Reaching a Target inside a Denied Area: What is the Optimal Control Strategy?

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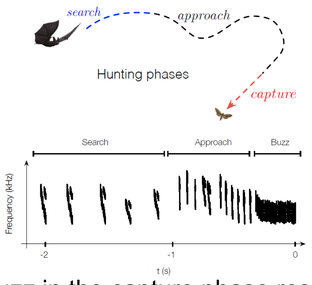
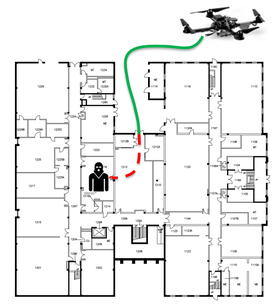
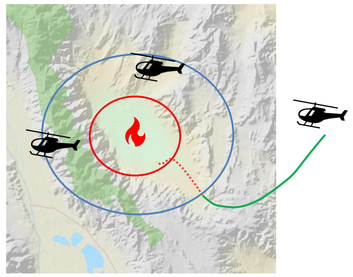
Motivation







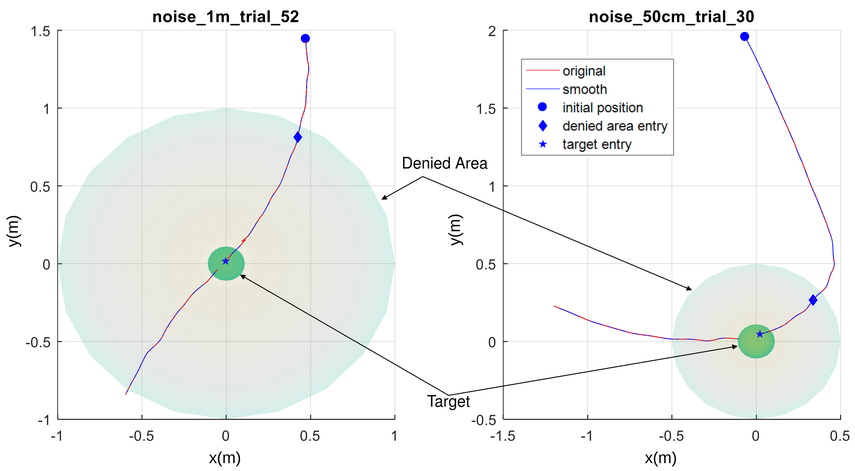
- Bat's buzz in the capture phase resembles open-loop control of a mobile agent in a denied area.
- Denied area is generalized to time-costly area.

Research Goals

1. Understand how to control a mobile agent to reach a target enclosed within a denied area.
2. Develop a systematic method to find the optimal control strategy to perform such task.
3. Compare trajectories from theory to trajectories from bat experiments.

Experiments: Bat vs. Denied Area

- Artificial denied area with adjustable sizes using white noise
- Success capture defined as bat's distance to the meal worm (at origin) ≤ 10cm
- Observation: bat's trajectories inside the denied area are not straight lines.



Theoretical Study I: Deterministic Problem[1]

Formulation: a two-stage optimal control problem with a specific time cost in the inner stage

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Method: augmenting the inner stage subproblem as the terminal performance index of the outer stage

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Key: find the optimal switching position and the optimal terminal position

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Difficulty: a nonconvex subproblem

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We found the *solution* and proposed an *algorithm* generating the optimal control by sequentially solving subproblems

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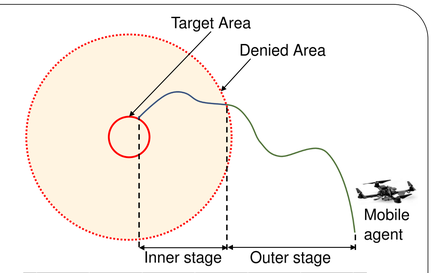
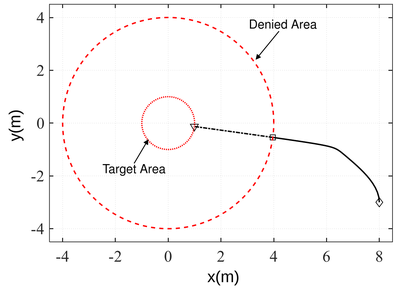
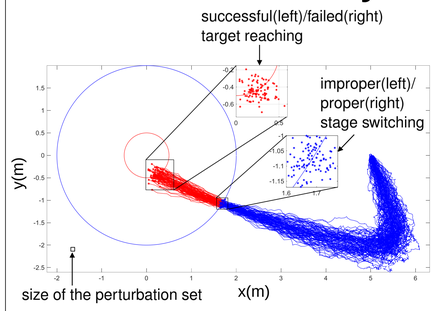
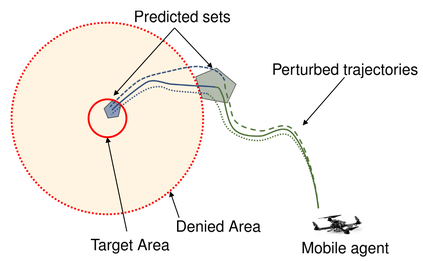
Results: controller successfully steers the mobile agent to the target in simulations





Theoretical Study II: Perturbed Problem





Formulation: perturbations bounded in convex polytopes

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Challenges with perturbation:

1. Stage switching at improper positions
2. Target reaching failures

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Method:

1. Trajectory planning with predicted sets
2. Variable horizon Model Predictive Controller

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Solution: solving for a local minimum using YALMIP

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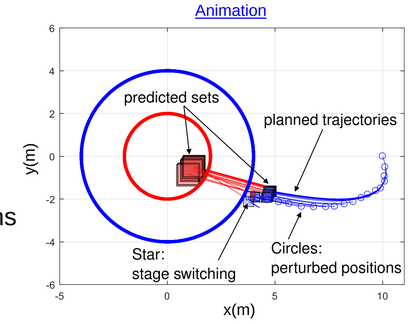
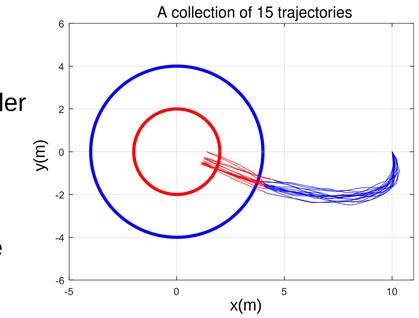
Result: provable guarantees on proper stage switching and target reaching

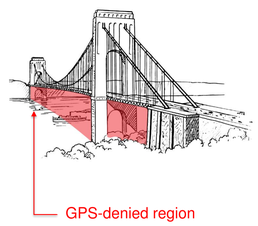
Animation





1 This work is in the paper: S. Cheng and N. Martins, "Reaching a Target in a Time-costly Area Using Two-stage Optimal Control Method", *in progress.*

Related Work: Optimal Sensor Scheduling for Station Keeping in Denied Environments

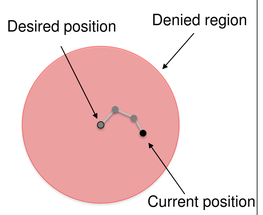


Motivation: monitoring of large structures

- GPS positioning unavailable in denied region
- Extra costs for agents to request position outside the denied region

Formulation:

- Modelling agent's position as a random walk
- Choosing cost as the infinite-time average of the expectation values of stage costs at each time
- The agent returns to the desired position once an observation is made.



This work is in the paper: E. Arvelo, N. Martins, "Optimal Sensor Scheduling for Station Keeping in Denied Environments", *submitted*

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