**Project Number:** 737669

**Project Acronym:** **VineScout**

**Project title:** VineScout – Intelligent decisions from vineyard robots

## Periodic Technical Report

## Part B - Explanation of the work - Overview of progress

**Period covered by the report**: from 01/12/2016 to 30/11/2017

**Periodic report:** 1st

| | |
|---|---|
| Grant Agreement number | 737669 |
| Specific call | H2020-FTIPilot-2016/H2020-FTIPilot-2016-1 |
| Project Acronym | VineScout |
| Project title | VineScout – Intelligent decisions from vineyard robots |
| Start date of the project | 1 December 2016 |
| Duration of the project | 36 months |

# Technical report index

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# 1. Explanation of the work carried out by the beneficiaries and Overview of the progress

## 1.1 Updated specific objectives. Overview of the progress

### Updated specific objectives

The specific objectives to move from a TRL 6/7-based VineRobot (Grant agreement number: 610953) to a TRL 9-targeted VineScout are directly related to Work Packages (WP). This fact assures the work to be aligned to the specific objectives of the project.

The specific objectives are:

1. **Optimization of mechanical design and external appearance**
2. **Industrialization of internal electronics**
3. **Maps validation and sensing capabilities**
4. **Software refinement, optimization, and market preparation**
5. **Construction of three prototypes with growing capabilities**
6. **Demonstration**
7. **Market introduction tactics, end-user acceptability, and dissemination**

### Overview of the progress

1. **Optimization of mechanical design and external appearance**

   - WALL, together with the ideas proposed by UPV, designed the external cover for the first prototype of VineScout, taking into account the harsh working conditions in the field, and the importance of an attractive look regarding marketing movements. Details on this will be commented in the paragraph *1.2.1 Work Package 1: Optimization of mechanical design and external appearance.*
   - Regarding traction abilities and power sufficiency, there have been some reinforcement in the mechanical torque and batteries. The torque was increased for the current version of the robot, and lead batteries has been replaced for Lithium ones for the second prototype, VS-2.

2. **Industrialization of internal electronics**

   - Fail-safe capabilities and environmental endurance are being achieved by designing a suite of modular electronic blocks that have been fabricated, and tested. This rational design enhances the seamless integration of software and electromechanical devices. The details of the internal electronics for VS-1, VS-1 ECS, are commented on paragraph *1.2.2 Work package 2: Industrialization of internal electronics.*

3. **Maps validation and sensing capabilities**

   - Maps built by the robot need to deliver truthful data, so it can be statistically compared to alternative measurements. Getting truthful data means having taken data with the appropriate sensors, thus, sensors were tested in field, not only integrated in the robot, but also independently from it, to check the values given. The tests where two sensors were integrated in the robot took place during VineScout Steering Week. The robot was able to get a temperature map with one of the sensors, while the images taken with the other sensor needed to be processed afterwards. In the description of the paragraph *1.2.3 Work package 3: Support* *knowledge of maps and sensing capabilities*, more details are given, and the temperature map is shown.

**4. Software refinement, optimization, and market preparation**

- Efforts were done to improve software performance in terms of runtime velocity and fail-safe response. As new sensors (not only for canopy sensing, but also for navigation) have been incorporated, modifications in programming were necessary; thus, program philosophy has turned more class-oriented (object-oriented programming). In paragraph *1.2.4 Work package 4: Software refinement, optimization, and market preparation* details regarding the new navigation sensors are described.

**5. Construction of three prototypes with growing capabilities**

- An active iterative process is necessary to converge to the optimal solution, which for agricultural environments requires heavy testing in actual environments. This specific objective is directly related to VineScout *milestones*, which consider the construction of approximately one new prototype built each year of the project; thus, there are three milestones, and one robot built per milestone. For the first year of the project, a prototype was delivered on 21 August 2017 (first milestone achieved), and the second prototype is planned to be delivered earlier than the past year (planned for January) in order to have time to replicate all the internal electronics, and improve what needed, to test that version during spring and summer field tests, and the second Steering Week (SW2, in 2018).

**6. Demonstration**

- Paragraph *1.2.5 Work package 5: Demonstration* describes the first Steering Week (SW1) of the project, which took place from 28 August 2017 to 1 September 2017. The Agronomy Day was on 30 August, during SW1, where the Consortium invited external people to see, touch, and even manage the robot, while they could make questions about either the robot or the project itself. Also, some data could be retrieved from the robot, so, in the afternoon session a round table to talk about robot data took place.

**7. Market introduction tactics, end-user acceptability, and dissemination**

- The most important activities for the project regarding visibility is done during the Steering Weeks. In the Agronomy Day, people with different backgrounds can give their opinion and tell the Consortium their suggestions, which are extremely valuable for the success of the project, as people can talk about their experiences with other robots (people from the Academia, supporting with technical issues), and with their vineyard fields (as owners or work in vineyards fields). The Agronomy Day ended with a questionnaire that covered, not only technical issues (robot mobility and handling, robot intelligence and automatic behavior, data management and interpretation), but also end-user acceptance and market issues, which are key for the final outcome of the project: a marketable vineyard robot. Despite the SW1 was considered successful in many senses, only eight people gave their questionnaire for us to be recorded to obtain conclusions (see paragraph *1.2.5 Work package 5: Demonstration* with information about the deliverable *D5.6 Testimony of Agronomy Day*). Plans to improve the presence of people in the Agronomy Day, including the Advisory Board, and increase participation with the questionnaire, are being carried out.

- Attendance to trade shows on robotics and agricultural equipment shows that interest in agricultural robotics is high, but competition is not too intense. The monitoring rate of 6 Ha/day is still an objective. As a revision of the three-stage strategy to penetrate the market, they occur concurrently over the first year rather than sequentially. The service robot market continues growing as well as the agricultural robots market. However, North America is dominant in the market doubling Europe. The Agronomy Day revealed that the main concern is the retail price of the robot, being reliability the second. For more information see paragraph *1.2.6 Work package 6: Exploitation & Market strategic plan* with information about the deliverable *D6.2.- Business model and exploitation plan).*
- Scientific dissemination has been achieved through conference research articles, where, one of them was published in a research journal. Moreover, several mass media were interested on the project, publishing some pieces of news. For more information see paragraph *1.2.7 Work package 7: Dissemination and promotion.*

## 1.2 Explanation of the work carried per WP

### 1.2.1 Work Package 1: Optimization of mechanical design and external appearance

WP1 consists of optimizing the mechanical design and external appearance of the robot, where the leader of this WP1, WALL, has also the higher workload as shown in table 1. The main objectives of WP1 are: improving the mechanical design of the initial robotic platform until it meets the requirements set by end-users and potential buyers, with especial attention paid to mobility, safety, and autonomy; delving into robotic aesthetics to propose a "catchy" and attractive exterior design from the consumer side; and building three ready-to-market prototypes for demonstrations and promotion.

**Table 1. Highlights and person-month for Work Package 1 in VineScout EU project**

| Work package number | WP1 | Start Date or Starting Event | | Month 1 | |
|---|---|---|---|---|---|
| Work package title | Optimization of mechanical design and external appearance | | | | |
| Participant number | 1 | 2 | 3 | 4 | 5 |
| Short name of participant | UPV | WALL | SUN | UDLR | SYM |
| Person/months per participant: | 9 | 42 | 4 | 3 | 3 |

According to table 2, activities in WP 1 already started by the beginning of the project, in December 2016, which would culminate with the delivery of the first prototype of the robot. The delivery of the first prototype was the first milestone, MS-1, achieved on 28 August 2017, and verified through deliverable D1.1-a. For the first public demo, the external shell of the first robot version was not used for reasons that will be explained in the following paragraphs.

**Table 2. Activities planned for Work Package 1 in VineScout EU project.**

| | 2016 Dec 1 | 2017 Jan 2 | Feb 3 | Mar 4 | Apr 5 | May 6 | June 7 | July 8 | Aug 9 | Sep 10 | Oct 11 | Nov 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WP1- Optimization of mechanical design** | | | | | | | | | | D | | |
| T1.1 Mechanical evaluation & improv. act. | | | | | | | | | | | | |
| T1.2 Construction of 1st prototype VS-1 | | | | | | | | | | | | |
| T1.3 Construction of 1st prototype VS-1 | | | | | | | | | | | | |
| T1.4 Construction of final VineScout prot | | | | | | | | | | | | |

In the Description of Activities (DoA) document (see table 2), the delivery of the first version of the robot was stipulated for month 10, this is, September 2017; however, the shell for the first version was delivered in August 2017 (month 9).

After checking all the tasks within WP1 (table 2), updated information is given below.

**Summary of work for WP1** (Lead partner: WALL)

- **T1.1 – Mechanical evaluation and improving actions of initial prototype** *(M1-M6)* The goal of the first task of WP1 was to rigorously detect weaknesses in the departing platform that evolves from the VineRobot project (TRL 6/7) from the mechanical standpoint, and propose a list of improvements to be incorporated along the project. WALL built the shell for the first version of VineScout, VS-1. UPV composed the list of the proposed improvements for VS-2 after conducting a set of tests, not only static, but also dynamic ones at a constant speed of about 2.5 km/h. The static tests took place in UPV campus, while the robot was tested dynamically in standard vineyard rows selected by the end-user, SYM, (first field tests in Portugal on 10-25 June 2017). The improvements were proposed in terms of the robot dynamic behaviour (tire-suspension system, and steering mechanism), effects of weight and weight-transfer between front/rear axles, battery autonomy in flat and sloping terrain, traversability in presence of cover crops and weeds, and safety protocols.
- **T1.2 – Construction of first prototype VS-1** *(M4-M10)* The first prototype was delivered on August 21. Due to mechanical needs, the system had to be reassembled and, therefore, it was not ready for the First Steering Week, using, instead, a previous prototype.
- **T1.3 – Construction of second prototype VS-2** *(M13-M22)* The conclusions drawn from Task 1.1 by WALL and UPV are being implemented by WALL in prototype VS-2. Also, the outcomes drawn from the SW1 have driven the design and construction of prototype VS-2. The delivery of VS-2 (programmed for month 22) will be earlier in 2018 (expected to be on month 14), in order to be able to test VS-2 in spring and summer to be prepared for the next Steering Week (SW2). SUN has also been testing the electronics for implementing the second version of the board processor in VS-2.

