AKADEMIA GÓRNICZO-HUTNICZA
IM. STANISŁAWA STASZICA W KRAKOWIE
AGH UNIVERSITY OF KRAKOW

High-Performance Computing for Event Cameras: DIF Filtering and Graph Convolutional Networks for Object Classification

Konferencja Użytkowników Komputerów Dużej Mocy 2025

Marcin Kowalczyk, Kamil Jeziorek, Tomasz Kryjak, Marek Gorgoń
Embedded Vision Systems Group
Computer Vision Laboratory
Department of Automatic Control and Robotics
EAIiIB Faculty
AGH University of Kraków, Poland

PLGrid Grants

Data Processing and Algorithm Evaluation for Dynamic Vision Sensors
Marcin Kowalczyk

Deep Neural Networks for Event and Image data processing
Kamil Jeziorek

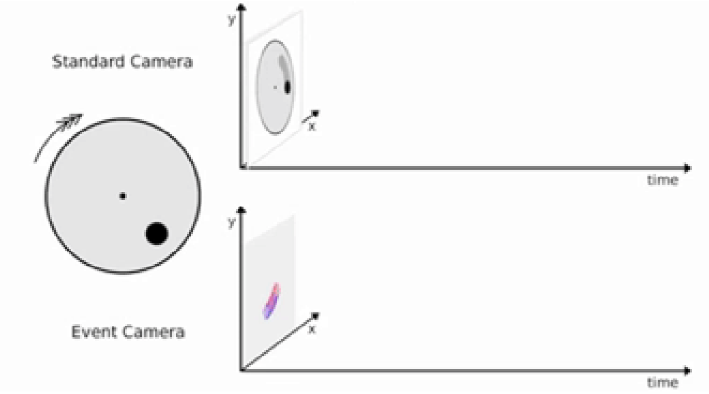
Introduction to Dynamic Vision Sensors

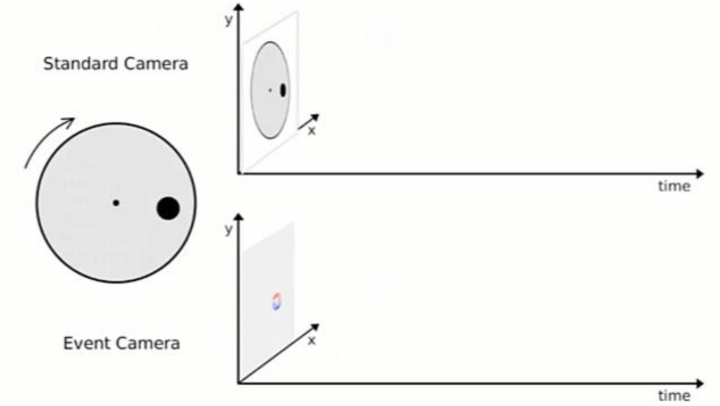
- What are **event cameras**?
- Event generation:

$$|logI(t) - logI(t-\Delta t)| > C$$

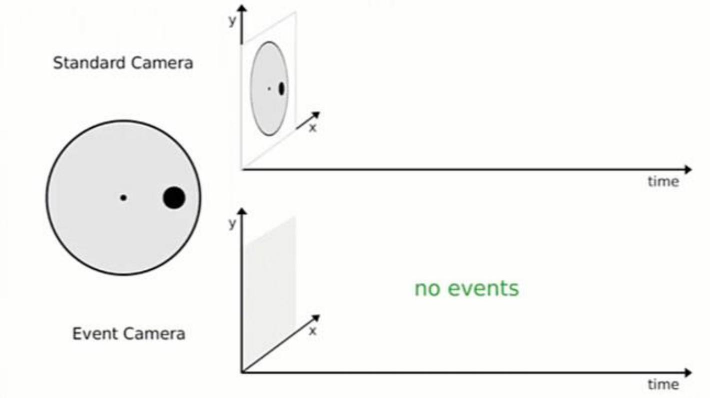
- Event:

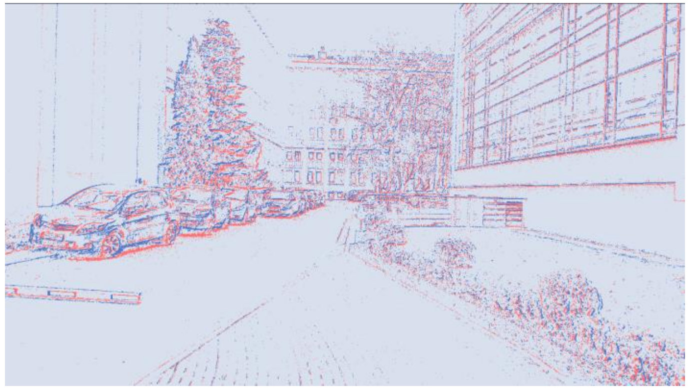
$$E = \{t, (x,y), sign(\frac{dI(x,y)}{dt})\}$$





Kim, H., Leutenegger, S., & Davison, A. J. (2016). Real-time 3D reconstruction and 6-DoF tracking with an event camera.

