LEASARD

Low-Energy deep neural networks for Autonomous Search-And-Rescue Drones

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LEASARD website

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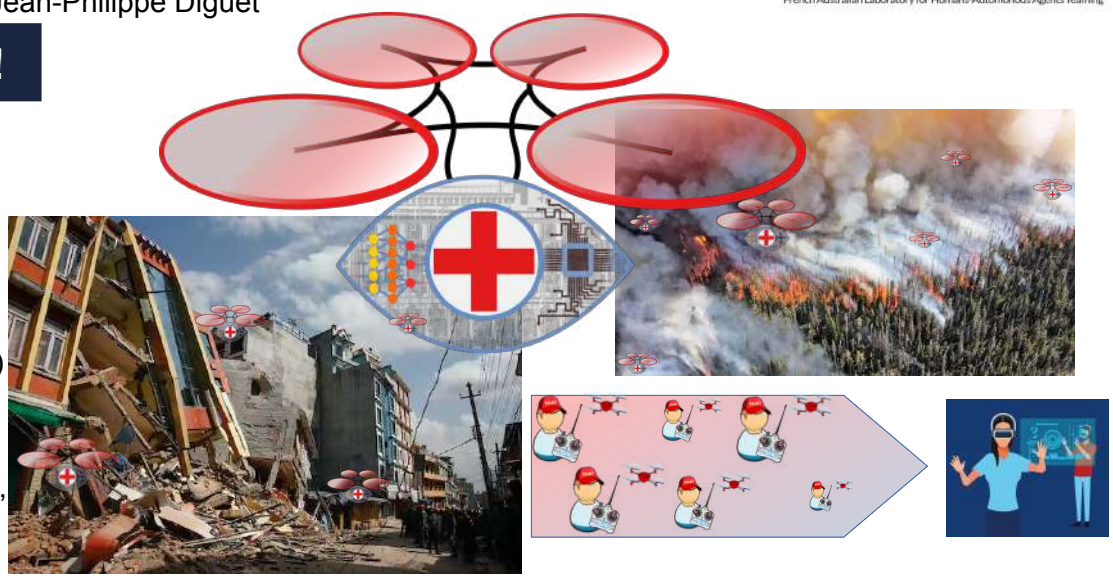
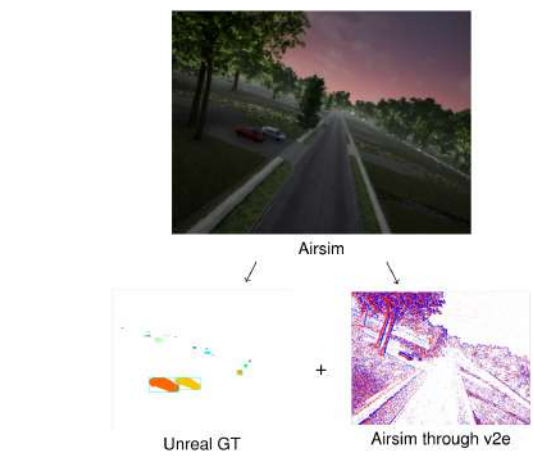
SAR missions need drones with more autonomy !

- Why ? To operate in unstructured and hostile environments during **many hours over a wide area**
  - no (stable) network access + no GNSS-based positioning,
  - excessive energy cost of a live video feed to a human operator,
  - one drone = one operator : too limiting !
- How ? With **smart artificial vision**
  - navigation autonomy (obstacle-avoidance, object-tracking, SLAM, etc.)
  - best in class : **Deep Neural Networks**
- But ? **The energy bottleneck : need for efficiency !**
  - heavy processing requires energy, but motors consume a lot also, need for an optimal trade-off !
  - resources are strongly limited in embedded systems !



