Drones Demystified!

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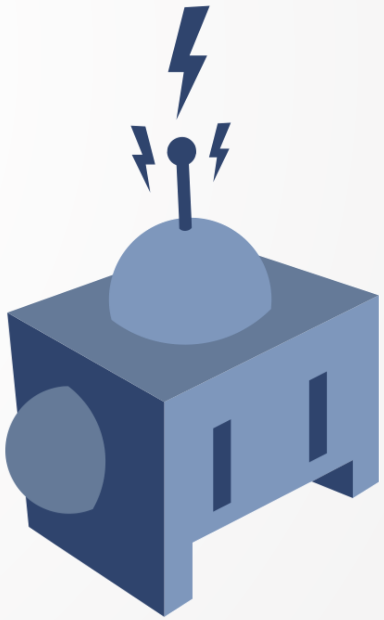
Drones Demystified!

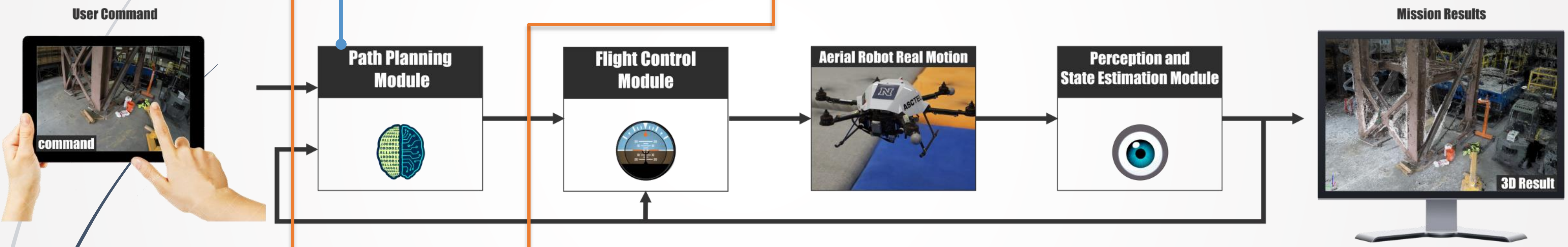
Topic: Introduction to Path Planning

How do I plan my motion and actions?



The Aerial Robot Loop

- Path planning in order to compute the path the robot should follow to ensure safe navigation and execute the desired mission.



Section 4 of our course

What is Path Planning?

- **Determining the robot path based on a set of goals and objectives, a set of robot constraints and subject to a representation and map of the environment.**

What is Motion Planning?

Hawk Navigation

Cheetah running

Eagle hunting

Nadia Comaneci, First “10”, 1976

Main Topics of Path Planning

Motion Planning

- Geometric representations and transformations
- The robot configuration space
- Sampling-based motion planning
- Combinatorial motion planning
- Feedback motion planning

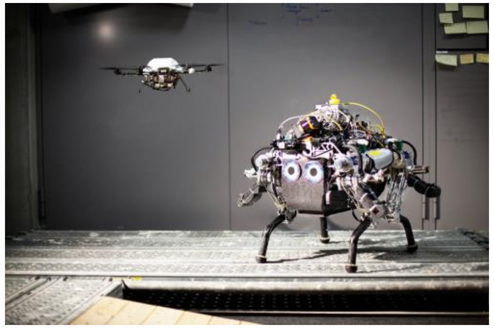
Decision-theoretic planning

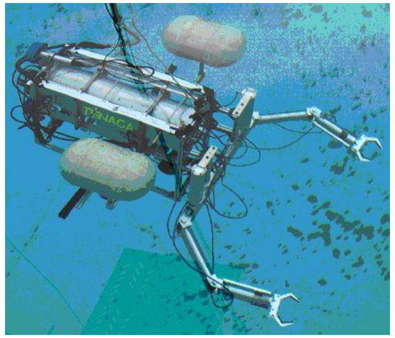
- Sequential decision theory
- Sequential decision theory
- Sensors and information
- Planning under uncertainty