**Development of the work for WP1**

- **Related information: D1.1-a, UPV monthly report, and conference article**

The deployment of prototypes is reported in the DoA as three deliverables (D1.1) in months 10, 22, and 34. To differentiate among them, the first deliverable (M10) will be reported as D1.1-a, the deliverable for M22 as D1.1-b, and the last one as D1.1-c (M34). For this First Periodic Technical Report, the D1.1-a is reported, which is a visual report of the construction and deployment of the first VineScout prototype. The report includes post-delivery amendments for the first-version of the robot, VS-1.

<u>Design models and preliminary drawings</u>

The following images show the first designs drawn for VineScout 1 (VS-1). Figures 1-a and 1-b provide the finished concept of the robot, and Figures 1-c to 1-f focus on the body details built in plastic composite, being 1-d the side view, 1-c and 1-e the frontal side, and 1-f the rear view.

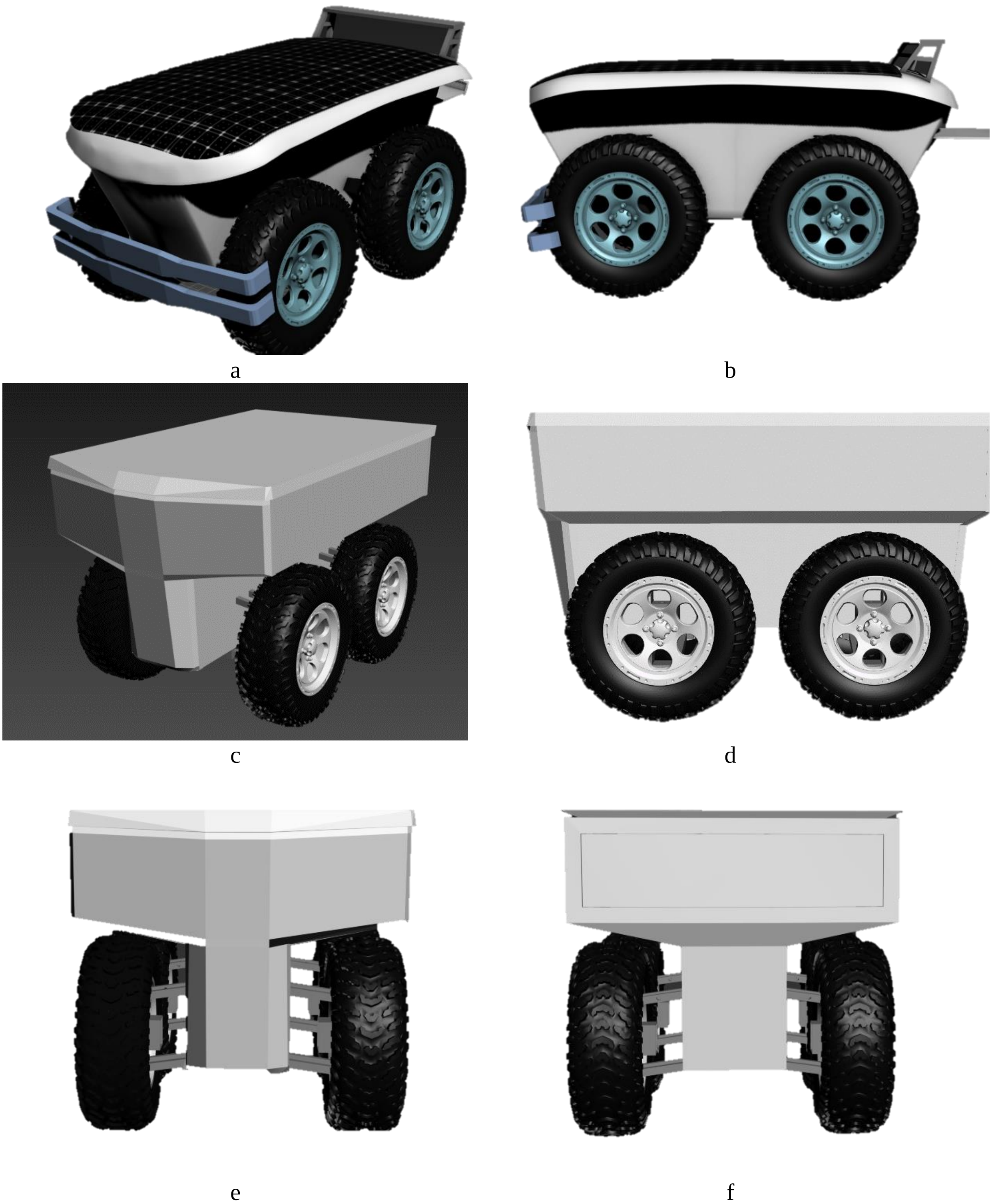



**Figure 1. Design models for the first version of VineScout I (VS-1).**

Deployment of the first prototype

The first prototype VineScout I, VS-1, arrived in Valencia (Spain) on 21 August 2017. Figures 2-a and 2-c show the frontal view of the robot, whereas Figure 2-b provides the side view of the prototype. The robot's steering capacity and suspension system for the front axle is given in Figure 2-d. The interior chamber where all the electronics will be installed is shown in Figure 2-e. Finally, Figure 2-f depicts the operating controls of the robot.


**Figure 2. Deployment of the first version of VineScout 1: VS-1**

<u>Limitations and amendments to the first prototype</u>

The prototype VS-1 could not be tested over the first Steering Week (SW1) due to the short period of time between robot delivery (21 August) and SW-1 organization (28-31 August), taking into account, in addition, that UPV campus is closed for vacation the entire month of August. Nevertheless, the robot was tested upon delivery by UPV, and the following facts were observed:

1- Due to the reduction of weight because of changing lead batteries by lithium batteries, the suspension system was too stiff to absorb terrain irregularities.
2- The turning capacity of the robot was not enough for making 180-degree turns with agility at the headlands in vineyards spaced 1.8 m - 2.0 m.
3- A more compact design will be beneficial for navigation, energy saving, and commercial success.

UPV made some mechanical modifications as the new suggestions need to be confirmed. After carrying out multiple tests it was observed that the robot needed more angle of the wheels to be able to turn properly. For this reason, the optimization of the geometry of the robot steering is necessary, extending the maximum angle of the wheels. All modifications already made in VS-1 are listed below:

- Steering rods were shortened from 200 mm to 190 mm.
- Distance between holes in the rack (supports of the steering rods) was modified from 200 mm to 233 mm.
- The useful rack length used goes from 110 mm to 160 mm.
- The rack was advanced 15 mm.
- The position of the steering potentiometer was modified due to the geometric change of the system.
- It was detected that one of the straps of the steering was not symmetrical to the other (angular deviation of 0.5 ° and displacement of 7 mm). The strap has been modified, being now symmetric.
- It was necessary to improve the transmission system of the new robot, from a direct motor-wheel connection to a bearing-plate assembly to avoid overloading the motor shaft. It was proved (in previous versions) that this system is robust and durable.
- As previous batteries were replaced by WALL for lighter ones, new springs needed to be mounted for increasing shock absorption and higher stability.
- A modification of the steering system was also done to avoid excessive slack and noise, including self-lubricated guiding, which provides softness and durability. Also, tougher end-of-stroke sensors were added.
- New powerful fans were installed to improve ventilation flow in the computer case and extract hot air.

Based upon the above observations, the following amendments are proposed to be incorporated in the second prototype VineScout 2, VS-2:

1- A more compact design, such as the concept given in Figure 3.
2- A softer spring for each suspension component (one per wheel), according to the specifications of table 3.
3- A longer rack to increase turning radius, with an underlying sliding bar that makes its movements smoother. The new gear rack is shown in Figure 4.

**Table 3. Specifications of proposed suspension springs**

| Technical data | |
|---|---|
| **VineScout 1 (VS-1)** | **VineScout 2 (VS-2)** |
| 170 x 50 x 11.5 x 6.00 | 170 x 50 x 12 x 5.50 |
| C = 1,616 kg x mm | C = 1 kg x mm |

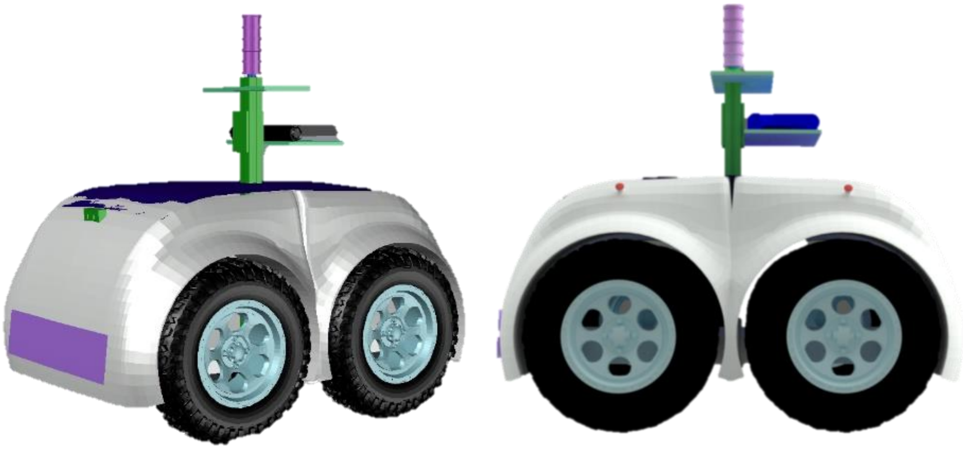


**Figure 3. Compact design for VS-2**

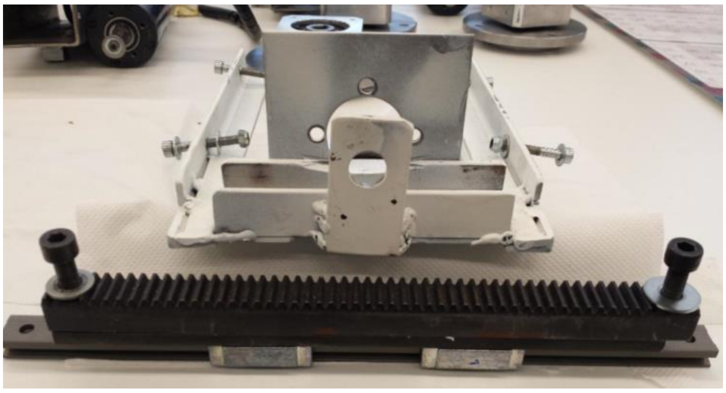


**Figure 4. Steering modifications to increase turning abilities of VineScout prototypes**

## 1.2.2 Work package 2: Industrialization of internal electronics

The leader of WP2 is SUN, who is in charge of the internal electronics of the robot, and has the higher workload in this WP as seen on table 4. The main objective for WP2 is to design, fabricate, install, and test the complete electronics network for each of the three robots deployed

**Table 4. Highlights and person-month for WP2 in VineScout EU project**

| Work package number | WP2 | Start Date or Starting Event | | Month 1 | |
|---|---|---|---|---|---|
| Work package title | Industrialization of internal electronics | | | | |
| Participant number | 1 | 2 | 3 | 4 | 5 |
| Short name of participant | UPV | WALL | SUN | UDLR | SYM |
| Person/months per participant: | 6 | 6 | 16 | 0 | 0 |

Tasks on electronics were stated from the beginning of the project (table 5). UPV, based on the experience from the previous EU project, VineRobot, proposed some necessities for the VineScout platform. In the same way, SUN used their knowledge from their active EU project Tulipp (Gran Agreement number: 688403) to build the processor for VS-1, and continue upgrading it for the next version, VS-2, in VineScout. Table 5 shows that the first version of the board was due in month 10 with the deliverable D2.1.

