Persistent Deployment of Micro-Aerial Vehicles

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Motivation

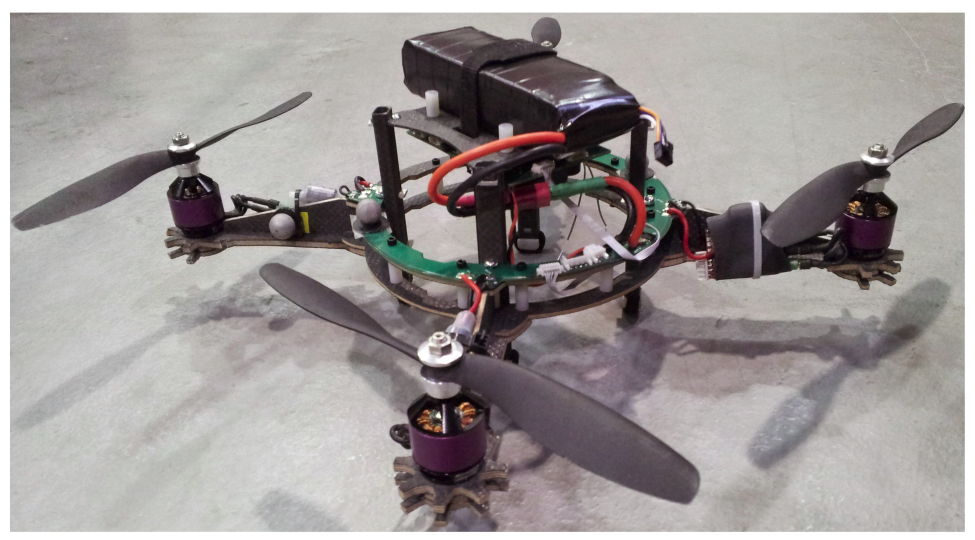
- Quadrotors can be useful for persistent automated tasks such as crop quality, security operations, or regular deliveries.
- **Challenges:**
  - Low battery life (~20min.)
  - Need for people in the loop

Proposal: Develop a system for persistent operation of multiple quadrotors with cyclic coverage of waypoints and automated recharging.

Problem Formulation

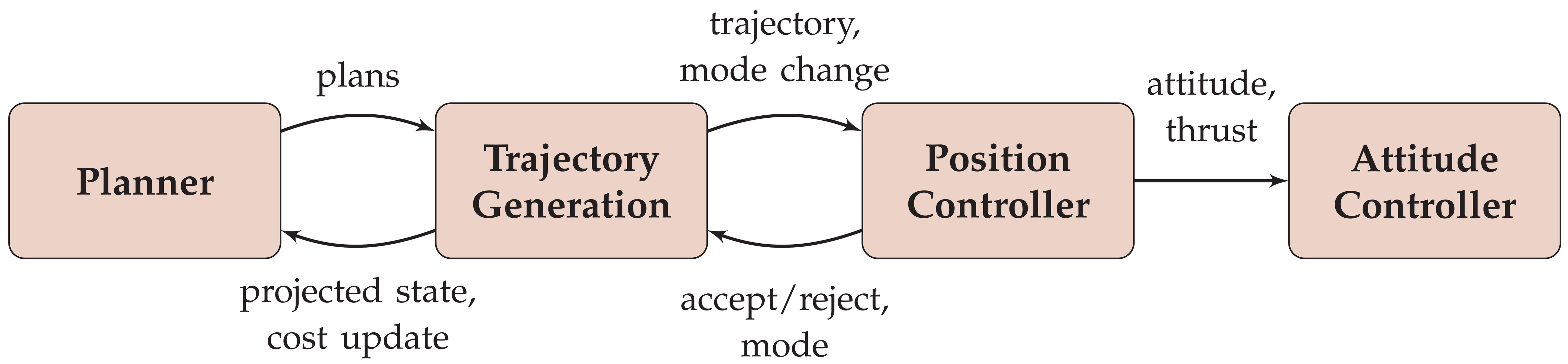
- **Given:**
  M robots
  N charging stations
  P waypoints
- **Generate** persistent cyclic paths $s.t.$ fuel constraints are respected
- **Implement** plans on the fly
  - Ensuring immediate feasibility
  - Updating travel costs from experience
  - Handling phase shifts, direction changes, and $plan \implies plan$ transitions

