

Join us and ride
the upcoming
neuromorphic AI wave

AESEMI

ASOCIACIÓN ESPAÑOLA DE LA INDUSTRIA DE SEMICONDUCTORES

Working Group on
Neuromorphic and AI
Technologies

Inspired by biological perception, neuromorphic
chips and IP selectively sense and process only
high-value data, delivering unprecedented energy
efficiency and low latency to revolutionize AI.



aeseми.org/neuromorphic

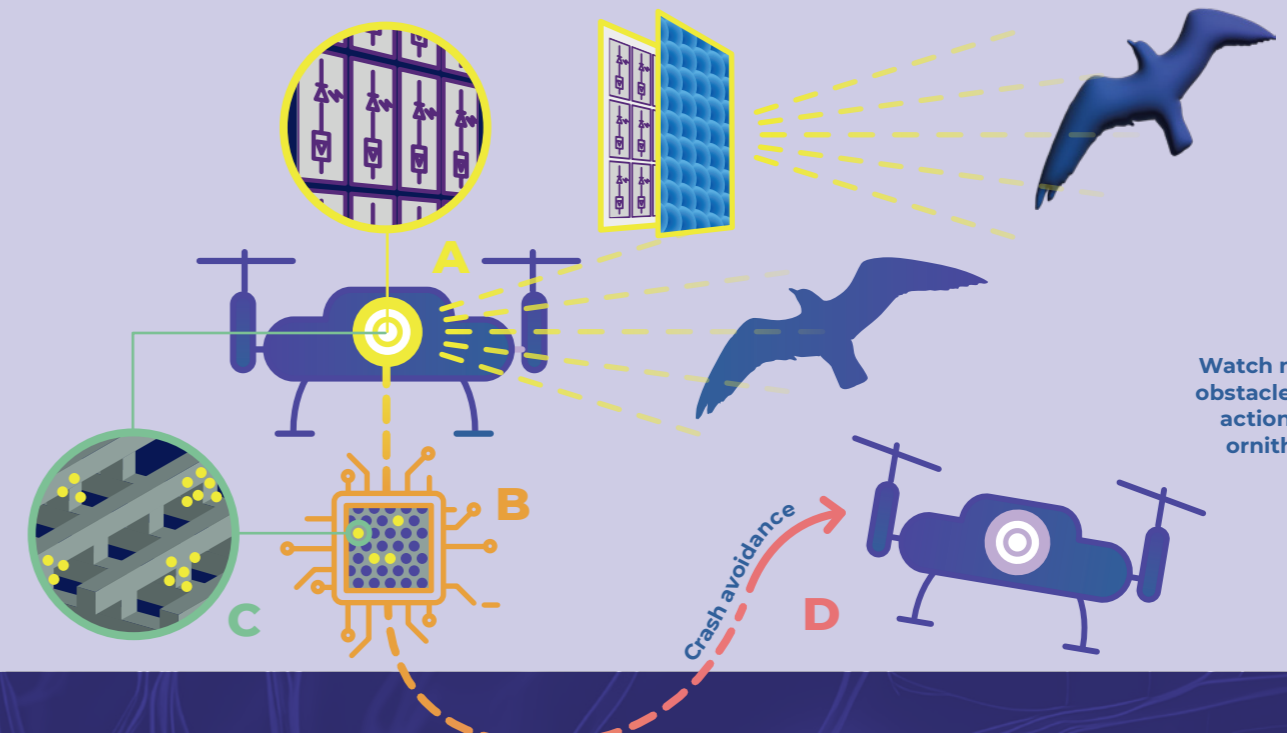
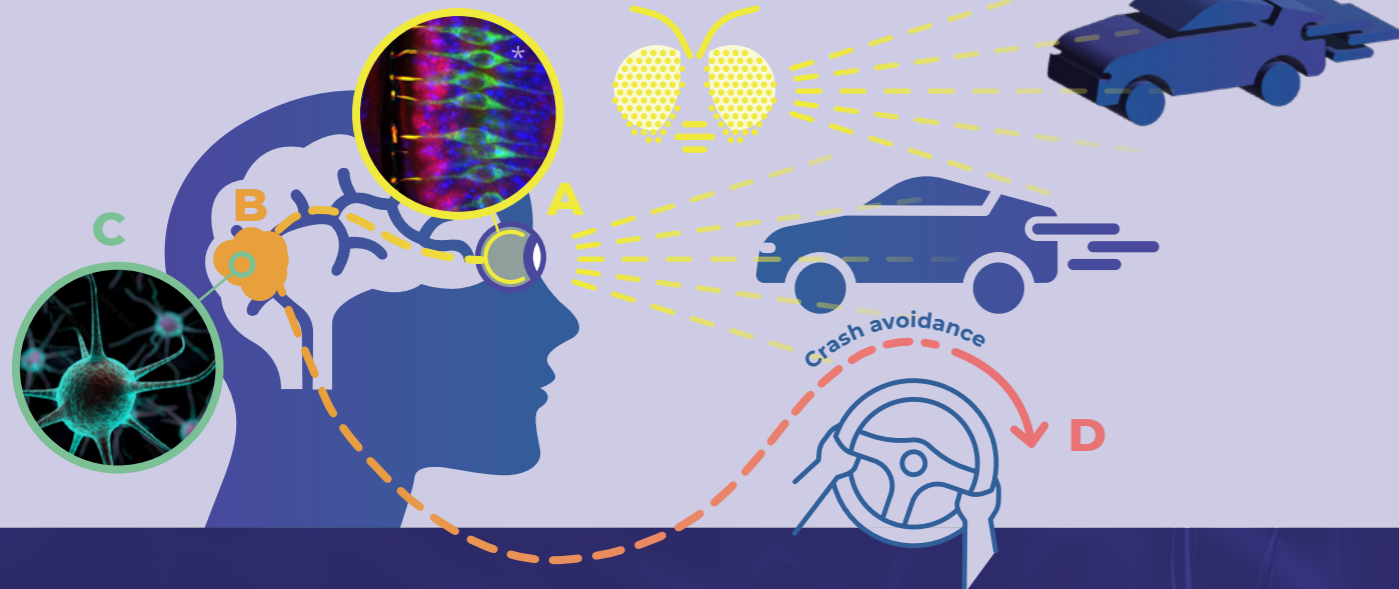
*“We expect up to 57%
penetration of neuromorphic
chips in most major
applications by 2034.”*

