ROBOPROX

Cooperative Aerial Robots for Advanced Industrial Production (RA8)

Martin Saska

Multi-robot systems group

FEE, CTU in Prague

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MINISTRY OF EDUCATION, YOUTH AND SPORTS

Robotics and Advanced Industrial Production
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Cooperative Aerial Robots for Advanced Industrial Production (RA8)

- Focus: Multi-robot autonomy in cooperative industrial production tasks
- Potential benefits:
  - Significant improvement in industrial production
  - Delivery of components inside and outside industrial facilities
- Current limitations in deployment of multi-robot aerial teams:
  - Quality of localization and mapping
  - Speed of flight in cluttered environments
  - Efficiency of task distribution among robots
- Objectives:
  - Develop novel multi-robot mapping and localization techniques
  - Motion planning for UAV agile flight in unknown dynamic environments
  - High-level mission planning for efficient deployment of multi-robot teams

RA8 research team

Team leader - Martin Saska

Senior researchers:

- Vojtěch Vonásek
- Tiago Nascimento
- Tomáš Báča
- Robert Pěnička

PhD students:

- Tim Felix Lakemann
- Filip Novák
- Matěj Novosad
- Václav Pritzl
- Michal Werner

https://mrs.felk.cvut.cz/

RA8 Objective 8.1 - Topological multi-modal mapping and cooperative localization (M. Saska)

Research Objective: Improve localization and mapping in multi-robot teams by addressing challenges in 3D mapping and communication bandwidth.

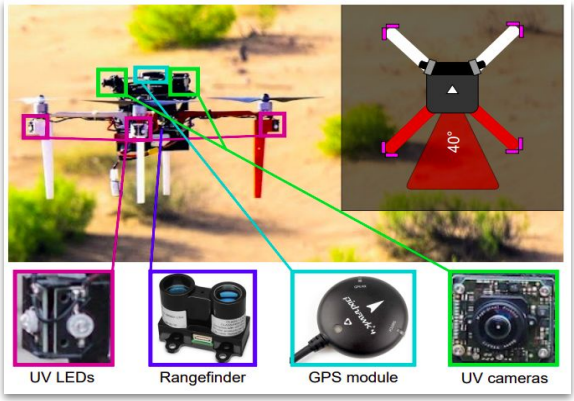
Activities and Methodology:

- Investigate new mapping techniques using topological multi-modal data.
- Extract multi-modal semantic features and describe their relationships.
- Research low-bandwidth natural language semantic map descriptors for sharing maps.
- Investigate methods for relative and cooperative localization of multi-robot team members.

Planned collaboration with other research areas:

- Collaborating with G6 (L. Přeučil) on localization and mapping methodology.

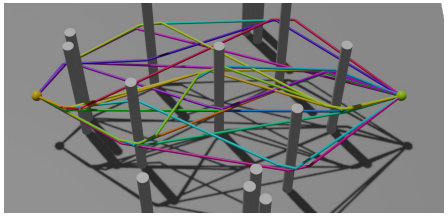
Pritzl 2024,"Drones Guiding Drones: Cooperative Navigation of a Less-Equipped Micro Aerial Vehicle in Cluttered Environments" submitted to IROS



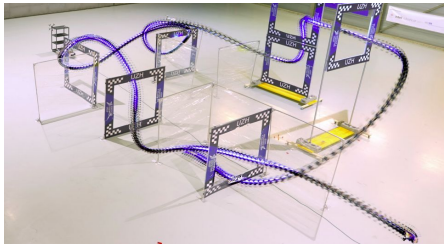
Walter 2019 "UVDAR System for Visual Relative Localization", RA-L

RA8 Objective 8.2 - Fast motion planning for agile flight and multi-robot operation (V. Vonásek)

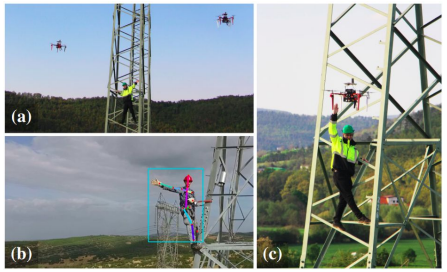
- **Research Objective:** Develop fast motion planning for agile flight and multi-robot operation to ensure human safety and optimize transportation speed.
- **Activities and Methodology:**
  - Investigate methods to identify topology of partially known environments using multi-modal maps to enable planning of distinct homotopy paths.
  - Develop model-based and learning-based approaches for agile navigation in cluttered environments.
  - Extend methods to facilitate multi-robot close interactions and industrial coworking through human multi-robot interaction techniques.
- **Planned collaboration with other research areas:**
  - On human multi-robot interaction methods within Objective 7.3 with G7 - R. Babuška.
  - On applying learning-based methods for aerial robot trajectory planning with G9 - T. Svoboda.



