VINEROBOT: ON-THE-GO VINEYARD MONITORING WITH NON-INVASIVE SENSORS

VINEROBOT: SURVEILLANCE EN MOUVEMENT DU VIGNOBLE AVEC CAPTEURS NON INVASIVES

Maria P. DIAGO[1*], Francisco ROVIRA-MÁS[2], Jose BLASCO[3], Verónica SAIZ-RUBIO[2], Enrico FAENZI[4], Sébastien ÉVAIN[5], Sébastien LABAILS[6], Manfred STOLL[7], Mathias SCHEIDWEILER[7], Christophe MILLOT[8], Esther CAMPOS-GÓMEZ[9], Javier TARDAGUILA[1,]

[1]*Instituto de Ciencias de la Vid y del Vino (CSIC, UR, Gobierno de La Rioja). Madre de Dios, 51 (26006) Logroño. La Rioja. Spain*

[2]*Agricultural Robotics Laboratory, Universidad Politécnica de Valencia, Camino de Vera s/n 3F, Valencia 46022, Spain*

[3]*Centro de Agroingeniería, Instituto Valenciano de Investigaciones Agrarias (IVIA), Moncada, Valencia, Spain*

[4]*SIVIS SRL, Viale Toselli 13, 53100, Siena, Italy*

[6]*FORCE-A, Centre Universitaire Paris Sud Bât 503, 91893 ORSAY Cedex France*

[6]*Société Coopérative Agricole des Vignerons de Buzet, 56 Avenue des Côtes de Buzet, BP17, 47160 Buzet s/Baïse, France*

[7]*Department of General and Organic Viticulture; Hochschule Geisenheim University (HSGM), D-65366 Geisenheim, Germany*

[8]*WALL-YE SARL, Rue Doyenne 5, 7100, Macon, France*

[9]*Avanzare Innovacion Tecnologica S.L., Avd. Lentiscares 4-6. Polígono Lentiscares (26370), Navarrete. La Rioja. Spain*

*Corresponding author: M.P. Diago, +34941299737, Fax: +34941299721, Email: mpaz.diago.santamaria@gmail.com

Abstract

In the last decades, the remarkable development of new technologies and the growing demand for greater competitiveness and sustainability have led to a great interest in precision viticulture, which proposes a differentiated agronomic management of vineyards based on the spatial-temporal variability of vegetative development, production, and quality of the grapes. A forefront and sustainable viticulture requires objective and continuous monitoring of key parameters for rational decision making. In this context, the first prototype of a novel use-case agricultural robot which will be equipped with several non-invasive sensing technologies is presented to monitor key agronomical and physiological parameters of the vineyard, such as vegetative growth, nutritional status and grape composition. This unmanned ground vehicle (UGV) is deployed with the aim of providing fast and accurate information to grapegrowers in order to optimize vineyard management and to improve grapes and composition and quality of wines. The integral monitoring of the vineyard over the entire season is intended, by placing the ground robot along the vineyards. The robot will incorporate an integrated sensing system that includes machine vision, fluorescence-based sensors and NIR spectroscopy devices. Canopy and fruit images and sensor data will be acquired on-the-go and processed in real time through customized map-building algorithms, displaying final maps in smart phones and other devices by grapegrowers and other end-users. Precision viticulture will capitalize from the scouting robot capabilities of not only being endowed with several non-invasive techniques to sense and assess crop status, but also with key data to allow for vineyard management, decision-making, forecasting and standardizing solutions.

Keywords: *precision viticulture, non-invasive sensing, nutrient status, grapevine water status, grape composition.*

