Quadrotor planning and execution with different RRT* sampling methods

Yathartha Tuladhar, Niraj Basnet, Golden Rockefeller

Motivation

- Sample-based planning methods like RRT* are popular for planning (especially in higher dimensional state spaces)

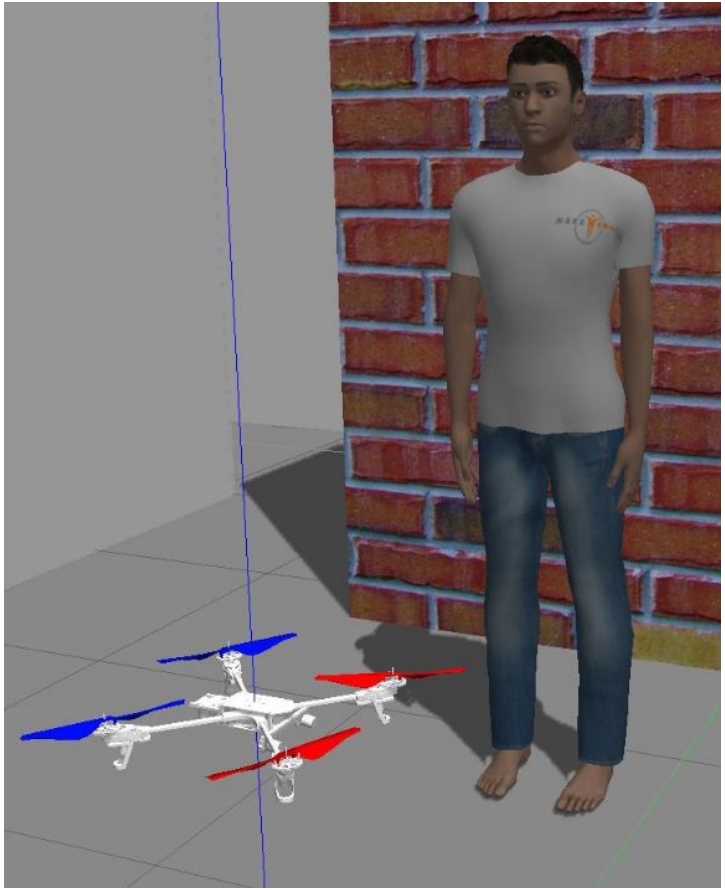
- But how does the sampling method affect the computational cost and plan quality?

ATLAS humanoid robot with 28 degrees of freedom

Goal

- Compare sampling techniques
  - Uniform
  - Obstacle Based
  - Gaussian
  - Maximum Clearance

