



清华大学

Tsinghua University

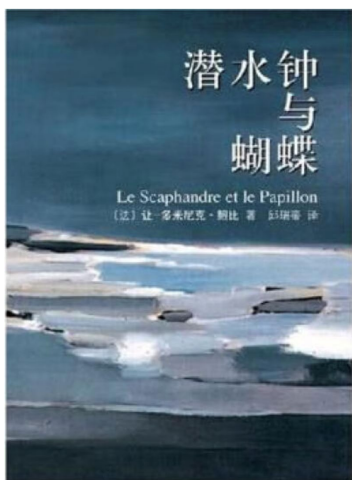
脑机接口：解码思维的力量

张丹，清华大学

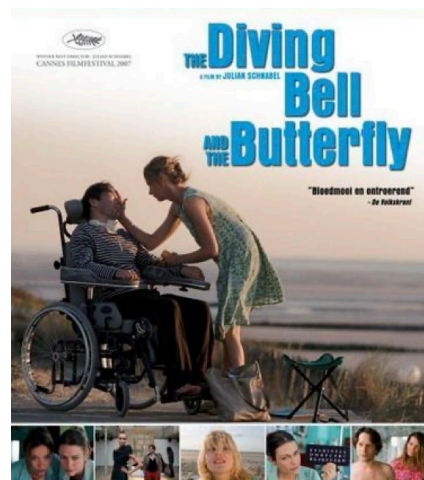


MATLAB EXPO

您知道闭锁综合征 (Locked-In Syndrome) 吗?

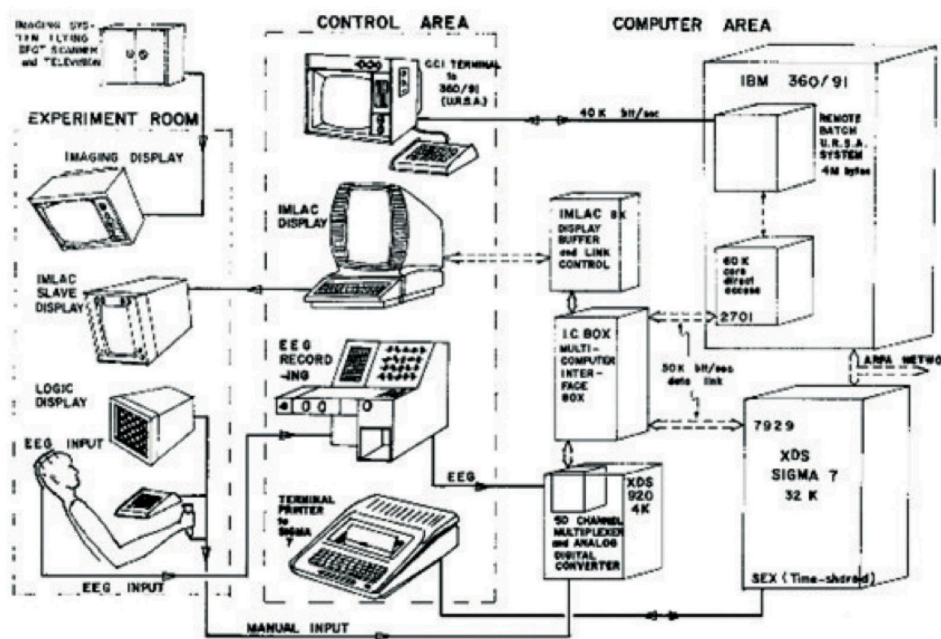


Jean-Dominique Bauby (1952-1997)

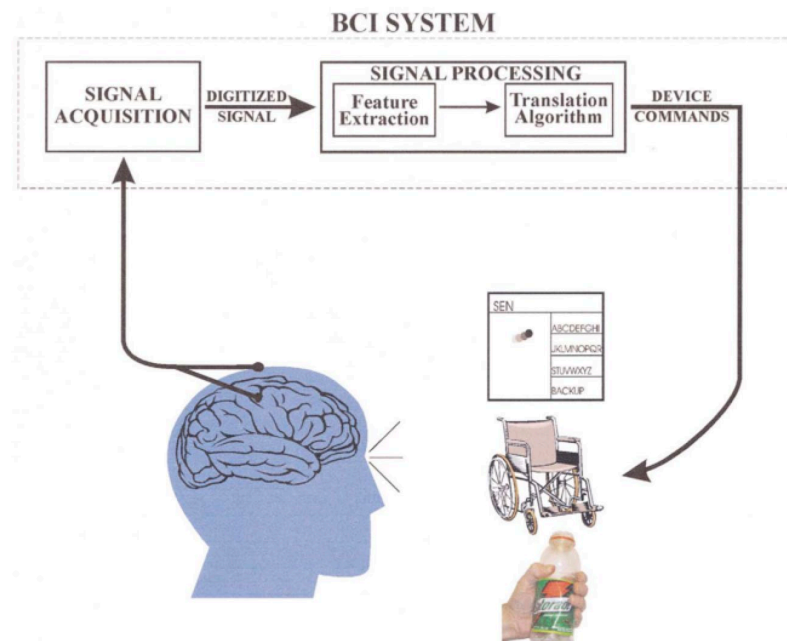


Stephen William Hawking (1942-2018)

脑机接口 Brain-Computer Interface (BCI)



