Motor Imagery for EEG Biometrics using Convolutional Neural Network

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INTRODUCTION

- Electroencephalographic (EEG) signals is a potential biometric trait for people recognition for its universality, security and robustness.
- Our current research investigates EEG-based biometric identification, using a motor imagery task, such as imaginary arms and legs movements.
- Deep learning methods such as Convolutional Neural Network (CNN) is used for automatic discriminative feature extraction and person identification.

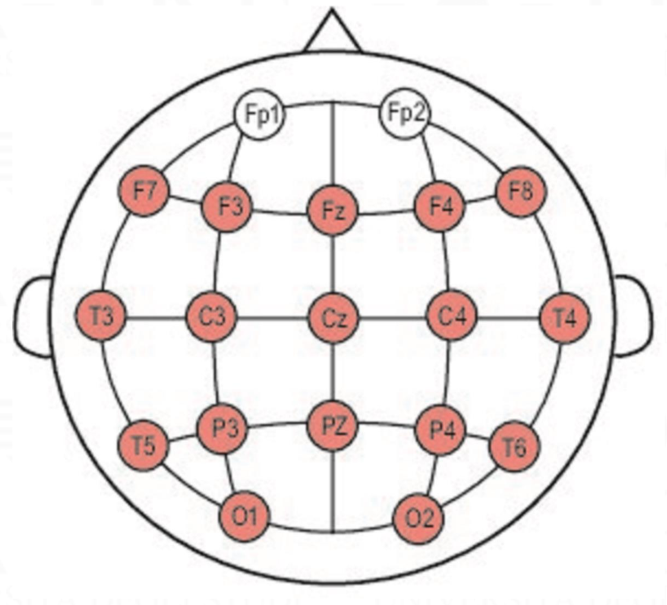
EEG DATA ACQUISITION

- **Motor Imagery Protocol:** Motor imagery tasks, performed by imaginary hands and feet movements, are used for EEG signal elicitation.
- Four different arrow images used as stimuli.
- Top Right-Arrow image corresponds to imaginary Right-Hand movement & top Left-Arrow image for imaginary Left-Hand movement.
- Similarly for feet movement lower arrow images are used.
- Each stimuli is randomly selected and displayed for 3s during its 50 occurrences.
- An empty black screen lasting 1.5s is displayed in between every two consecutive images.
- 6s rest is allowed each time the whole set of four stimuli has been presented for 5 times.
- EEG data are acquired from 19 different electrodes that are positioned on brain scalp according to the 10-20 international standards as shown in Fig.2.

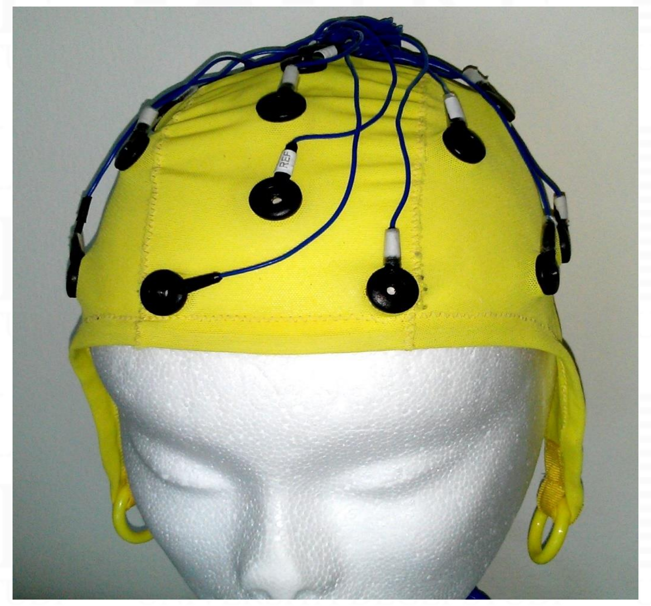
DATABASE

Database	No. of Channels	Sessions
40 Subjects	19	2 (Separated by a Week)

Figure 1: Images of "arrows" for imaginary limbs movement for "Motor Imagery" protocol



