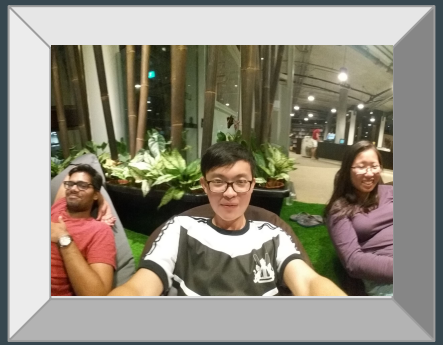
Grasp and Lift EEG



Group 24

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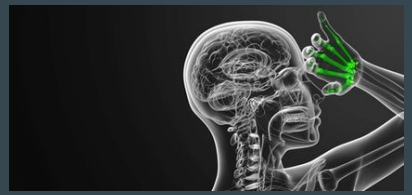
Competition Overview

Objectives



Wearable interfaces
for hAnd function recoverY
FP7-ICT-288551

- To have a better understanding between the relationship between EEG signals and hand movements
- Results could aid the development of BCI devices that would give patients with neurological disabilities the ability to move
- A non-invasive approach has been taken to collect EEG readings

Dataset Exploration

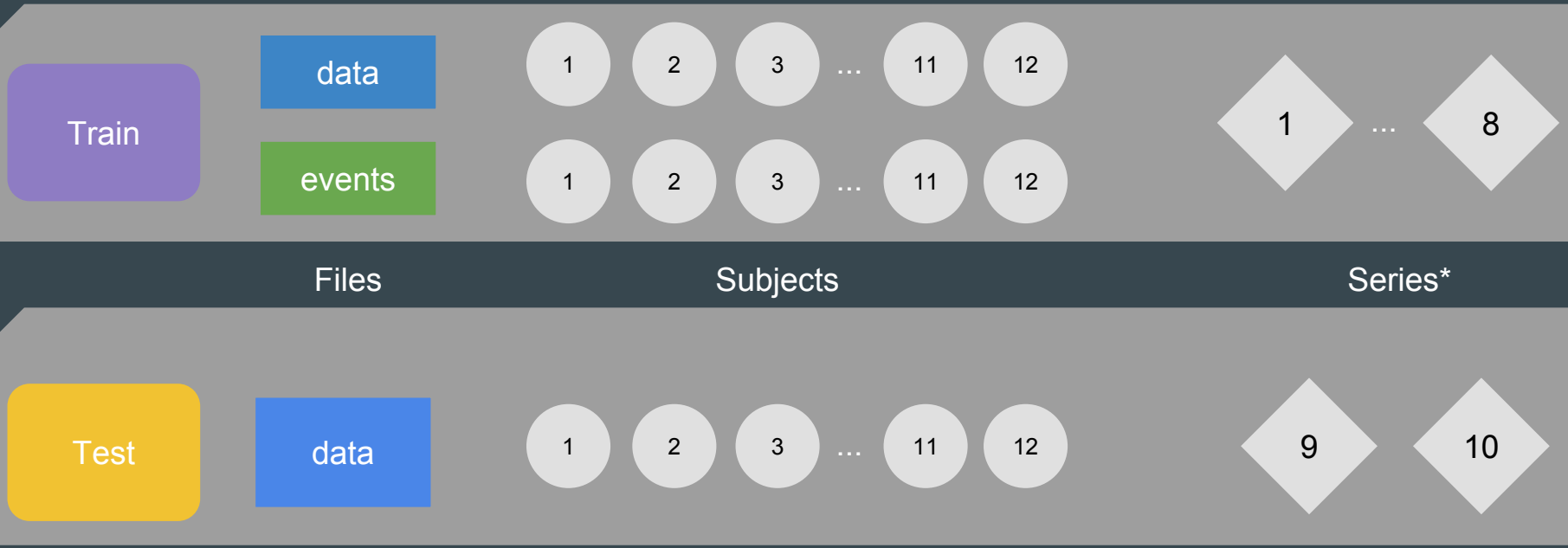
12 Subjects

X

10 Series*

*Each **Series** contains around 30 trials

Data by Kaggle

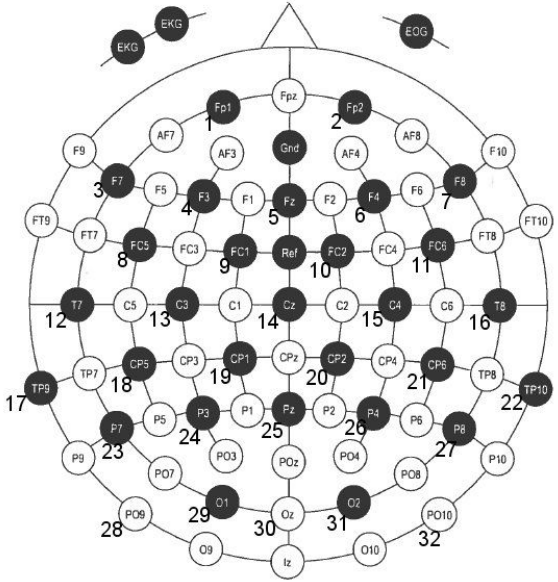


*Each **Series** contains around 30 trials

EEG Readings

Electrodes (32 Channels)

- EEG is the recording of electrical activity diffused from the cortex
- EEG measures voltage fluctuations resulting from ionic current flows within the neurons of the brain



data

id	Fp1	Fp2	F7	…	O2	PO10
subj1_series1_0	-31	363	211	…	120	704
subj1_series1_1	-29	342	216	…	83	737
…	…	…	…	…	…	…
subj1_series1_X	242	266	234	…	-229	-153

Events

- HandStart
- FirstDigitTouch
- BothStartLoadPhase
- LiftOff
- Replace
- BothReleased

Overview of steps taken

1. PRE-PROCESSING

Low-pass filter

2. TRAIN

Classification

- Linear Discrimination Analysis
- Logistic Regression
- Random Forest
- Artificial Neural Networks
- Ensemble Classifier

3. TEST

kaggle

Evaluated on Mean column-wise Area Under Curve on test dataset

4. EVALUATE

Select Best Model

Preprocessing

Why do we need to pre-process EEG data?

