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Neuromorphic Approach to Micro-Particle Tracking

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Escola Tècnica Superior d'Enginyeria

About the Speaker

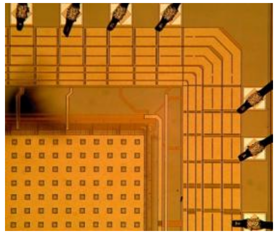
Javier Ramos is a Master's student in Electronic Engineering at the University of Valencia. He will soon be transitioning to doctoral studies in Microelectronics at the University of Valencia.

His research interest lies in SCD Cameras applied to Micro-Particle Tracking using microfluidic chips.

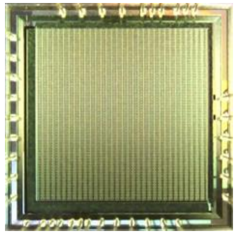
Microelectronics Design Group

IC Design and Sensors

- Event driven – Neuromorphically inspired



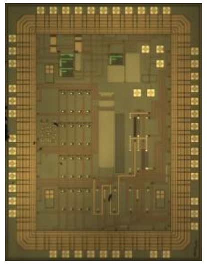
AMS035 – 32x32



TSMC180 – 64x64

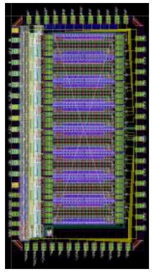
- GMR Sensors and CMOS Integration

CMOS IC current



AMS035 + GMR

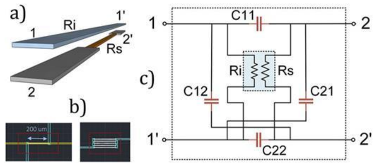
Magnetic event driven sensor

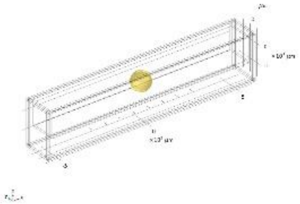


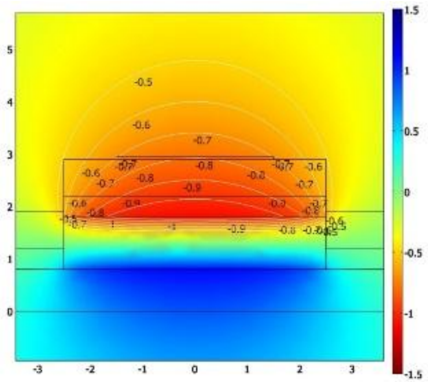
TSMC180 + GMR

Modeling and Simulation

- Device Modeling
  - Compact Electrical
  - FEM (multiphysics)
  - Thermal
  - Magnetic

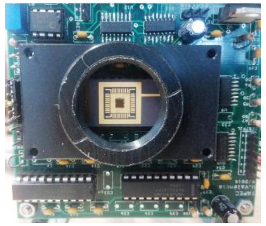






System Integration and Testing

- System Integration



Camera development

Open source mini drones

- Test and Characterization

- Noise
- Thermal
- Magnetic
- Microfluidics

LabVIEW MATLAB

Motivation & Limitations

Tracking micro-particles is essential for industrial and biotechnological activities.

The Problem:

- Frame-based cameras (CCD/CMOS) face limitations in **data generation and processing speed**.
- Furthermore, as the particle velocity increases, there is a **higher computational cost and noise sensitivity**.

The Goal:

- Implement a **neuromorphic approach** to achieve microsecond resolution with low data flow.

Event-Driven Vision Sensors

Solution proposed: Event-Driven Vision Sensors

Working Principle:

- Pixels detect luminance changes as events.
- Eliminates redundant data from static background.

Key Architectures

- **Dynamic Vision Sensor (DVS):** Works **asynchronously** detecting luminance changes as events.
- **Selective Change Driven (SCD):** Works **synchronously** selecting pixels more relevant using **WTA (Winner-Take-All)** circuit.