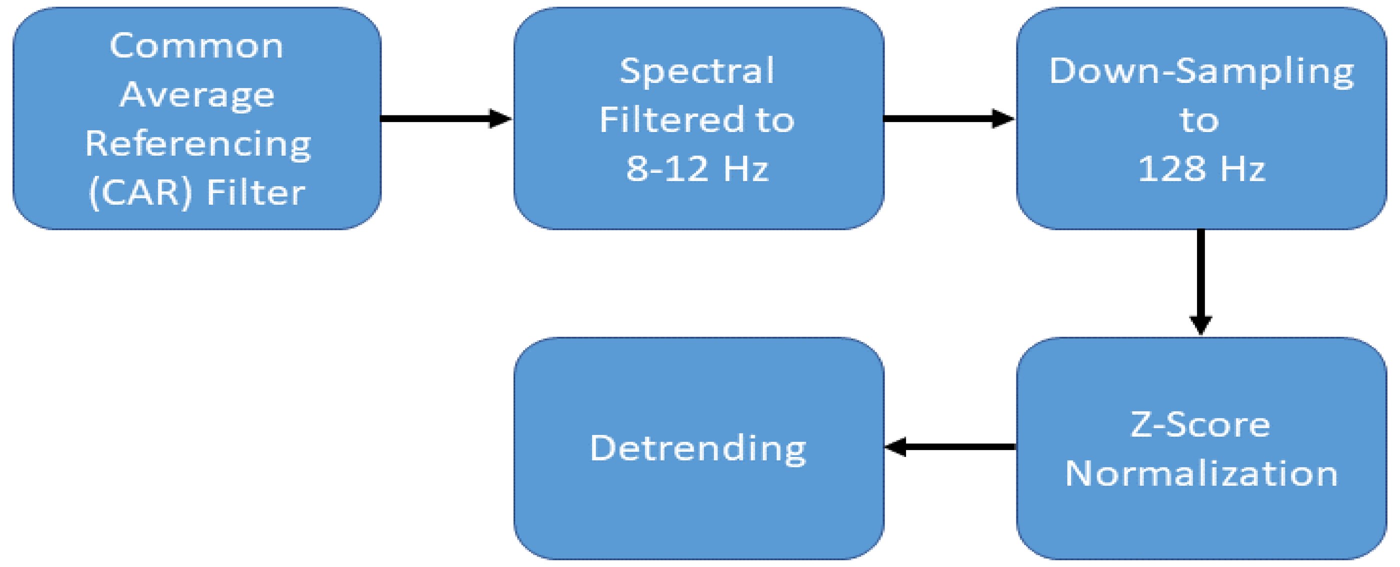
(a)



(b)

Figure 2: Selected electrode positions. (a)17 Selected electrodes or Channels, (b) EEG data acquisition system using BCI2000

