
Using Recurrent Neural Networks on the WAY-EEG-GAL dataset

Roman C. Podolski
roman.podolski@tum.de

Dominik Irimi
dominik.iriimi@gmail.com

Christoph Dehner
dehner@in.tum.de

Manuel Nickel
manuel.nickel@tum.de

Philipp Bergmann
philipp.bergmann@tum.de

Abstract

The *WAY-EEG-GAL* dataset is designed to allow testing of techniques to decode sensation, intention and action from scalp EEG recordings in humans who perform a grasp-and-lift task. In this paper we present our methodology to analyze the data and how we tackled the problem of classifying various stages of these tasks by using a RNN on EEG and EMG data. In particular we present particular findings in the EEG data and successes as well as pitfalls concerning the RNN runs.

1 About the WAY-EEG-GAL dataset

In order to allow for critical evaluations of the utility of EEG signals for prosthetic control of object manipulation, the *Wearable interfaces for hAnd function recoverY - EEG - Grasp And Lift (WAY-EEG-GAL)* dataset was created. In particular, it can be used to inter alia examine at what degree it is possible to identify the intention to reach and grasp, hand positions and velocities or that the object's properties have unexpectedly changed. The data was collected during the course of a series of experiments in which twelve right-handed individuals, both male and female, were selected as participants. Each participant was seated at a desk with his hand resting on the table. An LED signaled the person to reach for a small object, grasp it using his index finger and thumb, lift it up a few centimetres, hold it for a brief moment and finally return the object as well as his hand to their initial positions. In this paper, we will from now on refer to this sequence of events and actions as a *trial*.

Each participant then conducted 328 such trials under slight but to the participant unpredictably changing circumstances. That is, the object's weight to be lifted was augmented through an electro-magnet, resulting in weights of 165, 330 or 660g. Furthermore, the contact surface changed to be made of sandpaper, suede or silk. Depending on the specific trial, either only the surface, only the object's weight, both or none changed. In order to record kinematics, forces, muscle activations and brain activity, four types of sensors were used during the experiments. In particular, an electroencephalography (EEG) cap, illustrated in figure 1, with 32 electrodes was used to record the brain activity during the trials, sampling at 500Hz. Furthermore, five electromyography (EMG) sensors, as depicted in figure 2, were placed on the participant's right arm to measure muscle activity at a sample rate of 4kHz.

The resulting dataset, in the form that we used it, then provides the measurements for each participant and each trial. In this, the EEG and EMG signals are concatenated in matrices respectively with a time stamp decoding the exact record time for each measurement. Moreover, the time of the LED being turned on and off, the trial's start and end time, the type of surface and the object's weight are provided for each trial, as well. [1]



Figure 1: An EEG cap measures the participant’s brain activity [1] Figure 2: EMG sensors record the muscle activity of the right arm [1]

2 Analyzing the datas using t-SNE

In order to get a *feeling* for how the EEG as well as EMG datasets are inherently structured, we aimed to visualize them. In particular, we were interested in how the notion of *grasping an object* is captured. That is, does an individual measurement by itself carry enough information allowing to conclude that the participant is right now grasping an object or not? Or is this notion rather encapsulated within a series of measurements, with datapoints that change over time?

As the individual datapoints are high-dimensional ($\mathcal{D}_{EEG} \in \mathbb{N}^{32}$ and $\mathcal{D}_{EMG} \in \mathbb{R}^5$ respectively), a particularly suitable method of visualization seemed t-distributed stochastic neighbourhood embedding (t-SNE), which allows to represent high-dimensional data as a two-dimensional mapping by grouping similar state vectors close together and separating them from less similar ones. Specifically, we used an efficient Barnes Hut t-SNE implementation, created by L.J.P. van der Maaten [2]. Doing so, we created t-SNE plots of the EEG as well as the EMG data. An important property of t-SNE is that it cannot consider time-relations between individual data points, instead it sees each data point as its own entity. However, in order to make sure that the used implementation of t-SNE is not somehow influenced by the ordering of the states, all data points were shuffled and placed in random order before being fed to t-SNE.

In the following, we have a look at a subset of the WAY-EEG-GAL dataset. In particular we exemplarily examine participant 1’s first series, a dataset composed of 34 trials in total, which are collected in `WS_P1_S1.mat`. Each of the 34 trials were marked with a different color in the resulting plot, e.g. states of trial 1 might be colored in green while states of trial 2 in red. Furthermore, states that were measured within the time span of the LED being lid up are drawn with a black border in order to separate them visually from states with the LED being off.

Doing so, we expected to see one of these possible outcomes:

- The LEDon-states are grouped together in one place while the LEDoff-states are grouped in another place: We interpret this a sign that it is possible to extract information about the intention to grasp from individual data points. As t-SNE does not *understand* relations in time, even a simple Feedforward Net might work.
- All data points are distributed randomly and there is no apparent structure in the plot: This would signal that if there is a way to extract information about the intention to grasp, then it is not sufficient to use Feedforward Nets only. Instead, one needs to at least incorporate time relations. Thus, we try using Recurrent Neural Nets.

