	DOCTORATE	

ISAE department : Electronics, Optronics and Signal
CNES department : Optoelectronics and Detection (OED)

DEADLINE to apply: 14/03/2025

Tutoring : Aymeric Panglosse, Cédric Virmontois (CNES), Vincent Goiffon (ISAE-SUPAERO), Julien Michelot (Pyxalis)
Duration : 3 years
Start month : September 2025

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THESIS TOPIC DESCRIPTION

Ref :

Keywords: Event-based sensors, micro/nanoelectronics, semiconductor device physics, integrated CMOS devices, radiation, ionizing dose, displacement damage dose.

Title : **EVENT-BASED IMAGE SENSOR DESIGNED FOR SPACE APPLICATIONS**

A CMOS event-based image sensor, also known as an event-based camera, represents a cutting-edge imaging technology that operates differently from traditional sensors like CCDs (Charge-Coupled Devices) or conventional CMOS sensors. Rather than capturing frames at fixed intervals, an event-based sensor detects changes in a scene in real-time, pixel by pixel.

Event-based sensors are asynchronous devices inspired by the functioning of the human visual system. Each pixel operates independently and activates only when a change in light intensity surpasses a predefined threshold, generating an event that contains information such as the pixel's position, the precise timestamp, and the polarity of the light change (whether the brightness increased or decreased).

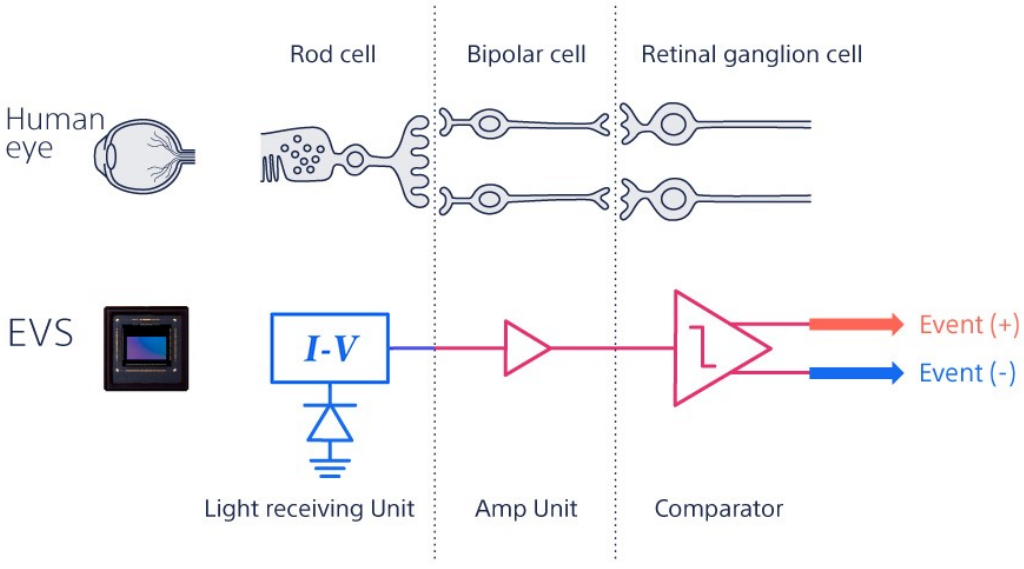

Fig. 1 – The operating principle of a pixel in an event-based vision sensor. Source: Sony.

An event-based camera can detect changes in a scene without transmitting redundant data. Pixels are no longer read at constant intervals but only when they contain useful information. The main advantages of this approach include lower power consumption, reduced data transmission, an increased dynamic range, and improved temporal response due to low latency (on the order of microseconds).

