WhiteICE software for altering brainwaves (EEG)

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WhiteICE software is machine learning software that alters EEG. It uses isochronic tones sound generator which parameters are optimized using reinforcement learning. Reinforcement learning is continuous reinforcement learning with small neural networks to predict response to audio stimuli. Using reinforcement learning means that solutions (audio stimuli parameters) are completely data-based (from EEG measurements). Therefore audio stimulation is personalized to each user's brain responses.

Because reinforcement learning starts from scratch to learn neural network models, the software requires much training data and many iterations of model updates. This means you must run software with a fast CPU for two to three hours (or six hours) before some useful results. Besides a fast CPU, the software also requires an EEG device for measuring audio parameters' EEG responses. Currently, Interaxon Muse EEG is supported through the Mind Monitor App (OSC-protocol) and BrainAccess HALO EEG is supported through LSL-protocol support. It might be possible to run software also with other EEG devices that support LSL protocol.

As the default, the software maximizes the average PLI (phase lag index) of ICA signals solved from raw EEG measurements. Using ICA signals instead of raw EEG signals seems to give qualitatively better results so using ICA-metrics is recommended.

To use software, you need to execute the command-line software with good speakers connected to the computer and let it run background playing sounds while using the computer or passively listening the sounds.

Commands that are used to run reinforcement learning (max ICA-PLV) and do the stimulation:

```
whiteice.exe --measure --device=lsl --debug-log --model-dir=model --lsl-
names='<stream-name>','<stream-type>' --lsl-channels=4
```

Or

```
whiteice.exe --measure --device=mindmonitor --debug-log --model-dir=model --muse-
port=4545
```

In the first command, you read measurements from BrainAccess HALO LSL stream with a given name ('`BA HALO 002_HALO_BrainAccess`') and type ('`EEG`'). In the second command, you receive OSC packets from the MindMonitor App which has to be configured to send OSC packets to the IP address of the computer and UDP port 4545.

You can also test the software using a command:

```
whiteice.exe --measure --device=random --debug-log --model-dir=model
```

You need to run the software for approximately 15 minutes during which random parameters are used to measure responses after which the first model is calculated and 80% of the audio parameters are chosen by the model and only 20% are random search for better solutions. Software manages to find some kind of useful result typically in two to three hours of stimulation. Also, when `--model-dir=` is used, measurements and models are saved to disk and reloaded from the disk when software is started again. You need to manually delete files in the model directory to start learning from scratch.

It is also possible to change the stimulation by giving 21 numbers (0 or 1 or -1 for not used) that specify the target values of the stimulation. Possible target signals are:

```
1: LSL_EEG: Delta (-1.00)
2: LSL_EEG: Theta (-1.00)
3: LSL_EEG: Alpha (-1.00)
4: LSL_EEG: Beta (-1.00)
5: LSL_EEG: Gamma (-1.00)
6: LSL_EEG: Total (-1.00)
7: LSL_EEG: Rel. Delta (-1.00)
8: LSL_EEG: Rel. Theta (-1.00)
9: LSL_EEG: Rel. Alpha (-1.00)
10: LSL_EEG: Rel. Beta (-1.00)
11: LSL_EEG: Rel. Gamma (-1.00)
12: LSL_EEG: Spectral Entropy (-1.00)
13: LSL_EEG: Phase Difference (T+A+G bands) (-1.00)
14: LSL_EEG: Phase Slope Index (T+A+G bands) (-1.00)
15: LSL_EEG: Phase Lag Index (T+A+G bands) (-1.00)
16: LSL_EEG: Phase Locking Value Lower Bound (T+A+G bands) (-1.00)
17: LSL_EEG: Spectral Entropy (ICA signals) (-1.00)
18: LSL_EEG: Phase Difference (ICA signals, T+A+G bands) (-1.00)
19: LSL_EEG: Phase Slope Index (ICA signals,T+A+G bands) (-1.00)
20: LSL_EEG: Phase Lag Index (ICA signals, T+A+G bands) (1.00)
21: LSL_EEG: Phase Locking Value Lower Bound (ICA signals, T+A+G bands) (-1.00)
```

The commands to use with target values are:

```
whiteice.exe --measure --device=mindmonitor --target=-1,-1,-1,-1,-1,-1,-1,-1,-1,-
1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1
```

```
whiteice.exe --measure --device=lsl --lsl-names=<stream-name>,<stream-type> --
target=-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1
```

Instead of optimizing the average PLI of ICA signals, one could maximize average Phase Locking Value (PLV) of ICA signals which improves focus (together with PLI). On the other hand, optimizing Spectral Entropy metrics doesn't seem to give interesting and useful results.

Performance

When the software is run, the program reports a hard performance number using the most recent 1000 responses to stimulation. Software compares delta distance differences between model stimuli and random stimuli. Delta distance is a change of distance caused by a single 500ms stimulation period. When the software stops, it reports a OVERALL (not just 1000 most recent responses) average distance changes in percentages caused by machine learning models and random actions. The OVERALL metric is maybe the most useful single value describing effects. Typically, after two to six hours the overall metric will be 0.1 - 1.0%.