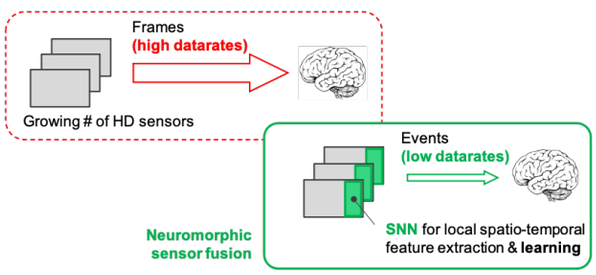
Boosting next level sensor fusion through event-based neural networks: a new generation of neuromorphic AI hardware

Tomorrow's sensor systems are facing serious challenges. Whether they drive perception for robots, drones, and self-driving cars, the rising number of sensors leads to ever increasing amounts of data, while the processing neural networks (NN) increase in complexity as well. And as sensors are becoming ever-more powerful and faster, and have higher resolutions, this data flood will become even more overwhelming. However, spatio-temporal features need to be calculated on the edge to allow for quick and reliable decisions, increasing compute requirements and thus power consumption and cost. Despite progress in machine-learning algorithms and hardware, massive amounts of raw sensor data still must be shuttled around and processed once they leave the sensor. IMEC is investigating new flexible neural network architectures and hardware implementations that exploit both event and NN weight sparsity to enable new extremely low latency and low power implementations.

In this collaborative R&D program, imec addresses this issue by integration of event-based neural feature extraction and sensor fusion on next-gen sensor and compute platforms directly. As a result, only relevant features are sent downstream as opposed to the full raw sensor data. To do so, imec is building sensor fusion systems that emulate aspects of event-based data processing and knowledge building. Using event-based, hybrid and spiking neural networks (SNN), imec is developing a new generation of neuromorphic AI algorithms and hardware with very short response times and low energy consumption, while not sacrificing accuracy.

In its new program, imec approaches the challenge by first developing event based NN algorithms for real-world datasets, and then hardwiring these algorithms in neuromorphic hardware. For the latter, we focus on digital implementations in commercially available CMOS technology that can be quickly implemented using industry standard tool flows. For the longer term, we also study mixed-signal solutions and emerging memory technologies to further boost performance.

Together with industrial partners we enable next generation perception and sensor fusion systems with these technologies, significantly reducing latency and power consumption.



Extreme edge AI for efficient sensor fusion

A successful proof of concept

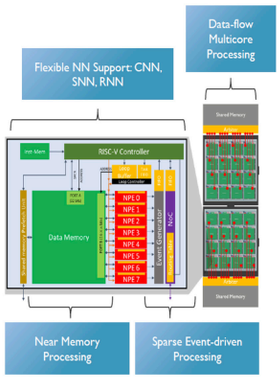
In 2020, we've first proven the feasibility of event based NN processing with a digital spiking neural networks (SNN) chip to process, among others, radar signals. The chip mimics the way groups of biological neurons operate to recognize temporal patterns. With this chip, we have demonstrated that micro-Doppler radar signatures can be classified using only 70µW of power. For ECG sensors, we have even shown it to work with a mere 13µW. SNNs like these would therefore also be ideal to empower a new generation of wearables, insertable, and even ingestible.

Towards on-chip deep fusion of camera-radar-LiDAR for AGVs, robotics and intelligent spaces

Our second-generation event-based NN sensor fusion HW/SW architecture (see Figure 2) targets smart, low-power perception systems for AGVs, robots, drones, cobots, autonomous driving etc.

These new perception systems will identify approaching objects in a complex, dynamic environment in a matter of milliseconds so that, for example, the robot or drone can react in time.

In addition, HW/SW approaches like these could also be used to create intelligent, context-aware spaces. And when scaled, they could boost autonomous driving, where the problem of sensor data overload is acute.



Gen2 HW (ASIC 22nm*)
Target Specs

- 32 Core + NoC
- 2Mb SRAM per core
- 2x32Mb shared memory
- 500 MHz
- <0.5 mm2 per core (16mm2 overall)
- Energy per SOp <2.8 pJ
- Effective SOp per Watt >4.5T
- Effective SOp/sec per Core >20G
- Effective >1.3 TOPs

*For test chip, IP can be easily ported to other nodes (digital).
** Effective operations assumes 90% activation sparsity

The second generation event-based NN sensor fusion processing chip (target specs for illustration)

Highlights

- Event-based neural networks, mimicking biology as engineering principle ("neuromorphic")
- Co-designing of task datasets, algorithms, and hardware
- Training algorithms for spiking neural networks – accuracy on par with deep learning but with a potentially 100x lower energy consumption
- Digital event-based, hybrid and spiking neural networks – optimized sync/async architecture

Applications

- Adding more powerful perception and sensing to:
  - AGVs, drones, rovers, Industry 4.0 platforms, autonomous vehicles, traffic infrastructure
- Medical sensors, heart, and brain monitoring, wearables, and ingestible
- Imagers, sonars, radars, lidars...
- Smart spaces sensors
- Extreme edge computing
- Radar target classification based on micro-Doppler
- Sensor data pre-processing and fusion

Design targets

- Multicore, with fully connected cores
- Sparse synapse connectivity between cores
- Memory/compute optimization

What imec offers

- Leader in process technology and system co- optimization
- Leader in sensor technology R&D, e.g,. radar and LiDAR
- In-house R&D, from design over modeling to actual prototyping
- Collaborative R&D
- Project-based development on demand, from idea to prototype
- IP licensing
- Specialty components development with road to volume fabrication

Looking for collaboration with

- Sensor system developers and vendors
- Application builders
- System integrators
- Fabless chip / sensor manufacturers: ISP, Vision SoC, radar, LiDAR, AI processor...etc.

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