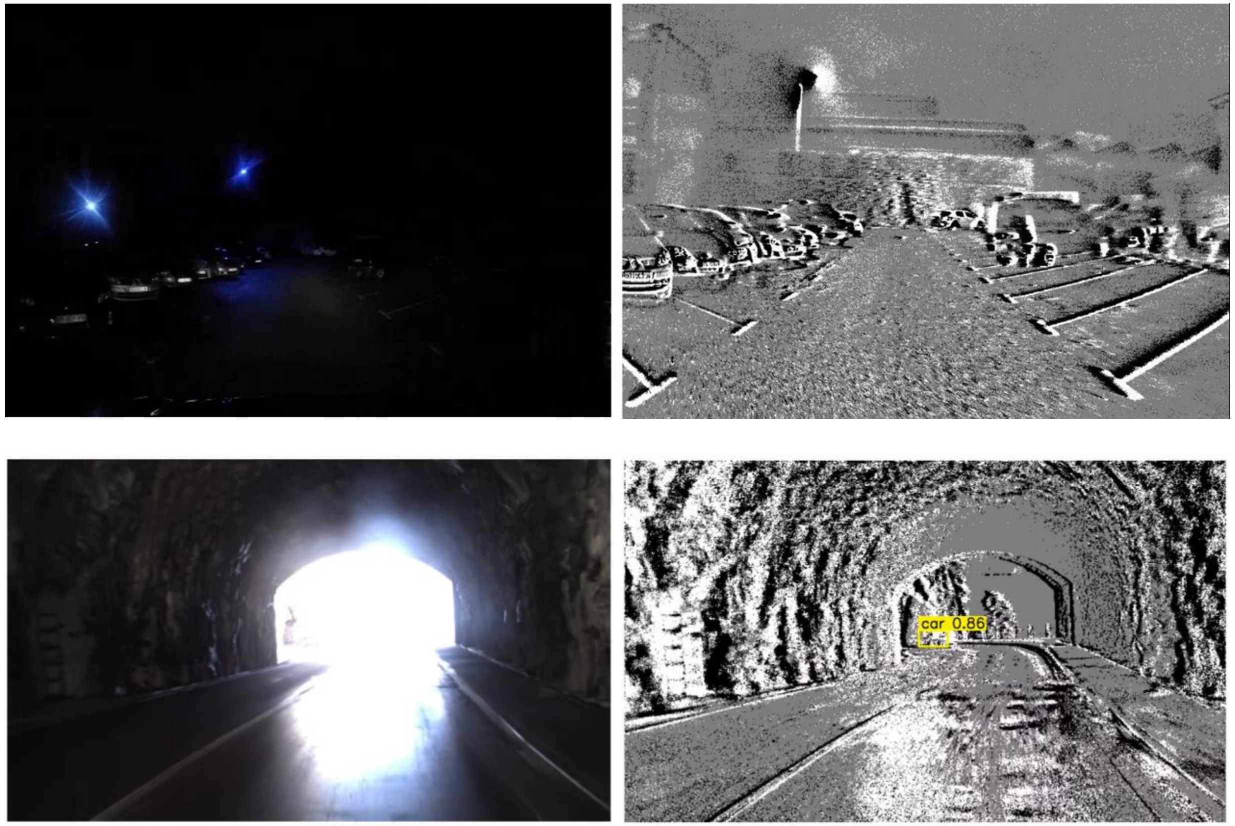




Introduction to Dynamic Vision Sensors

Advantages:

- **High temporal resolution**
- **Low latency**
- **High dynamic range (120 dB)**
- **Reduction of redundant data**
- **Low power**