Hardware

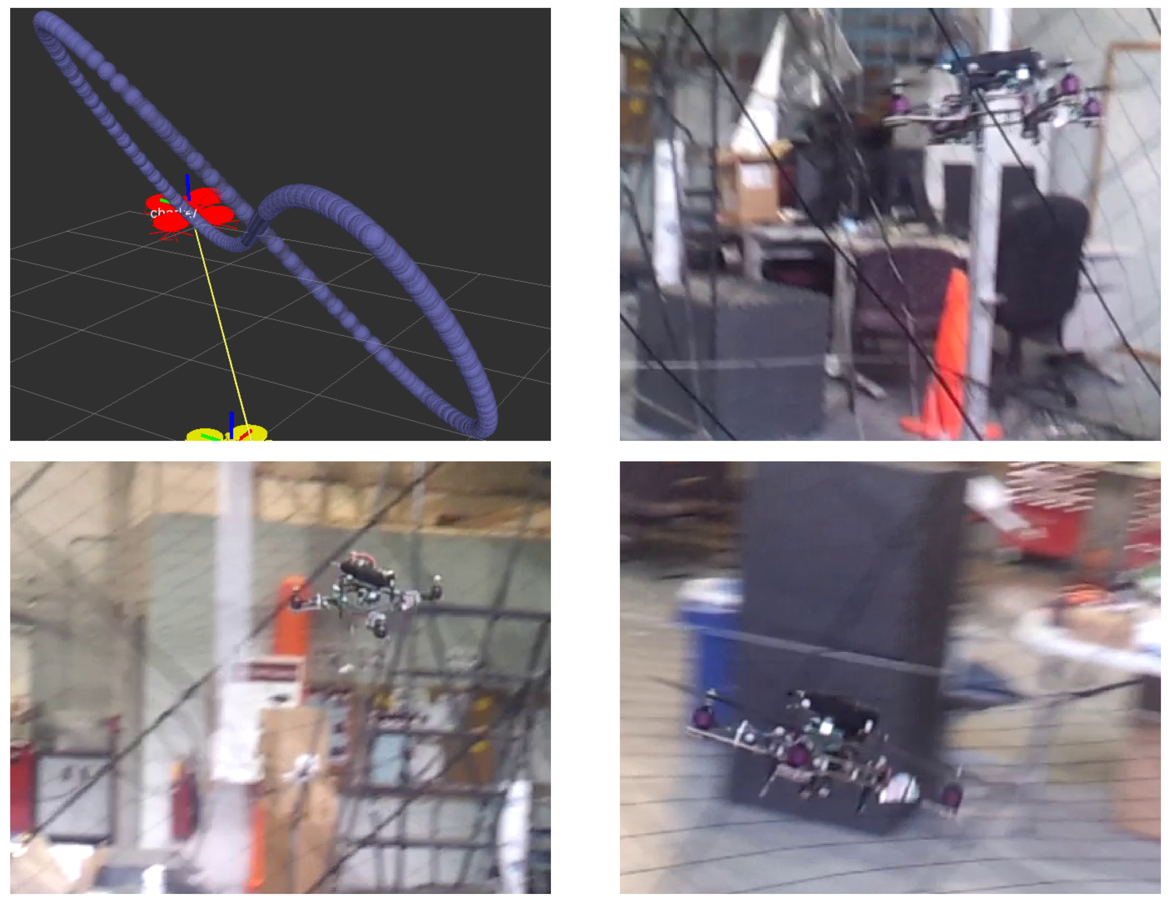


- Three custom quadrotors, 0.56m tip-to-tip
- Vicon motion capture arena
- Landing pads
- Charging stations (in development)

Software



Aggressive Flight



Trajectory generation:
Minimum snap trajectories respect 4^{th} order dynamics of quadrotors [Chamseddine et al., 2012].