- EEG only measures blurred cortical activities (due to the diffusion of the skull and the skin)
- EEG signals thus may be contaminated by noise from various sources such as ocular and myoelectric signals
- A healthy human brain generates waves at frequencies from 0.5 Hz to 100 Hz

Rhythms of EEG signal

Rhythm	Frequency Range*	Description
Alpha	8 - 13 Hz	Particularly evident during the absence of visual stimuli
Beta	12 - 30 Hz	Frontal region of brain and observed during concentration
Gamma	30 - 100 Hz	Motor activities
Delta	0.5 - 4 Hz	Observed at stage 3 and 4 of sleep
Theta	4 - 8 Hz	Observed during light sleep and during hypnosis
Mu	8 - 12 Hz	Used in Motor Imagery (MI) BCI paradigm

*Usually defined slightly differently by various authors

Rhythm Modulation for Hand Movements

- Competition focuses on Motor Imagery (MI) for hand movements.
- Hand MI of a healthy subject results in a desynchronization (ERD) of **mu** in contralateral EEG
- Hand MI also results in synchronization (ERS) of **beta** rhythm in ipsilateral EEG
- Examined signals within the range of 7-30 Hz

http://bmcneurosci.biomedcentral.com/articles/10.1186/1471-2202-11-S1-P127

Low Pass Filter

- Normalized values
- Very few input values below the required 7 Hz lower bound
- Used a low pass instead of bandpass filter
- Smooth values and expose features
    - Add low pass filtered values as extra rows to the input data
    - Annunciate the result by raising low pass filtered values to the 8th power

Classification Models*

1. Linear Discrimination Analysis (LDA)
2. Logistic Regression (LR)
3. Random Forest Classification (RFC)
4. Artificial Neural Network (ANN)
5. Ensemble Classification

Model 1: Linear Discrimination Analysis (LDA)

Reasons for Using LDA:

- Maximizes class separation
- Most widely used model for biological datasets
- High accuracy when applied to large datasets
- Allows both dimensionality reduction and classification

Model 2: Logistic Regression (LR)

Reasons for using LR:

- Robust
- Gets rid of unbounded nonsensical results from linear classification
- Achieves stable results with large sample size

Model 3: Random Forest Classification (RFC)

Reasons for using RFC:

- It has methods for balancing errors in datasets where classes are imbalanced
- Resistant to overtraining and outliers
- Very accurate for large dataset

Model 4: Artificial Neural Networks (ANN)*

Reasons for considering ANN:

- Efficient with large datasets
- Flexibility: Tune parameters for better results

* Stochastic Gradient Descent ANN

Ensemble Classification

Take the mean of individual model predictions - “bagging submissions”

Advantages:

- Averaging predictions often reduces overfit
- Ideal to have a smooth separation between classes
- A single model’s predictions can be a little rough around the edges.

Comparison of Results

Submission Results

Classification	Training Set	Kaggle Score (379 teams)
Linear Discriminant Analysis	Full	0.84757 (181)
Ensemble (LDA + LR)	Full	0.841 (225)
Logistic Regression	Full	0.84 (226)
Random Forest	100 Samples	0.784 (261)
ANN - Stochastic Gradient Descent	100 Samples	0.5420 (334)

Findings

Classifier	Training Speed	Performance
Linear Discriminant Analysis	Fast	
Ensemble (LDA + LR)	Slow	
Logistic Regression	Normal	
Random Forest	Very Slow	
ANN - Stochastic Gradient Descent	Normal	

- Scores for models of a sample size of 1000 performed more poorly than those of 100
- LDA outperformed LR in score and speed

Alternative Solutions

- Convolutional Neural Networks
  - Computationally Expensive
  - Submissions that beat the .89 marker often used CNN
  - Could be tweaked to fit in our ensemble to get better results
- Artificial Neural Network
  - Basic Model provides very bad results
    - Linear Hinge loss function
  - Expensive to tweak parameters to get result accuracy close to our final model

Thank you!

The 3 steps of Feature Extraction*

- Signal conditioning to reduce noise and to enhance relevant aspects of the signals
- Extraction of the features from the conditioned signals
- Feature conditioning to properly prepare the feature vector for the feature-translation stage

https://books.google.com.sg/books?id=IlZpAgAAQBAJ&pg=PA134&lpg=PA134&dq=band+pass+filter+bci&source=bl&ots=D793YZpHik&sig=y11LZaEBI6fQLtt2QkjCkq1JJWg&hl=en&sa=X&ved=0ahUKEwi5qJXNlPjLAhXPG44KHbG1CCcQ6AEIUTAJ#v=onepage&q=band%20pass%20filter%20bci&f=false

Results and Comparison with Submitted Entries

Model Used	**Kaggle Score (rank out of 375 entries)**
LDA	0.84288(221)
Linear Regression	0.82799 (234)
LR [-100]	0.82839(233)
LR (1000 Subsample)	0.774(262)
LR Full	0.840(226)
RF(100)	0.784(261)
Ensemble (LDA + Linear Regression)	0.84103 (225)
Ensemble Full	*0.84665(211)*