SYNDROME: SYNergetic DROne Delivery Network in MEtropolis

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Project URL: http://naira.mechse.illinois.edu/research-outline/#synergetic-drone-delivery-network-in-metropolis-syndrome

Motivation

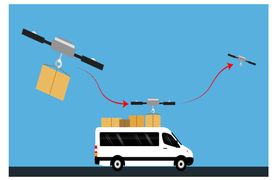
The proposed delivery network uses autonomous flying robots and existing transportation networks to improve last-mile delivery efficiently and safely .

Challenge Content

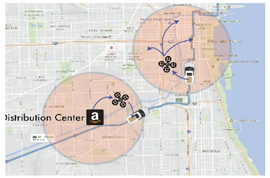
- **Efficiency and Effectiveness:** co-existing with traditional ground delivery system
- **Coordination and collaboration:** synergistic drone and ground networks in the last-mile delivery in populated urban areas
- **Human-machine interaction:** people's safety and comfort with drones flying around

Scientific Impact

Socially accommodative robot motion planning

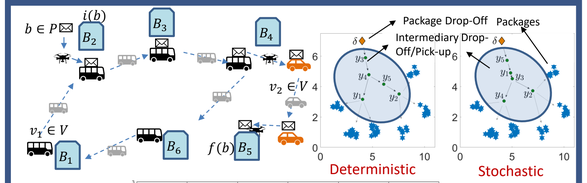


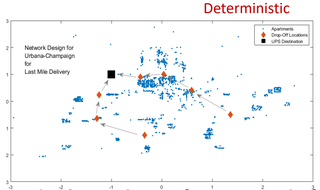
Safe and robust robot motion execution



Efficient package flow and network design

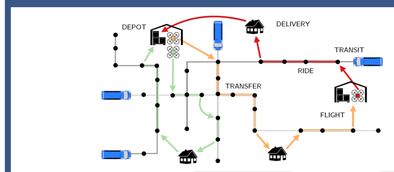
Optimizing Commodity Flow

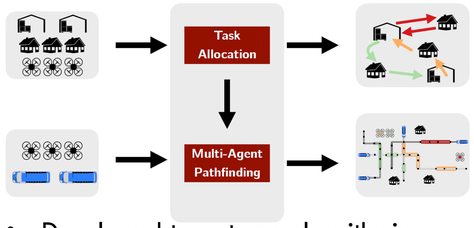




- Developed algorithmic framework for network-design and planning problems in LMDP
- Generalized the approach to Parameterized Sequential Decision Making (Para-SDM) problems
- Pick-Up/Drop-Off Depot LMDP Network Design for the City of Urbana-Champaign

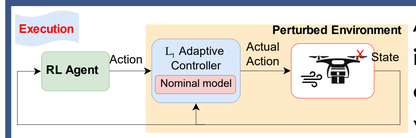
Multi-Drone Delivery





- Developed two-stage algorithmic approach with theoretical guarantees
- Decomposed the problem to task allocation and routing for multiple drones to deliver multiple packages to minimize make span

Safe Learning with Control

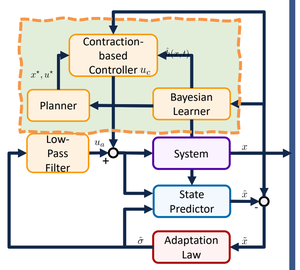


An add-on scheme to improve the robustness of a RL control policy, which

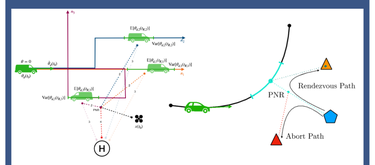
- Trains the RL policy in a nominal environment without dynamic variations
- Leverages $\mathcal{L}_1$ adaptive control during the policy deployment to actively compensate for the dynamic variations

Natural framework for learning using $\mathcal{GP}$:

- guaranteed performance during the learning transients
- improved performance of the $\mathcal{L}_1$ adaptive controller,
- improved quality of the planned trajectory



Risk-Sensitive Rendezvous



- Addressed the risks during rendezvous posed by driver behavior uncertainty and limited battery life.
- Considered drone-vehicle rendezvous over multiple possible paths.
- Implemented robust heuristics that combines Bayesian learning and MPC.

Socially-Aware Motion Planning

- Developed a novel index of human safety perception
- Examined human's safety perception of a flying co-robot using VR physiological and behavioral experiments
- Obtained human Preferred Stopping Distance (PSD) as a function of multiple factors.

Impact on Society

- A step forward for incorporating drones into daily life.
- More efficient logistics for better e-commerce experience.

Outreach

PI Hovakimyan visits Montessori school of C-U to showcase robotics to elementary-age students.

Broader Impact

- Market size: USD 860 million in 2021 (projected to reach USD 4,964 million by 2030)
- More than 2,000 drone deliveries are occurring each day worldwide
- Amazon's cost per package would be ~88 cents per parcel

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