Master Thesis Intermediate Presentation:

Decoding of 3D Reach and Grasp Movements from Non-invasive EEG Signals using SpiNNaker Neuromorphic Hardware

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Master: Robotics, Cognition, Intelligence

Chair for Neuroscientific System Theory (NST)

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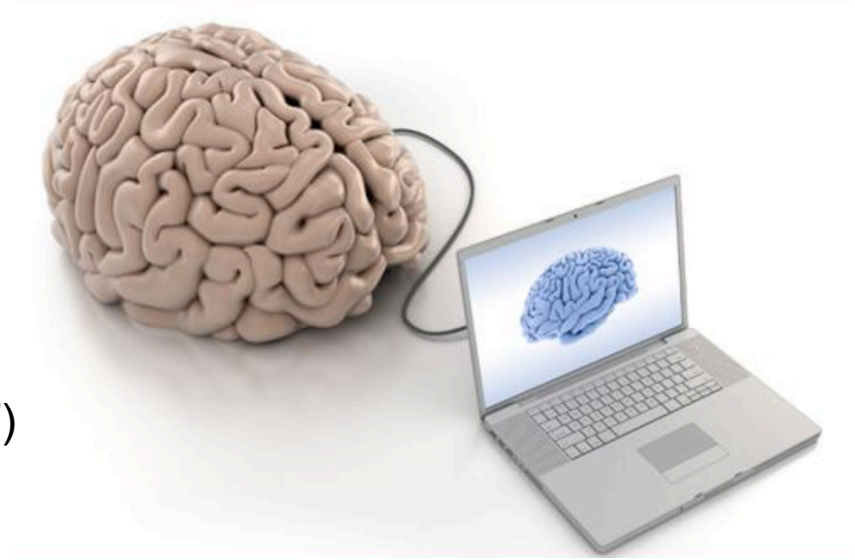

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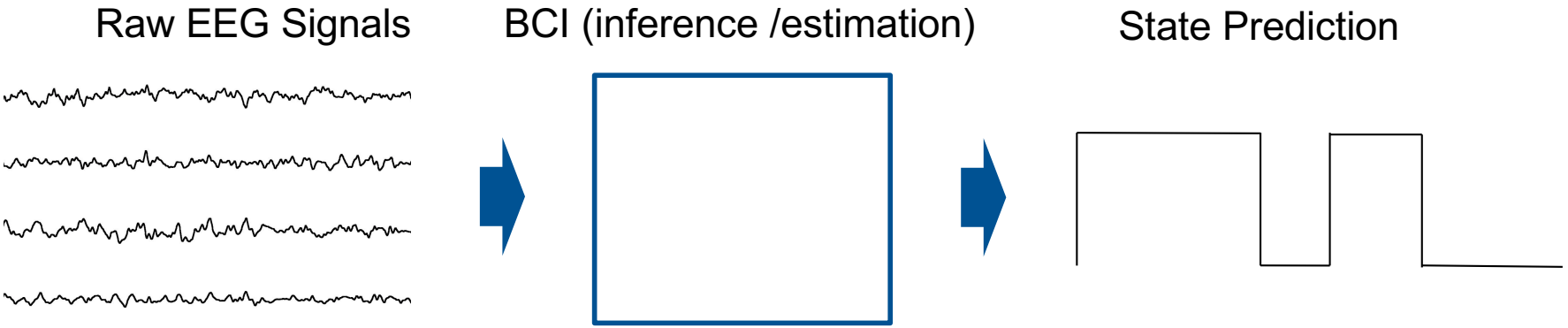
Overview

- Brain-Computer-Interfaces
- Feature Extraction
- Classification with Spiking Neural Networks on SpiNNaker
- Problems + Results
- Future Work