Résumé

Durant les dix dernières années, le développement fulgurant des nouvelles technologies et la demande toujours plus grande d'améliorer la compétitivité et la rentabilité, se sont traduits par un intérêt croissant vis à vis de la viticulture de précision. Elle permet une conduite agronomique différenciée du vignoble, basée sur la variabilité spacio-temporelle du développement végétatif, de la quantité et de la qualité de la récolte. Une viticulture durable et de premier rang a besoin d'un tableau de bord objectif et continu basé sur des indicateurs clés afin de mieux adapter les prises de décisions. Dans ce contexte, le premier prototype de robot agricole modulable et équipé de différentes technologies non-invasives de détection est maintenant d'actualité. Capable de suivre de près les paramètres agronomiques et physiologiques du vignoble (pousse de la végétation, statut nutritionale, composition des grappes), ce Véhicule Terrestre Autonome (Unmanned Ground Vehicle - UGV) est envoyé sur le terrain avec pour objectif de fournir des informations peu couteuses, rapides et précises aux vignerons afin d'optimiser la gestion du vignoble et améliorer la composition des grappes et la qualité du vin. En positionnant le robot terrestre dans les vignes, il pourra surveiller l'ensemble du vignoble tout au long de la saison. Le robot sera équipé d'un système intégré de détection, notamment de vision artificielle, de capteurs basés sur la fluorescence et la thermographie ou d'appareils utilisant le proche infrarouge. Les images de la canopée et les données des capteurs seront acquises et traitées en temps réel à travers des algorithmes de construction de cartes modulables qui seront affichées sur les smartphones des vignerons et autres utilisateurs. La viticulture de précision capitalisera sur les capacités d'exploration du robot, non seulement parce qu'il est doté de plusieurs techniques invasives de mesures et d'évaluation de l'état de la récolte, mais aussi parce qu'il sera capable de déterminer des données clés pour la conduite du vignoble, la prise de décision, la prévision et la normalisation de ces solutions.

Mots-Clés: viticulture de précision, technologies non-invasives de détection, statut nutritionnel, statut hydrique de la vigne, composition des baies

1. Introduction

Traditionally, European vineyards have not been technology driven. The human eye has been the only "sensor" steering vineyard management decisions, providing subjective evaluations on yield, vegetative growth and plant status regarding water stress, pests and diseases. Sustainable viticulture requires objective and continuous key parameter monitoring for rational decision-making with advanced technologies and sensors in the fields (Lee et al. 2010). These would allow for observing crops and quantifying important factors in vineyards such as grape yield, leaf development, disease incidence and detection of various stress agents (water, nutrition, etc.). Additionally, all this information can be globally referenced with GPS, enabling the periodic assessment of spatial variability for key agronomical parameters in the vineyard which may facilitate precision viticulture strategies, aimed at differentiated and optimized vineyard management.

Nowadays, there is no practical system in agriculture that integrates multiple sensors capable of acquiring information on agronomical, physiological and fruit composition simultaneously and on-the-go. Only some remote sensing solutions from aerial platforms or satellites have included the simultaneous acquisition of spectral information in the visible and infrared ranges allowing for the assessment of grapevine vigor and water status (Baluja et al. 2012). However, the small spatial resolution of multispectral devices together with the discrete architecture of grapevine cultivation in rows rather than bulk crop, the limited weather flexibility and the elevated cost of aerial monitoring are important drawbacks, which have practically led to discard remote sensing for most of the small- and medium-size European vineyards.

A promising and solid alternative to remote sensing for vineyard monitoring is proximal sensing, through which all the inconveniences mentioned above are expected to be overcome with the VineRobot project. The project consortium involves eight partners: five SMEs (small to medium enterprise), settled in three European countries (Italy, Spain, and France), and three RTD performers from Germany and Spain. The University of La Rioja (Spain) coordinates the project, and other partners involved in the project are the University of Geisenheim (Germany), the Polytechnic University of Valencia (Spain), the company FORCE-A (Orsay, France)-dedicated to the production of non-invasive sensors—, Les Vignerons de Buzet—a major wine production and wine-making corporation located just at the south-east of the Bordeaux region of France—, Wall-Ye (France)—which has developed one of the first robots in agriculture—, the Italian company SIVIS—leader in machine vision and surveillance and reconnaissance systems, and the Spanish SME Avanzare—dedicated to the creation of advanced sensors..