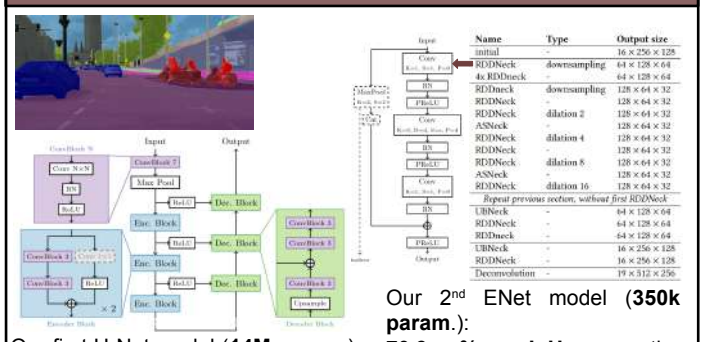
Results

On-demand event-based datasets for UAVs thanks to a simulated environment



Framework validated by training an event-based YOLOv7 model, published at ERF 2024.

DNNs on FPGA: RGB semantic segmentation and event-based detection

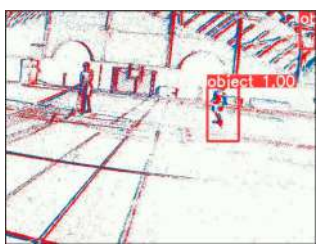


Our first U-Net model (**14M param.**): **62.9 % mIoU** on the Cityscapes dataset with a 4-bit integers, **23 FPS** and **44 ms** latency on Alveo U250. Presented at IEEE ICECS 2023. https://github.com/hleblevec/finn-semseg

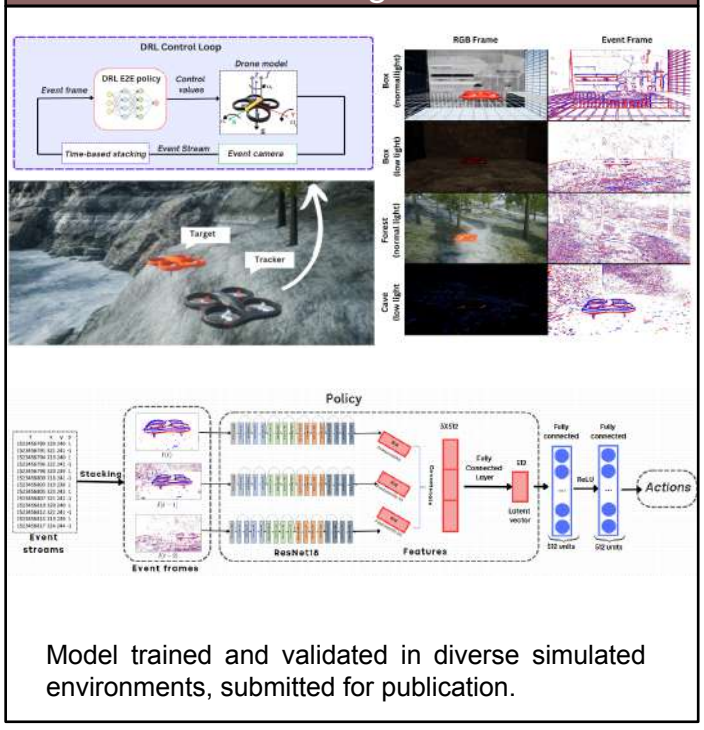
Our 2nd ENet model (**350k param.**): **70.3 % mIoU** on the Cityscapes dataset with 4-bit integers, **226 FPS** and **4.2 ms** latency, and **6.8W** peak power consumption (measured) on an AMD ZU19EG. Submitted for publication.

YOLOv5m (21M param.) tested on the **Jetson Orin Nano** (emb. GPU):
- trained on DSEC-MOD, quantized on 8 bits,
- **at most 14FPS**, not the best choice for SAR applications

TinyYOLOv3 (8M param., 13 conv layers) on a **modest** Pynq Z1 **FPGA** (FINN+BREVITAS)
- **50ms of latency, 18FPS** @100MHz with 8-bit quantization (to be reduced).

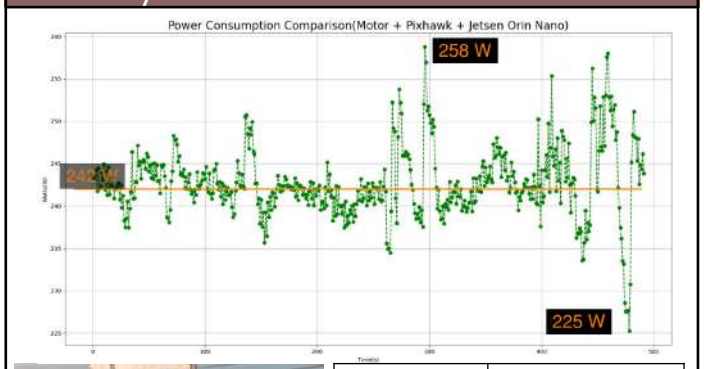


Event-based control: UAV Object Tracking based on Deep Reinforcement Learning



Model trained and validated in diverse simulated environments, submitted for publication.