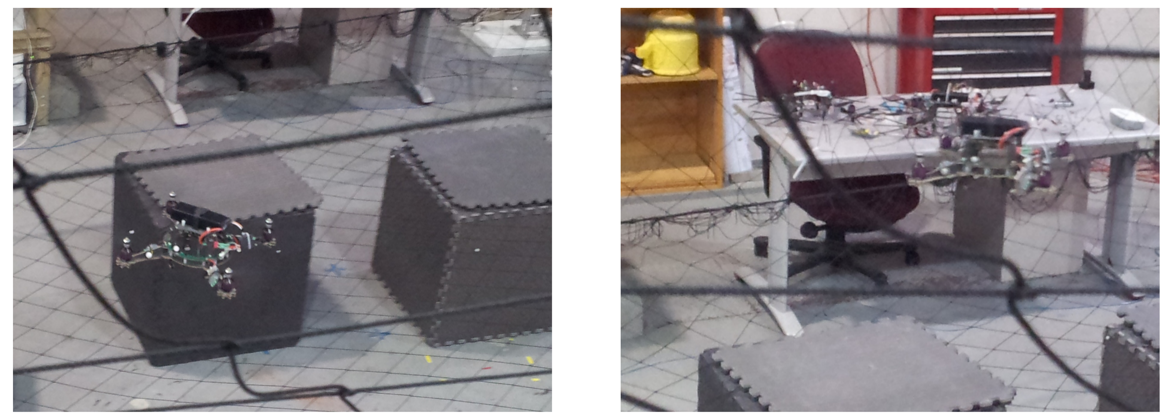
- Currently using fully constrained 7^{th} order polynomials.
- Smooth polynomial time-scales were used in the figure-eight performance test above.

Position control:
A linearized position controller coupled to a state machine controls the robot during take-off, landing, trajectory tracking, etc.

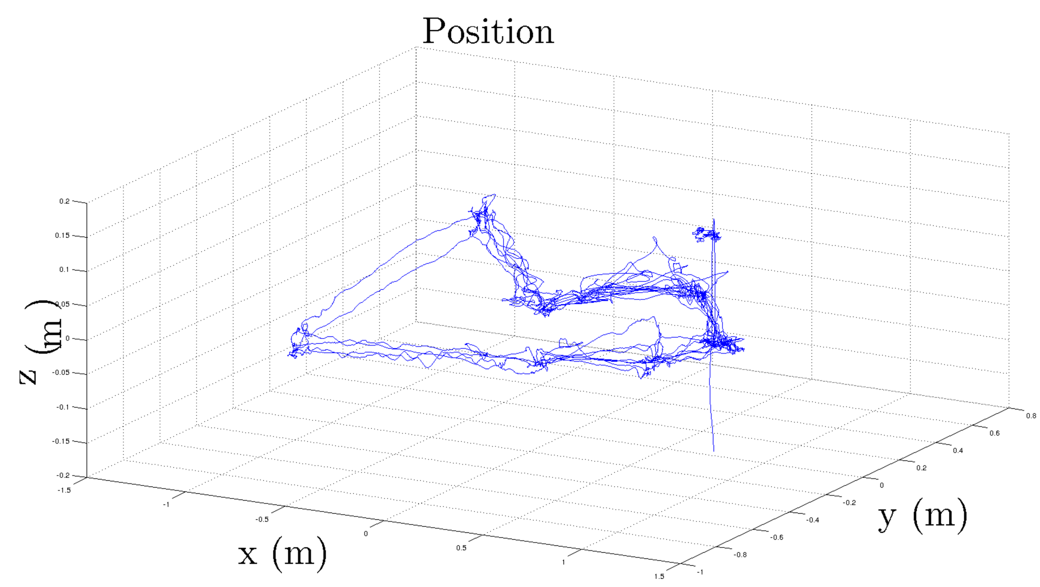
Trajectories are discretized in position, velocity, and acceleration with two tracking modes:

