Latent Spaces in a Self-Supervised Approach for Detection of Motor Imageries
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For a brain-computer interface (BCI) to be operational, a calibration phase is necessary because of the intra- and inter-subject variability of electroencephalography (EEG) signals. This reduces the limited available time to use the BCI, and induces fatigue in the subject. Goal: find a classification method that requires minimal training trials while maintaining high classification accuracy.

In this study, the classification task is between a motor imagery (MI) of an upper limb and a resting period. We compare classification methods with a feature extraction step that rely on latent spaces: EEGNet [1], Common Spatial Pattern (CSP) followed by Linear Discriminant Analysis (LDA), and a Self-Supervised Learning (SSL) approach called SSL-RP (Relative Positioning pretext task) [2].

SSL generates a large amount of self-labeled data, using a minimal training set, to learn features for the MI detection task. They are the result of a projection on a latent space, which strongly impact the classifier’s performance.

Uniform Manifold Approximation and Projection (UMAP) [3] is a dimensionality reduction method that tries to reproduce the topology of a high-dimensional space in a lower-dimensional space. It preserves the global structure of the data and is faster than other approaches, such as t-SNE [4].

Hypothesis: by adding a UMAP projection to the SSL-RP method, the MI and resting periods will be more easily distinguishable by the classifier.

Material:
The dataset 2a of the BCI competition IV contains recordings of 9 subjects performing 4 MI tasks, of which only right and left hand MI were used for this study. EEG signals were recorded with 22 electrodes at a sampling rate of 250 Hz. Training (session 1) and test (session 2) sets are composed of 6 runs, each of 12 trials per MI task. From 8 to 72 trials were used to learn the model.

Method:
- SSL-RP builds a latent space according to EEG segments’ distance in time.
- EGGLENet has $C=22$ channels, $T=512$ Hz, $F_r=8$ temporal filters of size $K_t=1$ (1, 32), $D=4$ spatial filters of size $K_s=(22, 1)$, a depthwise convolution filter of size $K_s=(1, 4)$ and $F_l=16$ pointwise convolution filters.
- UMAP takes into account the number of neighbors $n=2$ (local scale at which the manifold is approximated) and the minimal distance $m=0.1$ (how tightly packed are points in the low dimensional space).

Discussion:
- The addition of a UMAP projection does not facilitate the recognition of MI periods, as compared to when only EEGNet is the feature extractor.
- The negative (far) pairs of EEG windows may be from the same class. UMAP will keep the positive pairs together and negatives apart, emphasizing the distance between pairs of the same class. Thus, it is difficult for a simple logistic regressor to distinguish these classes.

Interesting leads:
- Because of the pretext task sampling method, a k-means approach might be more appropriated than a logistic regression.
- Using UMAP as unique feature extractor for the SSL-RP method.
- Using a larger database, like Cho2017 [6], with 52 subjects.

References:

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