HALO: Hazard-Aware Landing Optimization
(*for Autonomous Systems*)

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ICRA LONDON · 2023

Autonomous Controls Lab

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Introduction

Problem Statement

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Objective

Develop a framework that enables autonomous aerial vehicles to land ***safely*** in ***unknown*** environments with only ***depth*** information on their surroundings.

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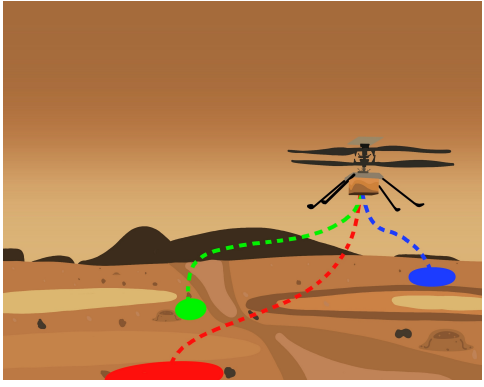
Contributions

Two key algorithms developed and integrated (closed-loop) in the **AirSim** simulation environment:

1. **H**azard-**A**ware **L**anding **S**ite **S**election (**HALSS**)
2. **Adaptive** **D**eferred-**D**ecision **T**rajectory **O**ptimization (**Adaptive-DDTO**)