**Table 5. Activities planned for WP2 in VineScout EU project**

| | 2016 Dec 1 | 2017 Jan 2 | Feb 3 | Mar 4 | Apr 5 | May 6 | June 7 | July 8 | Aug 9 | Sep 10 | Oct 11 | Nov 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WP2- Industrialization of electronics** | | | | | | | | | | D | | |
| T2.1 Electrical analys & modific prot VS-1 | | | | | | | | | | | | |
| T2.2 Upgrade electronic system prot VS-2 | | | | | | | | | | | | |
| T2.3 Commercially oriented modul design | | | | | | | | | | | | |

**Summary of work for WP2** (Lead partner: SUN)

- **T2.1 – Electrical analysis and proposed amendments for prototype VS-1** *(M1-M10)* Task 2.1 is the counterpart of Task 1.1 for the robot's electronics. Likewise, its goal is to carry out a detailed analysis of all the circuitry and processing boards already mounted on the initial prototype with the purpose of detecting important weaknesses. The following analysis was carried out by SUN assisted by UPV:

  - Power consumption of every component and appropriateness of its inclusion in the 12 or 24-Volt battery packs.
  - Computer performance, runtime saturation, and potential for re-designing threads.
  - Wiring optimization for the robot's available space. Safety-based cable reduction and reinforcement.
  - Upgraded environmental protection of electronics, especially for temperature, moisture, and dust.
  - Replacement of low-cost components (sensors, Arduino boards, etc.) for industrial-based solutions.
  - Selection of cost-efficient touchscreen monitor with the required IP protection.

  A new system architecture was outlined by SUN, constructed, and reported on deliverable D2.1.

- **T2.2 – Upgrade of electronic system for prototype VS-2** *(M12-M22)* This task is the natural continuation of Task 2.1. The field experience accumulated along the first steering week SW1 revealed the further steps to enhance reliability and performance. Important issues to deal with are the robust design of electronics to favour outdoors performance for long periods of time and battery saving mechanisms. These improvements are already proposed and will be implemented by SUN for the second prototype VS-2 (planned for February 2018, month 15), and field-tested along the second steering week SW2 (scheduled for M22).

**Development of the work for WP2**

- **Related information: D2.1-a, SUN monthly report, UPV monthly report**

The VineScout robot is the next generation of farming robots and it is being designed for providing high flexibility enabling users to decide what sensors to use. The robot will be equipped with a wide range of sensors and actuators; some of the sensors and all the actuators will be used for navigation and are considered critical, while the remaining sensors will be used for collecting data used for inferring the evolution of the crop (e.g. water stress, diseases propagation and quality of plants).

UPV provided SUN an electrical schematic of an optimized version of the previous robot (VineRobot) from which VineScout was going to start building. Then, SUN, made its improvement version.

Figure 5 shows the VineScout robot sensors schematic. In the Figure, the "?" sign is used because the consortium is still deciding if those sensors and actuators (namely, the LIDAR sensor, the rear potentiometers and the rear emergency stop bumpers) will be required. Nevertheless, the computing system should provide the required flexibility for installing such devices and actuators if required.

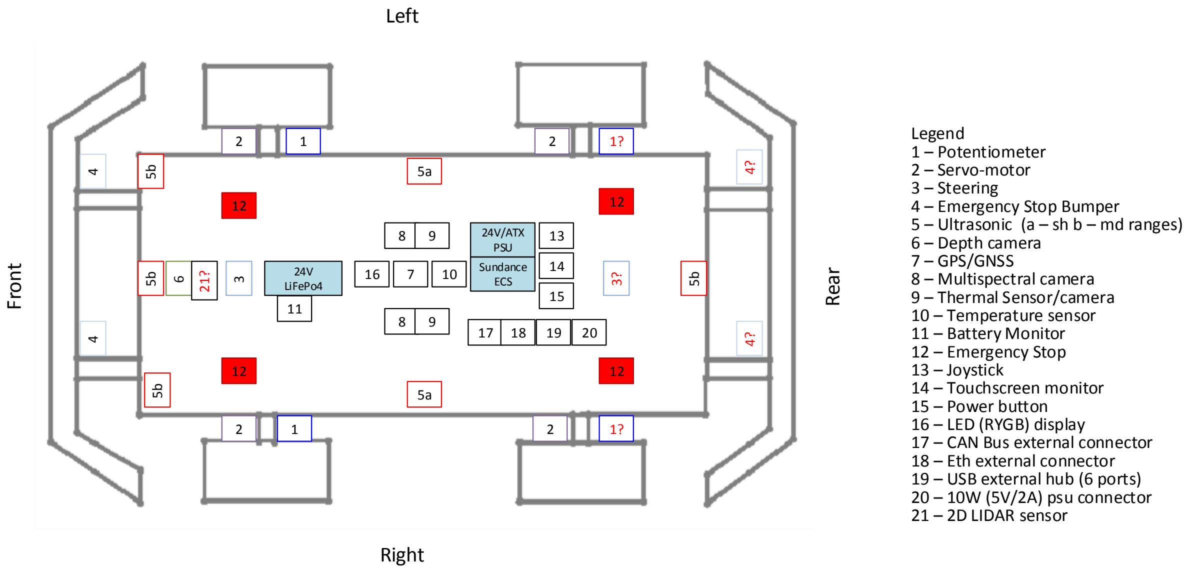



**Figure 5. VineScout robot sensors map.**

Power consumption is a major concern of the VineScout project's consortium as we aim to deliver a robot solution with an autonomy of *at least* 6 hours of continuous working. The 6 hours reference is used because that is the average time that a farmer uses a tractor without having to stop for refuelling the tractor. Table 6 lists the sensors, and actuators and its power consumption, assuming the worst-case scenario (when all the parts are draining 100% of the required power). In this case (worst-case scenario), the robot will drain 1952 W (including the motor drivers' maximum ratings and excluding the motor power consumption), but this is not realistic. Sensors and actuators only drain 100% of its full power consumption during the transactional state (e.g. an engine will drain 100% of its power consumption when in the transitional regime, when is starting, and then lowers the power consumption to 60%-50% of the initial power when it reaches the steady state). A much more realistic power consumption is considering the motors working at the steady state. Therefore, it is assumed that VineScout robot power consumption is 272 Wh. In that case, the robot power consumption will be 1,632 W for 6 h of continuous work. The actual design includes a solar panel capable to generate 60Wh which will generate approximately 300 W (assuming an efficiency of 80%) in 6 h of continuous working, representing 18% of the overall VineScout robot power consumption during the 6h of continuous working.

**Figure 6. Sensors and actuators (web-linked), and its power consumption**

| Device | Active mode |
|---|---|
| MB7139-200 XL- TrashSonar-WR ultrasonic sensors | 9.99mW×6 sensors=59.4mW |
| Zed Stereo camera | 1.9 W |
| National Instruments Touchscreen TSM-1015 | 96 W |

| | |
|---|---|
| Apogee SD-431 | 0.312 W |
| FLIR camera AX-8 | 3.1 W |
| 8-Channel 5V Relay module | 0.16 W |
| Sabertooth dual 12A motor driver | 576 W (maximum power) |
| Sabertooth dual 25A motor driver | 1200 W (maximum power) |
| SXBlue L1/L2 GNSS | 5 W |
| Power supply 24V to ATX DCX6-360 (360W) | 5.28 W |
| VineScout Embedded Computer System | 10 W |
| 12V@90W Solar Panel | No efficiency details available |
| Emergency push buttons | 3.6 W×4 buttons=14.4 W |
| Joystick | No power consumption available |
| LED (RYGB) display | 44.64 W |
| Emergency Stop Bumpers | N/A |
| 2D LiDAR Sensor OMD8000-R2100-B16-2V15 | 2.88 W |

First prototype of the Embedded Computer System (ECS): VS-1 ECS

The first prototype of the VineScout Embedded Computer System (ECS), VS-1 ECS, commercially called EMC2-ZU3EG (Figure 7), was designed, assembled, and tested by SUN.

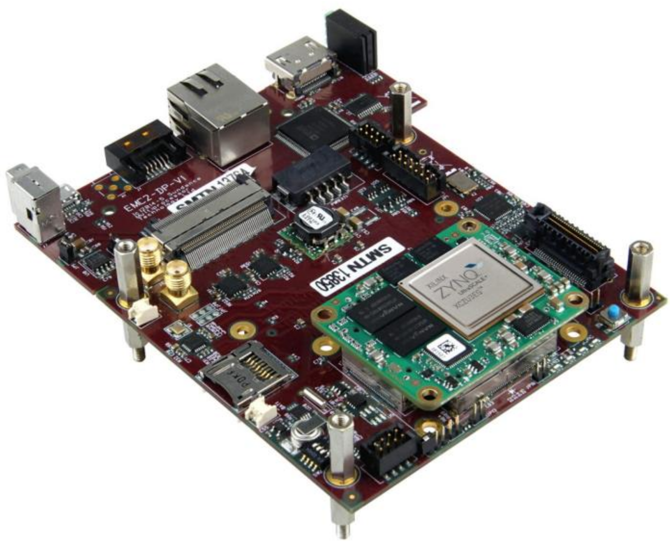


**Figure 7. First prototype of the Embedded Computer System for VineScout first prototype**

The EMC2-ZU3EG comes equipped with a powerful Xilinx Ultrascale+ Zynq MPSoC ZU3EG device (Figure 8) as the main processing unit. The Xilinx Ultrascale+ Zynq which MPSoC devices provide 64-bit processor scalability while combining real-time control with soft and hard engines for graphics, video, waveform, and packet processing. Such devices where built on a common real-time processor and programmable logic equipped platform. The EG comes with a quad application processor GPU and was specially designed for excelling the next generation wired and 5G Wireless infrastructure, cloud computing, and Aerospace and Defence Applications[1].