Vidal 1973



Wolpaw 2001

脑机接口科学研究



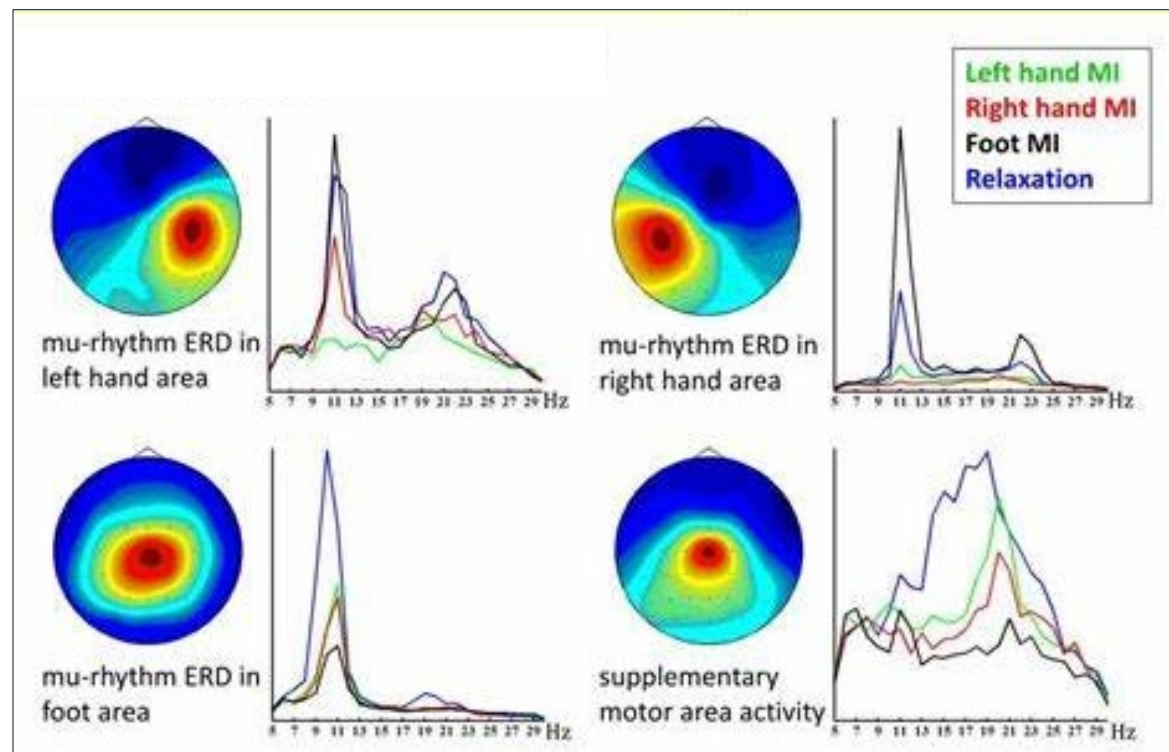
想象运动脑机接口

视觉脑机接口

情绪脑机接口

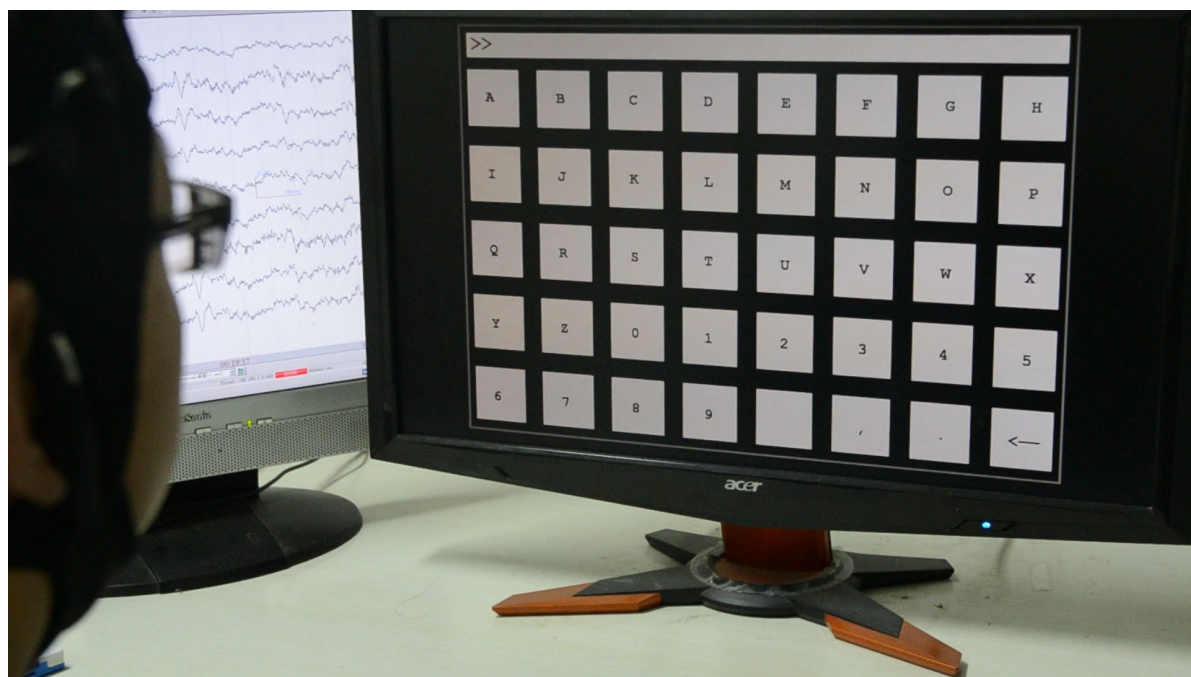
想象运动脑机接口 Motor Imagery BCI

最接近“所想即所得”的脑机接口



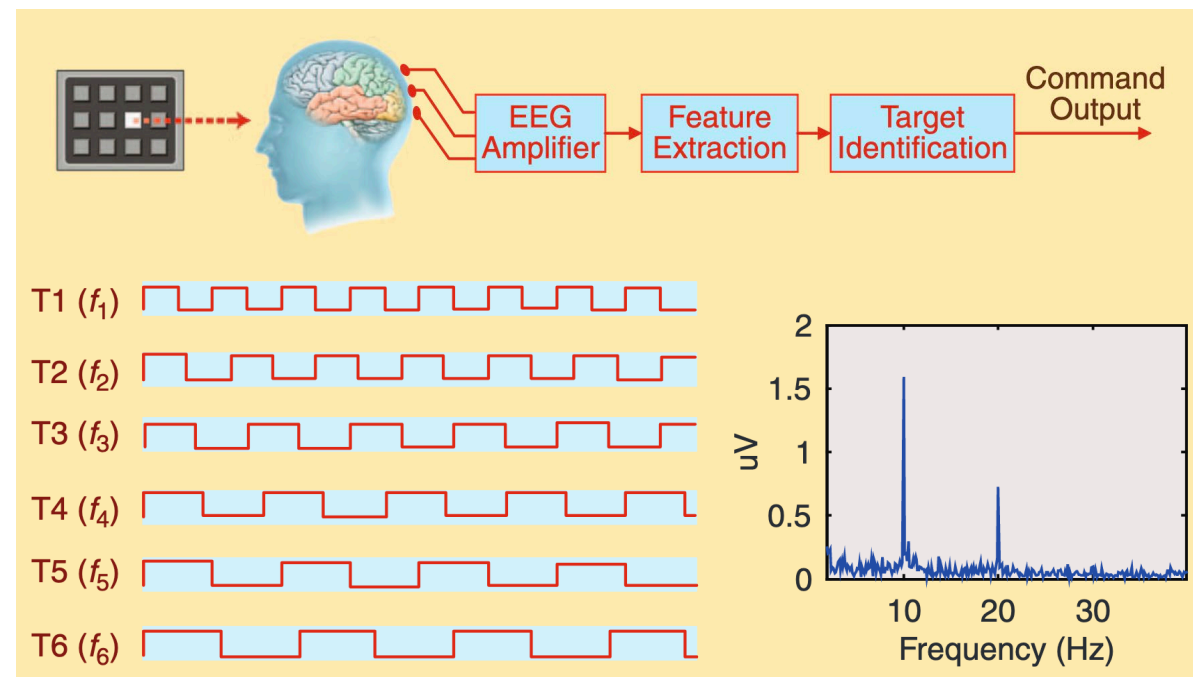
Frolov 2014

视觉诱发响应脑机接口 Visual BCI



Chen 2015

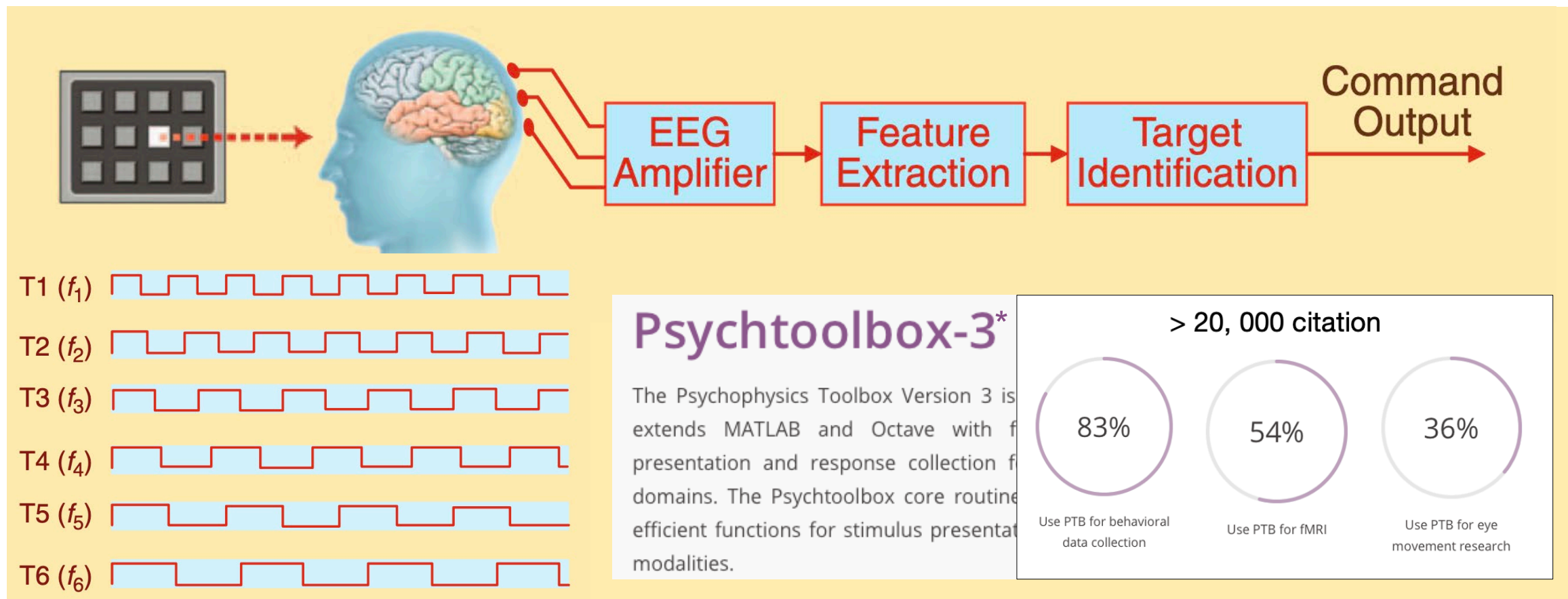
信息交互速率最快的脑机接口
信息传输率：75 character/min (Nakanishi 2018)



Bin 2009

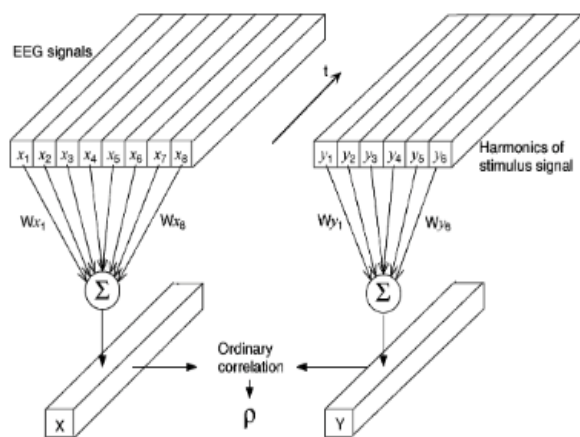
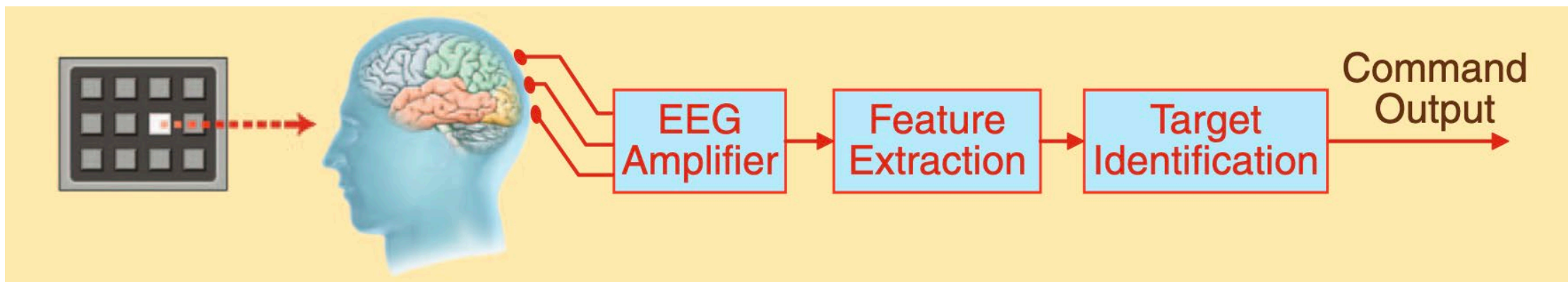