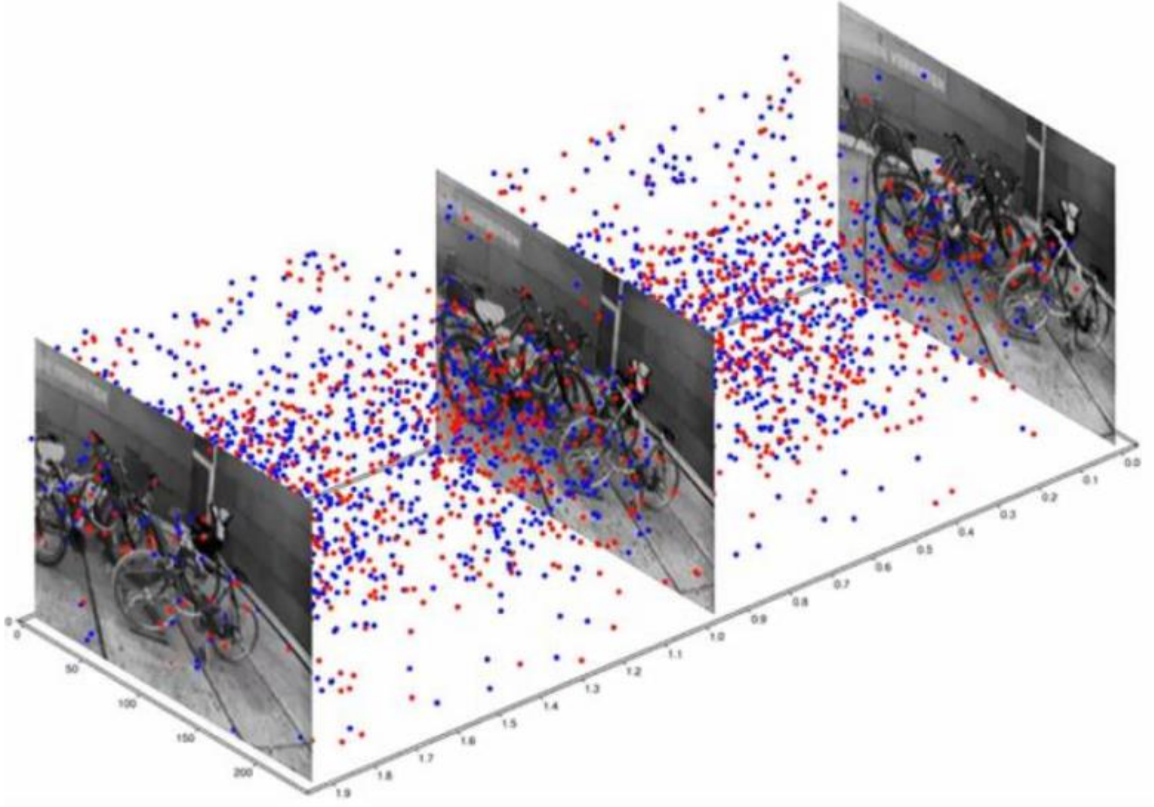


Source: *M. Gehrig, D. Scaramuzza "Recurrent Vision Transformers for Object Detection with Event Cameras" IEEE Conference on Computer Vision and Pattern Recognition (CVPR), Vancouver, 2023*

Introduction to Dynamic Vision Sensors

Challenges:

- Sparse space-time point cloud
- No “absolute” brightness
- Susceptible to noise
- Low resolution
- High cost and limited availability