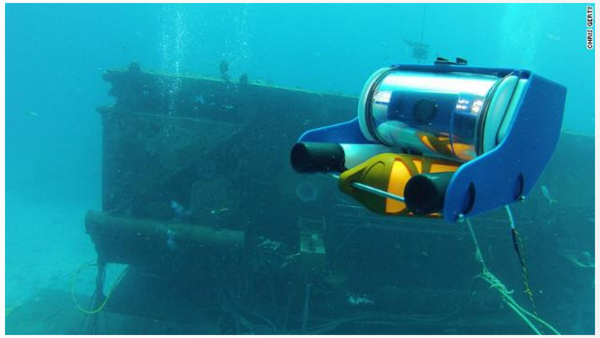
Planning Under Differential Constraints

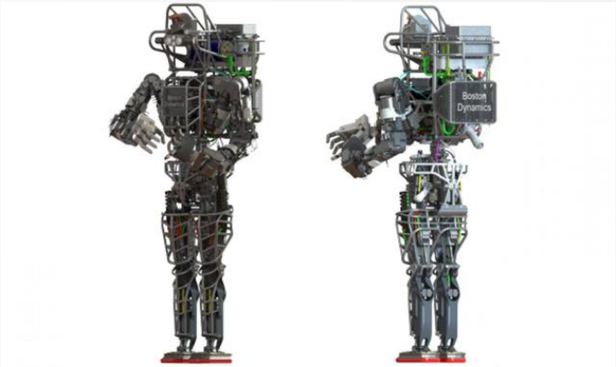
- Differential models
- Sampling-based planning under differential constraints
- System theory and analytical techniques

Robots exist in many configurations









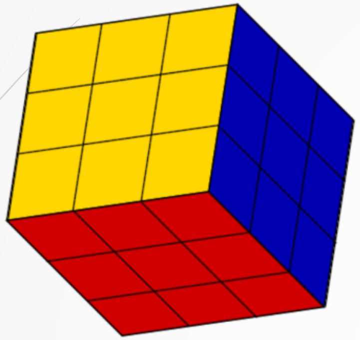
Overview of Concepts

- Planning Tasks
  - Navigation
  - Coverage
  - Localization
  - Mapping

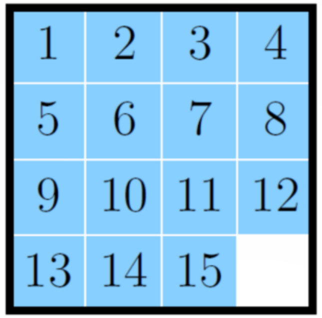
- Properties of the Robot
  - Degrees of Freedom
  - Non/Holonomic
  - Kinematic vs Dynamic

- Algorithmic Properties
  - Optimality
  - Computational Cost
  - Completeness
    - Resolution completeness
    - Probabilistic completeness
  - Online vs Offline
  - Sensor-based or not
  - Feedback-based or not

Indicative Examples



(a)