视觉脑机接口的关键技术 1: 精准时间的视觉信息呈现

失之毫厘差之千里：毫秒级的屏幕显示控制

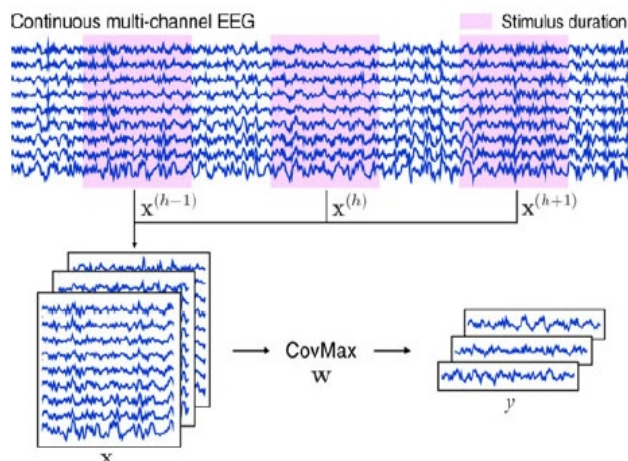


*为基于 MATLAB 的第三方工具箱 [Psychtoolbox-3](#)

视觉脑机接口的关键技术 2: 脑机接口解码算法



Lin 2006



Nakanishi 2018

Statistics and Machine Learning Toolbox

canoncorr

Canonical correlation

Syntax

```

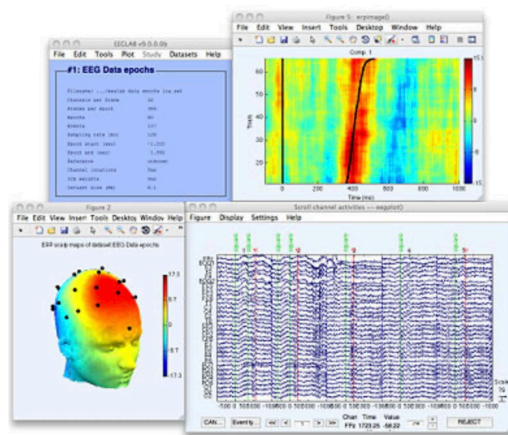
[A,B] = canoncorr(X,Y)
[A,B,r] = canoncorr(X,Y)
[A,B,r,U,V] = canoncorr(X,Y)
[A,B,r,U,V,stats] = canoncorr(X,Y)
    
```

