Developing computational infrastructure for an EEG-based Brain-Computer Interface

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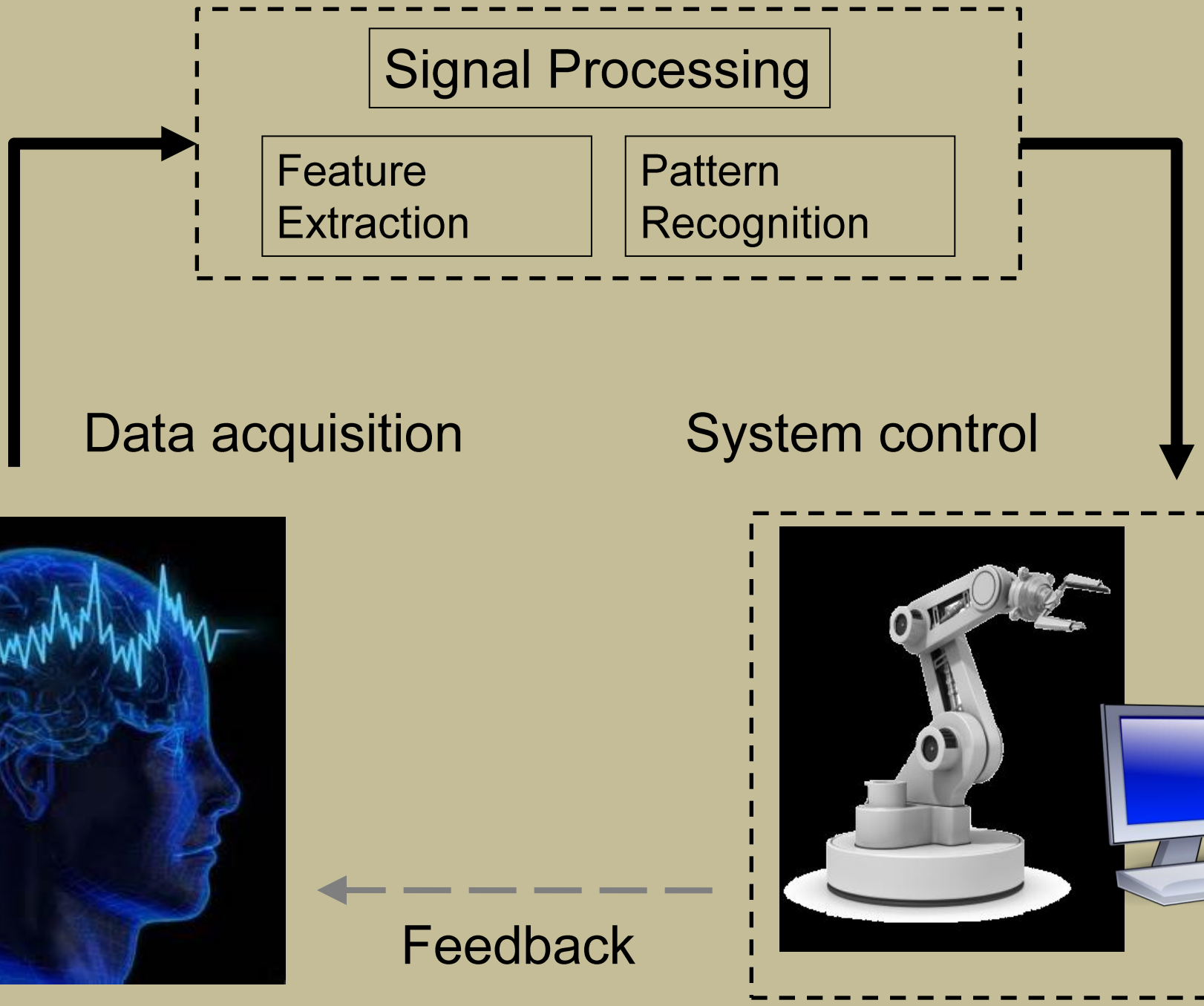
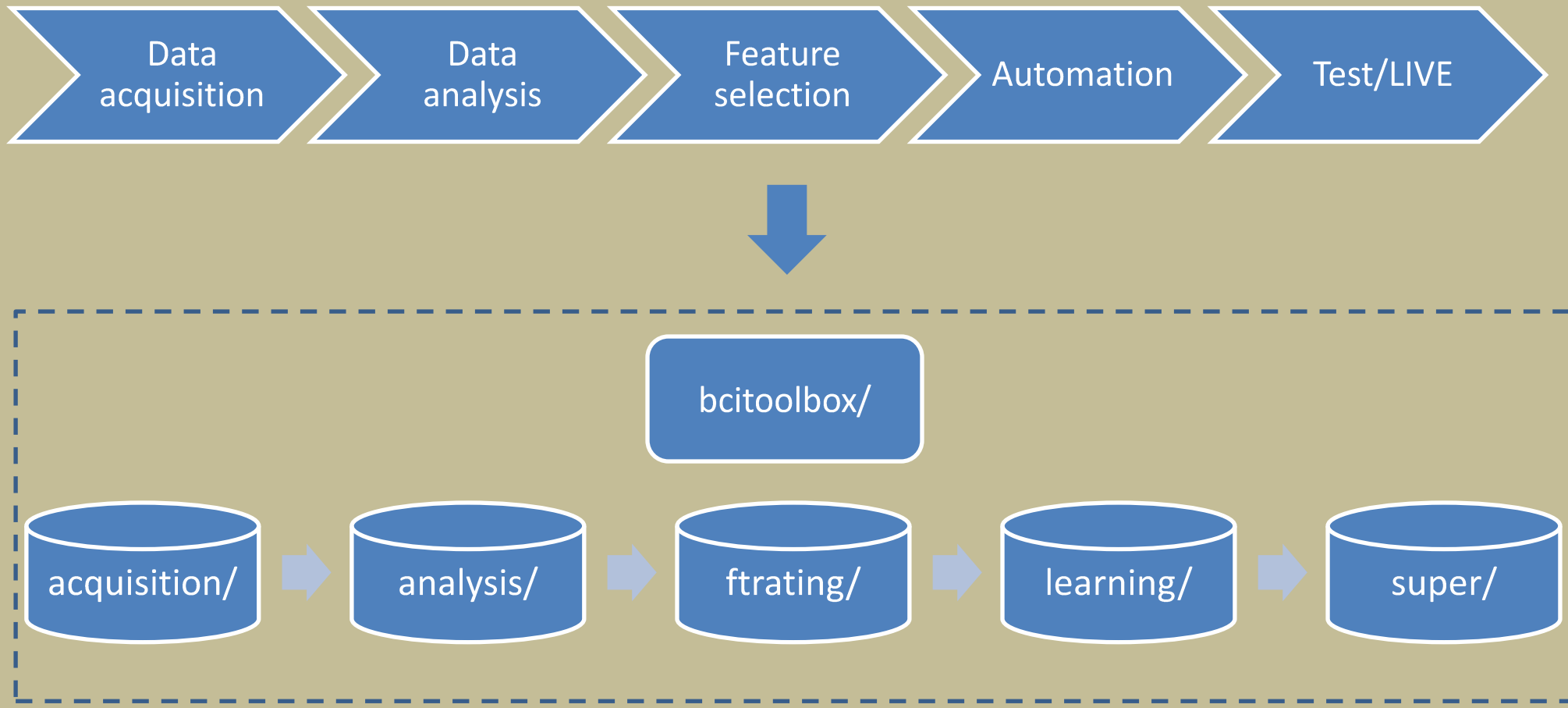