- Plan path for a Quadrotor in a simulated environment



Quadrotor navigating around obstacles

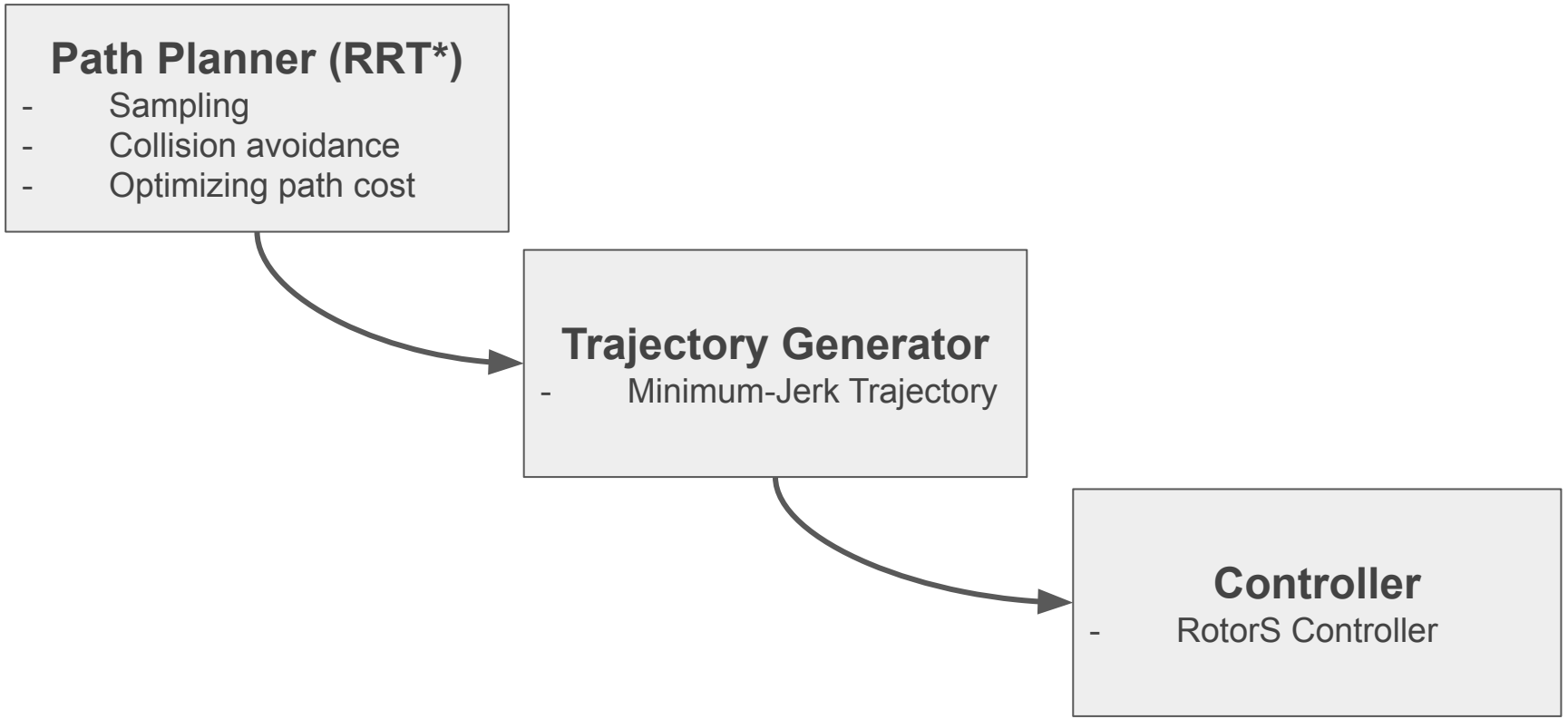
Approach

- RRT* algorithm (6 dimensions: x, y, z, row, pitch, yaw)

- Sampling techniques
  - Uniform
  - Obstacle Based
  - Gaussian
  - Max Clearance

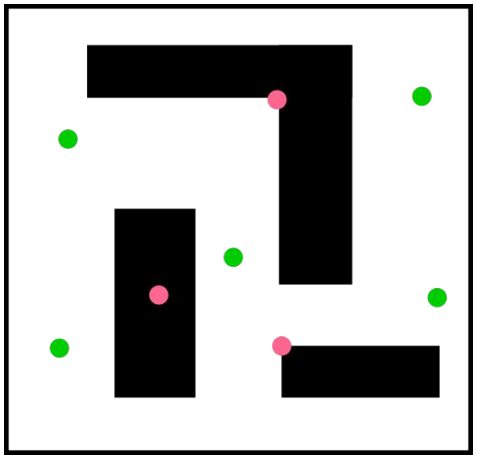
- Trajectory Optimization and Control
- Gazebo, ROS, OMPL, RotorS Simulator

