



Adaptive Multi-Agent Path Planning for Distributed UAV Systems

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Motivation

Proliferation of low cost UAVs facilitates the exploration of more dangerous environments. Novel path planning algorithms are needed to control these UAVs.

Problems:

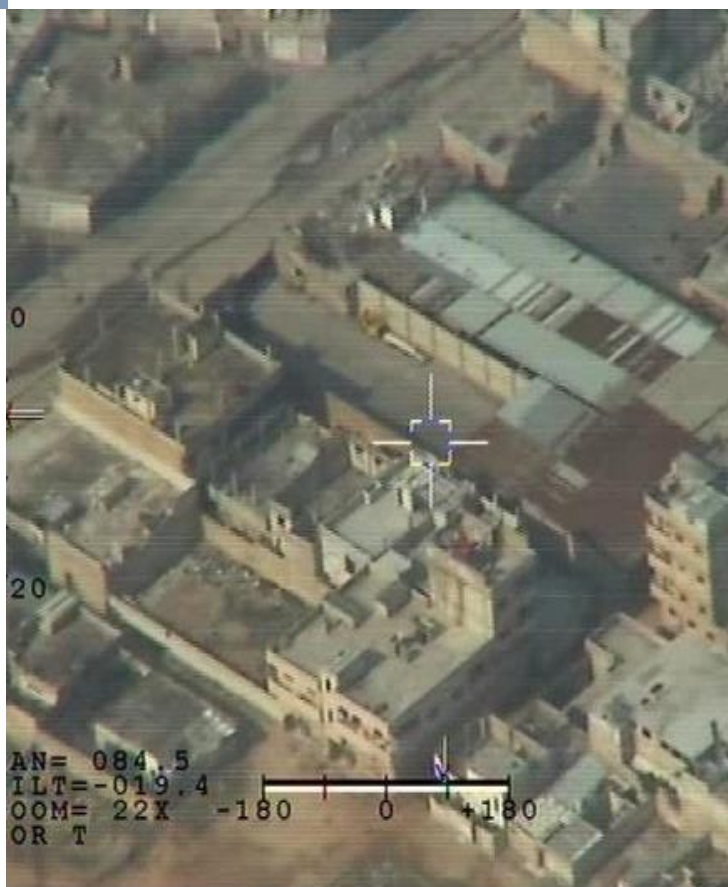
- Unknown risk environment
- Real time planning
- Multiple cooperative agents
- Multiple targets

Scenario



Threats such as anti-air and terrain are initially unknown to UAVs. Must be discovered.

Targets are initially known to UAVs. Scenario runs until UAVs have visited all targets or run out of fuel.



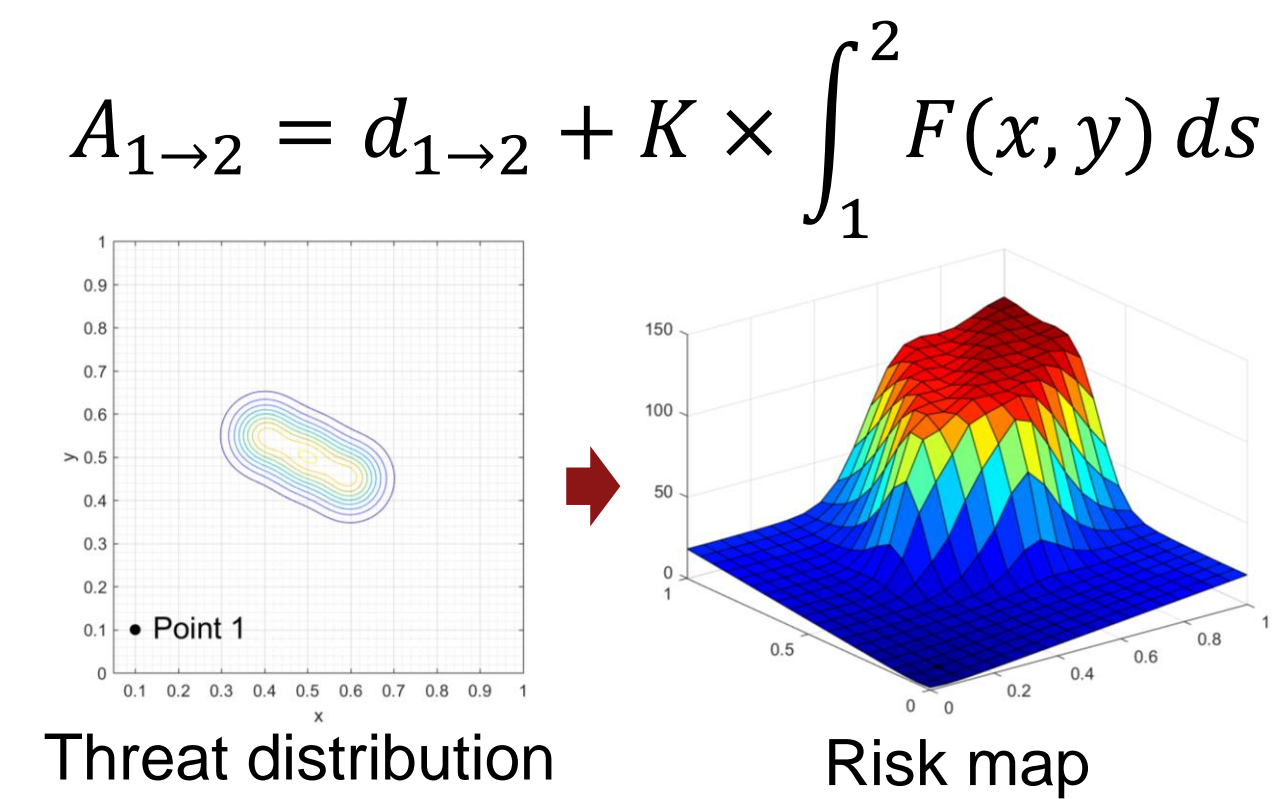
UAVs have realistic observation radii and fuel capacity. UAVs can share threat information.

