Distributed large scale simulation of synchronous slow-wave / asynchronous awake-like cortical activity

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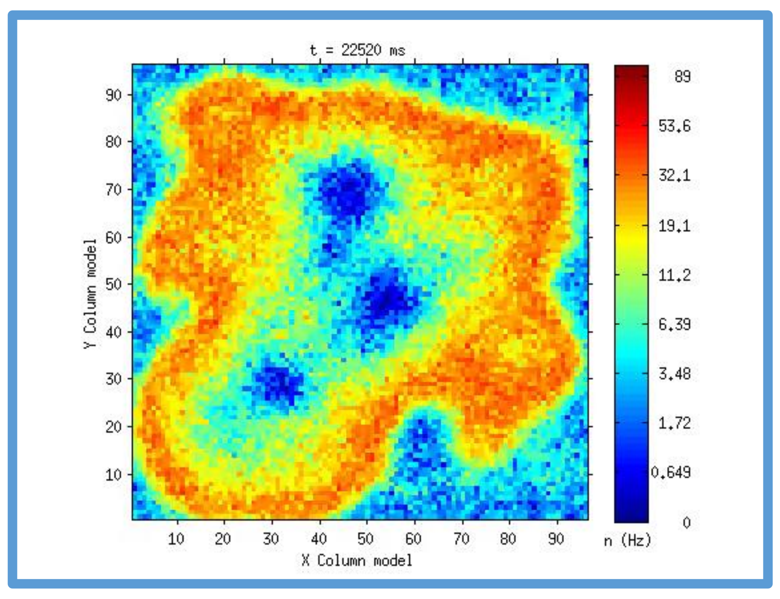
DPSNN simulation engine

DPSNN - Distributed Plastic Spiking Neural Network simulation engine

Large-scale spiking simulations (up to hundreds of billions synapses) distributed over (up to tens of) thousands of MPI processes, including columnar, areal and inter-areal connectivity models



GRID	NEURONS	SYNAPSES
192x192	46 M	70 G
96x96	11.5 M	18 G
48x48	2.9 M	4.4 G
24x24	0.7 M	1.1 G

The spiking networks of point-like neurons are spatially organized in 2-dimensional grids of layered local modules, connected to each other with a probability kernel depending on the distance, e.g. in the use-case here reported $p_{conn} \sim \exp(-r / \lambda)$.

DPSNN scaling

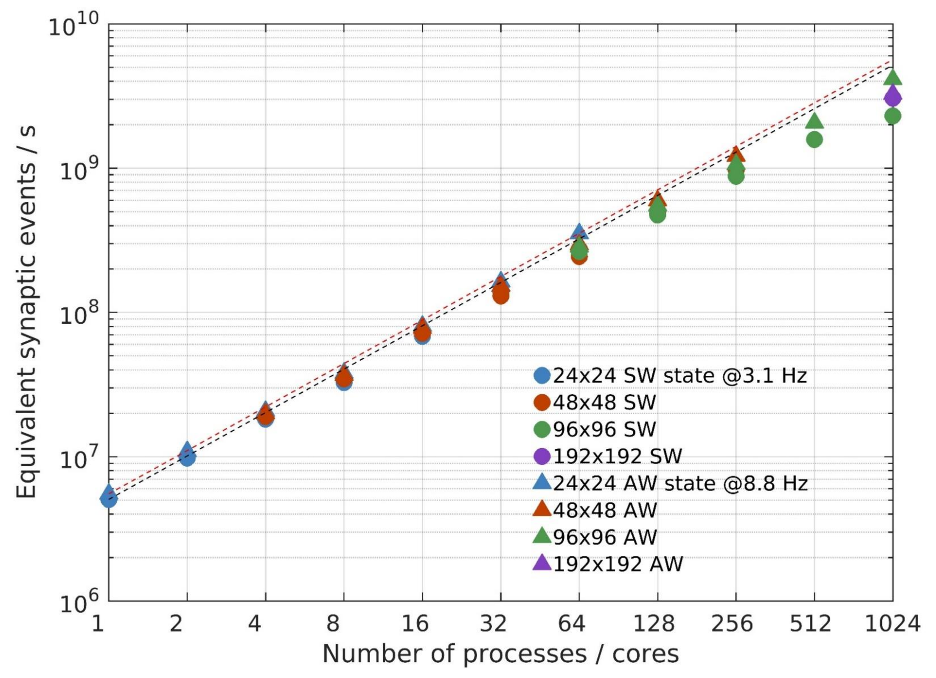
The mixed time-driven / event-driven simulator shows comparable performances in both SW and AW states. In addition, analysis have been executed on simulations presenting different loads in computation and communication, showing no impact on the scaling.

