Impact Objectives

- Enable faster information processing with lower energy consumption
- Develop artificial neural networks capable of processing information received from visual sensors that can process data inputs received from visual sensors
- Design hybrid systems composed of memristive devices and CMOS technologies

Innovative embedded vision systems revolutionise autonomous driving

***Dr Sylvain Saïghi**, of the **Université de Bordeaux**, France, discusses the innovative brain-inspired technologies that aim to enhance the vision and recognition of traffic events for autonomous driving*

What are the key objectives of the Ultra-Low Power Event-Based Camera (ULPEC) project?

First of all, ULPEC is a research project that is funded through the Smart System Integration (SSI) scheme from the European Commission's Horizon 2020 framework programme. ULPEC is a brain-inspired technology in which the key objective involves the development of advanced vision applications characterised by two distinct properties: they have ultra-low power requirements and ultra-low latency. A demonstrator is used to efficiently connect a neuromorphic event-based camera that can transmit information relevant to a virtual scene in an asynchronous manner, much like the brain does, to a high-speed ultra-low power consumption visual data processing system. Hence, we develop systems that not only effectively and rapidly process the information transmitted from the sensors but, most importantly, can gradually learn to improve their own performance, optimising the use of resources.

What do you mean when you say that ULPEC is a brain-inspired technology?

In the brain, learning is intertwined with synaptic plasticity i.e. the neuron's ability to reconfigure the strength with which it connects to other neurons. The ULPEC project was originally inspired by these biological neural networks and it is successfully mimicking this process through the development of biologically-based computational visual sensors. More specifically, when it comes to solid-state synapses (memristors), the underlying conductance can be fine-tuned by the application of voltage pulses that can allow systems to evolve according to a biological learning rule known as 'spike-timing-dependent plasticity' (STDP). STDP is characterised by temporal gaps in events that are prevalent components of the neuromorphic conception. To put it in simpler words, our aim is to develop artificial neural networks that process the various pieces of information they receive from the respective visual sensors by enabling faster processing of information with lower energy consumption. Neuromorphic architectures can be extremely complex because of their increasing number (billions) of nanosynapses. Therefore, it is extremely important to have a precise and spherical understanding of the physical mechanisms that contribute to synapse plasticity.

Why is it so important to drive developments in low-power advanced vision applications?

Despite the fact that vision systems based on artificial intelligence are becoming increasingly popular, the most attractive, promising and practical application field still remains the efficient provision of driving assistance to users and the manufacture of fully-autonomous vehicles. However, it is vital to develop systems that have reduced energy consumption. Low-power advanced vision applications can process information with minimal energy consumption, thus enhancing and extending their performance duration. I should mention that this has become feasible by means of processing data closest to the sensor. Consequently, less information is needed, which translates into lower power consumption. In fact, lower power consumption accommodates a power-limited environment within the car.

What are the main applications of this research project?

Primarily, this project focuses on vision and recognition of various traffic events such as the identification of obstacles, recognition of road-signs and people. In other words, events that are prevalent and challenging because they have the capacity to disrupt autonomous and computer-assisted driving. Therefore, the technology developed in the context of ULPEC targets autonomous vehicles while at the same time focusing on the development of applications for other transportation modes and drones. I need to highlight that the level of integration that we have already accomplished in ensuring that the underlying technology is viable and can be used for traffic road events and other applications is unique, and no commercial equivalent exists on the market. ▶

Developing advanced vision applications with ultra-low power requirements and ultra-low latency

***The Ultra-Low Power Event-Based Camera (ULPEC)** project team is developing an innovative brain-inspired approach to achieving novel embedded-vision systems that can revolutionise autonomous and computer-assisted driving in the transport and car manufacturing sectors*

A consortium of leading universities, technology companies and a research centre are collaborating on an ambitious project that seeks to develop ultra-low power, ultra-low latency advanced vision technology. Primarily targeted at monitoring traffic events and supporting autonomous and computer-assisted driving, the group also hopes to find applications for their technology reaching a wider audience: 'Beyond transportation, our long-term vision encompasses all advanced vision applications with ultra-low power requirements and ultra-low latency, as well as for data processing in hardware native neural network,' explains Dr Sylvain Saïghi, the ULPEC Project Coordinator and Associate Professor at the Université de Bordeaux, France.

SELF-ADAPTING ELECTRONIC ARCHITECTURES

Cortical information flows from one neuron to another through synapses that have variable connection strength and it is this variation in synaptic strength that provides the neural network with memory. On the other hand, the process of learning is accomplished through the plasticity or ability to reconfigure the synapses. One of the most prominent and promising mechanisms that has been suggested as being responsible for regulating the evolution of synaptic strengths is the spike-timing-dependent plasticity (STDP). This mechanism underlines that the timing and causality of the electrical signals stemming from neighbouring neurons are the two determinants of synaptic evolution. In other words, the learning process is independent of any external control on the synaptic strengths but also of the potential experience or exposure to the information being processed – a fact that is consistent with what actually occurs in biological systems. This model has therefore been at the core of autonomous unsupervised learning but it also forms the basis for the development of artificial neural systems and networks with self-adapting electronic architectures.

