First Field Tests of a Legged Robot in a Vineyard

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***Abstract*—In summer 2021, IIT's quadruped robot HyQReal was tested walking in a vineyard close to Piacenza (Italy). To the best knowledge of the authors this is the first time that a legged robot has been tested in a vineyard. Walking machines are a promising alternative to wheeled and tracked vehicles, due to their potential for higher mobility on uneven and steep terrains. This extended abstract provides a brief description of the locomotion tests with the quadruped robot under two different between-row floor management conditions: tilled vs. grassed soil.**

***Index Terms*—legged robot, vineyard, precision agriculture**

I. Introduction

Vineyard management includes different practices performed throughout the year aiming at achieving optimal plant growth, and productivity towards a desired fruit composition. Even though they are traditionally performed manually, mechanization of such operations in modern viticulture allows a significant decrease in labor demand [1]. Over the last few decades, advances in technology have contributed to improve final quality and efficiency in several agricultural systems. Precision viticulture protocols have been developed since the 90's and variable rate technologies can now assist cultural practices such as irrigation [2], fertilization [3] and harvest [4]. Future automation in vineyard requires autonomous vehicles that navigate through the rows to execute some of these operations and, in parallel, to guarantee a high resolution canopy monitoring. While most operations are currently executed by tractors in a non-selective way (e.g. pre-pruning, weeding, spraying, trimming, harvesting), certain practices are more selective and can currently only be performed by humans (e.g. manual winter pruning, shoot thinning, table grapes picking). Such operations are time-consuming and thus expensive [5], which makes them ideal candidates for automation. Smaller vehicles such as autonomous ground vehicles (AGVs), are promising alternatives to tractors and more suitable for the automation of certain operations. Additionally to the current list of yearly operations, AGVs can perform new tasks such as data collection that can feed into Decision Support Systems (DSS), optimizing the use of pesticides, water, nutrients, etc.

As mentioned in the 2021 review paper on advances in agriculture robotics [6], most agricultural robots and vehicles have wheels. Wheeled machines, however, might struggle with certain terrain characteristics, such as rocks or fallen branches, etc. Additionally, the wheels lead to a higher rate of soil compaction. Legged robots, on the other hand, can locomote in more rugged and harder to access areas: (a) they do not need constant contact with the ground, which allows them to step over obstacles and (b) the legs allow the robot to adjust its torso orientation to the slope inclination and to increase the workspace of the onboard tools, such as manipulator arms. These features make legged robots a promising solution to bring automation into vineyards, especially in places that have no continuous wheel access from the road, but can only be reached by steps, stairs or other uneven access paths. To the best of our knowledge, no legged robot has ever been tested in a vineyard to date. Although not for agriculture but for forestry applications, the *Plusjack* walking harvester was a pioneering, six-legged vehicle developed in 1999 by Plustech, Timberjack's R&D unit, now part of John Deere Group [7].

(a) (b)

Fig. 1. Pictures of IIT's HyQReal robot during the field tests in the vineyard walking on (a) tilled and (b) grassed soil.

In the last decade, several wheeled robots have been developed and tested for vineyard applications: The EU project VINBOT [8] resulted in a prototype of an all-terrain wheeled robot (based on Robotnik's Summit XL) with a set of sensors that can estimate grapevine yield of vineyards and assess other plant attributes. The project GRAPE [9] developed the tools required to perform autonomous vineyard monitoring and farming tasks to reduce the environmental impact of traditional chemical control by the deployment of pheromone dispensers. Botterill et al. presented a first prototype of a vineyard pruning robot [10] that is 3.5m long, 2m wide and 2.5m tall. The

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robot is moving on 4 wheels. At commercial scale, already existing AGVs are mainly focused on non-selective operations related to vineyard floor management encompassing mowing and within-row soil cultivation. Among them VITIROVER, vinescout, wall-ye, Naio and Vitibot etc. create an array of technical solutions differentiated in terms of AGV size, productivity, and operational context.

In summer 2021, we have conducted several field tests of IIT's HyQReal robot [11] in a mature vineyard close to Piacenza (Italy). The robot has walked in rows with different inter-row floor management: tilled vs. grassed soil, as shown in Fig. 1. To the best of our knowledge this is the first time that a legged robot has been tested in a vineyard. The remainder of this abstract briefly describes the robot and the tests.