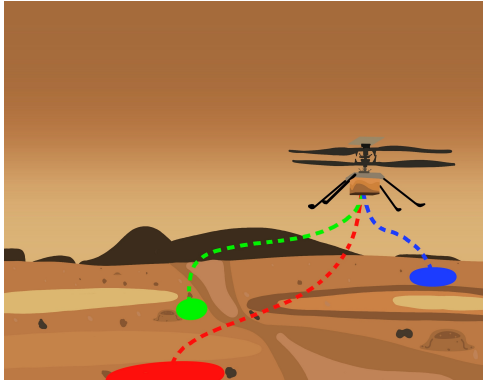
Mars helicopter



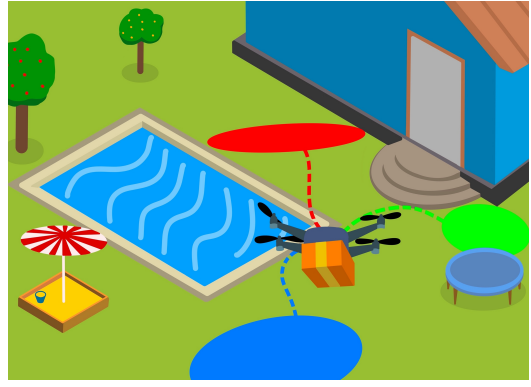
Problem Motivation

Introduction

Mars helicopter



Package delivery

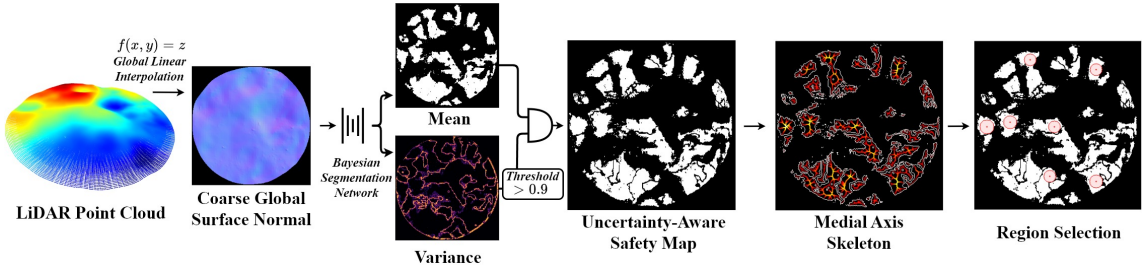


HALSS

Hazard-**A**ware **L**anding **S**ite **S**election

Coarse Hazard Detection

Hazard Aware Landing Site Selection

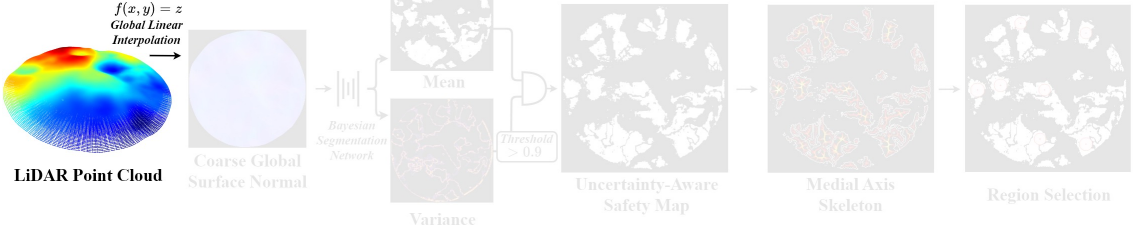


Overview

Perform a coarse search over all the observed map, use a learning-based approach to classify safety, and identify regions to further search for landing sites.

Coarse Hazard Detection: Point Cloud Interpolation

Hazard Aware Landing Site Selection

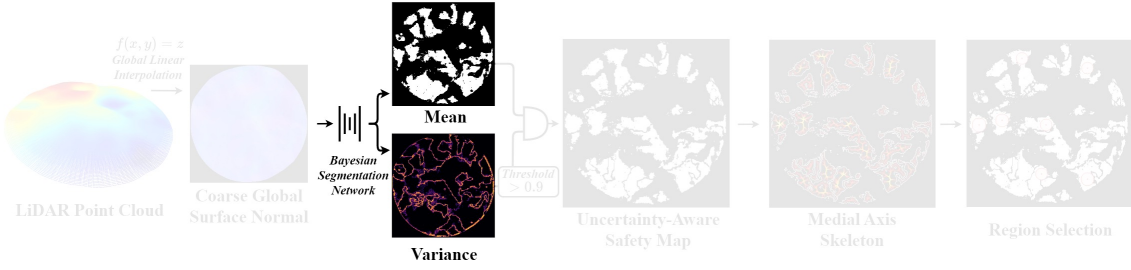


Coarse Hazard Detection: Surface Normal

Hazard Aware Landing Site Selection

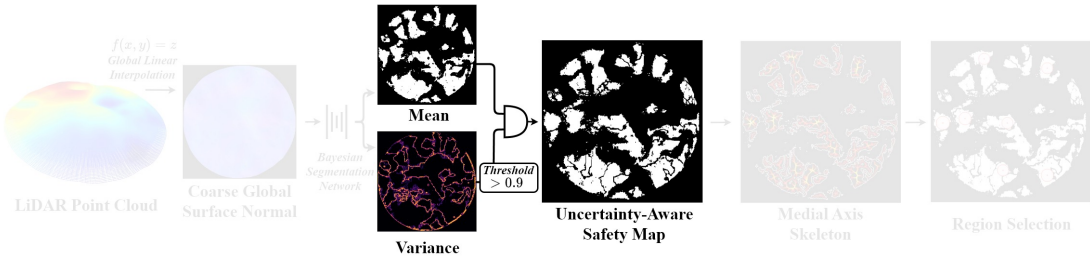
Coarse Hazard Detection: Bayesian Segmentation Network

Hazard Aware Landing Site Selection



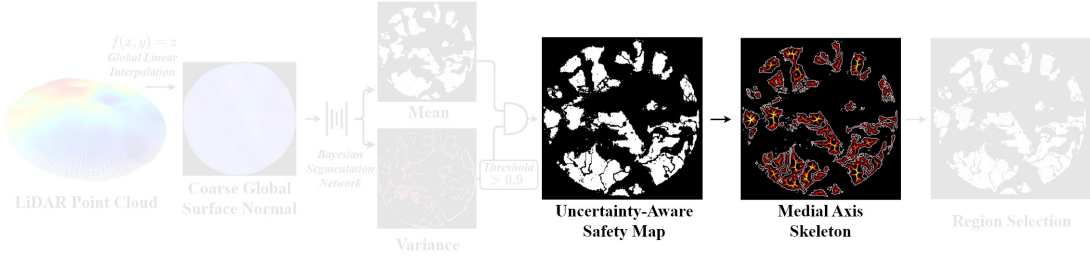
Coarse Hazard Detection: Variance-Aware Safety Map

