Small brain models distort contact intensity between neurons

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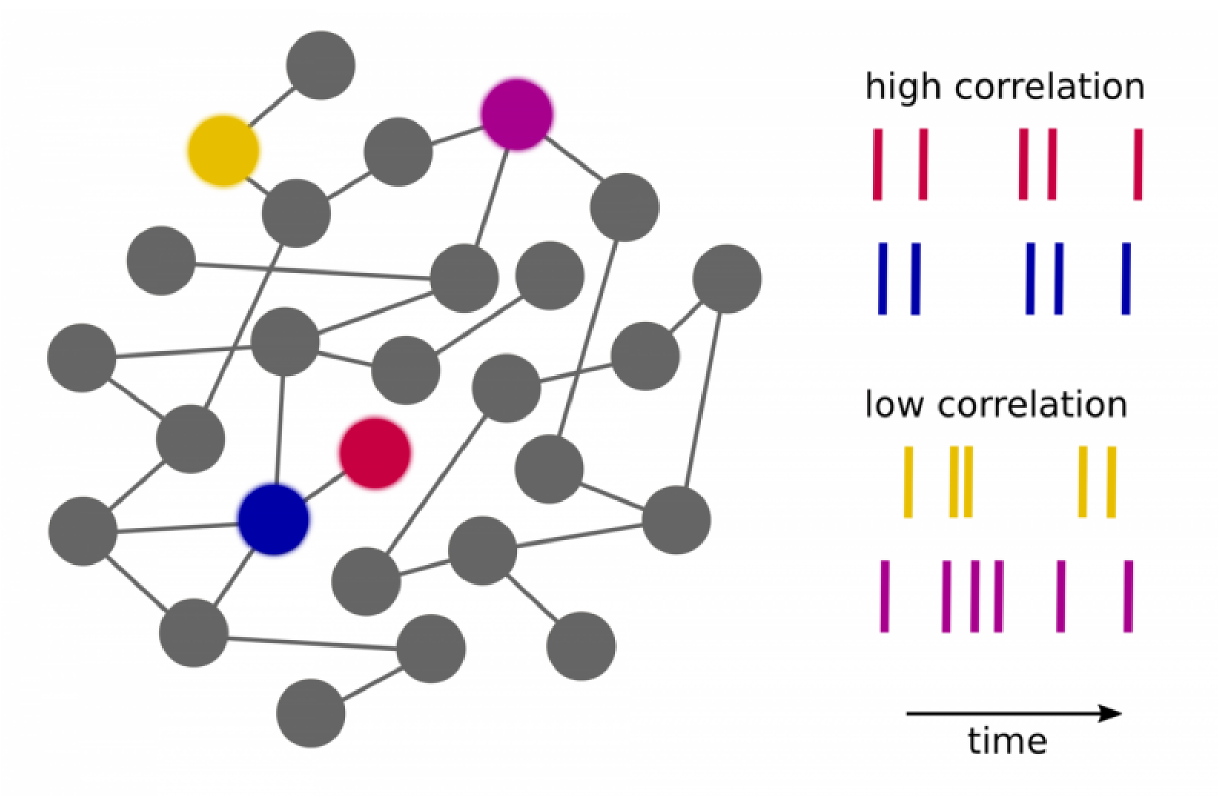

Neurons with synchronous activity have a high correlation while neurons with uncoordinated activity are weakly correlated. Credit: Forschungszentrum Jülich

The goal of brain simulations using supercomputers is to understand the processes in our brain. This is a mammoth task: the activity of an estimated 100 billion nerve cells - also known as neurons - must be represented . It is also a task that has historically been impossible because even the most powerful computers in the world can only simulate one percent of the nerve cells due to memory constraints. For this reason, scientists have turned to downscaled models. However, this downscaling is problematic, as shown by a recent Juelich study published in *PLOS Computational Biology*.

"The challenge of brain simulation is that the nerve cells enter into a temporary relationship with other neurons depending on the task at hand," says Prof. Dr. Markus Diesmann, director of Juelich's institute Computational and Systems Neuroscience (INM-6). Every nerve cell is linked to an average of 10,000 other neurons, which synchronize their activity with each other to varying degrees. The intensity of the relationship between neurons - referred to as correlation - varies depending on the task and the brain areas involved. Using mathematical methods, Dr. Sacha van Albada, research scientist in Markus Diesmann's lab, Dr. Moritz Helias, head of the group Theory of Multi-Scale Neuronal Networks, and Diesmann demonstrated that this correlation cannot be correctly preserved when the number of neuronal connections in a brain model is below a certain level. However, correlations form the basis of frequently used, measurable signals in the brain such as the EEG and the local field potential (LFP).

Each neuron has around 10,000 connections

The information flow in the human brain is extremely complex. Nerve cells exchange information with each other in the form of electrical signals via so-called synapses. Each nerve cell has around 10,000 such connections through which it communicates with other neurons. Just as the motorway network does not determine which car should drive where, data in the brain choose different routes and exits depending on the task. Today's computers cannot process or store such gigantic quantities of information. The number of synapses is therefore reduced in many brain models, which in turn diminishes memory usage.

The Human Brain Project (HBP) aims at detailed simulations of the human brain

Despite these difficulties, the detailed simulation of the entire human brain on a future supercomputer remains the aim of a large-scale scientific project. In the EU-funded Human Brain Project (HBP), neuroscientists and physicists like Markus Diesmann are working together with computer scientists, medical scientists, and mathematicians from over 80 European and international scientific institutions. "Our current research work is a further indication that there is no way around simulating brain circuits in their natural size if we want to gain solid knowledge," says Diesmann.

One of the biggest challenges of the Human Brain Project is the development of new supercomputers. Scientists from Juelich also have a leading role here: the Juelich Supercomputing Centre (JSC) is developing exascale computers to perform the complex simulations in the Human Brain Project. This requires a 100-fold increase in the computing power of today's supercomputers. Next to the mathematical modeling as in the recent study Markus Diesmann and his team therefore work in parallel on the creation of simulation software for the new generation of computers. This work is being performed at the institute Theoretical Neuroscience (IAS-6) and as part of the Neural Simulation Technology Initiative, which provides free access to the software NEST.

More information: Scalability of Asynchronous Networks Is Limited by One-to-One Mapping between Effective Connectivity and Correlations, van Albada SJ, Helias M, Diesmann M. *PLoS Comput Biol*. 2015 Sep 1;11(9):e1004490. DOI: 10.1371/journal.pcbi.1004490