Simulation cost per synaptic event

Elapsed time per simulated second normalized to number of synapses and firing rate:

$$\frac{\textit{elapsed time}}{\textit{num of syn} * \textit{firing rate}}$$

Scaling of DPSNN simulations in Slow Waves and Awake states



Execution platform

Galileo cluster at CINECA, 516 IBM nodes, each one being a 16-core unit made of two Intel Xeon Haswell E5-2630 v3 octa-core processors clocked at 2.40GHz

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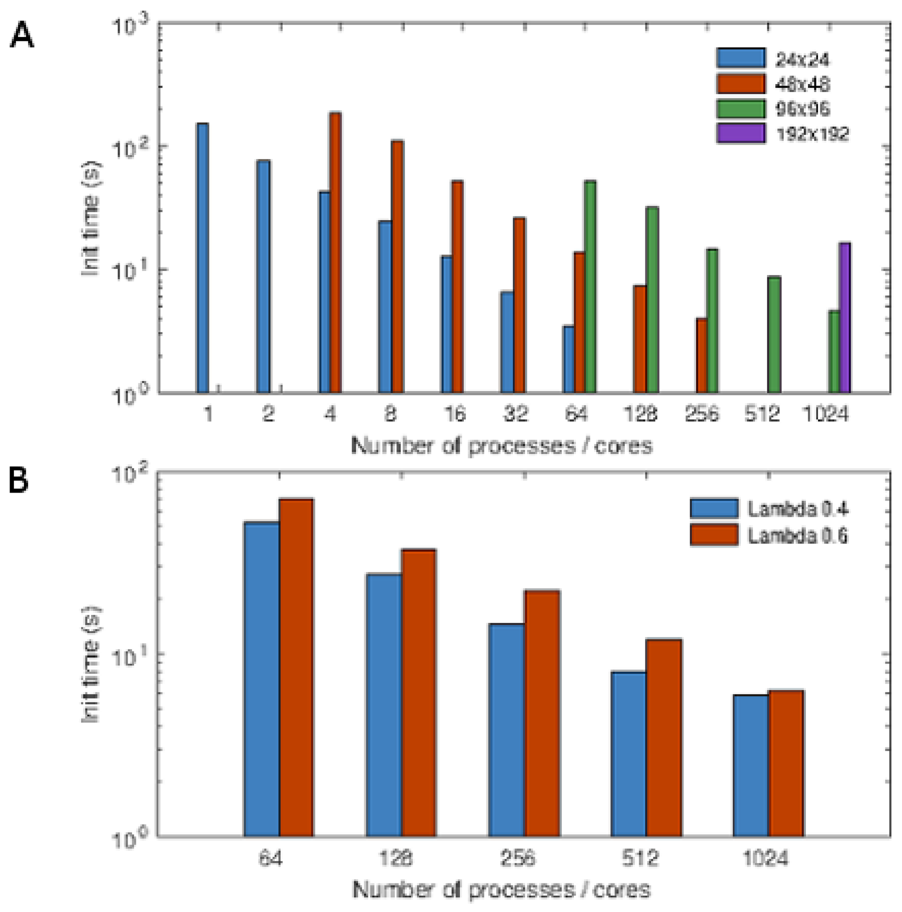
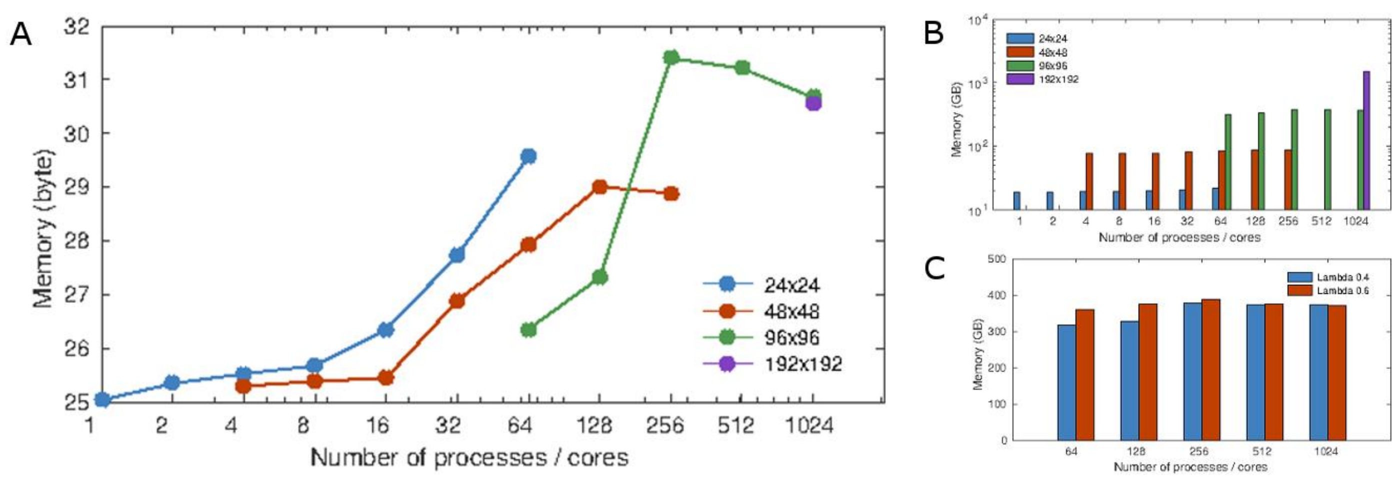
DPSNN initialization time



