Standardization of Biosignals in BCI systems
Needs & Challenges

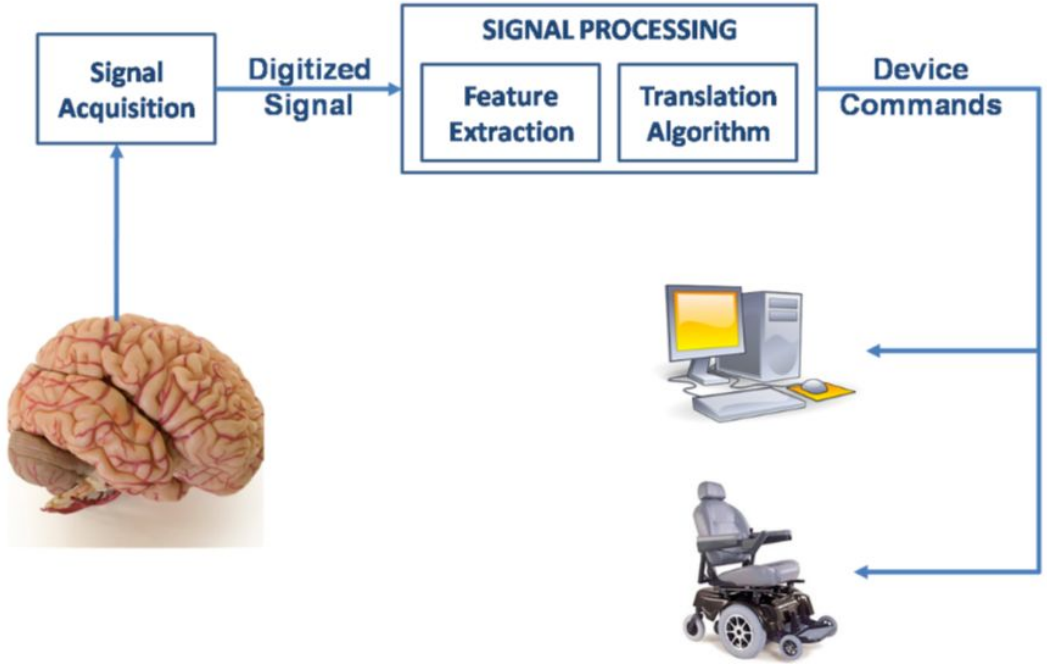
Sumit Soman
Principal Technical Officer, Health Informatics Group
Centre for Development of Advanced Computing (IN)

Workshop on Standardization of Neural Interface Research to Accelerate Interoperability, Clinical Integration, and Commercialization of Neurotechnologies
SMC 2019, Bari, Italy (06 Oct 2019)

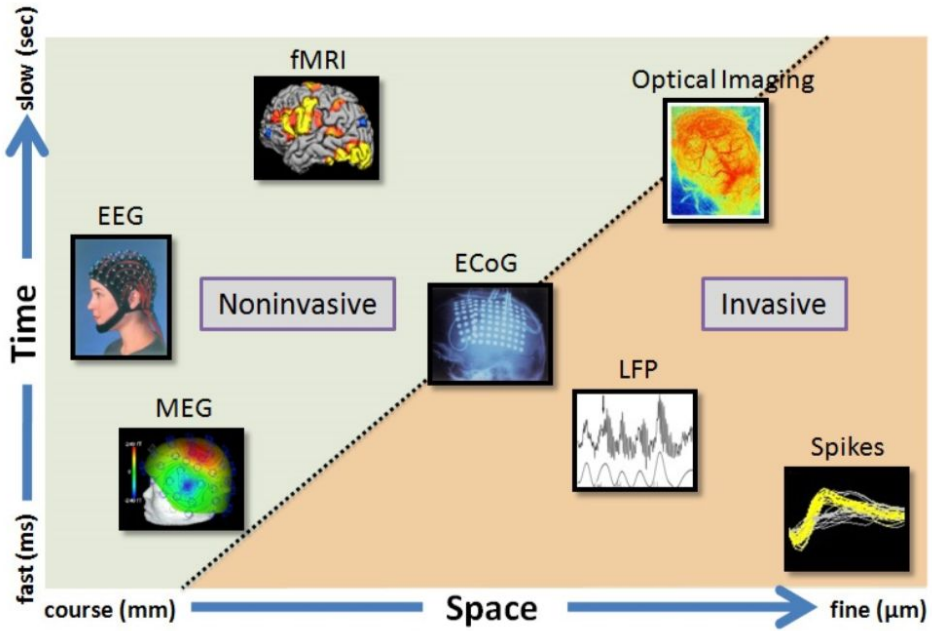
Introduction

Brain Computer Interface (BCI) / Brain Machine Interface (BMI) systems acquire biosignals and process them to detect user intents, which are used for various applications such as device control, neuro-rehabilitation, gaming and consumer electronics, among others.

