From electronic brains to the power of the mind...

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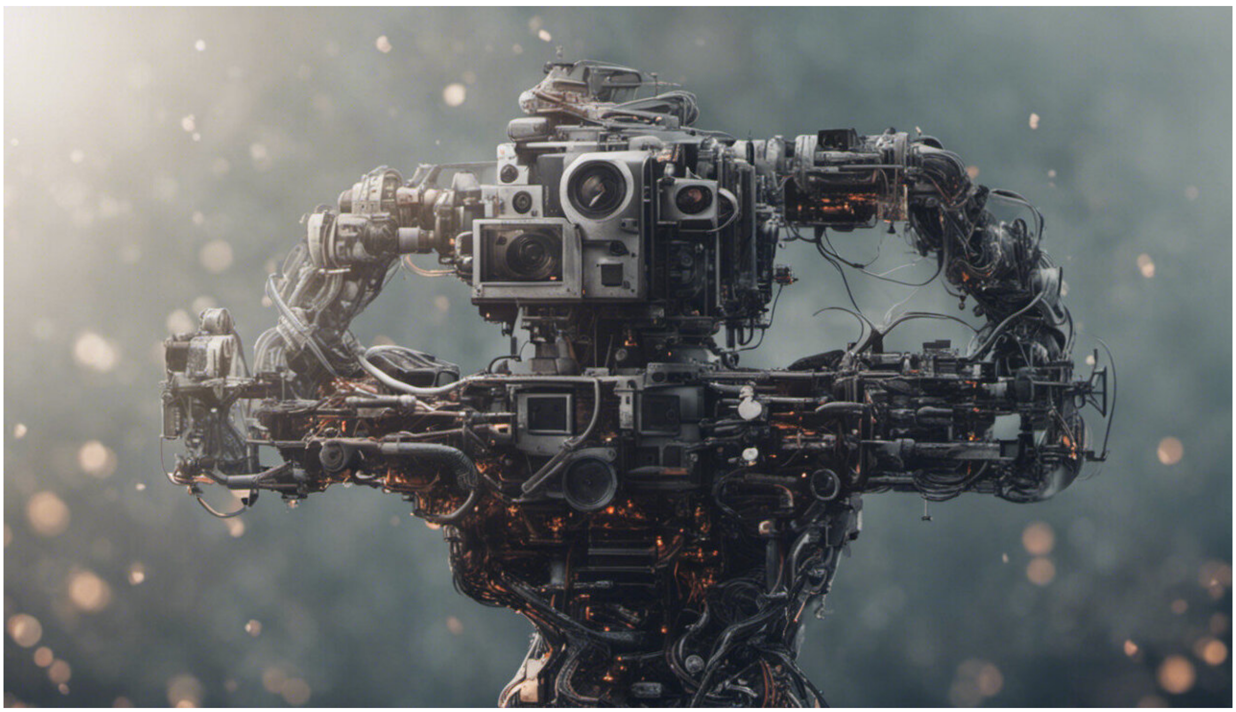

Credit: AI-generated image (disclaimer)

The EU budget has provided more than EUR 1.9 billion for brain research since the start of the current EU framework programme for research, FP7, in 2007. This has funded more than 1200 projects with more than 1500 participants from the EU and beyond. Looking back on the "European Month of the Brain" in May, we take a retrospective look at the range of brain-related research projects the EU is funding in the field of "Information and communications technologies" (ICT).

Information technologies have long had an association with the human brain: the old simple explanation of a computer was that "it"s like a sort of electronic brain". But computers have rapidly become so ubiquitous that nowadays the beginner"s explanation of the brain is often that "it"s like a kind of biological computer".

Commenting on this year"s announcement of EUR 150 million of funding for brain-related ICT research projects, Neelie Kroes, Vice President of the European Commission responsible for the Digital Agenda for Europe, said, "Despite great progress over recent decades, there is much more still to be discovered: from computers that think like our brains do - like computer networks that replicate brain structure to better cope with "big data" - to detecting and curing the brain disorders that affect up to one third of Europeans each year, from Alzheimer"s and autism to schizophrenia."

Brain box

Understanding the human brain is therefore one of the greatest challenges facing 21st century science. Ambitious new projects in the EU, the Future and Emerging Technology scheme (FET) Flagship "Human Brain Project" (HBP), and in the US, the BRAIN project, are now starting to try to meet this challenge, with the hope of gaining profound insights into what makes us human, developing new treatments for brain diseases and building revolutionary new computing technologies.

The HBP"s first goal is to build an integrated system of ICT-based research platforms, providing neuroscientists, medical researchers and technology developers with access to the innovative tools and services that could radically accelerate the pace of their research. The project will receive around EUR 1 billion in funding over 10 years, and will work closely with President Obama''s new initiative on ''Brain Activity Mapping'' (BAM), worth $100 million in its first year alone.

The HBP''s second goal is therefore to trigger and drive a global, collaborative effort that uses these platforms to address fundamental issues in neuroscience, medicine and computing. The end result should be not only a new understanding of the brain but also transformational new ICT. For example, the brain manages billions of processing units connected via kilometres of fibres and trillions of synapses, while consuming no more power than a light bulb. Understanding this could transform our computer power and help build a new ICT infrastructure.

Brain boxes: humans helping computers

We all know that modern life presents us with a dizzying range of information, from supermarkets to online advertising, and often demands quick decision-making in busy streets or shops. Perhaps surprisingly, these challenges have similarities in a range of sciences, such as astronomy, neuroscience, archaeology, history and economics.