Scaling of simulation initialization time. The initialization time, in seconds, is the time required to complete the building of the whole neural network. Panel A: initialization time scaling with the number of processes, for four different network sizes (λ fixed at 0.4). Panel B: scaling of the initialization time for a grid of 96x96 columns with two different λ values: 0.4 (blue) and 0.6 (orange)

DPSNN memory usage



~ 24B/synapse

Less then 32B/syn, even including MPI overhead

Memory usage. Panel A: memory footprint per synapse for four networks sizes, distributed over MPI processes. Used memory spread from a minimum forecasted cost of 24 up to 32 Byte/synapse, including MPI overhead. Panel B: maximum memory occupation (in GB) scaling with the number of processes, for four different network sizes (λ fixed at 0.4). Panel C: memory scaling for a grid of 96x96 columns with two different λ values: 0.4 (blue) and 0.6 (orange). The total number of generated synapses is nearly the same and the memory footprint remains substantially constant.

DPSNN and NEST cooperation framework

Porting to NEST

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

Specialized vs. general purpose engines

Specialized engines, like DPSNN, can be faster than user-friendly ones, like NEST. They play a role during exploration and for the acceleration of specific experiments. The price to pay is a limited configurability and heavy programming for the user.

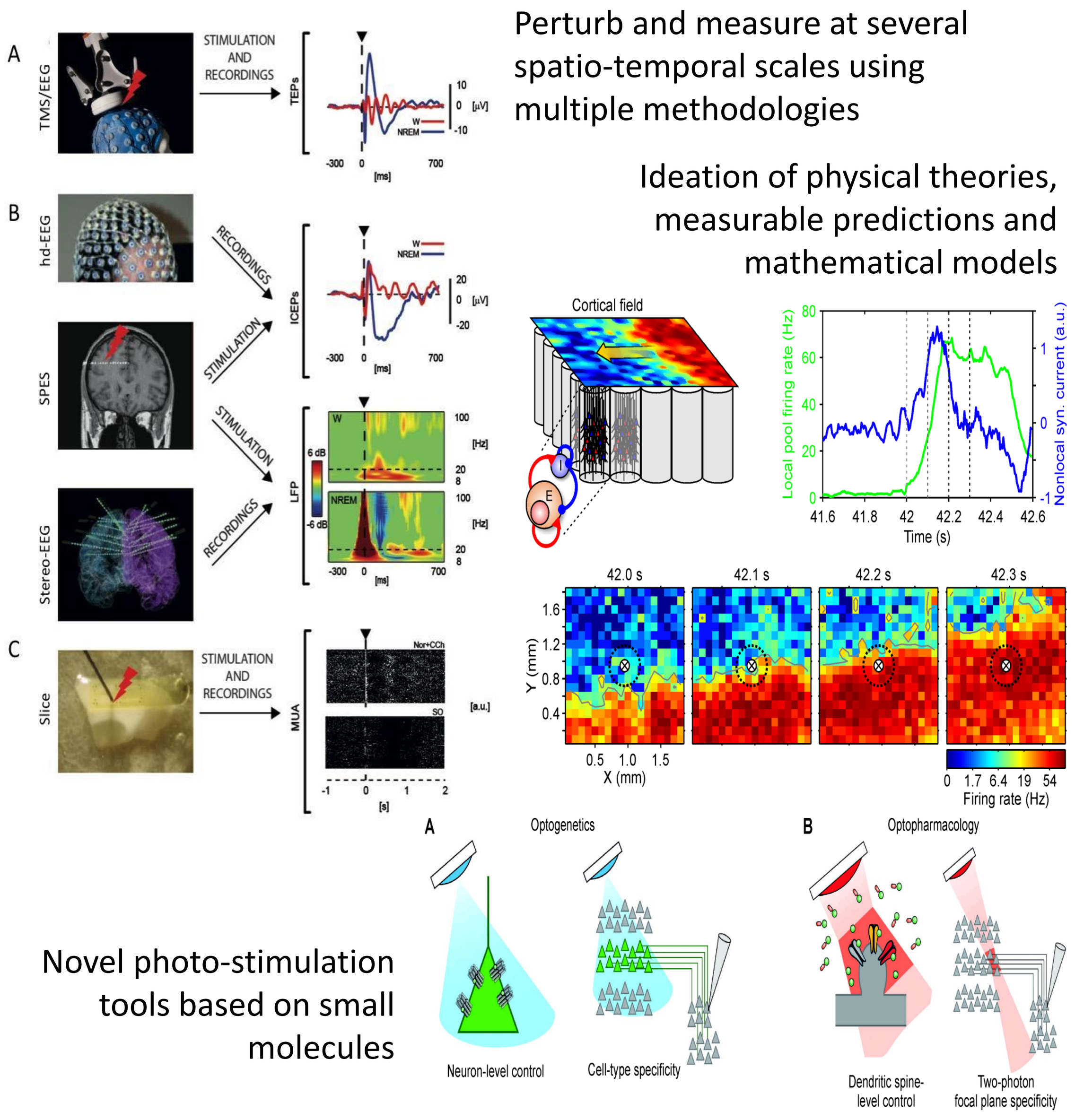
Performance comparison summary (DPSNN versus NEST)	
Initialization	30 time faster
SW state simulation	3.8 time faster
AW state simulation	2.5 time faster
Mem usage	2 times less demanding

Comparison performed on a specific configuration, 2.8M neurons and 4.4G synapses organized in a 48 by 48 grid of cortical columns, expressing SW and AW states, simulated using 4 nodes for a total of 96 hyper-threaded cores.