MEMRISTORS IN NEURAL NETWORKS

Memristors, the electronic equivalent of synapses in artificial neural networks, have shown themselves to be very promising and efficient architecture. They are nanoscale devices whose resistance depends on the history of electrical signals that they have previously been subjected to. This ability to fine-tune their conductance by using voltage pulses is subject to evolution based on STDP. These solid-state, artificial neural network synapses can exhibit plasticity and their resistance can define the level of synaptic strength. Low resistance will translate into a strong synaptic connection and vice versa.

THE PROJECT

The ULPEC project aims to exploit these technologies and develop pioneering vision applications with ultra-low power requirements and ultra-low latency. The underlying objective is to demonstrate that this technology is viable and, most importantly, can also be used for applications such as the recognition of traffic road events. Therefore, it comes as no surprise that the nature of this project is multi- and transdisciplinary. Saïghi explains: 'Our research work includes a wide range of technologies, from advanced materials to System on Chip (SoC), while defining a roadmap for exploitation.'

'ULPEC's success relies on the progress made on each technological subject, since all these aspects are intertwined and interdependent. This project structure requires an important investment from the teams working on ULPEC. But this is also what makes this project so ambitious and exciting,' states Saïghi.

Eventually, the output of this brain-inspired technology intends to, 'connect a neuromorphic event-based camera to a high-speed, ultra-low power consumption asynchronous visual data processing system,' describes Saïghi. However, the unique feature and target of this project is that it aims to go beyond current standards, resulting in the development of an SoC that will receive information from an ultra-fast visual sensor. The subsequent processing will then be performed by a neural network built on memristive synapses. Therefore, ULPEC, a four-year project that started in 2017, has an ambitious goal to introduce this innovative technology not only to autonomous vehicles but also to other transportation modes and drones.

COLLABORATING TOWARDS SUCCESS

There are several collaborators involved in the development of this project, at the forefront of innovation: three universities (the Université de Bordeaux in France, the University of Twente in the Netherlands and Sorbonne Université, also in France), a research institute (the Centre National pour la Recherche Scientifique (CNRS) in France), two start-up companies (Twente Solid State Technology B.V. in the Netherlands and Chronocam, now Prophesee, in France), and two industrial leaders with worldwide recognition (multi-national Robert Bosch GmbH and IBM Research Zürich GmbH, in Switzerland). Before this project was initiated,

> *We have the ambition to develop technologies that will change the everyday life of the European citizens*

CNRS had been developing the memristors, Prophesee had produced an effective visual sensor and the Université de Bordeaux had found a specific technique to steer the respective biomimicking architectures. Hence, and when all parties decided to collaborate, the scope of applications was shifted to autonomous vehicles, a direction that attracted the attention of the remaining collaborators. In fact, it was the vison of this project that attracted Bosch, with the company deciding to join this project to serve as an end-user as well as to supervise the exploitation framework of the project. 'The success of the project relies on the co-dependency of all partners for all of their tasks. Time dedicated to exchange on the progress made on all the aspects of the project, namely during consortium meetings is therefore essential,' says Saïghi.

CHALLENGES

The project has not been without its challenges. Perhaps the most important of these has already been overcome by appropriately and efficiently settling down the basis for the design. This is, after all, the foundation on which the project was originally initiated. However, it is evident that an innovative project with such a multi- and transdisciplinary nature is bound to face several challenges that are primarily related to the interdependency between all technologies of the project. For instance, all tasks need to proceed at the same pace to allow the harmonious incorporation of all aspects into the project. This is exactly why, as noted by Saïghi, 'the interdependency also implied that all partners involved were able to take other partner's core research activities into perspective when carrying out their own research work.' Therefore, the most critical challenge was to propel tight coordination of the progress made, and hence allow this project to achieve its targets in time for the first year.

The progress made by the ULPEC researchers and developers has exhibited very promising results. Therefore, the next step will soon involve the industrial exploitation of this project by building bridges with all stakeholders that may be interested in this work. However, and regardless of any future exploitations, the researchers are determined to make the best of this novel research work to fulfil the long-held hopes of the industry with their revolutionary technology. As Saïghi explains: 'Not only do we have the ambition to develop technologies that will change the everyday life of the European citizens, but we also have in mind the EU's wish for industrial leadership in this technological domain. The exploitation path to satisfy such ambitions does require time due to the variety of actors and the complexity of the processes we may be involved in.'

By providing an innovative and polyvalent solution for embedded vision systems, ULPEC technology will lead the way for the future of memristive neuromorphic systems. ●

Project Insights

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PROJECT COORDINATOR BIO

Dr Sylvain Saïghi is an associate professor at Université de Bordeaux. His PhD focused on the design of analogue operators dedicated to silicon neurons. Saïghi has pioneered the development of biologically-realistic, tunable silicon neurons. He has also authored and co-authored more than 70 peer-review publications. Thanks to a Fulbright Scholar grant, he was visiting associate-professor at Johns Hopkins University, USA, in 2011. He was involved in the EU FACETS project and was the scientific leader for IMS in the EU FACETS-ITN project. He is currently the Coordinator of the French MIRA project and the EU ULPEC project.

ULPEC
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ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich
cnrs CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE
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