System Block Diagram

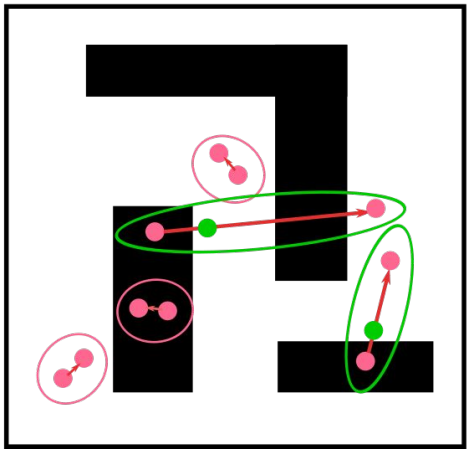


Sampling Methods

Uniform



Obstacle Based



Accepted Sample

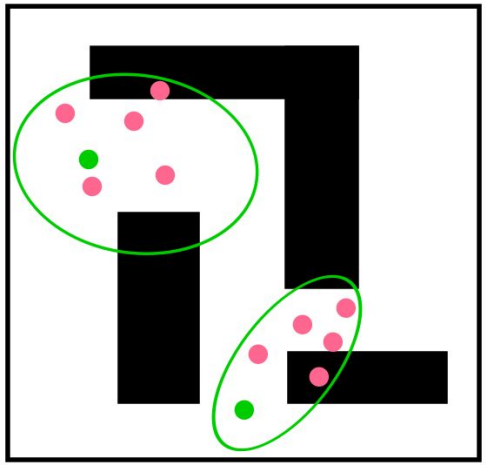
Rejected Sample

Accepted Sample Set

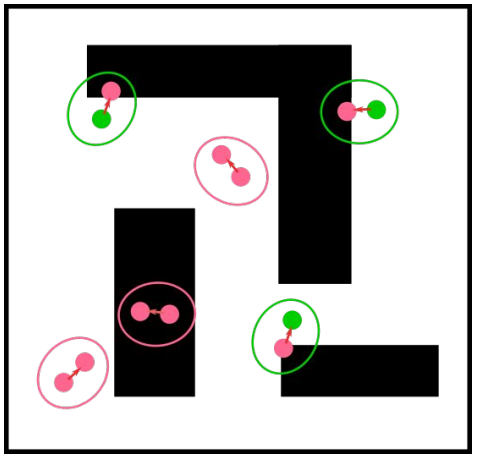
Rejected Sample Set

Sampling Methods (cont'd)