基于典型相关分析方法开发

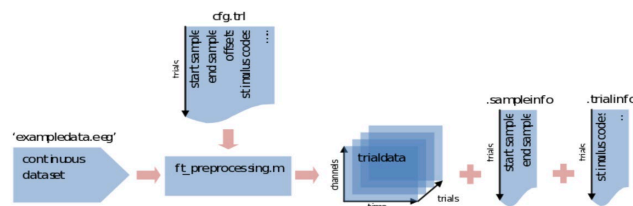
视觉脑机接口的关键技术 2: 脑机接口解码算法



EEGLAB*



FieldTrip*



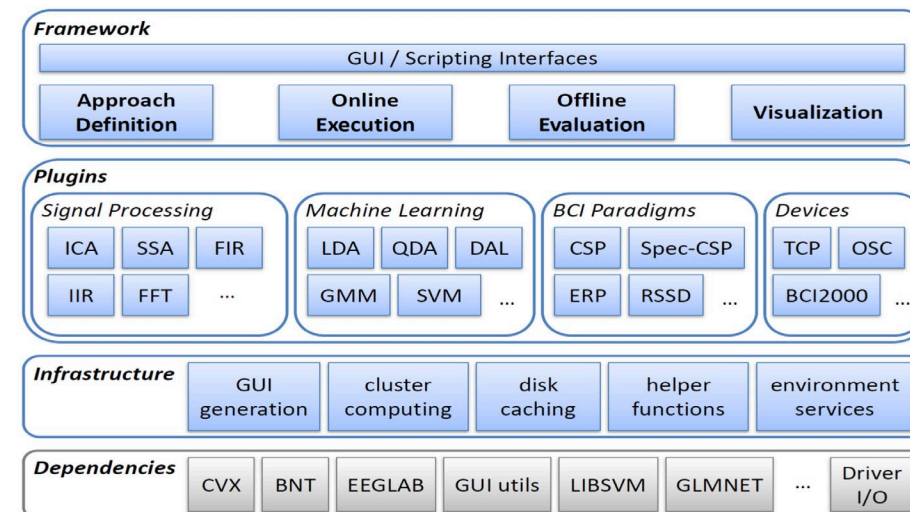
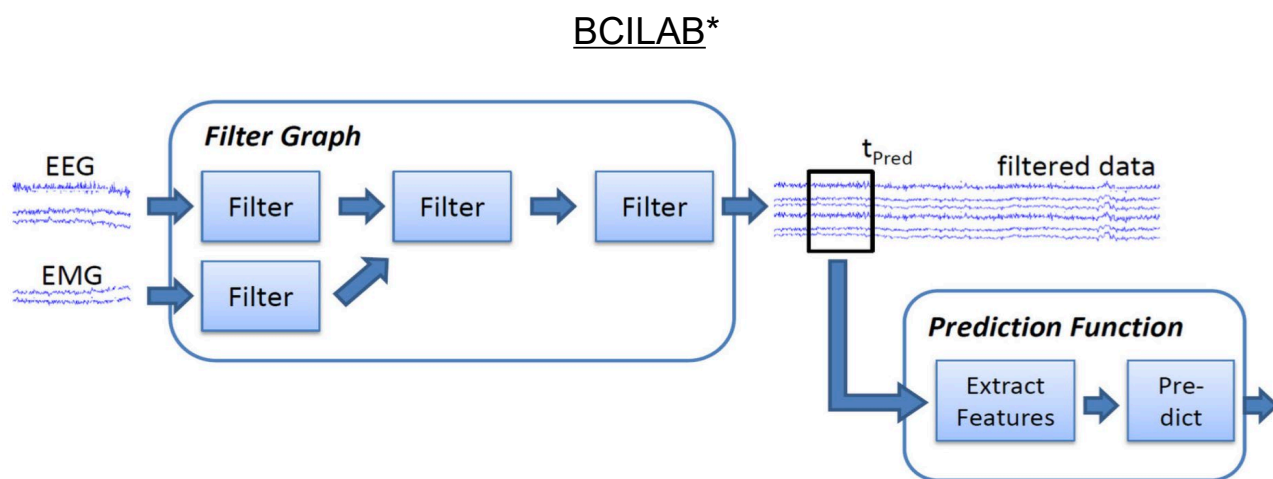
```

cfg.trl = trl;
cfg.dataset = 'exampledata.eeg';
trialdata = ft_preprocessing(cfg);
    
```

- 脑机接口数据分析最主流工具包
- 深度融合信号处理、机器学习方法
- 合计被引用 > 28,000次

*为基于 MATLAB 的第三方工具箱 [EEGLAB](#) [FieldTrip](#)

视觉脑机接口的关键技术 3: 实时数据处理与解码



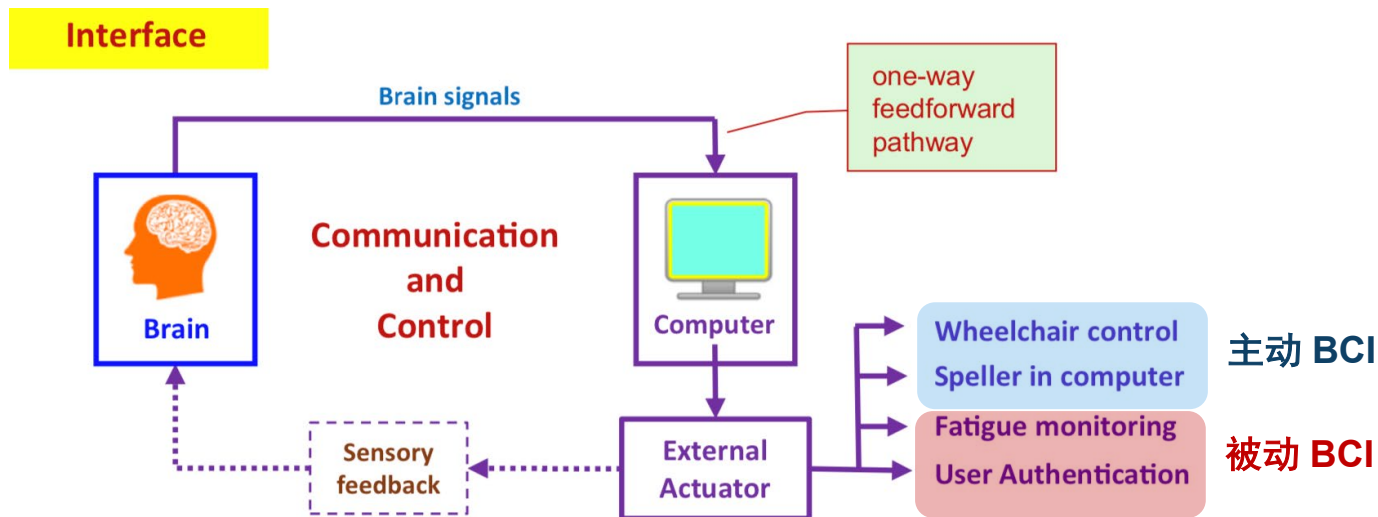
*为基于 MATLAB 的第三方工具箱 [BCILAB](#)