Method

Cooperative and Geometric Learning Algorithm (CGLA) [2]

- Offshoot of Q-learning
- Use UAV positions as states
- Balance between minimizing path length and minimizing risk
- Simplifies information sharing between agents

Generate **risk map** (A) of the known environment
 ↓
 Generate **cost matrix** (G)
 ↓
 Execute **path planning**
 ↓
 If an unmodeled threat is discovered, **repeat** from step 1



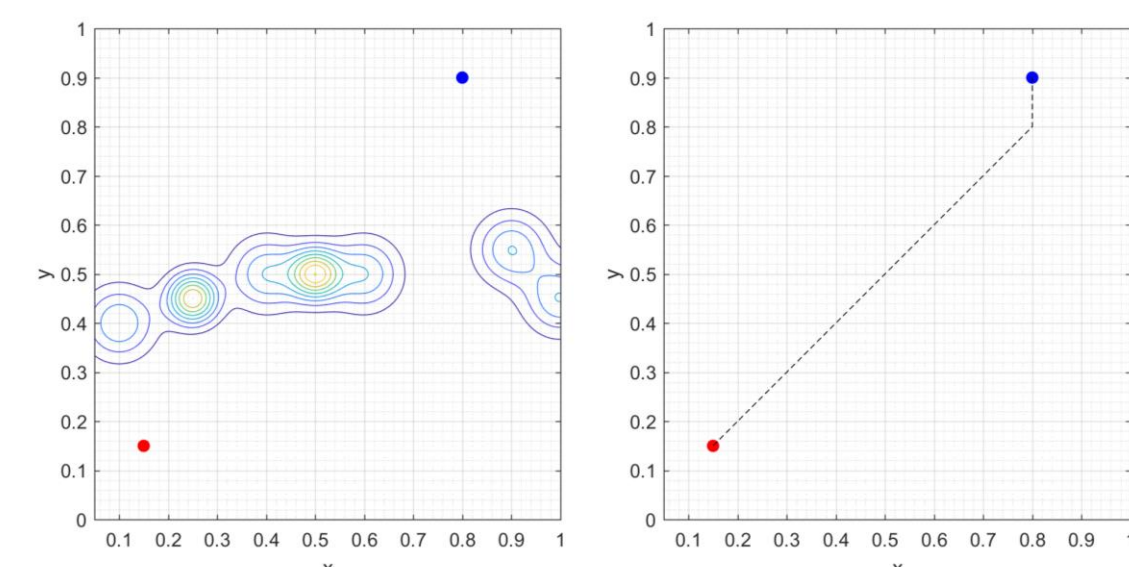
Conclusions

- CGLA does a great job of facilitating complex distributed tasks for UAV systems
- Handles an unknown dynamic environment robustly
- Easily allows many UAVs to cooperate on their tasks
- Algorithm runs quite slowly and may not work well for very large or finely discretized maps