YOLE Intelligence

*“Neuromorphic computing will
have a substantial impact on
existing products and markets,
taking three to six years to
cross over from early-adopter
status to early majority
adoption.”*

Gartner

Replicating Nature's efficiency in neuromorphic systems



Watch neuromorphic obstacle avoidance in action in real-world ornithopter drones



A Neuromorphic sensors

Dynamic Vision Sensors (DVS) mimic the functioning of the retina, encoding ONLY changes in light brightness over time: visual events – unlike frames in traditional image sensors that capture the state of all pixels, even those without change. DVS provides key advantages, including high dynamic range, ultra-low latency, and low energy consumption.

The AESEMI neuromorphic group advances DVS for passive 3D perception by coupling insect-eye-inspired light-field microlenses to the sensor, improves efficiency through vertebrate-eye-inspired foveated DVS, and integrates uncooled photonic detection directly onto the sensor chip to enable infrared DVS.

Beyond vision, 1D signals, such as vibrations, audio, or even chemical presence, can also be efficiently sensed and encoded with events.

B Neuromorphic processors

Event-driven neuromorphic processors mimic the functioning of the brain, consuming energy ONLY when specific neurons change state in response to sparse events, such as those delivered by neuromorphic sensors – unlike mainstream processors and GPUs, which process all neuron states sequentially layer-by-layer.

- Industry-standard AI models can be converted into event-based models (e.g., Spiking Neural Networks - SNNs) to fully exploit the capabilities of neuromorphic processors.
- Alternatively, neuromorphic sensor events can be converted into data structures compatible with industry-standard AI models, frameworks, processors and GPUs.

C New computing materials and devices

Emerging materials pave the way to implementing new energy-efficient device concepts, such as memristors, for processing events and neuron states in the analog domain – similar to biological neurons.

The AESEMI neuromorphic group designs advanced materials (graphene, perovskites and nitrides), develops devices (memristors, magneto-ionic heterostructures and magnetic tunnel junctions), and advances their characterization and modelling to enhance energy-efficient computing. The group also designs and prints ultra-low power neuromorphic circuits on flexible substrates, enabling seamless AI integration into physical objects, wearables, and artificial skin.

D Neuromorphic actuation

Event-driven sensorimotor algorithms integrate neuromorphic sensor event processing with continuous-action control (e.g., Spiking Linear Quadratic Gaussian), enabling quick decision-making in dynamic environments – unlike time-stepped perception-action loops.