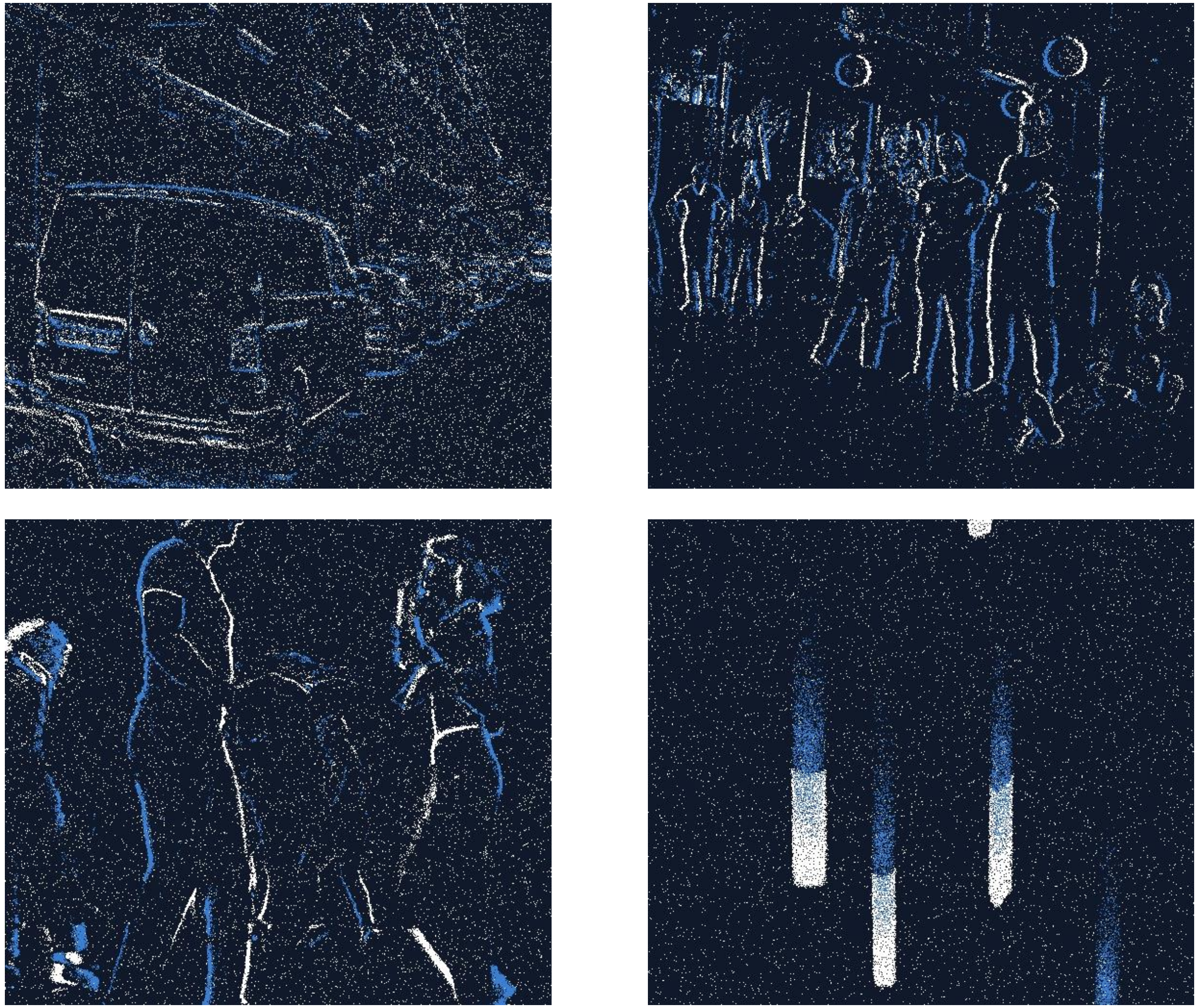


Source*: D. Scaramuzza "Tutorial on Event-based Cameras", ETH Zurich, University of Zurich*

Description of the problem

Event data filtering:

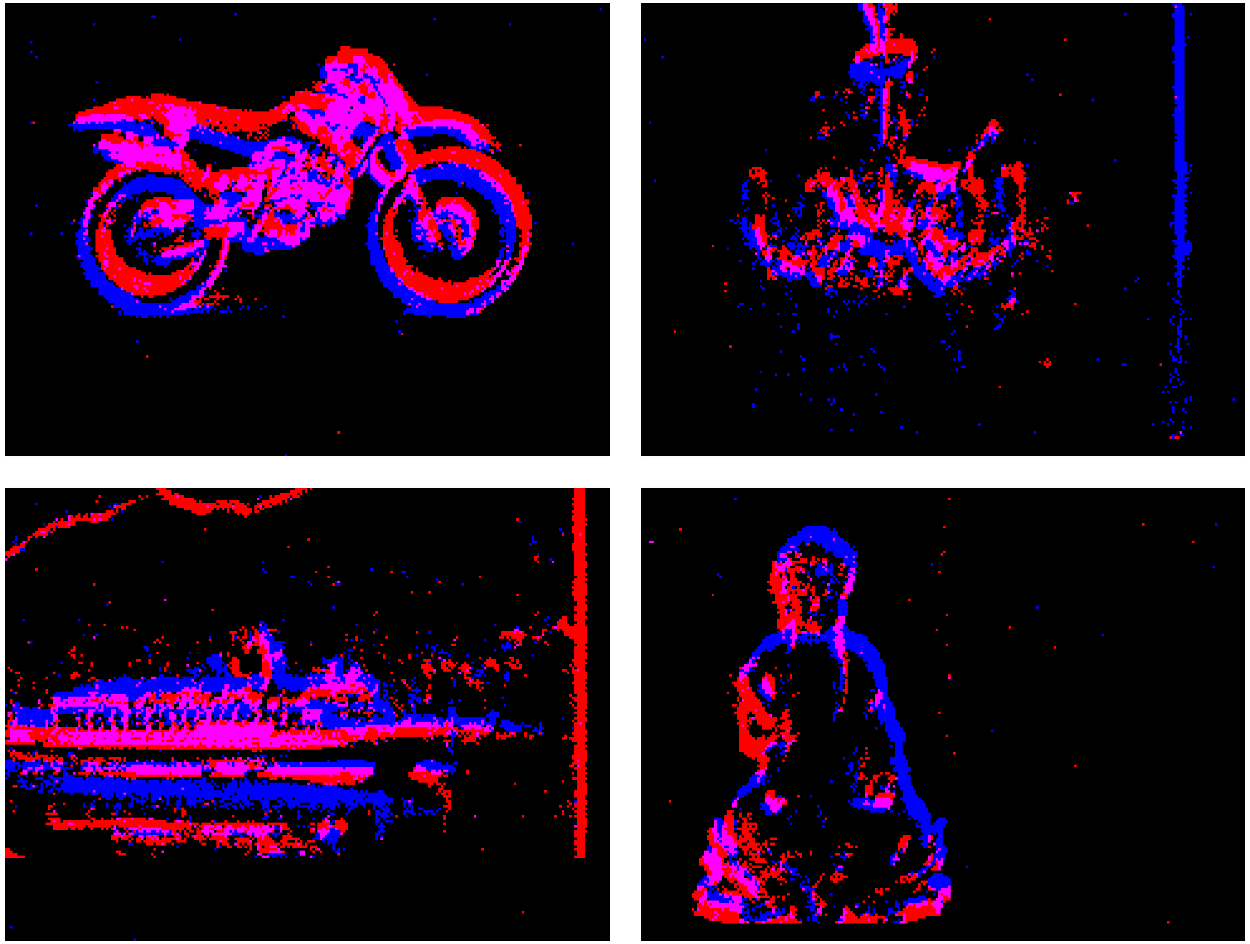
- Noisy event data
- High throughput
- Large datasets
- Algorithms evaluation
- FPGA resources
- Low-memory



