Master Thesis: Euclidean-Distance-Transform-Based Collision Avoidance Motion Planning

Company Research Group:	Bosch Research
Contacts:	Yunfan Gao (Yunfan.Gao@de.bosch.com)
	Dr. Niels van Duijkeren (Niels.vanDuijkeren@de.bosch.com)

Thesis Description

Collision avoidance is an important aspect in motion planning of mobile robots. Euclidean distance transform (EDT) [1], which provides information about the distance to the nearest obstacle, is commonly employed to achieve collision avoidance [2]. While collision avoidance constraints can be easily formulated for circular objects, the formulation of these constraints becomes significantly complicated for polygons and capsules (the Minkowski sum of a circle and a line segment). Nevertheless, these shapes can often bound the robot shape more tightly than circles, thus making it easier for the robot to pass through narrow corridors.

Optimization-based methods are often used to solve optimal control problems in model predictive control (MPC). While these approaches are appealing due to their ability to employ gradient information, numerical challenges can arise [3]. On the Voronoi diagram, for instance, the distances to two distinct obstacles are equal, causing a non-differentiable cusp in the EDT.

Your master thesis will focus on formulating a model predictive control (MPC) problem that uses the EDT to achieve effective collision avoidance:

- You will incorporate a more general shape description to model the robot shape and integrate this model into the EDT-based collision avoidance approach [4].
- You will develop innovative solutions to address the non-differentiability issues and to solve the optimization problem computationally efficiently.

The thesis will also involve conducting experiments on a physical robot platform. You will deploy your developed algorithm and compare it with some existing approaches, such as the model predictive path integral controller in nav2 [5]. By conducting these experiments, you will be able to validate the efficacy of your developed approach.

References

[1] "Euclidean distance transform." https://en.wikipedia.org/wiki/Distance_transform.

[2] M. N. Finean, W. Merkt, and I. Havoutis, "Simultaneous scene reconstruction and whole-body motion planning for safe operation in dynamic environments," in *2021 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, IEEE, sep 2021.

[3] J. Schulman, Y. Duan, J. Ho, A. Lee, I. Awwal, H. Bradlow, J. Pan, S. Patil, K. Goldberg, and P. Abbeel, "Motion planning with sequential convex optimization and convex collision checking," *The International Journal of Robotics Research*, vol. 33, pp. 1251–1270, 08 2014.

[4] S. Zimmermann, M. Busenhart, S. Huber, R. Poranne, and S. Coros, "Differentiable collision avoidance using collision primitives," in *2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, pp. 8086–8093, 2022.

[5] "Model predictive path integral controller." Available at https://github.com/ros-planning/navigation2/tree/main/nav2_mppi_controller.