视觉脑机接口应用案例: 渐冻人的信息交流



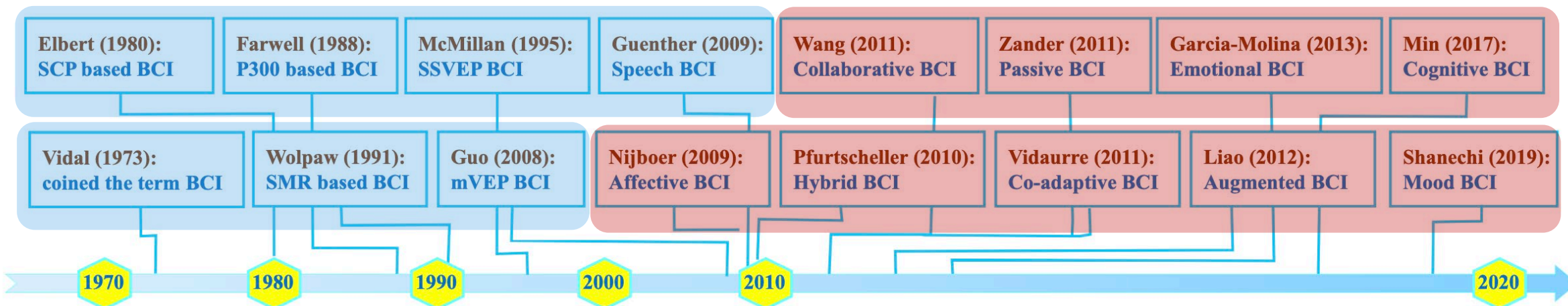
脑机接口: 状态识别与监测

情绪 BCI: 状态识别与监测研究热点



“问题不在于智能机器能否拥有任何情感，而在于机器实现智能时怎么能够没有情感？”

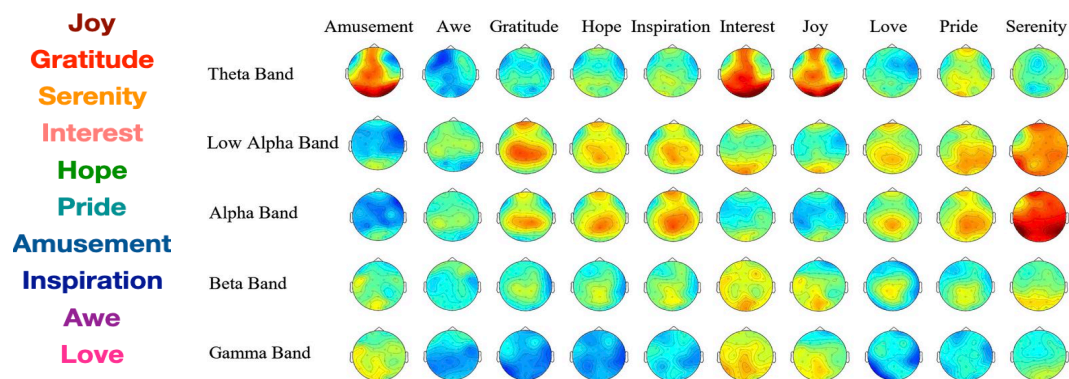
—— Marvin Minsky, 2006



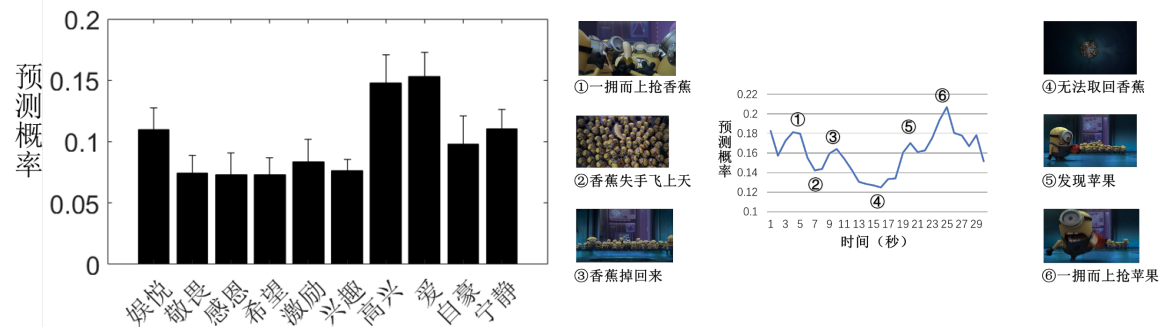
Gao 2021

情绪脑机接口: 解码实时情绪状态

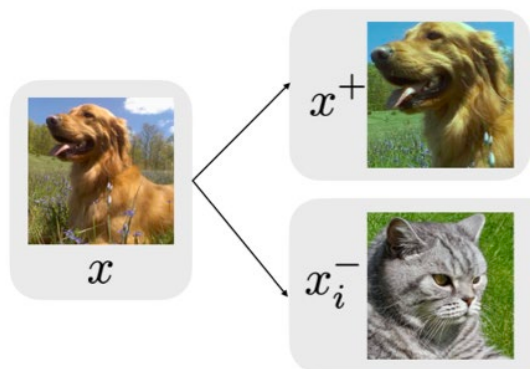
积极情绪的脑机接口计算模型, Hu 2017



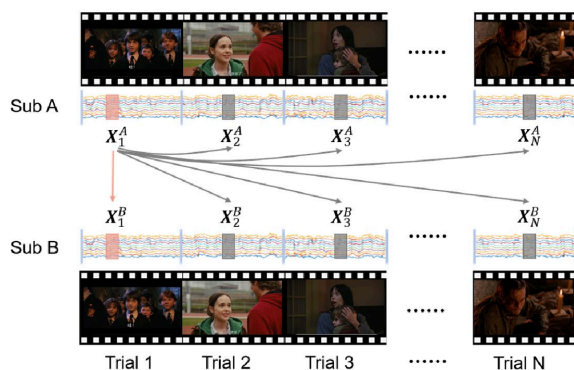
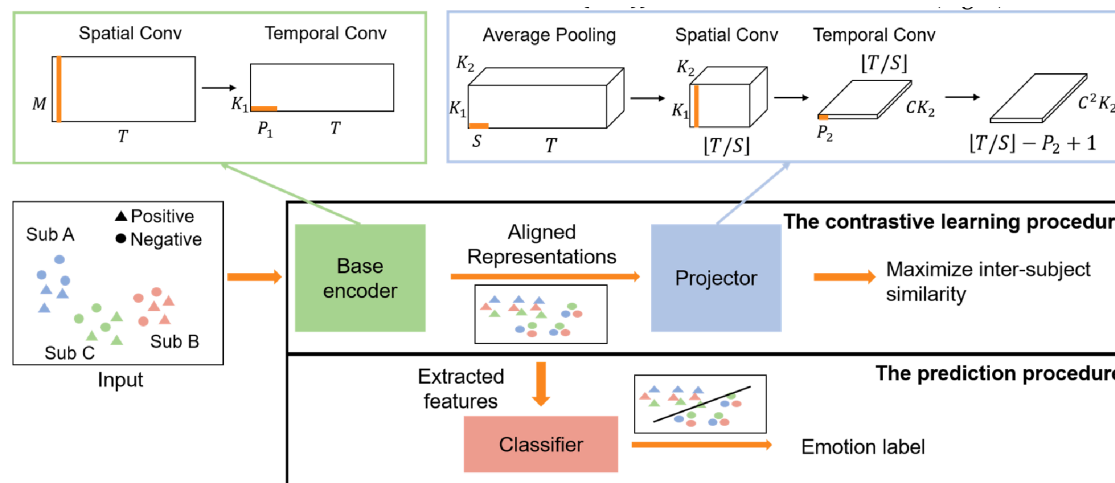
“萌”情绪体验的量化分析, Hu 2021