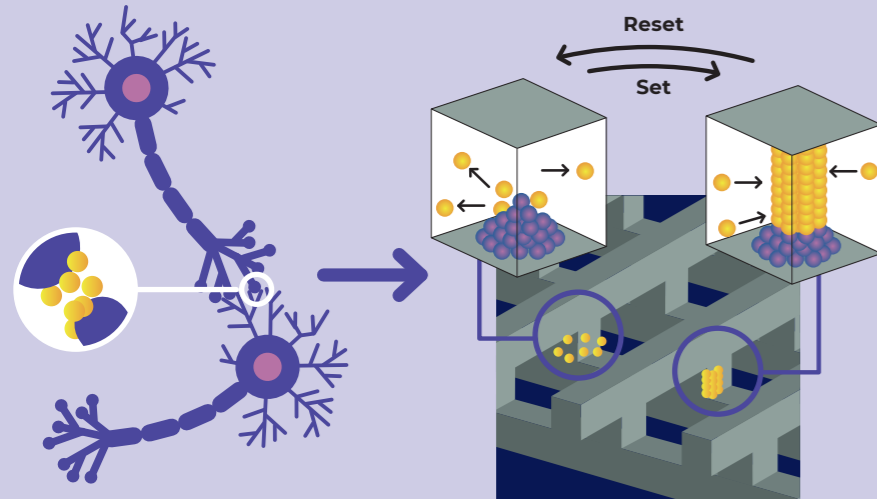
The AESEMI neuromorphic group designs advanced robotic navigation algorithms that integrate visual event-driven obstacle avoidance and auditory event-driven echolocation, leveraging spikes generated by SNNs to control the motors – analogous to how biological nervous systems control muscles.

* Adapted from Ogjenko [CC BY 4.0]

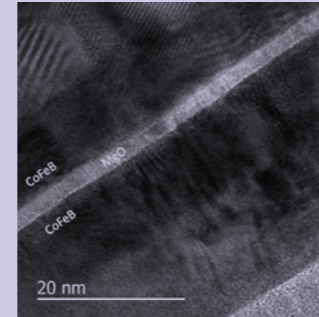
Enhancing neuromorphic processing in Spain

From Neural Functionality to Hardware Implementation

Next-generation devices can mimic neural and synaptic functions by analog tuning of their resistance levels. This enables the creation of energy-efficient and high-density neuromorphic computing networks that mirror the interconnected structure of the brain's synaptic networks.

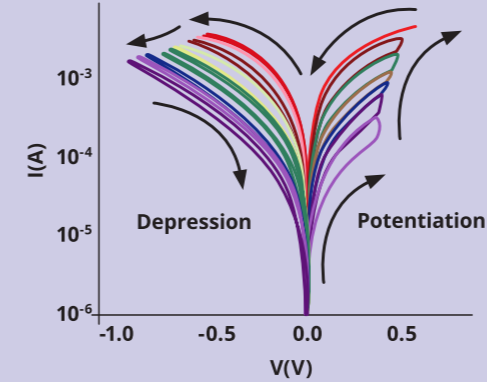


Materials & Devices for Neuromorphic Computing



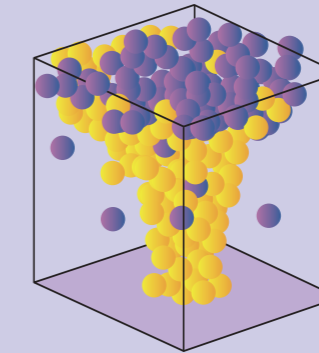
Materials

Advanced materials to improve performance and sustainability in neuromorphic devices. Spanish ecosystem works in a big variety of materials, including graphene, perovskites, magnetic materials, nitride thin films and heterostructures, high-k dielectrics and organic semiconductors.



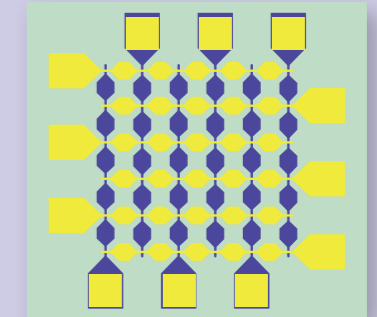
Advanced Characterization

Advanced characterization techniques to analyze materials from their structure to their electronic transport properties, including studies on impedance spectroscopy, noise, variability and reliability.



Modeling and Simulation

Experimental results are combined with the development of models to deeply understand the behavior of materials and devices for neuromorphic systems as well as simulate their circuit behavior. These methods range from Monte Carlo simulations, physical simulations, to SPICE and Verilog-A.

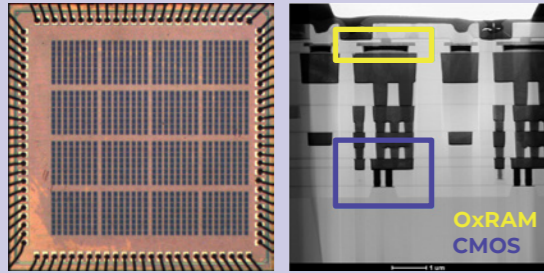


Devices

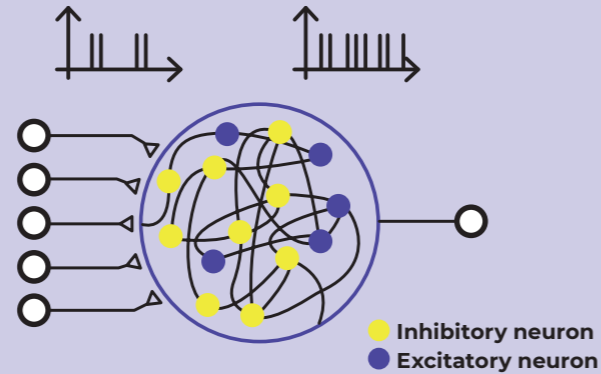
Innovative devices beyond CMOS that mimic neuronal functions to optimize energy efficiency in electronic circuits and computing systems. Examples are memristors, magnetic tunnel junctions and magneto-ionic devices. Clean-room processes and printed electronics are employed.



