Information gain-based autonomous exploration of 3D environments using an unmanned aerial vehicle

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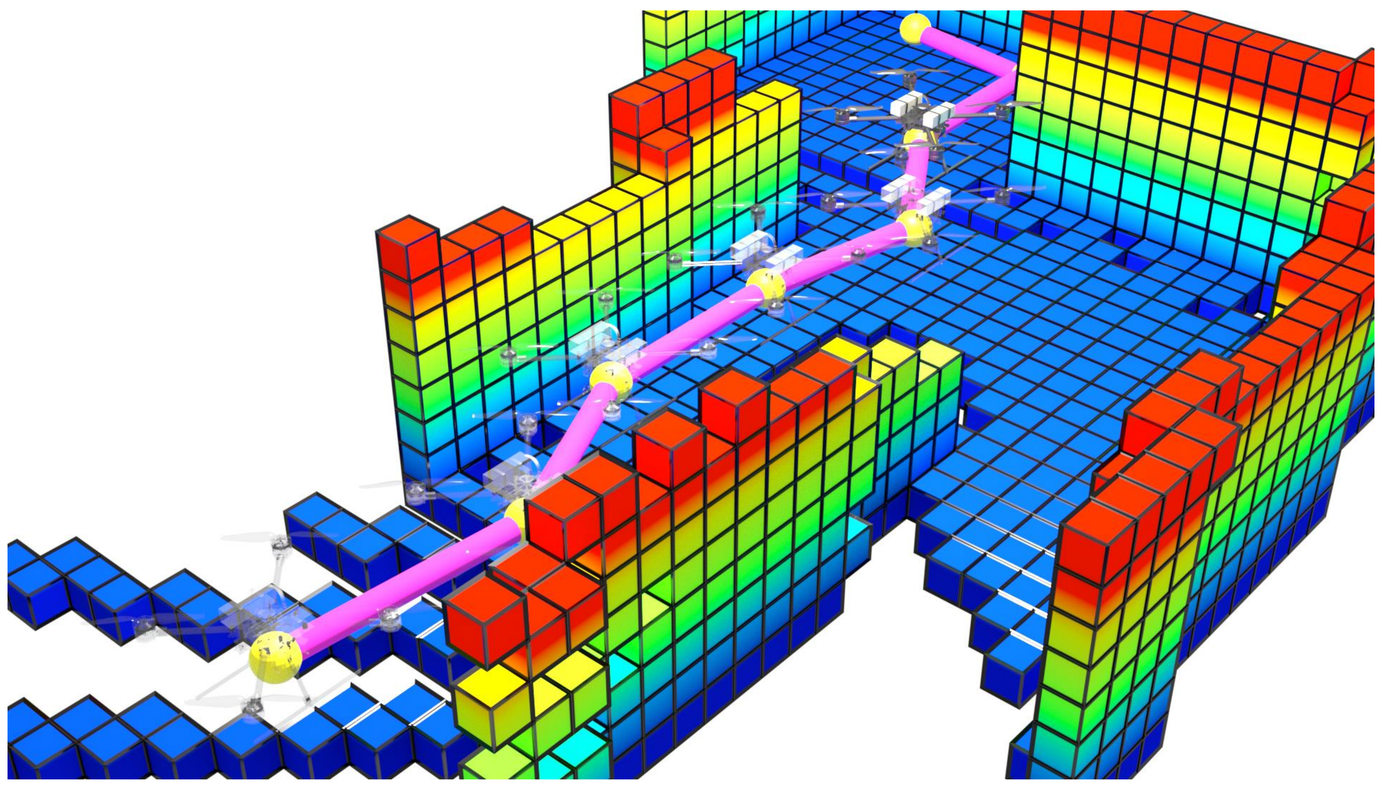
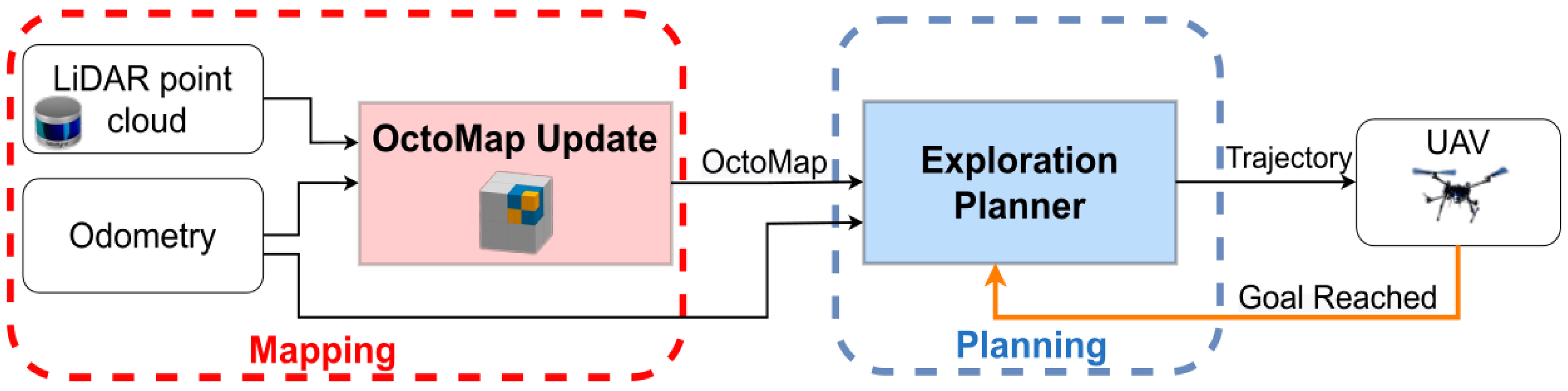
1. Introduction and Motivation