Description of the problem

Object classification:

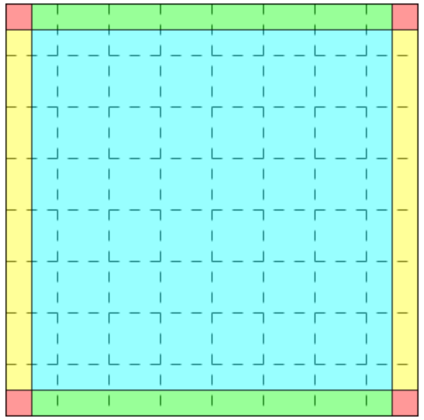
- Event representation
- High throughput
- Large datasets
- Architectures evaluation
- Training
- Inference

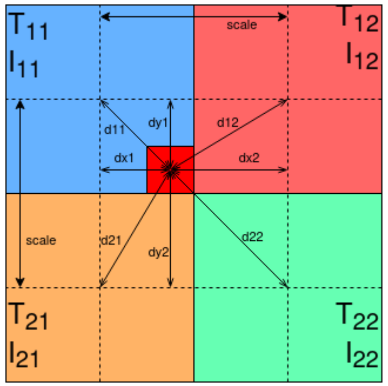


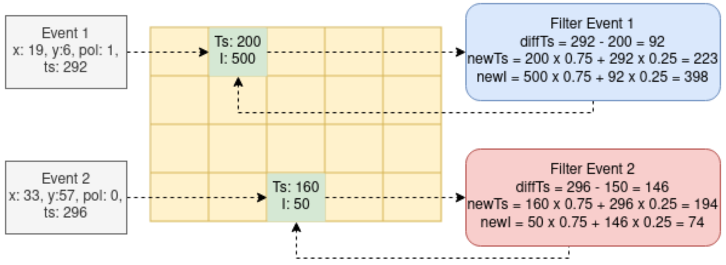
Distance-based Interpolation with Frequency Weights