Graphenea is a company that drives the fabrication of graphene-based devices through custom technology development, supporting Spain's path from materials innovation to manufacturing.



16-core memristor-CMOS neuromorphic chip prototype and cross-sectional view of a memristor (CSIC-IMSE)



Neuromorphic Algorithms

Learning: Large-scale SNNs with surrogate backpropagation and spike-timing-dependent plasticity (STDP). Advanced learning algorithms to ensure robust and safe operation of SNNs in open-world environments. Hardware plasticity and evolution.

Perception and action: Explainable analytical SNNs for tracking and controlling dynamical systems. Embodied SNNs to close perception-action loops in real-time to deal with changing environments. SNN-based vision algorithms to process DVS events: object detection and segmentation.

Neuromorphic Analog Processing

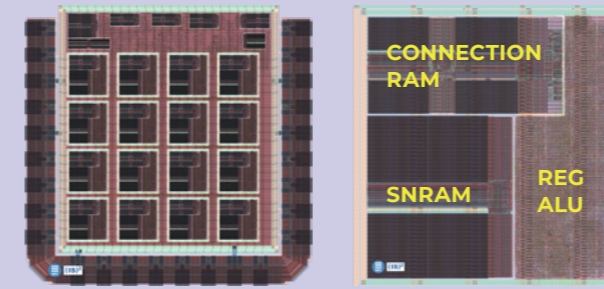
Neuromorphic chips based on hybrid CMOS-memristor technology integrating memristic crossbars.

Interface circuits to counteract **memristors non-idealities**.

Analog Resistive RAM (RRAM)-based synaptic arrays and neurons.

Nanoribbon graphene transistors for neuromorphic processing with sensitivity to structural defects.

Low-cost **inkjet printed RRAM** on rigid and flexible substrates.



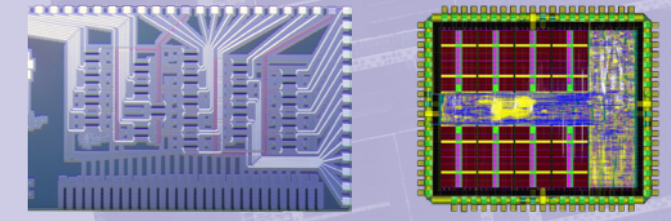
16 SIMD core SNN digital processor chip prototype and detailed view of one of the cores (IS2-UPC)

Neuromorphic Digital Processing

Digital structures with **RRAM** technology for **low-power in-memory computing**. Novel associative memories, together with mechanisms to enhance neural functionality through stochastic resonance.

Highly adaptable neuromorphic processors that integrate spiking primitives. Local memory SIMD multi-model biomimetic SNN architectures and FPGA/ASIC implementations.

RISC-V extensions implemented as **Coarse-Grain Reconfigurable Arrays (CGRAs)** that support neuromorphic operators to seamlessly accelerate SNNs.



Programmable 2D hexagonal grid photonic chip prototype (iTEAM-UPV)

RISC-V CPU with 4x4 CGRA chip prototype (UPM-CEI)

DVS front-end to acquire and process neuromorphic visual event streams, generating data structures compatible with industry-standard processors and AI accelerators.

Photonic Integrated Circuits (PICs) with ultrawide bandwidth and low propagation loss to accelerate neuromorphic computing, from fundamental operations like matrix-vector multiplications to optical signal recovery.

