Robotics & Mechatronics research team (REMIX)
Smart Systems & Networks
XLIM institute -- UMR CNRS 7252

Enactive perception and control of Autonomous Robotic Systems

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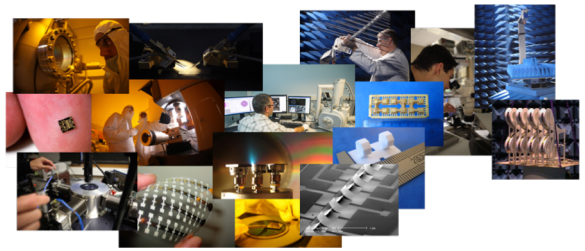
ouiddad.labbani-igbida@xlim.fr

XLIM *A multidisciplinary research institute*

465 > **243** + **222**

members — PhD & Research Fellows — Permanent staff

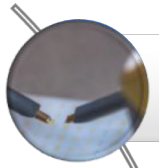


2 *Technology platforms*

6 *Joint labs with industrials*

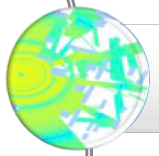
6 RESEARCH AXES

22 RESEARCH TEAMS

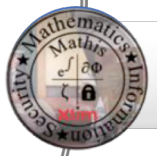


RF-Systems, Antennas, microwave circuits

RF and printed electronics for telecom and energy



Smart systems and networks — REMIX — RUBIH — SYCOMOR



Mathematics and information security

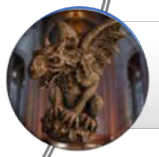


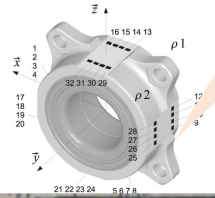
Image synthesis and analysis

Fibered photonics and coherent sources

REMIX research team: main skills…

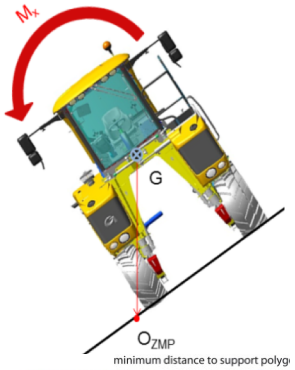
From systems to **Systems of systems…**

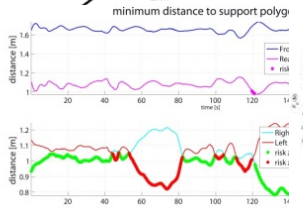
Model estimation, control

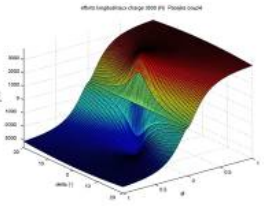


Set intervals modelling for **hybrid** data **fusion**

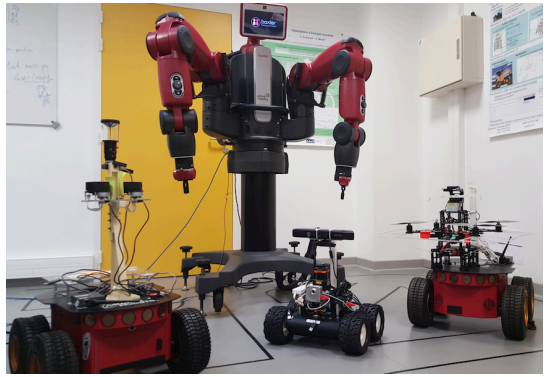
Dynamic vehicle modelling and risk estimation





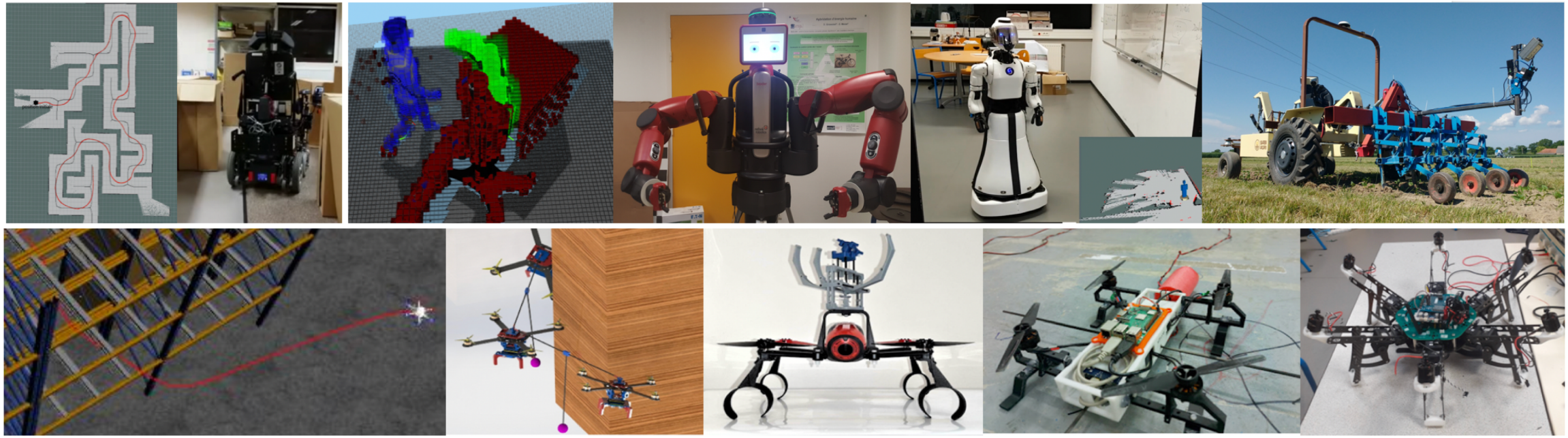


Perception, heterogeneous **cooperative** systems

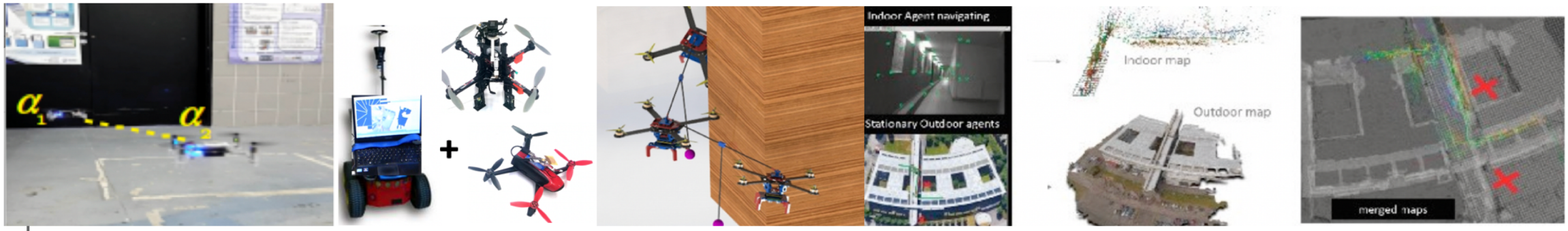


Overview of REMIX research activities

- **Enactive perception** and navigation of Autonomous Robotic Systems within complex environments



- **Cooperative heterogeneous MRS:** localization, control, exploration, mapping, interactivity...