Autonomous exploration and mapping is one of the fundamental tasks of robotics. Typical exploration methods are based on frontiers [1] or next-best-view methods [2] and used in both 2D and 3D space. The main goal of exploration is to increase the overall knowledge of the environment by directing the robot in a way that reduces the overall exploration time.



2. System Overview

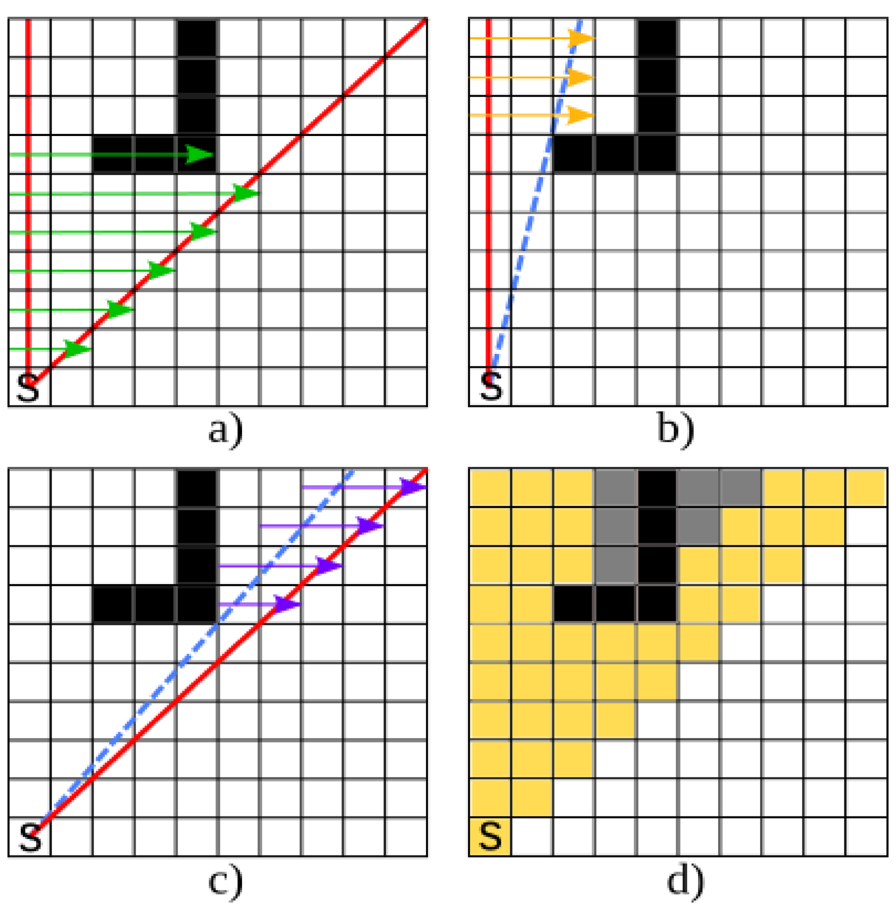
Our proposed approach is a sampling-based next-best-view exploration consisting of mapping and planning modules. The proposed information gain calculation and path evaluation ensures target selection in a short computation time. The proposed algorithm speeds up the exploration process.