Signal Processing
Feature Extraction
Pattern Recognition
Data acquisition
System control
Feedback

EEG BCI toolset

- Developed in the course of implementing a EEG-based BCI in our laboratory
- Supports and implements the elements of typical EEG BCI workflow

Workflow


Data acquisition
Data analysis
Feature selection
Automation
Test/LIVE
bcitoolbox/
acquisition/
analysis/
ftrating/
learning/
super/

Data acquisition

- Acquire data from EEG devices and save it to a MATLAB format for further (offline) analysis
- Provide real-time EEG data feed for (online or live) analysis and processing
- Offer user interfaces for BCI experiments

EEG data acquisition devices

Nihon Kohden EEG-1200

- *medical grade* EEG system, 38 channels max, 1000 Hz sampling rate, 0.01 µV resolution

EMOTIV EPOC (x3)

- *wireless* EEG headset, 12 channels max, 128 Hz sampling rate, 0.5 µV resolution

Data acquisition tools

emologger → emoExperiment

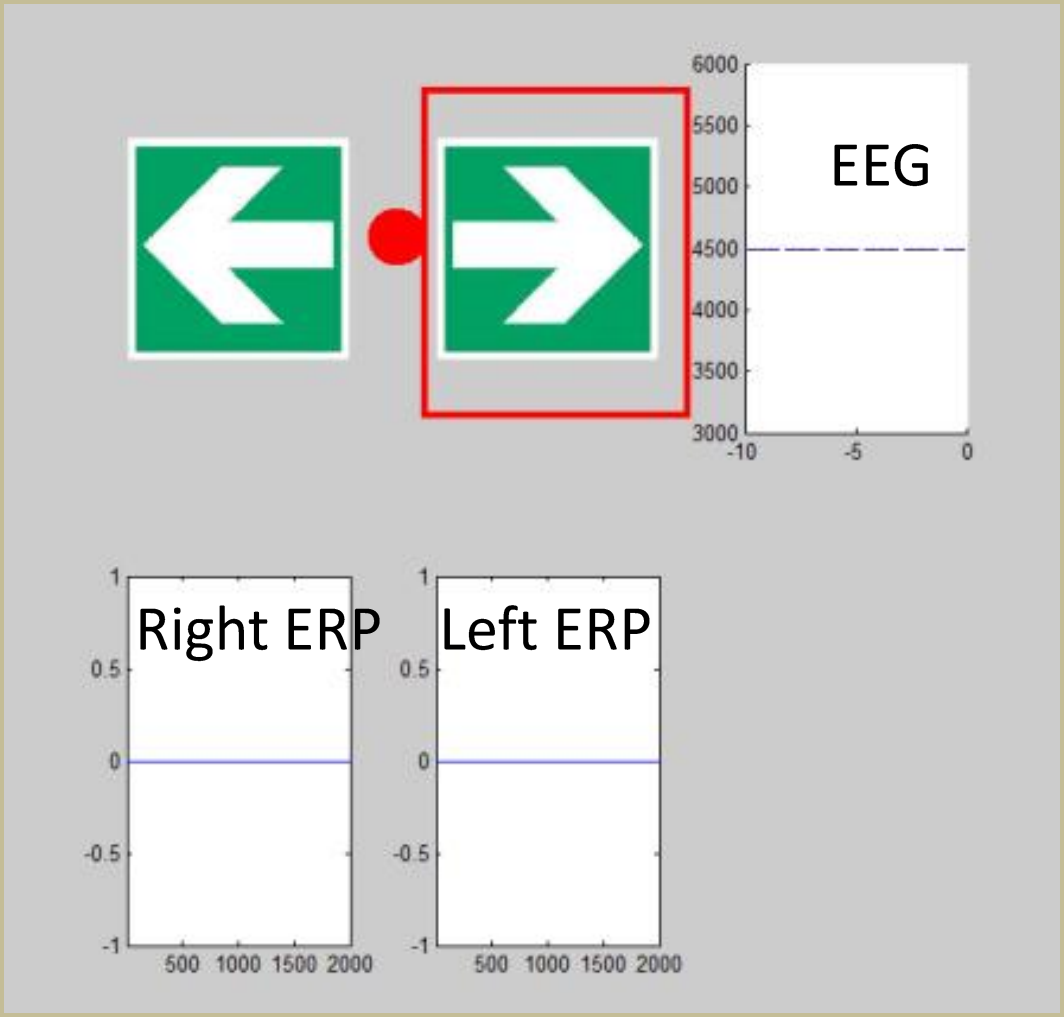
nklogger → nkiui

nkimport

nkExperiment

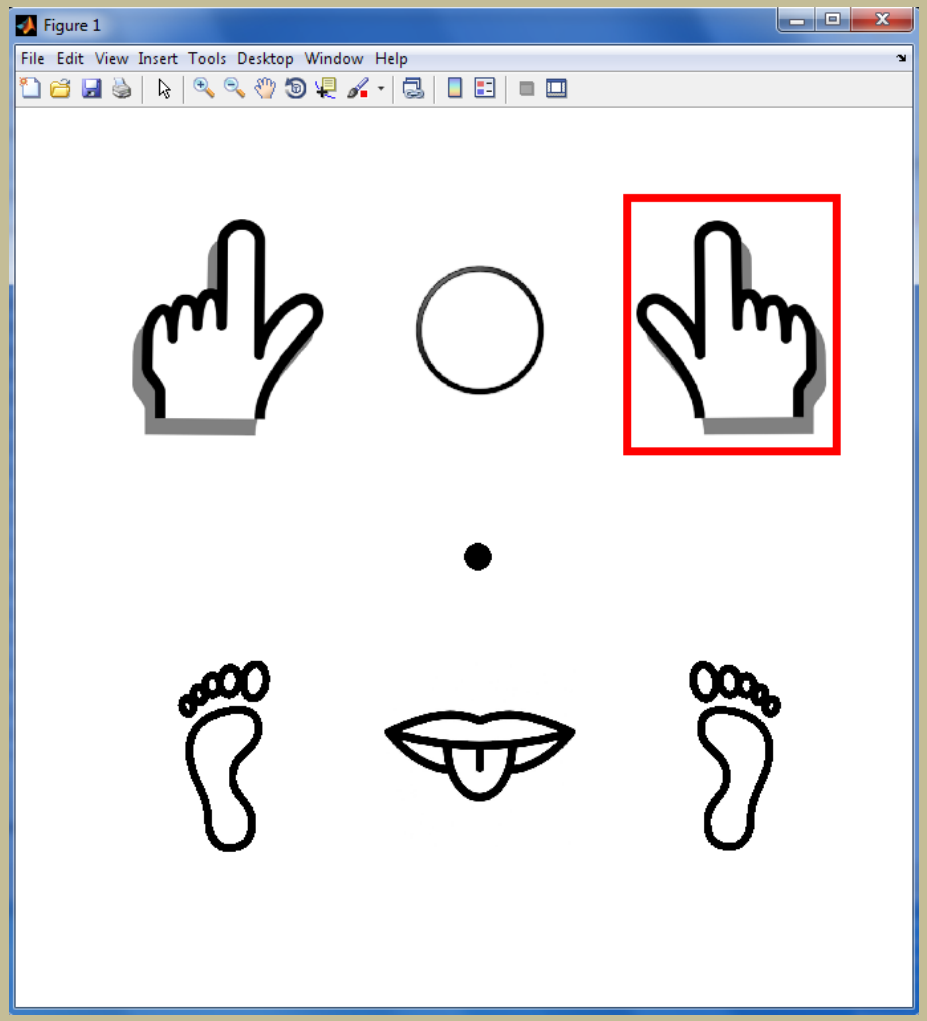
sync.ino

Data acquisition interfaces



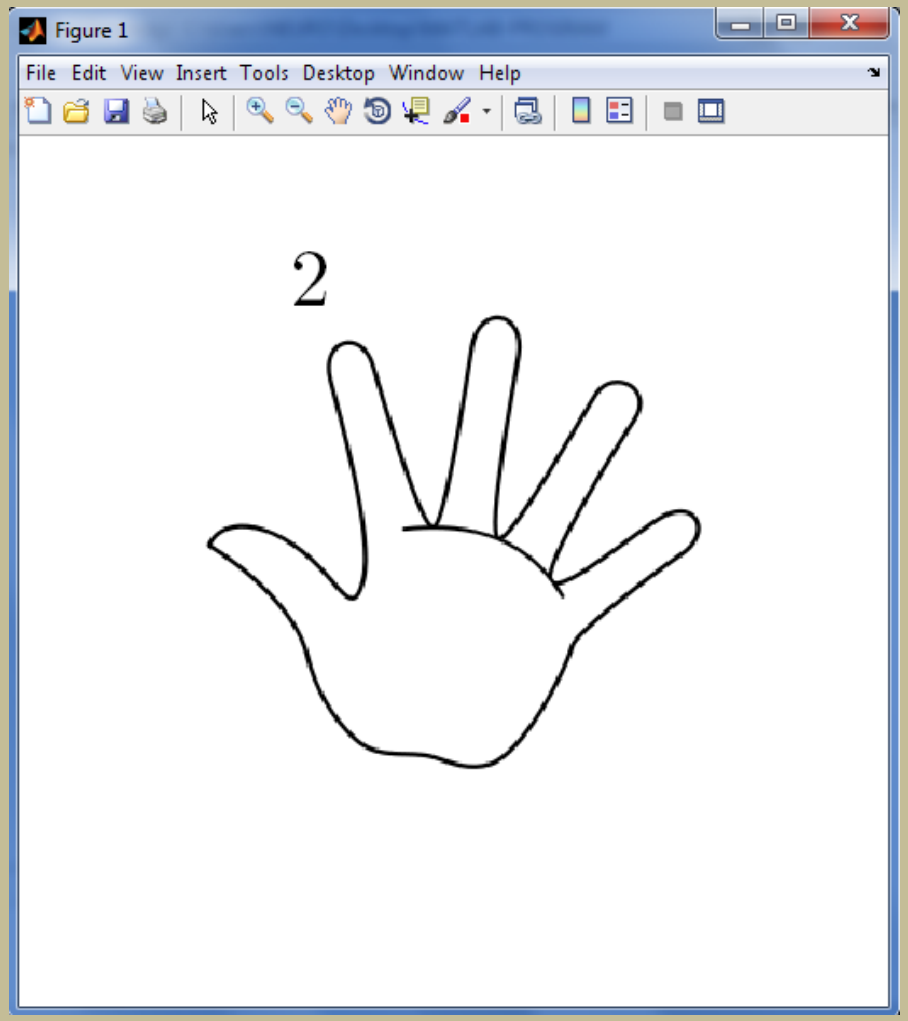
Emotiv Epoc interface for measuring right/left hand movement ERPs