- Position parametrized [Hoffmann et al., 2008]
- Time parametrized

Deployment Tests



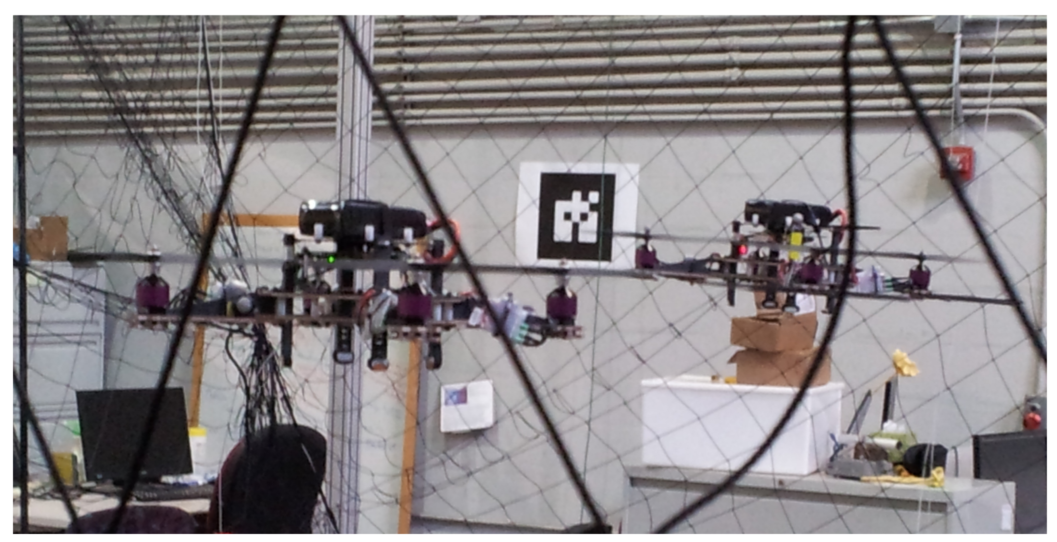
a. *b.*



c.

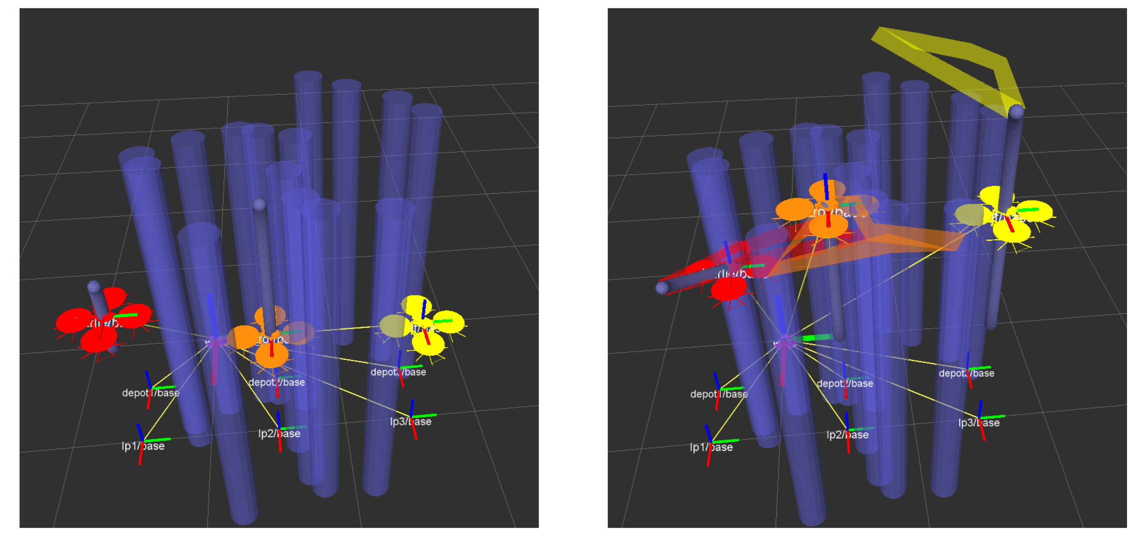
The system was tested with a single quadrotor as shown in *a.* and *b.* with position plotted in *c.*

