Technologies S.A.

Neuromorphic Event-Based Vision Platform

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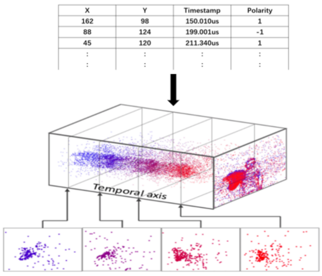
1 System Overview: Hardware and Solution

1.1 Neuromorphic/Event-Based Vision in Brief

Conventional frame-based cameras capture full images at a fixed rate, even when nothing in the scene changes. This produces redundant data, adds latency between frames and leads to motion blur and limited temporal resolution, especially for fast targets or rapid platform motion in challenging lighting. Neuromorphic, or event-based, vision follows a different, retina-inspired principle. Each pixel acts as an independent detector, continuously monitoring the logarithm of the incoming light intensity. Instead of outputting frames, the sensor generates events only when the local brightness changes by more than a configurable threshold. Each event is represented as (x, y, t, p) (Fig. 1.1[1]), where (x, y) are the pixel coordinates, t is a precise timestamp, and p is the polarity: ON for an increase in intensity and OFF for a decrease. Pixels operate asynchronously and react only to changes, producing a sparse, temporally precise stream of ON/OFF events rather than dense, clocked images. This data model provides very low sensing latency, very high dynamic range, absence of motion blur, reduced data rate and power consumption, as static regions generate almost no events. On this basis, event-based sensors support a wide range of perception tasks, including high-speed object tracking, motion and surveillance analytics, gesture and object recognition, optical flow, depth estimation (e.g., stereo or structured light), and SLAM.



X	Y	Timestamp	Polarity
162	98	150.010us	1
88	124	199.001us	-1
45	120	211.340us	1
:	:	:	:
:	:	:	:

Figure 1.1: Asynchronous events (x, y, t, p) form a sparse spatiotemporal stream, capturing motion without traditional frames.

1.2 Hardware Setup and Key Specifications

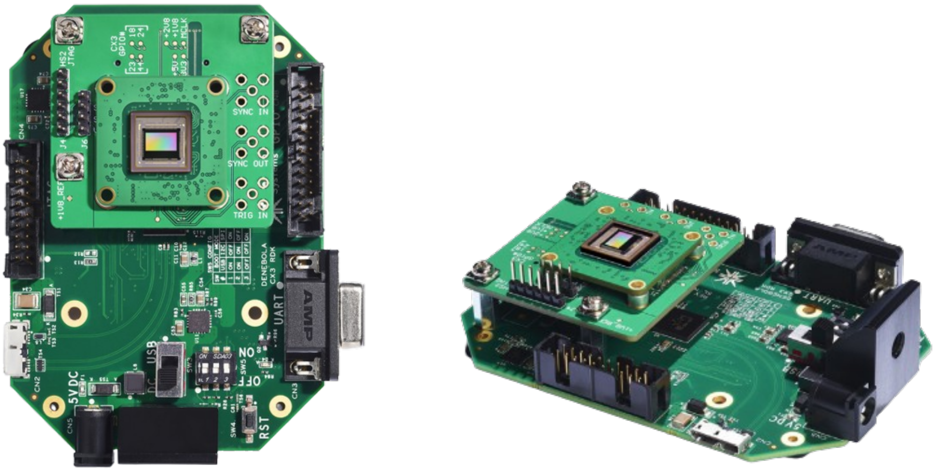


Figure 1.2: EVK3 neuromorphic vision board integrating Sony's IMX636 event-based sensor (perspective and top view).

The platform's neuromorphic sensing capabilities are built around a modular event-based vision board integrating Sony's IMX636 high-definition neuromorphic sensor. This provides the core hardware required to capture and process asynchronous visual information in real time.