Enactive perception: Autonomous navigation in unknown/uncertain environments

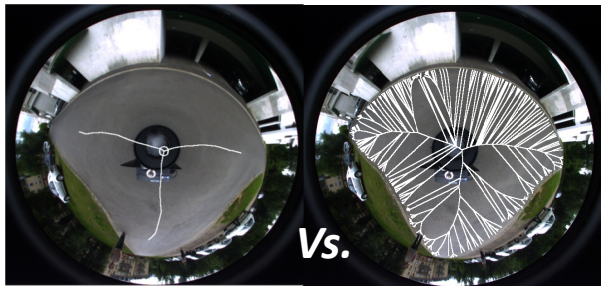
- Model a constitutive autonomy by supporting a form of autonomous sensorimotor contingencies through interaction with the environment

→ Consider the whole chain: from sensory input data to motion control

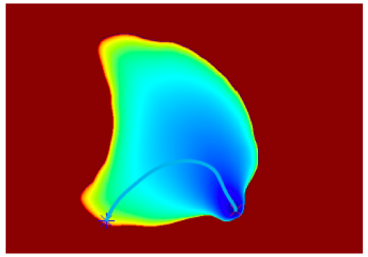
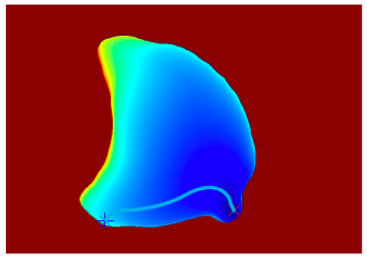
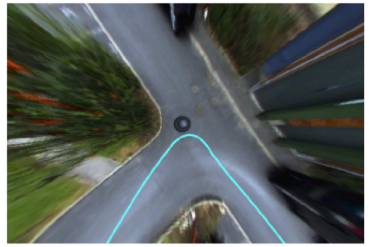
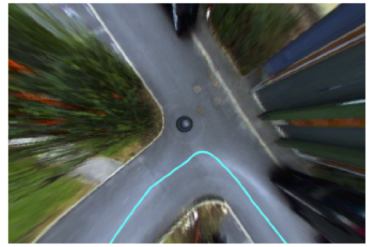
- Freespace detection (active contour propagation) [Merveilleux et al. 2013]



- Distance transform, free-space skeletonization (Delta-Medial Axis) [Marie et al. 2016, 2018]

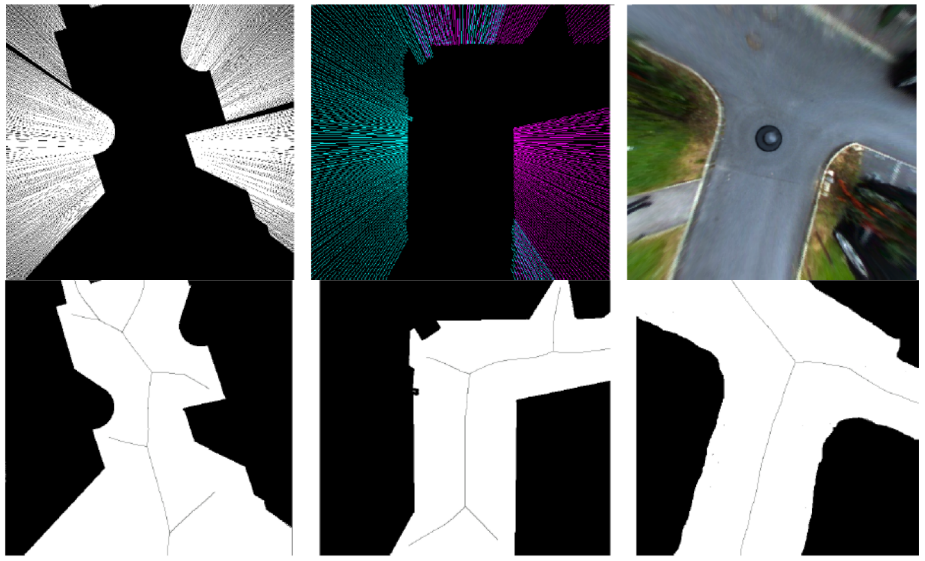



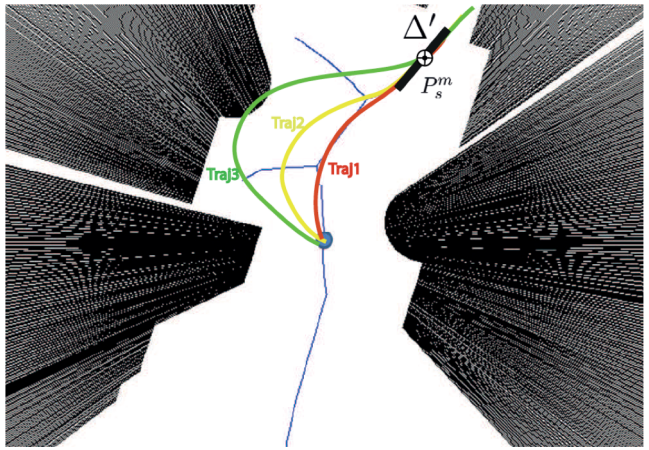
- Riemannian distance transform and geodesic path planning [Aziz et al. 2018, 2019]

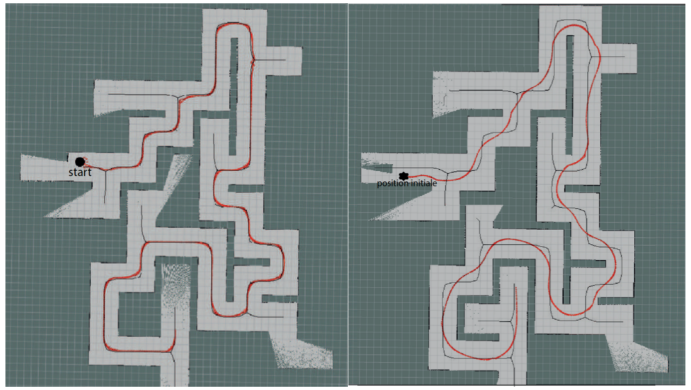
Enactive perception: Autonomous navigation in unknown/uncertain environments

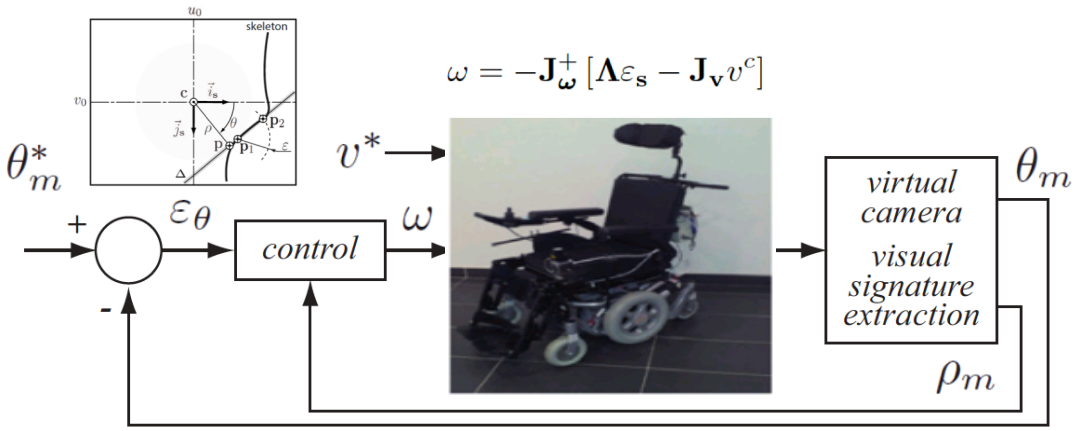
- Skeleton-based visual servoing in unknown environments





- Safety distance monitoring and velocity adaptation



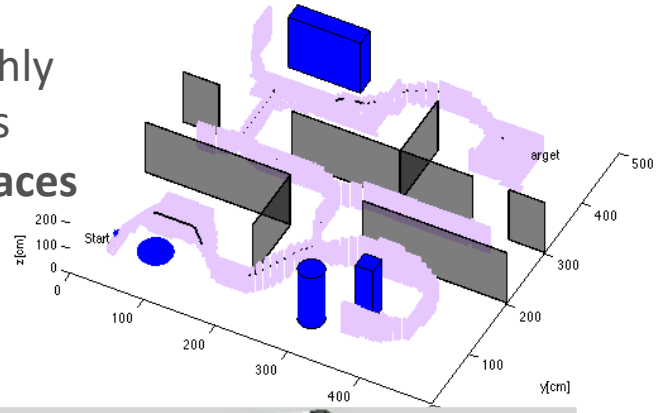


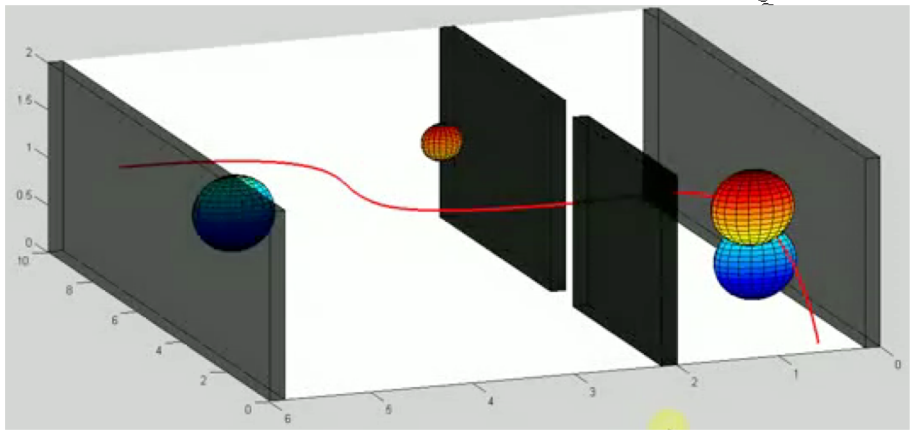
[BenSaid et al. 2017, 2018]