Data acquisition interfaces



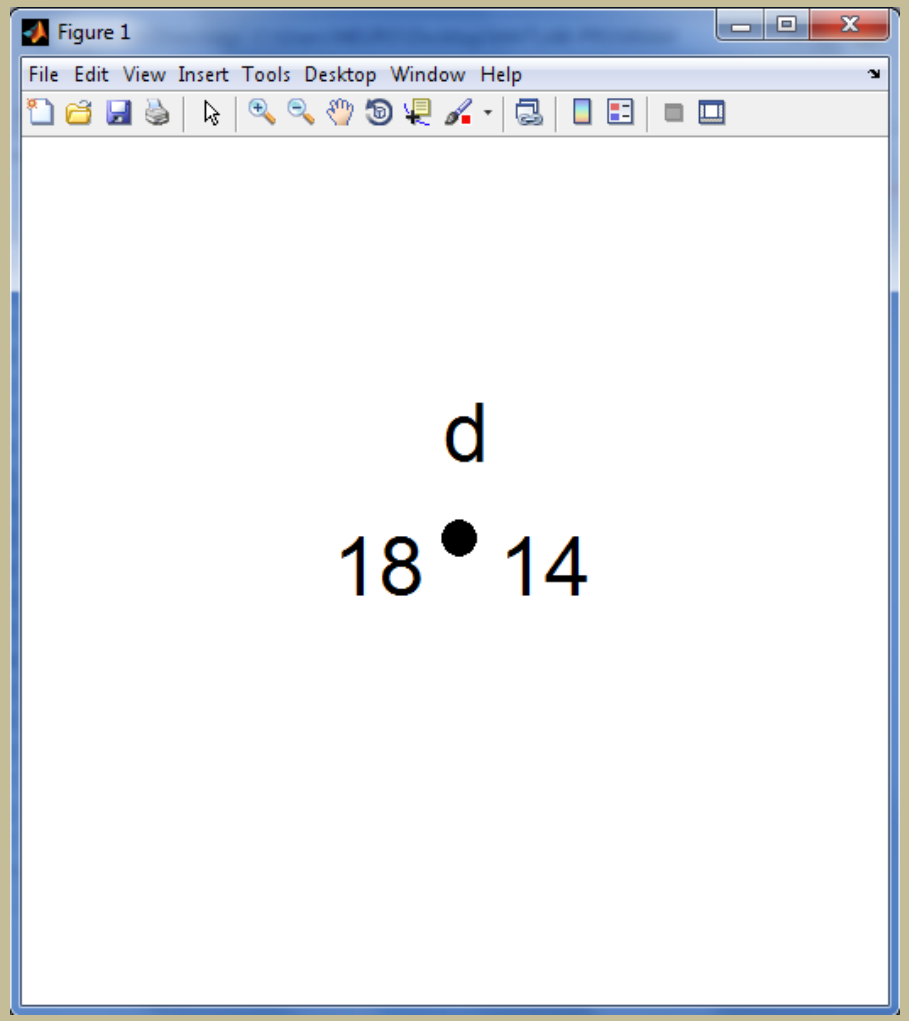
Nihon Kohden interface for Right/Left-Hand and Right-Left-Hand-Leg-Tongue BCI experiments