The aim of this ongoing project is the design, development, and deployment of a novel use-case agricultural robot under the scope of Unmanned Ground Vehicles (UGV), and equipped with several non-invasive sensing technologies to monitor: 1) grapevines' vegetative growth, 2) nutritional status and 4) grape composition in order to optimize the vineyard management and improve grape composition and wine quality. The project scope covers the integral monitoring of vineyards, over the entire season, by placing a ground robot along the vineyards, endowed with artificial intelligence techniques to operate in a changing environment. The final users will receive updated information in mobile applications (app). The proposed use-case agricultural robots (where key proximal sensing technologies are implemented) is intended to allow revolutionary and conclusive decision-making to optimize vineyard management and to drive agronomical fundamental decisions according to berry composition assessment (Figure 1). The successful deployment of a robot like this requires the effective solution of long time challenges such as: Physical constraints for mobility in off-road environments; Navigation planning and safeguarding; Synchronization of multiple perception systems, mapping and communication; Validation of the sensing solutions and agronomical parameters; Prototype construction and demo agenda.

The main capability expected from the VineRobot is the possibility of working (retrieving agronomical and physiological data from the grapevines) autonomously and safely over long periods of time under the uncertain environmental conditions typically found in vineyards. The presence of commercial robots in vineyards is practically inexistent. In addition to navigation, the VineRobot will gather key information from the vines and will convey it through compatible maps.

2. Materials and methods

The work conducted during the first year of the project was divided into two working areas: 1. Robot design and construction, and 2. Development of crop sensing units. In general terms, the first prototype of the VineRobot has been designed, built, and successfully tested in Buzet (Bordeaux, France). The requirements for the robot design in terms of "what the robot has to do" have also been defined. The first prototype is capable of moving in the field at ease (see navigation strategy in Figure 2) and at this point it can be manually operated with a joystick or remotely steered through a tablet. Efforts have been dedicated to improve the suspension and traction systems. The first version of the security network comprising four emergency stops and a collision-sensitive front bumper has been implemented and evaluated (Figure 3). The following stages will endow the robot with autonomous mobility, which will be demonstrated in the Buzet vineyards (Bordeaux, France) in 2015.

The work on the bio-sensing capabilities of the robot has progressed in four directions: 1. A vision system based on RGB and IR perception is being developed to identify and track grape berries on-the-go; 2. Fundamental research on NIR spectrometry has been conducted to measure water stress alternatively to thermography (data not shown) and some aspects of grape composition; 3. The FAsense® (ForceA, Orsay, France), a new fluorescence sensor to detect the level of anthocyanins in grapes and 4. To assess the grapevine's vegetative and nutritional status.

The scientific and technological impact of the VineRobot is mainly driven by the innovative nature of the vine scouting robot, as no other similar product exists in the market, in spite of the need for technology in the highly competitive world of wine making. The two main novelties are: i) the robot will be able to navigate in any standard vineyard for at least four hours without human intervention (at present there are no commercial robots that can be reliably left alone in outdoors fields for so long); and

ii) at the end of the monitoring mission, the robot will provide a set of crop maps of agronomical parameters in a time-based-compatible format to be easily stored and displayed in regular computers and smartphone-like devices.

3. Results and discussion

The VineRobot is generally targeted at the people who make crucial decisions about the vineyard's management or provide consultancy to grape growers and winery managers. The main potential impact for end-users involves several positive aspects: i) end-users will draw clear economic and environmental advantages from the scouting robot as they will optimize vineyard inputs and management costs; and ii) the fast and versatile display of the crop maps makes the robot a flexible and powerful decision-support tool for making educated decisions based on measurable data. The immediate display of valuable information on the own robot and alternatively on smartphone-like devices remotely operated will promote advanced business operations. For this reason, a standardized, simple, easy-to-use and understand mapping format is being developed, based on the use of global coordinates featuring Euclidean geometry for northing-easting, and the discretization of space into regular grids (Sáiz-Rubio and Rovira-Más, 2013).

In general, the robot is intended to provide final users with the following benefits: i) reasonably accurate yield forecast and consistent grape yield estimations on one hand, and quality improvements on the other hand, thanks to an optimized crop monitoring and advanced vineyard management; ii) continuous and accurate vineyard agronomical, physiological, and grape quality information to better cope with the impact of climate change and global warming on grape growing; iii) optimization of the labor demand and costs for vineyard management; iv) more sustainable vineyard management with optimization of chemical inputs (i.e. fertilizers, fungicides and pesticides for disease and pest control) and improved use of natural resources (water); and v) meet industry and community expectations, as well as government regulations on environmental vineyard management and long-term sustainability.