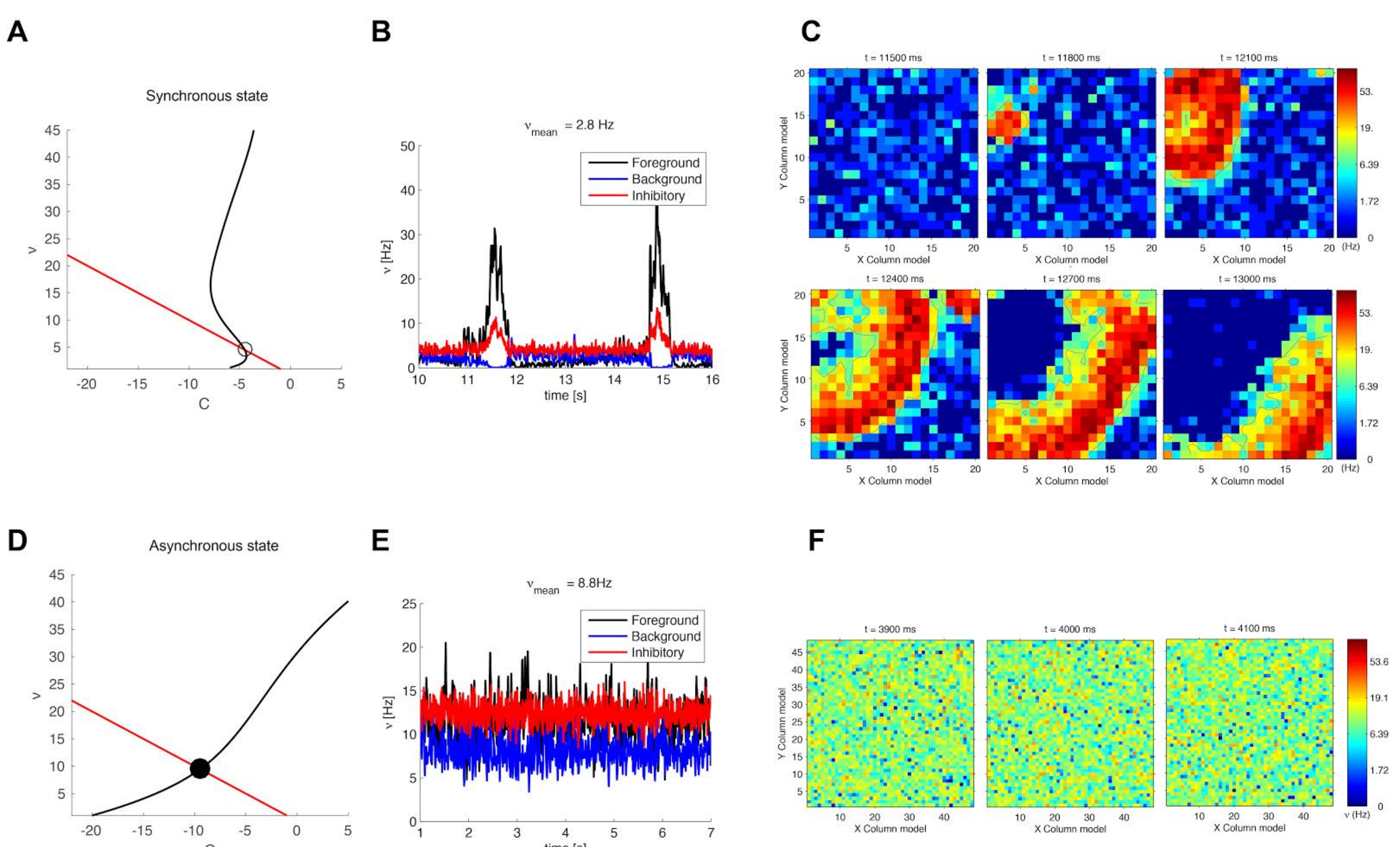
DPSNN simulation engine use-case: the WaveScalES experiment in HBP

The WaveScalES experiment

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



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



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).

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

$$\begin{cases} \dfrac{dv_i}{dt} = \dfrac{\phi_i(\vec{v}, \vec{c}) - v_i}{\tau} \\ \dfrac{dc_i}{dt} = -\dfrac{c_i}{\tau_c} + g_i v_i \end{cases}$$

WaveScalES teams and key-persons

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