Data acquisition interfaces



Nihon Kohden Interface for five-finger motor imagery

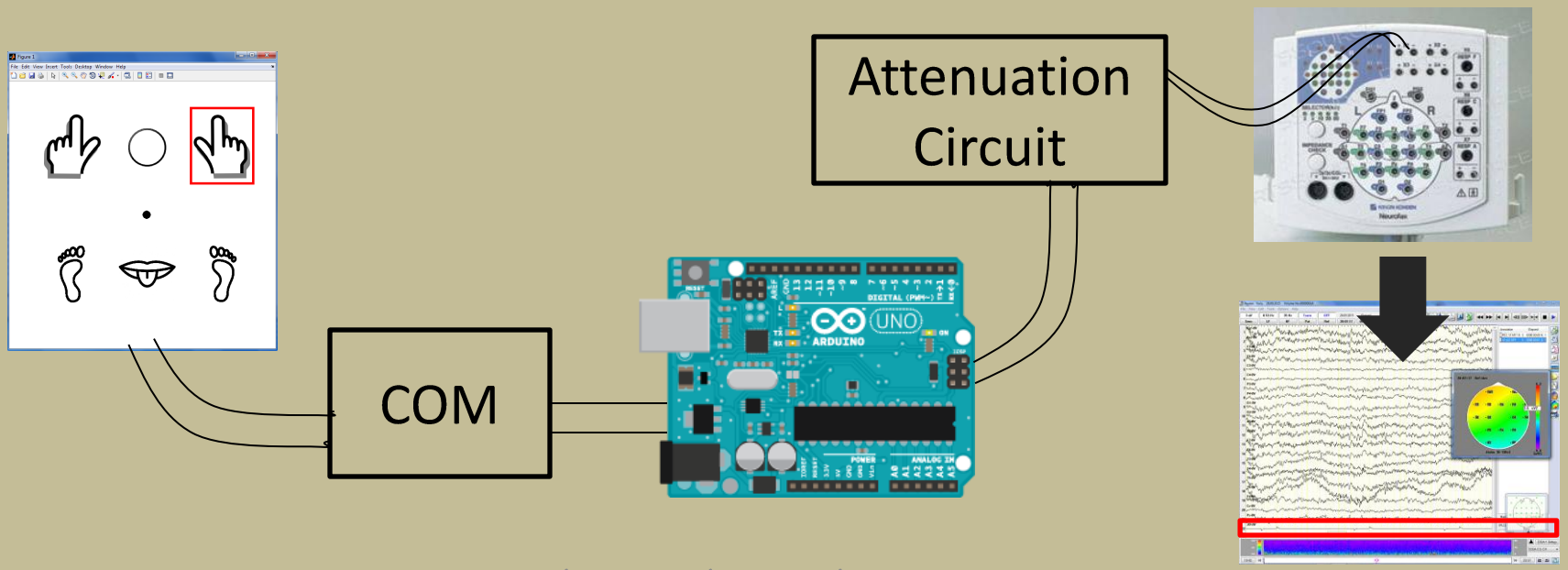
Data acquisition interfaces



Nihon Kohden Interface for free key-press motor imagery

Data acquisition

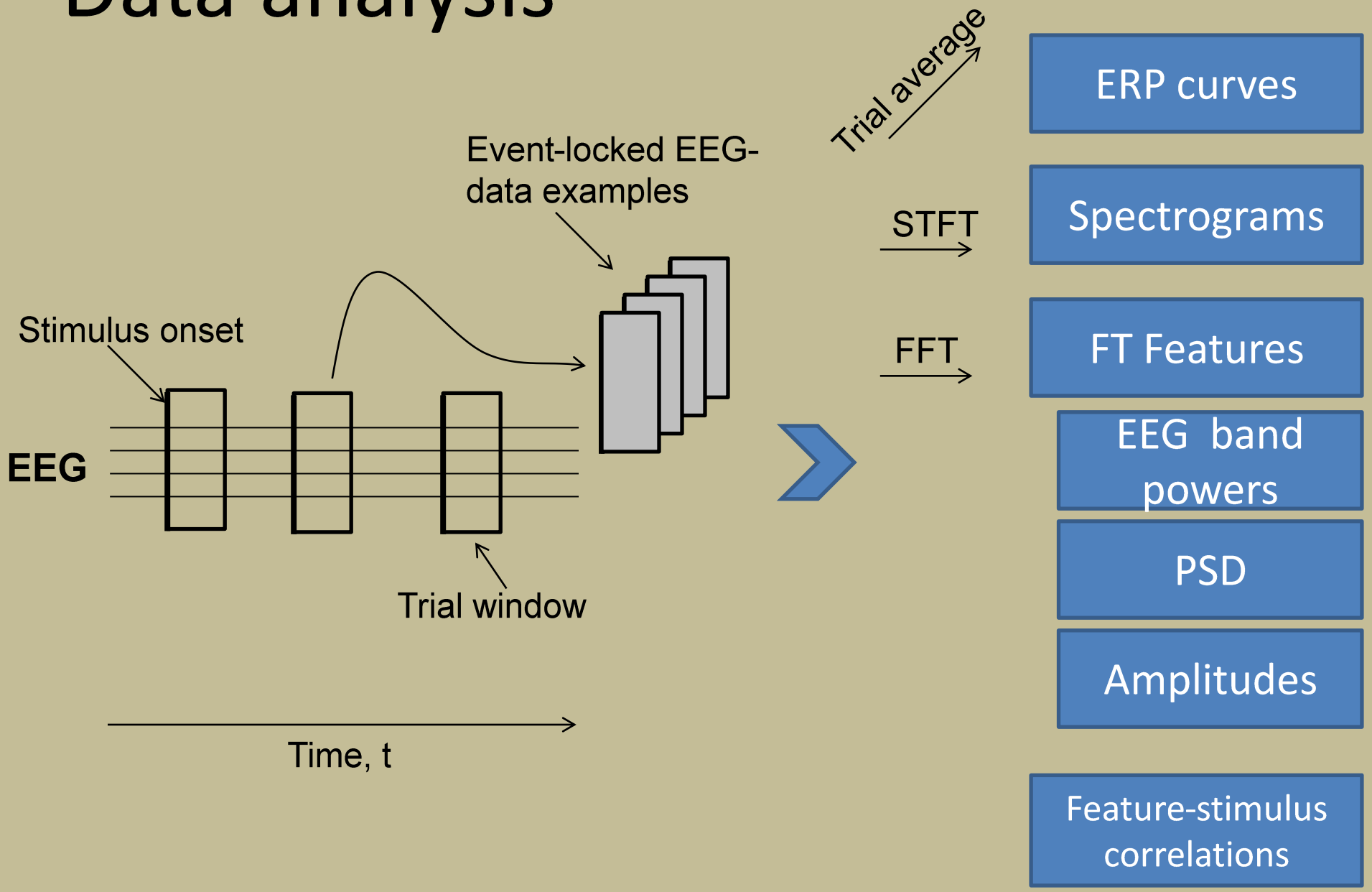
- A recurrent problem is inability to synchronize User Interface(s) data with EEG acquisition device(s) – Nihon Kohden EEG-1200 adds variable delay into its EEG data stream varying between 200 ms and 500 ms
- Our solution is to inject a ~ 1 uV Event Trigger signal directly to EEG-1200 signal acquisition box , and then find it in the EEG-1200's recording



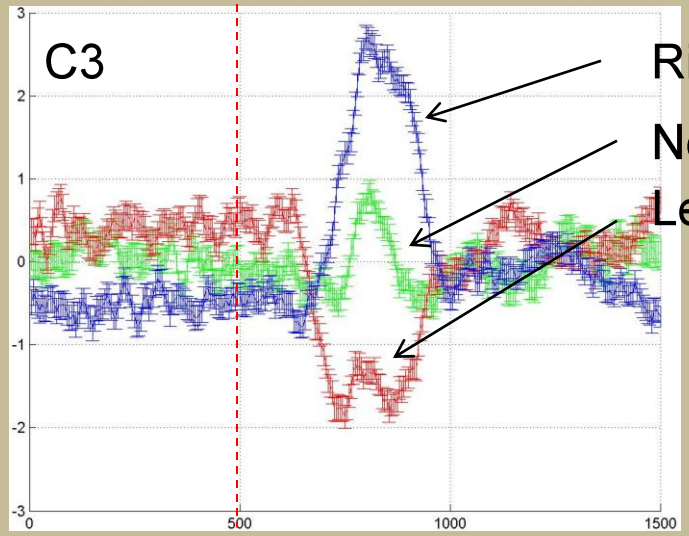
Data analysis

- Trials extraction
- Event -Related-Potentials (ERP)
- Data spectrograms
- Signal-stimulus covariances
- Features calculation