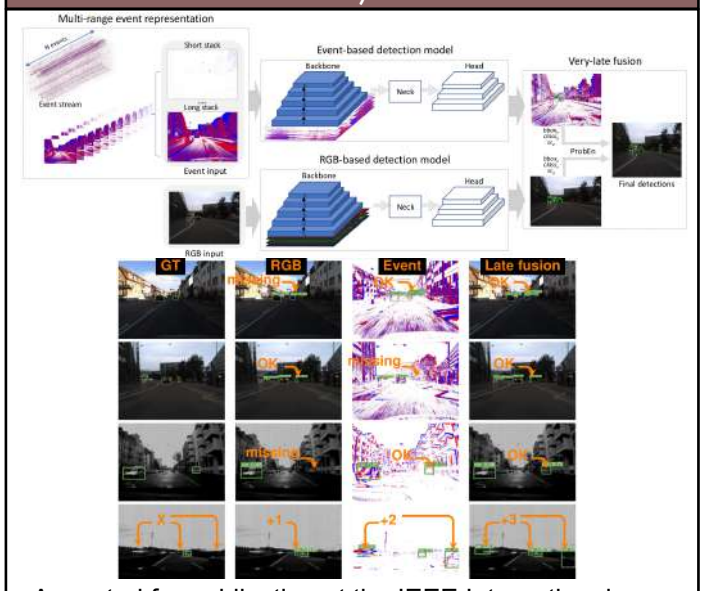
UAV platform: What about the power consumption of the whole system ?



Our quad-copter prototype based on :
- Crazy2fly frame
- Pixhawk flight controller
- Nvidia Jetson Orin Nano (on-board computer)

Measurement	Av. Power Consumption (W) of the emb. GPU
Camera off	4.139
Camera on	4.146
Visualization on	5.790
YOLOv5 on	9.404

Event-RGB sensor fusion: State of the art on two datasets (DSEC-MOD and PKU-DDD17)



Accepted for publication at the IEEE International Conference on Robotic Computing 2024

What next ?

- Maintain our simulated environment
- Add Hardware-in-the-loop (**HIL**) to our simulations
- Embed **event-based YOLOv3-5-7** on our UAV
- Evaluate **event-based semantic segmentation**
- Design a **rich end-to-end control chain for the UAV**
- Test in **complex environments** (forest, caves, destroyed buildings)
- Contribute to **an ANR project (2023-27)** CITI / ENSTA/ Lab-STICC/ LS2N/ ONERA

Publications

- Hugo Le Blevec, Mathieu Léonardon, Hugo Tessier, Matthieu Arzel. Pipelined Architecture for a Semantic Segmentation Neural Network on FPGA. IEEE 30th International Conference on Electronics, Circuits and Systems, Dec 2023,(hal-04262138v2)
- Ismail Amessegher, Hajer Fradi, Clémence Liard, Jean-Philippe Diguet, Panagiotis Papadakis, Matthieu Arzel.. Simulating Aerial Event-based Environment: Application to Car Detection. European Robotics Forum 2024, Mar. (hal-04497648)
- Hajer Fradi, Panagiotis Papadakis. Advancing Object Detection for Autonomous Vehicles via General Purpose Event-RGB Fusion. Accepted for publication at the IEEE International Conference on Robotic Computing 2024. (hal-04746439)
- Ala Souissi, Hajer Fradi, Panagiotis Papadakis. Leveraging Event Streams with Deep Reinforcement Learning for End-to-End UAV Tracking. Submitted for publication, 2024. (hal-04714734)
- Hugo Le Blevec, Mathieu Léonardon, Stefan Weithoffer, Matthieu Arzel. FPGA-Oriented Design Space Exploration of a Real-Time Road Scene Semantic Segmentation Deep Neural Network. Submitted for publication, 2024.