Brain-Computer-Interface: Overview

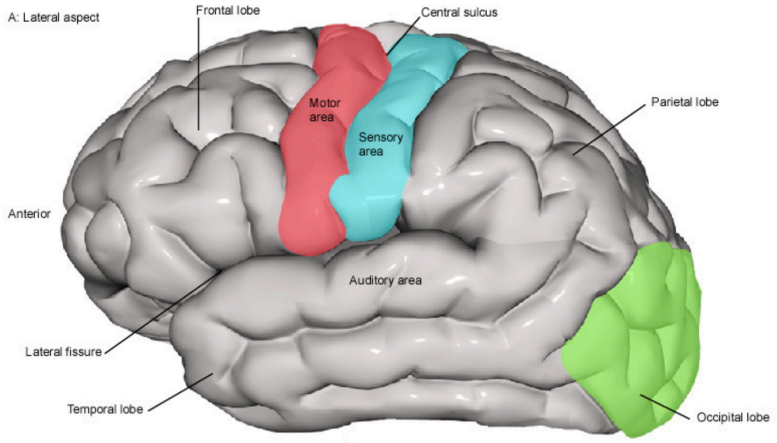


<u>BCI Systems</u>

- Active BCI: Measured brain activity is directly consciously controlled by the user
  - ➡ thinking to move right hand
- Reactive BCI: Measured brain activity arises in reaction to external stimulation
  - ➡ concentrate on flickering light
- Passive BCI: Derives its output from arbitrary brain activity
  - ➡ detecting someone's mood

Brain-Computer-Interface: Overview

Motor Cortex:



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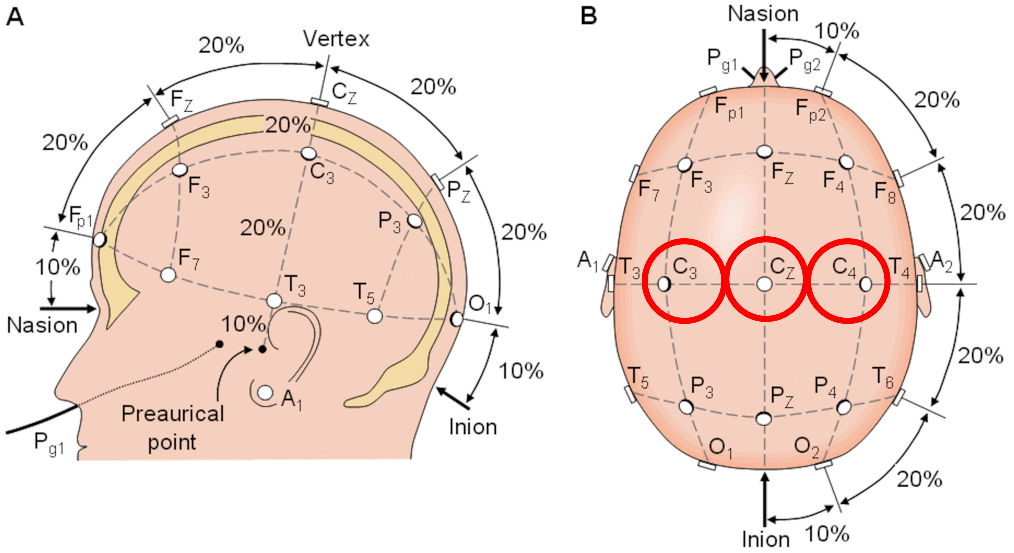
10 – 20 System:



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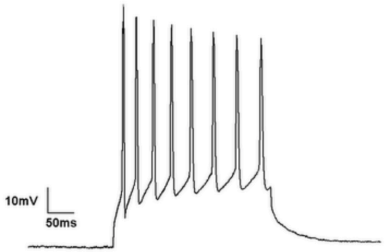
Brain-Computer-Interface: EEG

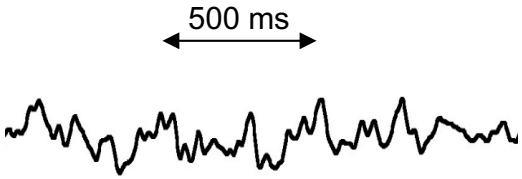
What is measured?

