Understanding the Dynamics of Neural Processes – Brain Research at the New Bernstein Centre in Freiburg

The Federal Ministry of Education and Research (BMBF) funds the "Bernstein Centres for Computational Neuroscience" in Freiburg, Berlin, Göttingen and Munich, which are all named after the German physiologist Julius Bernstein (1839-1917). The "Centre for Neural Dynamics Freiburg" (CNDF) is a part of this interdisciplinary network for the exploration of the neural basis of brain activity.

Prof. Ad Aertsen

In Germany, brain research has become a strongly funded research area. In the human brain around ten billion nerve cells absorb and process information about the surrounding environment. Without these neural processes, there would be no perception, no movement nor capacity for memory or learning. The new Bernstein Centre in Freiburg has placed "computational neuroscience" at the centre of its research and teaching. "We are trying to understand how the brain processes information, makes decisions and implements these into behaviour," the coordinator Professor Ad Aertsen says describing the most important research goal at the new centre.

Models of brain function

More than ever before, scientists are applying mathematical, physical and IT methods to their research in this area. While these have, thus far, mainly been applied to the analysis of measured data, at the centre they also serve as a basis for the construction of mathematical models of brain function. "With the computer, we model the neural processes of the brain," says Aertsen. The goal is to reach a better understanding of the brain's capacities. "By that we ultimately want to be able to say: This is how it works".

Once the mechanism is understood, the neurobiologists aim to go one step further by applying the modelled strategies to biomedicine and technology. Significantly, the entire weight of the 15 subprojects rests on basic research. Unlike previous research methods, Aertsen and his team interpret brain activity especially as a dynamic process. "The flow of stimuli does not produce static pictures like those in a photo album, but rather a film," says Dr. Stefan Rotter of the Bernstein Centre. "The brain has to cope with this continual flow of data. At the same time, the brain must continually control behaviour in a constantly changing environment".

Early detection of epileptic seizures

The colour in the coordinate plane provides information regarding the reaction of a nerve cell to inhibition or stimulation.

With a better understanding of dynamic brain activity and its modelling, the scientists hope to gain knowledge about processes that exhibit an abnormal dynamic. Through the recording of an electroencephalogram (EEG), "smart machines," fitted with new algorithms, could detect whether an epileptic seizure is developing. They might then be able to prevent the seizure with targeted electrical stimulation. The researchers are also interested in the transition from normal to abnormal activity. "We are investigating the mechanisms that are active in this very early phase," says Dr. Ulrich Egert of the Bernstein team.

With a broader understanding of the human locomotor system, neurobiologists are developing the theoretical basis for new humanlike robots. While these artificial beings have thus far been noted for their rather inflexible movements, they could gain a considerable degree of flexibility and robustness when controlled with adequate neural networks. "Until now, only engineering technology was responsible for the robots," says Aertsen. "We believe that it is possible to operate artificial beings with processes based on biology". In Japan, the application of such robots in households or care is already under consideration. "But at the moment, these applications are still science fiction,"

said Aertsen fending off overhasty expectations.

Brain activity operates prosthetic limbs

Based on their research findings concerning the direct interaction of brain and machine, neurobiologists are developing new approaches, such as how a human can control the cursor on a screen via brain waves. The long-term objective is the development of motor neuroprostheses. In addition, they are constructing an artificial cell culture network from nerve cells in the laboratory. "We can directly observe how cells establish contact with each other, and how they change their connections in the course of a dynamic process. In other words, how the network learns".

The BMBF will fund the work of the Freiburg brain researchers in the coming five years with eight million euros. A large part of the money will support the creation of new positions for Ph.D. candidates and young scientists as well as one professorship, which will then be taken over by the university. They will be accompanied by specially developed study and advanced training programmes. As non-university partners, the Honda Research Institute Europe GmbH in Offenbach and Multi Channel Systems GmbH in Reutlingen are also cooperating with the Freiburg Bernstein Centre.

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