情绪脑机接口: 解码实时情绪状态



基于对比学习的情绪解码深度学习, Shen 2022



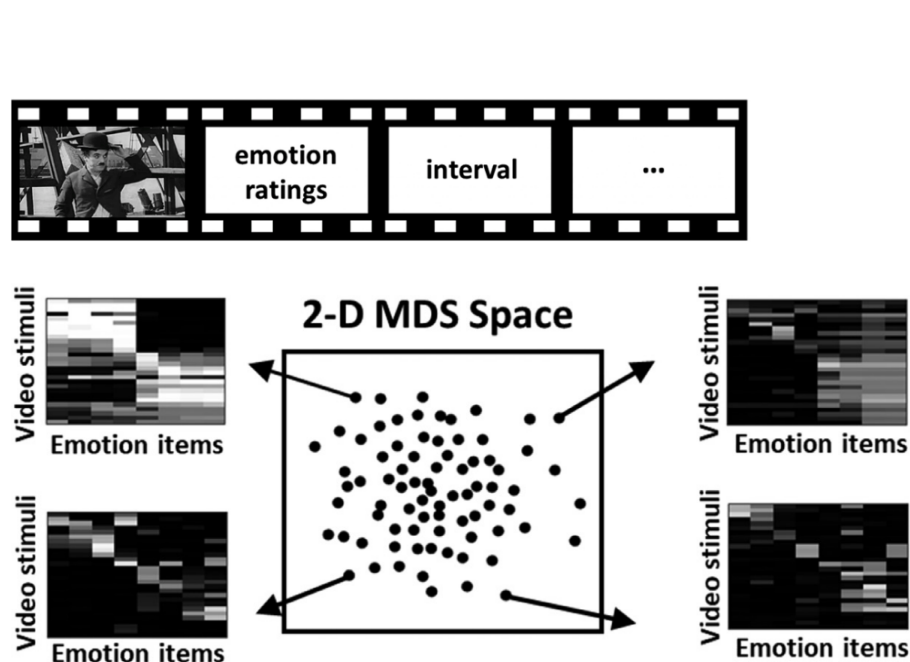
Chuang 2020

True label \ Predicted label	anger	disgust	fear	sadness	neutral	amusement	inspiration	joy	tenderness
anger	39.7	5.7	3.8	3.4	9.5	2.5	15.7	3.0	16.9
disgust	2.6	65.8	11.4	5.1	3.8	2.5	3.4	5.1	0.4
fear	1.5	11.3	46.8	8.7	6.3	9.7	6.8	7.3	1.7
sadness	6.8	4.2	8.4	32.1	16.9	5.9	8.3	9.7	7.6
neutral	5.4	2.7	3.0	6.6	65.3	5.1	3.3	4.0	4.7
amusement	3.7	3.0	10.7	4.0	10.4	46.0	8.2	8.8	5.3
inspiration	20.7	5.9	7.2	5.6	9.0	4.6	28.4	8.1	10.5
joy	4.8	8.7	9.5	9.9	9.3	15.6	8.1	25.7	8.4
tenderness	11.8	2.1	1.7	3.0	11.4	5.1	5.7	4.2	55.0

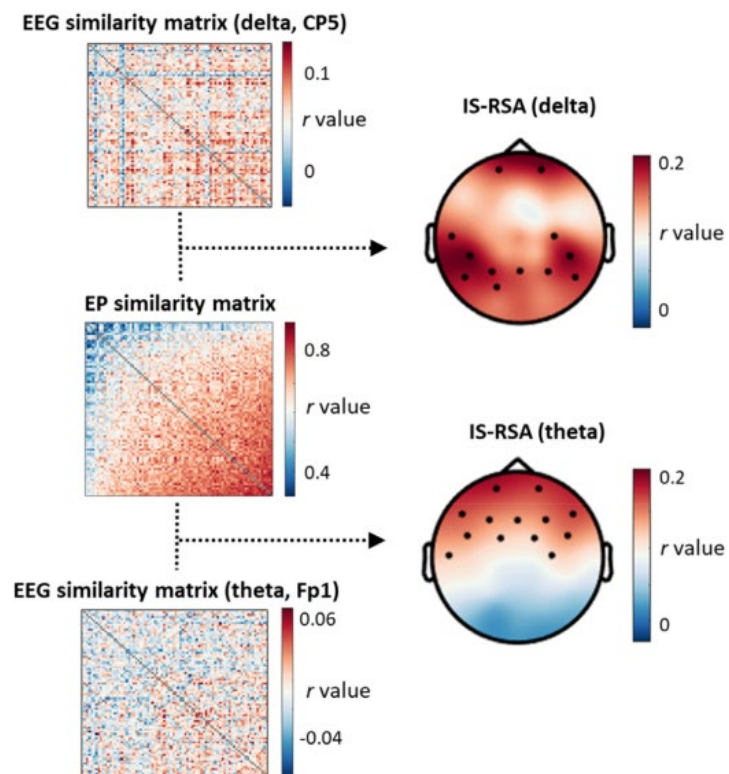
THE NINE-CLASS CLASSIFICATION ACCURACIES OF DIFFERENT METHODS ON THE THU-EP DATASET

Methods	Avg (%)	Std (%)
DE+MLP	35.3	11.1
SA	35.5	11.8
CorrCA	34.5	10.4
SeqCLR	34.3	10.5
CLISA (ours)	45.7	11.8