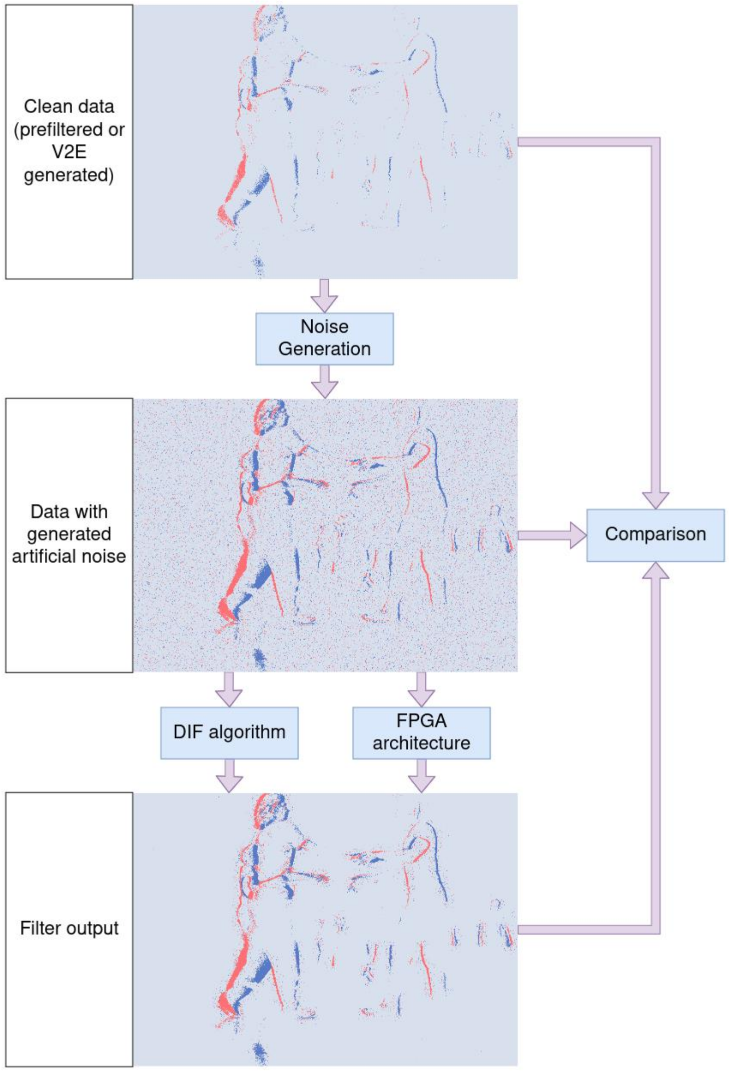
Algorithm:

- sensor subareas
- timestamp and interval filtering
- interpolation of features between subareas





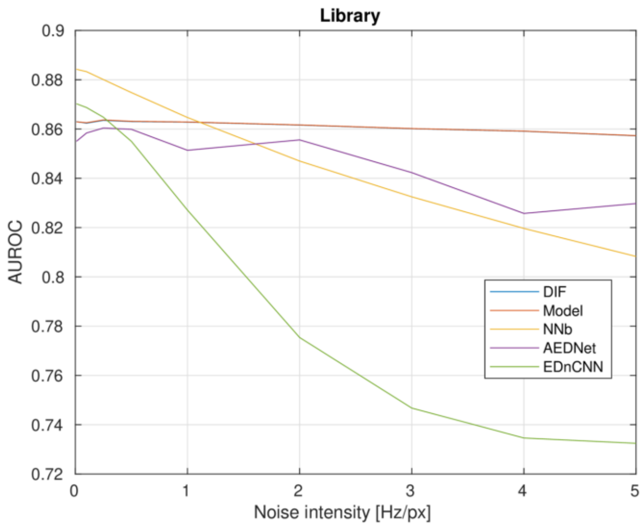


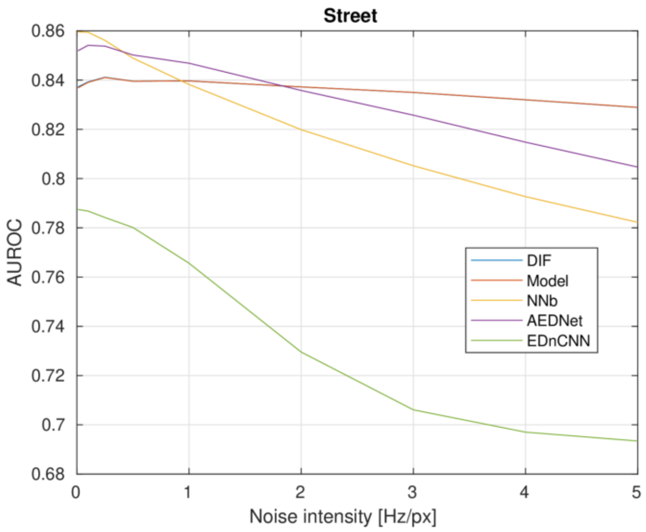


Distance-based Interpolation with Frequency Weights

Results:

- 445 MEPS
- 1280 x 720 resolution
- AUROC comparison
- Noise generation algorithm
- Different noise intensities





1. Kowalczyk, Marcin, and Tomasz Kryjak. "Hardware architecture for high throughput event visual data filtering with matrix of IIR filters algorithm." *2022 25th Euromicro Conference on Digital System Design (DSD)*. IEEE, 2022.
2. Kowalczyk, Marcin, and Tomasz Kryjak. "Interpolation-Based Event Visual Data Filtering Algorithms." *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshop*. 2023.
3. Kowalczyk, Marcin, and Tomasz Kryjak “High Throughput Event Filtering: The Interpolation-based DIF Algorithm Hardware Architecture” - in Review

