How does Tranquility EEG-manipulation software works

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Tranquility software alters EEG and EEG-related metrics using machine learning. First, it measures how audiovisual and verbal (only small-number-of-parameters LLM is used) alters EEG-brain-waves. After measuring changes to EEG caused by random stimuli, it then discretizes EEG+metrics vector to Hidden Markov Model states of the brain. Combined EEG-power band values, their metrics and Hidden Markov Model state data is used to fit a recurrent deep neural network model to predict changes caused by parameterized stimuli to EEG. Finally, neural network models

$$f(\text{eeg}(t), \text{HMM}(\text{eeg}(t)), \boldsymbol{p}_{\text{stimuli}}, t, \boldsymbol{r}(t)) = (\Delta\text{eeg}, \boldsymbol{r}(t+1))$$

are used to select parameters of stimulis $\boldsymbol{p}_{\text{stimuli}}$, which changes eeg-vector as much as possible towards target eeg-value (eeg power spectrum bands + spectral entropy, phase locking value and few other metrics calculated from eeg).

1 Optimization

Initially, a generic models which predict changes to the eeg-vector was calculated but resulting model didn't work well with more complex optimization targets or when a eeg-metric had small values while other eeg-values were large values meaning that optimization didn't optimize to predict small changes in eeg-vector. Because of this, optimization now happens specifically for each optimization target by setting those delta eeg-vector values zero which are not used. Without this mechanism, altering of phase locking values, for example, gives 0% change when with the specific optimization, changes to PLV are 7% - 50%.

Another version of the software was also created called whiteice. It uses reinforcement learning without recurrency and tries to learn to predict changes in EEG using neural networks. The learning happens live and resulting neural networks try to change EEG towards target value. However, without larger neural network and recurrency, the results are bad, changes to phase locking value (PLV) are only about 0.1% meaning model cannot really learn to change EEG. Because of this reinforcement learning is not used anymore.

2 Selection of parameters

For selection of parameters gradient-free methods should be used (something like genetic algorthms). For sound synthesis and picture synthesis, number of parameters is kept small (3-5) and random search of 500-1000 tries are evaluated to find the best next step stimulation parameters.

For verbal stimulation, feature vectors (50 dimensions) of words is calculated from english wikipedia (simplified smaller edition). After this, a small language model from huggingface is used to generate the N possible next words of from the previous K words. From the plausible N words, prediction model is used to predict change to EEG for each word. The best word is selected to be the next stimulus.

For a picture stimulation, ResNet model from pytorch is used to calculate feature vectors (2048 dimensions) of the pictures. During each step, M=100 pictures are selected from all pictures and their feature vector is used to find the 3 best pictures causing wanted change to EEG and one of them is used for stimulation.