Using structural plasticity to study the relationship between structure and function in the brain

Sandra Diaz-Pier[1], Christian Nowke[2], Juan P. Brito[3], Thanos Manos[4], Benjamin Weyers[2], Alexander Peyser[1]

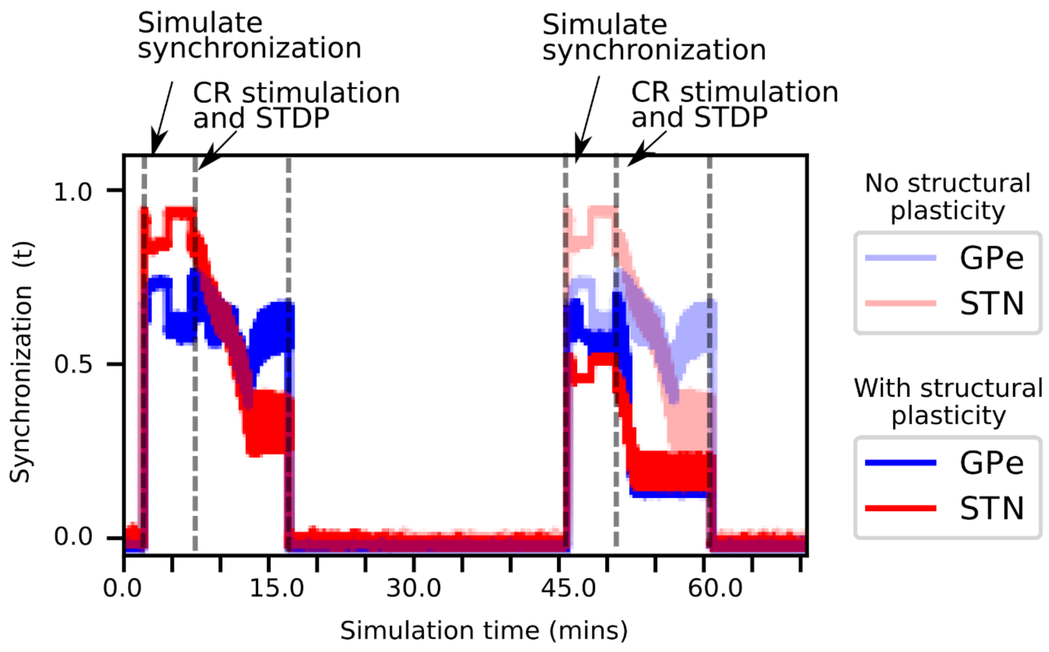
1. Simulation Laboratory Neuroscience -- Bernstein Facility for Simulation and Database Technology. Institute for Advanced Simulation, Jülich Forschungszentrum, Jülich, Germany
2. Visual Computing Institute, RWTH Aachen University, Aachen, Germany
3. Center for Computational Simulation, Universidad Politécnica de Madrid, Spain
4. Institute of Neuroscience and Medicine, Brain and Behaviour (INM-7), Jülich Forschungszentrum, Jülich, Germany

Motivation: We want to better understand the impact that changes in connectivity have on brain function at different scales.

Our approach: Use structural plasticity in nest::

Neurobiological modelling of **structural plasticity**

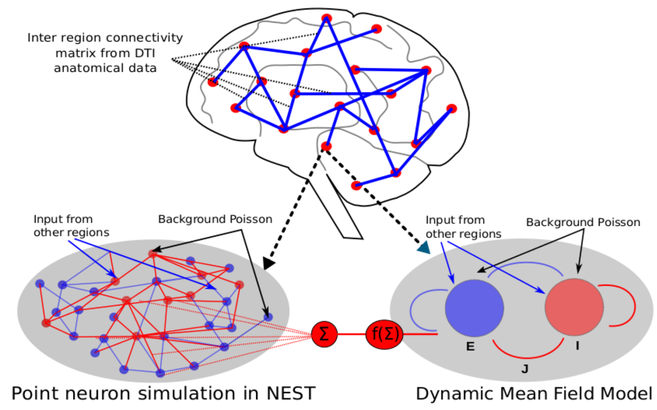
Understanding the long lasting effects of Coordinated Reset therapy