Hazard Aware Landing Site Selection



Coarse Hazard Detection: Medial Axis Transform

Hazard Aware Landing Site Selection

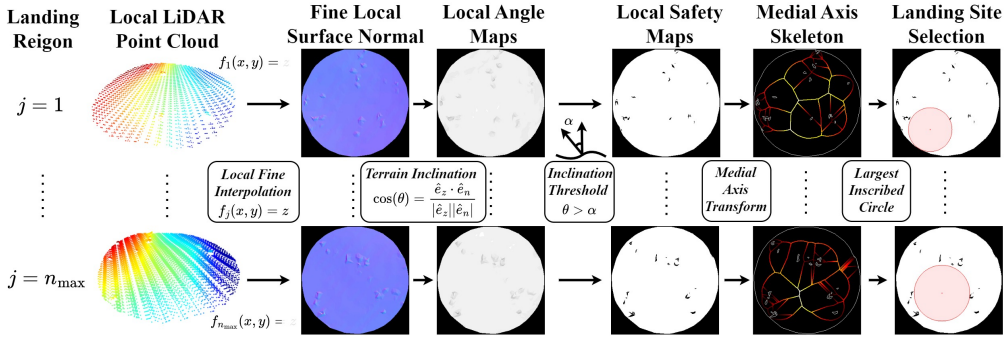


Coarse Hazard Detection: Region Selection

Hazard Aware Landing Site Selection

Fine Hazard Detection

Hazard Aware Landing Site Selection

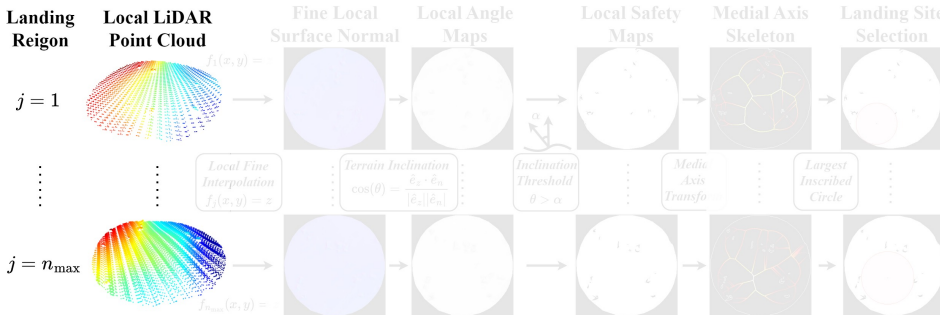


Overview

Given prospective regions, perform a fine search within each region, use a topographical-based approach to classify safety, and identify landing sites.

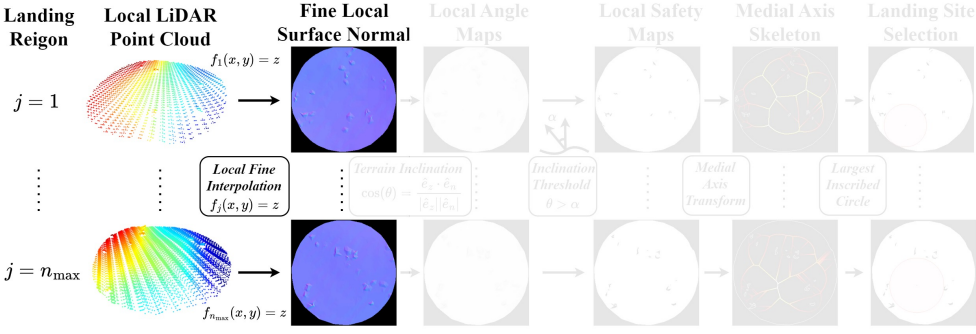
Fine Hazard Detection: Local LiDAR Resampling