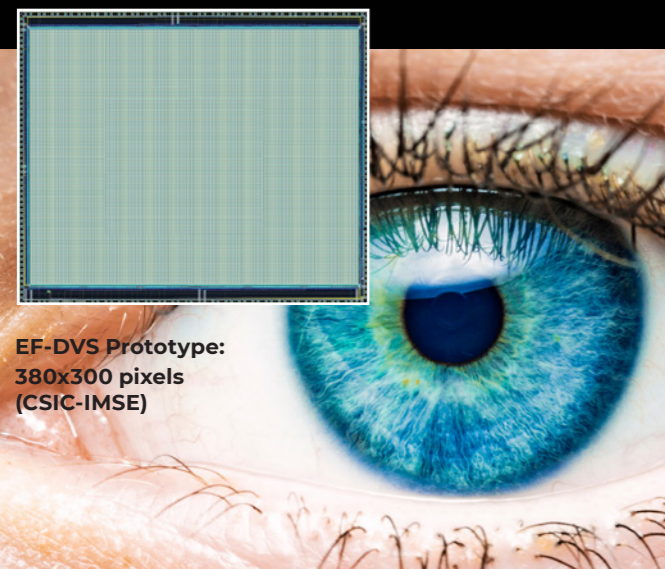


Pre-commercial DVS-based technology developed in Spain



Electronically Foveated DVS (EF-DVS)

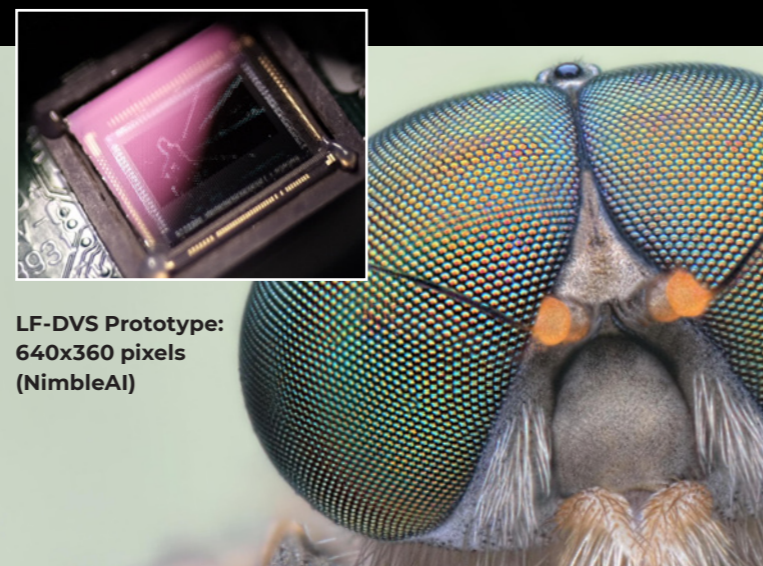
Enables dynamic resolution allocation based on the information gain provided by each sensor region. Low-resolution (LR) coverage of the full field of view enables the detection of potentially relevant regions, which can then be sensed in high-resolution (HR) for maximum accuracy.



EF-DVS Prototype: 380x300 pixels (CSIC-IMSE)

Light-Field DVS (LF-DVS)

Combines efficiency of DVS with directional light capture of light-field micro-lenses coupled to the sensor to achieve real-time, monocular, passive 3D perception with sub-ms latency. LF-DVS offers significant advantages in response time and energy efficiency over mainstream 3D sensing solutions such as RGBD and LiDAR, especially within operational ranges of up to 10 meters.



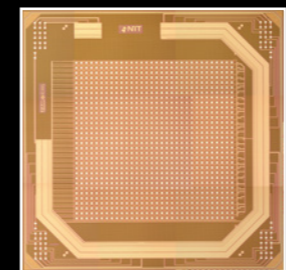
LF-DVS Prototype: 640x360 pixels (NimbleAI)

Hyperspectral DVS (HS-DVS)

Ongoing feasibility study on the use of Imec's on-chip mosaic filtering technology in conjunction with DVS sensors for autonomous navigation.

Infra-red DVS (IR-DVS)

Compact DVS pixel pitches tailored to NIT's uncooled detection technology to enable low-power, high-speed IR vision.



