Enabling Safe Guidance in Perceptually Degraded Environments with mmWave Radars

Abstract: A methodology for safely following waypoints or acting upon user-commands is crucial for autonomy, and especially interesting in environments featuring challenging conditions. For example, autonomous agents relying on vision or LiDAR sensors will find great challenge in navigating through dense fog or smoke. Recently mmWave radar sensors have become a hot topic in robotics research for their ability to operate in conditions which prove difficult for typical perception sensors like vision and LiDAR. Research has demonstrated capable estimation methods, however there is little progress made in closing the loop. In these environments application of mmWave radar technology for guidance and obstacle avoidance can prove interesting as not only is the sensor unaffected by these degradations, but it also manages to directly measure environment-relative velocity, providing unique opportunities for control and obstacle avoidance which is less vulnerable to estimation breaking due to poor associations. The main goal of this project is to develop and implement a safe guidance law which takes advantage of the features of mmWave radar sensing technology, namely direct velocity measuring and robustness to certain environmental conditions.

Tasks:

- Study and understand typical methods.
- Consider pros/cons for classical and learning-based methods.
- Design a controller and/or policy in simulation to perform guidance in environments with obstacles (both static and dynamic).
- Implement the method on a real robot and evaluate the method with experiments displaying the method's performance.

Literature (indicative):

[1] Q. Nguyen and K. Sreenath, "Exponential Control Barrier Functions for enforcing high relative-degree safety-critical constraints," 2016 American Control Conference (ACC), Boston, MA, USA, 2016, pp. 322-328, doi: 10.1109/ACC.2016.7524935.

[2] H. Nguyen, S. H. Fyhn, P. De Petris and K. Alexis, "Motion Primitives-based Navigation Planning using Deep Collision Prediction," *2022 International Conference on Robotics and Automation (ICRA)*, Philadelphia, PA, USA, 2022, pp. 9660-9667, doi: 10.1109/ICRA46639.2022.9812231.

[3] J. Kim and Y. Kim, "Safe Control Synthesis for Multicopter via Control Barrier Function Backstepping," *2023 62nd IEEE Conference on Decision and Control (CDC)*, Singapore, Singapore, 2023, pp. 8720-8725, doi: 10.1109/CDC49753.2023.10383446.

Relevant Project Information

- **SENTIENT Project - Funding Agency:** Research Council of Norway

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