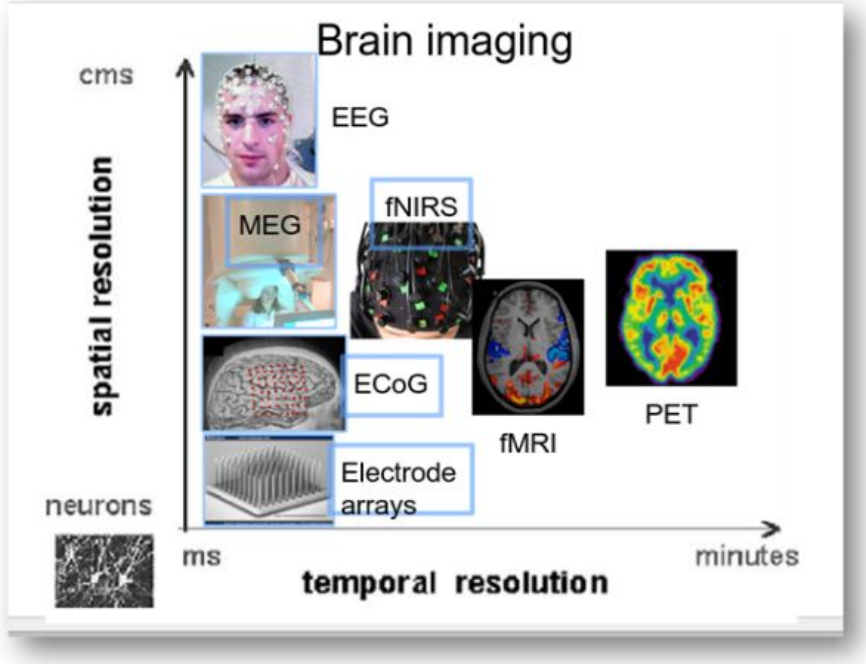
There is a growing need for standardization in BCI/BMI based systems for their interoperability and quality control.



The Spectrum of Bio-Signals



Source: http://lifesciences.embs.org/wp-content/uploads/sites/53/2012/03/thakor_02_lg.jpg



Source: http://learn.neurotechedu.com/images/introtobci/brainimaging.png

Need for Standardization in Biosignals

1. Biosignal datasets, including EEG, EOG, EMG, MEG, fMRI, among others, typically tend to be large datasets that require representation and compression schemes for efficient storage.
2. Emerging applications in the BCI/BMI domain require real-time processing and online learning, bringing additional constraints to the way data is stored and processed.
3. Data also needs to be annotated with subject-identifying information (suitably anonymized or coded), session and trial information (to represent events of interest that would need to be retrieved/detected subsequently) as well as other relevant metadata.

Recent Initiatives - Neurotech for BMI

1. Neuro technologies for Brain-Machine Interfacing Industry Connections Activity
   a. Provide an integrated overview of all standards activity that is specifically related to BMI-related neurotechnologies
   b. Identify any gaps in the existing standards and a plan to address these gaps
2. A broad spectrum of topics under “Neurotechnology” needed standardization, as such it was proposed to identify sub-groups and identify scope of standardization within each.

Neurotech for BMI Sub-Groups

1. Sensors and interoperability (sensors, processing, cybersecurity)
2. Effectors (prosthetics, AR/VR, rehab robotics)
3. **Data storage and sharing**
4. Performance assessment and benchmarking
5. User requirements - Clinical and non-clinical BMIs

Standardization Objectives - Data Sharing

1. Data sharing in the context of healthcare information systems and interfaces is a vital objective of standardization.
2. These bio signals are often used and shared between multiple systems, such as Electronic Health Record (EHR) systems, or other data processing nodes of BMI systems.
3. Bio signals are also shared between processing nodes in BMI systems, and these are also vulnerable to attacks.
4. Cybersecurity and data management was mentioned by BMI researchers as one of the top priorities for standardization.