- EEG (Electroencephalography): electrical activity of the brain
- EOG (Electrooculography): eye movements => Artifacts

Temporal Characteristics

- Neural vs Scalp Activity





- Event-Related Potentials:
  Averaging EEG activity relative to an event results in primary event-induced activity

- Oscillatory Processes:
  - Delta: 0-4 Hz
  - Theta: 4-7 Hz ➡ Bursts relative to events in certain brain areas
  - Alpha: 8-13 Hz ➡ Sensory and Motor Areas
  - Beta: 12-30 Hz ➡ Motor Area
  - Gamma: 25-100 Hz

Brain-Computer-Interface: Difficulties

Processing depends on unknown parameters:

- Person specific ➡ cortex is folded differently
  ➡ relevant function maps differ across individuals
- Task specific
- Recording specific
- Non-stationary signals
- Low signal to noise ratio

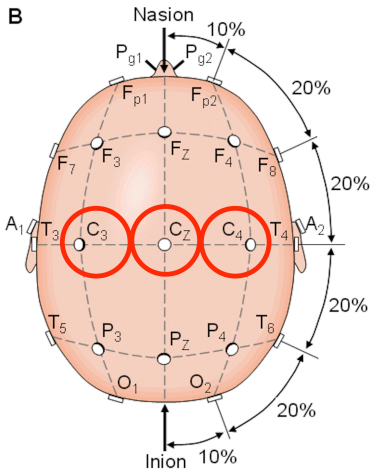
- Brain „computes“ many things ➡ difficult to determine what signal corresponds to what thought

- We don‘t know how the brain works

➡ All approaches are statistical
BCI systems often have to be calibrated before use (prior knowledge)

Brain-Computer-Interface: Our Approach

Signal recording



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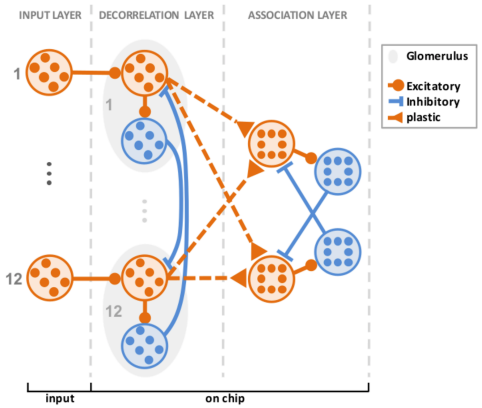
Preprocessing ,
Feature Extraction

Classification



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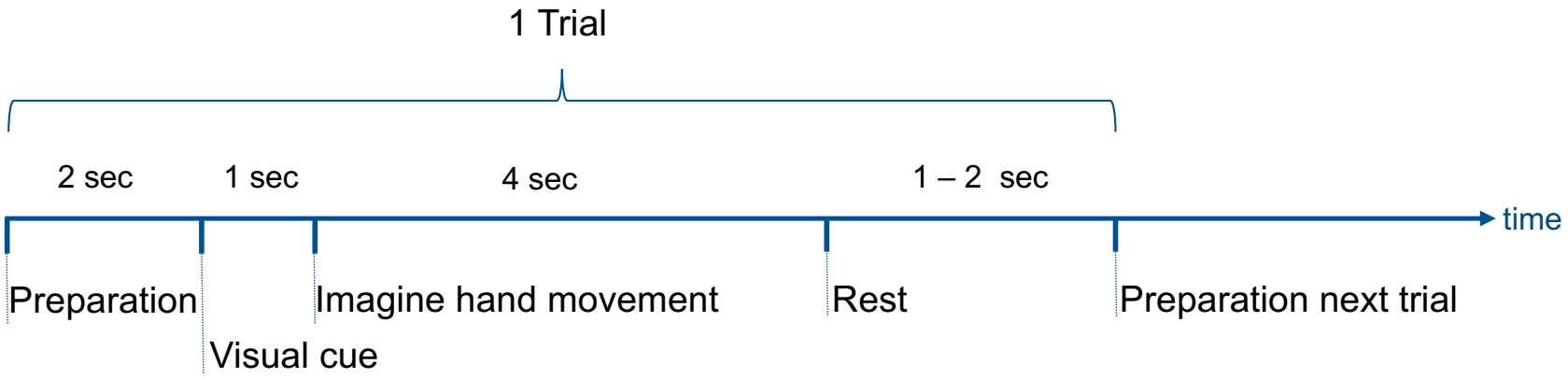
- Active BCI
- Oscillatory Processes / Event Related Potentials in alpha and beta band

