Alternative Algorithms in “Face Versus House” Discrimination Basing on Event Related Potential

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Outline

- Introduction
- Data and Preprocessing
- Methods
- Result and Discussions
- Conclusions
- Recommendations

Introduction

- The link between object perception and neural activity in visual cortical areas is a problem of fundamental importance in neuroscience.
- Electrical potentials from the ventral temporal cortical surface in humans have been showed to contain sufficient information for spontaneous and near-instantaneous identification of a subject’s perceptual state.
- A convolutional neural network (CNN) is trained, which discriminates the Event Related Potential (ERP) signals, which are responses to visual stimuli of different types of figures (Faces and Houses).
- The “Faces v. Houses Discrimination” is an existing work, in which the classification method was just linear. The main work in this project is developing alternative classification methods.
- The estimation accuracies are compared as performance evaluations.

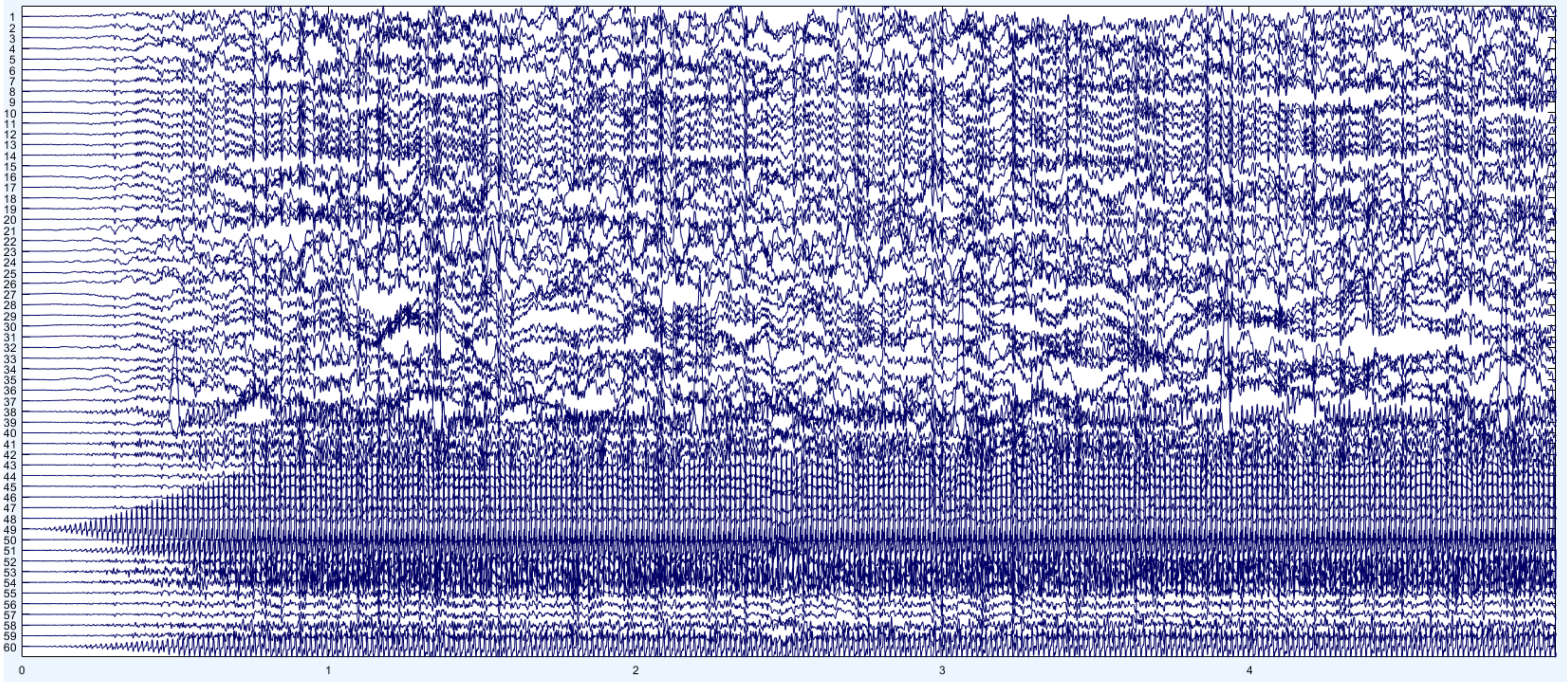
Existing Work to Compare with

- Miller, Kai J and Ojemann, Jeffrey G. (2015). Data and analyses for "Spontaneous Decoding of the Timing and Content of Human Object Perception from Cortical Surface Recordings Reveals Complementary Information in the Event-Related Potential and Broadband Spectral Change". Stanford Digital Repository.
- Technique Used:
    - Template projection technique.
    - Fisher linear discriminant analysis.
- Performance:
    - Error rate
        - Using ERP and ERBB: $\leq 5\%$.
        - Using only ERP: 3%~23%.

