

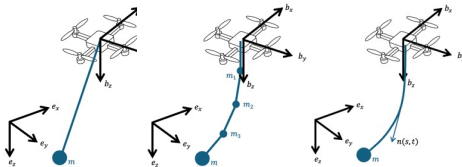
Collaborative Tethered Unmanned Aerial Vehicle

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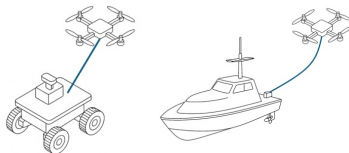
Tethered UAV System

- Benefits of Tethered UAV (TUAV)
 - Versatility: TUAV can operate in an environment where traditional aerial vehicles are not suitable
 - Unable to land
 - Constrained area
 - Indoor operation
 - Low cost: Compared to conventional aerial vehicle, TUAV has lower hardware and operation cost
 - Disposable
 - Low-cost operation
- Limitations of TUAV
 - Lower capacity: Limited battery life; limited payload capacity; limited on-board processing
 - Complex model: Dynamics of TUAV introduces unique challenges such as cable modeling, slack-to-taut cable state transitions
- Tether modeling
 - Different tether model
 - Single rod: simple yet not realistic
 - Hybrid: Can deal slack-to-taut hybrid system
 - Series of flexible links: Higher computational cost
 - Completely continuous



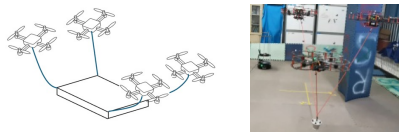
Collaborative Tethered UAV system

- Collaborative TUAV system
 - Address the limitations of TUAV
 - Limited payload capacity
 - Limited sensor/processor
- Cross-platform collaboration
 - UAV-UGV (Unmanned Ground Vehicle)
 - UAV-USV (Unmanned Surface Vehicle)

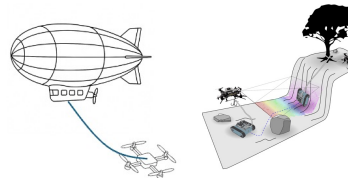


Applications

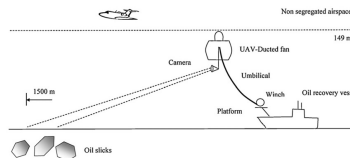
- Collaborative payload transportation
 - Two quadrotors transporting a rod
 - Four quadrotors transporting a rigid body



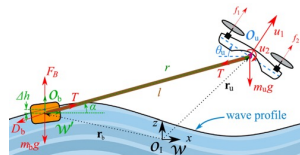
- Overcoming physical constraints
 - UAV-UGV collaborative system to overcome terrain challenges
 - Indoor navigation using UAV-UGV collaboration



- Communication
 - Communication between ground station and UAV through data cable
 - Disaster area network coverage
 - UAV providing vantage point

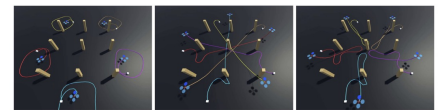


- Data collection
 - Collecting data from the buoy

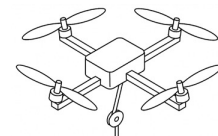


Collaborative mission: Open questions

- Tether entanglement
 - Multiple TUAVs → Entanglement issue
 - Path planning and trajectory optimization to avoid entanglement
 - Entanglement in the air
 - Entanglement with on obstacle
 - Underwater entanglement



- Varying length tether
 - Varying length adds more versatility
 - Indoor operation
 - Can fly through window
 - Obstacle constrained area
 - Simpler dynamics when tether is not deployed
 - Tether can be deployed when it is needed
 - More complex dynamics
 - Retractable system dynamics
 - Reaction forces and moments
 - Tether with pulley system:



References

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 [2] A. Kourani and N. Daher, "Marine locomotion: A tethered uav-buoy system with surge velocity control," *Robotics and Autonomous Systems*, 2021.
 [3] K. Sreenath, T. Lee, and V. Kumar, "Geometric control and differential flatness of a quadrotor uav with a cable-suspended load," in *Proceedings of the IEEE Conference on Decision and Control*, IEEE, 2013, pp. 2269–2274.
 [4] P. K. Takahiro Miki and K. Hori, "Uav/ugv autonomous cooperation: Uav assists ugv to climb a cliff by attaching a tether," *International Conference on Robotics and Automation*, 2019.

Future Study

- System modeling of collaborative TUAV system
- Controller design for multi-agent TUAV system
- System analysis of varying length TUAV system

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