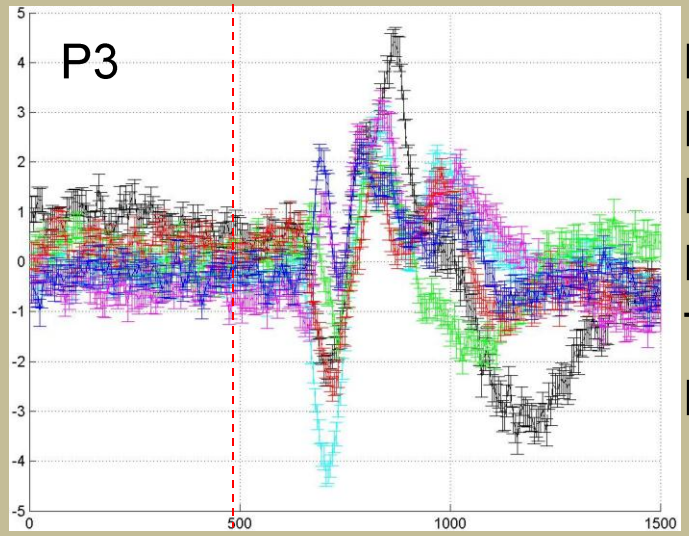
Data analysis



Examples of measured ERPs

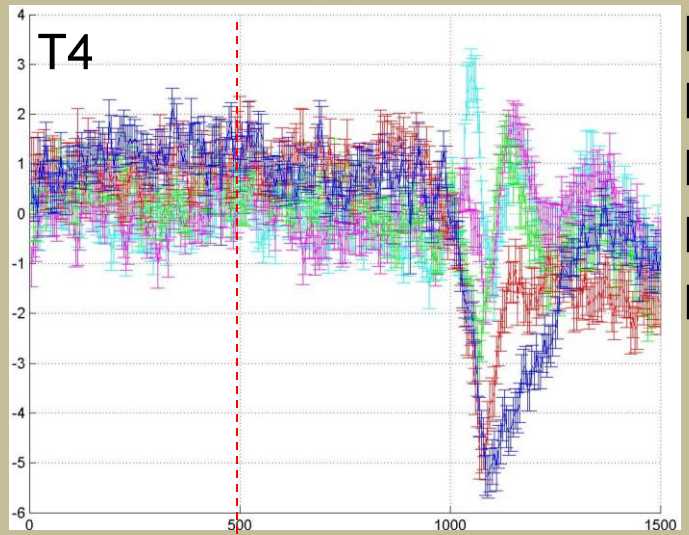


Right/left hand + neutral

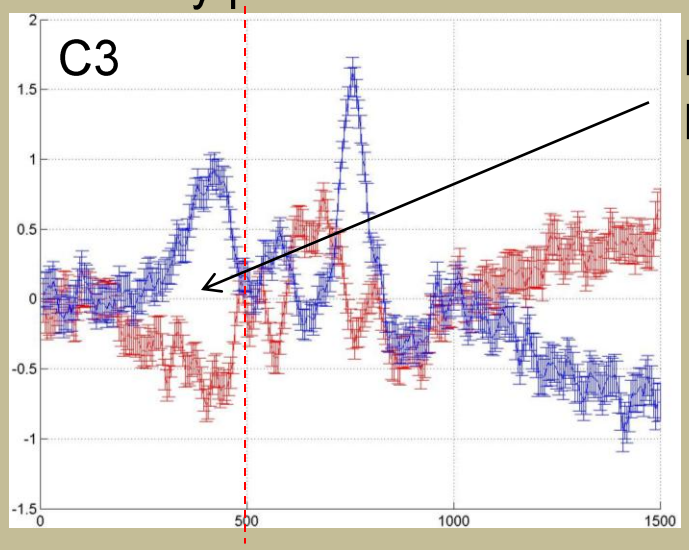


Right/left hand, leg, tongue + neutral

Five-fingers



Free key presses



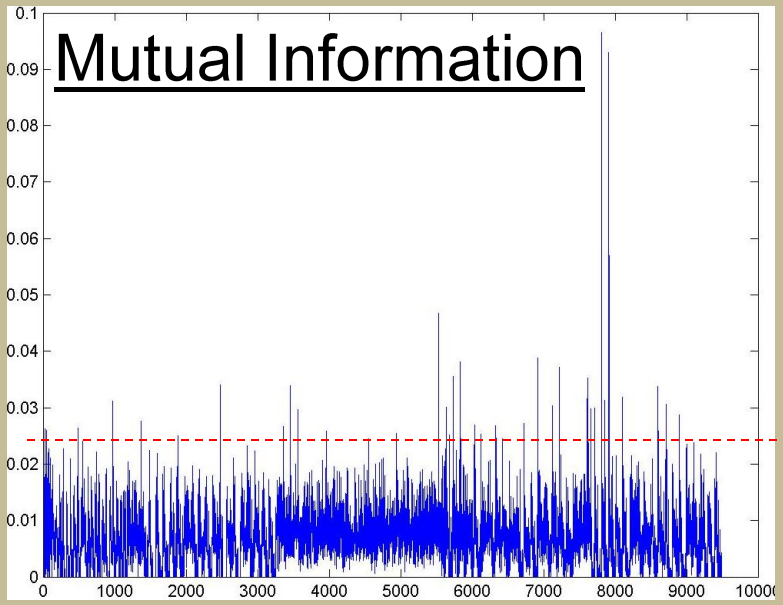
Feature selection

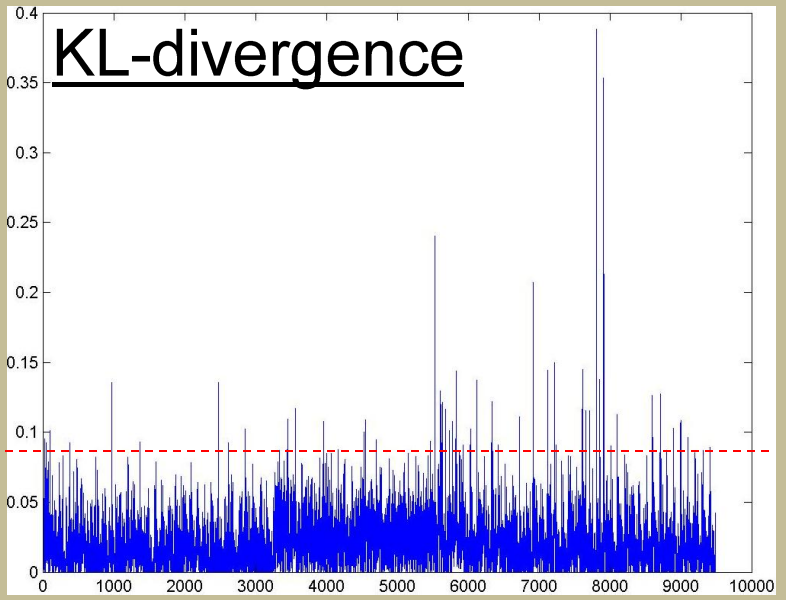
- Small amount of data
  - The number of event examples typically obtained from one 1-hour BCI experiment – 200-500, the number of features - > 9,000
  - The Rule of Thumb in Machine Learning – the number of examples >≈ 10x the number of features
- Pre-select features before trying to detect events in the EEG data

