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Row Detection and Graph-Based Localization in Tree Nurseries Using a 3D LiDAR

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Abstract : Agricultural robotics has been developing steadily over recent years, with the goal of reducing and even eliminating pesticides used in crops and to increase productivity by taking over human labor. The majority of crops are arranged in rows. The first step towards autonomous robots, capable of driving in fields and performing crop-handling tasks, is for robots to robustly detect the rows of plants. Recent work done towards autonomous driving between plant rows offers big robotic platforms equipped with various expensive sensors as a solution to this problem. These platforms need to be driven over the rows of plants. This approach lacks flexibility and scalability when it comes to the height of plants or distance between rows. This paper proposes instead an algorithm that makes use of cheaper sensors and has a higher variability. The main application is in tree nurseries. Here, plant height can range from a few centimeters to a few meters. Moreover, trees are often removed, leading to gaps within the plant rows. The core idea is to combine row detection algorithms with graph-based localization methods as they are used in SLAM. Nodes in the graph represent the estimated pose of the robot, and the edges embed constraints between these poses or between the robot and certain landmarks. This setup aims to improve individual plant detection and deal with exception handling, like row gaps, which are falsely detected as an end of rows. Four methods were developed for detecting row structures in the fields, all using a point cloud acquired with a 3D LiDAR as an input. Comparing the field coverage and number of damaged plants, the method that uses a local map around the robot proved to perform the best, with 68% covered rows and 25% damaged plants. This method is further used and combined with a graph-based localization algorithm, which uses the local map features to estimate the robot's position inside the greater field. Testing the upgraded algorithm in a variety of simulated fields shows that the additional information obtained from localization provides a boost in performance over methods that rely purely on perception to navigate. The final algorithm achieved a row coverage of 80% and an accuracy of 27% damaged plants. Future work would focus on achieving a perfect score of 100% covered rows and 0% damaged plants. The main challenges that the algorithm needs to overcome are fields where the height of the plants is too small for the plants to be detected and fields where it is hard to distinguish between individual plants when they are overlapping. The method was also tested on a real robot in a small field with artificial plants. The tests were performed using a small robot platform equipped with wheel encoders, an IMU and an FX10 3D LiDAR. Over ten runs, the system achieved 100% coverage and 0% damaged plants. The framework built within the scope of this work can be further used to integrate data from additional sensors, with the goal of achieving even better results.

Keywords : 3D LiDAR, agricultural robots, graph-based localization, row detection
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