Data

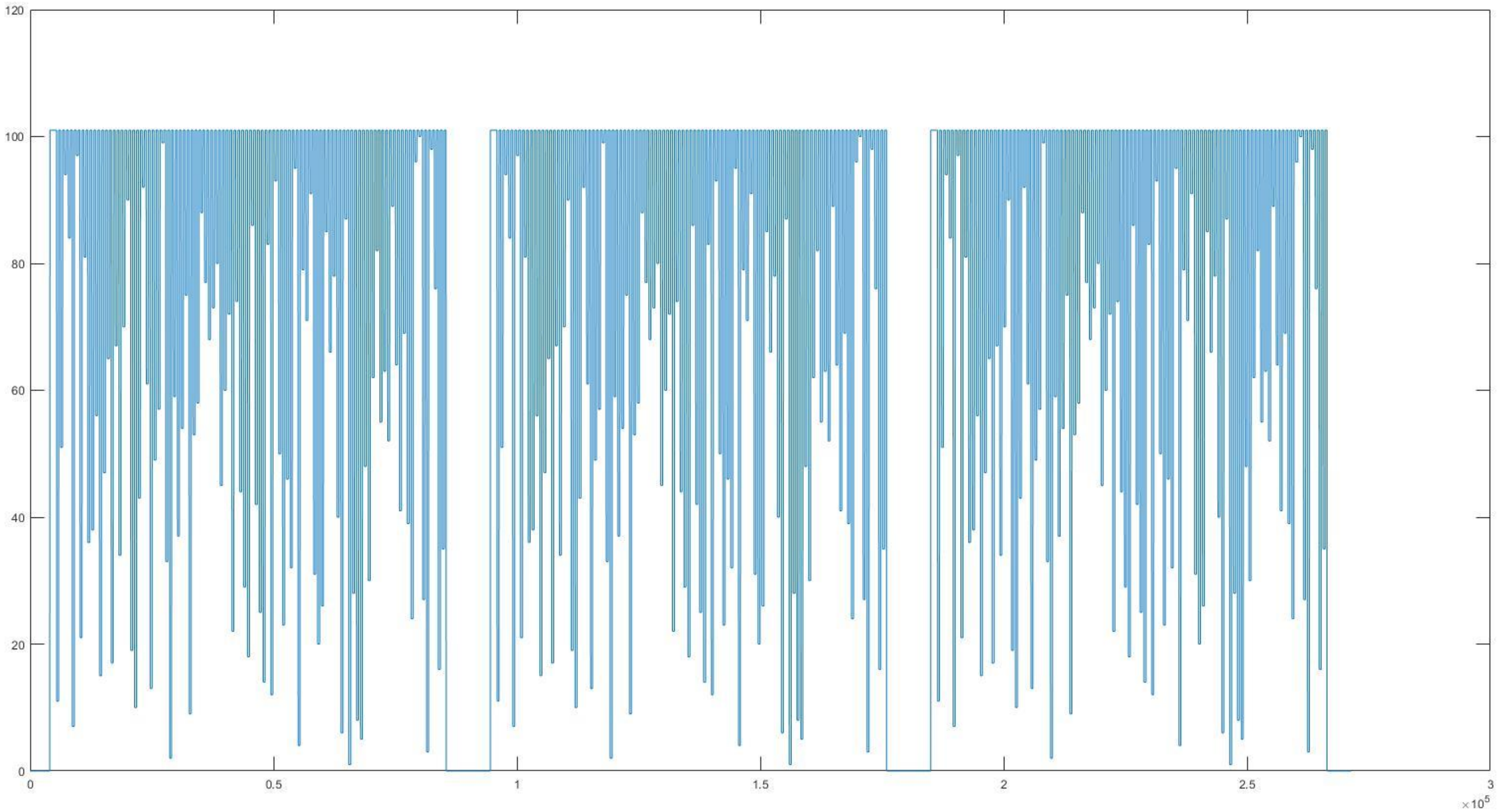
- EEG Data from 7 epilepsy patients (double, dim = # of channels x time stamps) along with the stimulus time course (categorical, dim = 1 x time stamps).
- While scanning, electrocorticographic (ECoG) arrays were placed on the subtemporal cortical surface of seven epilepsy patients.
- Sampling frequency: 1000Hz.
- Built-in Bandpass: 0.15-200Hz.
- Number of channels varies among members.
- Data available at: http://purl.stanford.edu/xd109qh3109.

