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XXXVII Cycle

Visual Navigation: from frame-based cameras to neuromorphic sensing

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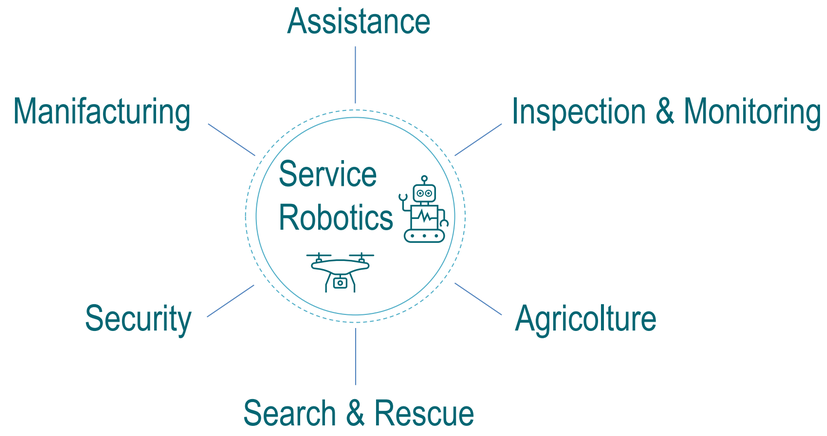
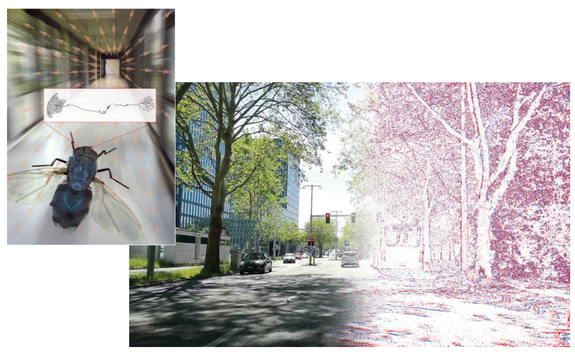
Research context and motivation

- A **robotic platform** can be defined **autonomous** if it is able, without human intervention, to **effectively navigate in known or unknown environments**, to **build a map of the scene** and to **localize itself** in it. **Service robotics** is a growing research area whose main **goal** is to **develop autonomous robots capable** of **helping people** in doing complex, dangerous and fatiguing tasks to finally improve the quality of their every-day life.



- **Neuromorphic approaches** are a huge source of inspiration for developing **navigation strategies** which are **faster, more lighweight and more efficient**.



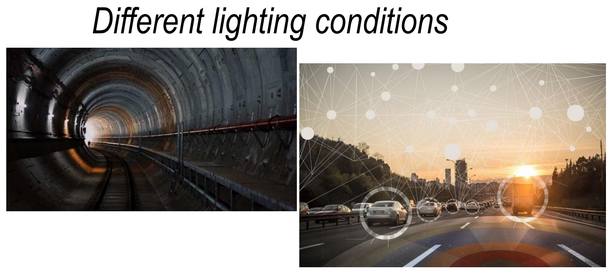
Sight is one of the main abilities that animals and humans use to **perceive the environment**. In robotics, **visual information** can be acquired with frame-based cameras and then processed to extract bio-inspired **visual cues**, or by vision sensors in which the **acquisition process is neuromorphic**.

Addressed research questions/problems

- In robotics, autonomous navigation is a very challenging aspect and there are still **open problems to be addressed**.

Crowded environment

Different lighting conditions



- The introduction of **event-based cameras,** novel sensors whose working principle is bio-inspired, could help solving some of the still open problems. In these vision sensors **each pixel** works in logarithmic scale and it **indipendently sends an event** every time it detects a **brightness change in the scene**.

- The **advantages** are **multiple:**
  - **High dynamic range** (120dB)
  - **Small time resolution (microsecond)**
  - **Very fast motion detection**
  - **No redundant information**
  - **Reduction** of the **power consumption**

Collaborations

- **Alba Robot**: development of an algorithm to perform the entrance and the exit from an elevator with an autonomous wheelchair.
- **Intesa San Paolo Innovation Centre**: development of a navigation strategy for an air sanitizing autonomous robot that should operate in the meeting rooms of *Grattacielo San Paolo*.

Submitted and published works

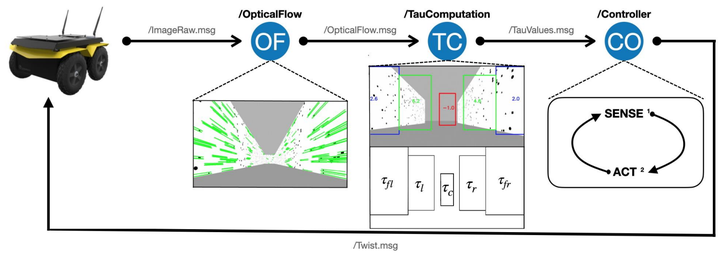
- Boretti, C. , Bich, P., Zhang Y. and Baillieul, J., "*Visual Navigation Using Sparse Optical Flow and Time-to-Transit* ", in IEEE International Conference on Robotics and Automation (ICRA), Philadelphia, May 23-27, 2022, pp. 9397-9403.