Brain-Computer-Interface: Data

Data Recording:

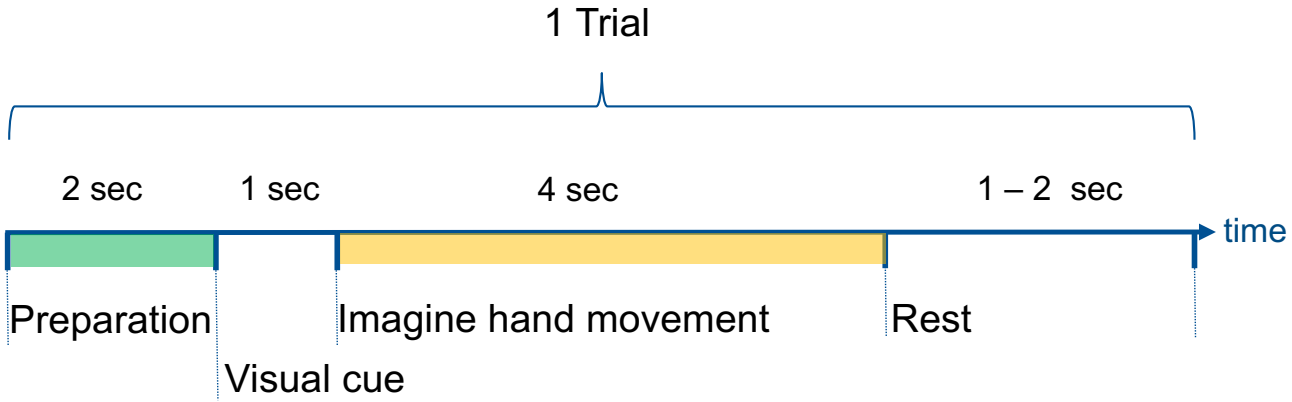
- Sampling frequency: 250 Hz
- 120 Trials / Session
- Random movements

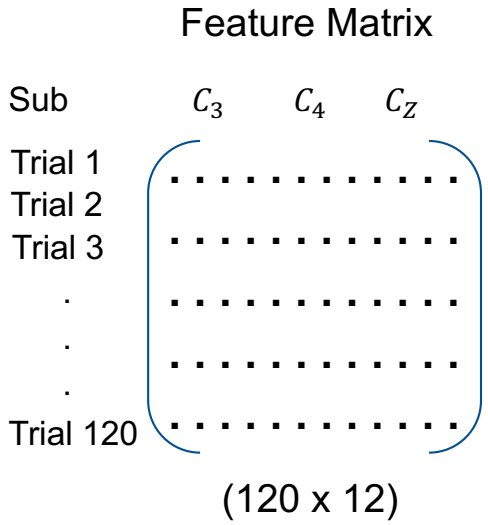


Feature Extraction: Sub bands

- Filter raw EEG signal alpha (8 – 12 Hz) sub bands:
  - 8 – 10 Hz
  - 9 – 11 Hz
  - 10 – 12 Hz
  - 11 – 13 Hz

  - Calculate Power of the sub bands during preparation(rest) and imagination time span



