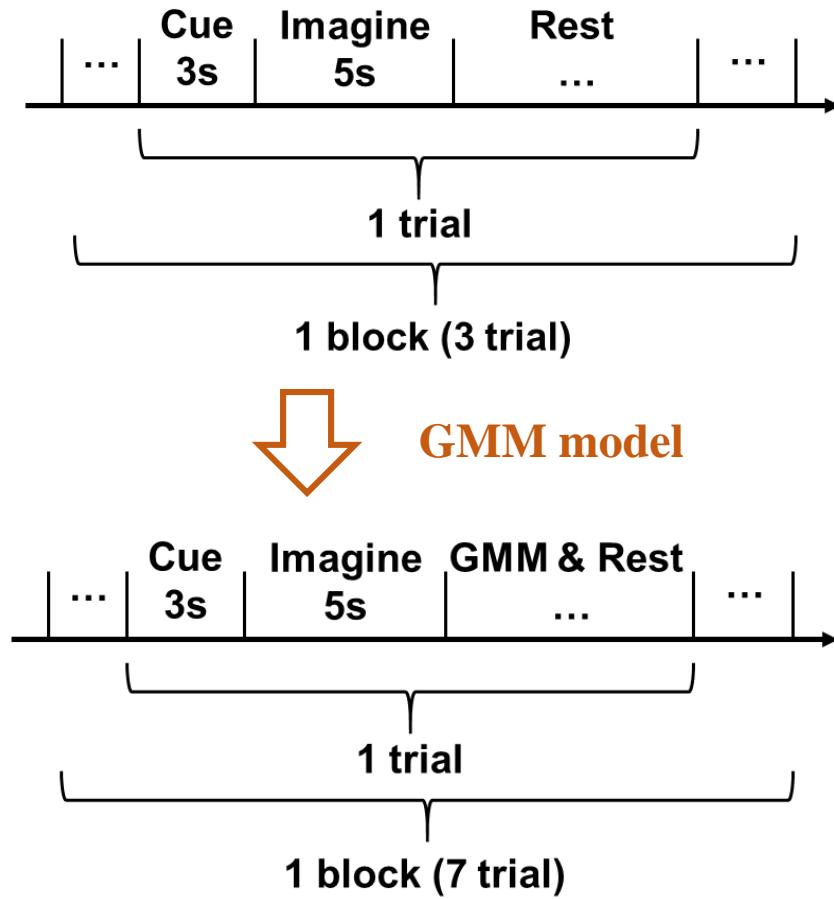


Others

➤ Using GMM method to improve the performance of BCI



Traditional experimental paradigm



GMM-method experimental paradigm

Thanks for listening!

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zhengshui13@gmail.com