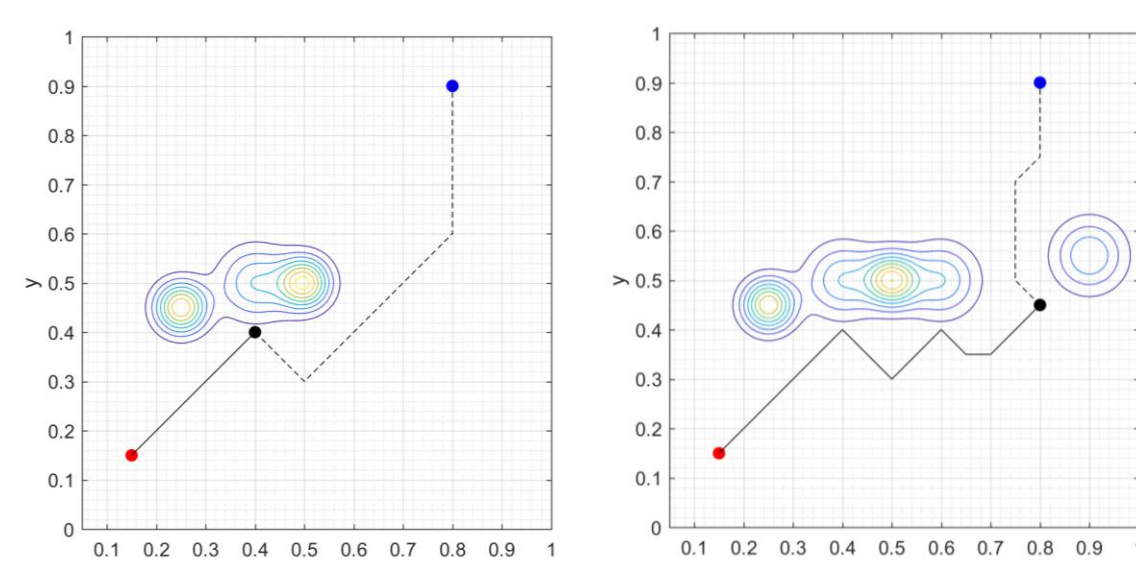
Results

Learning to Navigate in an Unknown Environment

The environment is initialized with a group of unseen threats



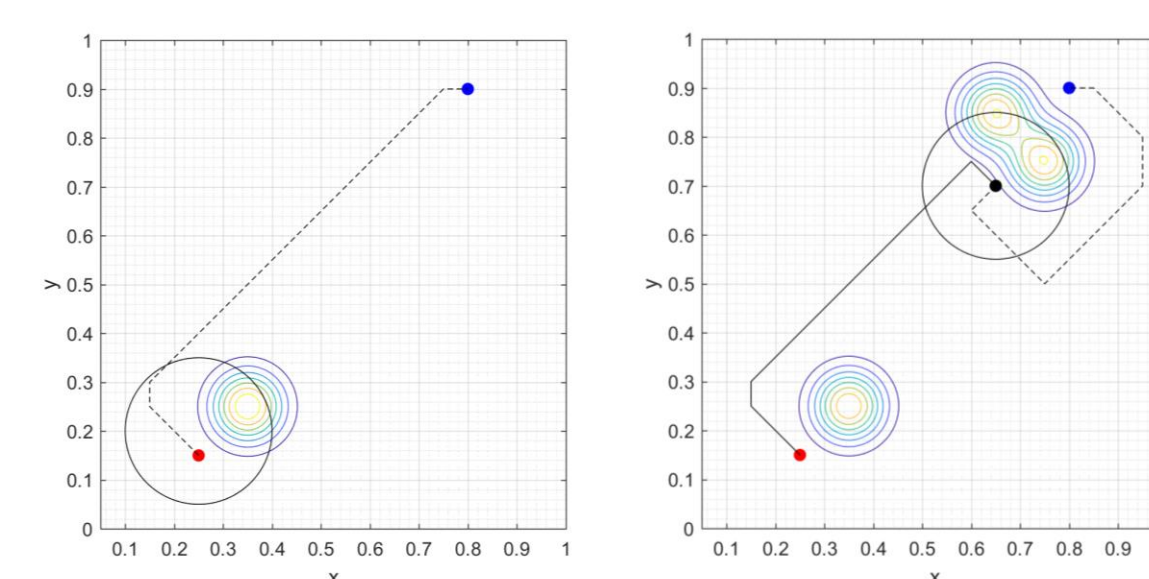
CGLA is iteratively executed to update the path as UAVs encounter unseen threats