Distance-based Interpolation with Frequency Weights

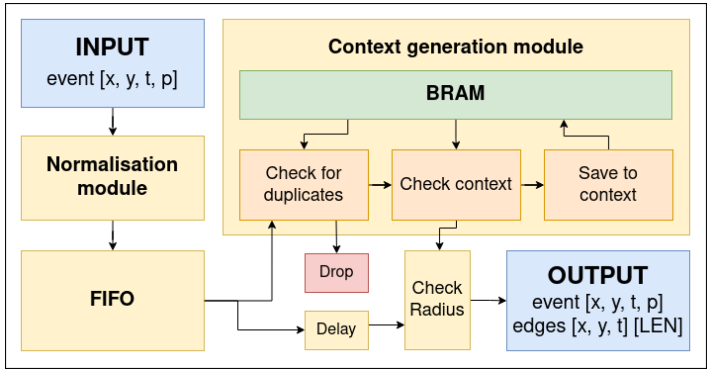
Tools used:

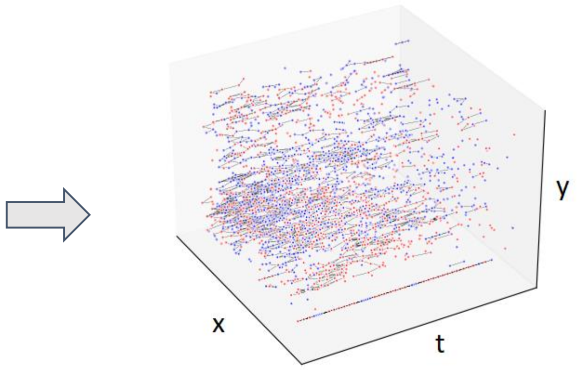
- **V2E** (Athena)
- **Apptainer** & **Metavision**, C++ (Ares)
- **MATLAB** (Ares & Athena)
- **Python** & **PyTorch** (Athena)

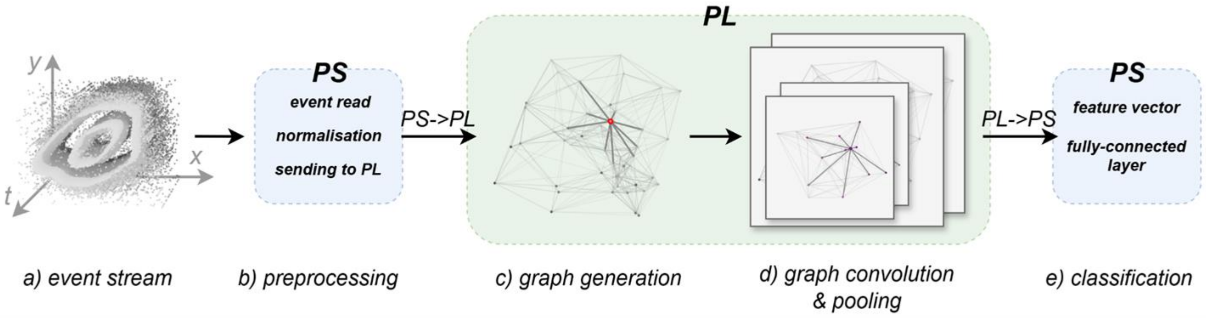
Graph Convolutional Networks for Object Classification

Algorithm:

- hardware-aware graph generation module
- graph max pool operations for complexity reduction
- evaluation on variety of datasets for vision and audio events