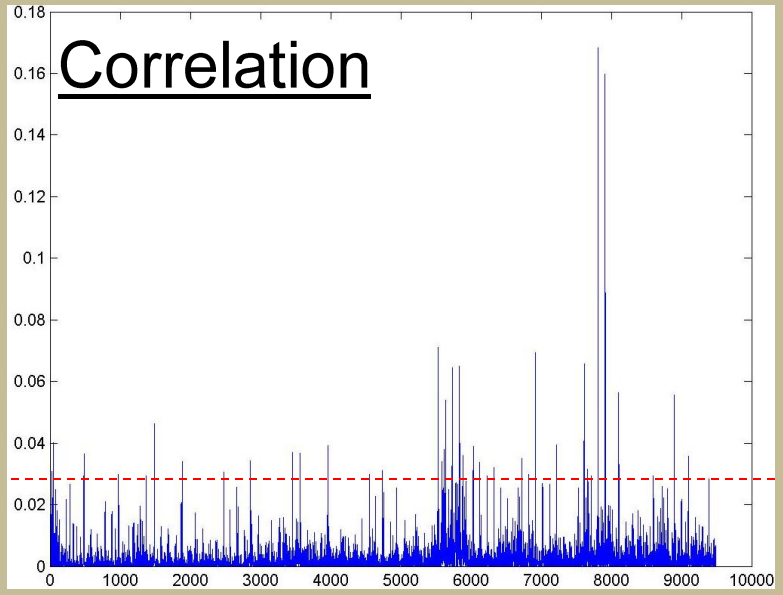
Feature selection

- Single feature ranking
  - Feature-stimulus Pearson correlation
  - Feature-stimulus Mutual Information
  - Kullback-Leibler (KL) Divergence
- Channel ranking
  - Add-one-in EEG channel ranking
  - Leave-one-out EEG channel ranking

Feature selection







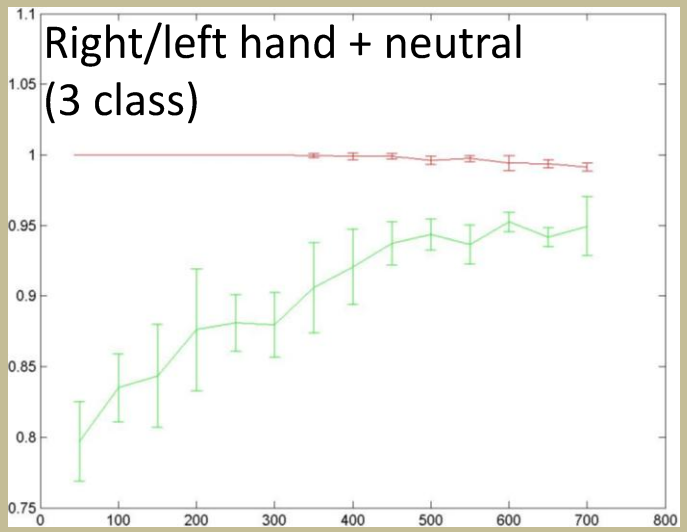
Automation

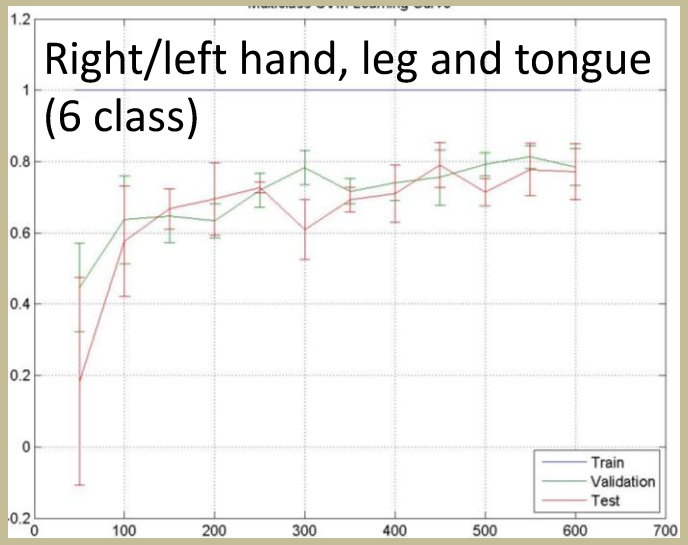
- Detect “events” in EEG data *automatically*
- Synchronous model - beginning of an event is known via a signal to the subject
- Use Machine Learning algorithms to machine-learn the ways to identify BCI events in EEG data

