Energy-aware UAV Path Planning with Adaptive Speed

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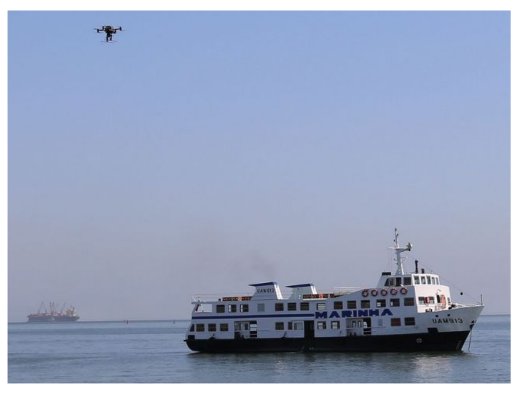
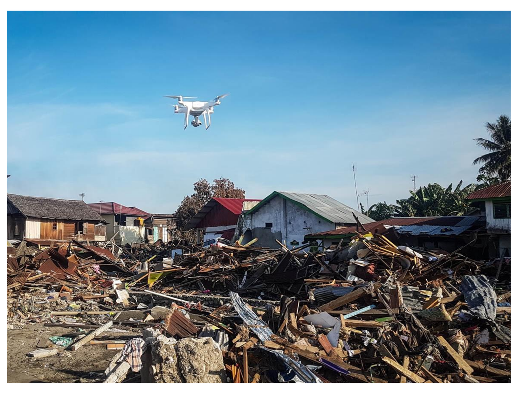
Application Scenario

Scenario considered: Unmanned Aerial Vehicles (UAV) data collection mission with a moving ground vehicle cannot stop and wait for a UAV to return



Maritime Search and Rescue



Disaster Response

Forest Fire Monitoring

Problem Definition

Given:

- Energy constrained UAV
- Set of waypoints to visit
- Starting position of ground vehicle (where UAV will launch)
- Function describing ground vehicle movements

Research Question:

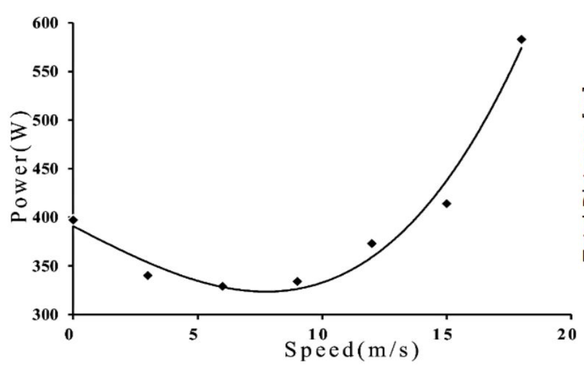
1. How can we plan UAV data collection routes while accounting for the movement of a ground vehicle that launches/receives the UAV?
2. How can we include a realistic model for energy in a UAV route planner?

UAV Speed & Energy Consumption

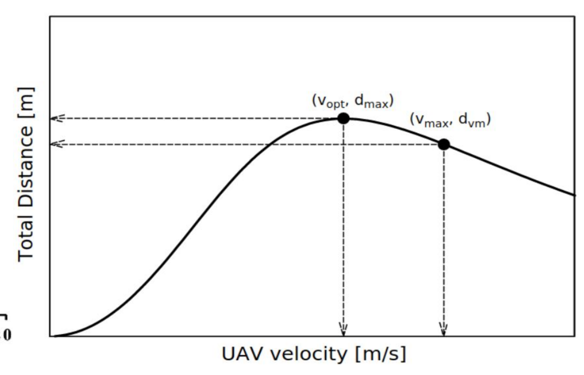
- Previous work found that increasing speed initially reduces power consumption but increases consumption at higher speeds [Zeng et. al., TWC, 2019][Shan et. al., INFOCOM, 2020]
- Using battery parameter and field testing from [Shan et. al., INFOCOM, 2020], we derived mapping from velocity to total distance

