Distributed Geometric and Optimization-based Control of Multiple Quadrotors for for Cable-Suspended Payload Transport

Authors
Khaled Wahba, Wolfgang Hönig

Introduction

- Multi-UAVs are well suited for collaborative applications:
  - Assisting in construction sites,
  - Payload collaborative transportation.

- Cable-Suspended payload transportation:
  - Not using manipulators/grippers,
  - Transportation of heavy objects.

Background

- Given:
  - \( n \) quadrotors carrying a cable-suspended payload,
  - Reference trajectory: \( \{p_0, \dot{p}_0, \ddot{p}_0\} \).

- Objective: payload to track the reference trajectory.

- State-of-the-art [1], [2] does not take into account:
  - Inter-UAV and UAV-obstacle collisions,
  - Formation changes between configurations,
  - Cable tangling,
  - Payload physical size.

Approach

- Distributed Quadratic Optimization Problem (QPs) Formulation:
  - Computation of desired cable forces \( \mu_{id} \).
  - Constraints:
    - Payload trajectory tracking,
    - Inter-UAV, obstacle collision avoidance.

Sim-to-Real Development

- 1) Python-only Simulation
  - Dynamics: Euler Integration,
  - State-of-the-art (SOTA) Controller,
  - QP optimization in CVXPY.

- 2) From Python to C.

- 3.a) Python Bindings (SWIG)
- 3.b) Software-in-the-Loop (SITL)

- 4) Test flight and tuning

Experiments

- 2 CrazyFlies (CFs) of mass \( m_i = 34 \text{ g} \) carrying a \( m_0 = 10 \text{ g} \) payload,
- Length of cables \( l_1 = 0.77 \text{ m}, \ l_2 = 0.705 \text{ m} \),
- STM32 microcontroller (168MHz, 192kB RAM),
- Objective: Track hovering reference trajectory,
- Constraints:
  - Normal vectors \( n_1, n_2 \) for desired hyperplanes,
  - Reference trajectory.

Results

- Each CF runs QPs on-board to compute optimal \( \mu_{id} \),
- The computed optimal solution of the QPs respects the constraints.

References