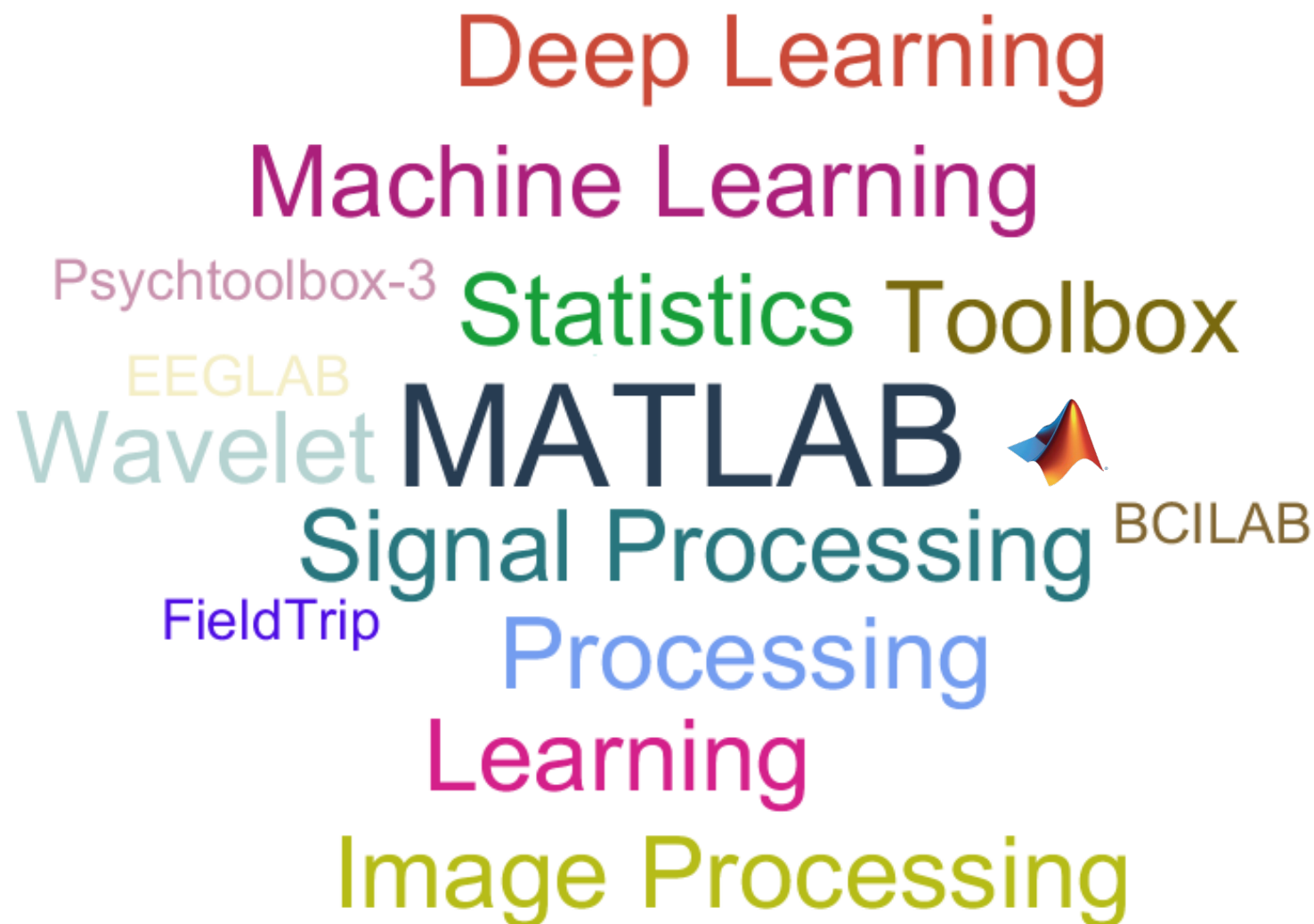
情绪脑机接口: 个体的情绪画像



Hu 2022



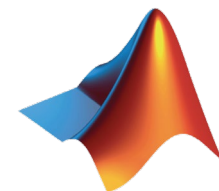
开发脑机接口技术



脑机接口教学活动

本研贯通课程：《脑成像数据分析》

- 课程教学目标：理论+实践，讲授脑成像原理、数据分析思想与数据分析方法
 - 目标学生群体：心理学及相关专业高年级本科生、心理学专业研究生
 - 脑机接口为本课程特色重点教学内容
- 数据分析实践教学平台：MATLAB + FieldTrip*
 - 主流脑成像数据分析工具支持
 - 丰富的学界案例资料
 - 易上手，学习教程、学习社区支持好
 - 可扩展性好，兼顾基础分析功能与前沿方法探索



本研贯通课程：《脑成像数据分析》

Learning by Doing

- 代码学习: 脚本 + 批注
- 脚本:
 - 交互灵活
 - 随时查看分析进展
 - 便于模仿和修改
- 批注:
 - 建议探索方向
 - 代码关键细节说明

```
%% take a look at the events before doing the event-related analysis
cfg = [];
cfg.dataset = '../raw_data/Subject01/Subject01.ds';
cfg.trialdef.eventtype = '?';
cfg = ft_definetrial(cfg);

%todo: open cfg.event and read all the information there

%% Example 3: back to a suggested FieldTrip usage for ERP analysis

cfg = [];
% cfg.dataset = '../raw_data/20150815_FYS.cnt';
cfg.dataset = '../raw_data/20150812_HCP.cnt';
cfg.continuous = 'yes';
cfg.bpfiler = 'yes';
cfg.bpfreq = [1 40];%[0.1 40]
%Caution: [0.1 40] will NOT work here due to a filter stability issue, more
%info on signal processing is required to understand this
%Rule of thumb: the width of the passband need to take a relatively large
%proportion of frequency range as compared to the range of [0 fs] and not
%too close to 0 or fs
%If your expected frequency range cannot be fulfilled given the original
%fs, consider downsampling (e.g. from 1000Hz to 200Hz)
%BUT: you will face the difficulty of using ft_redefinetrial(), here is one
%situation that padding can be useful
data_all = ft_preprocessing(cfg);
```

本研贯通课程：《脑成像数据分析》

Learning by doing

- 详实的数据结构体
- 结构化地存放关键数据
- 保留数据处理的历史“痕迹”

“Programming is indeed very hard. I often get confused by all those incomprehensible codes and abbreviations. Thanks God that TA Shui is always there helping me. He's a fantastic TA, you should buy him bubble tea!

Professor Zhang: you are an amazing professor! I have no idea that I can keep up with a class like this. I like your teaching style and the way you explain **MATLAB** and **Fieldtrip**. I'll keep practicing!

Huge thanks to you two!”

data	
1x1	
字段	
hdr	
trial	
time	
fsample	1000
label	9x1 cell
trialinfo	360x1 double
sampleinfo	360x2 double
cfg	1x1 struct

progress	1x1 struct
callinfo	1x1 struct
version	1x1 struct
tolerance	1.0000e-05
select	'intersect'
latency	'all'
channel	9x1 cell
frequency	'all'
nanmean	'no'
previous	1x1 struct

学生课外科技活动



DEAPdataset
a dataset for emotion analysis using eeg, physiological and video signals

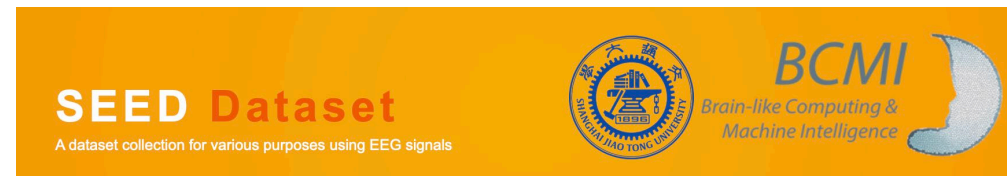
data_preprocessed_matlab.zip and data_preprocessed_python.zip

These files contain a downsampled (to 128Hz), preprocessed and segmented version of the data in Matlab (data_preprocessed_matlab.zip) and pickled python/numpy (data_preprocessed_python.zip) formats. This version of the data is well-suited to those wishing to quickly test a classification or regression technique without the hassle of processing all the data first. Each zip file contains 32 .dat (python) or .mat (matlab) files, one per participant. Some sample code to load a python datafile is below:


```
import cPickle
x = cPickle.load(open('s01.dat', 'rb'))
```