Figure 3 shows the t-SNE plot for the 34 trials of participant 1, series 1. Clearly, all data points are distributed randomly and no particular grouping is to be seen. Following the reasoning described above, we conclude that using a Feedforward Neural Net cannot suffice to extract the grasping notion out of the EMG data.

We then applied the same t-SNE implementation to the EEG data. The result can be viewed in figure 4. Here, the plot shows none of the expected characteristics. Instead, data points belonging to

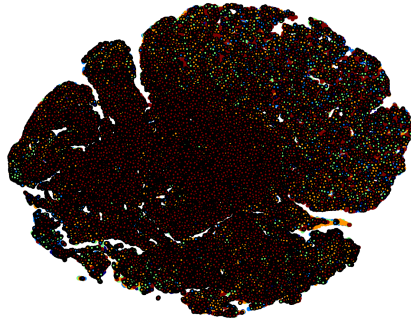


Figure 3: t-SNE plot for EMG data

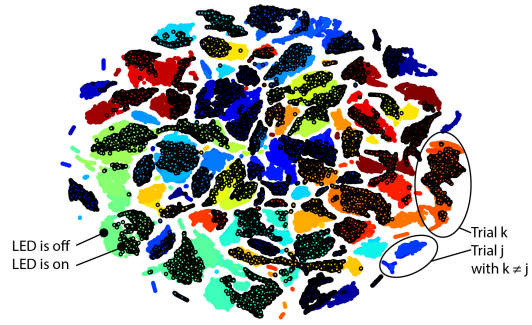


Figure 4: t-SNE plot for EEG data

the same trial clearly form clusters while these clusters, each representing a specific trial, are then separated from each other. This indicates, that the EEG data somehow comprises a notion of time, encoding which measurement was taken during which trial. This is, however, not reasonable as the individual measurements are expected to be independent from each other. Thus, we first verified multiple times and using different methods the correct function of the t-SNE implementation, making sure the plots are no result of merely faulty computation. But, the implementation turned out to be working fine.

In this case, however, figure 4 suggests that it should be possible to determine for a given data point, i.e. measurement, during which trial it was taken. This comes down to a classification problem which can be solved using a simple Feedforward Neural Net.

Thus, we created a Neural Net with one hidden layer, 32 input neurons and 300 hidden neurons. Furthermore, a tanh activation function and gradient descent optimization were used. The EEG data from participant 1, series 1 contains 146982 samples in 34 trials, which were put in random order and partitioned into a training-, validation- and test-set containing 4/9, 2/9 and 1/9 of the original samples respectively. The dataset was normalized to contain values between -1 and $+1$. In particular, each trial was normalized separately in order to remove a possible offset in the data, which might have caused the clustering in figure 4. However, the Neural Net confirmed the t-SNE results: Using above settings, a test error of only 2.38% was achieved for participant 1, series 1. The Neural Net was applied to a variety of other subsets of WAY-EEG-GAL, too. There, even better test errors of just about 0.01% were achieved. Overall, for any participant and series, the specific trials could be classified very easily by simply looking at a single measurement.

The above results suggest, that indeed information about the time of measurement is included within the measurements themselves. We suspect a continuous change in value for at least a subset of the electrodes measuring the brain activity, leading to characteristic patterns within each trial's data. We then applied various techniques trying to remove these unwanted characteristics. For this, different normalization and filtering methods with varying parameters were used. However, none of these succeeded. In fact, the normalization applied in above example even improved the Neural Net test error significantly: Without normalization a test error of comparatively bad 19.69%, with normalization a test error of 2.38% was achieved. Moreover, classification of trials turned out to be possible not only within a single series but over many more, too. For this, a Neural Net run was performed on the entire EEG data of participant 1, comprising 294 trials in total. This resulted in a test error of 15.65%, which seems still rather impressive considering that now there are many more classes than input neurons which the Neural Net can draw information from. Thus, of whatever kind the structure within the EEG data distinguishing the trials may be, it is not bounded by individual series but seems to be of global nature.

As unexpected as these results may be, they do not necessarily mean that the EEG dataset is entirely corrupted, as we will see in the following section.

References

[1] Luciw, M. D., Jarocka, E., EdinLandsberger, B. B. (2014) Multi-channel EEG recordings during 3,936 grasp and lift trials with varying weight and friction. Retrieved July 20, 2016, from <http://www.nature.com/articles/sdata201447>.

[2] van der Maaten, L. J. P., (2016) t-SNE Implementations. Retrieved July 24, 2016, from <http://lvdmaaten.github.io/tsne/>.