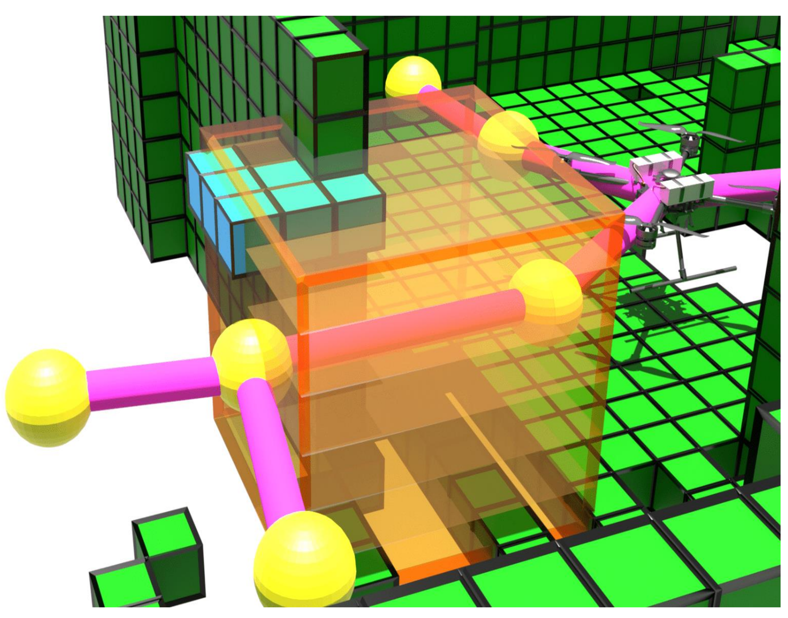


SAMPLING METHOD	INFORMATION GAIN CALCULATION	BEST PATH SELECTION
RRT	Recursive Shadowcasting Algorithm	Cuboid-Based Evaluation

3. Recursive Shadowcasting Algorithm

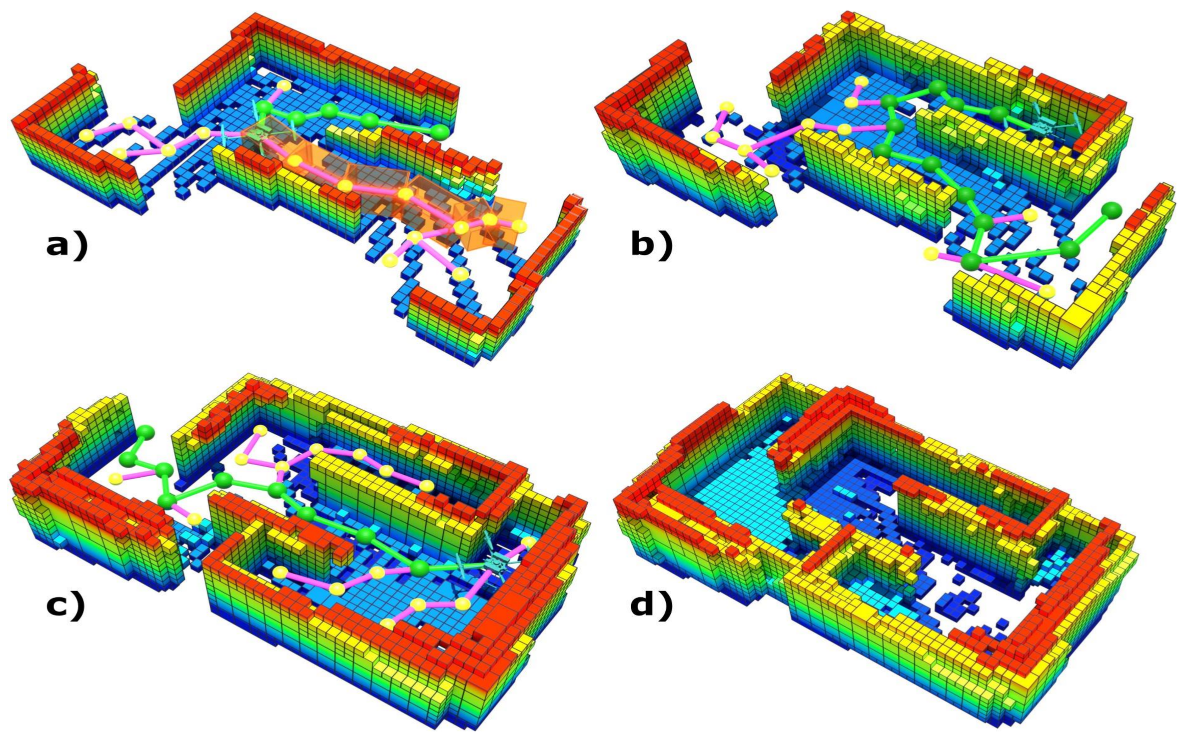
- Inspired by use in computer games for generating field of view
- Efficient information gain calculation