Maximize Clearance



Gaussian



Accepted Sample

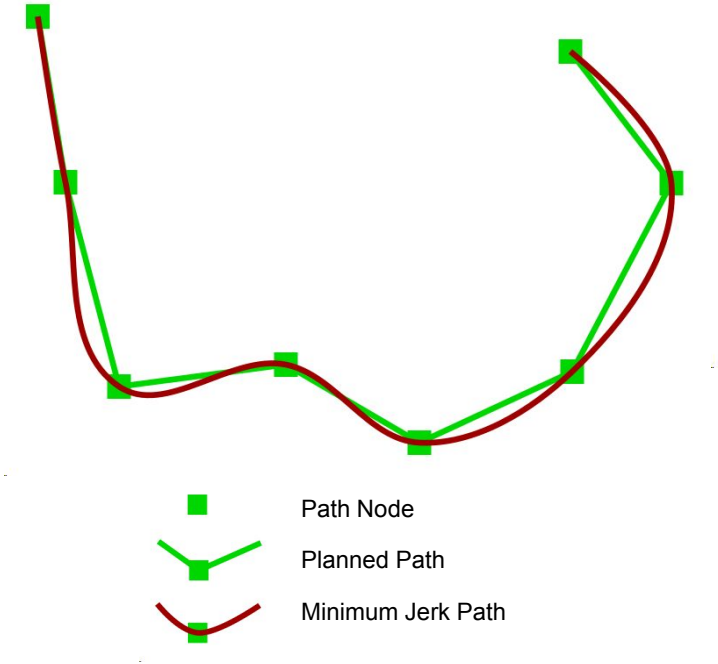
Rejected Sample

Accepted Sample Set

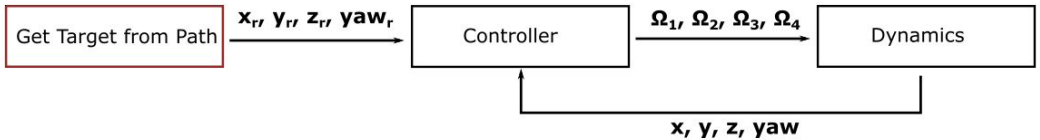
Rejected Sample Set

Trajectory Generation and Control

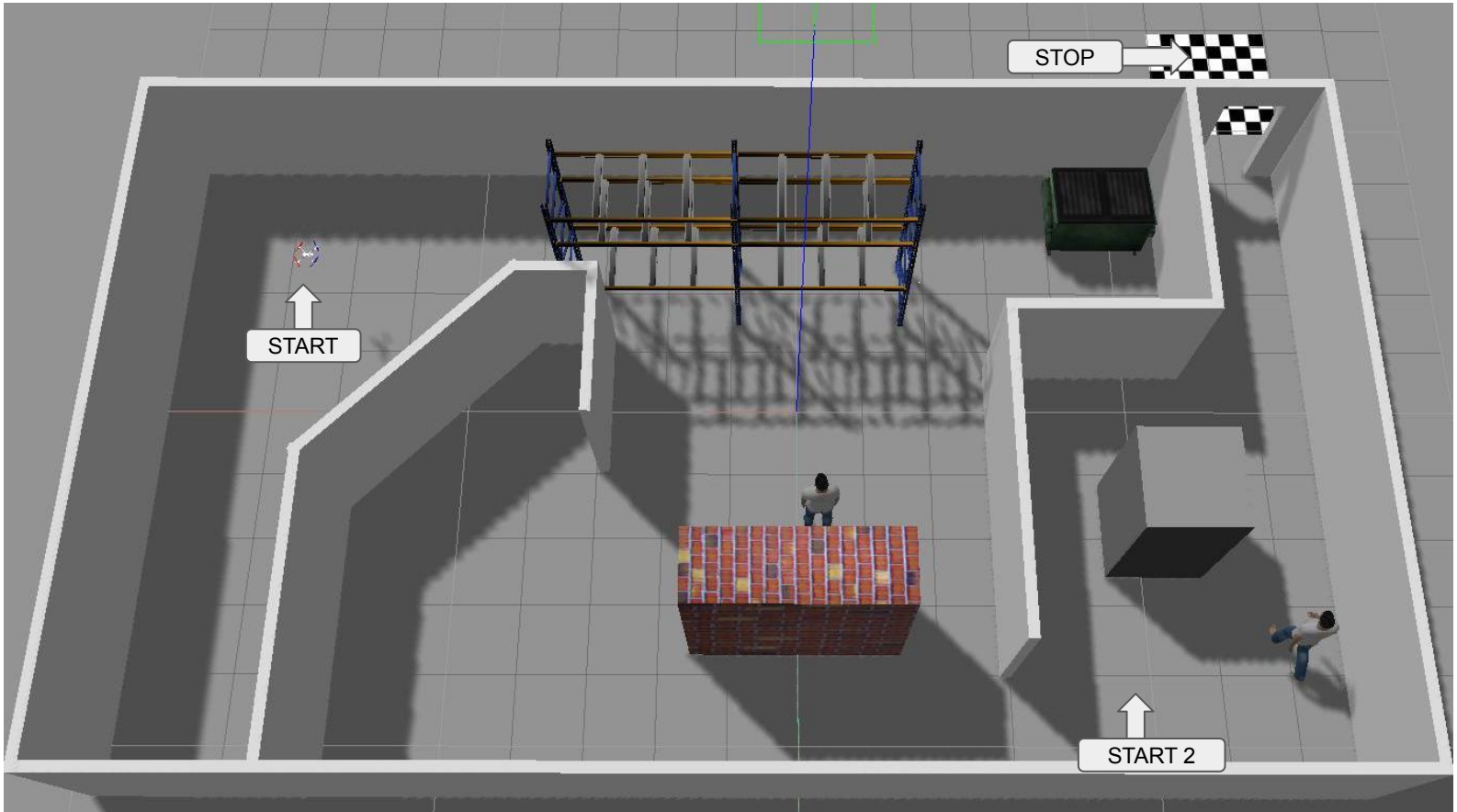
Minimum Jerk Trajectory
(6 dimensions)



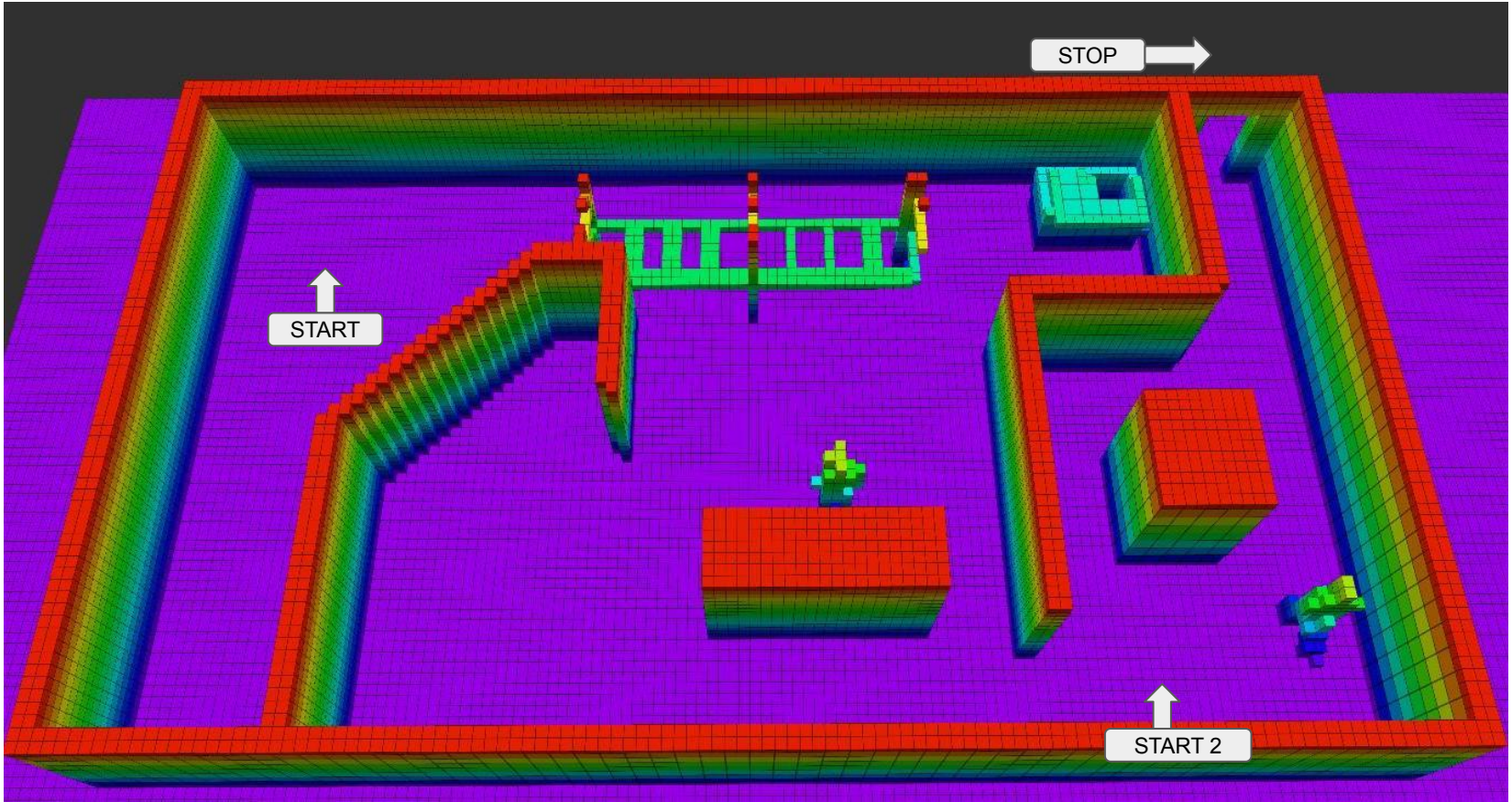
Proportional-Integral-Derivative (PID)
Controller (4 dimensions: x, y, z, yaw)