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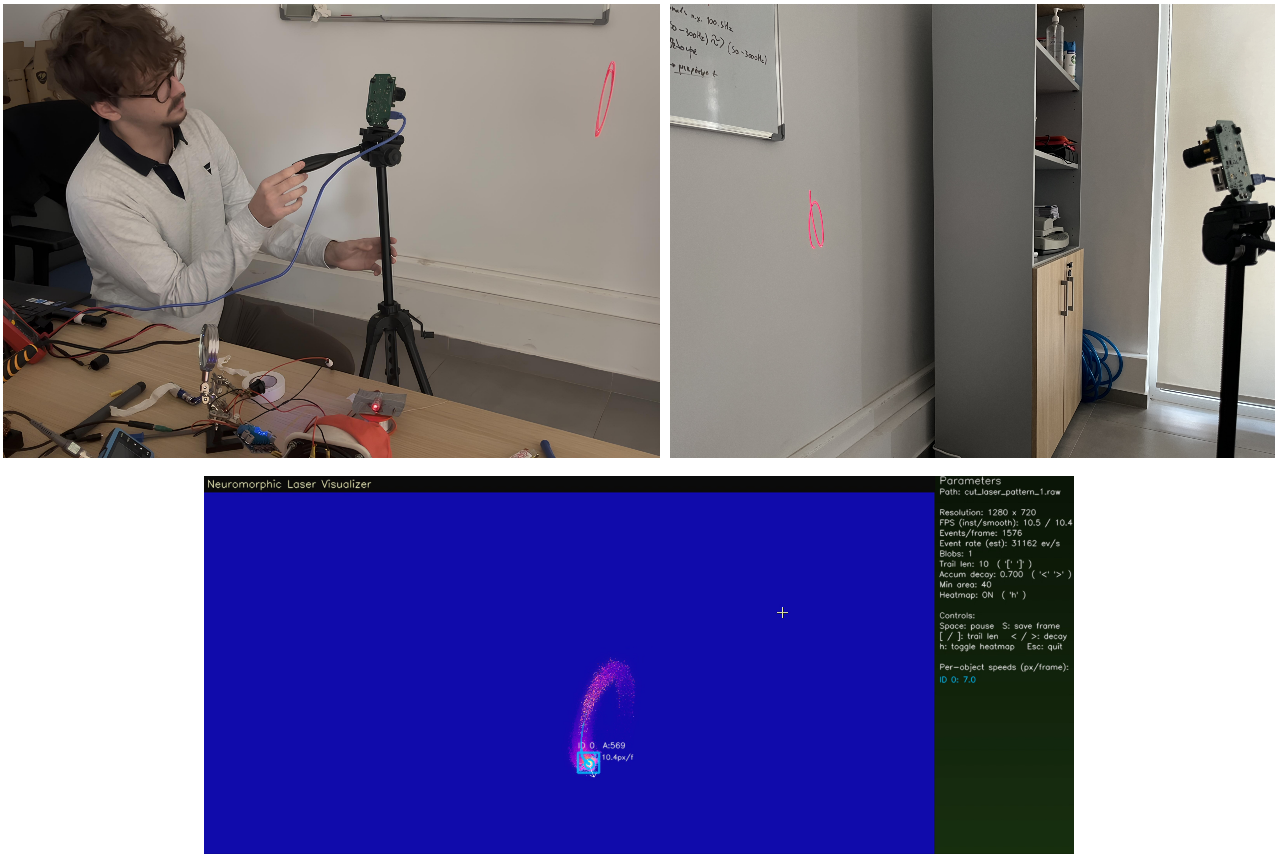
[1] Shixiong Zhang et al., "Evtracker: An event-driven spatiotemporal method for dynamic object tracking," *Sensors*, 22(16):6090, 2022.

Characteristic	**Specification**
Sensor type	Monochrome event-based CMOS vision sensor
Resolution	1280 × 720 event-based pixels
Pixel size	4.86 µm contrast-detection pixels
Latency	$<$ 100 µs at 1000 lux; $<$ 1 ms at 5 lux
Dynamic range	$>$ 120 dB (logarithmic pixel response)
Peak event rate	$\sim 1 \times 10^9$ events/s
Data interfaces	16-bit parallel output, compatible with LVDS serializers
Control interfaces	SPI and I^2C
ROI support	Random programmable region of interest (ROI)
Power consumption	Typically 50–70 mW; $<$ 100 mW peak; $<$ 5 mW standby
Operating temperature	–40°C to +85°C
Lens mount	Standard C-mount
Typical optics (short FL)	4–6 mm lenses for wide-angle UGV navigation, obstacle avoidance and SLAM
Typical optics (long FL)	100–400 mm lenses for long-range counter-UAV and airspace monitoring
Example resolution at 2 km	∼0.097 m/pixel @ 100 mm (∼5 px on 0.5 m drone, detection); ∼0.024 m/pixel @ 400 mm (∼21 px, recognition under Johnson criteria)
Spectral options	Supports near-infrared optics; can be co-integrated with thermal sensors

Table 1.1: Core IMX636 sensor and optic specifications.