- Do structural changes influence the effectiveness of the Coordinated Reset (CR) therapy?
- Simulations of the subthalamic nucleus (STN) and the globus pallidus externus (GPe) in NEST with STDP and structural plasticity
- Synaptic and/or structural plasticity in this model takes place only in the STN group
- Simulation results match behaviour seen in experiments. Iterative CR brings better and faster desynchronization

Structural plasticity as an optimization algorithm

Fitting connectivity in large scale simulations



$$L = \alpha \sum_{i=1}^{N} (\Delta_{+i} - 1)\,\Delta_{-i} + \sum_{i=1}^{N} (\Delta_{-i} - 1)\,\Delta_{+i}\,\phi\left(\frac{1}{n(u(t))}\sum_{j=1}^{N}\omega_{ij}(u(t))\,x_j\right)$$

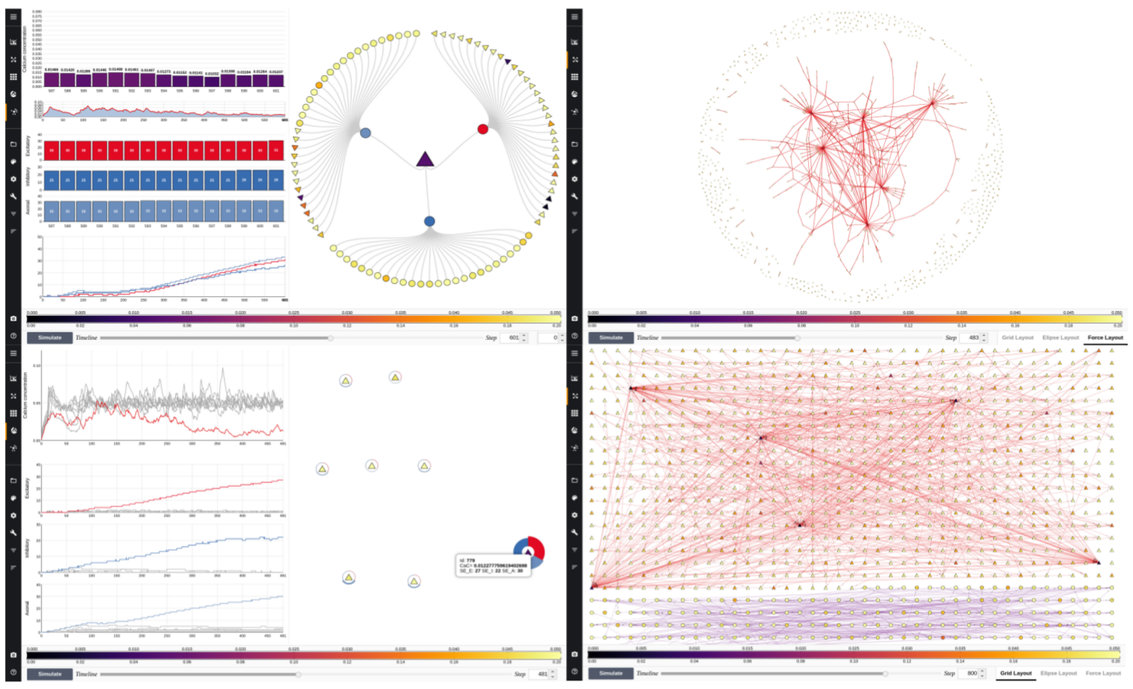
$$I_i^{(\mathrm{E})} = W_E I_0 + w_+ J_{NMDA} S_i^{(E)} + G J_{NMDA} \sum C_{ij} S_j^{(E)} - J_i S_i^{(I)} + I_{external}$$

