Collision Avoidance in Micro Aerial Vehicles Motion Planning

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Glareh Mir

Structure of Presentation

- Introduction: History and Background
- Motivation
- Control Methods
  - Backgrounds
  - Designs
- Discussion
- Conclusion
- References
- Questions

Introduction

- Unmanned Aerial Vehicles
  - ...
  - Micro UAV (MAV)
    - Usage
    - Limitations
- Concerns
  - Navigation
  - Path planning
  - Collision
    - Detection
    - Avoidance
- Drone Swarms

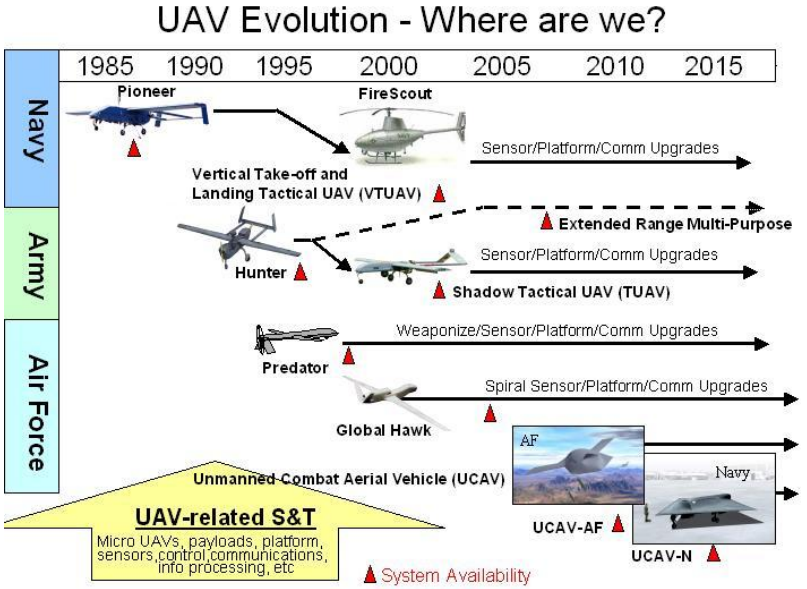

Fig 1: UAV Evolution
Source: https://fas.org/irp/program/collect/uav.htm

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Motivation

- Constraints... or what lead us to use swarms
  - Short flight times due to battery limitation
  - Size constraints
- Approaches
  - Collision-free Trajectory
    - Pre-planned
    - Replanning costs
  - Robust methods to avoid multi-MAVs collisions
    - Leader-Follower Formation Control
    - Nonlinear Model Predictive Control

Leader-Follower Formation Control

- Incorporating FTC capabilities
- Eliminating Collisions
  - Environment
  - Inter-formation
- Mechanisms
  - Fault Tolerant Control (FTC)
  - Collision Avoidance
- Useful info
  - Outer-Loop UAV Kinematics
  - Inner-Loop UAV Model Subject to Actuator Faults

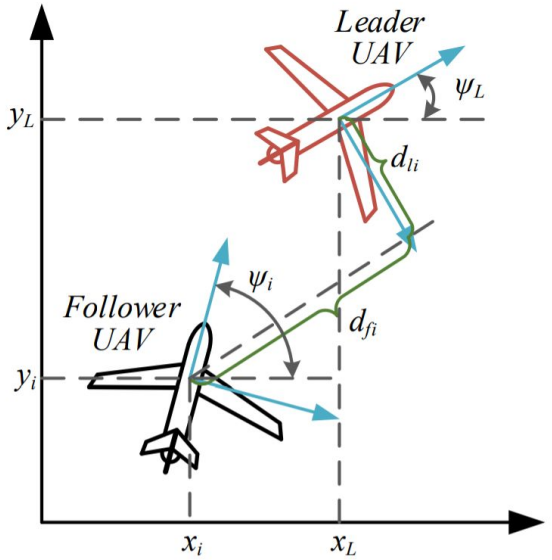

Fig 2: Formation Geometry [1]

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Leader-Follower Formation Controller Design

- Outer-Loop Controller Design
  - Rigid Formation Control Strategy
  - Semi-Rigid Formation Strategy
- Inner-Loop Controller Design
  - Direct Adaptive Control method in case of Actuator Faults
  - State Feedback State Tracking (SFST) adaptive control
  - Adaptive Feedback Control law

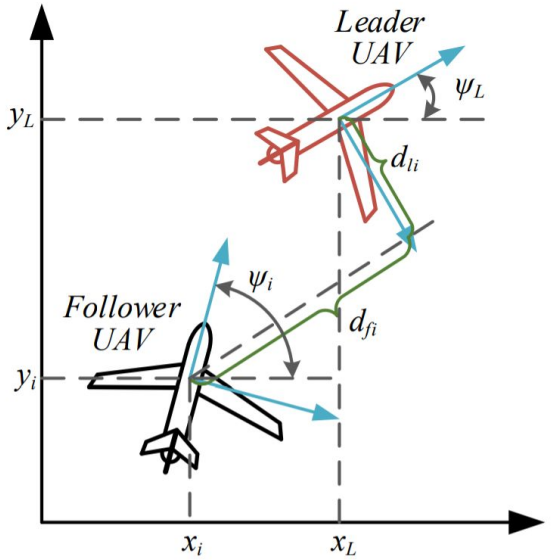

Fig 2: Formation Geometry [1]