INFILI operates a dedicated neuromorphic vision laboratory where engineering platform's microsecond temporal resolution and its ability to record extremely fast or subtle vibrations that remain invisible to conventional frame-based cameras.



```
Parameters
Path: cut_laser_pattern_1.raw

Resolution: 1280 x 720
FPS (inst/smooth): 10.5 / 10.4
Events/frame: 1576
Event rate (est): 31162 ev/s
Blobs: 1
Trail len: 10  ( '[' ']' )
Accum decay: 0.700  ( '<' '>' )
Min area: 40
Heatmap: ON  ( 'h' )

Controls:
Space: pause  S: save frame
[ / ]: trail len   < / >: decay
h: toggle heatmap   Esc: quit

Per-object speeds (px/frame):
ID 0: 7.0
```

Figure 1.3: A laser beam is reflected off a small, vibrating membrane driven by an audio waveform, producing rapid oscillatory motion on a surface. The neuromorphic vision sensor captures this motion as asynchronous events, allowing precise reconstruction of high-frequency patterns and Lissajous-type trajectories. This setup highlights the platform's microsecond temporal resolution and its ability to record motions far faster than conventional frame-based cameras, including subtle vibrations at different audio frequencies that are invisible to standard imaging systems.

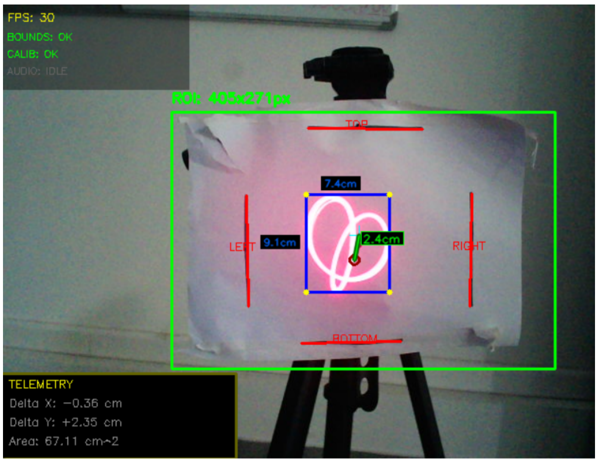


Figure 1.4: The image shows a calibrated laser-tracking system that detects a laser pattern projected onto a marked piece of paper. The drawn black boundary lines are automatically identified and used to establish a real-world coordinate frame. Inside this region, the program isolates the laser footprint by converting the ROI to grayscale and applying adaptive thresholding, producing a binary mask of the illuminated pattern. A reference center point and a dynamically sized analysis rectangle mark the region where the laser's deformation is measured in real time.

2 Use Cases and Application Scenarios

INFILI develops and investigates neuromorphic vision concepts in two defence-relevant application scenarios. Both are built on the IMX636-based sensor platform and are designed to explore where conventional electro-optical systems reach their limits: autonomous UGV navigation in GNSS-denied environments and early warning against aerial and surface threats around airfields and ports. In both scenarios, the same core hardware is combined with mission-specific optics and embedded processing and is operated in controlled but realistic environments.

2.1 Autonomous UGV Navigation in GNSS-Denied Terrain

In urban canyons, forests, tunnels and contested areas, GNSS is unreliable or denied and conventional cameras struggle with low light, strong contrast transitions and motion blur on rough terrain. INFILI is currently researching how neuromorphic event-based sensing can support navigation in these conditions. The concept under investigation includes:

- deploying a small drone that takes off from the UGV, or alternatively installing a neuromorphic camera head on a mast above the vehicle
- linking the elevated neuromorphic camera head to an embedded processing unit on board the UGV via an optical fibre connection
- using the elevated viewpoint to build a local map ahead of the vehicle, detect terrain hazards such as ditches, trenches and sudden drops, and extract safe corridors through cluttered areas
- converting this information into simple guidance commands such as “obstacle ahead, turn left” or “follow corridor to the right”, allowing the UGV to progress without GNSS or external infrastructure.