Enactive perception: Autonomous navigation in unknown/uncertain environments

➢ 3D path/trajectory planning and autonomous navigation of **aerial systems**

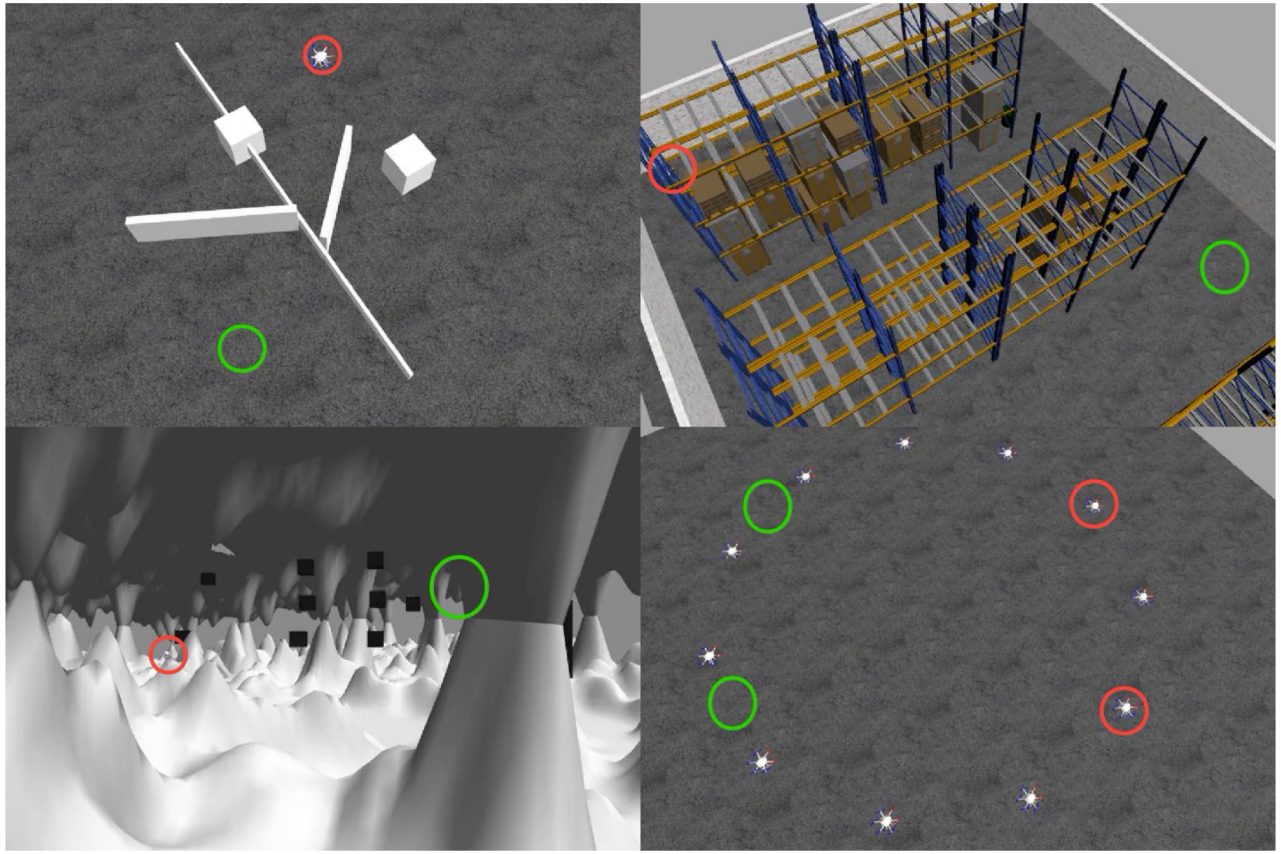
→ Path planning in highly cluttered environments using **2D skeleton-surfaces**





[Benzaid et al. 2017, 2018]

→ Autonomous flight and motion planning/control in dynamic environments (under UAV dynamics and safety constraint)

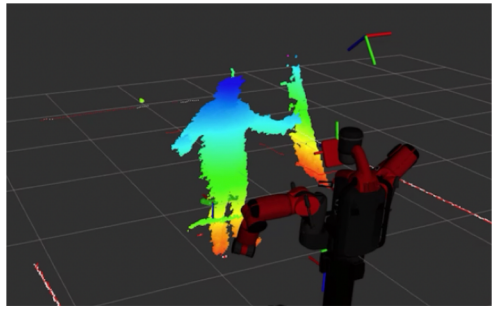


[Margraff et al., 2020]

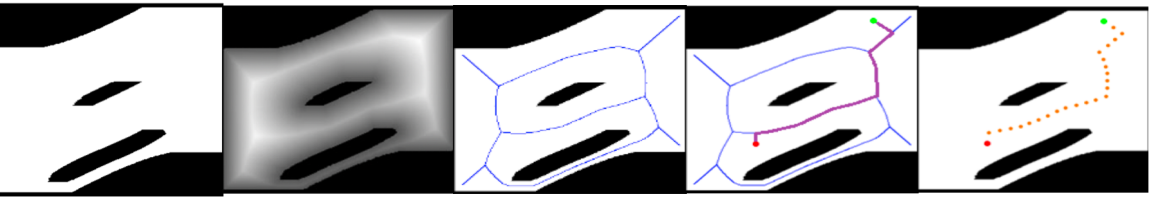
Enactive perception: Autonomous navigation in unknown/uncertain environments