Key Benefits

- **100x Bandwidth Reduction** vs Frame-based Cameras.
- **Real-time analysis** without memory restriction.
- Robustness in high-velocity environments

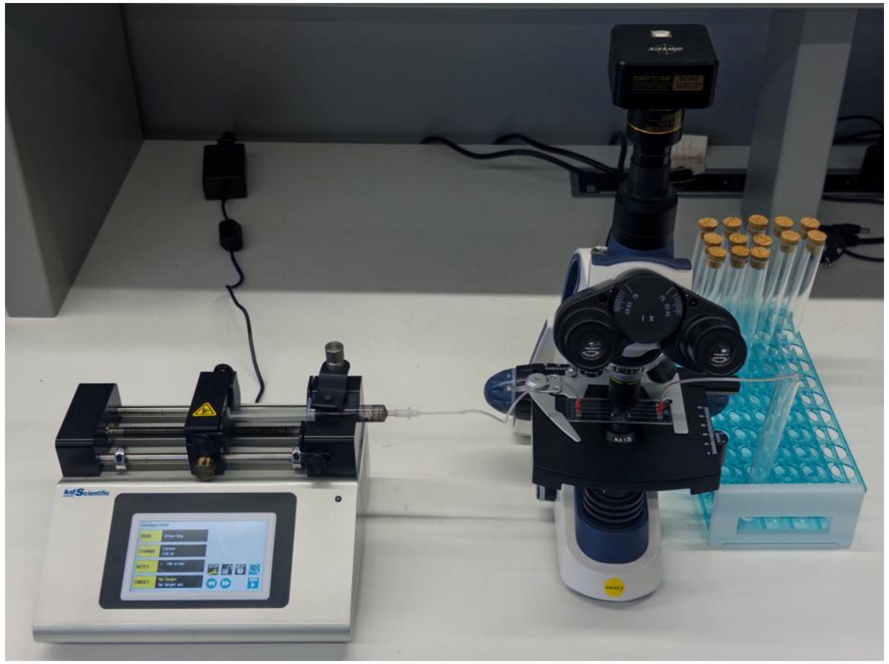
Microfluidic Experimental Setup

High Precision Flow Control: KD Scientific Legato 110 syringe pump (±0.5% accuracy).

Microfluidic Chip: Multi-channel thermoplastic chip (Fluidic 138) with four independent straight channels (1000 µm x 200 µm).

Flow Visualization: Fluorescent silica particles with a nominal diameter of 20 µm.

Optical Environment: Standard laboratory microscope with high transparency PMMA/Topas substrate for real-time visualization.



IARIA

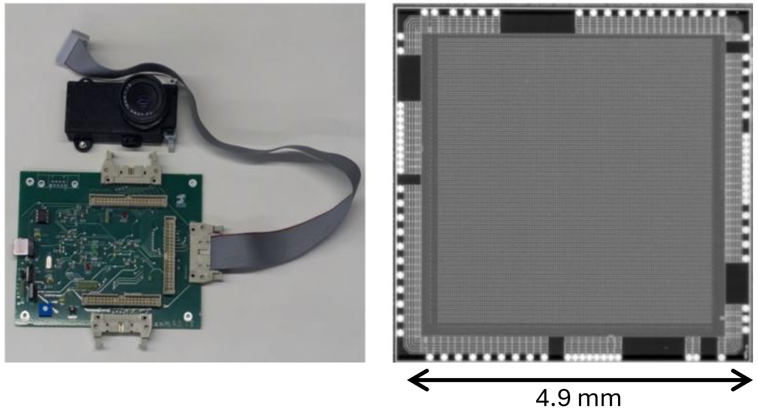
Neuromorphic Cameras Architecture

DVS Camera: 128 x 128 pixels. Individually responds to relative temporal variations of illumination.

