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Neuronal avalanches as alternative features for motor imagery-based brain-computer interface

Linda EK FLIESBERG¹, Pierpaolo SORRENTINO², Marie-Constance CORSI¹

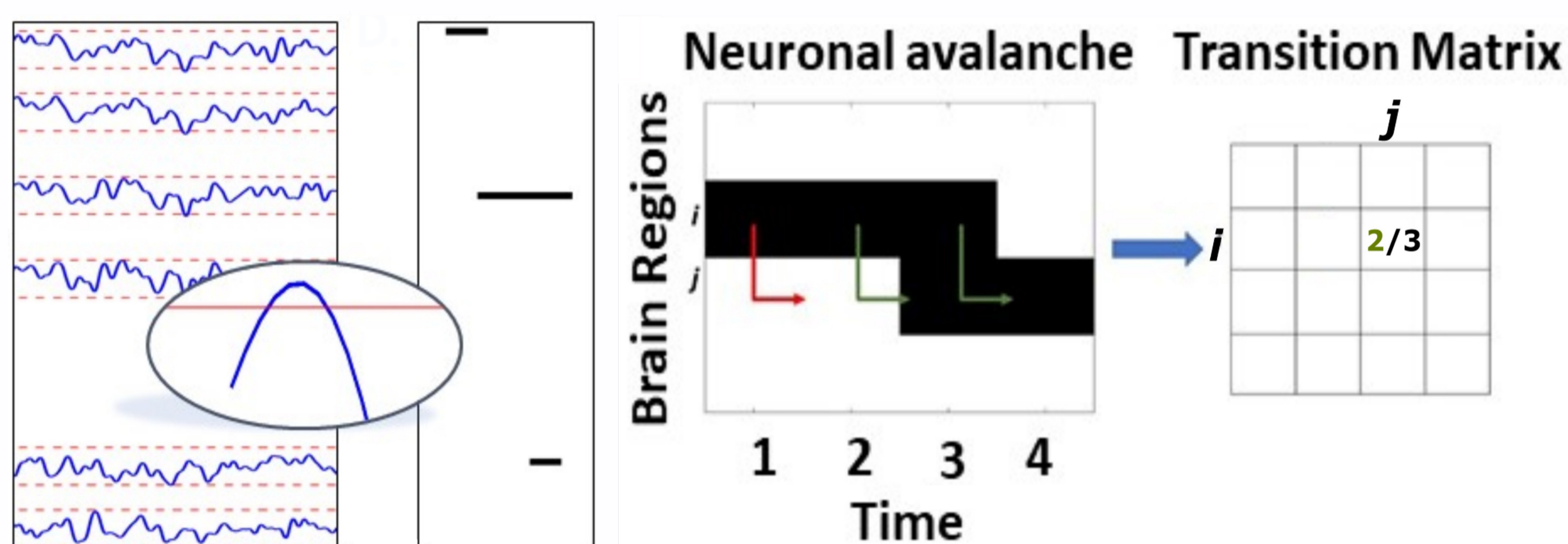
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Brain-Computer Interface (BCI) translates brain activity into commands for control and communication. However, the high inter-subject variability limits its efficiency. Most BCI studies use local measurements without considering the interconnected nature of brain functioning. As a result, mastering non-invasive BCI systems remains a learned skill that yields suboptimal performance in ~30% of users, referred to as the “BCI inefficiency” phenomenon [1]. In this study, we are therefore considering how communication between brain areas impacts BCI performance by studying neuronal avalanches that can be described as a non-linear dynamic biomarker where neurons fire together in a cascade-like pattern following an inverse power law [2]. To test our hypothesis, we are creating a BCI pipeline with neuronal avalanches as features and comparing this with state-of-the-art methods.