[1] Retrieved from https://www.xilinx.com/products/silicon-devices/soc/zynq-ultrascale-mpsoc.html on the 23/12/2017

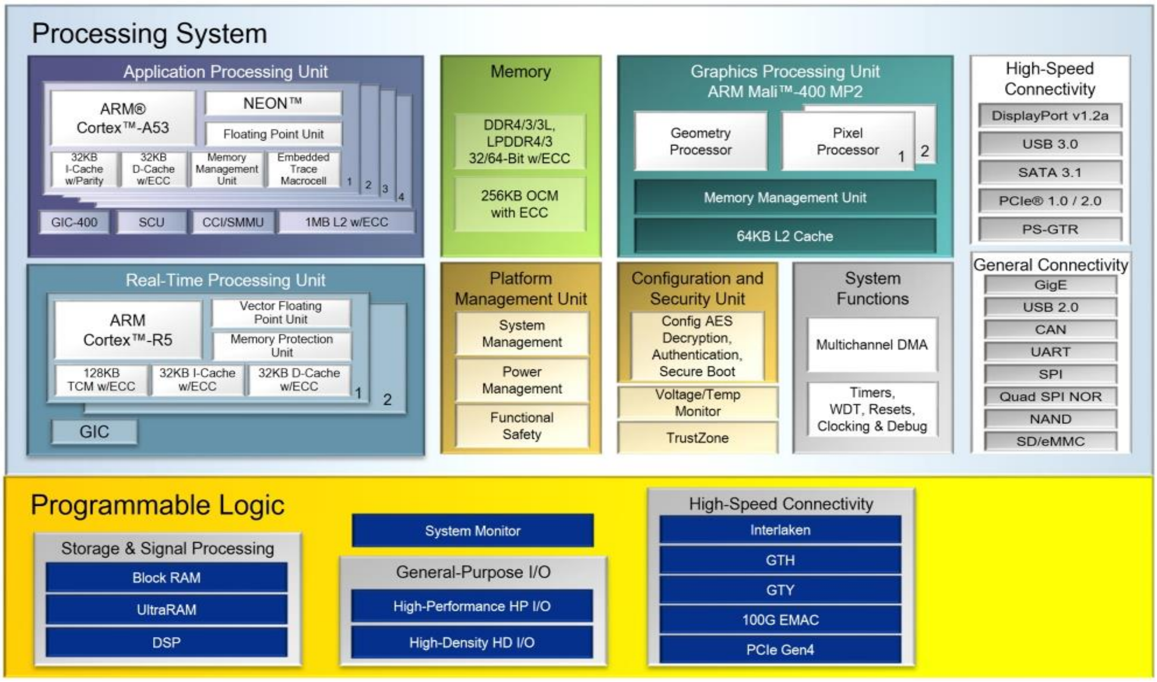



**Figure 8. Main processing unit of VS-1 ECS**

VS-1 ECS is composed of three boards and comes equipped with a Xilinx Zynq Ultrascale ZU3EG MPSoC device. The VS-1 Embedded Computing System (ECS) is solution composed of the following 3 boards:

1. Trenz TEO820 4x5 module (Figure 9) - The Trenz Electronic TE0820-02-03EG-1EA is an industrial-grade MPSoC module integrating a Xilinx Zynq UltraScale+, 1 GByte DDR4 SDRAM with 32-Bit width,128 MByte Flash memory for configuration and operation, and powerful switch-mode power supplies for all on-board voltages.
2. Sundance EMC$^2$ – DP (Figure 10) - The EMC²-SoM is a PCIe/104 OneBank™ Carrier for a Trenz compatible FPGA and SoC Module and has expansion for a VITA57.1 FMC™ LPC I/O board. It also has I/O pins, using a 100-way Samtec RazorBeam connectors system;
3. Sundance Expansion Interface Connector (SEIC) – a customised board for individual applications and bespoke connectors which connects to the EMC$^2$-DP via a 100-way Samtec RazorBeam connector.

This Platform was developed by Sundance for previous projects so was (is) well supported with connectivity to standard interfaces, like USB, HDMI and Ethernet on the ARM CPU Processing System (PS) of the Zynq SoC (System on a chip) and had flexibility to interface to specific vision interfaces(such as HMDI, CameraLink, etc) on the Zynq's FPGA side Programmable Logic (PL) The expansion boards are four-layer PCB, and are how the Consortium has customized it for VineScout application. The FMC-LPC connector enables to plug-n-play FMC-LPC daughter cards (e.g. ultra-high speed/resolution cameras) following the VITA 57.1 standard. All the features and standard interfaces in VS-1 ECS provide flexibility for designing a highly flexible software platform for making VineScout robot highly compatible in case of a future interaction with other robots running with Robotic Operating System (ROS) on the top of a standard Linux distribution.

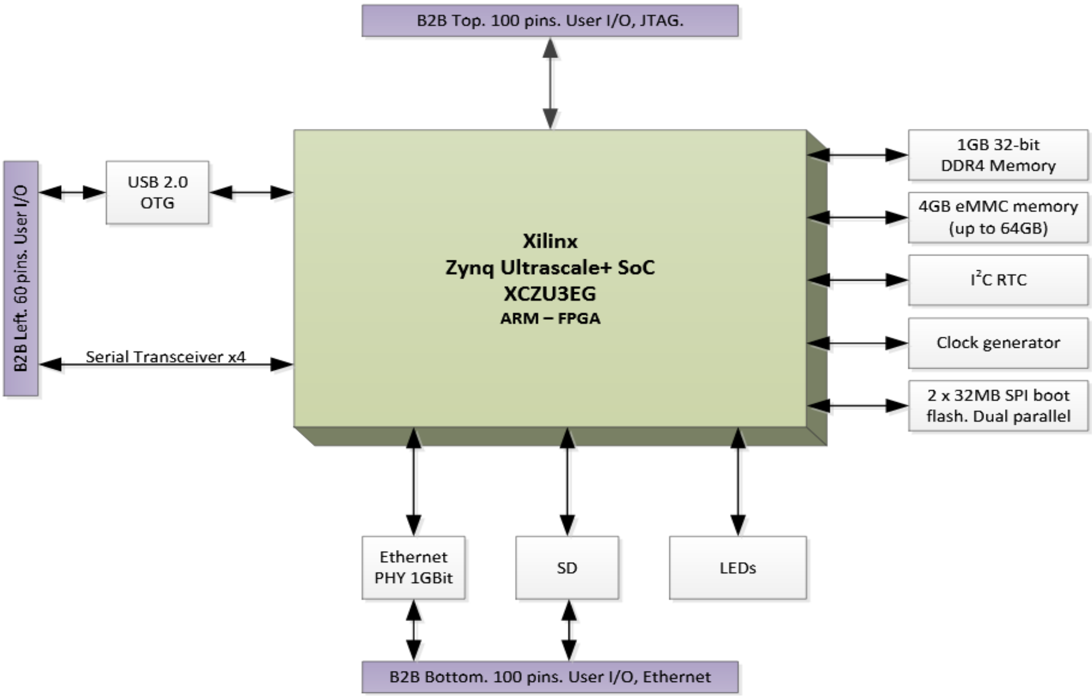



**Figure 9. TEO820-ZU4EG block diagram**

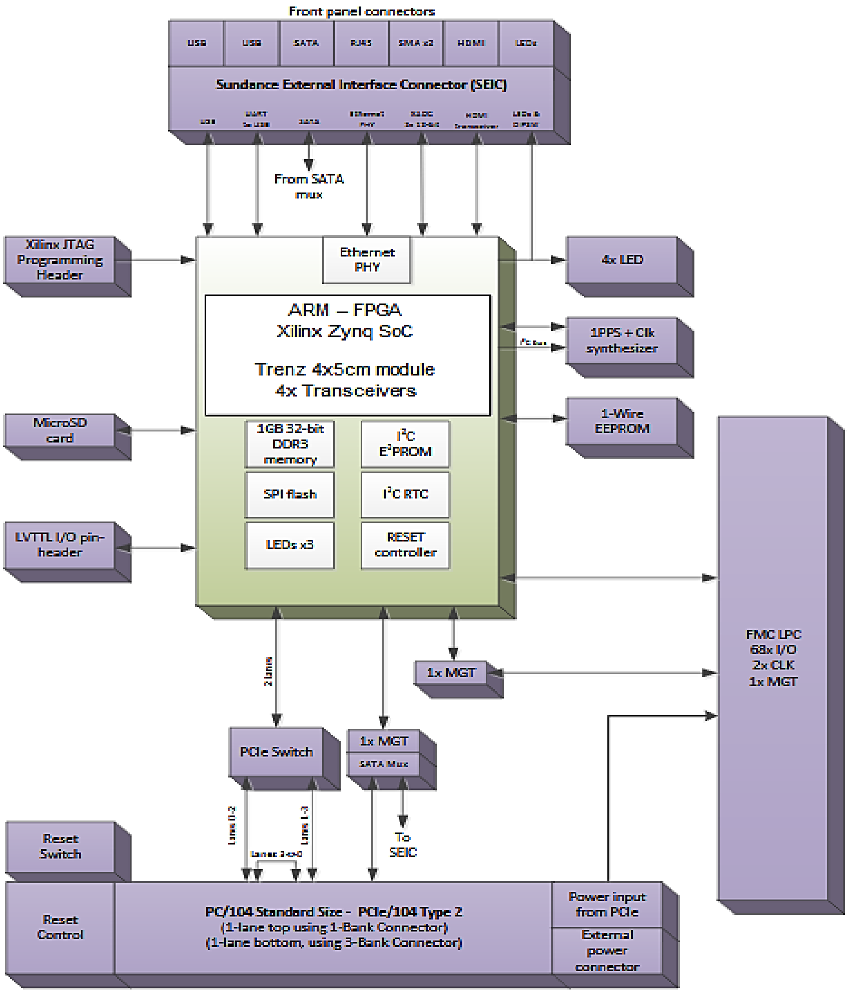



**Figure 10. Sundance EMC2-DP block diagram**

Work done and future work

The first months of the project were used for capturing and analysing the requirements and restrictions of the prototype, and for testing the first version of the VineScout robot. The results obtained from the field tests helped SUN in designing VS-1 ECS. The Xilinx Ultrascale Zynq ZU4EV, which is an optimised version of Xilinx Zynq Ultrascale ZU4EG MPSoC is prepared for VS-2 ECS (planned released in the following integration week in February 2018). VS-2 ECS is being designed for making the VineScout robot easy-to-use, highly compatible with other robotics and autonomous systems, reliable, safe and easy to integrate with other robots. VineScout robot is being designed to work side-by-side with humans and robots, but always under humans' supervision.

