Autonomous mapping of Rumex with a mobile robot

Niklas Fin Kompe[1], Floris Ernst[1] & Ngoc Thinh Nguyen[1]

Keywords: Rumex Detection; Mobile Robot; YOLOv8; Mapping; Exploration.

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 localization) and a stereo camera (used for Rumex detection).

Introduction and Objectives

Rumex obtusifolius L. is referred to as the most problematic weed on permanent pasture (Van Evert et al., 2009). It is very resistant with long taproots, spreads fast and can displace forage grasses while providing a lower energy density instead. Especially in ecological agriculture without the use of herbicides, monitoring and control becomes a very labor-consuming task and state-of-the-art 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. The navigation and mapping framework proposed in this work has been successfully applied with recently developed B-spline path planning algorithms for mobile robots (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)

---

[1] Institute for Robotics and Cognitive Systems, University of Lübeck, Ratzeburger Allee 160, 23562 Lübeck, Germany. Emails: niklas.komp@student.uni-luebeck.de, {floris.ernst, ngocthinh.nguyen}@uni-luebeck.de. Website: https://kribl.rob.uni-luebeck.de/

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 on both simulation and real experiments (demonstration video found at https://youtu.be/VC0rTd7HbiU). The package is tested with the Jackal mobile robot, equipped with a 16-layer LIDAR used for localization and mapping, and a front camera dedicated for Rumex detection (Nguyen et al., 2023). It has a Nvidia GTX 1050 GPU and runs on Ubuntu 18.04 with ROS Melodic installed.

The navigation and mapping package has proven its reliability in extensive simulation tests and experiments on the Jackal robot. However, terrain characteristics strongly affect the results, and thus, further investigation on the robustness is necessary. Localization performance could also be improved by utilizing the 3D data of the environment from the LIDAR instead of converting it into a 2D scan in the current setup.

The detection of Rumex plants using the YOLOv8 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 ones without missing any cluster. Tests have shown the robustness of the detection model under a changing environment.

The project has proven that using a small mobile robot with advanced AI techniques allows to detect and map Rumex plants automatically. We are currently constructing a larger mobile robot equipped with a 6-dof manipulator carrying a cutting tool to remove the Rumex plants at the marked locations acquired from the proposed procedure.

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 robustness analysis over different terrains, improvements on the reference patterns used for Rumex mapping and the usage of a larger platform with cutting tool integration.

Acknowledgement

This work is funded by the German Ministry of Food and Agriculture (BMEL) Project No. 28DK133A20.

Literature

Nguyen, N. T.; Gangavarapu, P. T.; Kompe, N. F.; Schildbach, G.; Ernst, F. (2023): Navigation with Polytopes: A Toolbox for Optimal Path Planning with Polytope Maps and B-spline Curves. Sensors. 23(7): 3532-3554.

Jocher, G.; Chaurasia, A.; Qiu, J. (2023): YOLO by Ultralytics, version 8.0.0, URL: https://github.com/ultralytics/ultralytics.

Van Evert, FK; Polder, G.; Van Der Heijden, GWAM; Kempenaar, C.; Lotz, LAP (2009): Real-time vision-based detection of Rumex obtusifolius in grassland. Weed Research. 49(2): 164-174.