Speed-Energy Tradeoff

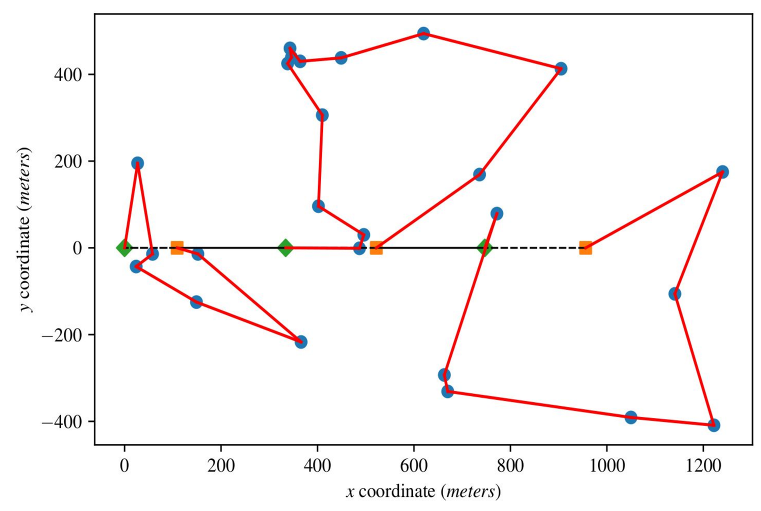
- Maximizing speed reduces total distance
- Maximizing total distance reduces speed
- Moving faster may reduce mission duration but may also require require stopping to change out battery



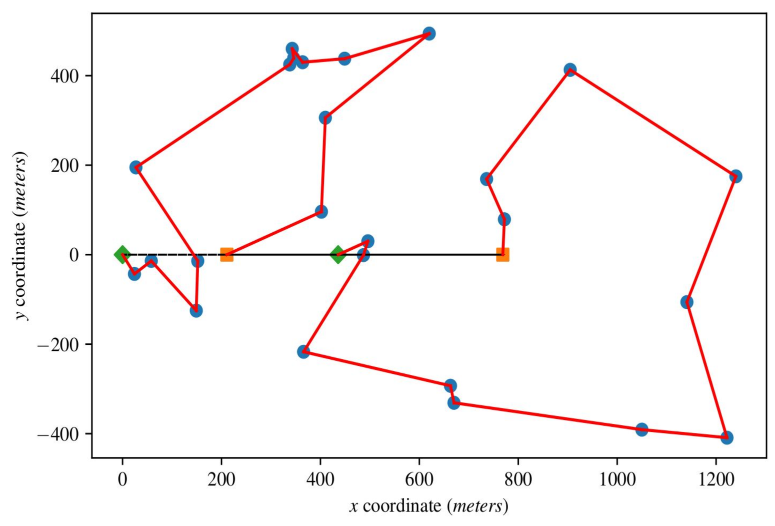
Speed vs. Power Consumption



Speed vs. Travel Distance



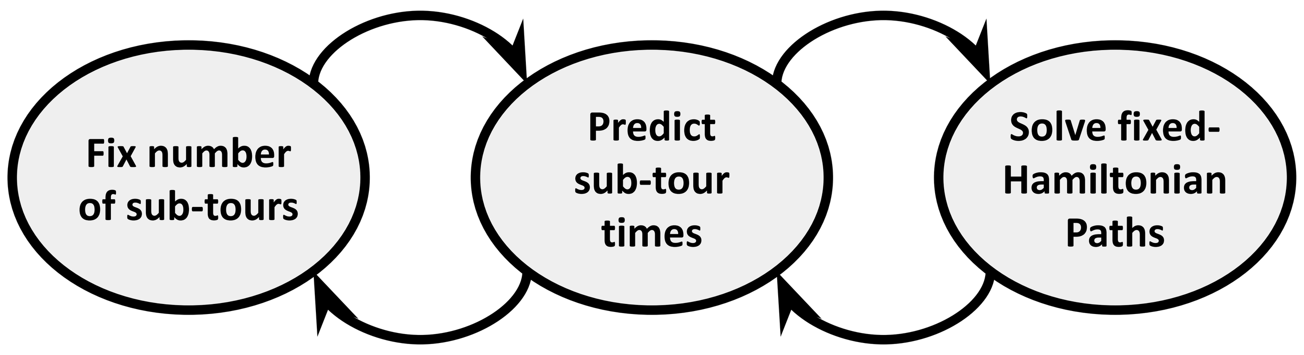
Path found using *k*-IP approach



Path found using MINLP approach

Our Approach

Iteratively fix number of sub-tours, predict sub-tour times, solver underlying fixed-Hamiltonian Paths Problem

