LSTM Autoencoders for EEG correction and an analysis of its latent space

A. Saumell[1], K. Chugani[1], A. Soria-Frisch[1]*

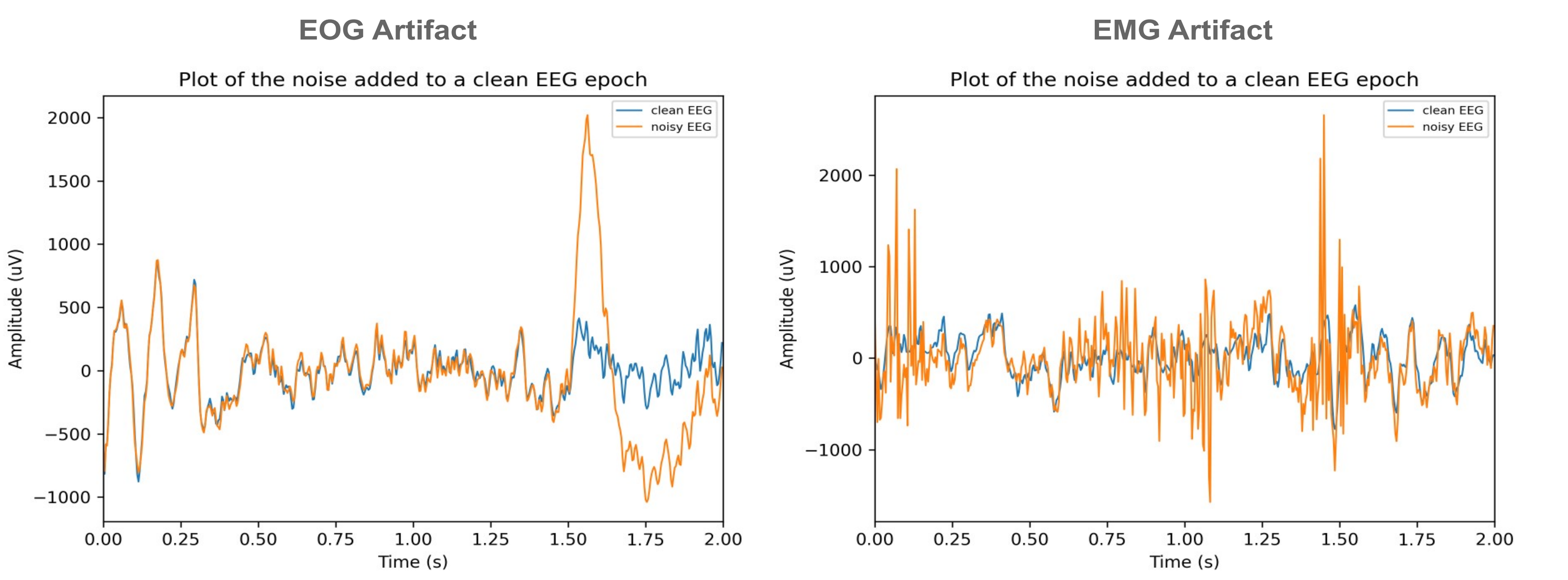
1 Starlab Barcelona SL, Spain
**corresponding author: aureli.soria-frisch@starlab.es*

Objectives

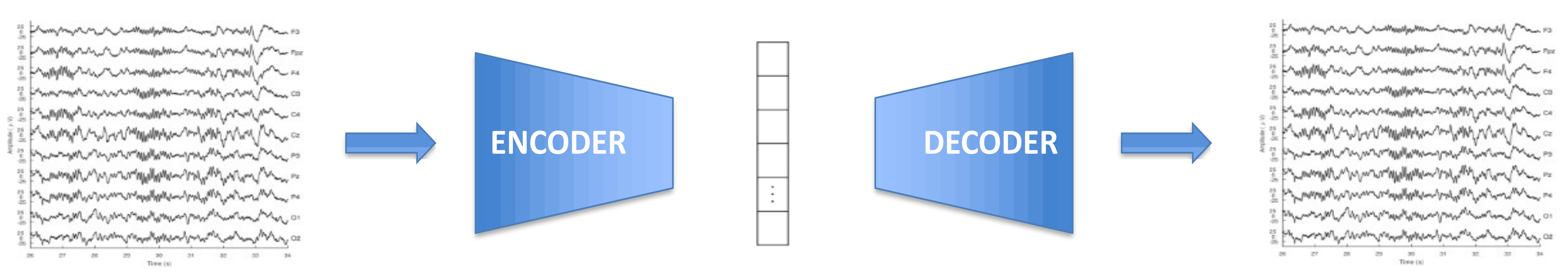
Our aim is to design an automated pipeline to detect and remove artifacts from EEG signals using LSTM neural networks within an Autoencoding structure. Using such a model, the user will be able to detect artifacts and reconstruct EEG in real-time. Moreover, thanks to the inner model structure, we have also performed an exploratory study on the projection of EEG signals over a lower dimensional space (the so called latent space).

Implementation

The dataset used contained 2 second clean EEG epochs and a set of ocular (EOG) and muscular (EMG) artifact segments. To train our models we compute for each clean epoch, two corrupted versions: one with EOG and another with EMG noise.