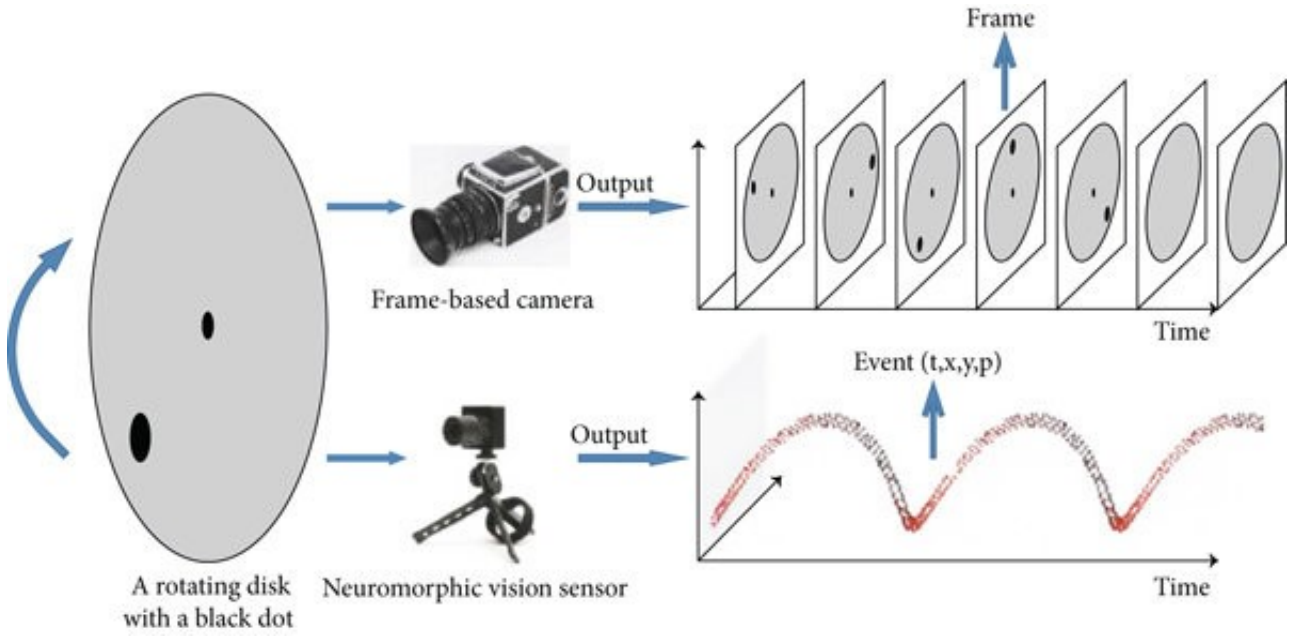

Fig. 2 - Comparison of the output of a standard frame-based and an event-based sensor when facing a rotating disk with a black dot [1].

In the space domain, potential applications of such sensors include space situational awareness (SSA), such as in-flight detection of orbital debris or spacecraft, autonomous satellite navigation for collision avoidance, or the landing of space vehicles on celestial bodies. Additionally, event-based sensors offer the potential to record high-frequency events with a suitably low bandwidth, making them ideal for observing lightning at the tops of thunderstorms and sprite phenomena, as FalconNeuro, an event-based sensor on the International Space Station, depicted hereafter.

Fig. 3 - Falcon Neuro: an event-based sensor on the International Space Station [2],[3].

This thesis will aim to analyze, design, fabricate, and test the performance of these sensors while exploring how the various pixel components, from the photodiode to the associated readout electronics, can be optimized to improve sensor performance for integration into

future space vehicles. Specifically, the research will investigate architectures that can mitigate the effects of the space environment, such as radiation. Other key areas for improvement, relevant to space applications, may include enhancing pixel sensitivity to minimal light variations while avoiding false triggers due to background noise, reducing noise to prevent false detections, and improving readout circuits in terms of energy consumption and detection speed—essential for applications like space debris detection or the observation of fast astronomical phenomena.

The candidate will need to:

- Conduct a comprehensive review of the current state-of-the-art research and technology, focusing on:
    - Different types of event-based sensors;
    - Understanding CMOS technology and its use in image sensors;
    - The components of event-based sensor pixels, from the photodiode to the integrated readout electronics;
    - The main architectures used for event-based pixels;
    - Key performance parameters of event-based sensors, such as sensitivity, background rate, latency, and dynamic range;
    - Characterization of these performance parameters;
    - Space applications using event-based sensors, such as space situational awareness (SSA);
    - The effects of radiation on semiconductors.
- Analyze, model, and simulate the sensors, particularly using Technology Computer-Aided Design (TCAD) to design and test representative test structures;
- Identify and develop techniques to mitigate parasitic effects;
- Design and fabricate test structures in CMOS technology;
- Perform electro-optical characterizations of these structures;
- Irradiate the structures with particles and flux representative of space and nuclear environments;
- Measure the performance degradation caused by radiation and analyze the effect of various test structure parameters on the extent of degradation;
- Synthesize the research findings and propose guidelines for designing event-based sensors optimized for space applications, particularly in terms of radiation resistance and other challenges related to space surveillance, navigation, and similar applications.

[1] Chen, Guang, et al. " Neuromorphic Vision Based Multivehicle Detection and Tracking for Intelligent Transportation System." (2018).

[2] Mc Reynolds 2022 – Applying Novel Event Cameras to Scientific and Space Sensing Tasks – US Air Force/ETH Zurich.
[3] McHarg 2022 - Falcon Neuro: an event-based sensor on the International Space Station – US Air Force/ETH Zurich.

CANDIDATE PROFILE

The candidate must be in the final year of a master and/or engineer diploma (or equivalent) specialized in at least one of the following topic : nano/microelectronics (conception, fabrication process) / optoelectronics / electronic imagery, detectors, semiconductor device physics / solid physics / analog and digital signal.