Data



A part of the EEG data of one patient (# of channels = 60, displayed by EEGLAB)

Data



The stimulus data given to a patient

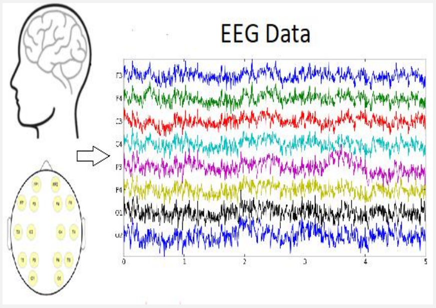
0: Pre-post task run
1-50: Picture of house being presented
51-100: Picture of face being presented
101: Interstimulus Interval

In training, the above 3 class will be just 0, 1 and 2 as labels.

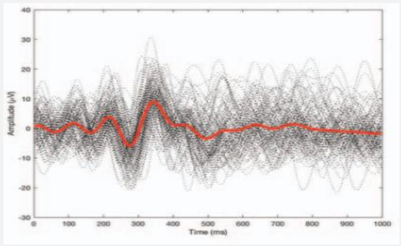
Data Preprocessing – Regular

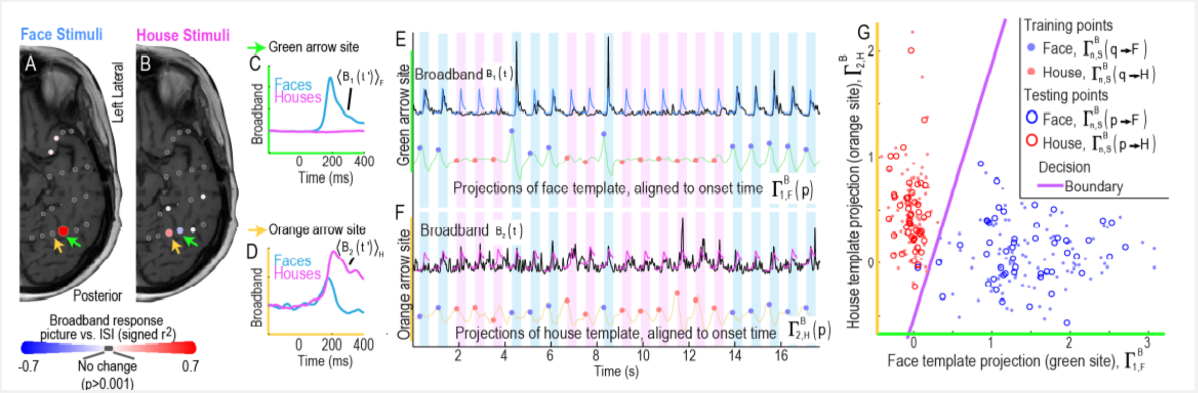
- Extract ERP data from EEG signal: Finding the mean of EEG epochs for the same repeated event.
- Template Projection: Convolve the ERP data with the stimulus triggered averages (STA) for “face” stimuli and “house” stimuli, respectively.