➢ 3D safe path/trajectory planning of **cobotic systems**

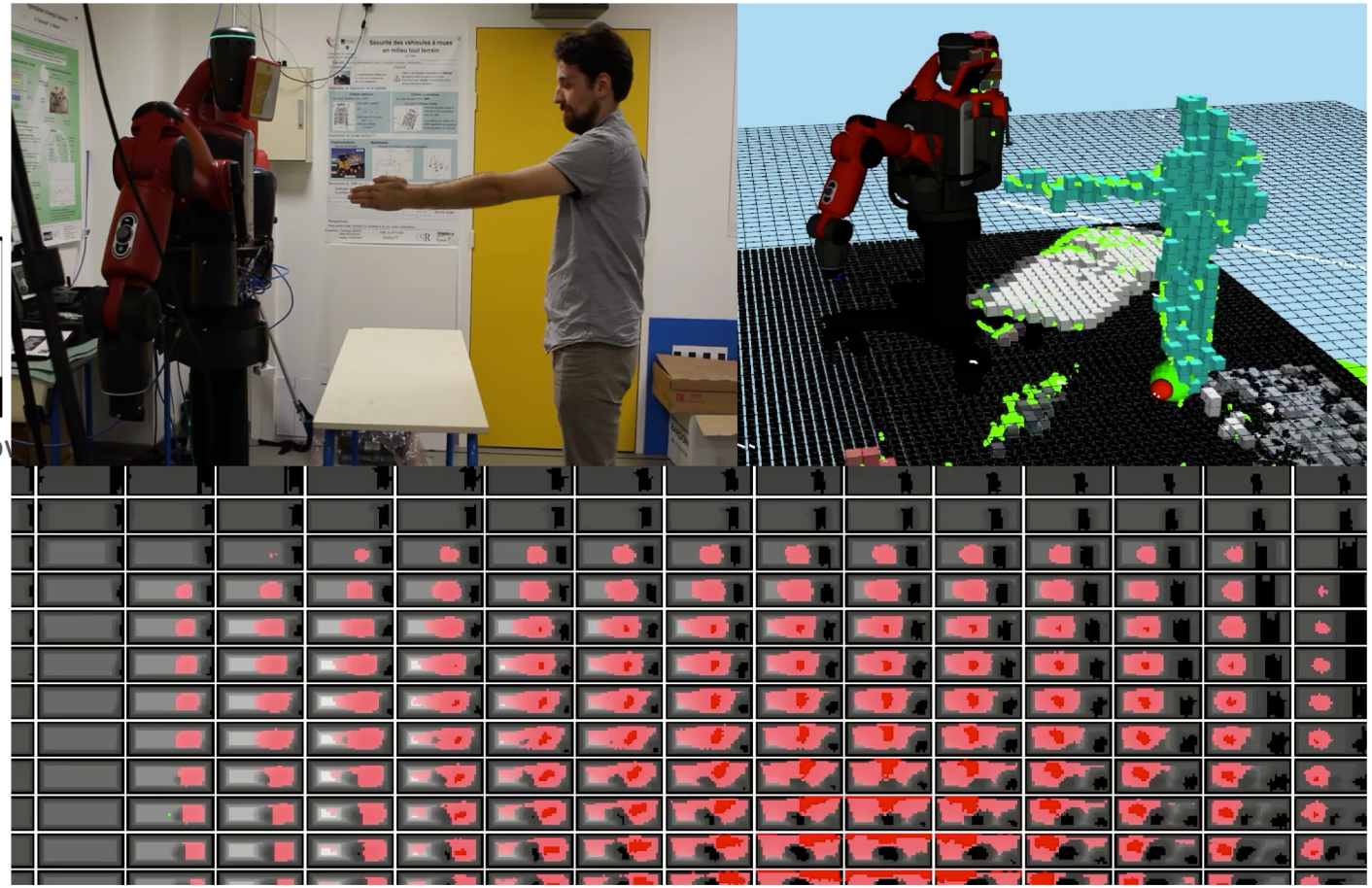
→ **Real-time 3D perception**

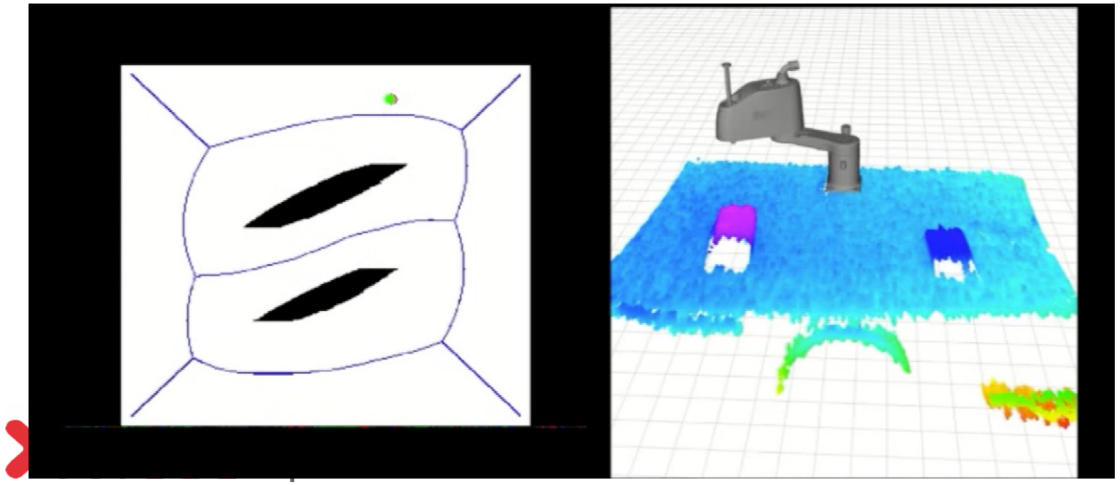


→ **Skeleton-based** planning in the **configuration space**



2d C-space | Distance transf. | DMA skeleton | Path planning | Trajectory follo

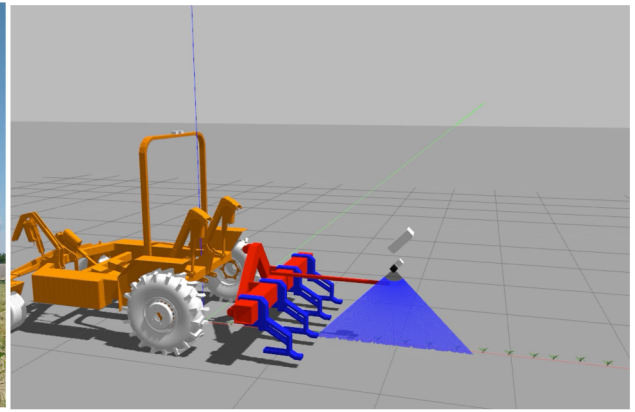




[Fuseiller et al., 2018, 2019]

Enactive perception: Autonomous navigation in unknown/uncertain environments

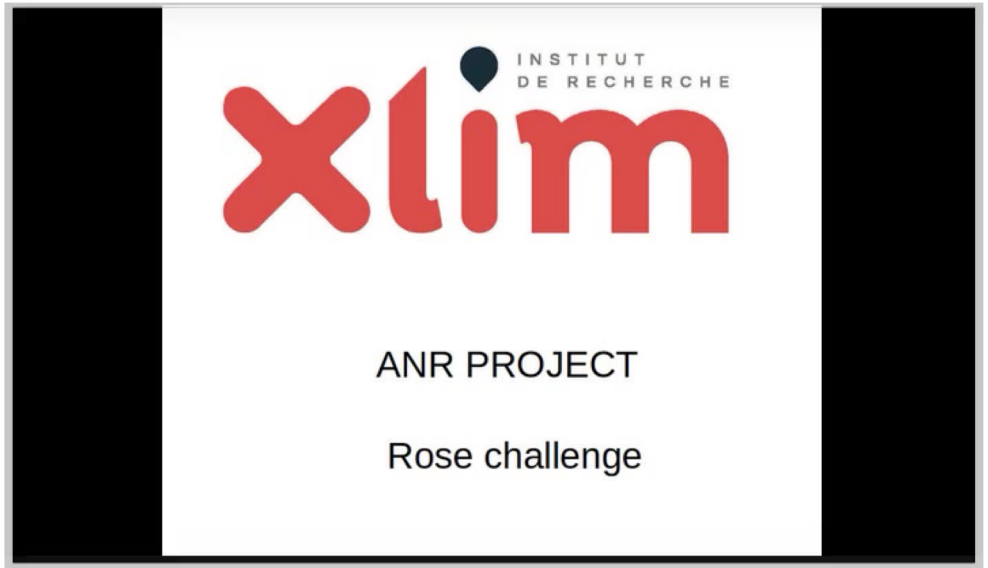
- Ongoing projects
  - *Autonomous weeding*
  - *HR interactivity*



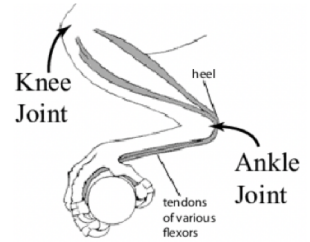
PEAD [ANR project, 2018]

Platform agnostic solution for robotics in agriculture

ARROW [NA project, 2018]

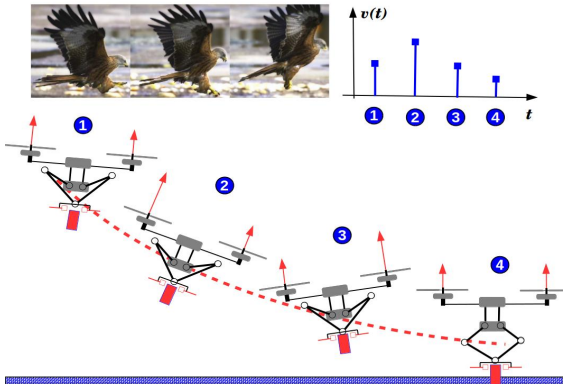


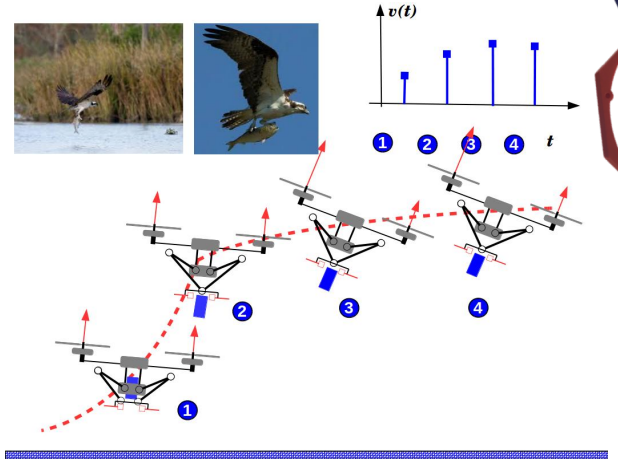
Enactive perception: Autonomous navigation in unknown/uncertain environments