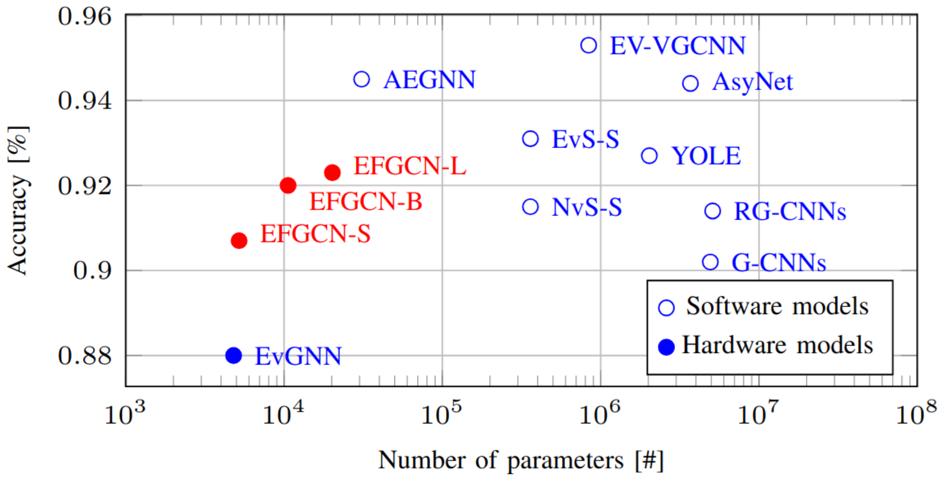


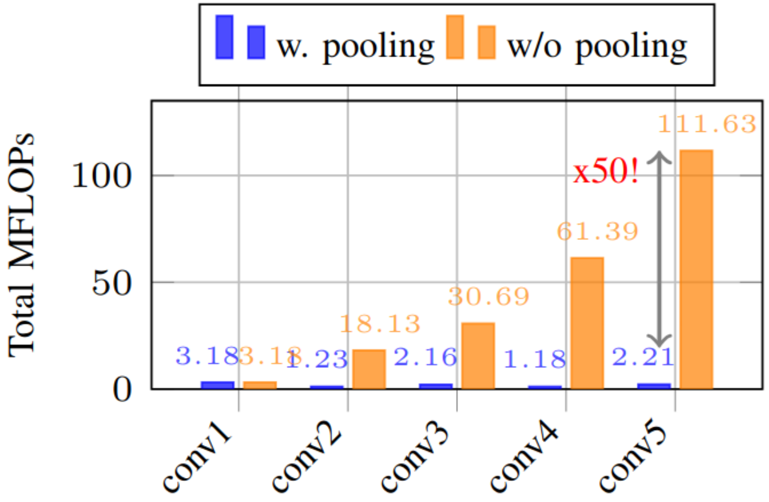
1. Jeziorek, Kamil, and, Pinna, Andrea, and, Kryjak, Tomasz, “Memory-efficient graph convolutional networks for object classification and detection with event cameras”. In *2023 Signal Processing: Algorithms, Architectures, Arrangements, and Applications (SPA)* (pp. 160-165). IEEE.
2. Jeziorek, Kamil, et. al. “Optimising graph representation for hardware implementation of graph convolutional networks for event-based vision”. In *International Workshop on Design and Architecture for Signal and Image Processing* (pp. 110-122). Cham: Springer Nature Switzerland.
3. Jeziorek, Kamil, et. al. Embedded graph convolutional networks for real-time event data processing on soc fpgas. *arXiv preprint arXiv:2406.07318*.
4. Wzorek, Piotr, etl. al. Increasing the scalability of graph convolution for FPGA-implemented event-based vision. *International Conference on Field Programmable Technology (FPT), PhD Forum*
5. Nakano, Hiroshi, et. al. Hardware-Accelerated Event-Graph Neural Networks for Low-Latency Time-Series Classification on SoC FPGA. *International Symposium on Applied Reconfigurable Computing (ARC)*

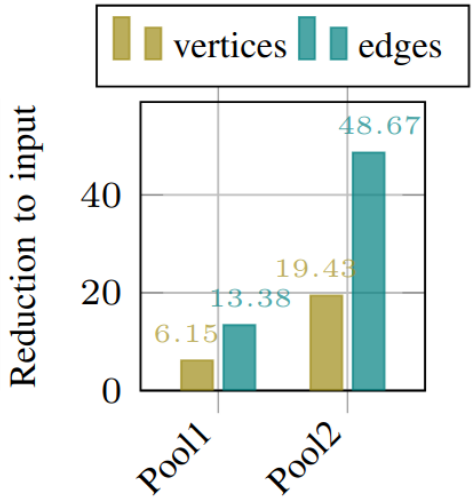
Graph Convolutional Networks for Object Classification

Results:

- 13.3 MEPS
- 50 times reduction in FLOPs for last convolution
- reduction in graph representation size
- accuracy similar to non-hardware models







Graph Convolutional Networks for Object Classification

Tools used:

- **Python** & **PyTorch** & **PyTorch Geometric** for model implementation
- **Conda** for environment
- **C++** with **Pybind11** for graph generation
- **PyTorch Lightning** for model wrapper with **W&B** for tracking model

Acknowledgements

This research has been supported by the National Science Centre project no. 2021/41/N/ST6/03915 (first author). The numerical experiment was possible through computing allocation on the Prometheus system at ACC Cyfronet AGH under the grants PLG/2023/016388 and PLG/2023/016897.

Thank you for your attention !!!

Marcin Kowalczyk
Embedded Vision Systems Research Group

kowalczyk@agh.edu.pl

Computer Vision Laboratory AGH | LinkedIn