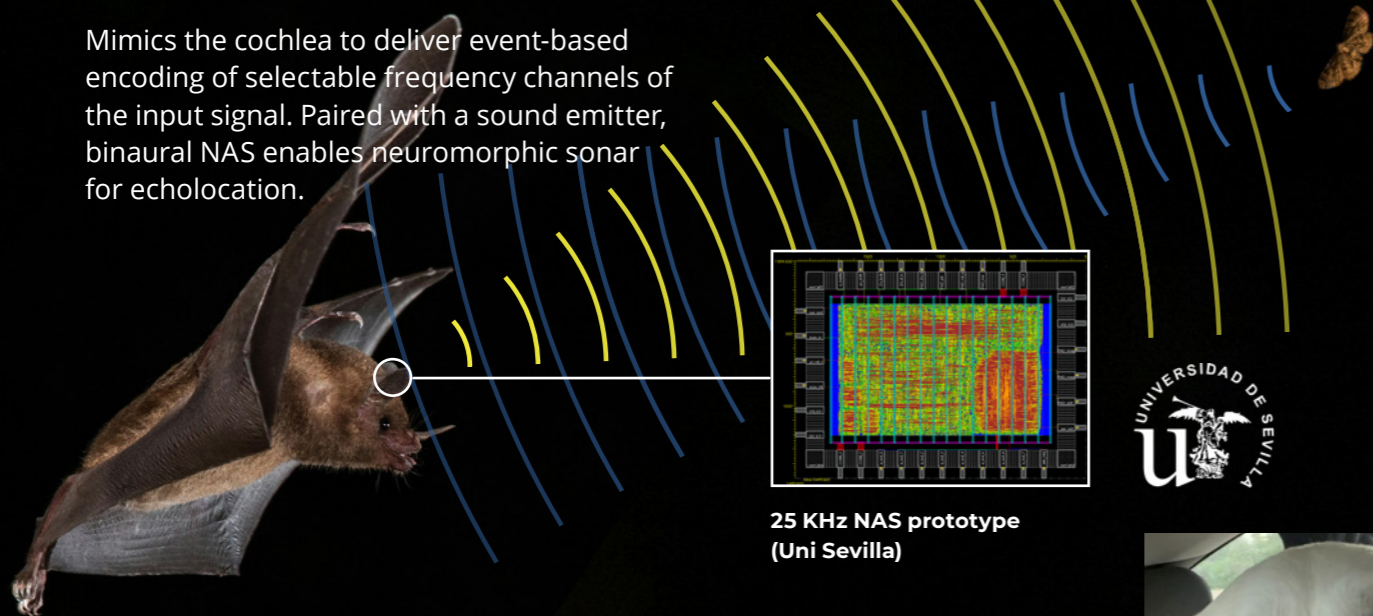
IR-DVS Prototype: 32x32 pixels (CSIC-IMB)

Photos background: AdobeStock.com

Other neuromorphic sensing technology developed in Spain

Neuromorphic Auditory Sensor (NAS)

Mimics the cochlea to deliver event-based encoding of selectable frequency channels of the input signal. Paired with a sound emitter, binaural NAS enables neuromorphic sonar for echolocation.



25 KHz NAS prototype (Uni Sevilla)

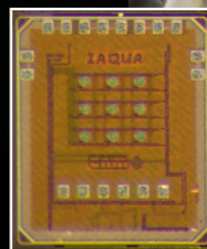


Photo: unsplash.com/Zdenek Machacek (bat)

Dynamic Electrochemical Sensor (DES)

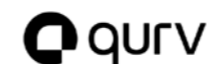
Incorporate neuro-inspired adaptive spike encoding to reduce background noise and variability in biochemical microsensors, enhancing dynamic range, accuracy, and energy efficiency based on signal dynamics.

Prototype of an integrated array with 11 multimodal DES sensors (CSIC-IMB)



Commercial pathways with Spain's technology companies and new startups

Vision



Qurv develops wide-spectrum image sensors using colloidal quantum dot-based process compatible with CMOS DVS pixel designs.



NIT develops and commercializes LWIR and MWIR high-speed cameras for industrial process control using advanced compact-pitch CMOS architectures, which can be further enhanced with DVS pixel designs.



IMASENIC has DVS pixel and sensor IP that can be scaled to high-resolution and adapted for 3D silicon stacking. This technology is compatible with standard CMOS image sensors and emerging LF-DVS, enabling advanced neuromorphic vision and event-based 3D perception.



BEGI is a digital processor optimized for SoC integration to bridge AI processing IP with emerging event-based vision technology: DVS, EF-DVS and LF-DVS. BEGI pre-processes DVS events to provide ultra-low-latency filtered event frames, time-surfaces, optical flow maps, and, when paired with LF-DVS, depth maps.

AI processing IP



Semidynamics designs RISC-V-based AI processing IP, including a CPU, a vector unit and a tensor unit, for the SoC, Chiplet and custom ASIC markets.



OpenChip designs RISC-V-powered SoCs for high-performance computing and AI acceleration, with the goal of strengthening Europe's semiconductor industry and enhancing its resilience.



VLC Photonics specializes in design and testing solutions for engineering photonic ASICs, providing tailored hardware implementation to functionalize AI neural architectures.

Audio



COBER develops and commercializes custom FPGA IP for NAS sensing and SNN processing, targeting next-generation AI applications.

Chemical



AiQUOS integrates DES sensors and neuromorphic processing into a single, autonomous lab-on-a-chip to enable comprehensive monitoring and control of aqueous environments at the edge.

Unlocking competitive advantages with neuromorphic technology

Robotics

01 In autonomous navigation, DVS captures only moving edges (typically less than 10% of the scene) greatly reducing data processing and sensor-to-actuator latency. This allows for:

- effective obstacle avoidance in (highly) dynamic environments.
- safer human-robot interactions.
- minimal motion blur in challenging conditions like vibrations in drone flights.
- easy detection and identification of moving objects through temporal motion signatures, such as drone rotors.