Custom World in Gazebo



Octomap of custom world



Results

Experiment Settings:

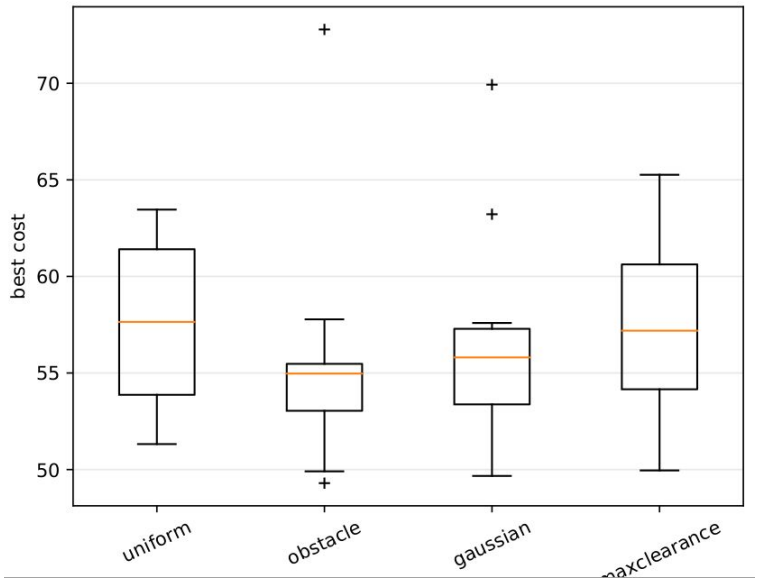
- Time limit (15 seconds)
- Trials (50)
- Highly cluttered vs. less cluttered environment
- Sample step size 0.5 meters
- Memory limit (100 MB)

Metrics:

