Increasingly involved in embedded artificial intelligence

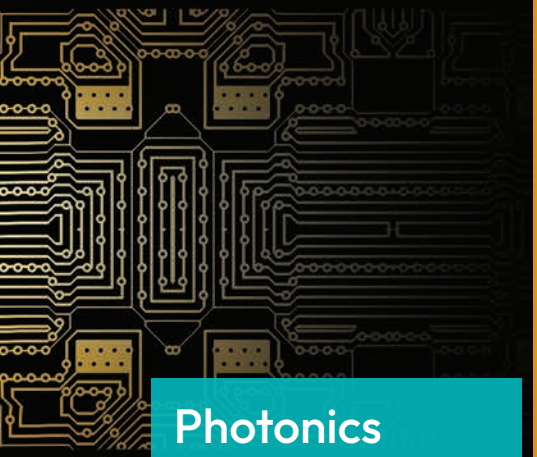
ARTIFICIAL INTELLIGENCE (AI) EXPERTISE IS INCREASINGLY IMPORTANT IN ORDER TO DIFFERENTIATE PRODUCTS DEVELOPED SPECIFICALLY FOR APPLICATIONS.

Nanoelec tackles AI from the embedded electronics standpoint: the development and generalized use of embedded AI applications is becoming essential to manage large quantities of data which require local processing at component and system levels. The aim is to make these components able to make decentralized, autonomous and reliable decisions.

Data processing must therefore be integrated close to the sensor in order to optimize the data stream and guarantee that the information remains intact and confidential. This offers a good compromise between the data streams from the sensor to the user and the energy footprints of the sensor and central computer processing smaller quantities of data.

The teams involved at Nanoelec are primarily focusing on image sensors and on the secure components and artificial intelligence systems.

Whether for designing new circuits and architectures, taking account of the environmental impacts of the technologies, or developing dedicated components, AI is identified as one of the major challenges for the electronics sector over the coming years and the Nanoelec partners have confirmed their interest in the subject.



Photonics on silicon

With the photonics on silicon platform developed at CEA-Leti, the teams mobilized in the Nanoelec/Photonic Sensors program are involved in a number of European projects to develop neuromorphic architectures dedicated to artificial intelligence applications (learning and inference) for ultra-fast detection of cancer cells (flow cytometry), security applications, image recognition and telecommunications. The circuits studied consist a pulsed laser associated with a Mach-Zehnder interferometer array controlled by BTO base phase-shifters. Developments are expected in lasers integrated on silicon and the use of non-volatile phase shifters based on phase change materials (PCM). ◊

Security of Machine Learning

Given the increasingly widespread use of neural network models, in particular in mission-critical embedded systems, the need to evaluate their security to guarantee their reliability is becoming urgent. More specifically, the models deployed in embedded platforms are physically accessible to attackers during the product lifecycle and thus vulnerable to hardware perturbations. Teams in Nanoelec/Pulse program study the threats by characterizing the vulnerabilities as well as the main defenses approaches by developing countermeasures on a wide range of hardware platforms. ◊

Autonomous vehicle

A team from Inria and its industrial partners, working within the framework of Nanoelec/Pulse, are focusing on the validation of artificial intelligence (AI) systems for mobility/vehicles. In 2023, they presented a new navigation-based metric to evaluate the similarity between occupancy grids. The study used a machine learning model that combines LIDAR data and camera data to generate semantic grids for different classes. The issue of evaluating and validating the efficiency of these technologies is one of the last major hurdles to the adoption of in-vehicle context capture technologies to enable vehicles to operate autonomously. ◊

Safe and autonomous smart hoisting

Autonomous Intelligent Vehicles (AIV) or Autonomous Mobile Robots (AMR) are now a feature of the industrial production chain. This new mobile handling technology must be able to be integrated without endangering the production line, surrounded by human employees. Following the mathematical modelling of an overhead crane, a team working under Nanoelec/Pulse defined an approach to the overhead crane control problem aimed at optimizing the parameterization of existing controllers. An AI learning pipeline for AI incorporating a digital simulator was then set up to assess and validate this approach before testing it on a physical simulator. ◊

AI for embedded intrusion detection

For several years now, CEA has been working on the use of hardware information to detect microarchitectural attacks, such as Spectre or Rowhammer, as well as attacks with an impact on the system, such as a cryptolocker. The Nanoelec/Pulse teams have developed an anomaly detection approach based on machine learning. The model is trained using only data on the normal behavior of the system to characterize it. During inference, any deviation from this normal behavior detected by the model is considered an anomaly. The results of this solution are highly promising, both in terms of sensitivity (all attacks detected) and specificity (no false alarms). ◊

Artificial intelligence of objects

The InSecTT EU program partners believe that Artificial Intelligence of Things (AIoT) is the natural evolution for both AI and IoT because they are mutually beneficial. AI increases the value of the IoT through machine learning by transforming the data into useful information knowledge, while the IoT increases the value of AI through connectivity and data exchange. Nevertheless, cybersecurity is crucial to protect data and privacy. Several platforms have been set up to evaluate and demonstrate the embedded neural network inference security technologies developed. The Nanoelec/Pulse teams focused in particular on mechanisms for authenticating the integrity of neural network inference embedded on a hardware platform based on blockchain and hardware secure components ◊

A third layer to support edge AI on the imager

Imaging is one of the three main fields that use AI. The aim is not only to achieve better image quality, but also to extract relevant data from the image, taking account of the environment, the object and the scene (potentially across a range of lighting conditions), and knowledge of the context.
The main objective of the Nanoelec/Smart Imager program is to prepare a 3D-stack technology to integrate the processing of artificial intelligence directly into an image sensor.
Research teams working on the Nanoelec/Smart Imager program are focusing on new advanced silicon technology bricks allowing 3D sensor assembly, on the design of new architectures allowing the implementation of adapted neural networks, and on the development of new design methodologies and tools simultaneously taking account of software and hardware requirements in dedicated EDA tools. ◊

Merging multimodal images

Teams involved in the Nanoelec/System Lab initiative define, develop and test cases using embedded AI technologies that are integrated into or associated with multiple image sensors. With regard to spatial coherence of images from different sources, data merging is based on artificial intelligence solutions. Artificial intelligence is usually developed specifically for a given use case in order to exploit nothing but the pertinent data. ◊