The model proposed is an autoencoder neural network using LSTM layers. The network projects EEG epochs onto a latent space of dimension *d*, and outputs back the input epoch without artifacts. The models tested were three LSTM autoencoders of latent dimensions of 16, 32 and 64. In order to compare them, we used two benchmark models: a fully connected and a convolutional net.



Models are trained to reproduce clean EEG epochs, so that when we input an artifact they remove it. We define the reconstruction error as the MSE between the input and the output EEG epoch. Since the goal of our model is to mantain unchanged clean epochs and remove the artifact from those containing them, by setting a threshold to this reconstruction error we have a classification method to detect epochs with artifacts.

Results on artifact detection

Model	AUC for EOG artifact	AUC for EMG artifact
fcNN	0.795	1.000
CNN	**0.989**	**1.000**
LSTM-16	0.904	0.954
LSTM-32	0.919	0.995
LSTM-64	**0.924**	**1.000**

Table 1. AUC for classification of EEG epochs

The convolutional neural network (CNN) and the LSTM autoencoder of latent dimension 64 (LSTM-64) are the best models for artifact detection. Nonetheless, the CNN slightly outperforms our model when classifying epochs with EOG artifacts. In general, we can see how the problem of detecting artifacts is indeed considerably solved by these kind of neural networks.

Results on artifact correction

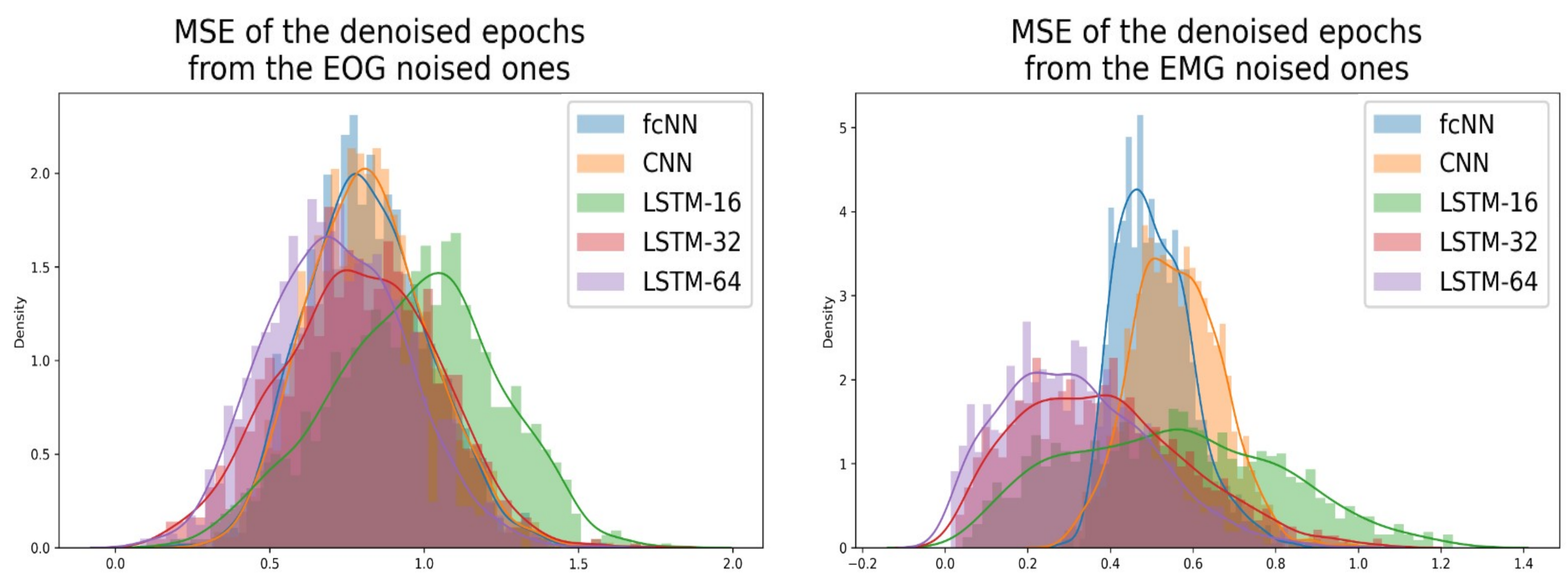


Image 1. Density distribution plot of the MSE betweeen the originallly clean epochs and the corrupted ones.

To evaluate artifact correction we compute the MSE between an originally clean epoch and its artificially noised version once it has been denoised by each of the models (for both cases, EOG and EMG artifacts). Image 1 shows the distribution of this MSE over the whole validation dataset. Here is where our set of LSTM autoencoding models clearly outperform the benchmark models proposed. We can see how the majority of epochs containing artifacts are more similar to their original clean version when using LSTM autoencoders.

Latent space study

The latent space generated by the autoencoding structure of our models can be studied from different perspectives. We can either study epochs directly as time signals or we can approach them from their spectrogram.
Our study focuses on understanding more deeply whether the latent space created is dense and sensible. In order to do so, we performed a bilinear interpolation in this latent space and create pictures as the ones shown here. These show how clearly, in the latent space, points located in between real EEG epochs lead to realistic epochs.