Hazard Aware Landing Site Selection



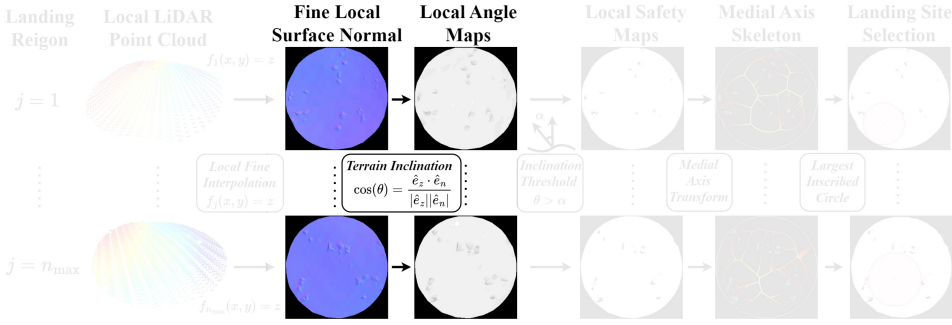
Fine Hazard Detection: Local Surface Normal

Hazard Aware Landing Site Selection



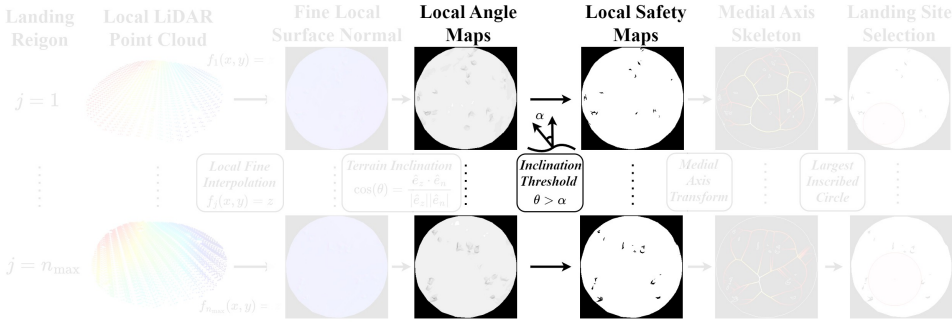
Fine Hazard Detection: Local Angle Map

Hazard Aware Landing Site Selection



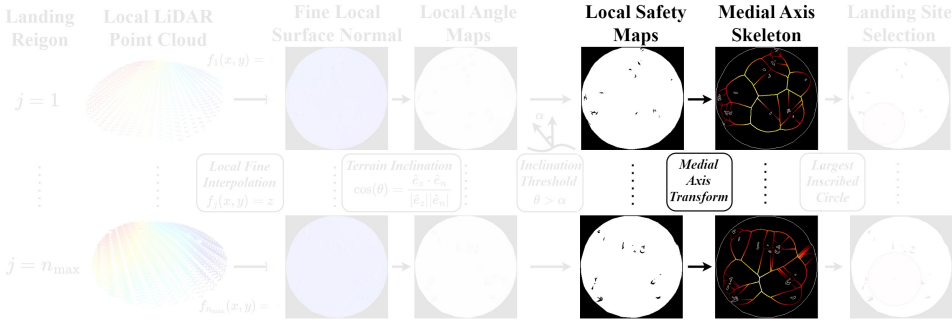
Fine Hazard Detection: Local Safety Map

Hazard Aware Landing Site Selection



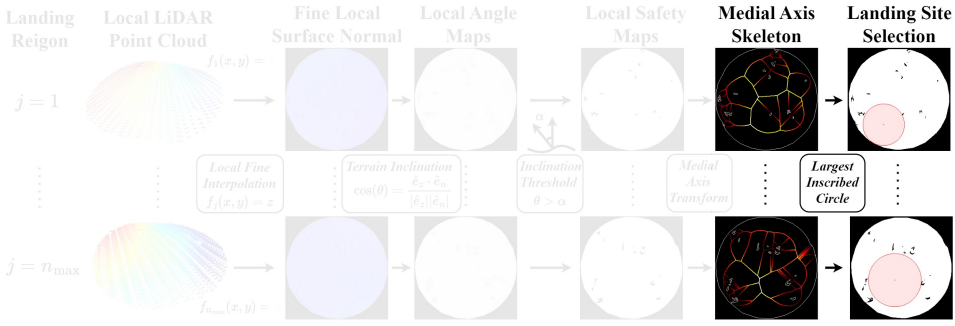
Fine Hazard Detection: Local Medial Axis Transform

Hazard Aware Landing Site Selection



