CS 532 Intelligent Computing

Project Phase 3 (21100187, 21000130) [***UPDATED***]

Hybrid Neuro-Genetic Fuzzy System (HNGFS)

Mental Attention State Classification for the Human Brain using EEG-based BCI data

Implementation

A hybrid fuzzy neuro-genetic network was also designed using the Takagi-Sugeno model and Gaussian membership functions and RMSE loss function. It was trained on pre-processed forms of the feature-scaled signals per channel. Each of the14 channels had various time features extracted from it - number of zero crossings, SVD entropy, Perm entropy, App entropy, Petrosian's and Higuchi's fractal dimension. ANFIS classifiers were trained separately on each feature type (14 inputs) as a result to determine the predictability contribution of each of these inputs. To determine the number of rules required for this ANFIS fuzzy inference system rule base and its sensitivity to training performance, a genetic algorithm was applied with the objective to minimize the final training loss given a range of the number of rules (14-1000) to find the optimum value with a fixed number of epochs and learning rate. The ANFIS model was also specifically trained for binary classification between the focused and unfocused mental attention classes, unlike the 3-class CNN/CRNN classifiers due to its architectural limitations.

Findings

The hybrid ANFIS model was trained as a binary classifier between focused and unfocused states, and tested on each of the different features extracted per EEG channel from the feature-scaled signal. The number of rules defined for the layers to generate was set to 100 initially. The number of zero crossings as inputs to the model yielded the highest accuracy achieved of 86.1% (training and prediction shown in Figure 1) among all other features, followed by Petrosian's Fractal Dimension with 84.1% and Perm Entropy with 83.5% test accuracy in Figure 2.

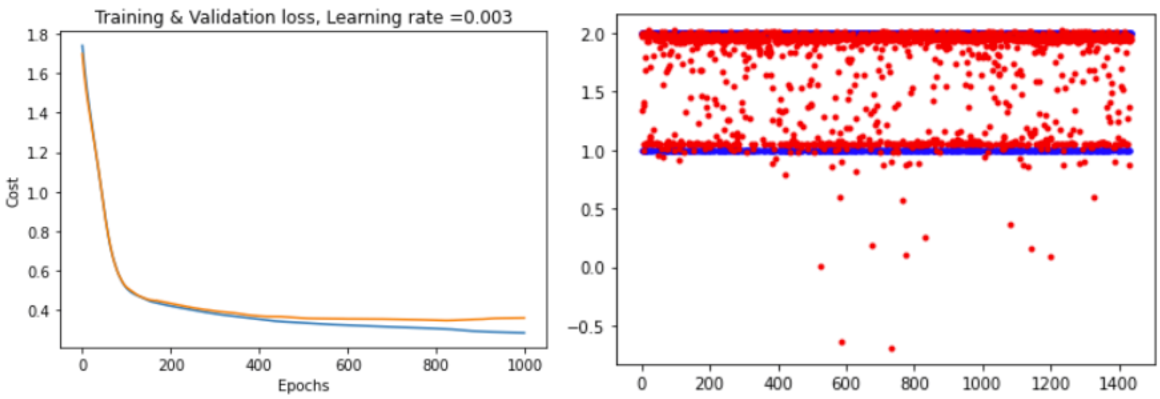

Fig. 1. ANFIS training and predictions with 86.1% test accuracy on the per-channel Number of Zero-Crossings after 1000 epochs.

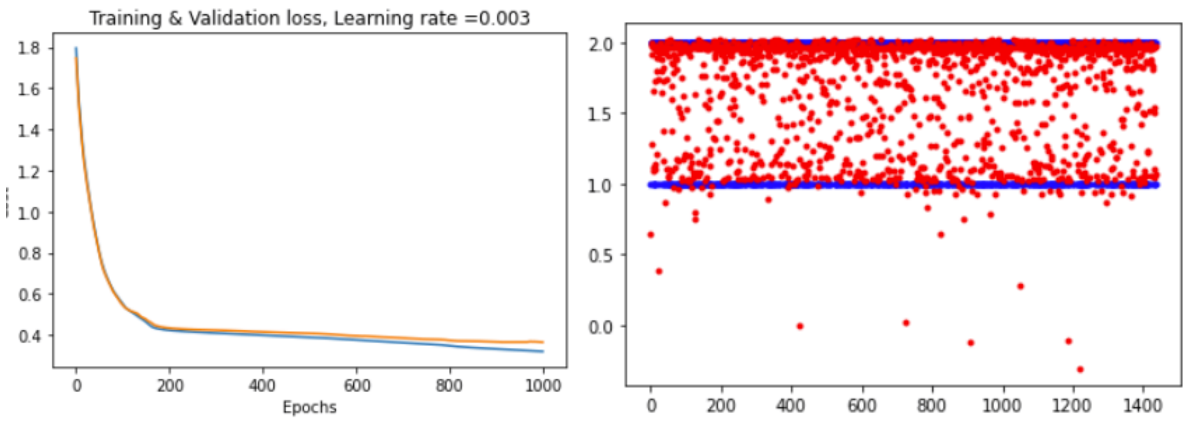

Fig. 2. ANFIS training and predictions with 84.1% test accuracy on the per-channel Petrosian's Fractal Dimension.

After testing combinations of these best-performing input features in pairs (28 in-puts) and 200 rules (obtained by genetic algorithm optimization on 100 epochs each, aimed to minimize the final validation loss), we found that a combined input of the mean-normalized Number of Zero-Crossings and Petrosian's Fractal Dimension gave us an improved 90.3% test accuracy on 1000 epochs for the HNGFS system. The combination of the Number of Zero-Crossings and Perm Entropy input features per-formed even better yielding a test accuracy of 91.8% as shown in Figure 3.

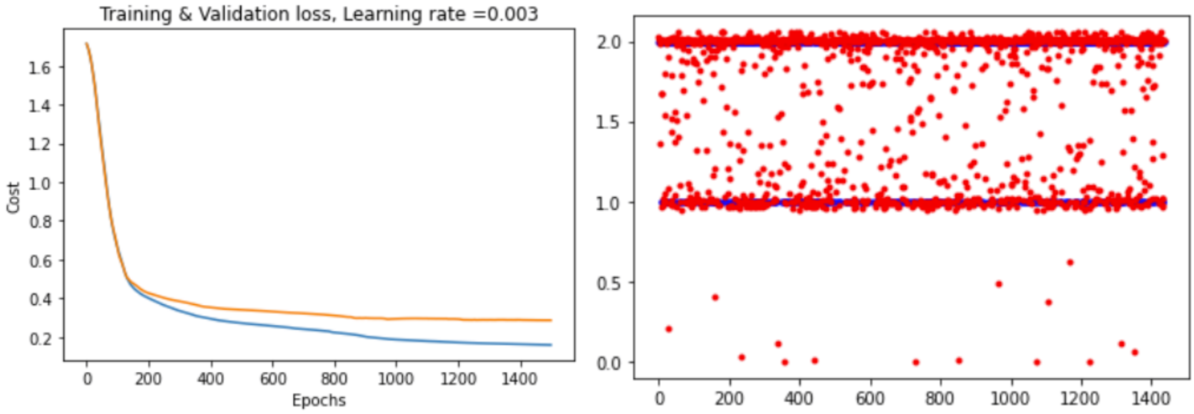

Fig. 3. ANFIS training and predictions with 91.8% test accuracy using a combi-nation of 28 inputs from Number of Zero Crossings and Perm Entropy