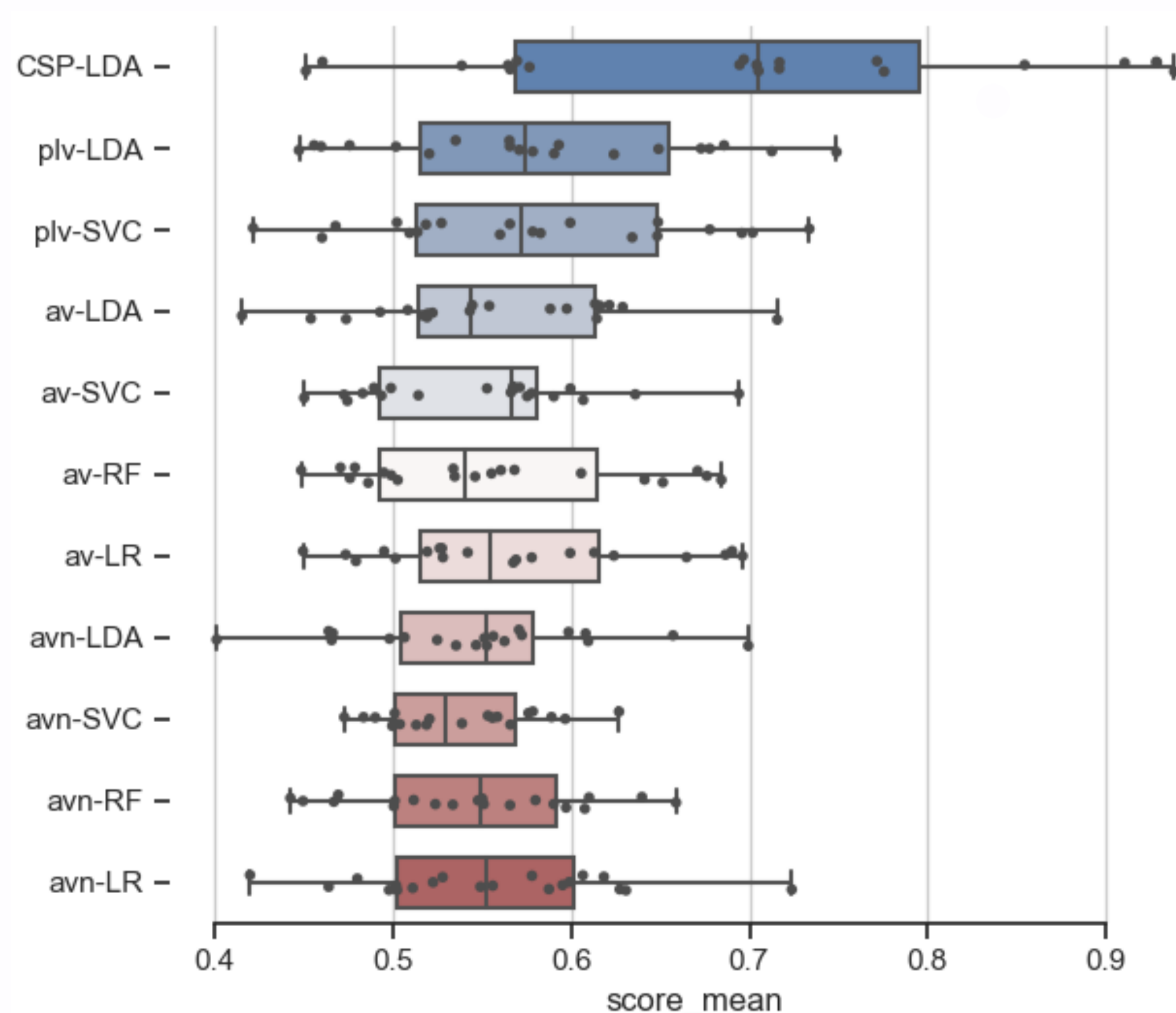
I. Neuronal avalanches computation

To capture the neuronal avalanches, each source reconstructed MEG signal was first z-scored with a threshold set to 3. When one region was above the threshold, the start of an avalanche is identified and when there is no region above the threshold, the end of the avalanche is identified. For each avalanche, a transition matrix is computed with regions of interest in rows and columns. The ij edge in the matrix is computed as the probability that region j would be active the following timestep $t+1$, given region i was active the previous timestep t [3].



