Simultaneous localization and mapping of crops for field monitoring

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***Abstract*—Agricultural robotics offers promising solutions to address the challenges faced by the agriculture industry in meeting the growing demands of a global population with limited resources. This article presents a mapping pipeline for detecting and mapping diverse crops and vines in agricultural fields using a combination of lidar, SLAM, and plant identification techniques. The proposed pipeline leverages a 3D lidar sensor to obtain robust plant measurements and incorporates simultaneous localization and mapping (SLAM) algorithms to ensure accurate field mapping. Validation of the pipeline is performed through simulations and real-world experiments, demonstrating its potential in estimating crop yield, identifying infected plants, and monitoring pests and infections. The research contributes to the field of agricultural robotics by providing a practical approach to precise plant localization and consistent identification, enabling optimized agricultural practices and sustainable farming.**

***Index Terms*—agricultural robotics, SLAM, crop monitoring**

I. Introduction

Agriculture plays a crucial role in meeting the food demands of a growing global population. However, limited resources and the need for sustainable practices pose significant challenges. Robotics has emerged as a promising solution for optimizing agricultural processes, reducing labor requirements, and enhancing productivity. The inherent challenges in agricultural environments include the raw and diverse terrains, varied plant/crop species requiring different treatments, and the need for precise plant monitoring to estimate crop yield and identify infected plants and pests. To this end, it is crucial to precisely locate and consistently identify diverse plants in agricultural fields, in order to monitor their growth and the potential loss of plants due to pests and diseases. In this work, we propose a simultaneous localization and mapping (SLAM) pipeline aiming to overcome potential misalignments and mapping errors that can occur due to the close proximity and indistinct nature of plants, aiding any subsequent crop monitoring task. We validate our pipeline with diverse localization sources, including RTK-GPS or less accurate odometry estimates, such as those from wheel encoders or visual odometry.

II. EKF Crop-SLAM

To obtain robust and dense plant measurements, we rely on a 3D lidar sensor, as it is capable of providing accurate plant data regardless of weather conditions and illumination changes. Initially, we process raw point clouds to remove the ground plane and focus solely on plant-like objects. This requires filtering points below a certain height and fitting a plane to the remaining points. Temporal filtering is applied to ensure consistency and exclude spurious detections. The details of this procedure are analogous to [1].

After isolating non-ground points, we identify each plant in the scene. We assume a priori knowledge of plant dimensions and field seeding parameters specific to the crops and field being monitored. This information, including trunk diameter, plant height, and average spacing between plants in the same row and between different rows, allows us to calibrate our preprocessing procedure. In this way, we can define a region of interest (ROI) that corresponds to the space where plant rows should be located on the left and right sides of the robot.

Within the ROI, we apply a clustering algorithm tailored to separate plants based on their average in-row distance. The centroids of these clusters serve as measurements for each individual plant's position (x, y)

We incorporate ego-motion information using an online landmark-based Extended Kalman Filter (EKF) SLAM algorithm. This allows us to refine the localization estimates and avoid propagating errors in the field map.

III. Validation

We conduct experiments in both simulated and real-world environments. Simulated trajectories in realistically simulated agricultural scenarios allow us to fine-tune parameters and evaluate the algorithm's performance. Additionally, real-world acquisitions from diverse crop fields provide validation on different plant species (maize, vines) and challenging realistic conditions.

IV. Conclusion

This research presents a mapping pipeline for the precise localization and consistent identification of diverse plants in agricultural scenarios. By leveraging a 3D lidar sensor and incorporating SLAM techniques, we address the challenges of mapping in agricultural environments. The proposed pipeline offers potential applications in estimating crop yield, identifying infected plants, and monitoring pests and infections. The validation process, including simulated and real-world experiments, provides confidence in the algorithm's performance and its practical applicability in real agricultural scenarios.

References

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