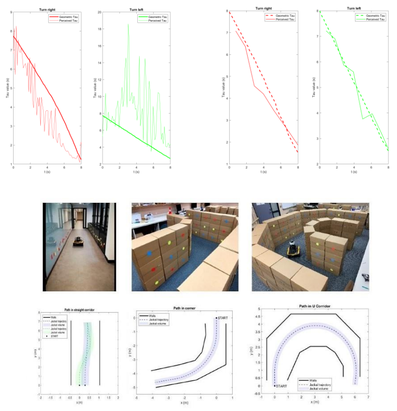
Novel contributions

- Development of a **control pipeline** based on **bio-inspired visual cues, time-to-transit (tau)**, to navigate in unknown environments. The entire algorithm has been **tested** on a **real platform** proving the effectiveness of the control strategy.
- Development of a **detection pipeline** in which **streams of events**, organized as Time-Ordered Recent Events (**TORE**) volumes, are given as **input to a standard object detection neural network**. This type of input allows the **detection of fast moving objects (pedestrians)** both **in day and in night light conditions**.

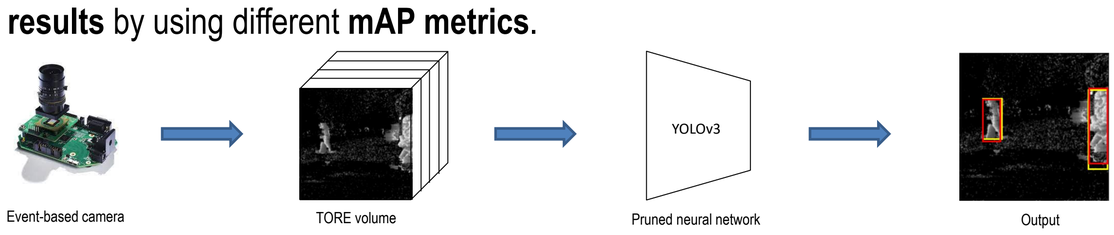
Adopted methodologies

➢ From **keypoints**, tracked in subsequent frames, and thanks to a **Sense-Act cycle**, tau values are correctly computed. Then the **control strategies (tau balancing and the single wall strategy)** which rely on these bio-inspired visual cues are applied to navigate.





➢ The **object detection pipeline** is composed of three main steps: **collect the events in TORE volumes**, **provide the volumes to YOLOv3 neural network, evaluate the results** by using different **mAP metrics**.



Dataset	mAP@50	mAP@75	mAP[0.5:0.05:0.95]
Complete 1 Megapixel Dataset (cars + pedestrians)	48.3 %	30.9 %	28.6 %
Reduced 1 Megapixel Dataset (pedestrians)	53.3 %	14.7 %	23.1 %

Future work

- **Improve the robustness of the control algorithm** based on frame-based cameras and time-to-transit values.
- **Prune the object detection neural network** to make the entire pipeline more efficient and a suitable candidate to be **deployed on constrained hardware**.
- Exploit the **pedestrian detection results** to develop a **navigation algorithm** which leverage event-based inputs. The algorithm should **operate in different lighting conditions** and the goal should be to **follow a person and/or to avoid moving obstacles** in a fast and effective way.

List of attended classes

- 01QTEIU – Data mining concepts and algorithms (03/02/2022, 4 credits)
- 02QUBRS – Statistical data processing (04/02/2022, 4 credits)
- 01UJUIU – Human-Ai Interaction (09/02/2022, 4 credits)
- 01UJBRV – Adversarial training of neural networks (06/06/2022, 3 credits)
- 01SCSIU – Machine learning for pattern recognition (22/07/2022, 4 credits)
- 01DNMIU – Optimized execution of neural networks at the edge (02/08/2022, 5 credits)
- 01SYBRV – Research integrity (06/12/2021, 1 credit)
- 01UNXRV – Thinking out of the box (17/12/2021, 1 credit)
- 01UNYRV – Personal branding (20/12/2021, 1 credit)
- 01RISRV – Public speaking (21/12/2021, 1credit)
- 01SWQRV – Responsible research and innovation, the impact on social challenges (24/12/2022, 1 credit)
- 01SHMRV – Entrepreneurial Finance (28/02/2022, 3 credit)
- 01UNXRV – The new Internet Society: entering the black-box of digital innovations (28/02/2022, credits)
- 01QORRV – Writing Scientific Papers in English (24/03/2022, credits)

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