VINESCOUT: A VINEYARD AUTONOMOUS ROBOT FOR ON-THE-GO ASSESSMENT OF GRAPEVINE VIGOUR AND WATER STATUS

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VineScout is an autonomous ground robot designed, built, and demonstrated in commercial vineyards. It has been developed in the context of a H2020 European project. The VineScout goal is assessing grapevine water and nutritional status. The current improvements concerning autoguidance have been the addition of a multi-beam lidar to assist in the 3D perception acquired by a stereo camera, and two ultrasonic sensors to enrich perception for headland turning. Regarding crop sensing, a multispectral camera (Bay Spec Inc., San Jose, USA) and an infrared radiometer (Apogee Instruments, Inc., Logan, Utah, USA) were mounted in the robot to measure vine vigour and plant water status.

The external dimensions of the VineScout autonomous vehicle are approximately 0.90 meters wide, 1.40 meters long, and 1.20 meters tall with the GPS antenna folded. Figure 1 displays three images of the robot front (Figure 1-left), side (Figure 1-center), and rear (Figure 1-right). The robot was powered by two electric lithium batteries of 12 V coupled to deliver 24 V, and it was also equipped with two solar panels supplying an extra power of 128 W in total. The robot dynamics were enhanced by four independent suspensions affixed to the electric motor propelling each wheel.

The VineScout robot was tested from May to November in season 2018. Navigation sensors, as well as crop sensors installed in the autonomous vehicle, were tested along various data-collection tests organized in commercial and experimental vineyards in Spain and Portugal. The goal of field-testing was, on one hand, to check the mechanical, electrical, and autonomous navigation behaviour, and on the other hand, to gather information with crop sensors under field conditions to check their data against widely accepted reference indicators (NDVI, CHL, and NBI).

Figure 1. VineScout status in November 2018: front view (left), side view (middle), and rear view during night mapping (right).

The autonomous navigation system is based on the augmented perception obtained by merging information from two sonar sensors, a binocular stereo camera, and a non-rotational multi-beam lidar rangefinder that was added to the robot in 2018 to increase robustness in

ranging measurements. The multi-beam lidar gives eleven measures at a time, covering a scanning zone of 88 degrees. The two ultrasonic sensors facing the lateral canopies assisted in the headland turning. The computer mounted in the robot is an embedded fanless processing unit, that also managed the ultrasonic sensors, the lidar, and the rest of sensors, through a multifunction I/O device. The tests to check the autonomous navigation capabilities followed the method described in Cuenca et al. (2018), for validating the new ultrasonic network model, recently installed in the robot and more adjusted to the constraints found in vineyards. The precision of autonomous guidance was checked by evaluating the deviations from the centre line between vineyard rows. Vehicle states data were saved by the robot computer along the tests. After the analysis of lateral deviations for straight guidance and headland turning, the autoguided performance was satisfactory with the ultrasonic sensors, the new lidar, and mechanical improvements in the steering system.
The autonomous robot carried two non-invasive crop sensors, which were located facing to the right side of the vineyard canopy: an infrared radiometer and a multispectral camera. The infrared radiometer measured leaf temperature at a rate of 1.8 Hertz. The reason for installing an infrared radiometer sensor to measure canopy temperature is based on the relationship between the leaf stomatal closure or aperture and its surface temperature: the increase in plant water stress is linked to leaf stomatal closure and implies a rise in leaf temperature. The areas of higher water stress on the studied vineyard plot were near the headlands of the rows, while less stressed plants were located around the middle of the row where there was a depression in the terrain, confirming visual assessment. The multispectral camera was used to measure leaf reflectance at different spectral bands from the visible to the near infrared region of the spectrum, that enable the calculation of the NDVI, and promising estimations of NBI (Nitrogen Balance Index), CHL (Leaf Chlorophyll Index), and ZTM (Zarco-Tejada & Ustin, 2001). The VineScout robot was also equipped with a Global Positioning System that provided global references for the maps. Two different sensors were used as the reference measurements for ground-truth validation contemporarily to vineyard monitoring with the robot, which moved at 1.5 km/h. The satisfactory correlations given for the vigour indices called for the inclusion of the spectral reflectance values at 720 nm, 560 nm as well as the NDVI and ZTM indices in the data output of the robot.

The second VineScout prototype allowed the massive acquisition of crop data for the non-invasive assessment of water status in vineyards. Automatic navigation, as well as power autonomy were satisfactory, and little changes are expected for its final version in terms of mobility and external design. Water status was assessed by the estimation of canopy temperature while plant vigour was evaluated using vegetation indices such as NDVI, CLH, and NBI. Proximal-sensed NDVI yielded values close to the ones manually determined in the field using the reference method. However, despite getting stable readings with the infrared radiometer and the multispectral camera, further research is needed to come up with more sophisticated algorithms that eventually correlate both temperature and vigour with the user-demanded water stress and vigour maps.

REFERENCES

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