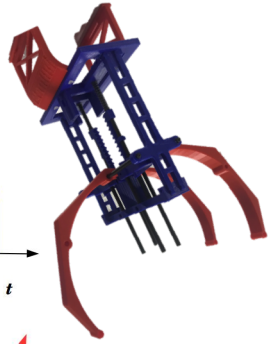


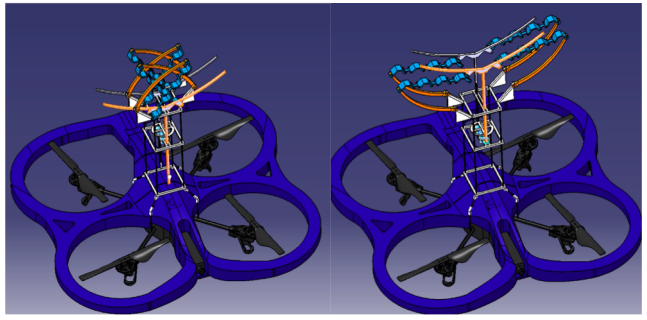
➢ Ongoing projects

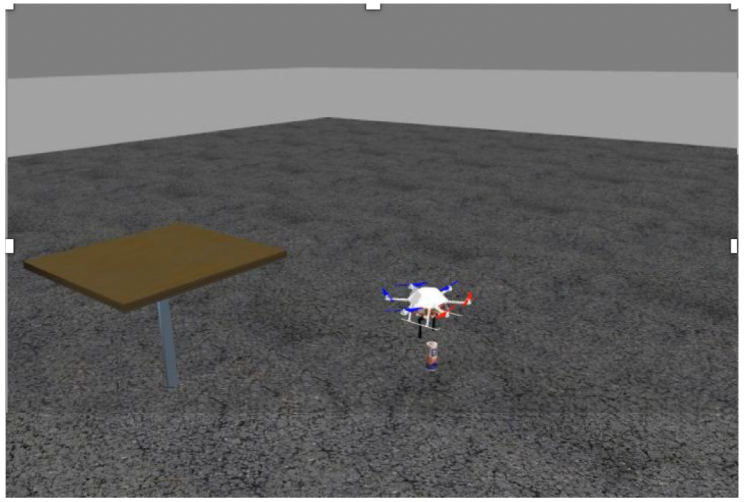
- *Bio-inspired trajectory planning and aerial interactivity*
- *Nonlinear robust control (disturbances estimation)*







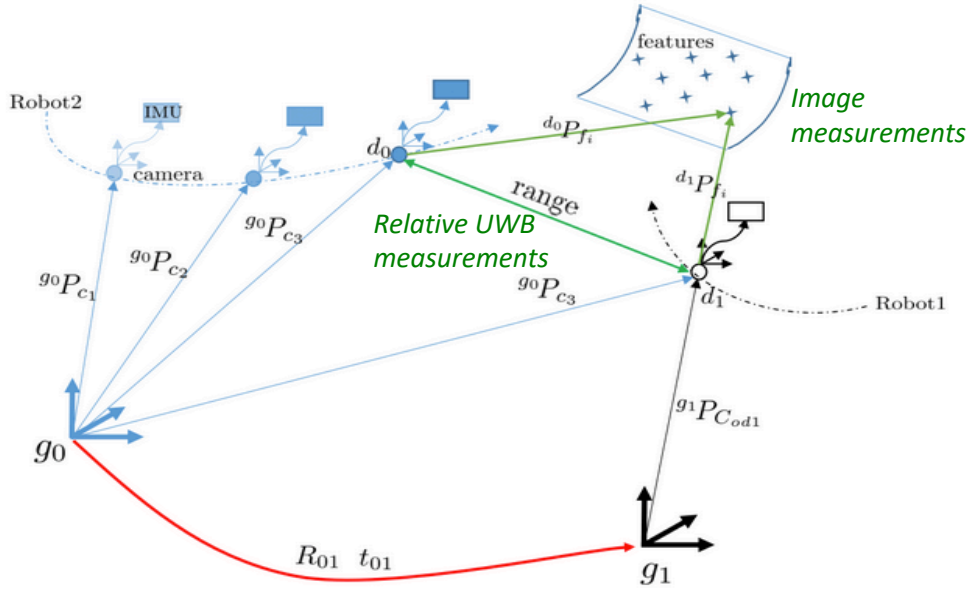




SAAMPLE [NA project, 2019]

Cooperative MRS: localization, planning, interactivity…

- Collaborative *Multi-State Constraint Kalman Filtering for decentralized cooperative localization*

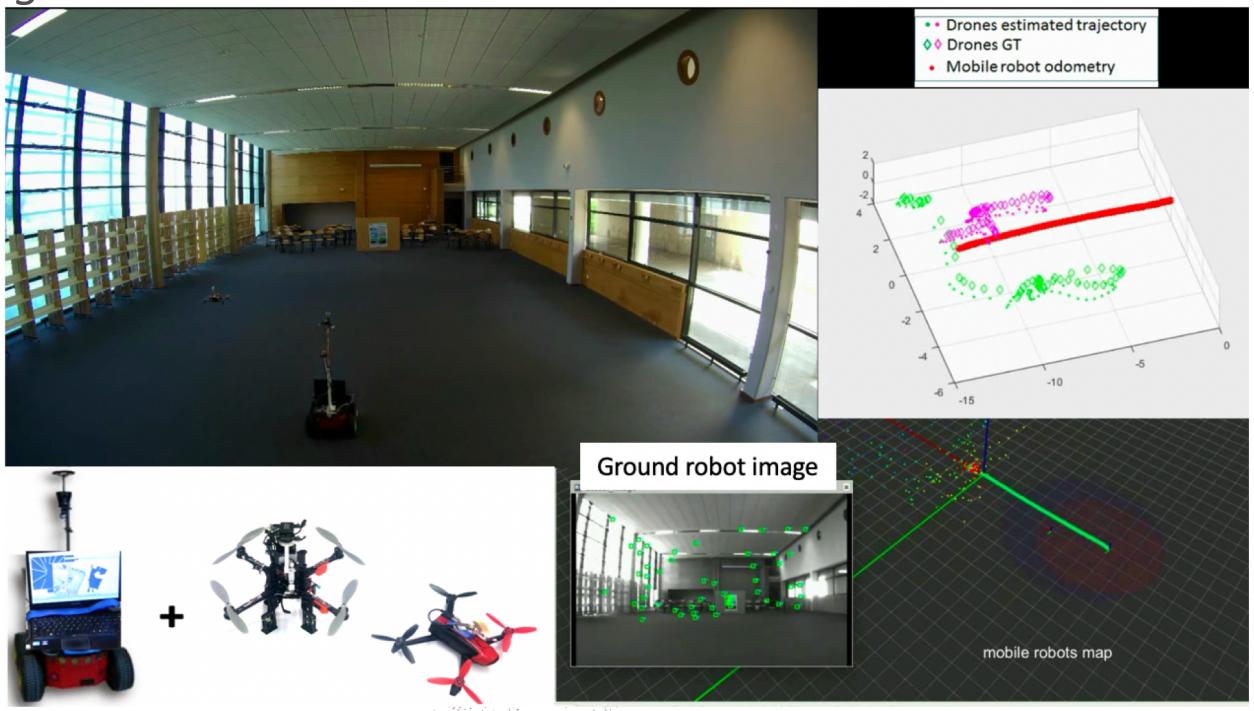


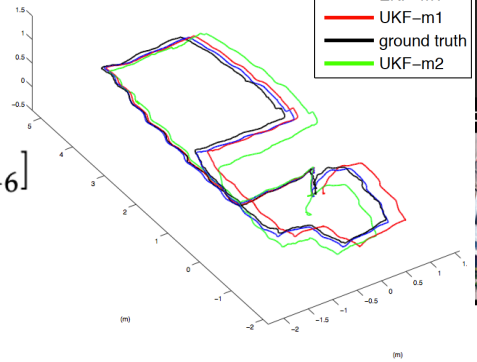
Unknown transf.