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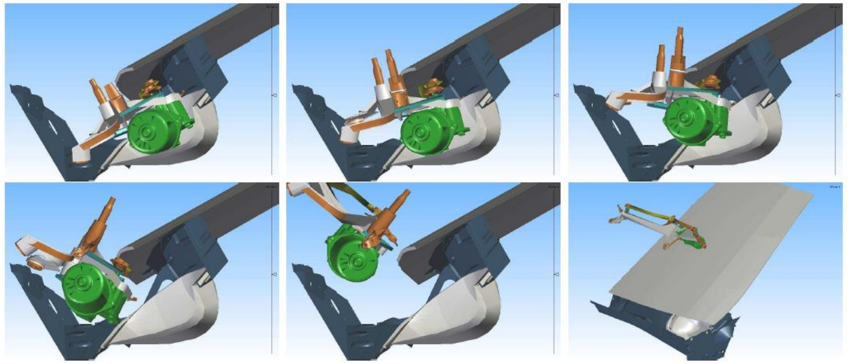
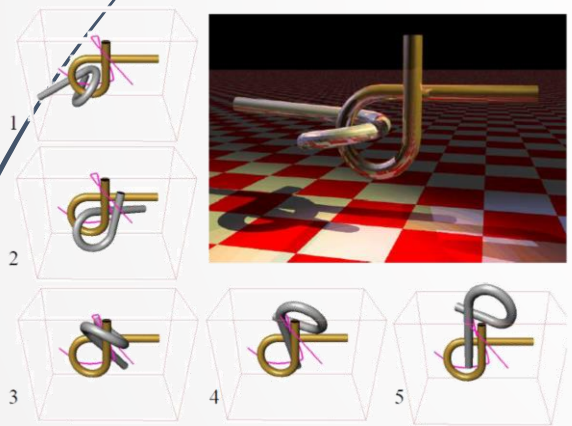
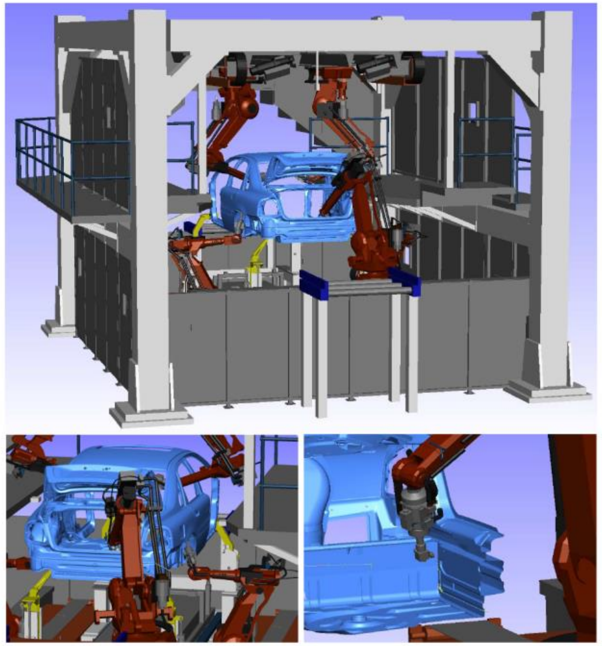
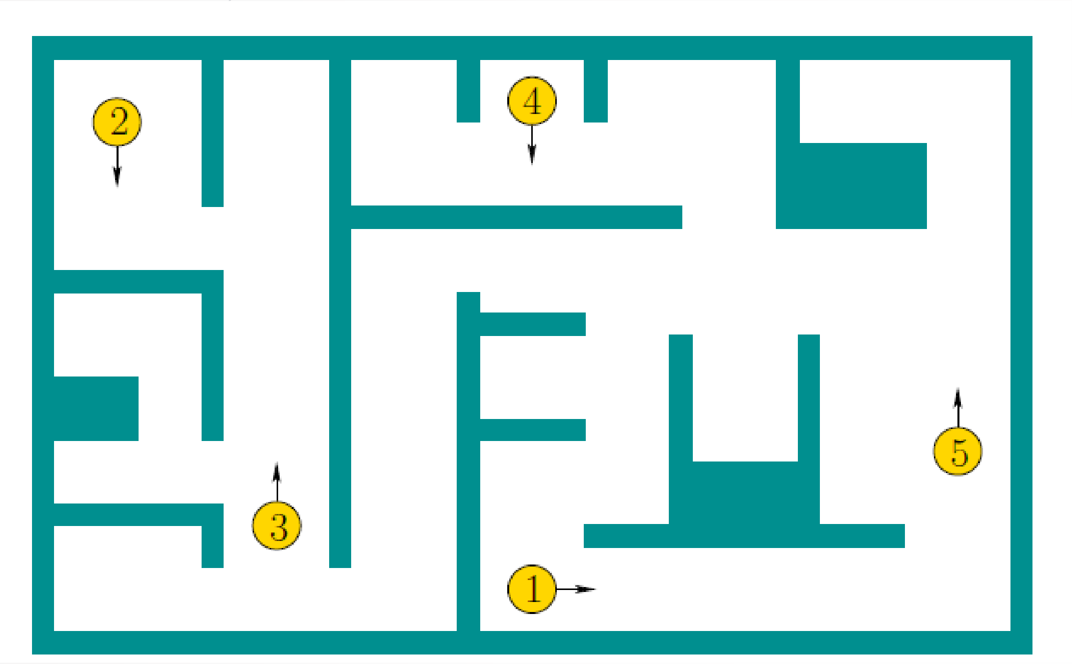