### 1.2.3 Work package 3: Support knowledge of maps and sensing capabilities

Table 6 contains the summary of work distribution for WP3, where the partner UDLR is the leader. The objective of WP3 is centered on enhancing the informative value embodied in the nitrogen and temperature maps. The expected outcome will be the combination of the different maps, presented in such a way that end-users can make advantageous management decisions with them, and that the data-based resulting wine is actually complying with the optimal requirements set by the end-users.

**Table 6. Highlights and person-month for Work Package 3 in VineScout EU project**

| | | | | | |
|---|---|---|---|---|---|
| **Work package number** | **WP3** | **Start Date or Starting Event** | | Month 1 | |
| **Work package title** | **Support knowledge of maps and sensing capabilities** | | | | |
| **Participant number** | 1 | 2 | 3 | 4 | 5 |
| **Short name of participant** | UPV | WALL | SUN | **UDLR** | SYM |
| **Person/months per participant:** | 12 | 0 | 0 | **24** | 9 |

Table 7 highlights that the work related to the first task of the work package, this is, the design and implementation of field maps, is a continuous work starting from month 1 in the project.

**Table 7. Activities planned for Work Package 3 in VineScout EU project**

| | 2016 Dec 1 | 2017 Jan 2 | Feb 3 | Mar 4 | Apr 5 | May 6 | June 7 | July 8 | Aug 9 | Sep 10 | Oct 11 | Nov 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WP3- Support knowled. maps & sensing** | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| T3.1 Design and implementat field maps | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| T3.2 Decision supp:def of operat maps | | | | | | | | | | | | |

**Summary of work for WP3** (Lead partner: UDLR)

- **T3.1 – Design and implementation of basic field maps** *(M1 - M25)*. The first data gathering tests were organized by UDLR, in a commercial vineyard of La Rioja, the famous region where there is a high concentration of wineries producing *Rioja* wine. The tests were still without the integration of crop sensors in the robot until confirming that the sensors would be useful. During these tests, UDLR tried three different sensors, two of them with the purpose of taking data of nitrogen from the canopy, and another sensor to measure temperature from the canopy. The nitrogen will be useful to get either any spectral vegetation index maps, such as NDVI (Normalized Difference Vegetation Index) maps, or chlorophyll maps, used by winegrowers to get a fertilization plan. For those purposes, a multisensor imager that allows taking data from four different spectral bands was tested, and, also, a hyperspectral camera that allows taking data from many different spectral bands.

Afterwards, during the First Steering Week, the multisensor imager was integrated in the robot, so some field tests were carried out, as well.

**Development of the work for WP3**

- **Related information: UDLR monthly report, UPV internal notes**

Tests with multisensor imager Parrot camera

All the data acquired during the 2017 campaign's experiments were from a commercial vineyard located in Tudelilla, La Rioja, Spain (Lat. 42°180' 18.26'', Long.-2°7' 14.15'', Alt. 515 m) throughout six weeks from early-July to early-August, 2017. The vineyard was planted in 2002 with grapevines of (Vitis vinifera L.) Tempranillo (Clone 776), grafted on rootstock R-110. The vines were trained to a vertically shoot-positioned trellis system on a double-cordon Royat. Vine spacing was 2.60 m between rows and 1.20 m within the row in a north-south orientation.

In order to induce an ample variability of grapevine water status, a completely randomized block design (Hinkelmann and Kempthorne, 2007[2]) with four blocks and three different water treatments was set (Figure 11). The three treatments were:

- T0: Full irrigation. Two water pipelines irrigating 6 L h -1 were installed.
- T1: Moderate irrigation. A single water pipeline irrigating half the amount in T0 was installed.
- T2: No irrigation. The plants were not irrigated during the whole experiment.

Each treatment involved four replications (one per block), therefore 12 different combinations of treatment and replication were present in the vineyard and located in three different parallel, equally-distanced vine rows. For each replication, comprising 25 plants (around 25 m of length), only the 15 middle ones were the ones in which the measurements were taken. The first and last groups of five plants were discarded to avoid edge effect (Figure 11).


**Figure 11. Experimental layout following a completely randomized block design with four blocks and three irrigation treatments (T0: full irrigation, T1: moderate irrigation, T2: no irrigation)**

[2] Hinkelmann, K. and Kempthorne, O. 2007. Design and Analysis of Experiments, Volume 1, Introduction to Experimental Design, 2nd Edition. Wiley.

Assessment of grapevine canopy vigor and nutritional status

On-the-go multispectral imaging and temperature measurements were conducted on six different dates: 12 July, 18 July, 25 July, 1 August, 7 August and 16August, during summer 2017.

Multispectral images were acquired under field conditions using the multisensor imager Parrot Sequoia (Parrot Drones SAS, Paris, France, Figure 12) working in four separated synchronized bands with 1.2 Mpx monochrome sensors; 550 nm (Green), 660 nm (Red), 735 nm (Red Edge) and 790 nm (Near infrared). The Parrot Sequoia sensor incorporates a 16 MPx RGB sensor and a GPS/GNSS to locate the camera images. The camera was placed targeting the canopy on the left side (respect to the driving direction) at a distance from the canopy of approximately 0.47 meters, and with a horizontal and vertical field of views (FOV) of 61.9 degrees by 48.5 degrees, respectively. Acquisition of the multispectral images, at one frame per second (FPS) was performed on the east side of the canopy at an average speed of 5 km/h at solar noon (between 2 pm and 3 pm, local time).

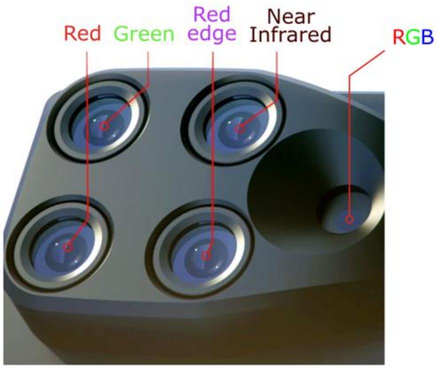



**Figure 12. Parrot Sequoia multispectral sensor with 4 separate bands and a RGB sensor (credit to Parrot website [www.parrot.com](www.parrot.com)).**

The Parrot Sequoia camera is used to get NDVI (Normalized Difference Vegetation Index) maps. The computation of the NDVI needed a complex processing (Figure 13).

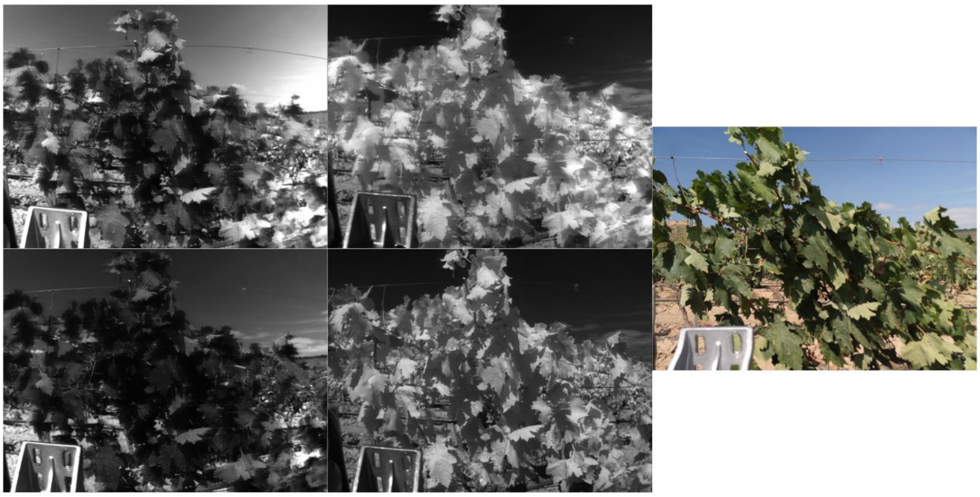


**Figure 13. On-the-go acquisition of a Sequoia's measurement. Four spectral channels and one RBG image are taken per measurement. NDVI must be computed from two of these channels**

As the camera is a drone-oriented device, its use in a land vehicle needed some adjustments. The use of this multispectral camera on a lateral view encounters a drastic change in the target objective (~ 0.5 m, parallax error) vs. aerial acquisition (20-30 m), so a considerable misalignment appears (Figure 14) in the four different spectral channels (specifically, in the two wavelengths involved in the NDVI calculation).

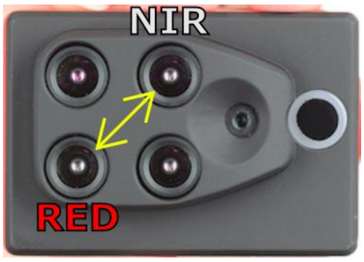



**Figure 14. Misalignment between lens in the Parrot Sequoia camera**

To minimize the impact of this issue rapidly, it is assumed that, as there is a constant distance between the camera and the target, the offset presented between NIR and RED images is also constant. Thus, an algorithm programmed in Python was developed for the correction of this misalignment (by an automatic alignment according to the fixed offset). The NDVI is calculated as equation 1 indicates:

$$NDVI = \frac{NIR-Red}{NIR+Red}$$ **Equation 1**

Assessment of grapevine water status by infrared radiometry

The surface canopy temperature measurements were carried out with an infrared radiometer sensor SI-421 (Apogee instrument Inc., Utah, USA; Figure 15). The SI-421 was targeted to the left at a distance from the canopy just below of the Parrot Sequoia. Collection of the temperature measurements at 0.67 frames per seconds (FPS) was performed also in the east side of the canopy.