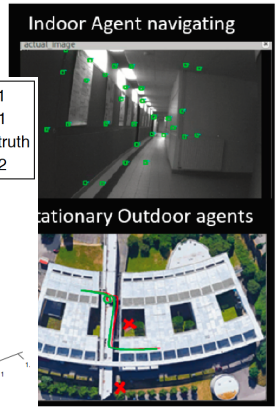
$$X^c_{r_i,k} = [X_k \; {}^G p^T_{r_i,r_1} \; {}^G \bar{q}^T_{r_i,r_1} \; \dots \; {}^G p^T_{r_i,r_n} \; {}^G \bar{q}^T_{r_i,r_n}]$$

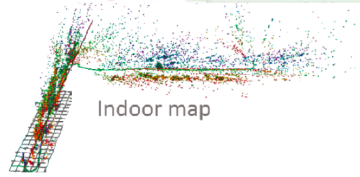
$$X_k = [X_I \; {}^G p^T_{k-1} \; {}^G \bar{q}^T_{k-1} \dots {}^G p^T_{k-6} \; {}^G \bar{q}^T_{k-6}]$$

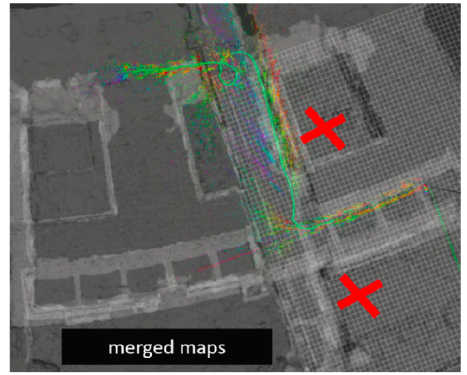
$$X_I = [{}^G p^T_I \; {}^G \bar{q}^T_I \; {}^G v^T_I \; b^T_a \; b^T_g]$$







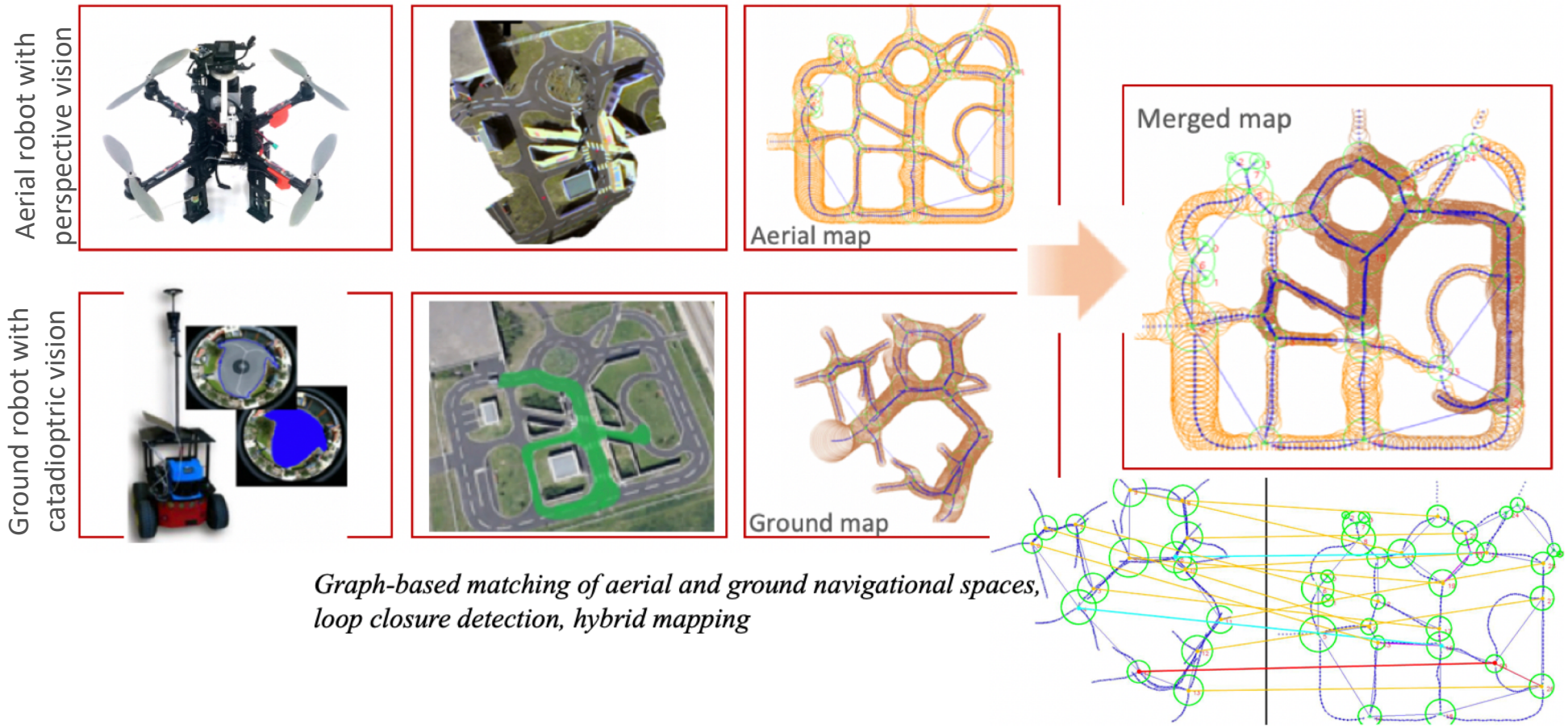




[Chenchana et al. 2018, 2019]

Cooperative MRS: localization, planning, interactivity…

- Augmented perception, aerial-ground map merging, loop closure detection (**skeleton-based graph matching**, hybrid graph descriptors…)

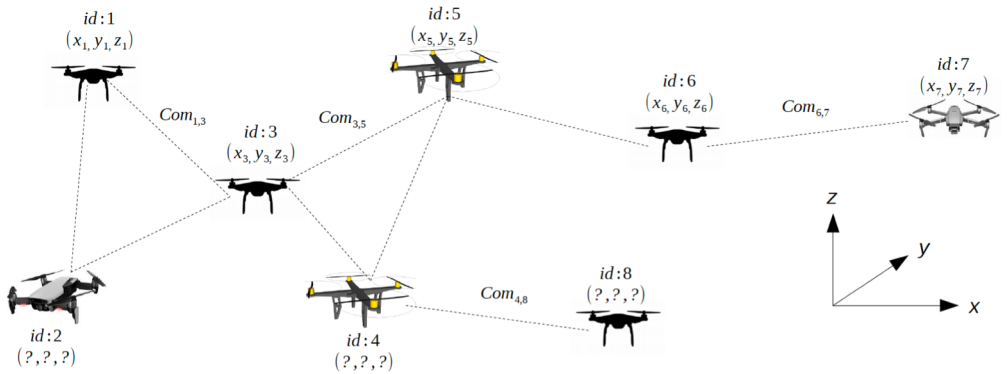


Graph-based matching of aerial and ground navigational spaces, loop closure detection, hybrid mapping

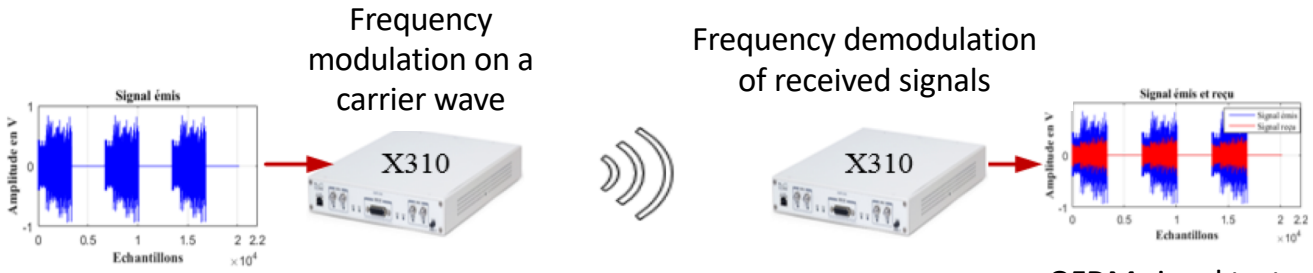
[Renaudeau et al. 2019, 2020]

Cooperative MRS: localization, planning, interactivity…

- Advanced fusion of perception and communication for network configuration optimization



