Enabling Reliable Long-Term Robotic Data Acquisition: An Exemplary Use-Case in Agricultural Plant Monitoring

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***Abstract*— Collecting large datasets in robotics is important for various research tasks and naturally requires reliable long-term data acquisition. Therefore, this depends on an adequately designed, reliably functional robotic platform and support infrastructure. This work sketches such a platform and infrastructure and demonstrates its application in an exemplary use-case in agricultural plant monitoring.**

I. Introduction

Collecting consistent, high quality datasets requires data acquisition over long periods [1], [2]. One example in the domain of agriculture is the phenotyping process within commercial plant breeding. Reliable autonomous platforms and supporting infrastructure are essential to automate this task. Robust design as well as suitable methods for autonomous handling of a dynamic environment are key to achieve this reliability. This work sketches such a platform and infrastructure, and demonstrates its application in an exemplary use-case in agricultural plant monitoring.

For systematic research of the performance of autonomous systems, a reduced data acquisition process can be modelled as a sequence of navigation and sensor recording actions repeated at regular intervals, e. g., twice a week over several months. This involves acquiring multi-modal, high-resolution sensor data from plants, but it could be any task the robot is equipped to perform. Between missions, the robot seeks shelter in a base station or recharges its battery. Ideally, the robot can stay deployed throughout the season without human intervention or supervision. Recent advances in commercial robotic platforms for agriculture have made machines available that are capable of fulfilling such tasks in principle, though customization and integration are often necessary. Here, we developed the Valdemar robot, the AI Market Garden research site, and a container as robot base station.

Bergerman et al. [3] provide an introduction to agricultural robotics, while Kisliuk et al. [4] give a current overview of AI in agriculture. Bao et al. [5], Xu et al. [6] and Atefi et al. [7] present the current state in robotic-based phenotyping. In this work, we refer to the Valdemar robot developed in the context of the PORTAL research project [8]*. The conceptual long-term autonomous scenario was described in [9], which was influenced by the general overview on long-term autonomy in robotics by Kunze et al. [10].

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II. Use Case and System

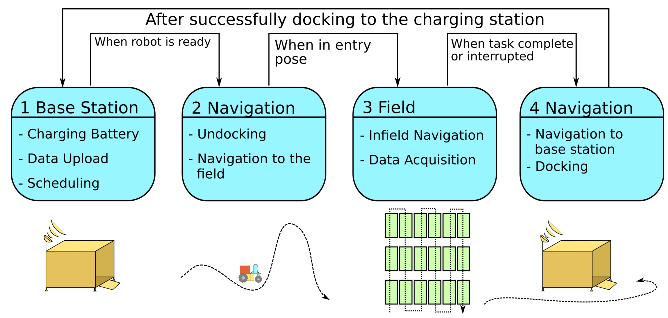

Fig. 1. Long term plant monitoring use case.

Plant Breeding Scenario. Figure 1 illustrates a model use case for automated monitoring in plant breeding. Wile developed in the context of the PORTAL project [8], this use case should be transferable to related scenarios. Fundamentally, it describes a data acquisition task that is repeated in regular intervals (i. e., twice a week) over multiple months throughout a season. During each run, the robot records multi-modal, high-resolution sensor data. For other scenarios, this could be complemented or replaced by any other task the robot is physically equipped to do. Between individual runs, the robot seeks shelter in a base station. It also returns there whenever it needs to recharge its battery. As in many related works, the robot can be transported to the field from somewhere else for each run and back after. However, with the goal of fully automated farming in mind, the robot should stay deployed deciding on its own when to start the next run.

Robotic Platform. The Valdemar robot is based on the modular, multi-purpose Thorvald II platform [11], e. g., being used in phenotyping, data acquisition [12] and other tasks [13]. Valdemar was developed within the PORTAL research project to assist the visual assessments in the process of plant breeding [14]. For this purpose, the robot is equipped with a set of multi-modal sensors such as high resolution RGB cameras, multiple RGB-D cameras, LIDARs, thermal and multi-spectral cameras and a high accuracy RTK-GNSS system for localization. All components are integrated into the ROS (noetic) [15] framework, with move_base_flex (MBF) [16] for navigation, providing different controllers depending on the robot's operation state, as shown in Figure 1.

Container Base Station. The Valdemar robot is supported by a container as a mobile base station, as depicted in Figure 2. The container is based on a Rytle Hub and has a swap body and hydraulics in the stamps, which allows mounting it on a truck without external tools for transportation of the robot. In addition, it has equipped solar power and an optional wind generator. The container provides self-sufficient operation of the robot, in combination with an integrated battery solution and an inductive charging plate.

Fig. 2. The Valdemar Robot in front of the Container Base Station.

AI Market Garden. Figure 3 shows the AI Market Garden, developed as a site to conduct experiments with agricultural robotic systems. While previous, ongoing and future projects are working with partners from industry to get access to commercial farming areas, the AI Market Garden has been established as an environment which is similar to farmland, but provides additional control and features for robotic research: The area of ca. $2400m^2$ is surrounded by a 193m long metal fence with a concrete foundation. This allows autonomy-experiments to be conducted without human supervision as the robot is kept on site even in an error case. Within the area there are multiple patches for different crops, a $100m^2$ poly tunnel greenhouse and features like trees, wild flower patches and space for the Container base station (the little box near the edge of the wood in Figure 3) as well as a shed for storage and working and a second base station for other robots. As of 2025, the AI Market Garden is used for multiple research projects in the context of robotics, AI research and for data acquisition and validation.

III. Conclusions

This work outlined a platform and infrastructure for collecting large datasets in robotics, in particular, for reliable long-term data acquisition. This approach was used within the PORTAL project to acquire 5.2TB of compressed raw data for 1.546 plant breeding plots in a top-down view in the season 2023 as well as 2024 and for additional experiments within the AI Market Garden.

The system outlined in this work has been adequately designed as a reliable functional robotic platform and support infrastructure – with demonstrated application in an exemplary use-case in agricultural plant monitoring,

Fig. 3. AI Market Garden (Spring 2024) near Bohmte (OS), Germany

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