Formation and orientation-based control of UAVs and coordination with UGVs

Popular science summary of the Master Thesis [1] in Automatic control and robotics

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Although there has been advancement in drone (UAV) technology [2], issues like flight duration, computation load and mission complexity still limit usage of the full potential of this technology. In this thesis, this problem is tackled using multiple drones and mobile robots(UGV).

Nowadays, drone missions are becoming complex and drones are used for long-range missions. This has resulted in the need for strategies that can leverage the current limitation of this technology, while performing these missions and satisfying energy and time constraints. Imagine if, instead of one drone performing a surveillance mission, we have two or more. We can cover larger areas faster. Now, consider long-range surveillance missions. One downside of drones is their limited battery life. Constantly returning them to a home base might waste mission time. In addition, installing multiple charging stations along the drone path is expensive, time-consuming and in most cases impossible because of the mission topology. In this situation, by combining mobile robots and drones, we get the benefits of both worlds. Mobile robots can carry more weight and have longer battery lives, while drones can perform more complex maneuvers.

This thesis tries to solve the following problem: how do we coordinate fleets of drones and fleets of mobile robots while avoiding collisions with obstacles. The investigated approach considers two aspects: how to maintain the desired formation between the drones and how to coordinate the drones and the mobile robot. In the first case, a potential-based approach similar to how animals flock in nature is used to maintain the desired shape between the drones. One way to understand the idea of potential is to assume they are the tension applied to a spring that connects the robots, see Fig. 1. The goal is to arrive at a configuration where no tensions exist in the springs. In the second case, a cluster-based leadership-follower approach algorithm is used where the mobile robot has to follow clusters of the drones.

An essential aspect of the approach used is that it does not depend on a central planning and control system and it is intended to run on computationally constrained hardware. In addition, the number of drones can be modified even after reaching the desired formation shape. This is quite useful, especially when the use case requires flexibility, like when one drone in the formation might have to land on the mobile robot for recharging without affecting the other drones in the formation shape. The developed approaches were implemented and evaluated both in simulations and in experiments on hardware. Video demonstrations can be found in the link https://youtube.com/playlist?list=PLdsouUoVwMKNFyUv798AElfGWj3b5Zl1F.

Fig. 1: Concept of formation

References

[1] Stevedan Omodolor: Formation and orientation-based control of UAVs and Coordination with UGVs. Master's thesis, Department of Automatic Control, Lund University, Sweden (2022). TFRT-6181. https://lup.lub.lu.se/student-papers

[2] Nex, F., Armenakis, C., Cramer, M., Cucci, D.A., Gerke, M., Honkavaara, E., Kukko, A., Persello, C., Skaloud, J.: UAV in the advent of the twenties: Where we stand and what is next. ISPRS Journal of Photogrammetry and Remote Sensing **184**, 215–242 (2022). https://doi.org/10.1016/j.isprsjprs.2021.12.006