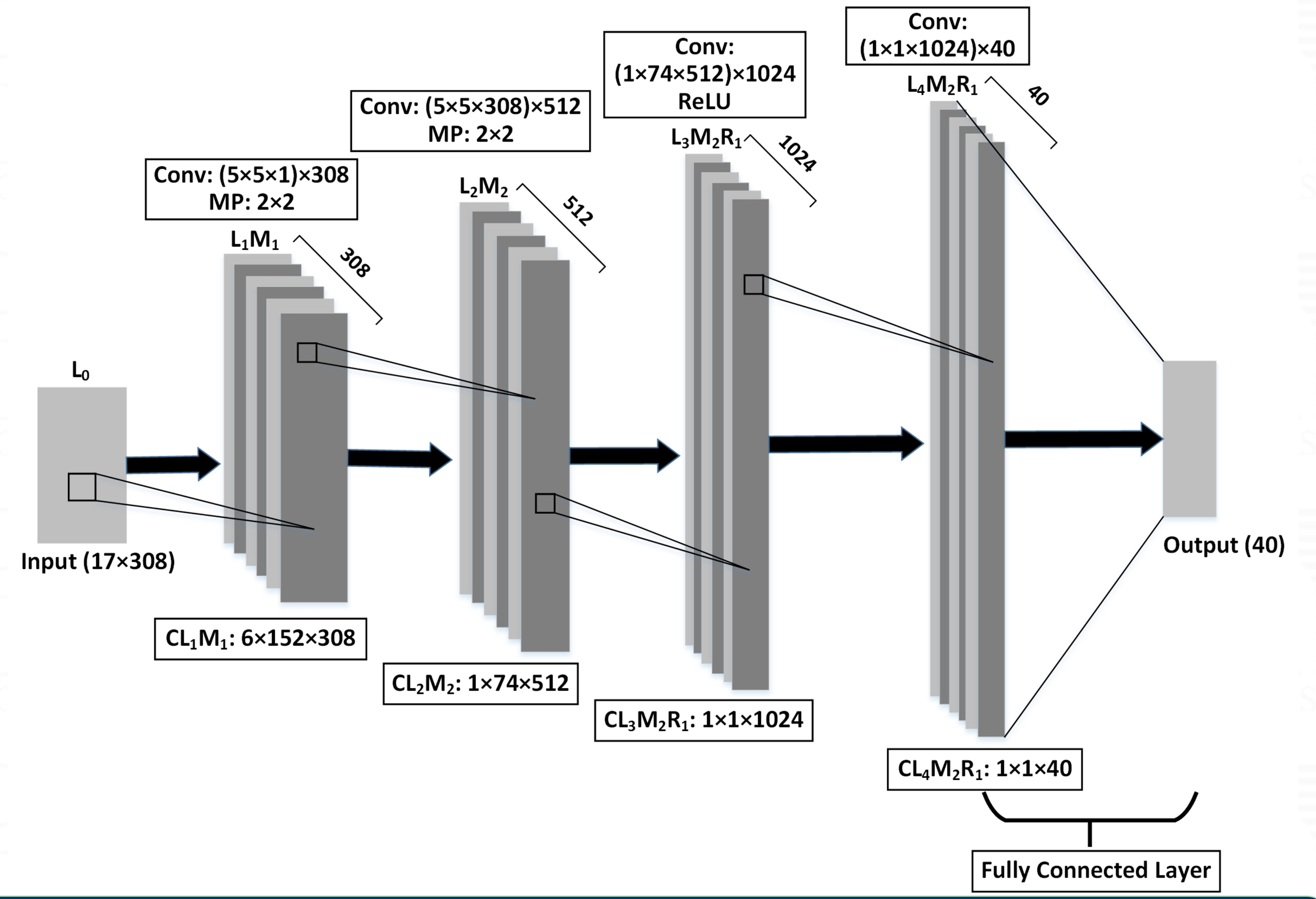
PREPROCESSING



PROPOSED RECOGNITION SYSTEM

- MI elicited EEG signals are spectral filtered for [8-12]Hz.
- One single stimuli elicited signal is not sufficient for generating a signature template, therefore all 4 stimuli elicited signal is horizontally concatenated in order to generate a signature template.
- Time intervals Δ_t= [0.4,0.5,0.6,0.7,1,2,3] sec, following the presentation of a stimuli, are analyzed for finding the best suited one for biometric identification.
- Based on the best Δ_t value a biometric identification system based on CNN is developed where the network training and testing sessions are separated by one week.

PROPOSED CNN ARCHITECTURE



TRAINING & TESTING

- Input signal size is 17 × 308, where 17 corresponds to 17 Ch.s and 308 corresponds to 600ms signal from each of the 4 stimuli are horizontally concatenated.
- CNN network designing and training we use the MatConvNet-1.0-beta24 tool of Andrea Vedaldi [6].
- CNN is trained using EEG data collected from Session-1 and tested over Session-2.
- 90% of each subject's data is used for training and rest 10% for validation.
- The learning rate of the CNN is set at 0.0001 with a batch size of 5.
- 200 number of epochs/iteration is enough to achieve optimal accuracy.
- For every testing sample, the trained CNN network returns probability values corresponding to all the 40 classes/subjects.
- Maximum probability value identifies the subject with which the testing sample is more similar.