Fine Hazard Detection: Landing Site Selection

Hazard Aware Landing Site Selection

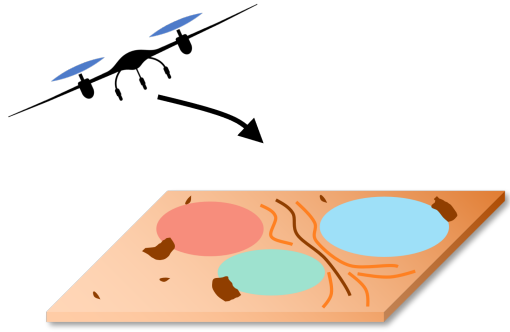


Adaptive-DDTO

Adaptive Deferred-**D**ecision **T**rajectory **O**ptimization

High-Level Approach

Adaptive-DDTO



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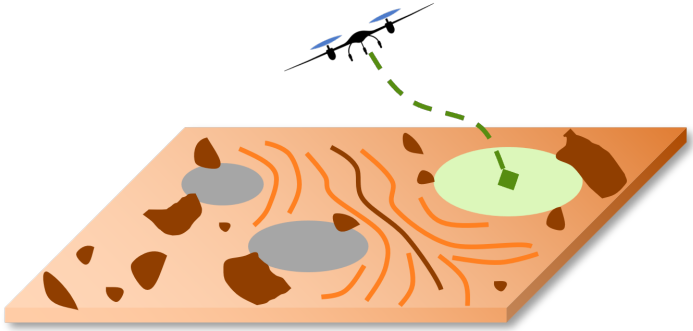
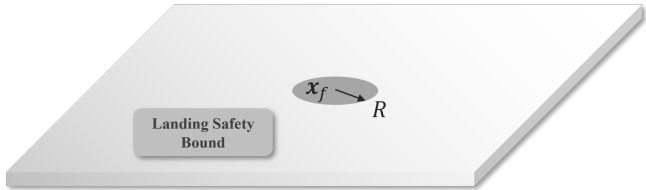


Single-Target Trajectory Optimization

Adaptive-DDTO



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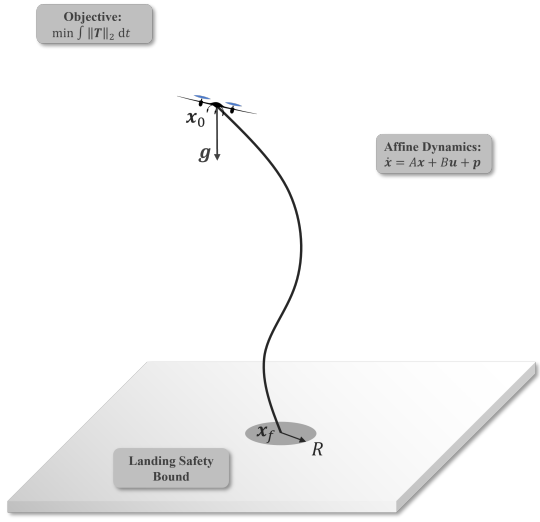