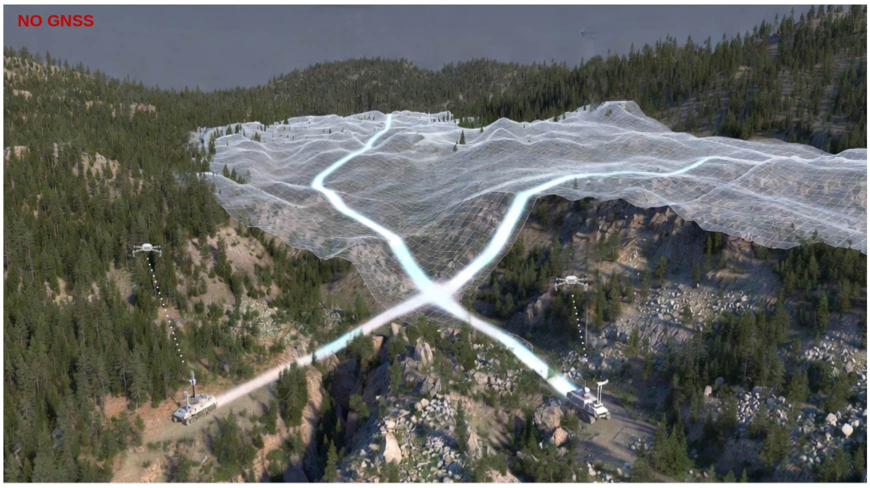


Figure 2.1: Neuromorphic vision drones mapping safe routes for UGVs in GNSS-denied terrain.

2.2 Early Warning System for Aerial and Surface Threats

Recent incidents have shown that small UAVs and FPV drones can repeatedly disrupt operations at airfields, especially in regions close to hostile borders, by forcing runways to close for safety. Naval bases and commercial ports face a similar challenge, both from low-altitude aerial platforms and from small or partially submerged objects moving close to critical infrastructure. Conventional electro-optical systems struggle with glare, reflections, haze and night conditions, while continuous video streams impose high bandwidth and operator load. INFILI is investigating how distributed neuromorphic vision and edge computing can support perimeter protection in such environments. The concept under investigation includes:

- installing a ring of four to five neuromorphic camera units or rooftop positions around an airfield or port
- configuring the optics of each unit to cover a configurable protection radius and altitude band above ground and over the water surface
- generating asynchronous event streams as soon as motion appears in each field of view and processing them locally at the edge
- fusing detections from multiple nodes to detect, track and localise targets across the protected perimeter

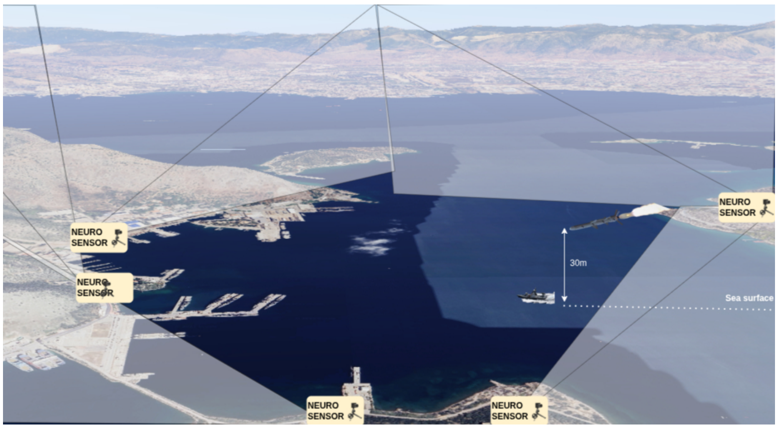


Figure 2.2: erimeter network of neuromorphic sensors around a naval port, monitoring the sea surface to detect and track small vessels and emerging surface threats.