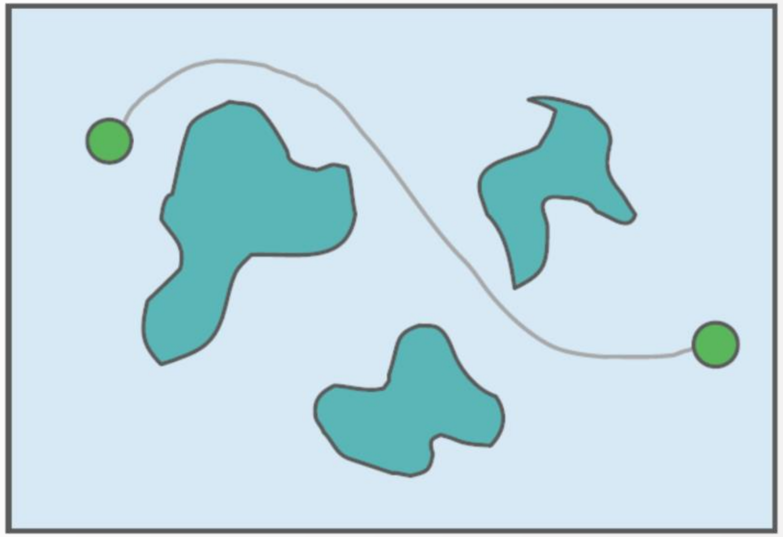


Example of a world (and a robot)



Fundamental Problem of Path Planning

- **Problem Statement:**
  - Compute a continuous sequence of collision-free robot configurations connecting the initial and goal configurations.



- Geometry of the environment
- Geometry and kinematics of the robot
- Initial and goal configurations

Path Planner

Collision-free path

Fundamental Problem of Path Planning

- **Problem Statement:**
  - Compute a continuous sequence of collision-free robot configurations connecting the initial andgoal configurations.
- **Motion Planning Statement for collision-free navigation**
  - If W denotes the robot's workspace, and WO_i denotes the i-th obstacle, then the robot's free space, W_{free}, is defined as: $W_{free} = W - (\cup WO_i)$ and a path c is $c: [0,1] \rightarrow W_{free}$, where $c(0)$ is the starting configuration q_{start} and $c(1)$ is the goal configuration q_{goal}.

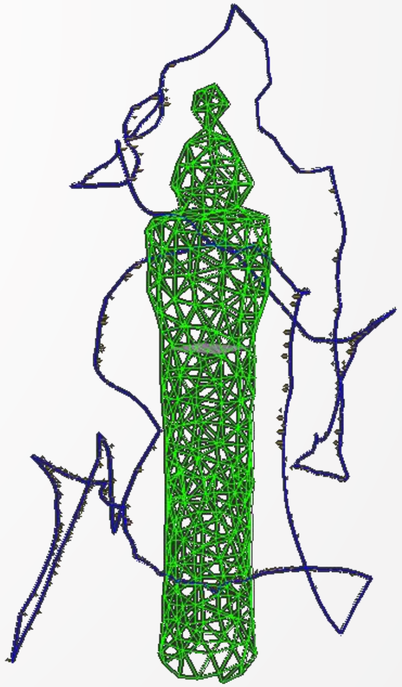

ETH zürich
Autonomous Systems Lab
Continuous-Time Trajectory Optimization for Online UAV Replanning
Helen Oleynikova, Michael Burri, Zachary Taylor, Juan Nieto,
Roland Siegwart and Enric Galceran

Coverage Path Planning Problem

- **Problem Statement:**
  - Consider a 3D structure to be inspected and a system with its dynamics and constraints and an integrated sensor, the limitations of which have to be respected. The 3D structure to be inspected is represented with a geometric form and the goal is to calculate a path that provides the set of camera viewpoints that ensure full coverage subject to the constraints of the robot and the environment.