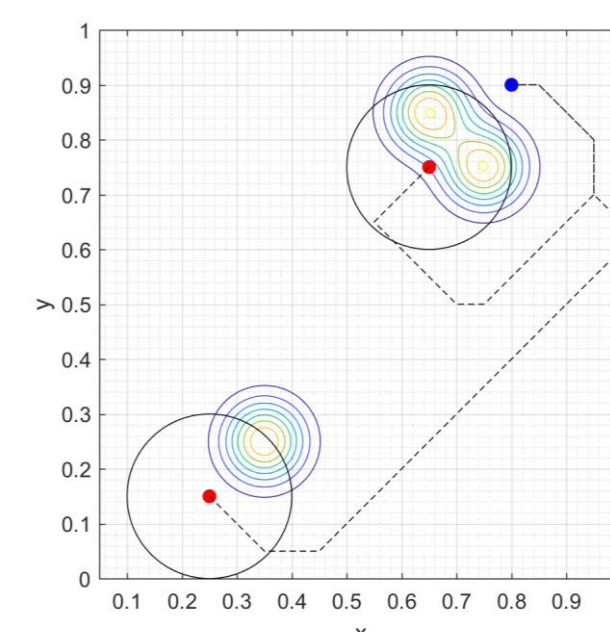
Blue – Target position
Red – UAV starting position

Information Sharing in an Unknown Environment

Scenario with one UAV must handle each threat as it encounters them

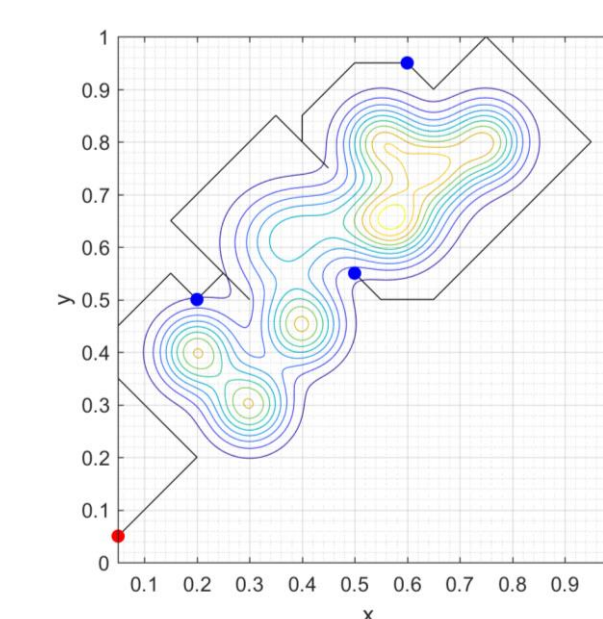


Teams of UAVs share information as threats are discovered, leading to smarter paths

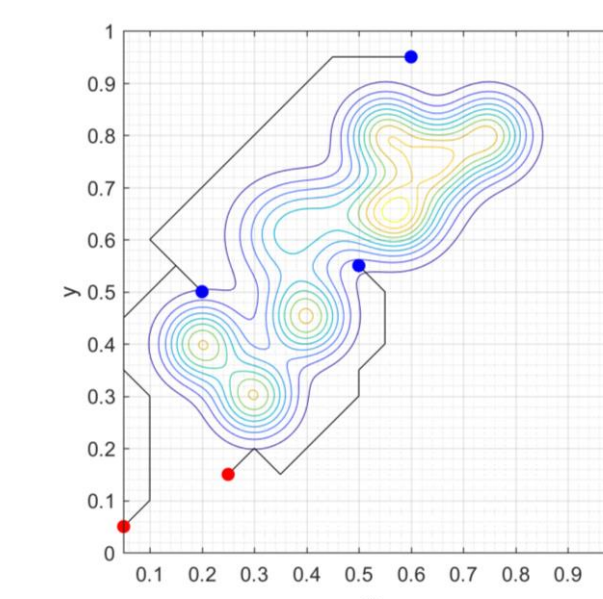


Multiple Target – Multiple UAV Environment

A single UAV must try to find the optimal path that visits all targets



Efficient target assignment speeds up the target observation with multiple UAVs



Future Work

- Performance improvements to speed up algorithm
- Introduce additional states (e.g. 3rd dimension)
- Compare CGLA performance against Q-learning or other deterministic baseline
- Add the ability to handle unknown mobile threats
- Implement on hardware

References

- [1]: Zhang, B., Mao, Z., Liu, W., et. al. "Geometric Reinforcement Learning for Path Planning of UAVs," Journal of Intelligent and Robotic Systems, Volume 77, No. 2, 2015, pp 391–409.
 [2]: Zhang, B., Mao, Z., Liu, W., et. al. "Cooperative and Geometric Learning Algorithm (CGLA) for path planning of UAVs with limited information," Automatica, Volume 50, No. 3, 2014, pp 809-820.