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Multi-Sensor Fusion with Radar and Ultrasound for Obstacle Avoidance on Capra Hircus 1.0

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1. Mobile robotics

Obstacle avoidance is a fundamental requirement for mobile robotic systems to operate safely and efficiently in unknown environments. The challenge lies in the uncertainty of obstacles' location and the movements of dynamic obstacles, which makes it difficult for navigation systems to compute collision-free paths. To tackle this issue, a common approach in mobile robotics is to rely on sensors such as laser radar, LiDAR, and camera based sensors. However, these sensors have their limitations, particularly in extreme outdoor weather conditions and heavy occlusion.
Because of these limitations, this project strives to explore the possibilities of sensor fusion for obstacle avoidance. This is done in cooperation with Capra Robotics, who are currently looking into implementing obstacle avoidance on their robot platform, Capra Hircus 1.0, seen in Figure 1.

Figure 1: Render of the Capra Hircus 1.0 with the radar module developed in this project.

2. Related work

The proposed solution to the problem can be divided into two elements, namely the obstacle avoidance and the sensor fusion. To achieve a thorough understanding of both elements, a literature study was conducted. The study was conducted in each element separately, as there is no earlier work that reflects the goal of this project directly.

From the literature study it was found that the PointBug algorithm comply with the necessary requirements for obstacle avoidance along with being easy to implement. This choice also motivates for more time to be allocated to the second element, namely sensor fusion.

For fusing the data of the ultrasonic spoon sensors and the radar, it was found that a particle filter could be beneficial, as this allow for multi obstacle detection and works on imperfect sensor data.

3. Implementation

With basis in the choice of implementing a particle filter and base the obstacle avoidance on the PointBug, C++ and ROS 2 was used to develop software. It was found that the PointBug could not be directly applied on the Capra Hircus 1.0, as necessary information about the robot was impossible to access. This led to an algorithm for obstacle avoidance that was only inspired by the PointBug.

The sensor based input for the obstacle avoidance was achieved by fusing the ultrasonic sensor data and radar data with a particle filter. The particle filter use the range measurements from the two ultrasonic sensors and the points from the radar, to determine where the actual obstacles are most likely to occur.

4. Verification

The fused data was verified through 3 tests with different angles of the front wheel and attached RadarIQ-M1. From the tests, it was observed that the sensor fusion was able to estimate the environment with higher accuracy compared to the individual sensors. An illustration of test 2 can be seen in Figure 2.
In order to compare the solution to other systems for obstacle avoidance, environments for testing was conducted. These environments were based on earlier work and the accessible resources.
Both the Capra Hircus 1.0 and MiR100 was tested in these environments.
The results can be seen in Figure 3.

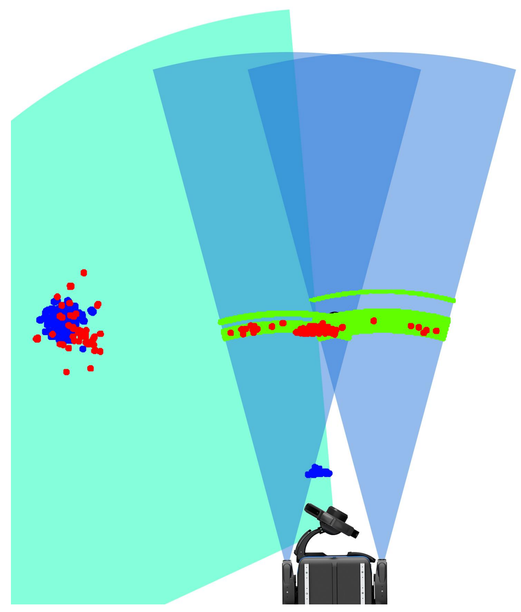

Figure 2: Radar point cloud marked blue, ultrasonic measurements marked green and fused point cloud marked red.

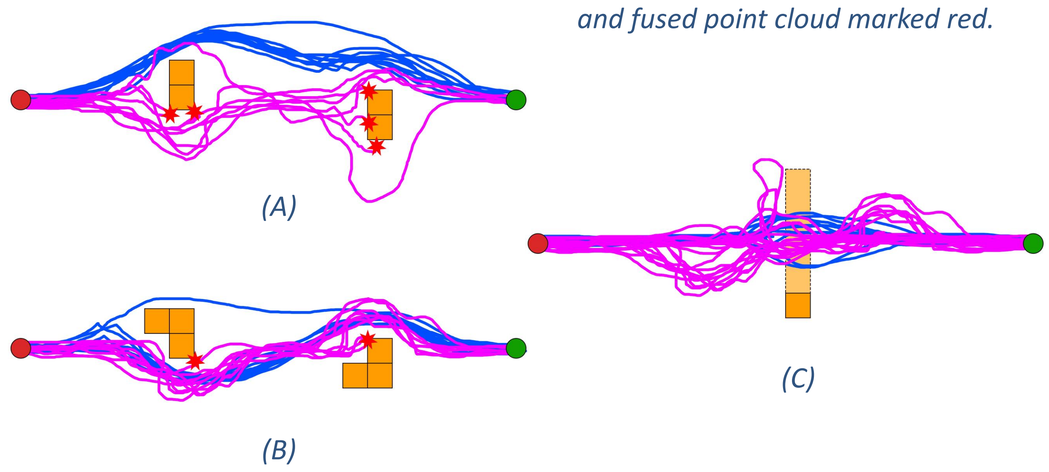

Figure 3: The recorded path of the Hircus (purple) and MiR100 (blue), with collisions marked red. (A) is from test B, (B) is from test C and (C) is from test D.

From the results, it can be concluded that the obstacle avoidance system developed in this project performs worse than the MiR100. However, the tests show that the solution potentially could be optimised by further tweaking of parameters and integration of the missing information about the robot.

5. Conclusion

This project aimed at investigating how fused sensor data can be used with a PointBug algorithm, to obtain obstacle avoidance on the Hircus 1.0 platform. During the implementation, it was discovered that the obstacle avoidance must deviate from the originally proposed PointBug algorithm, as the robot is currently lacking necessary information for doing a full implementation of a PointBug algorithm. However, the project did succeed in developing an algorithm for fusing the sensor data and avoiding obstacle to a certain degree.

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