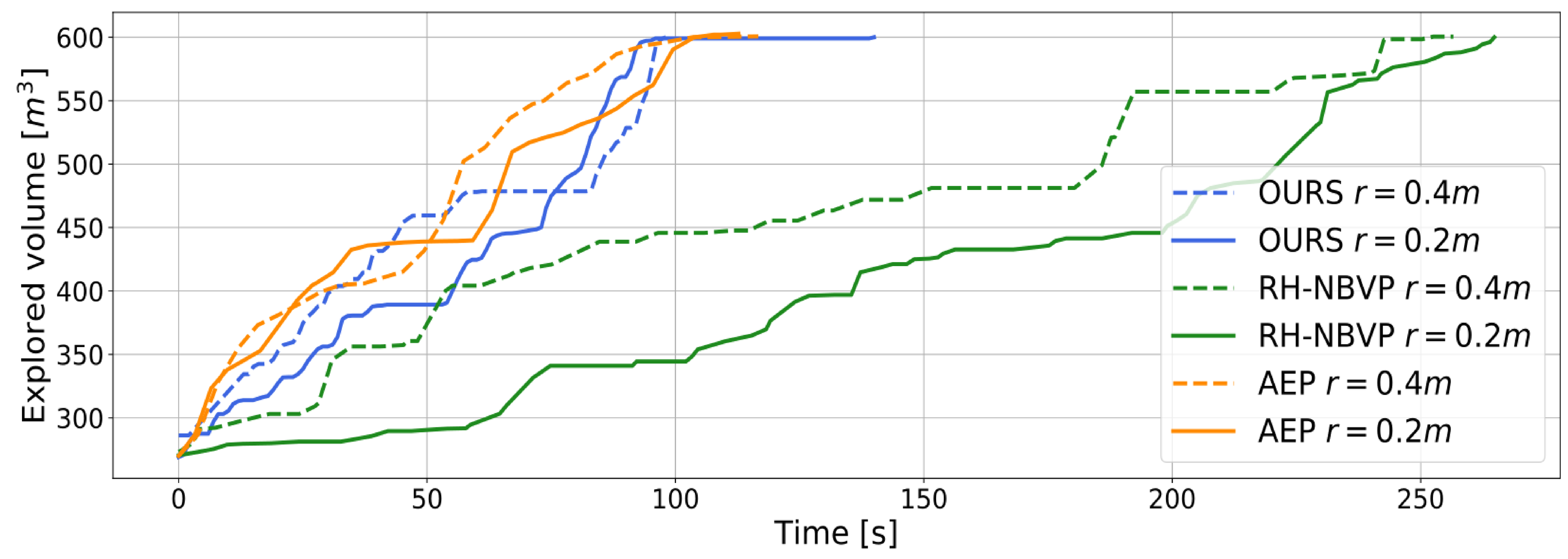


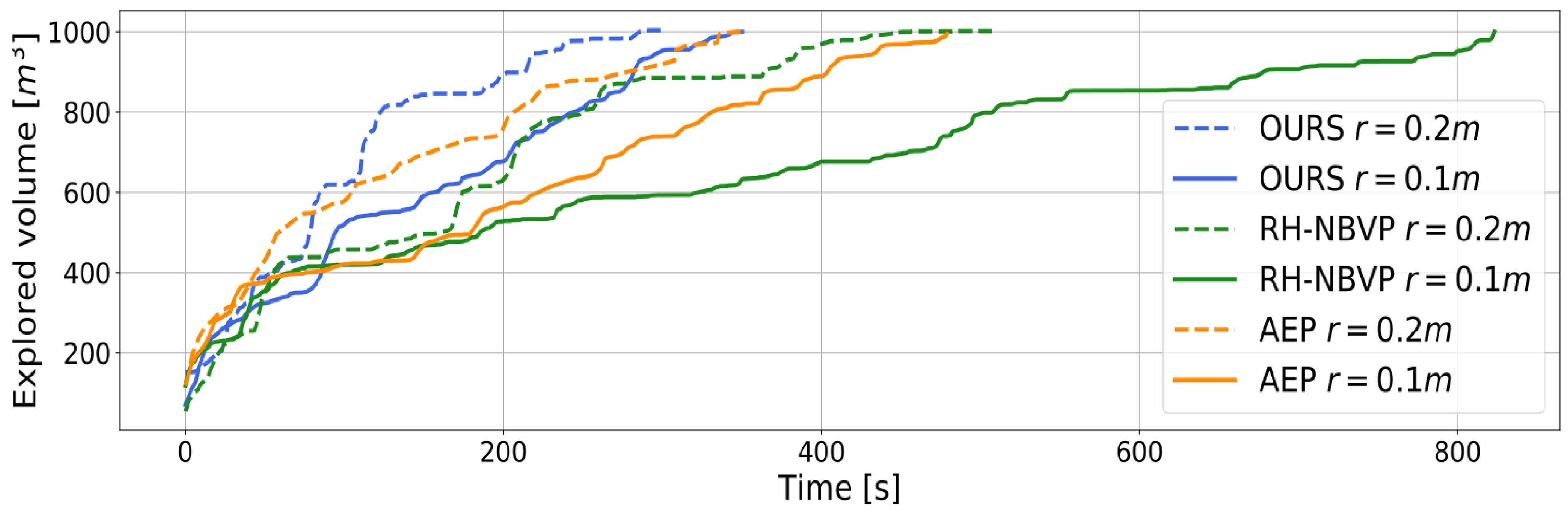


4. Results

Simulations are performed in the Gazebo environment using the Robot Operating System (ROS). The results show an improved behavior in terms of both computation and total exploration time compared to state-of-the-art strategies.







The explored volume in total exploration time

		OURS		RH-NBVP		AEP	
Scenario	r [m]	t_c [ms]	t_{exp}[s]	t_c [ms]	t_{exp}[s]	t_c [ms]	t_{exp}[s]
Apartment	0.4	(4.41, 2.39)	(87.82, 13.10)	(15.39, 9.74)	(242.36, 51.63)	(75.96, 99.69)	(92.90, 17.21)
	0.2	(19.63, 10.37)	(113.51, 29.30)	(135.16, 57.86)	(276.84, 70.54)	(248.70, 125.46)	(119.89, 22.69)
Maze	0.2	(25.08, 10.89)	(209.24, 31.03)	(383.33, 124.38)	(504.566, 75.23)	(288.29, 128.48)	(362.01, 17.86)
	0.1	(81.61, 18.84)	(350.05, 87.33)	(1024.19, 297.34)	(832.51, 183.34)	(509.26, 323.56)	(485.79, 90.46)
Large Maze	0.2	(48.67, 19.12)	(1017.23, 271.34)	(744.01, 244.53)	(1847.66, 305.78)	(617.48, 722.61)	-
	0.1	(98.71, 37.52)	(1324.89, 283.22)	(2230.46, 579.43)	(2351.64, 547.52)	(624.08, 583.34)	-

The tuples of mean and standard deviation for the total exploration time t_{exp} and the computational time per iteration t_c

5. Conclusion

The proposed planner is capable of autonomously exploring a previously unknown bounded area and creating an OctoMap of the environment. This 3D exploration planner has been successfully tested in simulation scenarios, as well as in a real world experiment, using a quadcopter equipped with a LiDAR.

EXPLORATION VIDEOS

SOURCE CODE

Acknowledgments

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References

[1] Batinovic et al. (2022), A Shadowcasting-Based Next-Best-View Planner for Autonomous 3D Exploration, in IEEE RA-L, vol. 7, no. 2

[2] Batinovic et al. (2021), A Multi-Resolution Frontier-Based Planner for Autonomous 3D Exploration, in IEEE RA-L, vol. 6, no. 3

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