Novosad 2023,"Clustering Topological PRM" RA-L



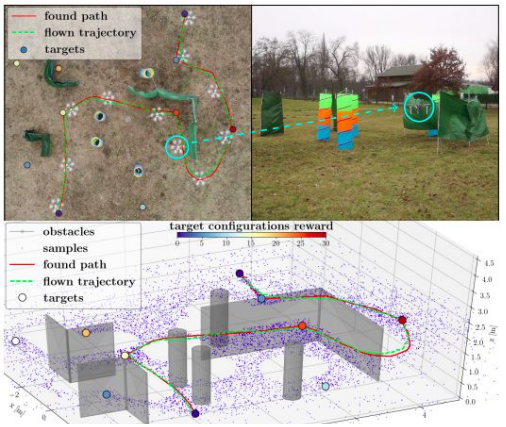
Penicka 2022, "Learning Flight in Cluttered Environments", RA-L



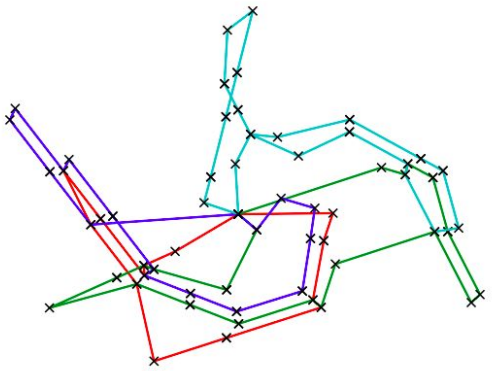
Kratky 2024, "Gesture-Controlled Aerial Robot Formation", IROS submission

RA8 Objective 8.3 - High-level mission planning for multi-robot operation (M. Saska, R. Pěnička)

- **Research Objective:** High-level mission planning for efficient multi-robot aerial operation in industrial settings, including task allocation, scheduling, coordination, and exploration.
- **Activities and Methodology:**
  - Utilize classical approaches like TSP, OP, and VRP adapted for dynamic and partially unknown environments.
  - Develop efficient mission planning methods considering dynamic obstacles and full robot dynamics.
  - Focus on methods with low computational footprint to enable replanning.
- **Planned collaboration with other research areas:**
  - Collaborate with G11 (Z. Hanzálek) for scheduling and optimization.
  - Collaborate with G10 (J. Faigl) on multi-robot routing problems.



Penicka 2019, “Physical Orienteering Problem for UAVs” RA-L, **M17+ 2022 Excellent evaluation**



Nekovar 2021, “MS-TSP in Planning Power Transmission Line Inspection” RA-L

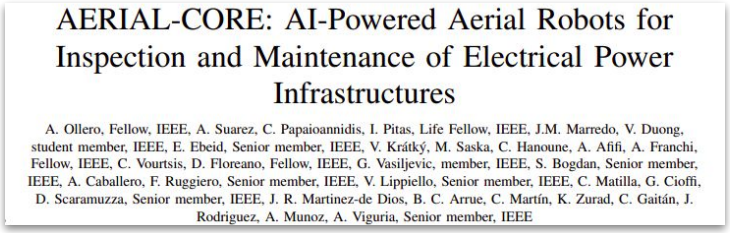
RA8 International collaborations

- **RO 8.1 - K. Alexis from the Norwegian University of Science and Technology** on multi-modal topological mapping.


Present and Future of SLAM in Extreme Underground Environments

Kamak Ebadi, Lukas Bernreiter, Harel Biggie, Gavin Catt, Yun Chang, Arghya Chatterjee, Christopher E. Denniston, Simon-Pierre Deschênes, Kyle Harlow, Shehryar Khattak, Lucas Nogueira, Matteo Palieri, Pavel Petráček, Matěj Petrlík, Andrzej Reinke, Vít Krátký, Shibo Zhao, Ali-akbar Agha-mohammadi, Kostas Alexis, Christoffer Heckman, Kasra Khosoussi, Navinda Kottege, Benjamin Morrell, Marco Hutter, Fred Pauling, François Pomerleau, Martin Saska, Sebastian Scherer, Roland Siegwart, Jason L. Williams, Luca Carlone

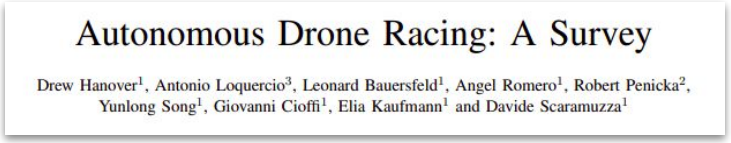
- **RO 8.3 - A. Ollero, University of Seville** on multi-robot mission planning


AERIAL-CORE: AI-Powered Aerial Robots for Inspection and Maintenance of Electrical Power Infrastructures