Standardization Objectives - Interoperability

1. There are different EEG acquisition systems available and the biosignal recordings generated are often dependent on the hardware being used.
2. System interfaces that require to process these datasets need customized interfacing modules to acquire and/or stream biosignals from the respective acquisition devices.
3. The development of data representation and storage standards is expected to bridge the gap between the diverse data formats prevalent and contribute to greater interoperability across diverse hardware and acquisition devices.

Some Data Formats for EEG Signals - Data Storage

1. Generic Data Format (GDF)
2. European Data Format (EDF)
3. Easy
4. SdEEG
5. BCI2000
6. Medical waveform Format Encoding Rules (MFER)
7. eXtensible Data Format (XDF)
8. Lab Streaming Layer (LSL) is also considered as a de-facto standard for multimodal recordings.
9. … and many others

Data Sharing Initiatives

1. **NeuroData Without Borders** – unified data format for cellular neurophysiology data
2. **Neuroscience Information Framework (NIF)** – Open source network providing dynamic, searchable inventory of neuroscience resources, including public research data, learning materials, and tools – all publicly accessible via the Internet.
3. **Brain-CODE** – Networked database established by Ontario Brain Institute for sharing brain research data between >40 research sites across Ontario, Canada
4. **NeuroData** – building and deploying open source data-driven tools that run at scale on open access data.
5. **Project Data Archive for the Brain Initiative (DABI)** : This NIH-funded project focuses on the development of "*web-accessible data archives to capture, store, and curate data related to the BRAIN Initiative proposals that collect invasive human neurophysiological data and make them broadly available and accessible to the research community*".
6. **Brain Imaging Data Structure (BIDS)** is a community-driven standard inspired by the format used in the OpenNeuro.org repository (formerly OpenfMRI) to organize and share data from (fMRI-based) neuroimaging experiments.
7. The **International Neuroinformatics Coordinating Facility (INCF)** is an international non-profit organization with the stated mission of advancing the field of neuroinformatics.

Reporting BCI Research - Requirements

- **Data Acquisition**
  - Signal recording modality
    - Experimental Protocol
      - Stimulus presentation paradigm
      - Number of sessions
      - Inter-session and inter-trial interval
      - Randomization aspects of stimulus presentation
      - Pre and post stimulus presentation activities (session and trial)
    - Details of participating users/subjects
      - Number of participants
      - Age/Gender statistics
      - Neurological status/history (based on experimental requirements)
      - Left/Right handed
      - Demographic/Geographic distribution

Reporting EEG for BCI Research - Requirements

- **Data Acquisition (contd.)**
  - Data Acquisition Device(s) Used
    - Number of channels/electrodes
    - Channel/electrode configuration
    - Sampling rate(s)
    - Pre-processing on device (filtering/ noise-removal etc)
    - Type of electrodes (active/passive) and their details
    - Amplifier configuration details
- **Bio-signal Processing Pipeline**
  - Pre-processing
    - Artifact removal methods
    - Signal quality measures
    - Implementation platform/framework
    - Details of parameters used in any method(s) adopted for pre-processing
  - Feature Extraction
    - There are multiple methods that are used for feature extraction/selection. They should be reported in adequate detail to enable reproducibility.

Reporting EEG for BCI Research - Requirements

- **Bio-signal Processing Pipeline**
  - Classification/Learning Model
    - Model architecture details
    - Implementation platform, including system configuration and compute specifications
    - Model parameters and training parameters - batch size, epoch presentations
    - Hyperparameters - initializations and update rules for hyperparameter tuning
    - Convergence criteria and optimization routine/algorithm adopted
  - Outcome Evaluation
    - Performance metric(s) adopted
    - Baseline scores and significance measures
    - Validation metrics
    - Details of qualitative measures adopted (eg visualizations)
- **End-User applications**
  - End user applications are likely to have a wide plethora of parameters and reporting on those facilitating reproducibility should be considered.

Moving Forward

- The first step is to identify and consolidate the scope of existing reporting practices being adopted in the EEG for BCI segment.
- Invite volunteers to contribute with inputs from publications to finalize this scope.
- Identify the scope of reporting research for hybrid and multi-modal BCI systems.
- Identify potential interest groups and conduct surveys.
- Assimilate results and disseminate.
- Incentivize reporting compliant research?

Ideas and suggestions are welcome...

Thank You

sumitsoman@ieee.org

Workshop on Standardization of Neural Interface Research to Accelerate Interoperability, Clinical Integration, and Commercialization of Neurotechnologies
SMC 2019, Bari, Italy (06 Oct 2019)