The way computers work today is still far from reaching the brain's efficiency. © Dan Brandenburg

Nano-oscillators mimic human memory

A new kind of computer memory that works by storing and recognising patterns is being developed by a multidisciplinary team of scientists from five countries. Partners in the DYNAMO project will use recent mathematical insights to create a network of nano-scale electrochemical cells that imitate the behaviour of neurons in the brain. If successful, the project could bring us closer to building a 'neurocomputer' that functions more like the human brain than the digital computers of today do.

We often think of a computer as being analogous to a human brain, but the more we learn about the brain the less apt the comparison becomes. Computers can play chess as well as a grand master, but while the human player decides on a move through experience and intuition, the computer uses brute force, evaluating the consequences of all possible moves. In part, this is because of the different ways in which computers and human beings organise their memories.

Most computers use 'random access' memory where each piece of information is stored at a particular location. To retrieve the information the computer looks up its address. In contrast, the brain uses 'associative' memory where a stimulus, such as the arrangement of pieces on a chessboard, will retrieve records of similar patterns that have been seen before. Associative memory allows us not only to recognise at a glance the face of a friend but also to recall immediately the last time we saw him or her and a huge amount of information we know about the person.

Natural oscillations

Until now it has been difficult to design a practical computer memory that would work in this associative way. But in the past few years new advances in the mathematical theory of networks have given clues as to how this might be done. Scientists have known for a long time that neurons – the cells that make up the brain – have a natural rhythm that appears as an electrical oscillation. It now appears that a network of linked neurons oscillating at different frequencies can act as an associative memory. The interesting thing is that the memory arises from the mathematics of the interactions and is independent of the biological nature of the cells – it should work for any similar network of oscillators through the coupling of all of them, the so-called global coupling. The group at Munich, led by Prof. Krischer, has already demonstrated that the general principles of global coupling do apply to electrochemical systems.

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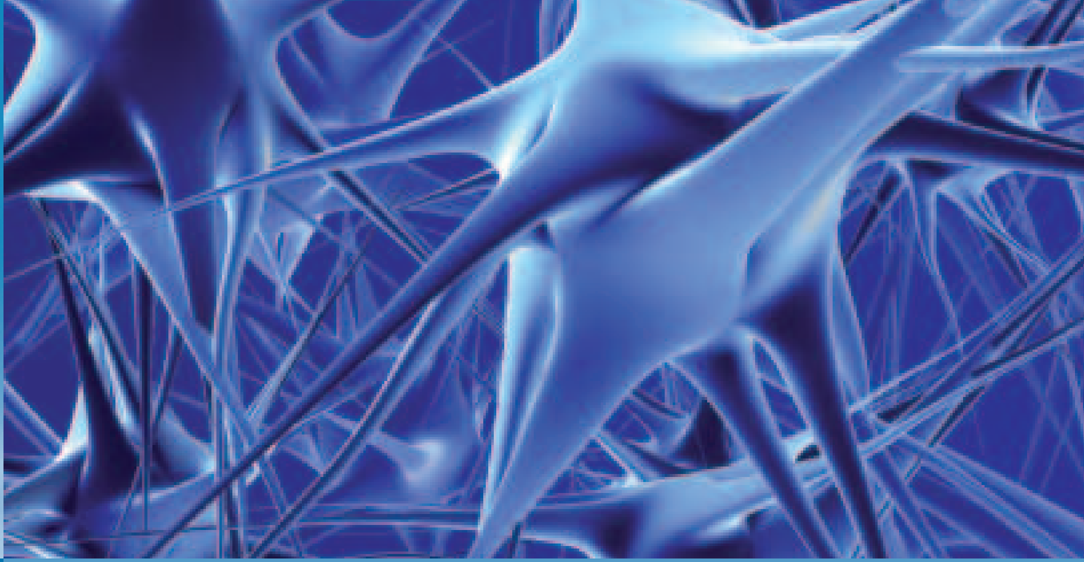

DYNAMO

NEST ADVENTURE

Can we build a computer to act like a network of nerve cells?

AT A GLANCE

Official title
Design and functionality of non-linear electrochemical nanoscale devices

Coordinator
Finland: Helsinki University of Technology

Partners
- *United Kingdom: University of Liverpool*
- *Germany: Technical University of Munich*
- *Sweden: University of Göteborg*
- *Spain: University of Valencia*
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The objective of DYNAMO, coordinated by Professor Kyösti Kontturi at Helsinki University of Technology, is to use these insights to build a new kind of computer memory. Rather than using neurons, the Dynamo partners will construct their memory from tiny electrochemical cells.

Rather than using neurons, the DYNAMO partners will construct their memory from tiny oscillators.

Some well-known chemical and electrochemical reactions, instead of showing a smooth transition from reactants to products, display oscillatory properties. The DYNAMO partners consider that these can be made to mimic the rhythmic pulsing of a neuron. One of the first challenges of DYNAMO, indeed a very big challenge, will be to replicate oscillatory reactions using tiny electrodes only a few nanometres in diameter. Some of these are well-known but new reactions based on non-linear properties of electron transfer reactions will be investigated both experimentally and theoretically. This work is being done in the Universities of Munich, Gothenburg, and Liverpool.

Towards a neurocomputer

At the same time, the University of Valencia will then work with the Helsinki group to tackle the important problem of developing a theoretical framework for describing the statistical behaviour of such tiny oscillators.

Meanwhile, the Institute of Molecular Biology of Barcelona will construct molecular 'scaffolds' made from DNA molecules to support and link the arrays of oscillators.

The final phase of the project will be a joint effort by all the partners, bringing all this work together, to build and test an associative memory assembled from a network of up to several hundred nano-oscillators. Information will be stored in the complex patterns of oscillation by applying a suitable electrical signal to the network, and retrieved by presenting a similar signal at a later time. As part of the NEST Adventure portfolio, the DYNAMO project cannot be guaranteed to deliver the advances it is seeking. But if it does, and if the arrays of little oscillators do behave as theory predicts, then this work will bring closer the practical realisation of a neurocomputer that works much more like the human brain than conventional computers. As no single European country possesses the necessary expertise in this area it will also create a strong collaborative base for future research.

SIXTH FRAMEWORK PROGRAMME