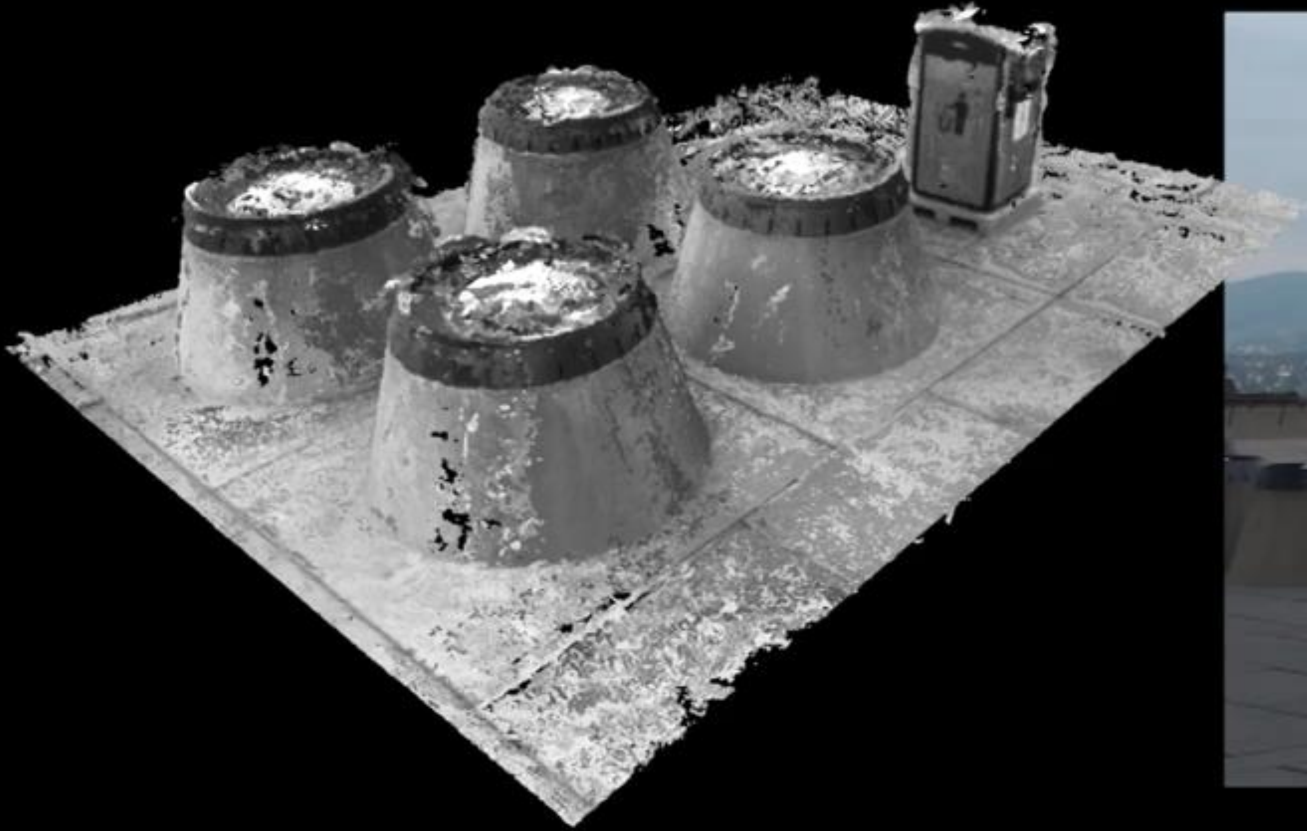
- Geometry of the environment
- Geometry and kinematics of the robot
- Structure to be inspected

→ **Path Planner** → Full coverage path



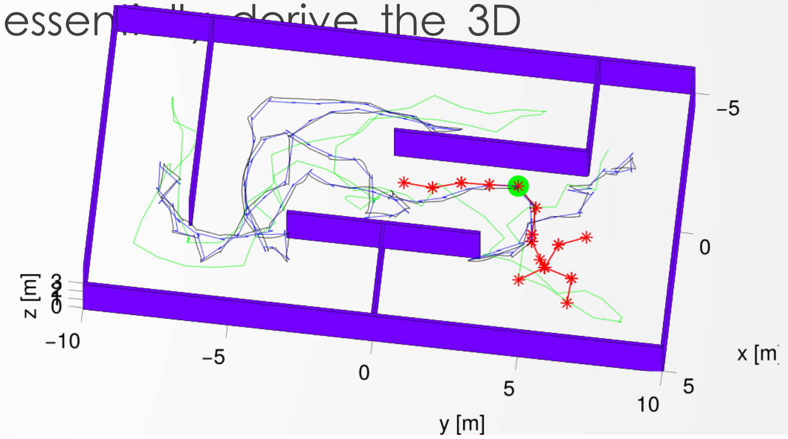
Three-dimensional Coverage Path Planning via Viewpoint Resampling and Tour Optimization using Aerial Robots