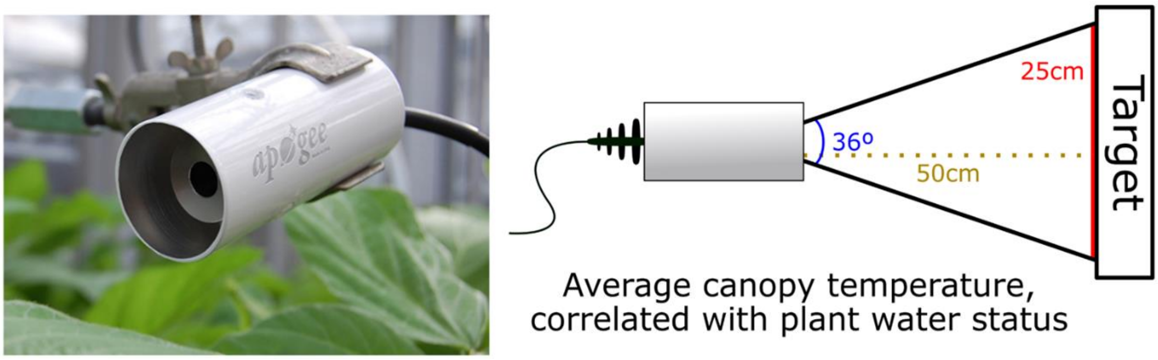



**Figure 15. Infrared radiometer sensor SI-421 and optical geometry scheme (credit to Apogee website www.apogeeinstruments.com)**

To develop different canopy temperature indices, lower and upper boundary temperatures ($T_{wet}$ and $T_{dry}$, respectively) were acquired using an *evaposensor* (Skye Instruments, Llandrindod Wells, UK) having two artificial leaves: a dry leave (dry reference) and another one covered with a black cotton wick and receiving continuous water absorption for the wet reference. Reference temperatures were acquired once per each measurement day. Additionally, two thermal indices — crop water stress index

(CWSI; Jones, 1992[3]) and conductance index (Ig; Jones, 1999[4]) — were calculated. Midday stem water potential ($\psi_{stem}$) was used as reference indicators of the plant water status and their measurements were taken near solar noon (Figure 16). A random vine was selected from each group of five plants (of the fifteen middle ones in each replication) and its $\psi_{stem}$ was measured upon a leaf taken from the central part of the canopy. A Scholander pressure bomb (Model 600, PMS, Instruments Co., Albany, USA) was used for the stem water potential determination. The selected leaves were covered with aluminum foil bags to drive them into dark adaptation one hour before the measurements. A total of 36 measurements of the plant water status were performed per day (twelve different replications and three selected plants per block).

**Figure 16. Measurement of plant water status reference indicators ($\psi_{stem}$)**

The data acquired were filtered and processed. The statistical summary of the water status reference parameter (stem water potential, $\Psi_{stem}$) is shown in Table 8Table 8. Statistical summary of the vineyard water status, using stem water potential as reference parameter (mean, minimum, maximum and standard deviations are expressed in MPa).

**Table 8. Statistical summary of the vineyard water status, using stem water potential as reference parameter (mean, minimum, maximum and standard deviations are expressed in MPa)**

| Number of samples | Mean | Minimum | Maximum | Standard deviation |
|---|---|---|---|---|
| **251** | -1.33 | -1.95 | -0.50 | 0.293 |
| | | | | |

All the measurements acquired with both devices (Apogee IR sensor and Parrot Sequoia) were georeferenced using a GPS receiver Ag Leader GPS 6500 with RTK correction at a frequency of 20 Hz (Figure 17).

[3] Jones, H.G. 1992. Plants and Microclimate, 2nd ed. Cambridge University Press,Cambridge, pp. 428
[4] Jones, H.G. 1999. Use of infrared thermometry for estimation of stomatal conductance as a possible aid to irrigation scheduling. Agric. Forest Meteorol. 95,139–149

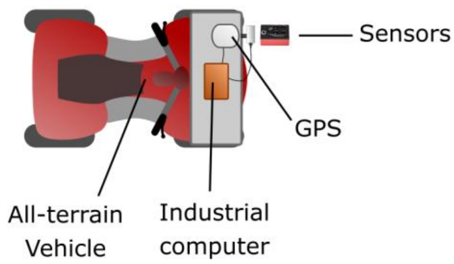



**Figure 17 – Schematic of the on-the-go measurements**

Both Apogee's and GPS' information was synchronized by time, so each measurement had linked a timestamp, and with it an offline match between GPS position and sensor acquisition could be performed. The recording of Apogee's thermometric information was carried out using an Arduino Mega 2560 connected to an industrial computer, and the data strings transmitted by Serial Port were received using ExtraPuTTY 0.29, with the timestamp added. Knowing the syntax of Apogee's output, an algorithm was developed in Python to extract all the temperatures given by the sensor within each one of the treatment blocks in the experimental vineyard. This information was prepared for its future spatial representation in variability maps.

Results from the study of the camera and the infrared radiometer

Correlation analyses between the canopy temperature values recorded by the infrared sensor and the reference indicator ($\Psi_{stem}$) were not conclusive, as the obtained determination coefficients $R^2$ did not surpassed the 0.50 mark. Similar findings were observed for the determination of spectral indices (such as the NDVI), responsive to differences in Nitrogen in the canopy vegetation.

Further steps remain to be undertaken in order to deep into the best configuration and methodology of both devices for the on-the-go prediction of key plant traits. Several problems from the Parrot Sequoia that appeared during the performance of the experiments were analyzed. The main problem was evidenced by the difficulties in the deployment of the multisensor imager for real scenarios when considering its attachment to the VineScout's prototype robot. The connection to the camera is only available via WiFi (an undesirable connection interface due to an unacceptable instability for end-users), and the camera's automatic management is virtually impossible. All this, jointly with the alignment issues, suggested that this specific device would not fit into the final VineScout robot. Because of this, further research on wavelengths selection for the development of ad-hoc sensors (using hyperspectral imaging) arises. Thus, there is a necessity to find new ways to determine spectral bands that are more informative and relevant to the evaluation of nutritional status in leaves of grapevine, in order to build or choose an alternative multispectral sensor. For this reason, new data has been acquired to explore the possibility to incorporate an innovative technology like hyperspectral imaging to identify the nutritional composition, such as nitrogen and chlorophyll levels in leaves.

Hyperspectral imaging technology

The objective of this study was the use of hyperspectral imaging to identify the key and more informative spectral bands and indices about the nutritional status of the grapevine, with an especial focus on nitrogen estimation and concentration of chlorophyll.

A total of two-hundred samples were collected at harvest time from five varieties (*Grenache noir*, *Grenache blanc*, *Malbec*, *Mission* and *Verdejo*) from the Institute of Grapevine and Wine Sciences grapevine variety collection (Figure 18; table 9).

**Table 9. Number of samples collected from 5 varieties on 26 October 2017 from the Institute of Grapevine and Wine Sciences grapevine variety collection**

| Varieties | Nº Samples |
|---|---|
| Grenache noir | 100 |
| Grenache blanc | 25 |
| Malbec | 25 |
| Mission | 25 |
| Verdejo | 25 |

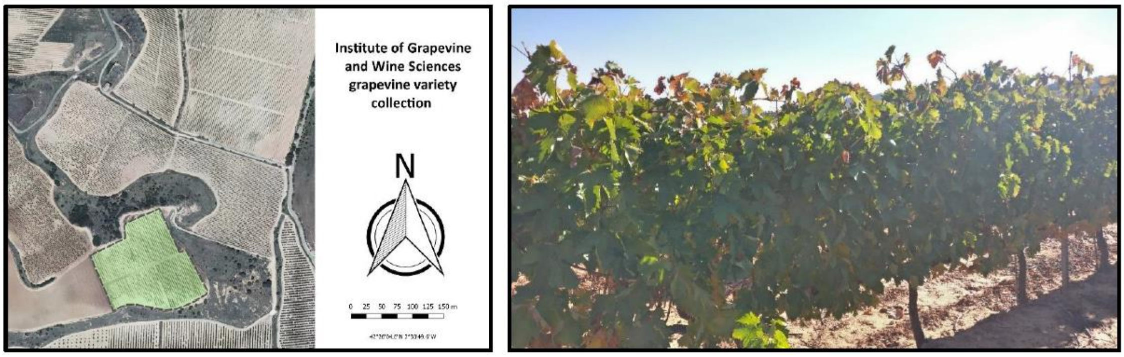



**Figure 18. Institute of Grapevine and Wine Sciences, grapevine variety collection**

For the spectral acquisition, a Hyperspectral Camera (Pika L, Resonon Inc., Bozeman, MT, USA) was used. Hyperspectral measurements were performed at 60 cm above the samples (Figure 19), under controlled illumination conditions in the laboratory. The main specifications of the spectral camera are:

- spectral range from 389 nm to 1030 nm
- spectral resolution 2.1 nm
- 281 spectral channels
- dispersion per pixel to 1.07 nm.

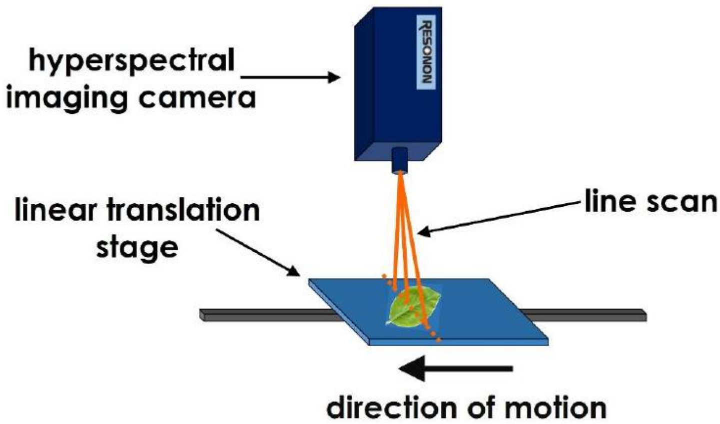



**Figure 19. Benchtop hyperspectral imaging system pushbroom line scan diagram *(credit to Resonon website www.resonon.com)***

The determination of the nutritional status of the samples, the nitrogen balance index (NBI) and the leaf chlorophyll index (Chl) were obtained using the Dualex Scientific + TM. Dualex Scientific + TM is a chlorophyll fluorescence sensor that measures flavonol, anthocyanin and chlorophyll indices. To calculate the nitrogen status, the Dualex Scientific + TM uses the nitrogen balance index (NBI), which is the ratio Chlorophyll/Flavonols (related to Nitrogen/Carbon allocation) (Figure 20). The Dualex sensor has been widely proved to successfully measure the N and chlorophyll content in leaves (Cerovic et al. 2015[5]).