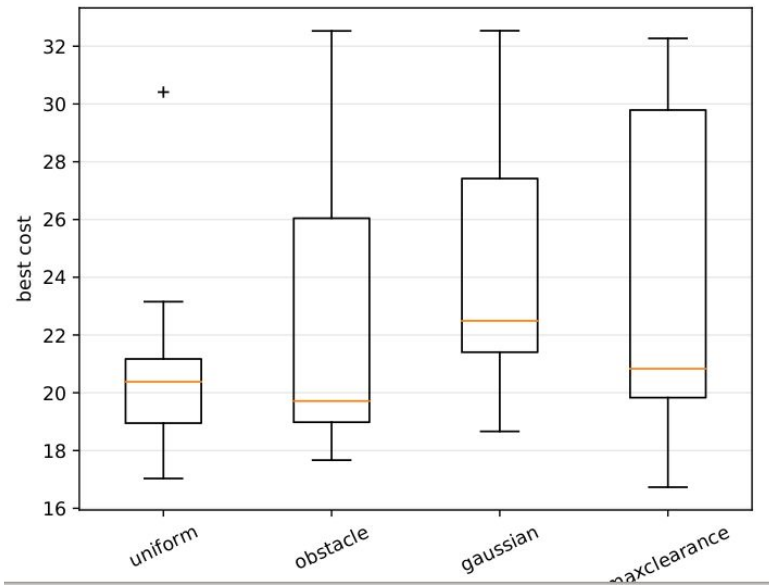
Best cost, Valid segment fraction, Memory