- **Channel probing** using embedded Software-Defined Radio

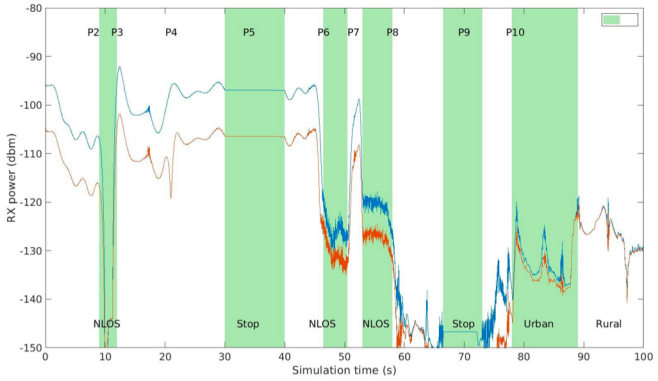


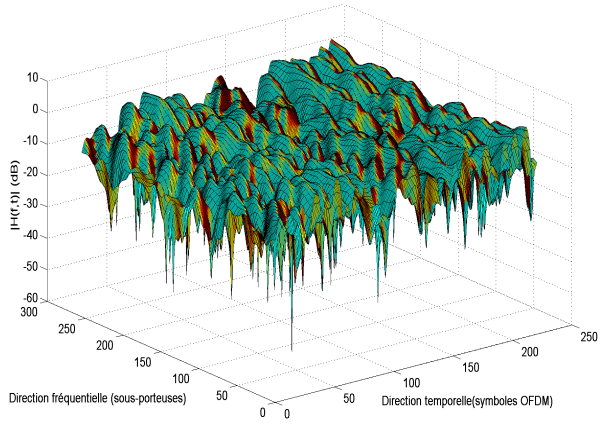
OFDM signal test generation

Propagation channel

OFDM signal test (emitted & received)

- Communication/Perception-based mobility control

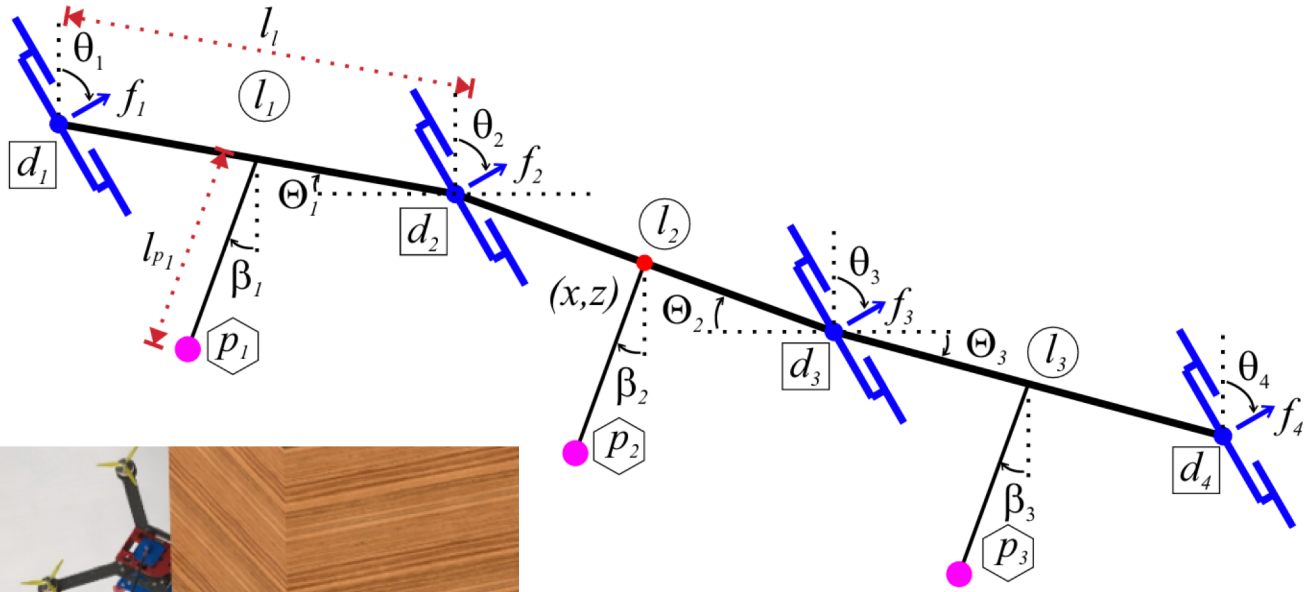


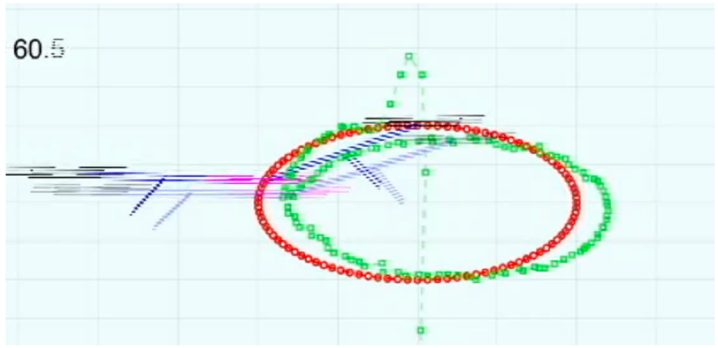


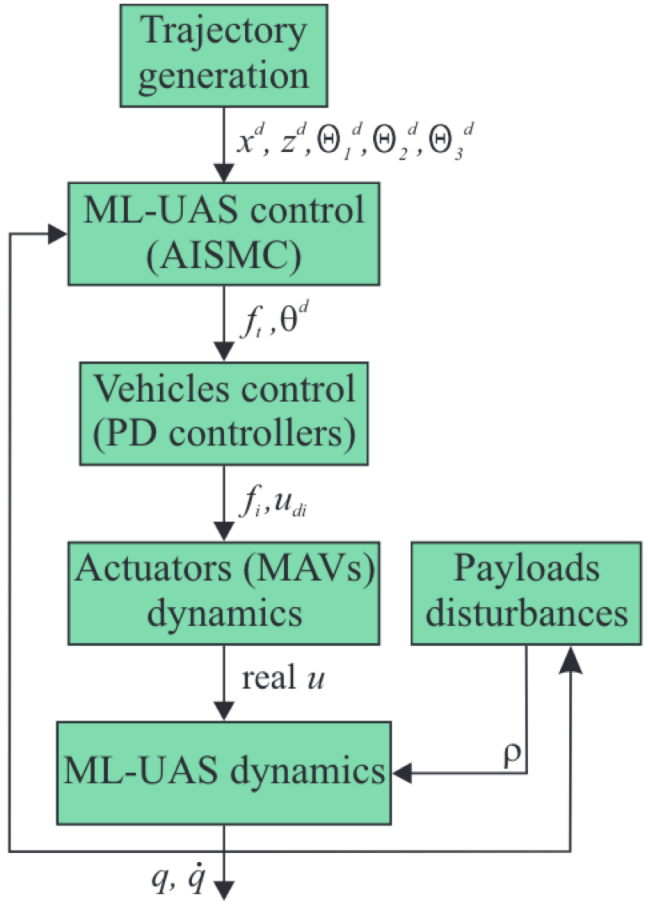
Cooperative MRS: localization, planning, interactivity…