A. Bircher, K. Alexis, M. Kamel, M. Burri, P. Oettershagen, S. Omari, T. Mantel, R. Siegwart

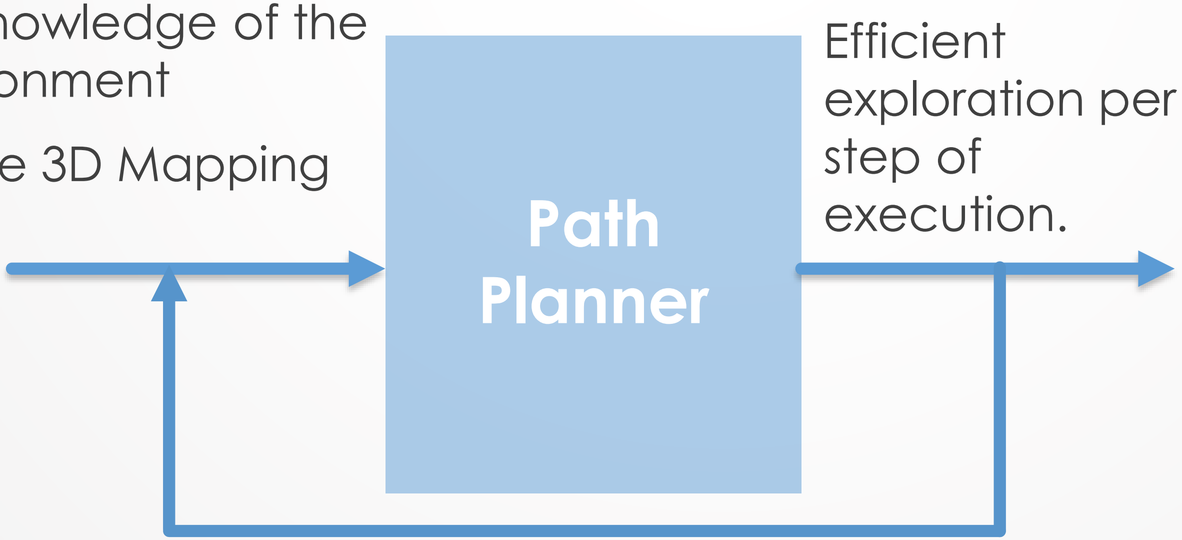


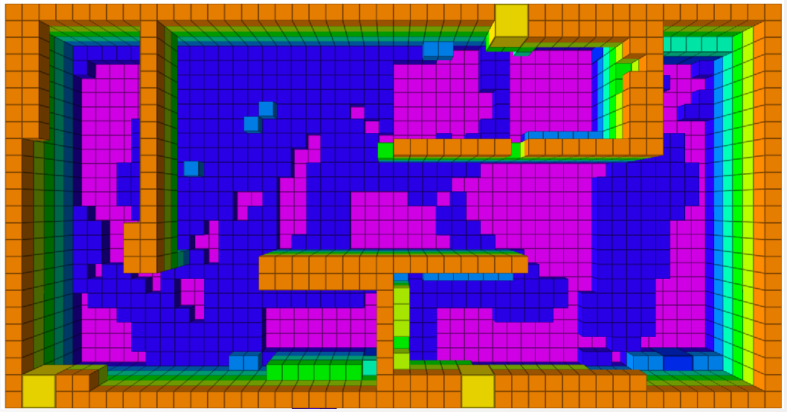
Exploration of Unknown Environments

- **Problem Statement:**
  - Consider a 3D bounded space V unknown to the robot. The goal of the autonomous exploration planner is to determine which parts of the initially unmapped space are free V_{free} or occupied V_{occ} and essentially derive the 3D geometric model of the world.



- No knowledge of the environment
- Online 3D Mapping





Code Example

- Python examples on Boundary Value Solvers
  - https://github.com/unr-arl/DubinsAirplane/tree/52ce13e4a6dea9005da702095e6b0acbb175e008
  - https://github.com/unr-arl/drones_demystified/tree/master/python/DubinsCar
  - https://github.com/unr-arl/drones_demystified/tree/master/python/HAV_BVS

Find out more

- http://www.autonomousrobotslab.com/holonomic-vehicle-bvs.html
- http://www.autonomousrobotslab.com/dubins-airplane.html
- http://www.autonomousrobotslab.com/collision-free-navigation.html
- http://www.autonomousrobotslab.com/structural-inspection-path-planning.html

- http://ompl.kavrakilab.org/
- http://moveit.ros.org/
- http://planning.cs.uiuc.edu/

- http://www.autonomousrobotslab.com/literature-and-links1.html

Thank you!

Please ask your question!