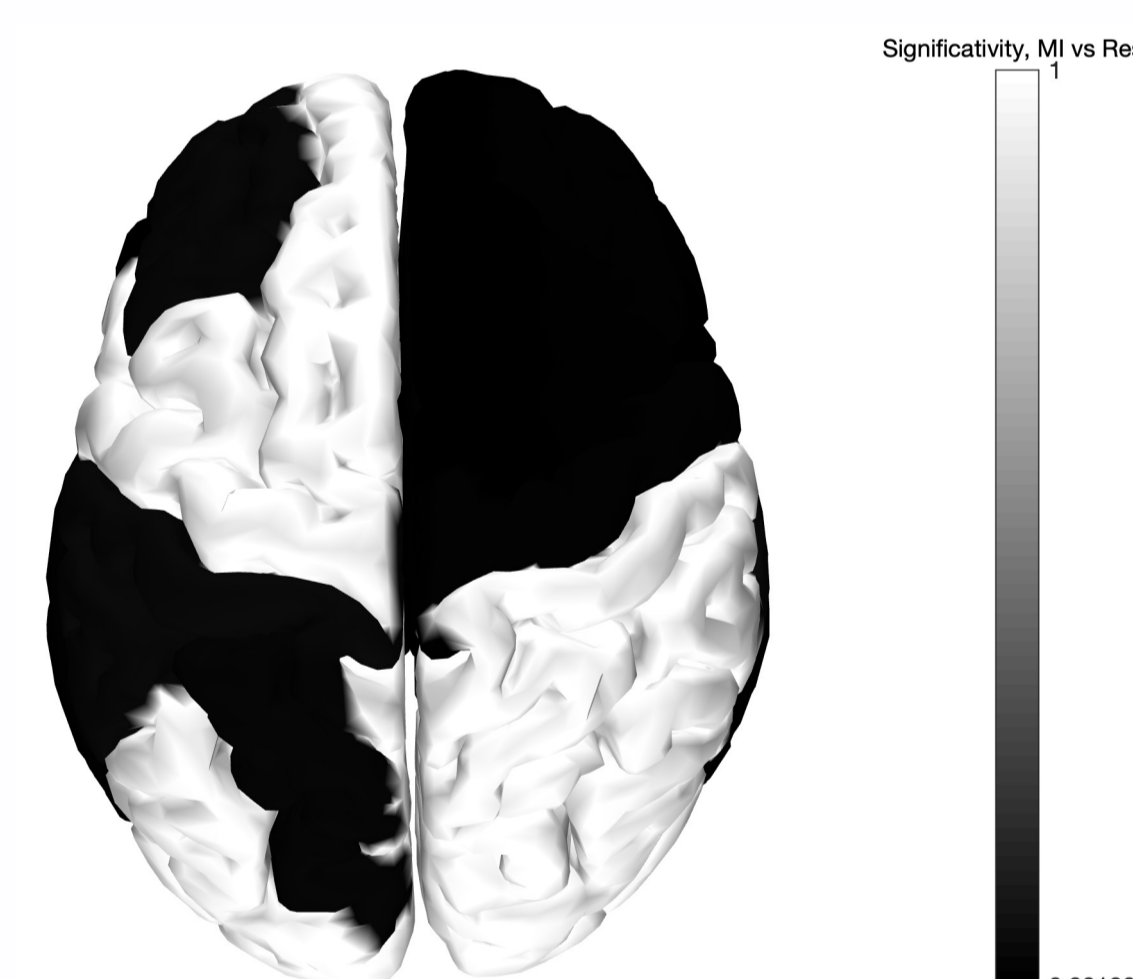
II. Classification and pipeline comparison

The neuronal avalanche transition matrices were implemented as features in a BCI pipeline with different classifiers including, linear discriminant analysis (LDA), support vector machine (SVM), random forest (RF), and logistic regression (LR). The classifiers were compared to other pipelines using the same MEG data but instead using common spatial patterns (CSP) and functional connectivity (plv) as features.



III. Feature importance and selection

To improve the performance of the classifiers we rank the importance of each feature to potentially select a subset of important features. Regions of interest that have been identified include premotor, motor, and parietal areas. The image shows a heatmap of random forest feature importance score to help identify regions of interest.



To validate the significance of the functional links we perform a t-test on the neuronal avalanche transition matrices to compare the two conditions (rest and right). On a single subject level, we can identify certain relevant edges in the premotor and motor areas which are represented in the heatmap.

IV. Discussion

To further improve the classification performance, we are focusing on feature selection by eliminating certain features based on the feature ranking and validating the significance of the features using ANOVA. Additionally, we are working on manipulating the threshold that identifies when a neuronal avalanche has started and ended to be less restrictive and potentially identify smaller avalanches.

References:
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