The trial continued until a low voltage was detected, and the robot landed.

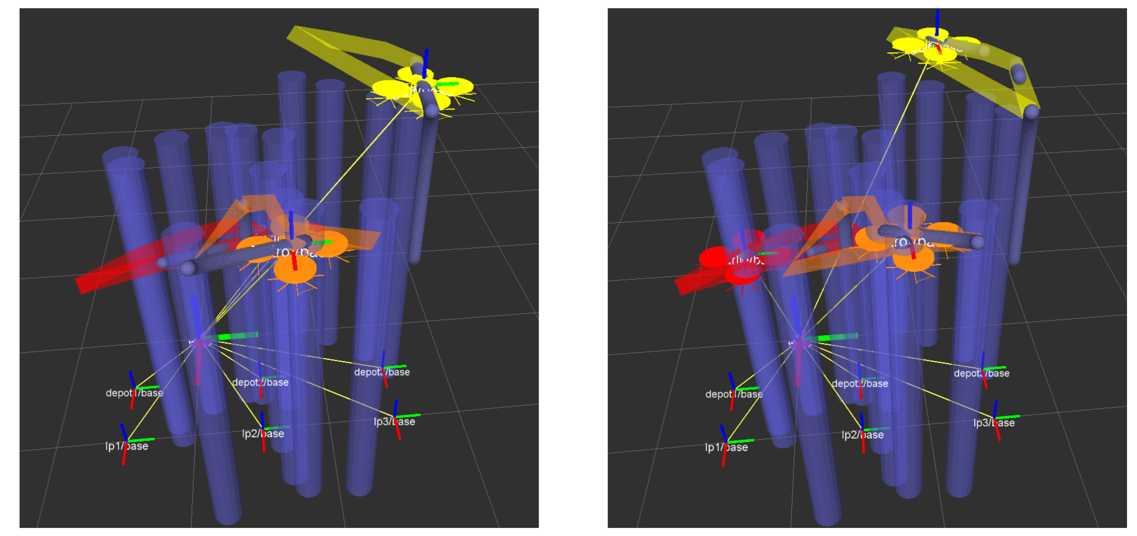


(Technical difficulties limited the above deployment test to one robot.)

Simulation



a. *b.*



c. *d.*

a. Quadrotors ascend to desired altitude
b. Planner generates initial plans
c. Flying to first waypoints
d. Following planned deployment

Future Work

- Deploy larger teams
- Long term deployments
- Develop an accurate cost model for the system
- Generate collision free trajectories as described by Mellinger et al. [2012].

References

Abbas Chamseddine, Youmin Zhang, Camille Alain Rabbath, Cedric Join, and Didier Theilliol. Flatness-based trajectory planning/replanning for a quadrotor unmanned aerial vehicle. *Aerospace and Electronic Systems, IEEE Transactions on*, 48(4):2832–2848, 2012.

Gabriel M Hoffmann, Steven L Waslander, and Claire J Tomlin. Quadrotor helicopter trajectory tracking control. In *AIAA Guidance, Navigation and Control Conference and Exhibit, Honolulu, Hawaii*, pages 1–14, 2008.

Daniel Mellinger, Aleksandr Kushleyev, and Vijay Kumar. Mixed-integer quadratic program trajectory generation for heterogeneous quadrotor teams. In *Robotics and Automation (ICRA), 2012 IEEE International Conference on*, pages 477–483. IEEE, 2012.