MODELING AND SIMULATION OF A FARMER ROBOT FOR INFIELD VINEYARD MONITORING

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Digital twin technology has opened new avenues for enhancing agricultural practices through advanced simulation and control systems. In this study, we present the development and implementation of a digital twin for an outdoor mobile robot specifically designed for agricultural tasks. The digital twin comprehensively represents the robot's mechanical system, including its sensors and actuators. The digital twin simulates the robot's movement, perception, and interaction with the surrounding environment. The results of our simulations aim at demonstrating the effectiveness of the digital twin-based simulation approach in improving the performance and productivity of the outdoor mobile robot in agricultural settings.

Keywords: *digital twin, agricultural robotics, simulation frameworks*

1. Introduction

The Digital Twin (DT), which represents a virtual counterpart of a physical product, system, or process, is a rapidly emerging technology that has gained popularity due to its versatility across various application fields such as manufacturing, smart cities, healthcare, and agriculture [1] [2] [3]. In agriculture, one of the open issues to face is to develop autonomous navigation algorithms as a fundamental prerequisite for achieving full autonomy in performing agricultural tasks [4]. The availability of digital version of real platforms allows algorithms to be tested in advance and to observe the platform behavior under different operating conditions. In [5], a DT has been used during the initial phases to test the navigation algorithm for an AMR (Autonomous Mobile Robot) vehicle in a production hall. In [6] the DT of an underwater platform has been presented and is used to validate the feasibility of control algorithms for unmanned systems in real marine environments.

This work deals with the development of the digital twin of an all-terrain robotic platform operating in a vineyard. The implementation of a realistic model of the agricultural scenario and of the mobile robot is presented. The primary objective of the digital twin is to enhance the development and validation of autonomous navigation algorithms in a simulated world, allowing for thorough testing prior to deployment in actual operational conditions. The virtual representation of the robotic platform and the agricultural environment has been generated using Gazebo 11 [7], an open-source 3D robotics simulator. This enables the testing and validation of algorithms developed within the ROS (Robot Operating System) framework.

2. The mobile robotic platform CNRbot

This work introduces the digital twin of a research robotic platform here referred to as CNRbot, depicted in Fig.1. The CNRbot is an all-terrain mobile robot equipped with a locomotion system consisting of four steering and driving wheels, as well as two swing arms with suspensions. Its versatile design allows it to be used in a wide range of applications, both indoors and outdoors, including agriculture and industrial settings. Thanks to its robust suspension system, the vehicle delivers excellent performance even on rough terrains and during heavy-duty

Figure 1: The unmanned ground vehicle available at CNR-STIIMA.

Figure 2: The simulated environment developed in Gazebo composed by a vineyard row and the digital twin of the robotic platform equipped with several sensors.

tasks. Additionally, the robot exhibits omni-directional movement capabilities, as its four wheels can rotate by 180 degrees around their vertical axis.

3. Design and development of the digital twin

This section will discuss the digital twin of the robotic platform, introduced in Sec.2. The digital version of the robot has been developed using ROS and Gazebo. ROS is an open-source framework designed to assist developers in creating and managing robot applications. Gazebo refers to a simulator engine that enables the configuration of customized environments and the simulation of real robotic devices. As depicted in Fig. 2, the model includes a simulated environment, which consists of a vineyard row, and the robot model. The 3D model of the vineyard was created using a 3D modeling software, namely Blender, from which the DAE (Digital Asset Exchange) file was obtained. Then, the simulated environment in Gazebo has been created by adding the DAE file and the texture representing the vineyard row into a custom WORLD file.

Since the CNRbot is a customized robot, there was no existing model available in Gazebo. Therefore, a URDF (Unified Robot Description Format) file was generated using a SolidWorks plugin, starting from the CAD model. The URDF file incorporates information about the robot's links, such as the base and the various components including the wheels, and how those components are related to each other. Furthermore, physics engine like Gazebo require physical properties, such as inertial characteristics, to be specified. Gazebo allows also simulation of sensors, which can be added as a geometric component of the robot. To enable the publication of sensor data, it is required to incorporate the corresponding plugin for the used sensors into the robot model. In our case study, the robot is equipped with sensors that allow it to perceive the environment and perform self-localization, in detail, sensory device capable of creating a 3D model of the surrounding environment, such as an RGB-D camera or a lidar. In order to simulate properly, it is necessary to specify the transmission attribute for each non-fixed joint, specifically for each of the robot's wheels, as well as the speed controller. Without loss of generality, we assume that the robot moves with a speed controlled by a skid steering drive controller, despite having steering wheels.

Finally, in this simulated environment, it is possible to estimate the robot's relative pose (i.e., distance and orientation with respect to the row) [8], test and validate the row-following algorithm [9], and observe the performance of the system prior to deployment in actual operational conditions.

4. Conclusion

This paper presented the development of a digital twin built using ROS and Gazebo 11 for an all-terrain robotic platform operating in a vineyard. The implementation included the creation of a realistic model of the agricultural scenario and of a customized agricultural robot.

By leveraging the capabilities of the digital twin, it is possible to optimize algorithms, assess their performance, and identify potential challenges in a safe and controlled virtual environment. This approach significantly reduces the risks associated with field testing, while improving the overall reliability and robustness of the autonomous navigation system.

REFERENCES

1. Cimino, C., Negri, E. and Fumagalli, L. Review of digital twin applications in manufacturing, *Computers in Industry*, **113**, 103130, (2019).

2. Erol, T., Mendi, A. F. and Doğan, D. The digital twin revolution in healthcare, *2020 4th International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT)*, pp. 1–7, (2020).

3. Pylianidis, C., Osinga, S. and Athanasiadis, I. N. Introducing digital twins to agriculture, *Computers and Electronics in Agriculture*, **184**, 105942, (2021).

4. Bai, Y., Zhang, B., Xu, N., Zhou, J., Shi, J. and Diao, Z. Vision-based navigation and guidance for agricultural autonomous vehicles and robots: A review, *Computers and Electronics in Agriculture*, **205**, 107584, (2023).

5. Stączek, P., Pizoń, J., Danilczuk, W. and Gola, A. A digital twin approach for the improvement of an autonomous mobile robots (amrrsquo;s) operating environmentmdash;a case study, *Sensors*, **21** (23), (2021).

6. Hu, S., Liang, Q., Huang, H. and Yang, C. Construction of a digital twin system for the blended-wing-body underwater glider, *Ocean Engineering*, **270**, 113610, (2023).

7. *Gazebo*. `https://staging.gazebosim.org/home`.

8. Rana, A., Vulpi, F., Galati, R., Milella, A. and Petitti, A. A pose estimation algorithm for agricultural mobile robots using an rgb-d camera, *2022 International Conference on Electrical, Computer, Communications and Mechatronics Engineering (ICECCME)*, pp. 1–5, (2022).

9. Rana, A., Milella, A. and Petitti, A. A row following algorithm for agricultural multi-robot systems, *2023 International Conference on Control, Decision and Information Technologies (CoDIT)*, pp. 1–6, to appear, (2023).