INTERVIEW

THE INFN-LED WAVESCALES CONSORTIUM WILL PARTICIPATE IN THE HUMAN BRAIN PROJECT

Interview with Pier Stanislao Paolucci, researcher at the INFN and head of the WAVESCALES project

The INFN will participate in the European Commission's international Human Brain Project (HBP). It will lead the WAVESCALES (WAVE SCALing Experiments and Simulations) Consortium, one of the 4 winning projects selected from among the 57 proposals submitted in response to the Call for Expressions of Interest (CEoI) launched by the HBP. The WAVESCALES Consortium will be coordinated by Pier Stanislao Paolucci, a researcher at the INFN. We asked him what this achievement means and to tell us about the winning project.

What is the Human Brain Project (HBP)?

The Human Brain Project is an international research effort funded by the European Union with a budget of about € 500 million between 2013 and 2023. It is one of the two Future and Emerging Technology (FET) Flagship projects that will run for the next ten years. The other FET Flagship project is Graphene. The project's ultimate goal is to improve our understanding of the human brain, and to build and simulate the first model of its cognitive capabilities. The HBP is running in synergy - but also scientifically competing - with other research collaborations, such as the Allen Institute for Brain Science and the BRAIN Initiatives of the National Institutes of Health (NIH), both in the US. The specific mission of the HBP is to construct an "information technology infrastructure", integrating data obtained from experiments in the fields of neuroscience and medicine with instruments that simulate the human brain, and the brains of mice.

Can you tell us what the WAVESCALES project, which won the international call launched by the HBP, consists of?

The WAVESCALES Consortium, led by the INFN, is a team of five research institutes. Three of the partners are specialised in experiments on the human brain and the brains of rodents, the other two will

INTERVIEW

concentrate on developing theoretical models and computer simulations. The INFN's Array Processor Experiment laboratory (APE lab) will develop the neural network simulator, which will mimic the behaviour generated by several tens of billions of nerve cell connections, or synapses. The partners in the experiment will measure the slow cerebral waves propagated in the cortex during deep sleep and the waking state, and observe the cortical response to localised spatio-temporal perturbations. The experimental techniques used will include non-invasive observations in humans, such as high resolution electroencephalographic response to transcranial magnetic stimulation, performed by the team led by Marcello Massimini at the University of Milan. And electrophysiological measurements on rodents in response to opto-pharmacological stimulations, conducted by teams led by Maria Victòria Sánchez-Vives, from the *Institut D'Investigacions Biomèdiques August Pi i Sunyer* (IDIBAPS) in Barcelona, and by Pau Gorostiza, from the *Institut de BioEnginyeria de Catalunya* (IBEC), also in Barcelona. The theoretical models will be developed by the Italian Institute of Health (ISS - *Istituto Superiore di Sanità*), under the direction of Maurizio Mattia and Paolo Del Giudice.

The project makes reference to neural networks: can you explain what these are?

The human brain is an extremely complex system. We believe it has about 90 billion neurons and several hundred thousand billion (that's a number with 14 noughts) synapses and neural connections. Using an extremely simplified model, we can say that the neurons perform computations using the information transmitted by the synapses, on the basis of which they decide whether to switch from around a resting state - like the zero in a binary system - to a spiking state - like the unit in the binary system - which lasts about one millisecond. Typically, each neuron produces a few tens of potentials, or spikes, per second. The incredible thing is that if a single neuron performs a different computation, the brain can significantly change its global state and objectives, within less than a second. Therefore, to understand the principles underlying the brain's computational activities, we need to simulate the activity of a relatively extensive network of neurons.

What is the INFN's contribution in terms of skills and technology in a field like neuroscience, which is apparently so different?

A single computer could not perform simulations of large scale neural networks. We need computers that work in parallel, that process data simultaneously and in a coordinated way, and a series of dedicated parallel algorithms. Here at the INFN we have long-established traditions that will offer a key contribution to research into the human brain. One strategic asset is the APE lab, set up by Nicola Cabibbo and Giorgio Parisi, central figures in the fields of numerical simulation and complex systems.

INTERVIEW

Since 1984, the APE lab has been one of the key centres for research on parallel computing. Over the years the INFN has developed several generations of computers and algorithms that work in parallel, as well as dedicated interconnection systems. The activities of the APE lab originally focused on simulations in subnuclear physics, especially Quantum-Chromo Dynamics (QCD). Over the years we have developed specific expertise that we have also applied to various other fields where high data processing efficiency is required, such as simulations of neural networks. We should also remember that one of the pioneers in theoretical and computational neuroscience was Daniel Amit, who worked at the INFN and founded a school in Rome of scientists with expertise in this field.

Why is studying the brain so important?

In Europe the cost of brain disorders and traumatic brain injury was estimated at € 798 billion in 2010. Given the ageing population, this cost is likely to increase unless we make real progress in gaining a better understanding of the brain. Moreover, understanding how the human brain works has always been regarded as a major intellectual challenge. Now, especially by harnessing information technology to new experimental techniques, Brain Research is emerging as a new quantitative science, with a potentially huge impact.

Where will the INFN's participation in the HBP lead to in the future?

The WAVESCALES project will study the brain's overall response to localized perturbations in its simplest state, deep sleep, and during waking. If we manage to develop a theory that faithfully mimics these responses by simulating a large-scale neural network, that will mean we have discovered some fundamental elements in the overall architecture of the brain. But the human brain contains far more computational elements than our simulations will ever be able to mimic in the coming years. Research involving simulations of the brain using parallel processors and dedicated calculation systems will therefore be fundamental for many decades.
We will also need to develop experimental methods with increasing numbers of acquisition channels and higher temporal and spatial resolutions. The INFN will definitely be able to contribute and also play a central role in the experimental field, drawing on decades of experience in the construction of some of the most complex experimental equipment in the world. This equipment provides much higher temporal and spatial resolutions than the apparatus currently used in the field of neuroscience. ■