4. Conclusions

This project deals with the fields of precision viticulture and robotics and is also a novel technological challenge; since it represents a large step forward in agricultural robotics and the application of advanced non-invasive proximal sensing to provide reliable, fast and objective information to state-of-the-art vineyards. Therefore, the robot holds potential for viticulturists and winemakers in making better and more precise management decisions.

5. Acknowledgments

The work leading to these results has received funding from the European Union under grant agreement nº610953.

Literature cited

BALUJA, J., DIAGO, M.P., BALDA, P., ZORER, R., MEGGIO, F., MORALES, F., TARDÁGUILA, J. 2012. Assessment of vineyard water status variability by thermal and multispectral imagery using and unmanned aerial vehicle (UAV). Irrigation Science 30, 511-522.

LEE, W.S., ALCHANATIS, V., YANG, C., HIRAFUJI, M., MOSHOU, D., LI, C. 2010.Sensing technologies for precision specialty crop production. Computers and Electronics in Agriculture 74, 2-33.

SÁIZ-RUBIO, V., ROVIRA-MÁS, F. 2013. Proximal sensing mapping method to generate field maps in vineyards. Agricultural Engineering International: CIGR Journal 15, 47-59.

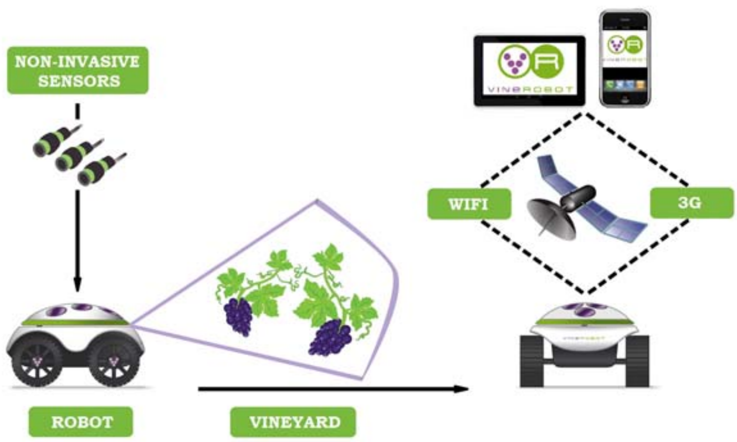

Figure 1. *Overall concept of the VineRobot project.*
Figure 1. Concept global du project VineRobot.

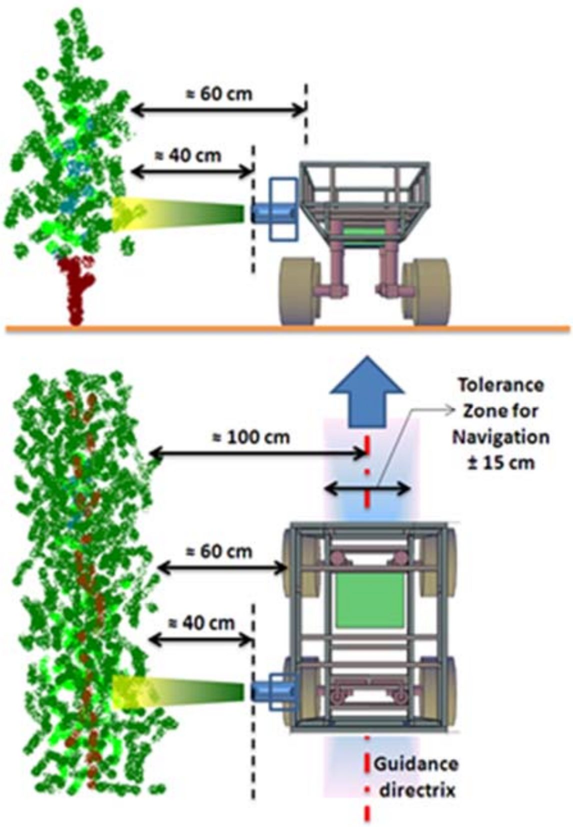

Figure 2. *Initial navigation strategy for the VineRobot*
Figure 2. Première stratégie de navigation pour le VineRobot

Figure 3. *Images of the first prototype of the VineRobot*
Figure 3. Images du premier prototype du VineRobot