A. Ollero, Fellow, IEEE, A. Suarez, C. Papaioannidis, I. Pitas, Life Fellow, IEEE, J.M. Marredo, V. Duong, student member, IEEE, E. Ebeid, Senior member, IEEE, V. Krátký, M. Saska, C. Hanoune, A. Afifi, A. Franchi, Fellow, IEEE, C. Vourtsis, D. Floreano, Fellow, IEEE, G. Vasiljevic, member, IEEE, S. Bogdan, Senior member, IEEE, A. Caballero, F. Ruggiero, Senior member, IEEE, V. Lippiello, Senior member, IEEE, C. Matilla, G. Cioffi, D. Scaramuzza, Senior member, IEEE, J. R. Martinez-de Dios, B. C. Arrue, C. Martín, K. Zurad, C. Gaitán, J. Rodriguez, A. Munoz, A. Viguria, Senior member, IEEE

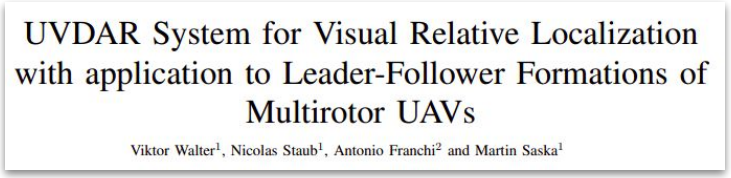
RO 8.2

- **D. Scaramuzza from University of Zurich** on trajectory planning for agile flight in cluttered environments


Autonomous Drone Racing: A Survey

Drew Hanover[1], Antonio Loquercio[3], Leonard Bauersfeld[1], Angel Romero[1], Robert Penicka[2], Yunlong Song[1], Giovanni Cioffi[1], Elia Kaufmann[1] and Davide Scaramuzza[1]

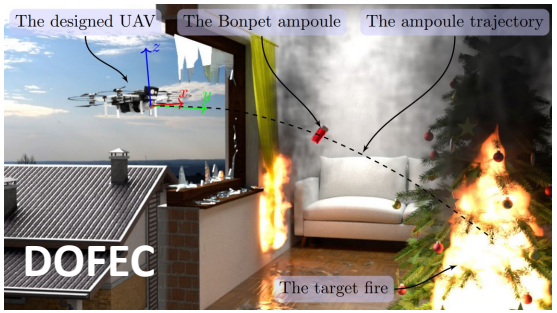
- **A. Franchi, University of Twente** on robust aerial robot control for human-machine collaboration

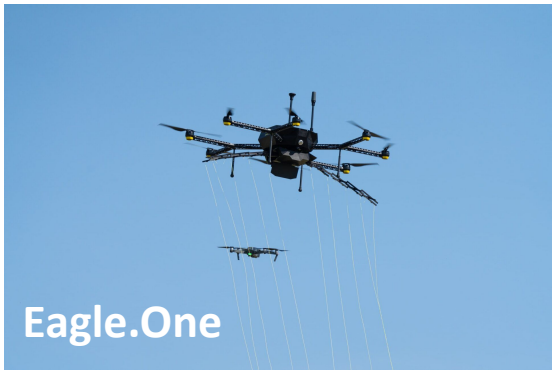

UVDAR System for Visual Relative Localization with application to Leader-Follower Formations of Multirotor UAVs

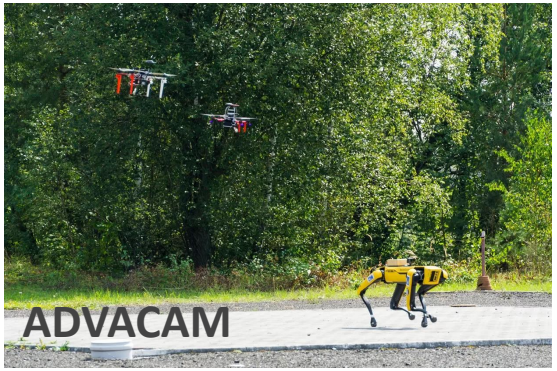
Viktor Walter[1], Nicolas Staub[1], Antonio Franchi[2] and Martin Saska[1]

RA8 Industrial collaborations

- **Using a team of robots, especially aerial ones (UAVs), brings redundancy and reduces per-unit costs in industrial applications.**
- **Industrial Partners:**
  - **Packeta (Zásilkovna.cz):** Prototype system for last-mile delivery featured at EXPO2020.
  - **DOFEC:** UAV for autonomous fire detection and extinguishing, developed with industrial partners.
  - **Eagle.One:** Autonomous drone hunter for protecting vital areas like airports.
  - **ČEPS and EON:** Inspection of powerlines and power towers using autonomous drones.
  - **ADVACAM:** Application of multi-robot methodology for regular inspection of radiation hazards in nuclear facilities.







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