Input



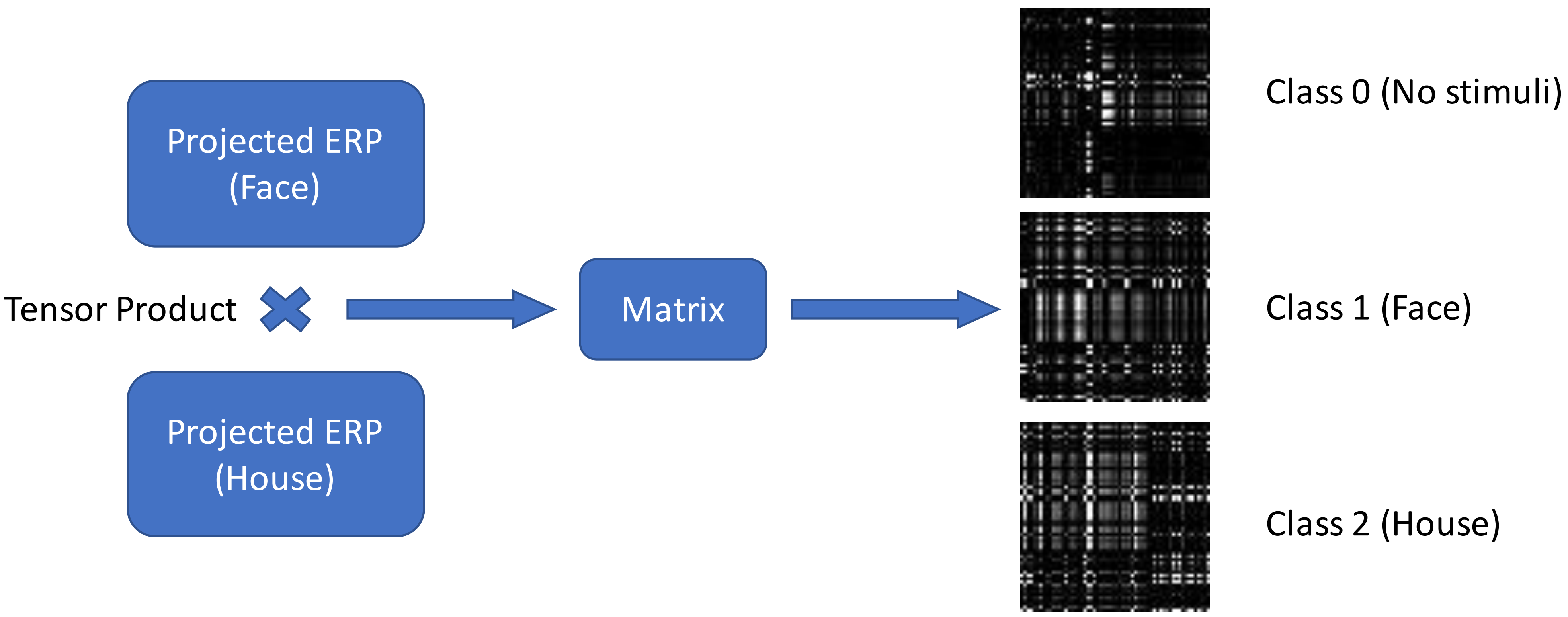
Find ERPs





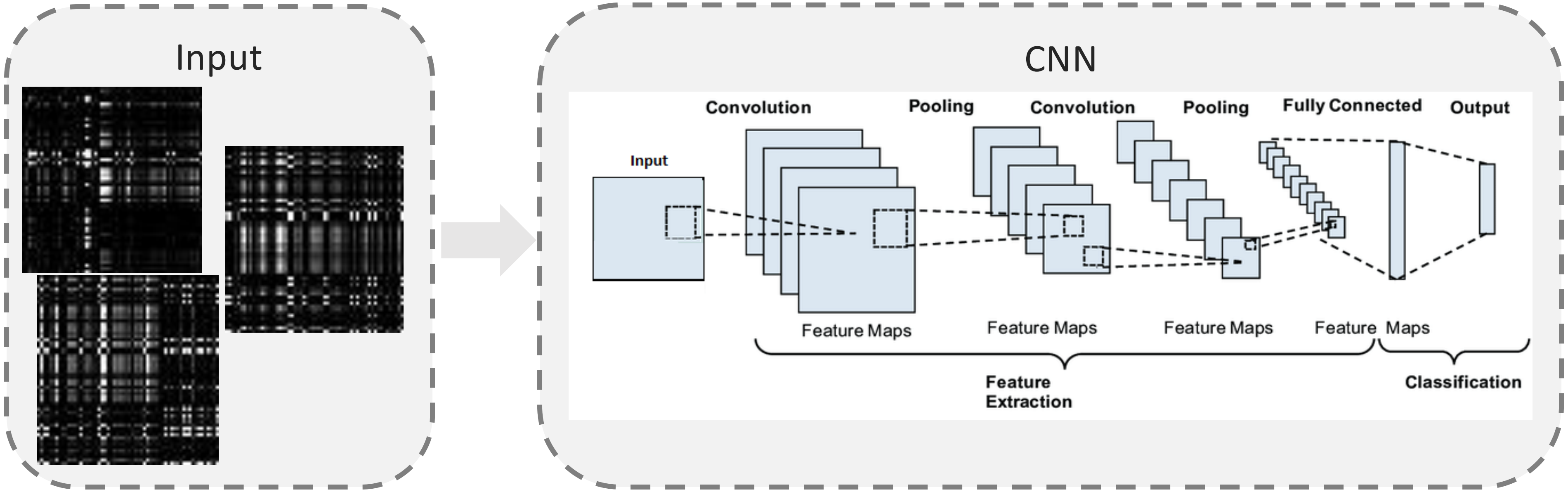
Template Projection

Data Preprocessing – Creating Images



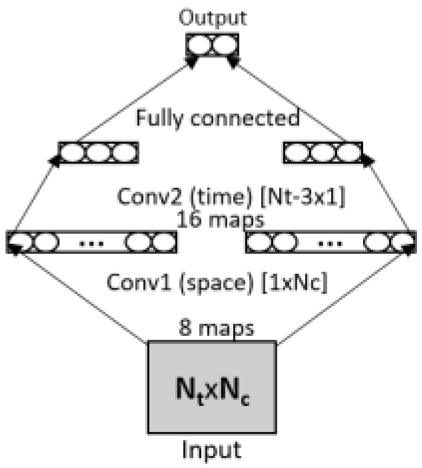
Grayscale images

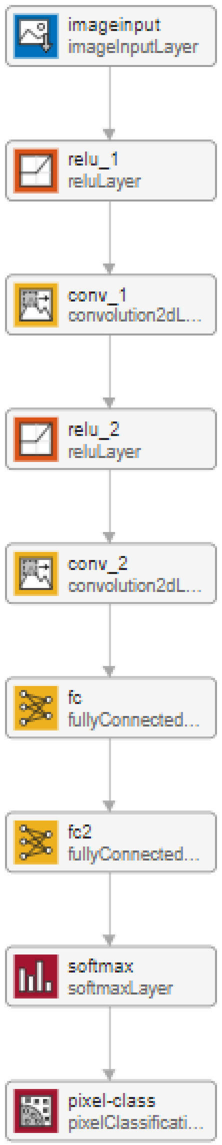
Framework


Input
CNN
Convolution
Pooling
Convolution
Pooling
Fully Connected
Output
Input
Feature Maps
Feature Maps
Feature Maps
Feature Maps
Feature Extraction
Classification

CNN$_1$ Structure

- Convolution layer 1
  - Dimension equals the number of channels
  - Number of filters: 8
- Convolution layer 2