II. Robot Specifications

The HyQReal robot is a hydraulically powered quadruped robot developed by the Dynamic Legged Systems (DLS) lab of IIT in Genova, Italy. The robot weighs 140kg and is 1.3m long. Its 12 degrees of freedom are powered by torque-controlled hydraulic actuators. HyQReal carries 2 hydraulic pump units (one for the front and one for the hind legs) and a LiPo battery. A roll bar around the torso acts like a rib-cage protecting the battery, hydraulics and electronics from impacts. A Kevlar and glass fibre skin adds further protection. In the current configuration it carried a Velodyne Puck LIDAR sensor and a Realsense RGB-D sensor. The robot's estimated payload is around 30kg. Figure 2 shows a picture of HyQReal with labels describing the main features. For more details refer to [11].

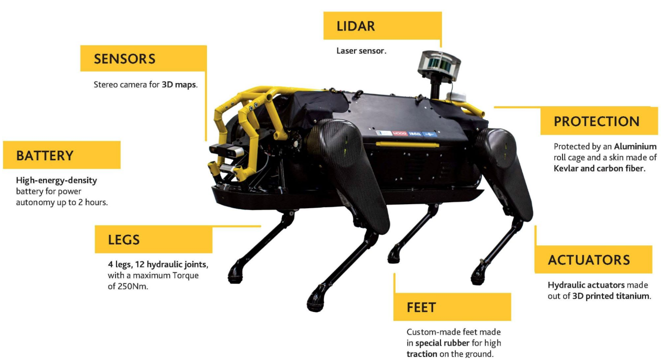

Fig. 2. Picture of HyQReal with labels showing the main features.

III. Field Tests in the Vineyard

The vineyard for the tests was established in 2001 in Calstelnuovo Calstelnovo Val Tidone, Colli Piacentini wine district, La Pernice Estate, (44°97' N, 9°42' E, 213m a.s.l.), Italy. The vineyard is perfectly flat with North-South (NS) oriented rows, and vines trained to a single-cane vertically shoot positioned (VSP) Guyot trellis at a spacing of 2.4m x 1m (inter- and intra-row) for a corresponding density of 4166 vines/ha. The vineyard features two different types of inter-row floor management: Tilled (T) vs. Grassed (G) soil, as shown in Fig. 1. According to the protocol adopted by the winery, in T, the inter-row was spaded regularly depending on grass growth and weather conditions to avoid weed development. Permanent native grass (G) established since 2003 has been mowed when average grass height exceeded about 35 cm. Prior to the test, the T inter-row has been harrowed to remove weeds and to create soft terrain conditions while the grassed inter-row has been mowed at 5 cm height and cut swards kept in place.

The robot performed several walking tests in both types of floor conditions, as well as tests on unconsolidated obstacles in the form of rocks and soil clumps. The standard test protocol for all tests was:

1) robot standing up from a resting position parallel to (and in the center of) two rows
2) robot doing initialization procedure
3) robot moving forward with crawling gait [12] at 5-10 cm/s walking speed
4) robot stopping and sitting down.

The accompanying video shows footage of three tests: walking on (a) tilled soil, (b) grassed soil and (c) tilled soil with unconsolidated obstacles.

The locomotion control framework combines a crawl motion generation module, with different features that allow the robot to handle rough terrain: haptic touch-down, surface reaching, terrain estimation, online replanning, etc. [12].

The tests showed that our 140kg legged robot can successfully navigate in vineyards with different types of soil. As expected, the maximum foot penetration into the soil was higher on the tilled soil (*ca.* 6-7cm), compared to grassed soil (*ca.* 1-2cm). For all experiments, we used a static crawl that projects the ground reaction forces orthogonal to the surface to reduce tangential foot motions during the support phase.

IV. Future Prospects and Opportunities

The field tests with the quadruped are part of the VINUM project, a collaboration between IIT and UCSC, with the goal to develop a robot for automated winter pruning of grapevines. In the first years of the project the focus has been on pruning region detection with neural networks [13], image segmentation for plant organ classifications and pruning points detection [14] and mobile manipulation for pruning with whole body control [15]. The future steps are to combine the vision and manipulation sub-systems with the legged robot and perform field tests with the fully-integrated system.

Robotics in agriculture is developing later than other fields (i.e. manufacturing, medical), however viticulture seems a promising area for field robotics because of: (a) high percentage of vineyards are established in steep conditions; (b) high needs of automation also for selective operations in a context characterized by skill shortage and limited labor availability; (c) grapevine is a high value crop (instead of commodities).

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