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DanielMiklody 10.07.2018 15:06:05
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very good concept!

Concept for Project 4: EEG Simulation

Tasks:
• Translate network activity to source activity
• Introduce timing /time delays
• Simulate source activity as oscillations
• Simulate noise (1/f in sources)
• Generate an EEG signal

Translate network activity to source activity and generate oscillation

In order to model the source activity we need to map the activation of the CNN in every layer (composed of specific filter activations) to different oscillation in the specific regions of interest. The CNN group will give us an output array of size: filter height x filter width x #filters. Therefore we thought of creating for each filter activation one sinusoid representing the activity caused by the feature represented. This would mean we would have height x width number of neurons with certain activities that need to be combined to one oscillation. We would start by translating the single activities into frequencies. Higher activity would hence mean a higher frequency. Since the activity will be a real number between 0 and 1 this can be easily mapped into a frequency range from, for example, 7-40 Hz covering alpha to theta oscillations. This is close to reality because most neurons have just an all-or-none action potential and strong excitation over time is coded as a high firing frequency. We would then use this frequency to modify a normalized sine signal. So for every filter we would have height x width number sine curves with different frequencies but same amplitudes. These can then be added in order to construct complex oscillation for this feature (e.g. edges). The beauty of this approach is that this somewhat corresponds to reality. Low frequency oscillations, like alpha waves are often associated with a resting state and probably come about by all neurons (in a specific area) firing at the same low frequency. This is then often used to classify the activity in the respective brain region by an ERD. The difference to our approach is that we will have a higher frequency present instead of no synchronous firing. Since the adding will shift our oscillation up to a very high range we would need to normalize this by the number of neurons taken into account (height x width). This normalized curve can then be shifted into a realistic EEG μV range.

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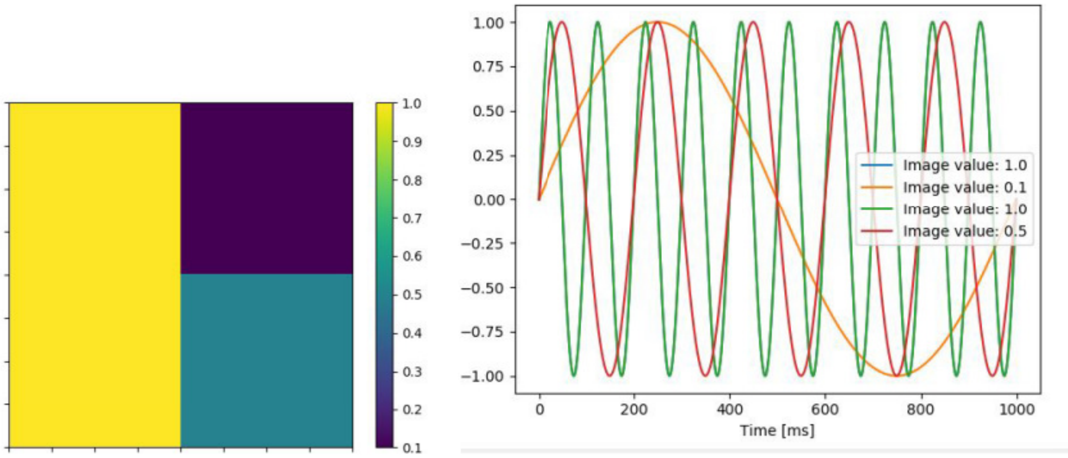
this is an interesting approach, however oscillations are usually at a more or less fixed frequency and your model would lead to a broad frequency spectrum rather than to peaks



Mock image from a 2x2 filtered input, in which the intensity of each corresponds to the frequency of a sinusoidal wave.

The only question left then (regarding the oscillations) is how to combine the responses to different features belonging to the same feature class. For example different edge filter activations, which would correspond to activation in V1, or different color filter activations, which would correspond to activation in V4. The solution to this problem is highly dependent on the plan of the head modeling group. If they, for example decide to map every feature to a different region inside the corresponding overall area (e.g. having multiple dipoles at the area of V4) we would use these sinusoids separately and project them onto different dipoles in the area corresponding to this feature class. The advantage of this approach would be that one would be able to directly read from the EEG topography the features of the input (given that you know what kind of activity is corresponding to what feature strength e.g. high activity means strong presence of this feature). Another possible approach would be to combine all different sinusoids for this feature class and project them onto one dipol (i.e. one oscillation for every region of interest e.g. V1, V4 ect.). In this case we could just use the same procedure as described above. Adding the sinusoids, normalizing them and ~~than~~ shifting them into a realistic regime. The advantage of the approach would be, that this would resemble reality more than the first approach. This is because feature representations are usually not found in such big clustered in the cortex but rather in small scattered ones (which would result in one big dipol independent of the specific features). In V1 for example the sensitivity towards the orientation is scatter over the flattened cortex area like this:

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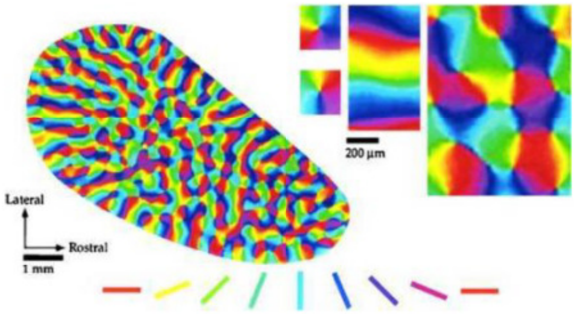
It's not only their decision, you should work together and tell them what you want/need!



Simulate noise

The simulation of the noise can be done in a straightforward way by using our constructed sinus. The main question here is at which step we should add the noise. For now we have decided to add the noise in the end. So as soon as we have constructed our final sinusoids (either several ones or just a singular one for each region of interest e.g. V1) we would then Fourier Transform it into frequency space and add randomly generated pink noise (just like in the exercises). Since the pink noise is probably due to the background noise of neural activity on one hand and due to the amplifier on the other hand this should resemble reality quite nicely. Another approach could be to add the pink noise to the sinusoids of every neuron.

Introducing time delays

In order to create a time delay for each higher region (e.g. V4 responding later than V1) we can simply add a phase shift to the constructed oscillations on one hand and delay the onset of the activation on the other hand. This means, that we would have a simple alpha oscillation present as long as we do not have any input and as soon as the input ‘arrives’ in a region we are using our constructed sinus signal with the respective time shift.

References:

Orientation map picture:
Afgoustidis, Alexandre. (2015). Orientation Maps in V1 and Non-Euclidean Geometry. Journal of mathematical neuroscience.
Information:
Michael X Cohen (2017). Where Does EEG Come From and What Does It Mean? Trends in Neurosciences