Each participant file contains two arrays:

Array name	Array shape	Array contents
data	40 x 40 x 8064	video/trial x channel x data
labels	40 x 4	video/trial x label (valence, arousal, dominance, liking)



SEED Dataset
A dataset collection for various purposes using EEG signals

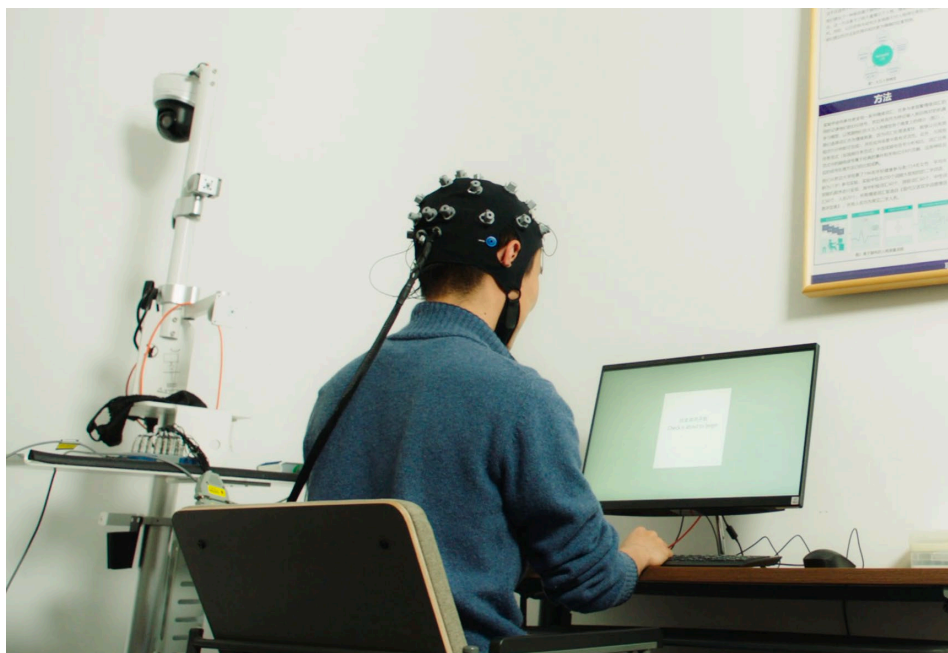


BCMI
Brain-like Computing & Machine Intelligence

In the "Preprocessed_EEG" folder, there are files that contain downsampled, preprocessed and segmented versions of the **EEG data** in **MATLAB** (.mat file). The data was downsampled to 200 Hz. A bandpass frequency filter from 0 - 75 Hz was applied. We extracted the EEG segments that correspond to the duration of each movie. There were a total of 45 files with the extension .mat (MATLAB files), one per experiment.

基于公开数据集开展算法研究，学术社区支持下的优秀算法代码学习，提升学生实践能力

学生课外科技活动

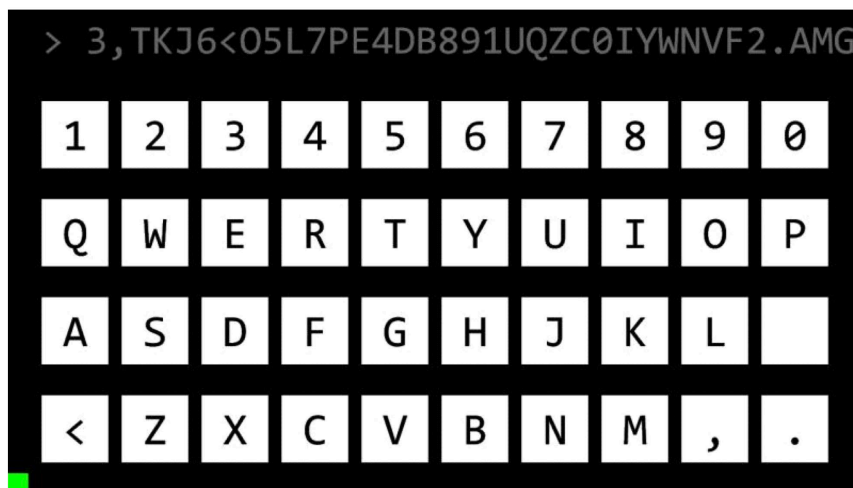


易读、易分享、易修改的情绪脑机接口系统代码；便于学生学习、改进、合作，开展科研学习探索

学生竞赛：世界机器人大赛 - BCI 脑控机器人大赛



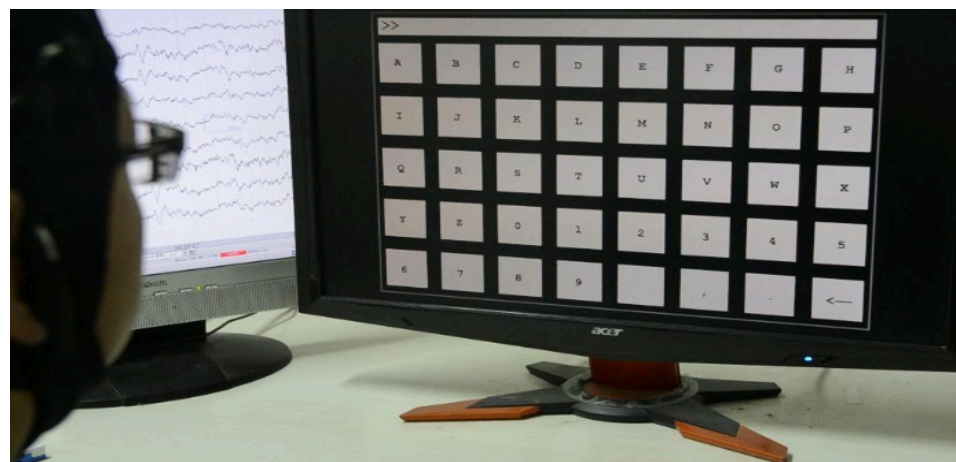
- 2022年赛题：视觉脑机接口
- 2023年赛题：情绪脑机接口，敬请关注情绪脑机（青年组）



2022年 MATLAB 青年组冠军指导团队

选择 MATLAB 用于科研与教学

- 丰富的教学资源支持多样化教学需求
 - 学生“手把手”学习资源
 - 系统、全面的心理学与神经科学教学资料
 - 做中学：知识 + 案例 + 代码的教学资源
- 活跃的科研社区支持前沿科研活动
 - 经典和前沿的信号处理、统计与机器学习工具
 - 具有广泛影响力的第三方科研工具
 - 脑机接口学界的“默认”交流平台



总结

愿景：更高效、更温暖的脑机接口



脑机接口科学研究

脑科学原理 + 机器学习算法

实时界面交互、数据处理与反馈

视觉脑机接口：高效信息交互

情绪脑机接口：个体状态与特质的测评



脑机接口教学活动

课程教学：灵活、交互的学习模式

课外科技活动：学术社区支持、交流合作与进步

培养学术和产业的后备军

MATLAB EXPO

谢谢!

Thank you!



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