**Figure 20. Dualex Scientific + TM *(credit to Force A website)***

The study was carried out on 26 October 2017. Measurements of the leaf samples were taken under laboratory conditions. For the calculation of the average nitrogen balance index (NBI) and the leaf chlorophyll index (Chl) per leaf, using the Dualex Scientific +TM, three different areas (Figure 21) of the leaves were selected and their values averaged.

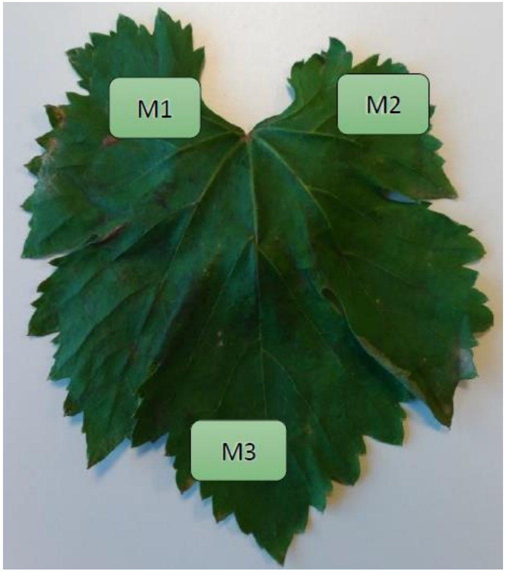



**Figure 21. Three measurements per leaf to calculate the average nitrogen balance index (NBI) and leaf chlorophyll index (Chl) with Dualex Scientific +TM**

[5] Cerovic, Z.G., Ghozlen, N.B., Milhade, C., Obert, M., Debuisson, S., Le Moigne, M. 2015. Nondestructive diagnostic test for nitrogen nutrition of grapevine (*Vitis vinifera* L.) based on Dualex leaf-clip measurements in the field. J. Agric. Food Chem., 63 (14), pp. 3669-3680

For each one of these leaves, one hyperspectral image was recorded and processed. The program used to analyse these samples was SpectrononPro 2.1. The methodology involved the identification and the delimitation of the region of interest (ROI) that corresponded to the whole leaf (Figure 22).

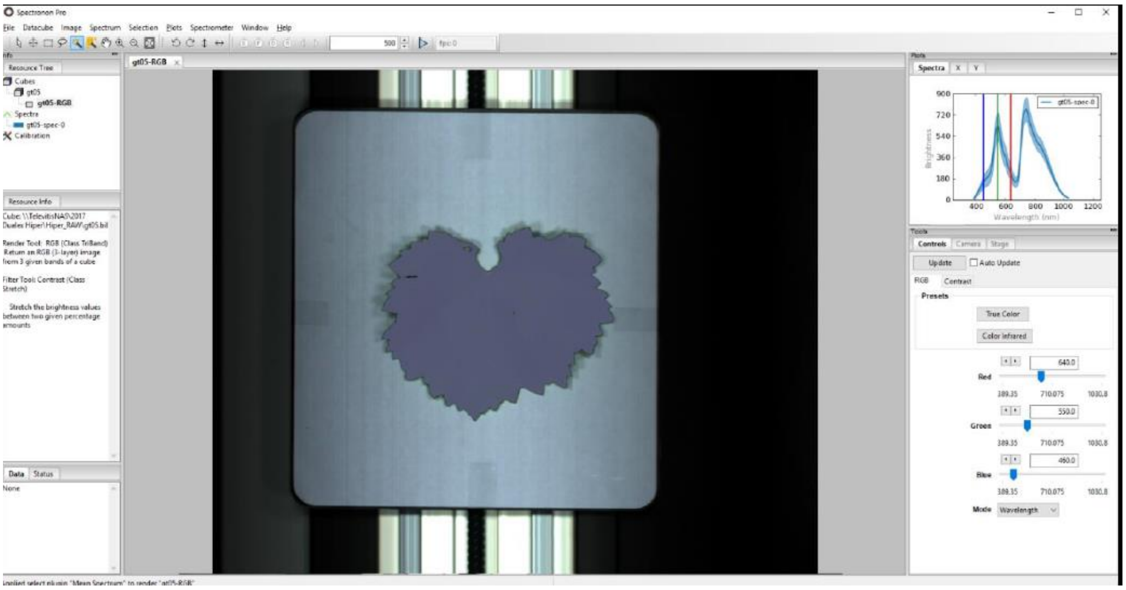
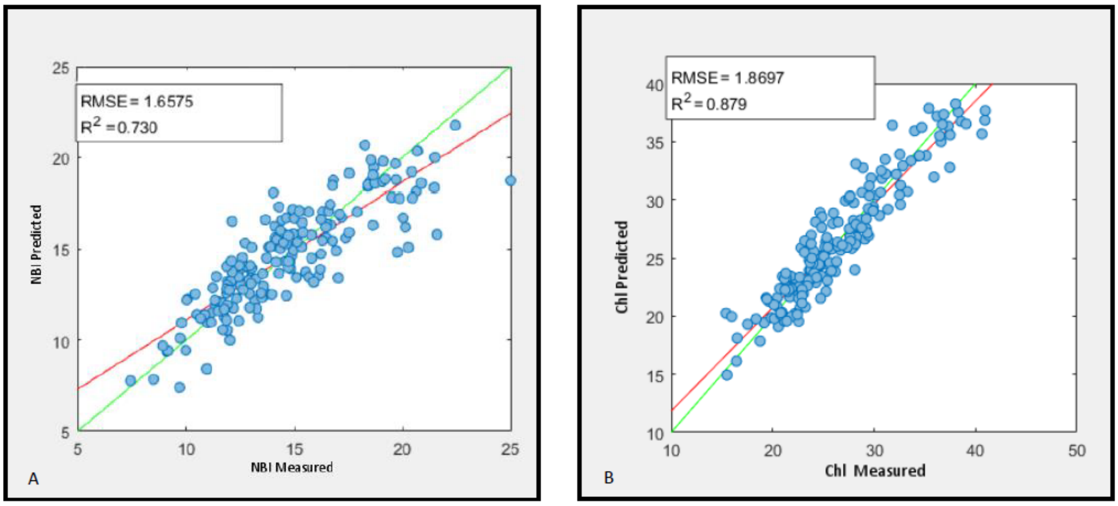


**Figure 22. Region of interest (ROI) of a leaf area using SpectrononPro 2.1**

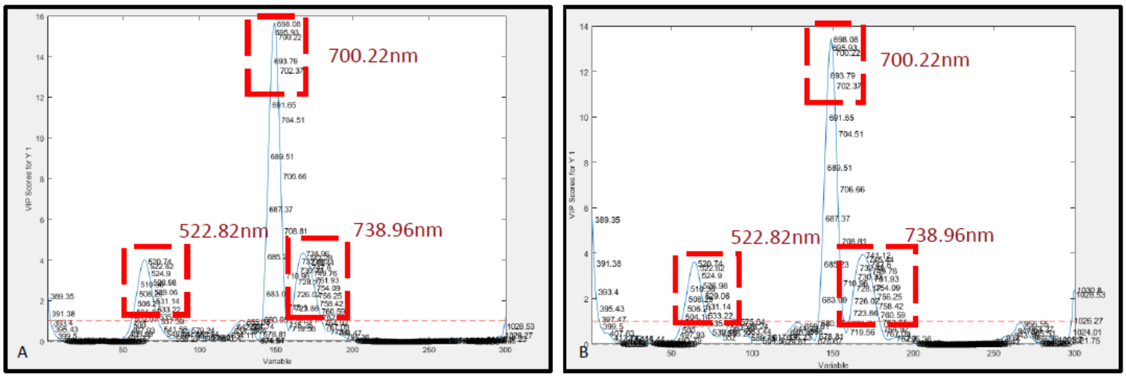
For the identification of the most indicative spectral bands, Partial Least Squares (PLS) regression was performed using the 300 spectral variables (in the wavelength region from 400 nm to 1000 nm) as input. The correlation plot from a 10-fold venetian blind cross validation is presented in Figure 23a for NBI prediction, and in Figure 23b, for Chl prediction. The results show a great level of correlation as it can be seen in both plots. Regression analyses yielded determination coefficients of $R^2 = 0.73$ for NBI (RMSE = 1.658), and $R^2 = 0.88$ for Chl (RMSE = 1.870).




a b

**Figure 23. Partial Least Squares regression for NBI (a). Partial Least Squares Regression for Chl (b).**
***Red line: regression line from the model; green line: regression line for the maximum value of correlation***

With regard to the obtained correlation, Variable Importance in Projection (VIP) scores, which estimates the importance of each variable in the model, was calculated for the two indices (NBI and Chl) to identify the most important variables in the obtained PLS models. Figure 24a presents the VIP scores for Chl while Figure 24b reports the VIP scores for NBI. For both nutritional indices, the VIP scores for the wavelenghts 522.82 nm, 700.22 nm, and 738.96 nm surpassed the value 1, indicating that these spectral bands were the most informative wavelengths to explain prediction (PLS) models.




a b

**Figure 24. VIP scores for NBI (a). VIP scores for Chl (b).**

The spectral measurements were compared with 62 vegetation indices (Rodríguez-Pérez et al. 2005[6]) to find the best correlations between the spectral variations with the nitrogen balance index (NBI) and the leaf chlorophyll index (Chl). The best correlation between the NBI and Chl indices and the spectral one was found with the family of the Vogelmann indices, for which the wavelengths used for their calculation correspond with the wavelengths selected using the VIP scores models (equation 2). Vogelmann indices are narrowband reflectance measurements that are sensitive to the combined effects of foliage chlorophyll concentration, canopy leaf area, and water content. Applications include vegetation phenology (growth) studies, precision agriculture, and vegetation productivity modelling (Vogelmann, J., B. *et al* 1993[7]). The index exhibiting the strongest correlation was the Vog1 index (equation 2), which yielded a $R^2$ value of 0.52 for NBI and a $R^2$ value of 0.80 for Chl (Table 10).