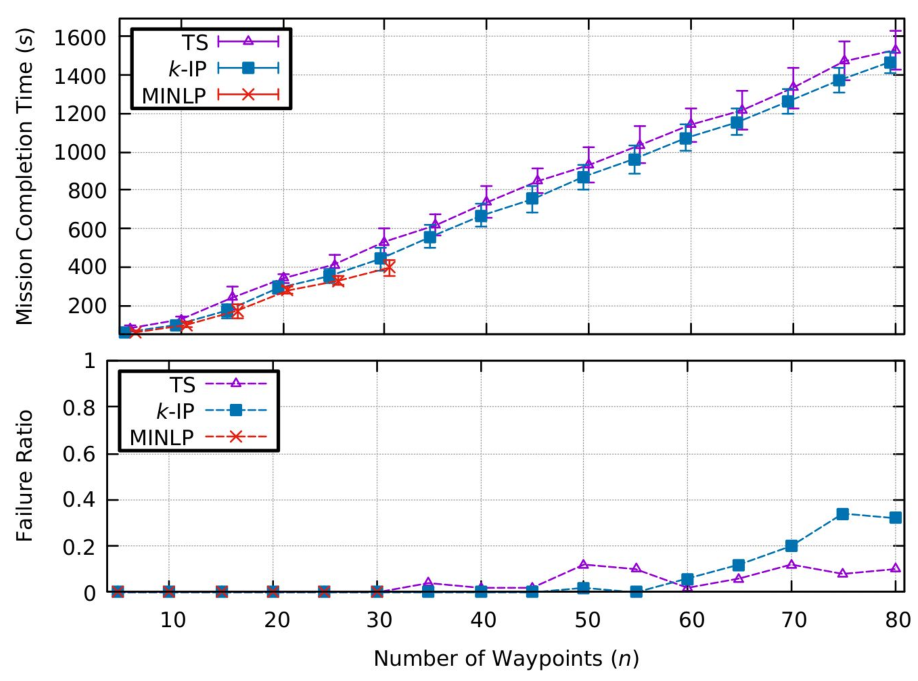


Developed two ways to solve fixed-Hamiltonian Paths:

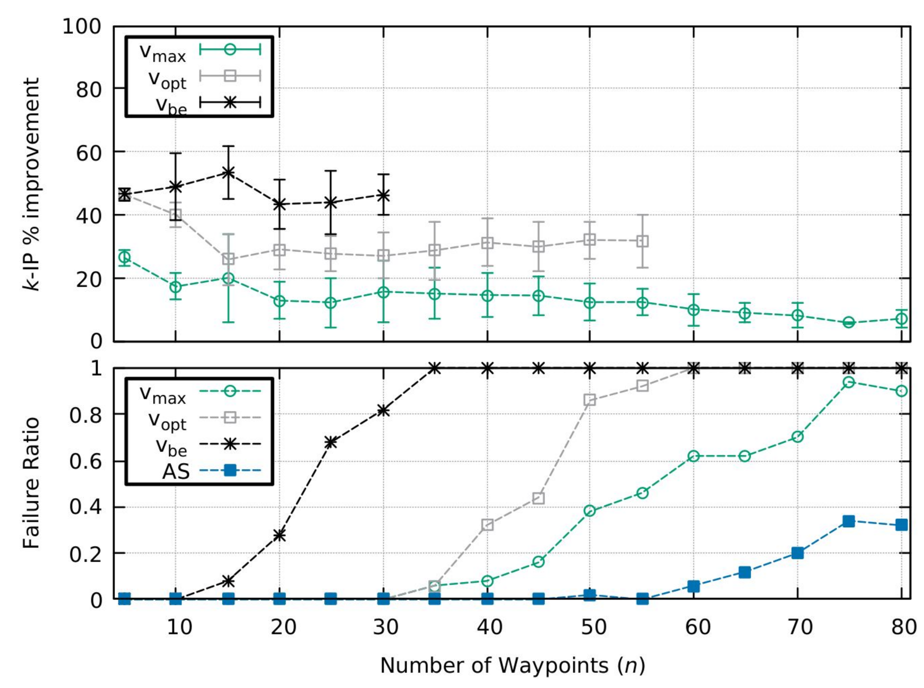
- *k*-means clustering with TSP solver (*k*-IP)
  - First clust waypoints the treat clusters a TSP
  - Optimize UAV speed after solving sub-tours
- Mixed-Integer Nonlinear Program (MINLP)
  - Minimize mission completion time by jointly minimizing sub-tour distance and maximizing UAV speed for sub-tour

