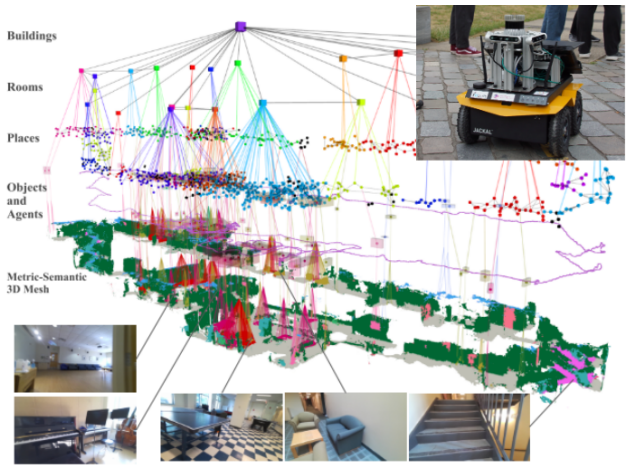
# 3D Environment Representation for Mobile Manipulation with Focus on Real-World Implementation

MSc. Thesis Project at AMR and AIR Lab, Cognitive Robotics, TU Delft




Adapted from [3]

**Brief Description:** Autonomous mobile robots increasingly populate complex and dynamic environments shared with humans. In these environments, manipulation skills are often necessary to perform useful tasks such as transporting objects, opening doors, or moving obstacles out of the way. Mobile manipulators combine the strengths of a mobile base with the strengths of manipulators and thus increase the operational space and extend the manipulability.

In order to operate safely in dynamic and unstructured environments mobile manipulators need to perceive their surroundings. Mobile manipulators typically have two different perception pipelines and environment representations for navigation/localization and manipulation [2]. This is because usually the movement of the base and the movement of the manipulator are decoupled to simplify the control problem. Recent approaches however aim to combine the planning of base and arm, which requires a 3D geometric representation of the entire space.

Several libraries for dense voxel-based representations have been created based on CPU [4] and GPU (nvblox). Another promising recently emerged representation method is Neural Radiance Fields (NeRF), which describe the information (e.g. occupancy, color, and illumination) of a 3D point as the output of a neural network [1, 5]. Furthermore, 3D scene graphs, which describe the environment as a layered graph where nodes represent spatial concepts at multiple levels of abstraction, have been applied to include semantic knowledge in the environment representation [3]. An important challenge for 3D scene representation is the inclusion of dynamic obstacles (e.g. humans).

Additionally, the perception pipeline for these representations should be able to efficiently combine the information from multiple onboard camera viewpoints of the robot into a single coherent 3D semantic scene representation. Although there has been a surge of interest towards 3D environment representations for motion planning, it remains an open area of research how an updatable, compact representation of a dynamic environment that includes semantic understanding and allows for real-time performance can be generated.
To this end, the goals are twofold: First, to research 3D representations of dynamic environments including humans as well as their applicability to motion planning for mobile manipulators. Second, to set up the currently available perception pipeline on the new mobile manipulator, and extend it to provide an updatable 3D representation of dynamic environments.
Within this project, the focus is on the application of the developed approach on the robot. You will mainly work with a mobile manipulator consisting of a Clearpath Dingo-O base and a Kinova Gen3 lite arm which you will equip with Realsense cameras and a Lidar (see image). Doing both the research assignment and thesis within this project is encouraged.

**Desired Qualities:**

- Motivated and independent
- Good problem-solving skills (especially with the robot)
- Experience with ROS (knowledge of ROS 2 is a plus) and Python

**Start Date:** January 2023 (or later)

**For further questions or to apply,** please contact Luzia Knoedler (l.knoedler@tudelft.nl), Chadi Salmi (c.salmi@tudelft.nl) and Khaldon Araffa (k.araffa@tudelft.nl). When applying, please provide a short motivation, an up-to-date CV, a transcript of your current degree program, and the intended start date.

**Group information:** www.autonomousrobots.nl, www.icai.ai/airlab-delft

**References:**


[1] Michal Adamkiewicz, Timothy Chen, Adam Caccavale, Rachel Gardner, Preston Culbertson, Jeannette Bohg, and Mac Schwager. Vision-only robot navigation in a neural radiance world. *IEEE Robotics and Automation Letters*, 7(2):4606–4613, 2022.

[2] Kenneth Blomqvist, Michel Breyer, Andrei Cramariuc, Julian Förster, Margarita Grinvald, Florian Tschopp, Jen Jen Chung, Lionel Ott, Juan Nieto, and Roland Siegwart. Go fetch: Mobile manipulation in unstructured environments. *arXiv preprint arXiv:2004.00899*, 2020.

[3] Nathan Hughes, Yun Chang, and Luca Carlone. Hydra: a real-time spatial perception system for 3d scene graph construction and optimization. 2022.

[4] Helen Oleynikova, Zachary Taylor, Marius Fehr, Roland Siegwart, and Juan Nieto. Voxblox: Incremental 3d euclidean signed distance fields for on-board mav planning. In *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2017.

[5] Albert Pumarola, Enric Corona, Gerard Pons-Moll, and Francesc Moreno-Noguer. D-nerf: Neural radiance fields for dynamic scenes. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pages 10318–10327, 2021.