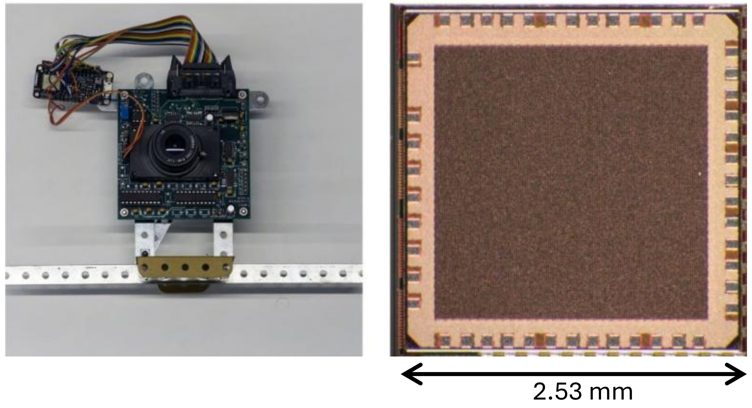
SCD Camera (64 x 64): Implemented in 180 nm CMOS technology. Features a continuous-time logarithmic photoreceptor.

SCD Camera (128 x 128): Evolution implemented in 65 nm CMOS. Includes a double parallel **WTA** circuit for enhanced velocity and ON/OFF event management.

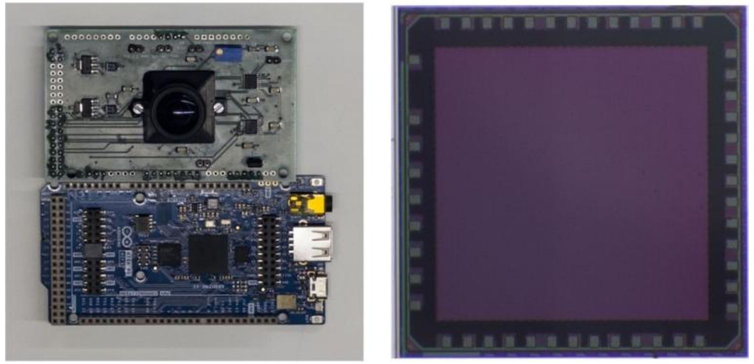
Comparison: All sensors were validated against a conventional frame-based digital camera.



DVS Camera



SCD Camera (64 x 64)



SCD Camera (128 x 128)

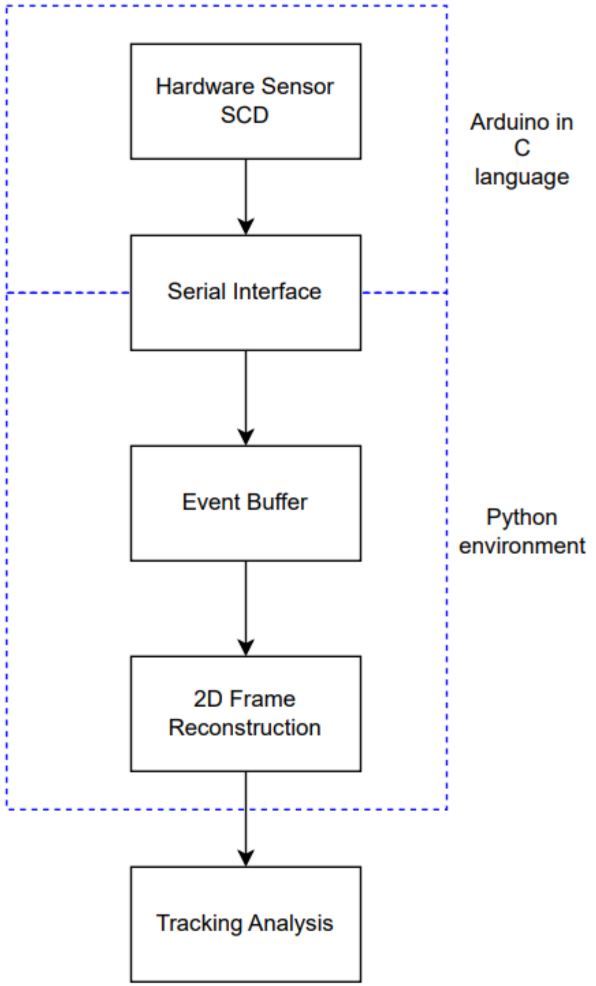
Data Processing Pipeline

Low-Level Acquisition: Event data acquisition and transmitted via a standard port connection using **Arduino (C language)** to a **PC (Python Environment)**.