02 DVS's high dynamic range and event-based visual information encoding minimize

the impact of lighting conditions on robotic perception.

03 LF-DVS allows for monocular sub-ms depth and 3D flow estimation, improving RGBDs and LiDAR for perception in fast-moving and occluded scenarios This is particularly advantageous for energy- and mass-constrained robotics, such as lightweight drones, or for aiding in docking and refueling maneuvers.

04 EF-DVS enables the creation of retinotopic multi-resolution maps of the surroundings, which are useful for estimating depth and optical flow.

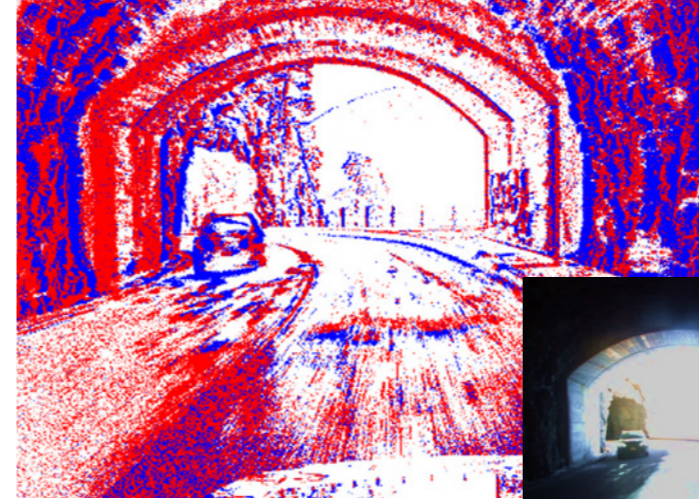
05 NAS enables efficient echolocation for obstacle-free robotic navigation in complete darkness.

Agri-food & Water Management

01 DES miniaturization and energy-efficiency allows for precise multi-attribute monitoring and control at any point of the industrial process, even in narrow, intricate pipes, purifiers, and reactors.

02 The adaptive neuromorphic readout/encoding provided by DES reduces OPEX and CAPEX by enabling on-chip self-calibration to specific operational conditions at deployment and compensating for manufacturing imperfections.

03 HS-DVS can detect foreign particles like microplastics in high-speed food processing systems and reduce drone-based crop inspection time by supporting high-speed flights while identifying spectral signatures for early disease detection, pest monitoring, water stress, and soil quality assessment.



Transportation

01 Neuromorphic technology minimizes computational demands and accelerates response times for real-time autonomous driving decisions and in-cabin driver monitoring, improving the performance of crash avoidance systems.

02 DVS's event-based encoding reduces video transmission bandwidth for teleoperation. EF-DVS further cuts bandwidth, especially when used alongside eye-tracking for remote operators.

03 DVS's ultra-low-latency and high dynamic range provide inherent robustness against

motion blur and changes in lighting conditions, such as when leaving tunnels at daytime.

04 Passive LF-DVS offers faster and more energy-efficient alternative to current active depth perception systems, such as LiDAR, leading to cost savings and extended autonomy in electric vehicles.

05 IR-DVS and HS-DVS potentially enable sensing in low visibility and adverse weather, enhancing context understanding and target discrimination in (highly) dynamic environments.

Medical & XR

01 DVS's ultra-low-latency allows for precise tracking of eye fixations, saccades, and microsaccades, offering new insights for diagnosing and treating neurological disorders.