RESULTS AND DISCUSSION

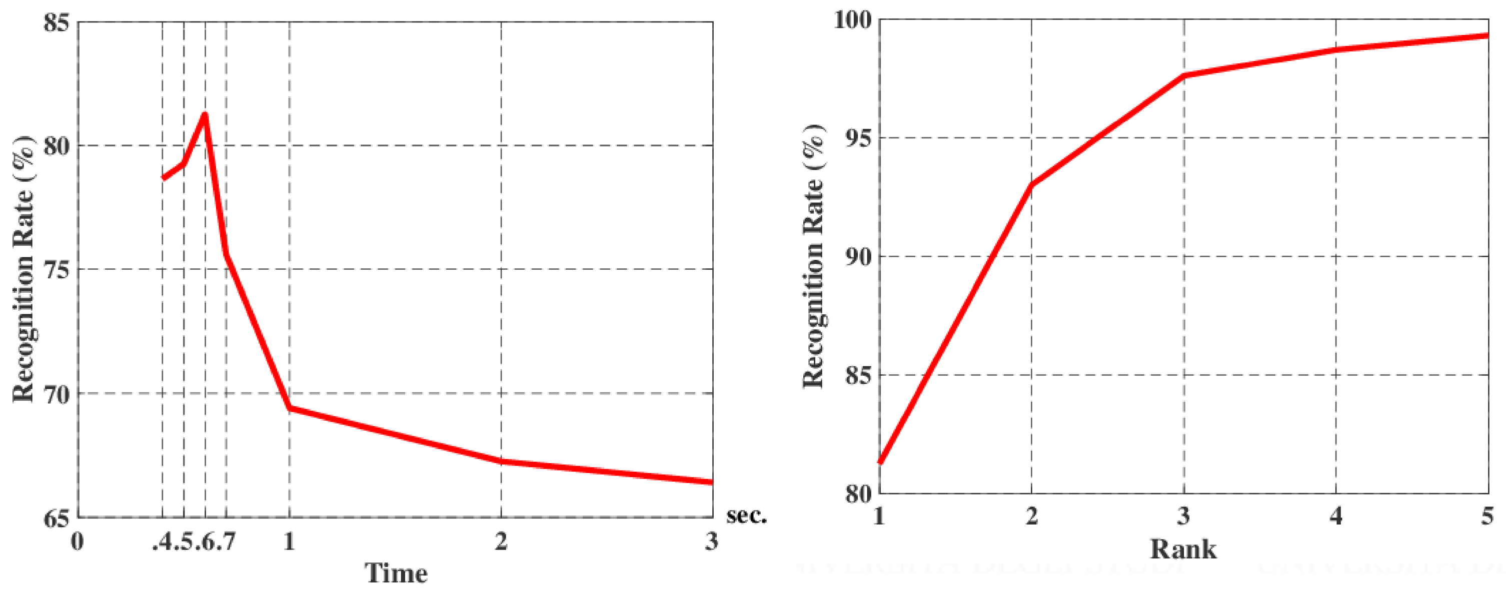


Figure 4: "Motor Imagery" protocol: (a) Time interval selection (b) Cumulative Match Curve (CMC) for 17 Ch.s.

- The best performance can be obtained by considering EEG signals lasting 600ms, while worse identification rates are obtained taking into account more information.
- Rank-1 & Rank-2 results are respectively 81.25% and 93% accuracy, showing a significant increase in performance at Rank-2 over the considered database with 40 subjects.
- The achieved accuracy reaches 99.3% for Rank-5 identification.
- EEG data possess permanency, therefore encourages for the adoption of brain signals for futuristic biometric identification systems.

SELECTED PUBLICATIONS

[1] R. Das et al., *"EEG biometrics using visual stimuli: A longitudinal study"*, IEEE Signal Processing Letters, vol. 23, no. 3, pp. 341–345, March 2016.

[2] R. Das et al., "*Visually Evoked Potential for EEG Biometrics using Convolutional Neural Network*", 25th European Signal Processing Conference (EUSIPCO), Kos, 2017, pp. 951-955.

[3] E. Maiorana et al., "*Longitudinal Evaluation of EEG-Based Biometric Recognition"*, IEEE Transactions on Information Forensics and Security, vol. 13, no. 5, pp. 1123-1138, May 2018.

[4] P. Campisi et al., "*Brain waves for automatic biometric-based user recognition*", IEEE TIFS, vol 9, no. 5, pp. 782–800, May 2014.

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[8] E. Maiorana et al., "On the Permanence of EEG Signals for Biometric Recognition", IEEE Transactions on Information Forensics and Security. Vol. 11(1), pp. 163-175. IEEE.