Results

- **Best cost**
- Valid segment fraction
- Memory



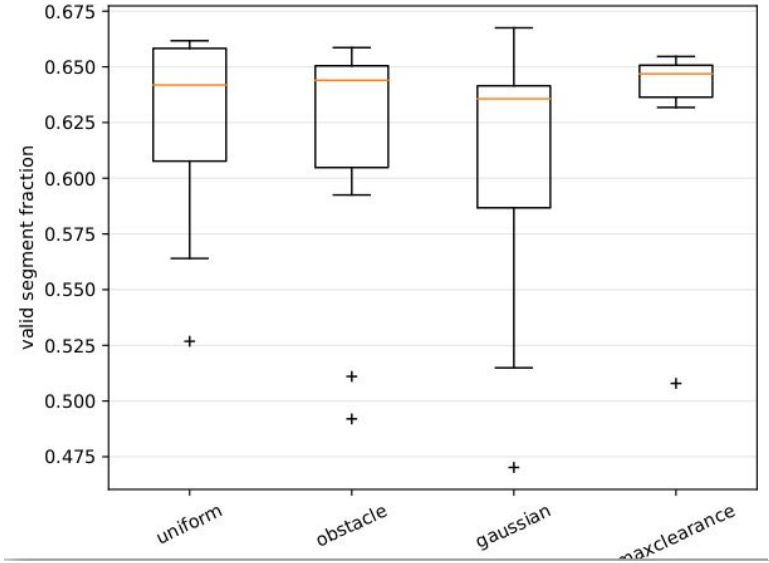
Highly cluttered environment



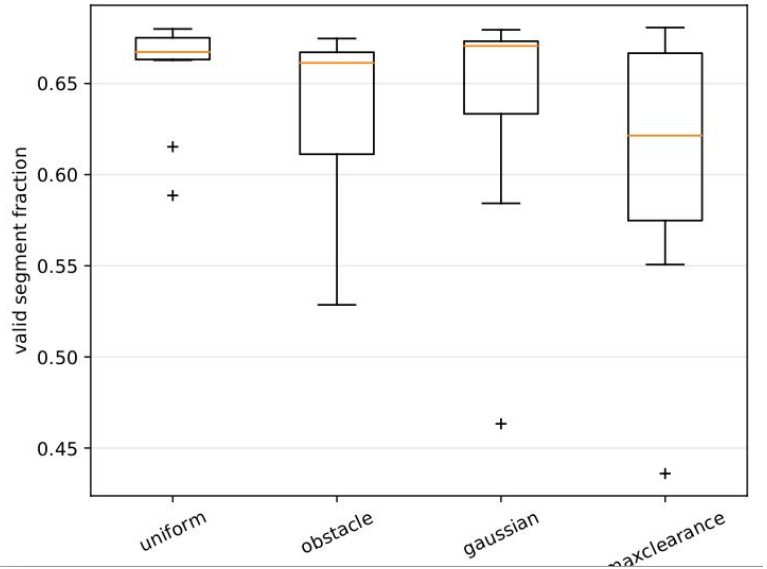
Less cluttered environment

Results

- Best cost
- **Valid segment fraction**
- Memory



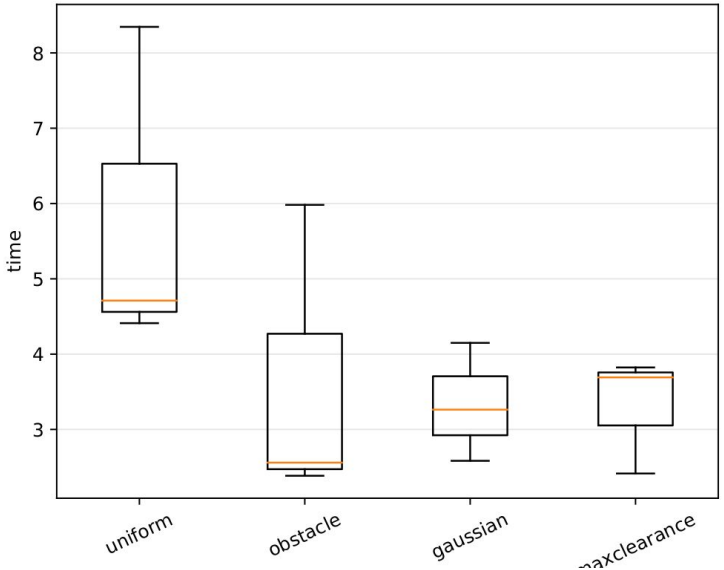
Highly cluttered environment



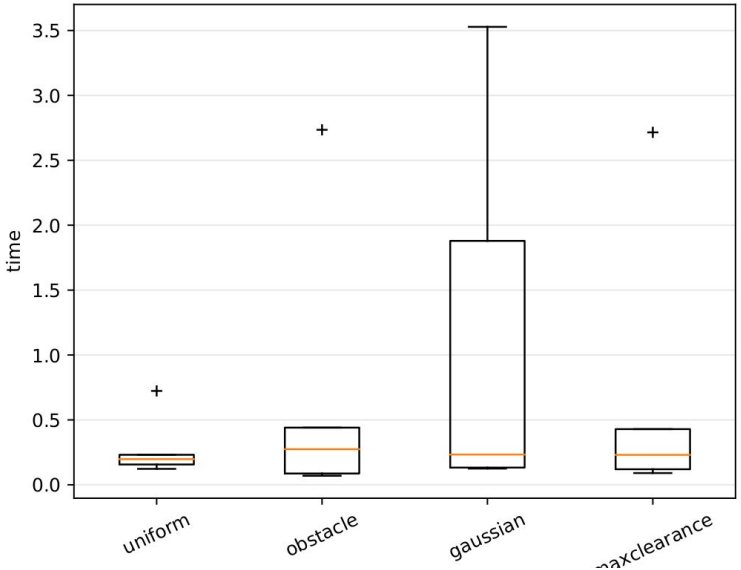
Less cluttered environment

Results

- Best cost
- **Valid segment fraction**
- Memory



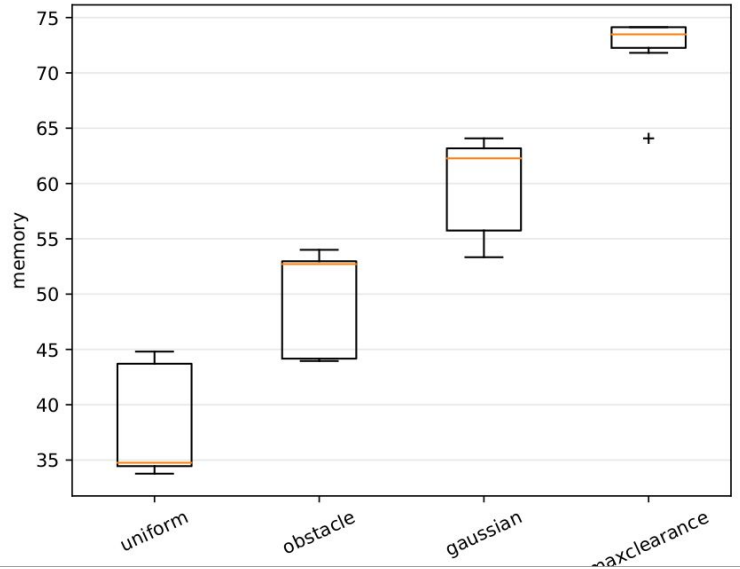
Highly cluttered environment



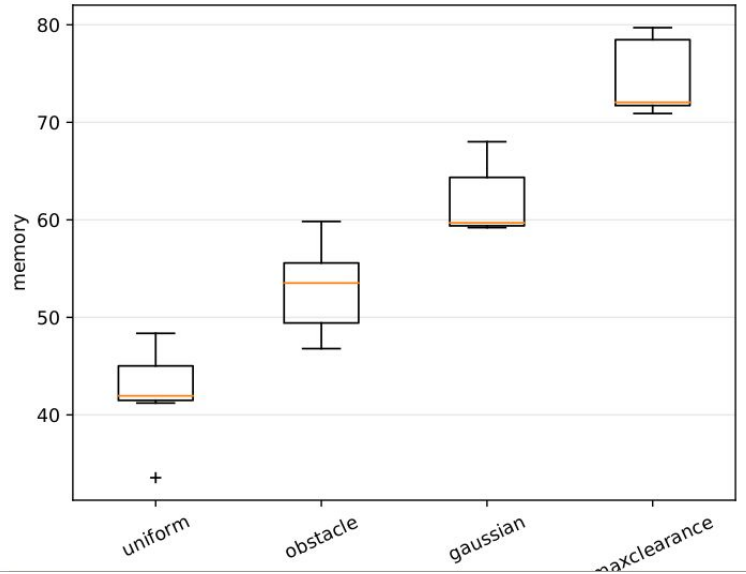
Less cluttered environment

Results

- Best cost
- Valid segment fraction
- **Memory**

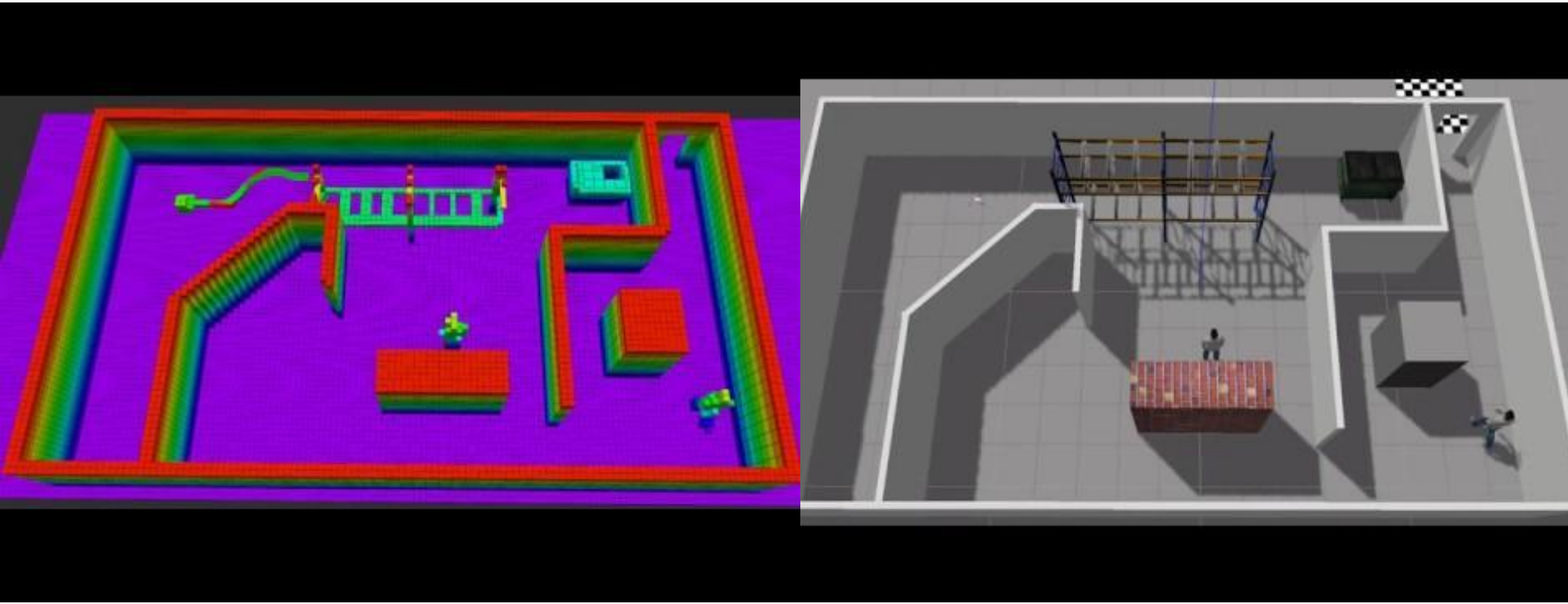


Highly cluttered environment



Less cluttered environment

Simulation in Gazebo and RVIZ



Conclusion

- How does sample technique affect planning?
- Compared 4 sampling techniques (Uniform, Obstacle Based, Gaussian, Maximum Clearance)
- Quadrotor domain
- Found similar performances with sampling techniques
- No dominating sampling technique, given costs and memory metrics
- Sampling technique depends on problem definition

Future work

- Sampling technique comparison for full 12 dimensional state (include velocities)
- Account for critical dynamics differences between RRT* planning and real-world execution
- Compare to obstacle-edge-based sampling technique

Comments and/or Questions?