  - Dimension equals the transpose of conv_1
  - Number of filters: 16
- Fully connected layers
  - Dimension of fc: 25
  - Dimension of fc2: 3 (or 2 for stimulation-only classification)
- Activation function: ReLU
- Validation Data: 30% of the original data

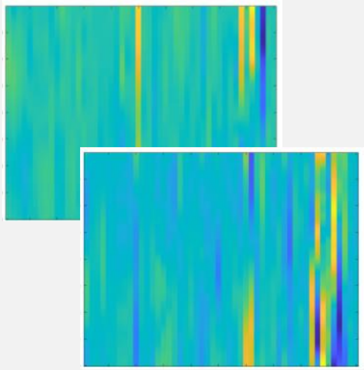




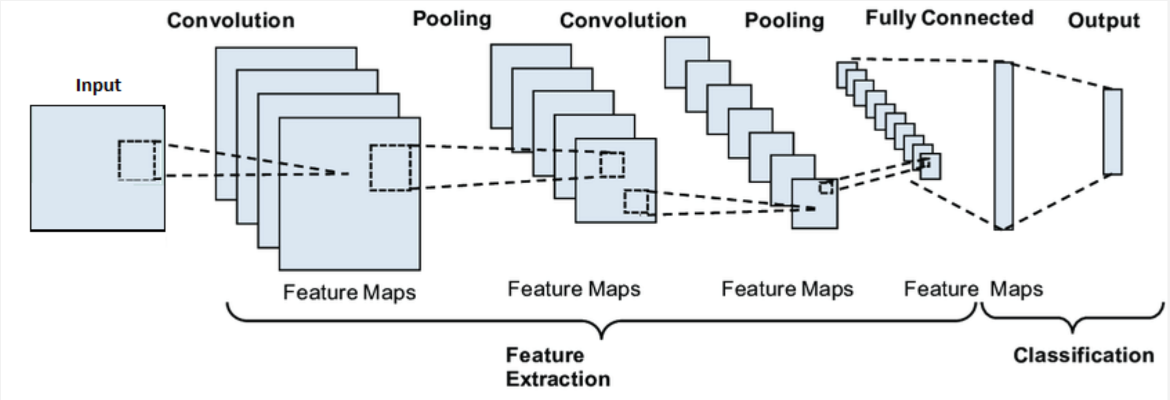
Creating Images for CNN_2

- Images of the projected signals on each of the intervals where a stimulus occurs.
- N_t x N_c matrices where N_t is the number of samples of the stimulus signal (400ms) and N_c is the number of channels.