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Nonlinear Model Predictive Control

- "Unified framework to achieve reference trajectory tracking and multi-agent reactive collision avoidance" ([2] Kamel 2017, Page 1)
- MPC based Control
  - Forecast based on a dynamic model of the system
  - Solve a finite horizon optimization control problem
  - Most often Linear
    - Non-optimal in a multi-variable nonlinear system
- For a robust collision avoidance
  - State estimator uncertainty
  - Communication delay

Nonlinear Model Predictive Control

- Models
  - System Model
  - Attitude Model
- Optimal Control Problem
- Agents Motion Prediction
- Uncertainty Propagation
- Agent Priority

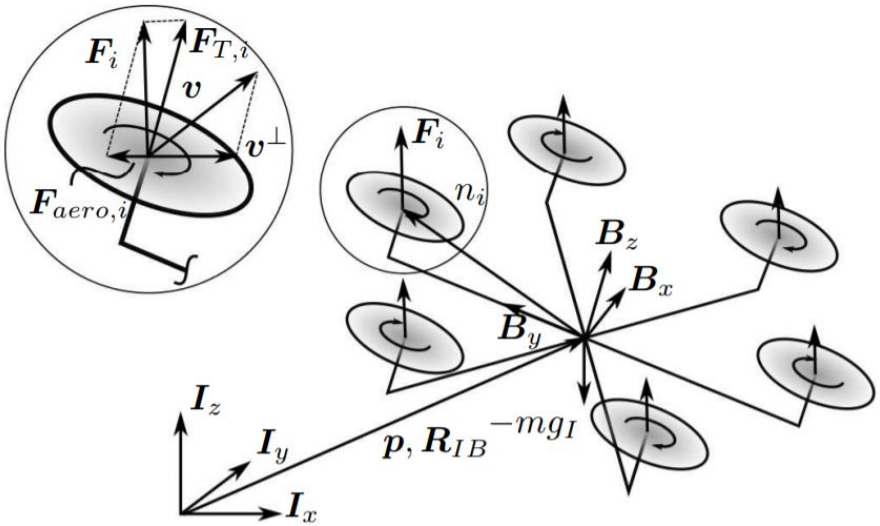

Fig3: Schematic of MAV [2]

Discussion

- A mixture of the two approach
  - Advantages and Disadvantages
- Newer approaches
- Possible extension of methods to other robotic gadgets and pieces
  - 3D or 2D
  - Robotic arms and legs: Dependent 3D moving points
- Moving forward with a chance of collision: prediction vs taking action
- Recovery from collision
- Intelligent swarms

Conclusion

- MAV: Future looks bright
- Collision Avoidance in MAV
  - Why swarms of drones?
  - Leader Follower Approach
  - Model Predictive Approach
- Further applications and possibilities

References

- Figures
  - Fig 1: UAV Evolution, Source: https://fas.org/irp/program/collect/uav.htm
  - Fig 2: Formation Geometry, from Reference [1], Page
  - Fig 3: Schematic of MAV, from Reference [2], Page
- Literature

  - [1] Liu, Z. X., Yu, X., Yuan, C., & Zhang, Y. M. (2015). Leader-follower formation control of unmanned aerial vehicles with fault tolerant and collision avoidance capabilities. 2015 International Conference on Unmanned Aircraft Systems (ICUAS).
  - [2] Kamel, M., Alonso-Mora, J., Siegwart, R., & Nieto, J. (2017). Robust collision avoidance for multiple micro aerial vehicles using nonlinear model predictive control. 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS).
  - [3] Saska, M., Kasl, Z., & Přeucil, L. (2014). Motion planning and control of formations of micro aerial vehicles. IFAC Proceedings Volumes, 47(3), 1228–1233.
  - [4] Grancharova A., Johansen T.A. (2012) Nonlinear Model Predictive Control. In: Explicit Nonlinear Model Predictive Control. Lecture Notes in Control and Information Sciences, vol 429. Springer, Berlin, Heidelberg
  - [5] Tao, G., Joshi, S., & Ma, X. (2001). Adaptive state feedback and tracking control of systems with actuator failures. IEEE Transactions on Automatic Control, 46(1), 78–95.

Questions?

Videos: Do we have time?

- NMPC path plan & follow: https://www.youtube.com/watch?v=WgihttkwfFA
- Leader-Follower: https://www.youtube.com/watch?v=pDTKeyGI5gE
- NMPC, motor fail: https://www.youtube.com/watch?v=cocvUrPfyfo