In these areas, experts need to make sense of and find meaning in very large and complex data sets. The CEEDS project is working on new tools for ''human-computer interaction'' (HCI) that aim to help both everyday decision-making and scientific information analysis. The team''s approach uses new ''synthetic reality'' (SR) systems to help people browse large data sets consciously, while also exploiting the power and potential of the unconscious mind.

We are only aware of a small subset of the information we receive from our senses, but our brains still process the rest - and are very good at subconsciously detecting patterns. CEEDS therefore plans to look for signs of discovery or surprise in these subconscious processes, using wearable technologies that measure people''s reactions to visualisations of large data sets in SR environments. The system will then direct users to areas of potential interest in the visualisations and guide their discovery of patterns and meaning in the data sets.

By unlocking the power of the subconscious, CEEDS will help users find patterns or signals hidden in large quantities of data. This new "confluent technology" - where the computer and the user are integrated parts of a system - could even enable multiple users to link together and create a collective discovery system.

CEEDS is helping computers and humans to work together, but the BRAINSCALES project is helping computers "think" more like humans. Our brains work at different scales simultaneously: from individual neurons to large areas devoted to functions like sight or smell, and from milliseconds (physical reactions) to hours or days (learning). The project team is using simulations on ultra-fast supercomputers to build "an artificial synthesis of cortical-like cognitive skills", and is developing a "non-von Neumann hardware architecture".

Traditional computers are based on the "von Neumann" architecture familiar to us from dealing with our PCs, using separated memory/storage and processing units. But by using structures that mimic the multi-scale functioning of the human brain, the team have designed a non-von Neumann computing device. As well as having applications outside the realm of brain-science, this work by the BRAINSCALES project helped in the preparation of the FET Human Brain Project.

Similarly, the REALNET project aims to develop the first realistic real-time model of the "cerebellum" - a part of the brain with an important role in motor control and involved in cognitive functions such as attention and language. The team is developing specific chips and imaging techniques to take neurophysiological recordings from neurons in the cerebellum.

The end result will be a realistic neuronal network based on anatomical and physiological data, connected to both simulated and real robots to evaluate its functioning. REALNET aims to provide a radically new view on the computation carried out in central brain circuits - laying the basis for new technological applications in sensing, motor control and cognitive systems.

Mind control: computers helping humans

As well as learning how the brain works - and copying it - ICT brain research is working towards making into reality a dream as old as fairy tales and daydreams: control of the physical world by the mind alone - moving objects just by thinking.

One of the biggest contributions brain research could make is to help the wheelchair-bound victims of car accidents or people suffering full-body paralysis or locked-in syndrome. Millions of Europeans have some form of motor disability that restricts their ability to move, interact or communicate with others.

The BRAINABLE project is a three-year initiative supported by EUR 2.3 million in funding to develop and integrate advanced "brain-computer interface" (BCI) systems, "ambient intelligence" (AmI), "virtual reality" (VR) and other technologies that, when used in combination, promise unprecedented autonomy for those with such disabilities.

"Our aim is to give people with motor disabilities as much autonomy as technology currently allows and in turn greatly improve their quality of life," says Felip Miralles at Barcelona Digital Technology Centre, a

Spanish ICT research centre, who is coordinating the project.

By combining BCI and other assistive technologies, the researchers have enabled users to remotely control a robot and manoeuvre it around the house, and improved such patients'' ability to communicate with people. The BRAINABLE researchers are overcoming the slow reaction speeds of previous systems by embedding intelligence into their platform, so that the system understands the user''s context and habits and can act proactively. The platform even enables simplified access to social networking platforms such as Twitter and Facebook, which are becoming increasingly important tools in helping disabled people overcome social isolation.

In another, dramatic application of BCI technology, the EU-funded MINDWALKER project could help the thousands of people in Europe paralysed by a spinal-cord injury. The project''s mind-controlled robotic exoskeleton should help such patients walk again - and could also assist in the rehabilitation of stroke victims or astronauts who need to rebuild their muscles after long periods in space.

Most BCI systems are either invasive, with electrodes placed directly into brain tissue, or require users to wear a "wet" cap on their head, using special gels to reduce electrical resistance. MINDWALKER uses a "dry" technology with electronics to amplify and optimise the brain''s signals.

"The dry EEG cap can be placed by the subject on their head by themselves in less than a minute, just like a swimming cap," explains Michel Ilzkovitz, the project coordinator at Space Applications Services in Belgium.

In addition, the project team have developed a new walking strategy which differs from most previous exoskeletons, which are designed to be balanced when stationary and to move slowly by very small steps.

MINDWALKER uses a controlled loss of balance in the walking direction which replicates the way humans actually walk.

"This approach is called "limit-cycle walking" and has been implemented using "model-predictive control" to predict the behaviour of the user and exoskeleton, and control the exoskeleton during the walk," Mr Ilzkovitz says. Greater efficiency means that the exoskeleton has a longer range and lighter battery packs.

Physical disabilities do not just limit mobility, they can also leave people socially isolated and unable to make the most of the modern networked world. The ASTERICS project has been developing a support platform that facilitates and improves communication for people with motor disabilities in their upper limbs by combining BCIs and computer vision with basic actuators to control a computer system.

By the time it ended in December 2012, the project had developed a product that allows access to different devices - such as PCs, mobile phones and smart-home devices - with its functionalities integrated in a platform that can be adapted to each user. It is available both as open-source software and as a preconfigured device sold through distributors.

These kinds of prosthetics have the potential to change thousands of lives for the better. In the second part of this article we will look at some of the other medical applications of the brain-related ICT research being funded by the European Union.

Part 2: From electronic brains to the power of the mind...
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