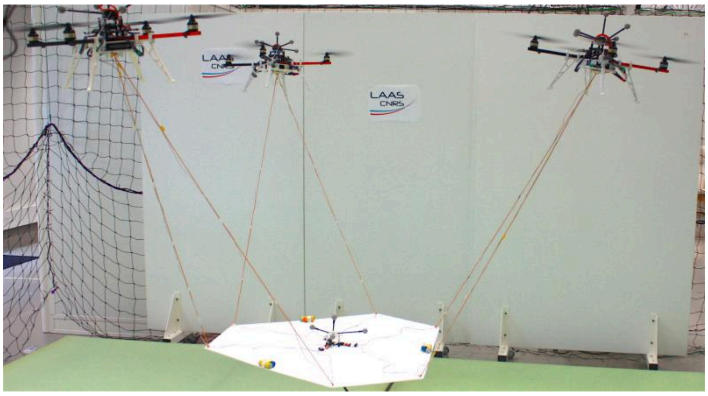
Privileged learning for distributed aerial robot control for collaborative object manipulations

Background

Transporting and manipulating an object in the air with multiple aerial robots is a promising technique. However, existing approaches typically rely on a centralized policy to fully leverage the robots' capabilities. This reliance is due to the centralized controller's ability to observe or estimate the full state, and generate control commands that comply with kinodynamic constraints of the system. Nevertheless, such a system often struggles to scale to large numbers of agents and is constrained by limited computational bandwidth.

Privileged learning is a promising avenue for addressing robotic control problems with limited system observation. It has already seen successful application in robotic systems with limited sensor capabilities, such as in quadrupeds and drones. Privileged learning involves using a teacher policy to impart knowledge, followed by training a student policy. This student policy aims to achieve performance comparable to the teacher policy, albeit with only limited, partial observation of the system.

In this research, the student will investigate the potential of privileged learning to address multi-agent control problems, focusing on the use of multiple aerial robots for collaborative object manipulation in the air. An existing centralized policy based on nonlinear Model Predictive Control (MPC) will serve as the basis for the teacher policy. Experimental validation of the algorithm is anticipated.



Research question

- Given a centralized teacher policy, how can we design a decentralized policy for multi-agents to achieve comparative performance as the centralized policy?
- What techniques should be devised to design the privileged-learning-based decentralized controller tailored for collaborative object manipulation with multiple aerial robots?

What we expect from you:

- Highly motivative.
- Interest and experience with machine learning, preferably transfer learning.
- Experience in programming languages such as Python and C++.
- Experience with Matlab \ Simulink is a bonus.
- Experience with real-world experiments with drones is a bonus.

What you can learn from this project:

- Hands-on experience with the modelling and control of multi-UAV (aerial robot) systems.
- Access to our optimization-based control framework of drone systems in C++ and Matlab \ Simulink.
- Hands-on experience and knowledge in machine learning for robots.
- Chance to publish in high-ranking robotic and ML conferences/journals.

Reference
[1] Sun, Sihao, and Antonio Franchi. "Nonlinear mpc for full-pose manipulation of a cable-suspended load using multiple UAVs." 2023 International Conference on Unmanned Aircraft Systems (ICUAS). IEEE, 2023.

[2] Kaufmann, Elia, et al. "Deep drone acrobatics." RSS 2020.

[3] Loquercio, Antonio, et al. "Learning high-speed flight in the wild." Science Robotics 6.59 (2021): eabg5810.

[4] Vapnik, Vladimir, and Rauf Izmailov. "Learning using privileged information: similarity control and knowledge transfer." *J. Mach. Learn. Res.* 16.1 (2015): 2023-2049.

Contact:

If you are interested in conducting this cool project, please contact Dr. Sihao Sun via

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When applying, please provide a short motivation, an up-to-date CV, a transcript of your current degree program and an intended start date.

Short bio of the supervisor:
Dr. Sihao Sun is a new member of CoR funded by the NWO talent program “Veni” grant. He has intensive experience in the control, planning, estimation and machine learning of aerial robotic systems by working with Prof. Davide Scaramuzza, Prof. Antonio Franchi, and Prof. Guido de Croon. He’s the winner of the Best Paper Award of Robotics and Automation Letters (RAL) and the NASA Tech Brief award. He has supervised over 20 MSc students, and three of them won CumLaude respectively in TU Delft and ETH / Zurich.

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Collaborative object manipulation with multiple flying robots is a promising technique as the object can transverse in 3D space without the limitation of ground robots. Collaborations among various flying robots also circumvent the problems of the payload capacities of a single flying robot. Therefore, this is a promising technique for various applications such as payload transportation, or autonomous constructions.

Existing approaches are composed of two categories, centralized or decentrialized. The decentralized methods are promising directions as they can be scaled to arbitrary numbers of agents and do not suffer from communication issues. However, since with a decentralized method, each agent only has partial observation of the entire system, the overall performance is usually suboptimal. As a consequence, existing decentralized approaches for collaborative object manipulation with aerial robots are extremely slow and inaccurate.