Simulation Evaluation

- Considered randomly placed waypoints application with linear ground vehicle
  - Ground vehicle moves at fixed velocity
  - Waypoints generated at fixed density
- Compared against *tour-splitting* (TS) approach from related works
- Evaluation metrics:
  - Total Mission Completion Time
  - Mission failure ratio

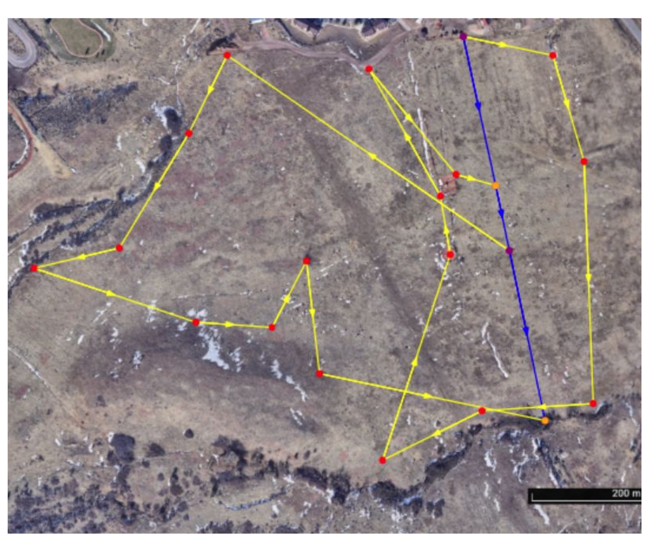


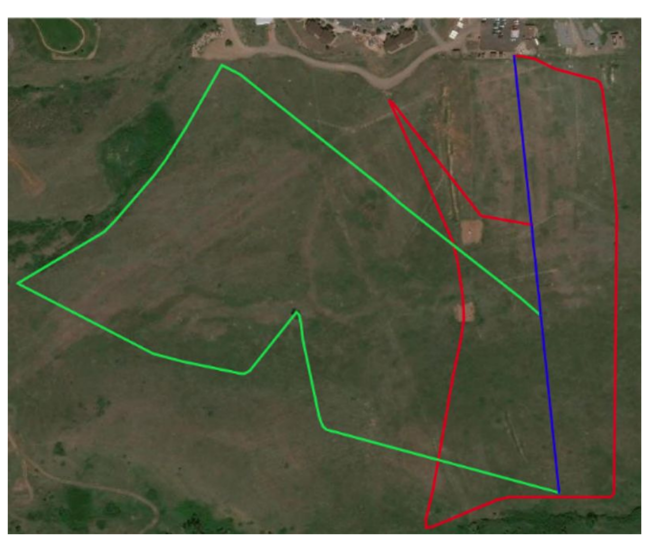
Result: MINLP, k-IP provide 23.8%, 14.5% improvement in mission completion time over TS, respectively



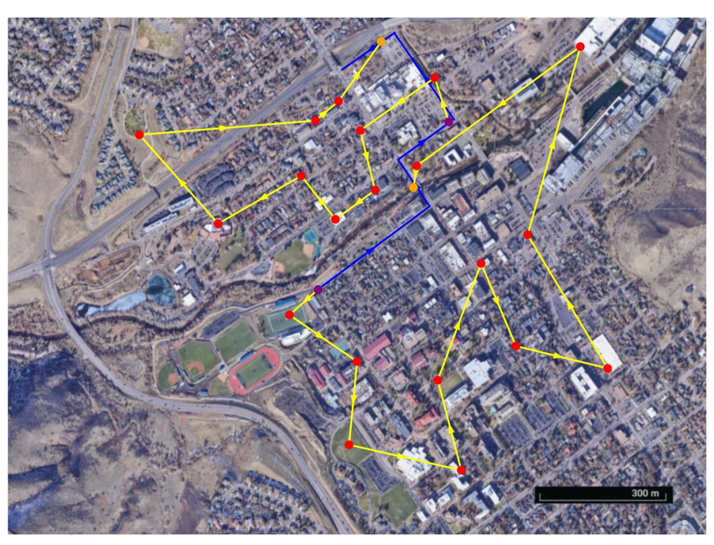
Result: Adapting speed improves mission completion time 11.9% ~ 47.1% compared to fixing speed (depending on approach)

Field Test





Physical Prototype: Modeled problem setup in field experiment with quadcopter drone



Urban Environment: Considered urban environment with ground vehicle following street grid, solved using MINLP

PeCS

Checkout a digital copy of our poster!