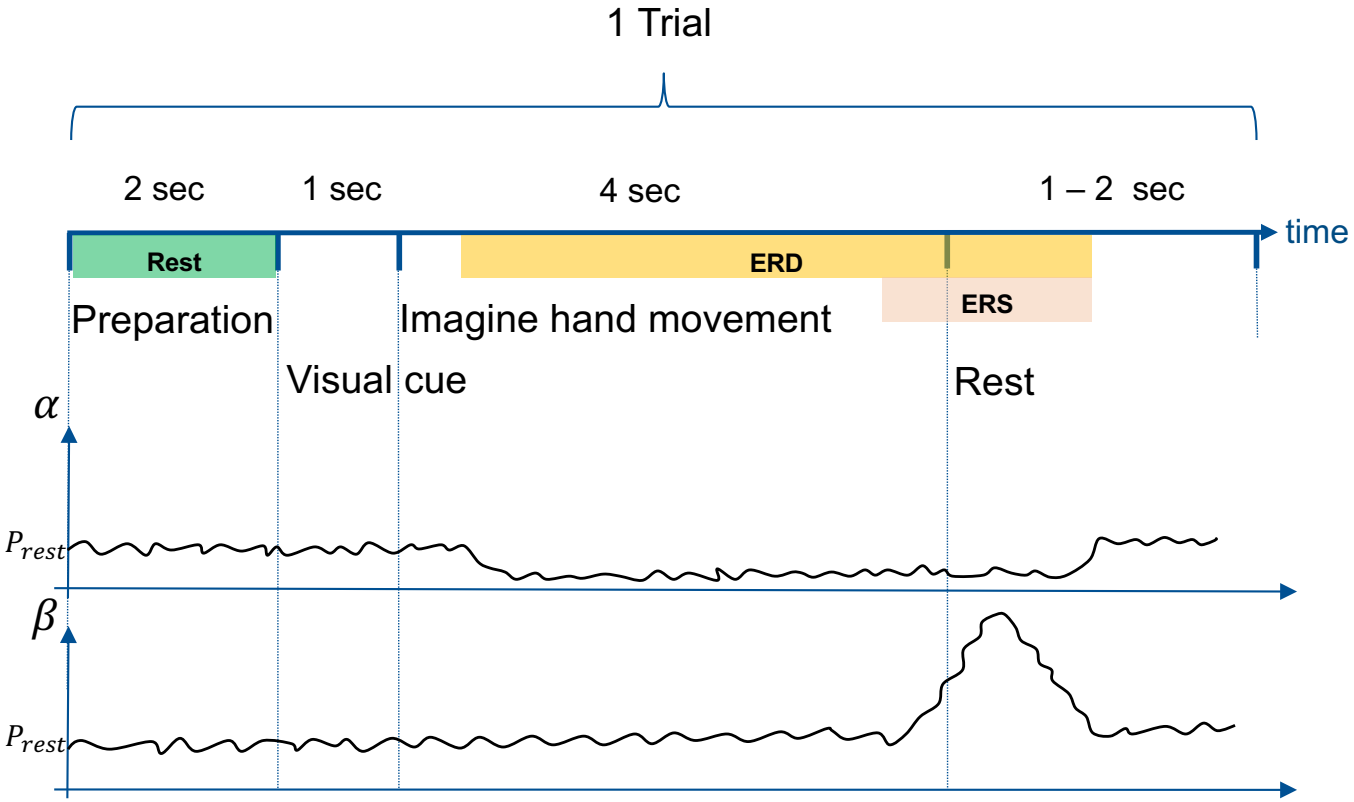


Feature Extraction: ERD% / ERS%

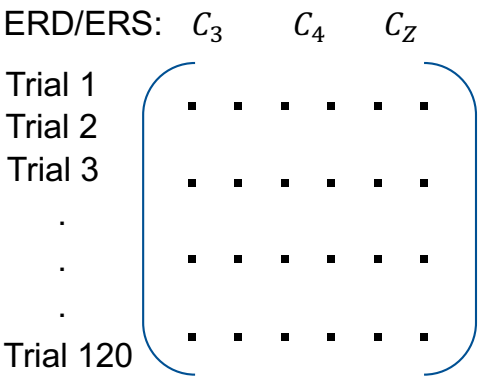
- Bandpass filter alpha (8-12Hz) and beta (13-26Hz) band
  - ERD in alpha band
  - ERS in beta band