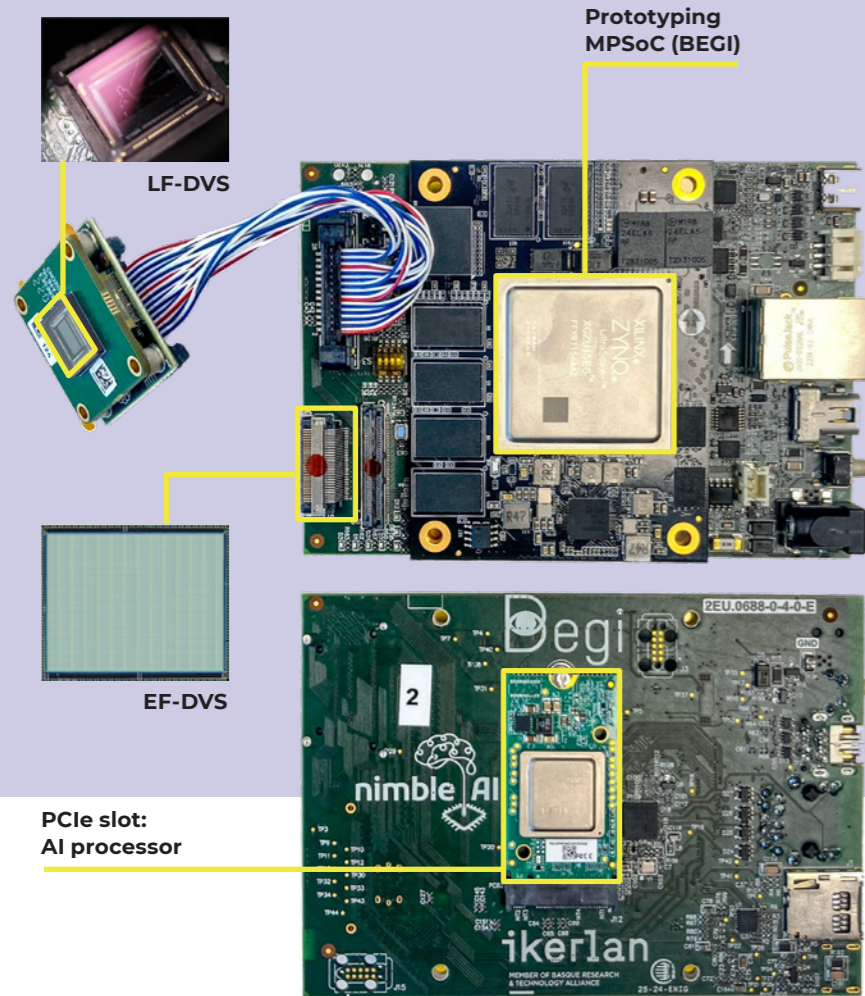
02 IR-DVS helps enhance the efficiency and wearability of eye-trackers, which often rely on IR lighting.

03 NAS and DVS enable event-driven fusion of sound and vision for improved voice recognition with maximum energy-efficiency.

04 Neuromorphic technology enables more straightforward human-machine interfaces by using biologically plausible information-encoding principles. This paves the way for more effective prosthetics, exoskeletons and neurorehabilitation treatments.



Quickly test neuromorphic technology in your vision applications



The BEGI-EVK supports prototyping of BEGI-powered neuromorphic vision applications using real-world live data. It integrates EF-DVS and LF-DVS pre-commercial neuromorphic sensors and commercial AI chips like HAILO.

Surveillance

- 01** Integrating DVS with SNN processing cuts power use, enabling AI on low-energy, battery-powered edge devices.
- 02** Event-based encoding reduces sensitivity to background noise, reduces energy use in static settings and improves moving target detection in cluttered environments.
- 03** The high dynamic range of DVS makes it particularly well-suited for use in challenging lighting conditions, day and night, expanding the surveillance use cases.
- 04** Neuromorphic vision technology provides minimal motion blur, enabling detection of high-speed targets even from fast-moving surveillance systems.

Space

- 01** DVS's high dynamic range is effective for challenging space lighting conditions, including high-contrast and low-light, as well as to handle rapid lighting changes due to spacecraft movement with respect to intense light sources.
- 02** Neuromorphic technology improves onboard computing efficiency, reducing ground dependence and broadening mission scope, especially in deep-space missions.
- 03** DVS's event-based encoding reduces bandwidth and storage needs, while its ultra-low latency enables capturing in detail high-speed phenomena like transient luminous events in Earth observation missions.
- 04** Rapid visual response improves situational awareness and autonomous decisions. Near-instant depth maps from LF-DVS aid in docking and rendezvous maneuvers.

Factory Automation & Machine-tool

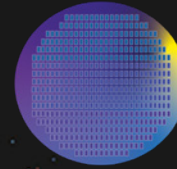
- 01** DVS's cost-effective high-speed vision (eq. to 10 kfps) allows to:
 - Count and size high-speed objects on conveyors.
 - Monitor liquid and plume flows, such as those in spraying processes and combustion analysis.
 - Track small particles with spatter-like motion in additive manufacturing.
 - Localize objects at high-speed for pick-and-place.
 - Detect and analyze high-frequency vibrations for predictive maintenance.
- 02** DES enables the detection of specific chemicals in aqueous environments in industrial processes.
- 03** LF-DVS enhances the ability to distinguish high-speed objects and particles in 3D and estimate flow densities, providing clearer visibility across flow layers.
- 04** DVS can easily identify moving robots, vehicles and human operators in complex, cluttered industrial environments by focusing solely on motion detection.
- 05** IR-DVS enhances DVS by focusing solely on IR wavelengths common in industrial processes like melting, achieving faster data acquisition, ultra-low latency, and lower energy use.

The AESEMI Working Group on Neuromorphic and AI Technologies is aimed at aligning industry with the activities of leading Spanish research centers and universities, as well as the roadmaps of deep-tech companies in the field of neuromorphic sensing and processing.

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Join us now!

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Cover: Lightning phenomenon captured with a neuromorphic event-based vision sensor. Courtesy of the International Centre for Neuromorphic Systems | Western Sydney University