In airfield scenarios, the neuromorphic nodes are used to:

- detect and track small UAVs and FPV drones flying close to runways, taxiways and other airport infrastructure
- provide an overview of what flies within the monitored radius beyond the normal aircraft traffic pattern In port and naval-base scenarios, the same setup is used to:
- monitor the water surface around critical infrastructure and pick up subtle motion patterns, such as the wake of very small craft, low-profile USVs, or periscope-like structures that briefly break the surface, including at night
- extend the protection envelope to low-altitude aerial targets approaching over the harbour area

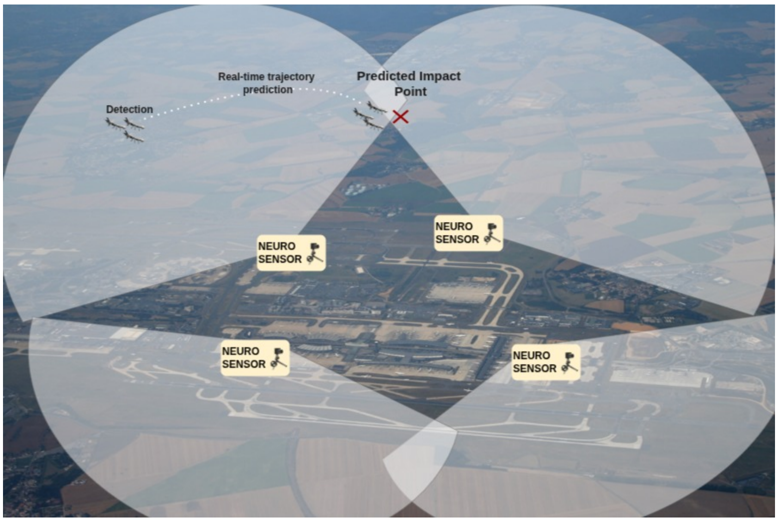


Figure 2.3: Perimeter network of neuromorphic sensors around an airfield, detecting an incoming small UAV and fusing their coverage to estimate its predicted impact point.

The research focuses on how to design and tune this distributed system: how to place and connect the sensor nodes, how to define and adjust the detection range of each camera, how to route and aggregate information between nodes under bandwidth and SWaP constraints, and how to perform multi-camera localization when different sensors see the same target from various angles.

3 Potential Extensions and Future Applications

Beyond the evaluated scenarios, the neuromorphic vision platform can be further evolved and adapted to new operational needs.

3.1 Extensions of the Current Setup (Hardware & Software)

The modular architecture supports incremental evolution of the platform along three main axes:

- multi-sensor configurations, providing panoramic, stereo or layered coverage with several neuromorphic cameras on a single platform or mast-mounted node
- hybrid payloads and form factors, where the event sensor is integrated with near-infrared or thermal channels in compact EO/IR heads, gimballed turrets or UGV/UAV modules, reusing common mechanics, power and data interfaces
- extended processing and interfaces, adding software modules for advanced event pre-processing, multi-target tracking, basic behaviour or anomaly analytics and standardised interfaces towards radar, RF and legacy EO/IR systems

These extensions move the system from standalone neuromorphic nodes towards integrated sensor elements within broader situational-awareness and command-and-control architectures.

3.2 New Application Domains

In defence and security, the same sensing principles could support, for example:

- counter-RAM and indirect-fire sensing, using neuromorphic nodes to detect and characterise very fast ballistic trajectories over short time windows
- distributed border and perimeter surveillance, deploying networks of event-based sensors along extended land or coastal boundaries to provide low-power, always-on cueing for other sensors
- platform and force protection in complex terrain, adding neuromorphic layers around vehicles, temporary bases or urban strongpoints to detect fast motion and anomalous activity close to friendly forces

In parallel, the platform can be adapted, with appropriate optics and software, to civilian domains where high-speed perception, low power consumption and robust performance in difficult lighting are important, such as:

- industrial automation and robotics, for high-speed inspection, counting of small items and monitoring of fast mechanical motion on production lines
- automotive and mobility, as a complementary low-latency, high-dynamic-range sensor for collision avoidance, low-light navigation and selected driver-monitoring functions
- smart cities and security, where always-on, low-power event cameras could support people-flow monitoring, traffic analysis and more privacy-aware surveillance concepts

These directions outline potential growth paths for the same event-based sensor core and processing stack across advanced defence applications and selected civilian markets.