Autonomous mapping of Rumex with a mobile robot

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Abstract

This paper presents an autonomous process for the mapping of Rumex weed in an unexplored pasture using a mobile robot equipped with a LIDAR sensor (used for mapping) and a stereo camera (used for Rumex detection).

Introduction and Objectives

Weeds present a challenge in agriculture. Rumex obtusifolius L. is referred to as the most problematic weed on permanent pasture (Van Evert et al., 2009). It spreads fast, displaces forage grasses, is very resistant and has a lower energy density. Especially in ecological agriculture without the use of herbicides, monitoring and control becomes a very labour-consuming task and state-of-the-art high-technology solutions are mostly not economically viable for smaller farms.

This work presents the core ideas and the implementation of a ROS software package with a user interface for mapping Rumex plants in grassland by use of a small mobile robot. The contributions include an autonomous navigation and mapping framework and the application of the state-of-the-art YOLOv8 neural network for Rumex detection trained on a new recorded dataset (see https://youtu.be/tRPE4z3HKN8). The navigation and mapping framework proposed in this work has been successfully applied with recently developed path planning algorithms with B-spline curves (Nguyen et al., 2023).

Methods

The first phase of the process is the autonomous exploration. A top-down view of the field must be provided by the user (e.g., satellite image from Google Earth, drone image, sketch). After loading the image to the program window, the user can specify the target area by selecting its corner points. Next, the robot starts the exploration by moving to all corner points in sequence. In the meantime, an occupancy grid map is constructed by the ROS GMapping package.

The second phase is the mapping of Rumex plants in the target area. In the constructed grid map, a reference path is planned in the form of a simple lawn mowing pattern consisting of parallel lines. While following the reference, encountered Rumex plants are plotted in the program window. In addition, perceived obstacles, explored and unexplored parts of the map and the current position of the robot are displayed as well. The program streams the camera data with the live predictions of the Rumex detector.

For the detection of Rumex plants in the RGB-images, the state-of-the-art real-time one-stage CNN-based YOLOv8m (You Only Look Once version 8, medium-sized model)

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object detector (Jocher et al., 2023) is used to process the frames obtained from one single left lens of the stereo ZED camera. The model is trained on a novel recorded Rumex dataset consisting of 6534 images. In addition, a simple centre-based object tracker, tracks plants through successive frames.

Results and Discussion

The validation of the software is performed based on both simulation and real experiments. A demonstration video can be found at https://youtu.be/tRPE4z3HKN8.

We test the package with the Jackal mobile robot, which is a small, customizable, easy-to-use research platform for field robotics from Clearpath Robotics utilising off-the-shelf components (Nguyen et al., 2023). It is equipped with a Nvidia GTX 1050 GPU and runs on Ubuntu 18.04 with ROS Melodic installed, providing a structured communications layer.

The navigation and mapping packages have proven reliable in extensive simulation tests and experiments on the real Jackal robot. Different pastures strongly affect the results, thus, further investigation on a robust navigation and mapping method w.r.t. GMapping is necessary. Localization performance could be improved by utilizing the 3D data of the environment from the LIDAR and extending the sensor fusion.

The detection of Rumex plants using the YOLO object detector reaches a mAP@0.5 of 60% on the test dataset with a precision of 72%. Larger Rumex plants are getting detected more reliable than smaller, younger plants. Most Rumex plants are getting detected at one point or another. Tests have shown the robustness of the model under a changing environment.

Throughout this project, it has been proven that using a small mobile robot with advanced AI techniques allows to detect and map Rumex plants automatically.

Conclusion

In this paper, an autonomous process for Rumex mapping using a small mobile robot equipped with a LIDAR sensor and a stereo camera is presented. The model is able to detect most Rumex plants and shows robustness in extensive tests under both simulation and real experiments. Future works include further experiments on real platforms and improvements on the path planning algorithm for Rumex mapping.

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Literature

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