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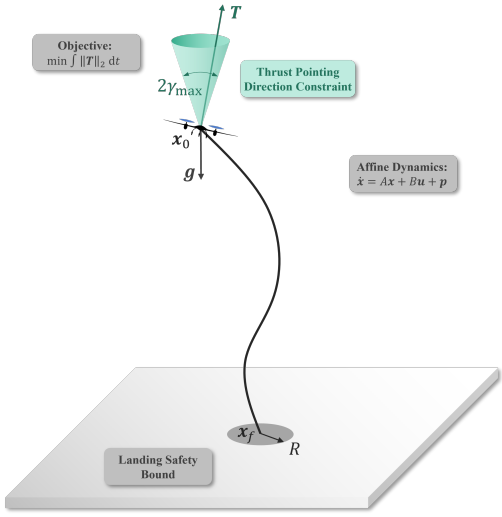

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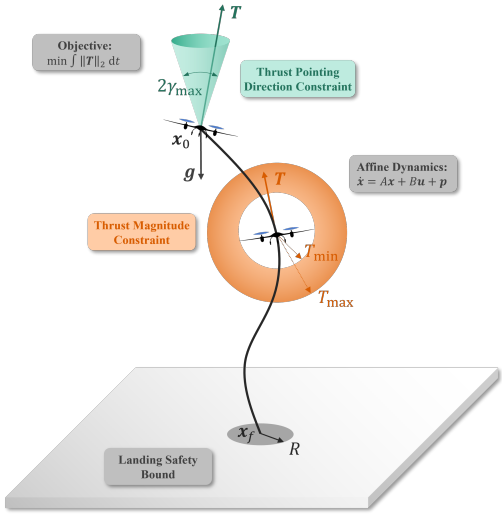
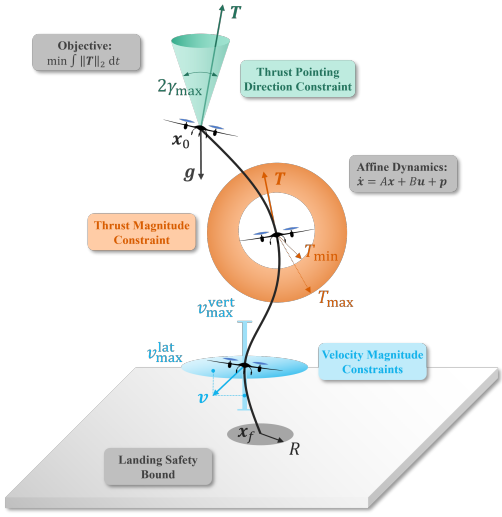


Single-Target Trajectory Optimization

Adaptive-DDTO



Deferred-Decision Trajectory Optimization (DDTO)