$$ERD = \frac{P_{ERD} - P_{rest}}{P_{rest}} * 100\ \%$$

$$ERS = \frac{P_{ERS} - P_{rest}}{P_{rest}} * 100\ \%$$



Feature Matrix



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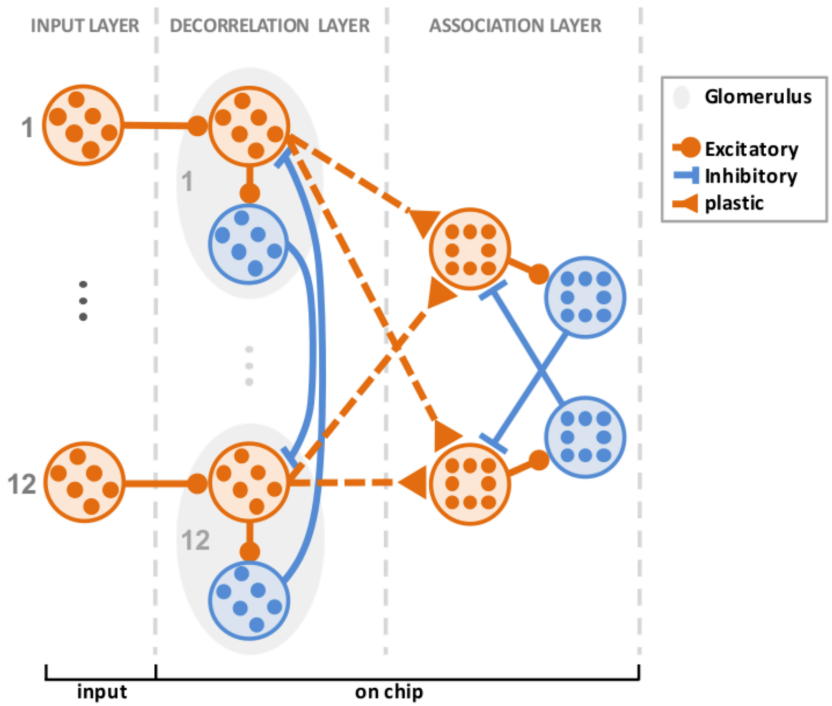
Classification: Spiking Neural Network

- Architecture based on Olfactory system of insects
- Population coding of features
- Learning with STDP + teaching signal



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Classification: Results

- Reached accuracy:
  - 90 – 100 % on Iris data set
  - 68 % on EEG data set (75 – 85 % with statistical machine learning algorithms)

- Problems:
  - Too high deviation in results (100 tests with outliers from 0.56% - 92% accuracy)
  - Small data sets

- Tested approaches:
  - Stepwise elimination of randomness in the network
  - Homeostasis

Future Steps

- Future tasks during my thesis:

  - Increasing the accuracy of the network
    - Feature extraction with wavelet transform
    - Time Coding

  - Implementing live demo (live EEG recording and classification with the network)

  - Integrate error related potentials

Thank you for your attention!

Questions or Suggestions?

Quellen:

[1]: http://alsn.mda.org/files/alsn/imagecache/story_main_image_620x/brain,%20computer,%20alsno%20lead%20art.jpg
[2]: Motorcortex: https://d1tb9j1fbhww3m.cloudfront.net/uploads/media/file/12843/cns050.JPG
[3]: https://www.researchgate.net/profile/Madeleine_Grigg-Damberger/publication/257625325/figure/fig1/AS:297420501078020@1447921981814/Fig-1-The-International-10-20-System-seen-from-A-left-and-B-above-the-head-A.png
[4]: Iulia-Alexandra Lungu, Alexa Riehle, Martin Paul Nawrot, Michael Schmuker: “Predicting voluntary movements from motor cortical activity with neuromorphic hardware“
[5]: single neuron spiking: http://www.democritique.org/Cerveau/IMG/neuron-spike-train.png