Python Environment: A custom pipeline designed for receiving data events and converting them into real-time frames.

<u>**Key Stages**</u>

- **Event Buffer:** Temporary storage to handle high-speed data.
- **2D Reconstruction:** Mapping events into 2D images for tracking.
- **Tracking Analysis:** Estimation of fluid velocity and particle trajectories.



Experimental Results

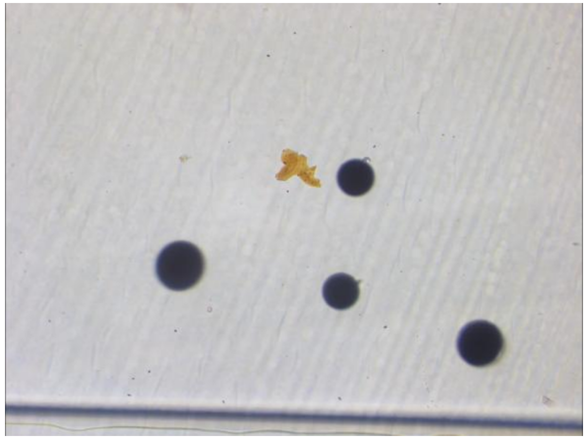
Results taken at 1.33 mm/s.

Baseline: Conventional cameras suffer from high redundancy in static backgrounds.

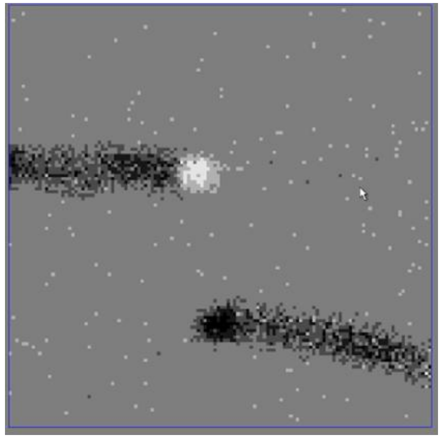
DVS Advantage: Purely movement-based information extraction with no data overhead.

SCD Performance: Validated efficacy of continous-time photoreceptors.

Resolution: 128x128 SCD camera provides the highest spatial detail and noise inmunity.

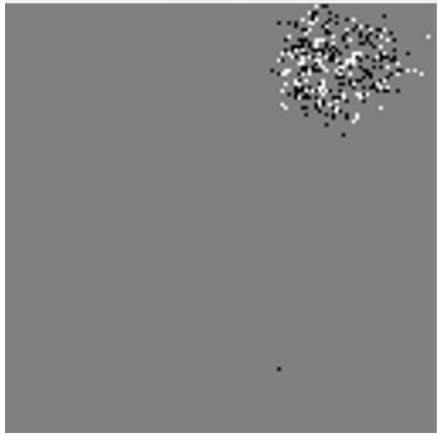


Conventional Camera



DVS Camera

SCD Camera (64 x 64)



SCD Camera (128 x 128)

Conclusions & Future Work

Conclusions

- Successful tracking at **1.33 mm/s** using event-based vision.
- Drastic reduction in data overhead compared to conventional cameras.
- Validation of **SCD 128x128** as a robust tool for micro-particle monitoring.

Future Research

- Performance qualification across different architectures.
- Optimization for **velocimetry algorithms.**
- Scaling to higher particle velocities and concentrations.

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