Input

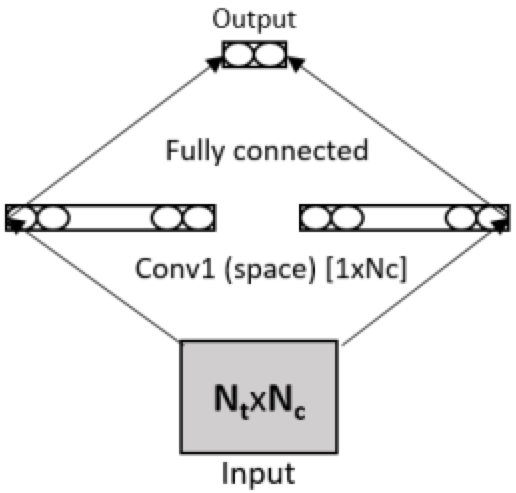


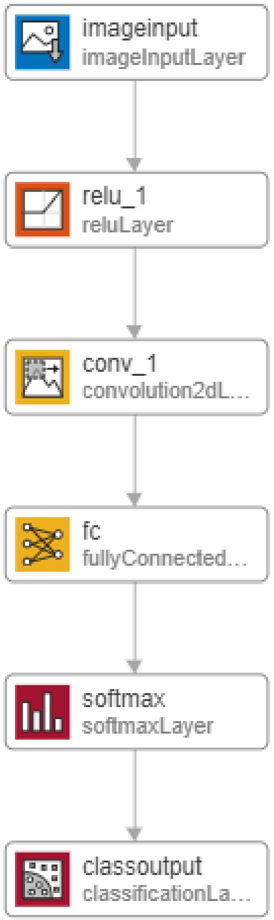
CNN



CNN_2 Structure

- Convolution layer 1
  - Dimension equals the number of channels
  - Number of filters: 8
- Fully connected layers
  - Dimension of fc: 25
  - Dimension of fc2: 2 (stimulation-only classification)
- Activation function: ReLU
- Validation Data: 30% of the original data