Adaptive-DDTO

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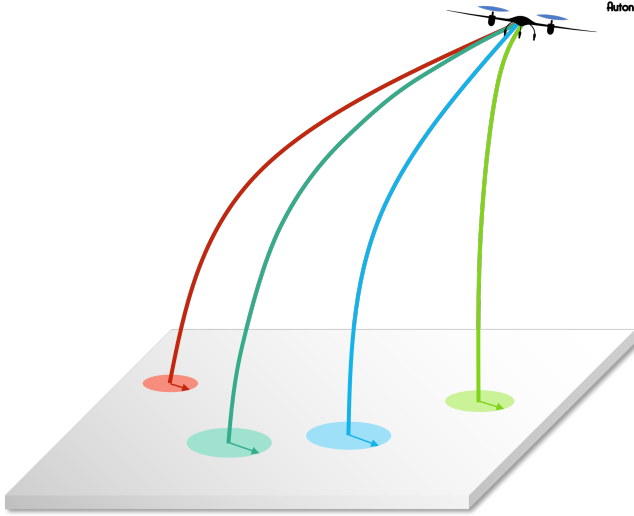
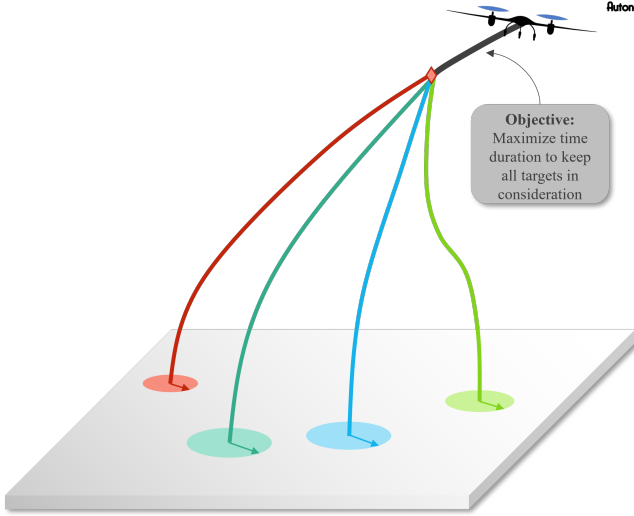


Deferred-Decision Trajectory Optimization (DDTO)

Adaptive-DDTO



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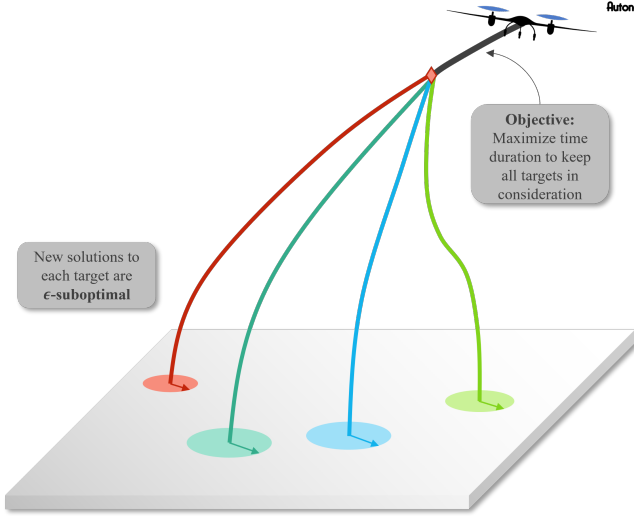

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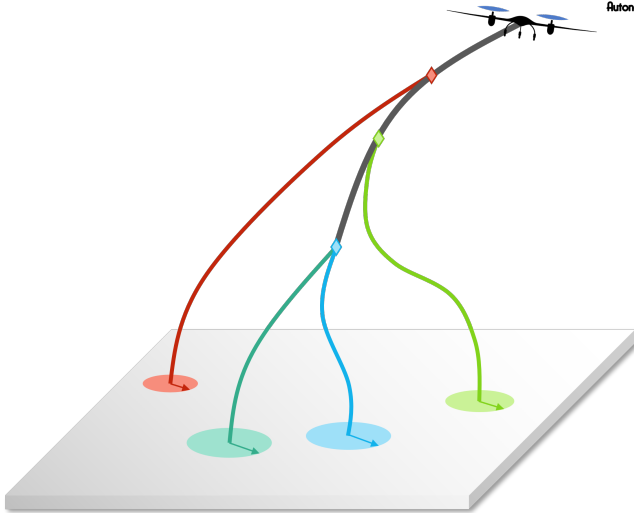

Deferred-Decision Trajectory Optimization (DDTO)

Adaptive-DDTO

Problem

Targets can be lost while executing solution due to:

1. Perception updates
2. Dynamic changes in the environments
3. DDTO's tree-like structure

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Adaptive-DDTO

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Targets can be lost while executing solution due to:

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Solution

Adaptively recompute DDTO solutions whenever target count falls below a minimum threshold.

Simulation Results

Github Repository

Thanks for watching!

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