➢ Ongoing projects

- *Multi-link aerial system modeling and control (cargo transport)*





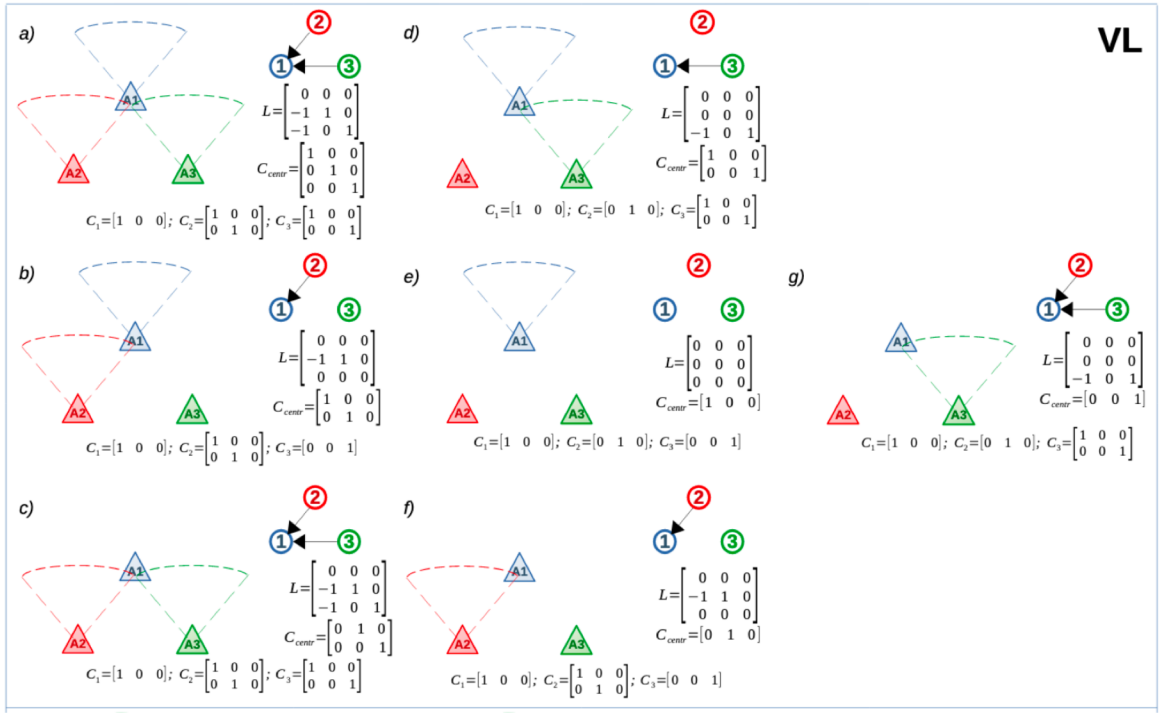


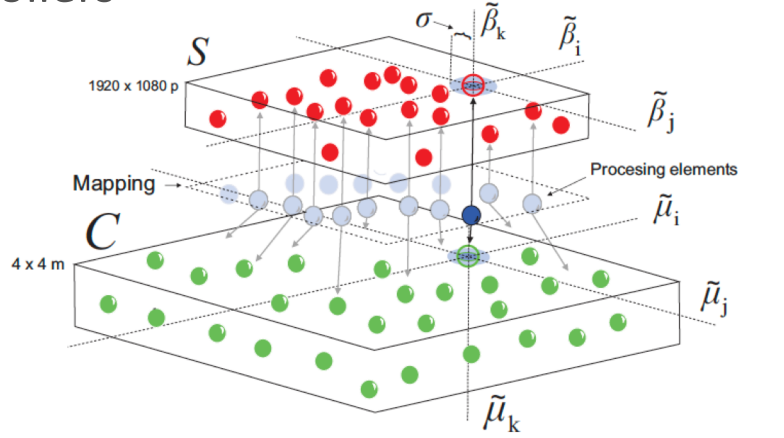
[Castillo et al. 2019, 2020]

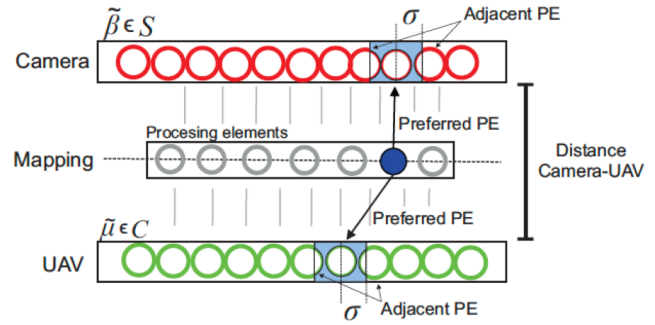
Cooperative MRS: localization, planning, interactivity…

➢ Ongoing projects

- *Bio-inspired fleet formation and control: Consensus*, observability and controllability under disturbances (wind, communication loss…), body-schema controllers

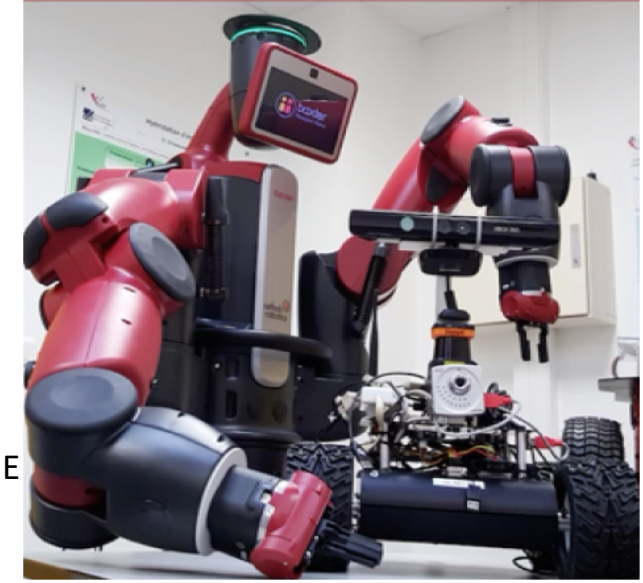






BoS-based controllers for interactive UAVs, body-arms motion

Some biblio references:



F. Aziz, O. Labbani-I., A. Radgui, A. Tamtaoui. A Riemannian approach for free-space extraction and path planning using catadioptric omnidirectional vision. Image and Vision Computing (2020), Vol. 95.
F. Aziz, O. Labbani-I., A. Radgui, A. Tamtaoui. Generic spatial-color metric for scale-space processing of catadioptric images. Computer Vision and Image Understanding (2018). Vol 176-177, 54-69.
H. Ben Said, R. Marie, J. St.phant, O. Labbani-I. Skeleton-based visual servoing in unknown environments. IEEE/ASME Transactions on Mechatronics (2018). Vol 23-6, 2750-2761.
K. Benzaid, R. Marie, N. Mansouri, O. Labbani-I. Filtered Medial Surface Based Approach for 3D Collision-Free Path Planning Problem. Journal of Robotics (2018). Vol. 56, 26-39.
J. J. Castillo-Zamora, J. Escareno, I. Boussaada, J. Stephant and O. Labbani-I., Nonlinear Control of a Multi-Link Aerial System and ASEKF-Based Disturbances Compensation, in IEEE Transactions on Aerospace and Electronic Systems (2020), doi: 10.1109/TAES.2020.3034010.
J. J. Castillo-Zamora, J.A. Escareno C., I. Boussaada, O. Labbani-I, K. Camarillo. Modeling and control of an aerial multi-cargo system: Robust acquiring and transport operations. European Control Conference (ECC 2019), June, 2019. DOI: 10.23919/ECC.2019.8796045
B. Chenchana, O. Labbani-I., S. Renault, S. Boria. Range-Based Collaborative MSCKF Localization. IEEE Int. Conf. on Mechatronics and Machine Vision in Practice (2018). DOI: 10.1109/M2VIP.2018.8600900
G. Fuseiller, R. Marie, G. Mourioux, E. Duno, O. Labbani-I. Reactive path planning for collaborative robot using configuration space skeletonization. IEEE Int. Conf. on Simulation, Modeling, and Programming for Autonomous Robots, SIMPAR (2018). DOI: 10.1109/SIMPAR.2018.8376267
J. Margraff, J. Stephant and O. Labbani-I., UAV 3D path and motion planning in unknown dynamic environments, 2020 Int. Conf. on Unmanned Aircraft Systems (ICUAS), Athens, Greece, 2020, pp. 77-84, doi: 10.1109/ICUAS48674.2020.9214057.
R. Marie, H. Ben Said, J. Stephant, O. Labbani-I. Visual servoing on the generalized Voronoi diagram using omnidirectional camera. Journal of Intelligent & Robotic Systems (2019). Vol. 94, 793-804.
R. Marie, O. Labbani-I., M. Mouaddib. The Delta Medial Axis: A fast and robust algorithm for filtered skeleton extraction. Pattern Recognition (2016). Vol. 56, 26-39.
R. Marie, O. Labbani-I., Squelettisation robuste de forme 2D dans l'image. Interdeposit certification: UNIVERSITE 20180321 IDDN FR.001.230011.000.S.X.2018.000.21000, 2018.
B. Renaudeau, O. Labbani-I., G. Mourioux. Air-Ground cooperative topometric mapping of traversable ground. Autonomous Robots, 44, 705–720 (2020).