Training Examples

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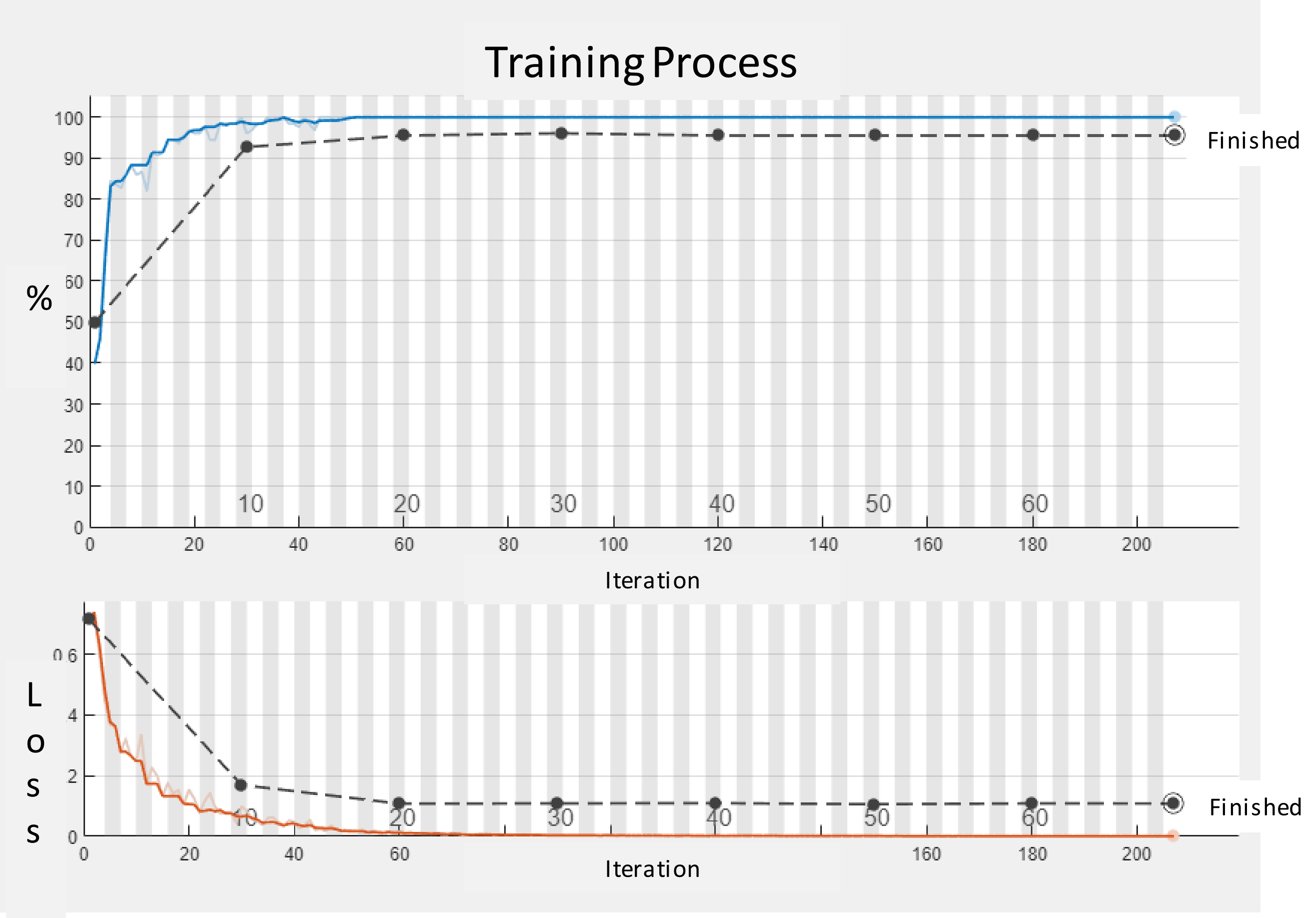

Results

Patient No.	CNN1 Accuracy (3 classification)	CNN1 Accuracy (Stimulus-only)	CNN2 Accuracy (Stimulus-only)	Original Method
ja	82.5%	**92.22%**	89.00%	90.00%
ca	82.14%	90.00%	**94.00%**	91.00%
de	93.64%	95.56%	81.00%	**97.00%**
fp	82.14%	92.78%	**93.00%**	89.00%
mv	80.92%	**88.89%**	59.00%	77.00%
wc	94.64%	**96.67%**	91.00%	96.00%
zt	87.50%	**99.44%**	91.00%	95.00%

Conclusions

- The alternative algorithms improve the accuracy in the “Faces v. Houses Discrimination” basing only on ERP for some subjects
- The alternative algorithms seems to be more stable for different subjects
- In the classification provided in this project, discriminating only stimulus type is more accurate

Recommendations

- Limited by the dimensions of the datasets, we could not try to classify the mixture of the ERP signals collected from all the patients.
- The detailed information of electrode placements were not found for the original experiment, making it hard to improve the method using tools that involves spatial properties (e.g. the current source density (CSD)).
- Brain information for individuals vary in many aspects, it is not possible to guarantee if good accuracy will still appear if more subjects are involved.

Reference (Part)

- Miller, Kai J and Ojemann, Jeffrey G. (2015). Data and analyses for “Spontaneous Decoding of the Timing and Content of Human Object Perception from Cortical Surface Recordings Reveals Complementary Information in the Event-Related Potential and Broadband Spectral Change”. Stanford Digital Repository.
- Miller KJ, Schalk G, Hermes D, Ojemann JG, Rao RPN (2016) Spontaneous Decoding of the Timing and Content of Human Object Perception from Cortical Surface Recordings Reveals Complementary Information in the Event-Related Potential and Broadband Spectral Change. PLoS Comput Biol 12(1): e1004660. https://doi.org/10.1371/journal.pcbi.1004660
- Cecotti H. Convolutional neural networks for event-related potential detection: impact of the architecture. Annu Int Conf IEEE Eng Med Biol Soc. 2017 Jul;2017:2031-2034. doi: 10.1109/EMBC.2017.8037251. PMID: 29060295.