WaveScalES models in NEST

Single-area non-laminar model for Slow Waves and Asynchronous State simulations

Spiking networks of point-like neurons organized in 2-dimensional spatial grids of local modules (grid step dx = 400 μm), including 1250 neurons per module, interconnected with a probability kernel depending on the distance. In this case, pconnect ~ exp (r / λ), λ = 240 μm.

NEST implementation:

- Grid of cortical modules described with NEST topology
- Neuron model is a variant of LIF neuron with spike frequency adaptation model with NESTML
- Layered structure for the description of excitatory and inhibitory sub-populations
- Connectivity implemented with exponential distribution kernel with masks for excitatory and inhibitory neurons
- Synaptic weights following a normal distribution
- Synaptic delays described with exponential distribution not depending on the distance (custom). To be improved
- External spikes generated as a Poissonian
- 400 Poissonian generators for each neuron are required by the WaveScalES model

Neuron model
Leaky Integrate-and-Fire neuron with Spike-Frequency Adaptation modelled as an activity dependent after-hyperpolarization current described by the fatigue variable w.

\[ \frac{dv}{dt} = -(v - E_l) - g_{ww} w + I \]
\[ \frac{dw}{dt} = \alpha \left( \frac{V - V_{reset}}{V_{reset}} - w \right) \]

if V > Vpeak: 

V = Vreset  

w = w + α

Power Spectrum Comparison between DPSNN (blue) and NEST (red) simulations for the three neural sup-populations

DPSNN and NEST cooperation framework

DPSNN

- Distributed Plastic Spiking Neural Network simulation engine for large-scale spiking simulations distributed over thousands of MPI processes, including columnar, areal and inter-area connectivity models.

Porting to NEST

All WaveScalES simulation models are ported from DPSNN to NEST, to be offered to the research community in the framework of HBP platforms.

Use-case: the WaveScalES experiment in HBP

The WaveScalES experiment

Measurement, perturbation, theoretical modelling and simulation of cortical Slow Waves in deep-sleep / anaesthesia and during transition to consciousness.

Modeling of memory consolidation during deep-sleep.

Perturb and measure at several spatio-temporal scales using multiple methodologies

Ideation of physical theories, measurable predictions and mathematical models

Dynamical representation of SW and AW states. Panels A and D: nullcline representation in the phase space for, respectively, the unstable fixed point that induces oscillatory dynamics (A) and the stable fixed point at high level of activity representing the asynchronous awake state (D). Panels B and E: firing rate time course of a sample module made up of foreground, background and inhibitory sub-populations (respectively in black, blue and red) for sleep state (B) and asynchronous state (E). Panels C and F: time consecutive sketches of the activity distribution in space, showing wavefront propagation of a wave in sleep state (C) and showing the activity during an awake state (F).

Simulation aims: 1) Reproduction of Slow Waves Activity (SWA) and Asynchronous Awake (AW) states. 2) Match with experimental data acquired by the WaveScalES team

Mean field theory, describing the dynamical activity of single modules, is used to set the asynchronous or bistable working regime of the network

WaveScalES teams and key-persons

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