HPC for optimization of hyper-parameters of brain signals decoder

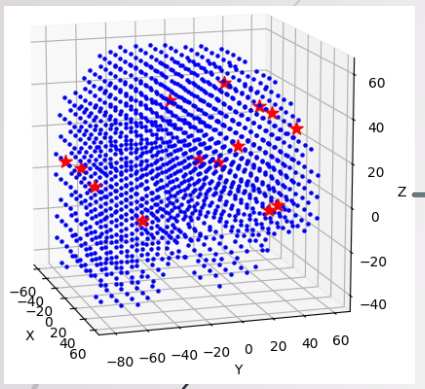
Petia Koprinkova-Hristova

Institute of Information and Communication Technologies,

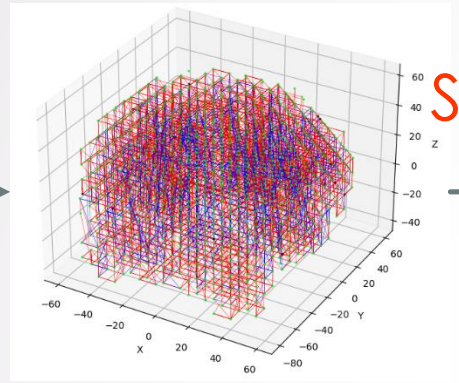
Bulgarian Academy of Sciences

Neuromorphic decoder: NeuCube + ESN classifier benchmark test example

EEG electrodes

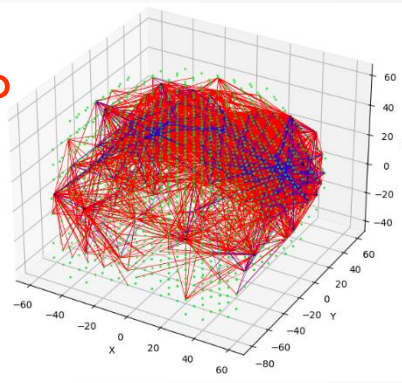


NeuCube structure:
1471 neurons
14 EEG electrodes
1000 ms recordings
60 examples
3 classes



Initial small world connectivity

STDP

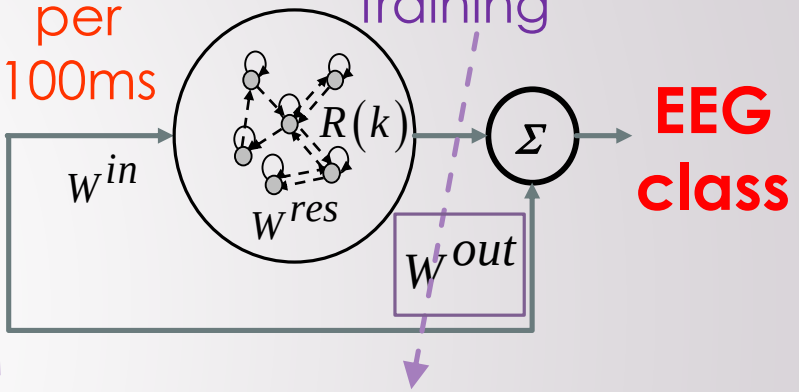


Connectivity after STDP training

nest ::

Firing rates per 100ms

On-line RLS training



EEG class

Python

ESN reservoir of tanh neurons
in 1471x10, out 1
RLS training

Test example dimensions

- ✓ 14 channels Emotiv measuring device collecting EEG data for 1000ms with sampling frequency of 128Hz.
- ✓ 3 EEG classes, 20 examples per class are collected - total number of samples 60.
- ✓ The Cube consists of 1471 neurons with initial randomly generated connectivity having
- ✓ 80% positive and 20% negative values.
- ✓ The parallel implementation of the ESN module in Python was done using mpi4py library 1.
- ✓ The NEST Simulator has its own MPI that distributes the SNN module simulation among the specified number of threads.

Optimization experiments performed:

1. Complete SNN-ESN model exploration running consecutively each one of them
2. Exploration of the ESN module that receives as input directly EEG data

Optimization task dimensions

Table 1. Hyper-parameters subject to optimization

Parameter	Values
SNN	
threshold of membrane potential V_{th}	$-60, -55, -50$
refractory time t_{ref}	$0, 1, 2, 3, 4, 5$
STDP learning rate λ	$0.1, 0.01, 0.001$
ESN	
leaking rate	$0.4, 0.5, 0.6, 0.7, 0.8$
reservoir size	$3000, 3500, 4000, 4500, 5000$
reservoir sparsity	$0.4, 0.5, 0.6, 0.7, 0.8$
scale in	$0.00001, 0.0001, 0.001, 0.01, 0.1, 1$
scale out	$0.00001, 0.0001, 0.001, 0.01, 0.1, 1$

All possible combinations of optimized parameters:

- SNN module 3×6×3 = 54
- ESN module 5×5×5×6×6 = 4500 combinations

Total number of tested combinations:

- 243000 for SNN-ESN model
- 4500 for only ESN model

Optimization times on HPC and desktop

Table 2. Estimated optimization times on desktop and HPC architectures in days.

Task	Module	Time	Processes	Nodes (Cores)
Desktop				
1	SNN	0.868	1	1(2)
1	ESN	112.808	2	1(2)
2	ESN	1.981	2	1(2)
Supercomputer				
1	SNN	0.622	32	1 (16)
1	ESN	8	54	4 (64)
2	ESN	0.124	30	2 (32)

The desktop configuration has 2.60 GHz Intel(R) Core(TM) i7-6500U CPU with 2 cores and 16.0 GB RAM.

The HPC System Avitohol consists of 150 servers ProLiant SL250s Gen8 each with dual Xeon CPU E5-2650 v2 at 2.60GHz and dualXeon Phi 7120P accelerator cards. In total it has 9600 GB RAM accessible by the regular CPUs and 4800 GB RAM on the accelerator cards.

Application under development: HORIZON-EIC action Auto-adaptive Neuromorphic Brain Machine Interface: toward fully embedded neuroprosthetics (NEMO-BMI), No 01070891/01.10.2022