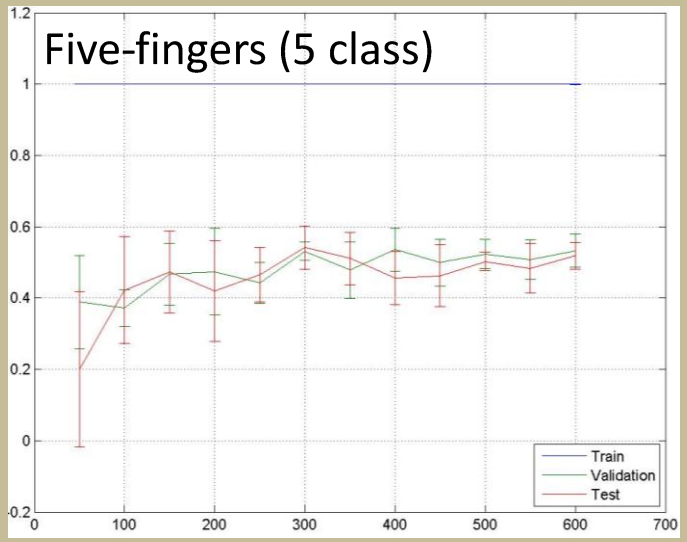
Automation

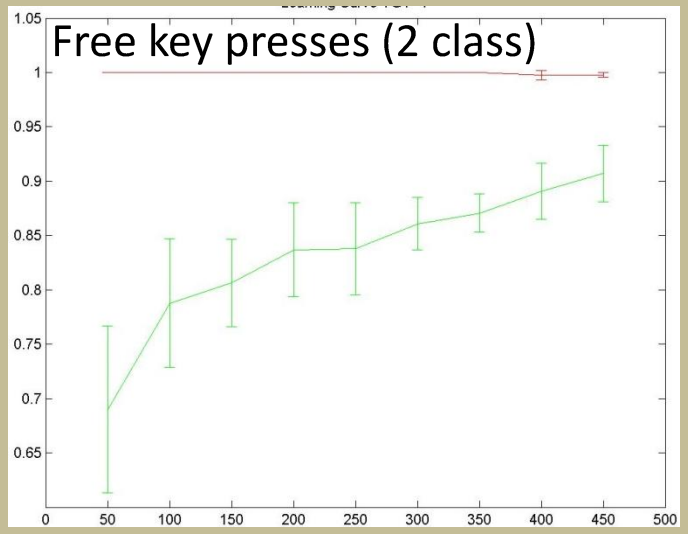
svm_tr	General Support Vector Machine for 2-class separation
mcsvm_tr	Multiclass Support Vector Machine, voting implementation
mnlr_tr	Multinomial Logistic Regression for direct learning of class-probabilities
svm_lc	Learning curves for 2-class Support Vector Machine
gen_lc	General learning curves for (any, multinomial) given classification method

Automation


Right/left hand + neutral
(3 class)


Right/left hand, leg and tongue
(6 class)
Train
Validation
Test


Five-fingers (5 class)
Train
Validation
Test


Free key presses (2 class)

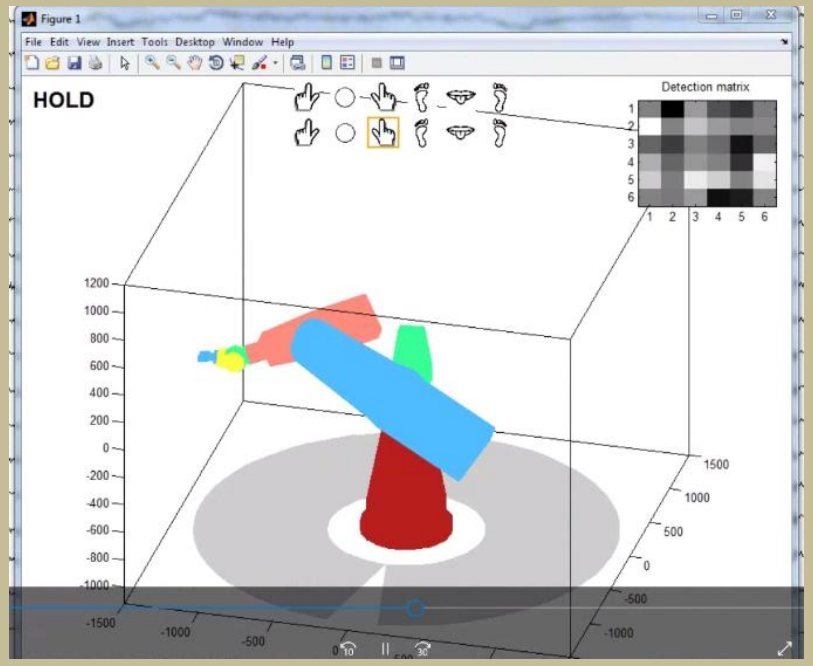
Tests/LIVE

- Automate (offline) analysis of experiments using a batch script
- The batch script pulls together the above tools to perform data synchronization, extraction of trials, ERP calculation, features ranking, training and validation of ML event-models automatically

Tests/LIVE

- Experiments with live events detection began recently using our NK EEG-1200 Interactive User Interface (nkiui)
- Subjects control a virtual robot arm in 3D using Left/Right-Hand-Leg-Tongue BCI model (5 dof + neutral)

LIVE experiments



Tests/LIVE

- (limited) First results:
  - 2 dof + neutral arm control – 70-85% accuracy
  - 5 dof + neutral arm control – 40-50% accuracy
- These are comparable to our offline results so far

Acknowledgements

Lab members:

- Murat KAYA
- Hilmi YANAR
- Erkan ÖZBAY

Former lab members:

- Emre SAĞLAM
- Umut SÜRMELİ

Funding sources:

- TUBITAK ARDEB 1001 (113E611) "Development of more efficient Noninvasive Brain Computer Interfaces"
- Toros University BAP (TUBAP135001) "Founding of the Noninvasive Brain Machine Interfaces Research Laboratory"
- Bilim Akademisi BAGEP-2013 Young Scientist Award

Questions about toolbox etc.:
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