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Target Search Using a Swarm of UAVs: a Game Formulation with Dynamic Information

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Unmanned aerial vehicles (UAVs), like drones, are at the heart of high intensity military conflicts due to their versatility and tactical capabilities. Beyond defence applications, UAV swarms are being explored for civilian tasks such as surveillance, disaster response, and environmental monitoring. One critical challenge in these applications is target search, where UAVs aim to locate hidden objects or adversaries while operating under constraints such as limited energy and communication ranges. We formulate target search by a swarm of UAVs as a dynamic game considering different coordination schemes and information structures.

The target location being unknown, it is common to use a Bayesian framework, allowing to capture dynamic information. We define the UAVs' beliefs about the target's location as a probability distribution on the search area. At each time step, based on the sensor observations and conditional target detection probability, we update the UAVs' belief using Bayes' rule.

The target search is formalized as a discrete-time dynamic game with incomplete information, in which, at each time step, the UAVs maximize their information gain while minimizing their energy consumption. Our objective is to optimize the trajectories of the UAVs by tracking the equilibria solutions of the game over time. Further, we consider two coordination schemes:

- a **centralized coordination scheme** where a central unit gathers information from all UAVs and optimize their strategies to minimize the swarm's social cost;
- **decentralized coordination schemes** where UAVs optimize their strategies based on local information. As benchmarks, we consider two extreme cases: (i) UAVs operate in stand-alone without information exchange, and (ii) UAVs can share information with others within a predefined neighborhood. Between these cases, we propose a single leader multi-follower Stackelberg game to model UAV interactions and information exchange, where a leading UAV constrains the feasibility set of the followers to enforce information exchange, giving rise to a noncooperative game with an endogenous information structure. Conjectural variations game extensions will be considered.

Simulations are conducted to evaluate and compare the performance of each coordination scheme.

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