- Connectivity fitting setup based on [Deco et. al. J. Neurosci. 2014]. Brain regions modeled as small 2 population point neuron networks in NEST and a Dynamic Mean Field (DMF) model
- Structural plasticity is used to calculate missing inner inhibition by matching experimentally measured firing rates
- Feed this information to the DMF model for long time calculations

Steering, exploring and analysing **structural plasticity**

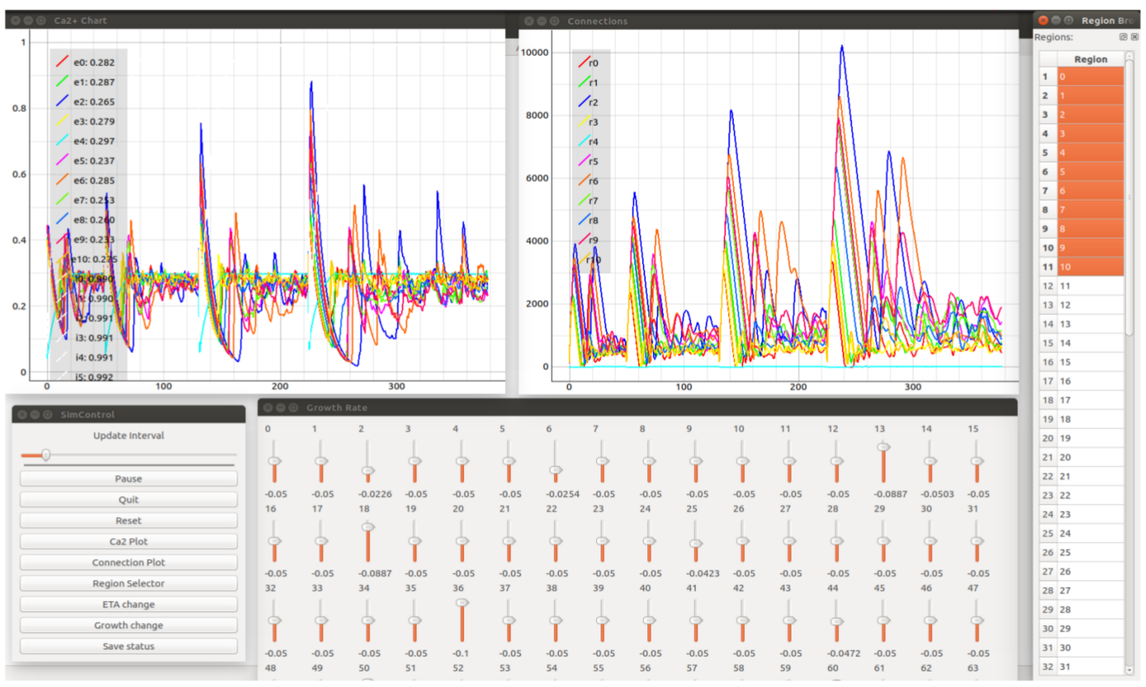
Offline analysis with MSPViz

- Offline visual analysis and exploration of the complex connectivity data generated by structural plasticity
- Different views allow structured information visualization
- Navigation through the network's dynamic structure at different scales
- Step by step detailed analysis of firing rates and connectivity



Interactive steering and visualization with nett

- Visualization and steering of structural plasticity during simulation
- Enable exploration of network trajectories and state space
- Modular design which allows steering and visualization of other variables in the network aswell
- Can be used interactively on supercomputers for large networks



Acknowledgments

Funded by the European Union's Horizon 2020 Programme under grant no. 720270 (HBP SGA1), the Spanish Ministry of Economy and Competitiveness under grants C080020-09 and TIN2014-57481, JARA - HPC, the Helmholtz Association through the Portfolio Theme SMHB and the CRCNS grant.