| | | |
|---|---|---|
| Vogelmann (Vog) | $Vog = \frac{R_{740}}{R_{720}}$ | Vogelmann 1993, Zarco-Tejada et al. 1999 |
| Vogelmann (Vog1) | $Vog1 = \frac{R_{734} - R_{747}}{R_{715} + R_{726}}$ | Vogelmann 1993, Zarco-Tejada et al. 1999 |
| Vogelmann (Vog2) | $Vog2 = \frac{R_{734} - R_{747}}{R_{715} + R_{720}}$ | Vogelmann 1993, Zarco-Tejada et al. 1999 |

**Equation 2**

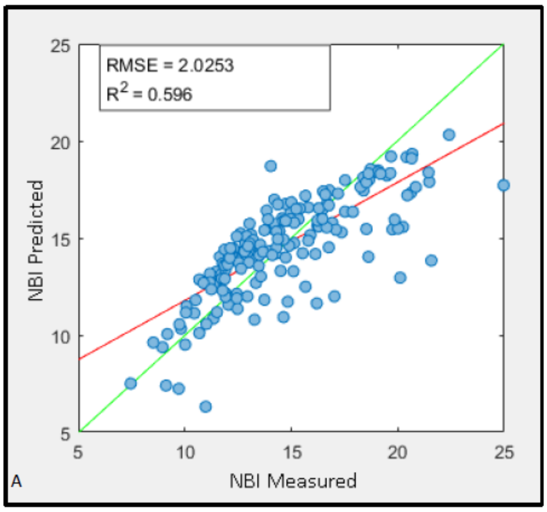
**Table 10. Values of the coefficient of determination (R2) corresponding to the correlations between the Vogelmann indices and the NBI and Chl, nutritional indices**

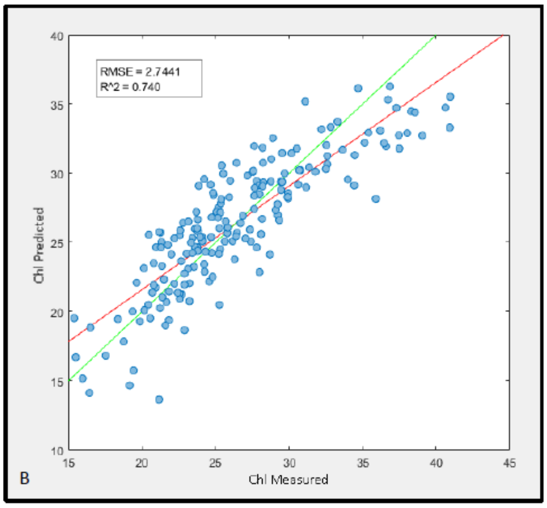
| NBI | |
|---|---|
| Index | $R^2$ |
| Vogelmann1 | 0.5247 |
| Vogelmann | 0.5221 |
| Vogelmann2 | 0.5211 |

| Chl | |
|---|---|
| Index | $R^2$ |
| Vogelmann1 | 0.7974 |
| Vogelmann2 | 0.7922 |
| Vogelmann | 0.7785 |

[6] Rodríguez-Pérez, J., Riera, N. and Traveset, A. 2005. Effect of seed passage through birds and lizards on emergence rate of Mediterranean species: differences between natural and controlled conditions. Functional Ecology, 19, pp. 699–706.
[7] Vogelmann, T.C. 1993. Plant-Tissue Optics. Annu. Rev. Plant Phys. 44, pp. 231–251.

The best wavelengths to explain models (522.82 nm, 700.22 nm and 738.96 nm) were utilized as variables in a Multiple linear regression (MLR) analysis for NBI and CHL. Figure 25a (for NBI prediction) and Figure 25b (for Chl prediction) show a large level of correlation only using these three variables. Analyses yielded determination coefficients of $R^2 = 0.6$ for NBI (RMSE = 2.025) and $R^2 = 0.74$ for Chl (RMSE = 2.744).




a b

**Figure 25. MLR for NBI with variables 522.82 nm, 700.22 nm and 738.96 nm (a). MLR for Chl with variables 522.82 nm, 700.22 nm and 738.96 nm (b).**

<u>Conclusions about the hyperspectral imaging</u>

The work regarding hyperspectral imaging performed by UDLR has shown the results of three different methods (Variable Importance in Projection (VIP) scores, study of the correlations with the main spectral Vegetation Indices, and Multiple Linear Regression analysis) to identify and evaluate the most informative and relevant spectral bands (in the range between 400 to 1000 nm) for the assessment of the nutritional status in leaves of grapevines. All three methodologies have agreed on the identification of the most relevant wavelengths: **522.82 nm, 700.22 nm and 738.96 nm**. Filters corresponding to these three wavelengths could potentially be used and assembled to manufacture a new, non-invasive, multispectral sensor to be installed in the Vinescout prototype.

<u>Map testing during the first Steering Week – SW1</u>

The Apogee sensor was integrated in the robot so that UPV could check how was the state of the mapping program that they did for VineRobot and improved for VineScout, but not yet checked in field. In August 28-29, the robot was tested in the field where the Agronomy was going to take place: the field *Coleçao de Castas* (41° 14' 41.4" N, 7° 06' 52.9" W), owned by SYM. Partners that were present were able to see how the robot displayed the path on its screen thanks to the GPS integrated (SXBlue, Montreal, Canada) as shown in the robot Graphic User Interface (GUI) of Figure 26.

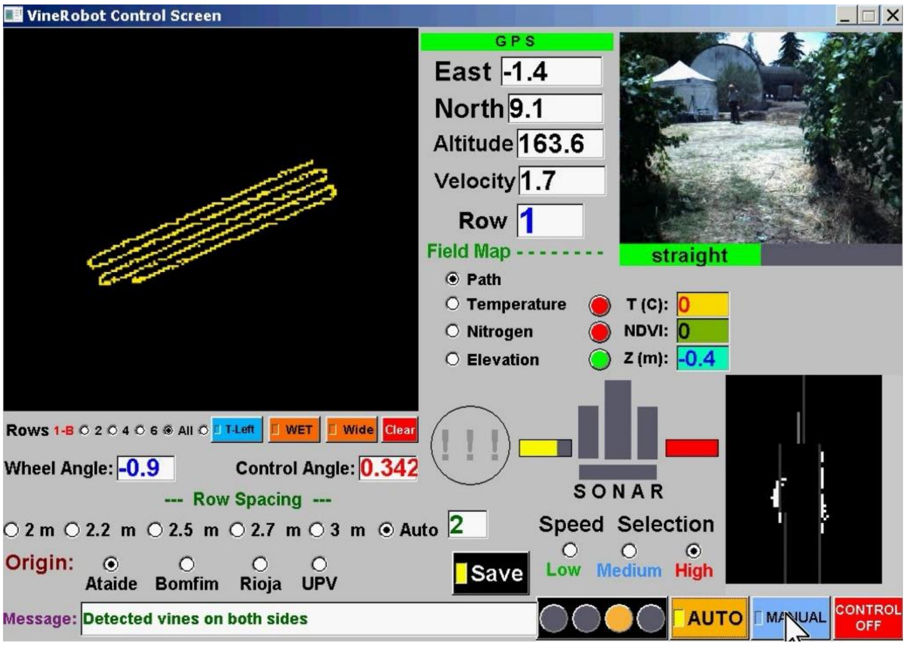



**Figure 26. Robot screen (GUI)**

After retrieving the data collected by the robot, the map of Figure 27 was generated. The map contains the data coming from two sources: the Apogee sensor, which generated the temperature of the canopy values, and the GPS sensor to locate each datum of temperature collected. Differences in temperature can be seen easily. For example, the lowest canopy temperatures were registered by white varieties of vines, which are located in the middle (direction SW-NE) of the field.

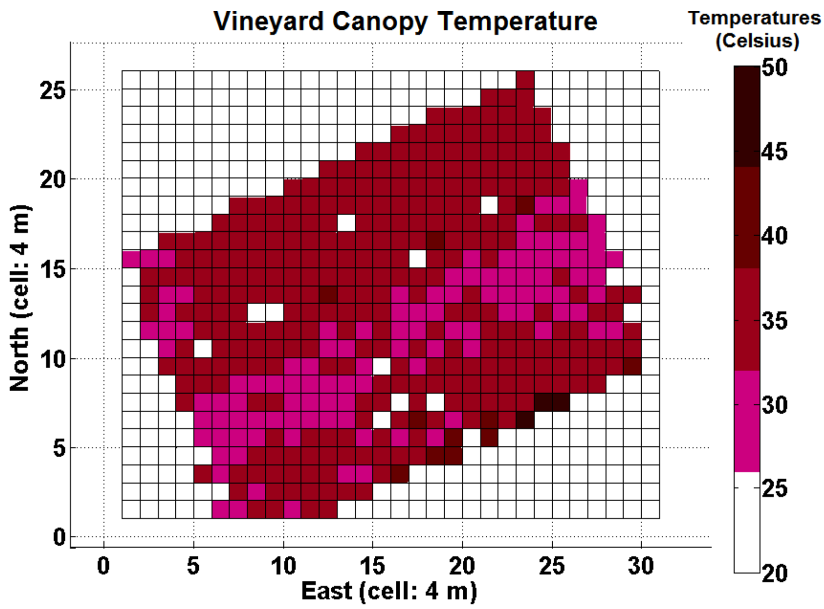



**Figure 27. Vineyard canopy temperature grid map**

The program shows that the robot is capable of displaying the path and collecting data from sensors.

## 1.2.4 Work package 4: Software refinement, optimization, and market preparation

The principal objective of WP4 is to coordinate the refinement and optimization of all the software applications embedded in the robot, in such a way that a new software framework needs to be developed with the requirements of being long-lasting, and easy to protect, reproduce, commercialize, and upgrade. The WP leader is UPV with the highest amount of workload (table 11).

**Table 11. Highlights and person-month for Work Package 4 in VineScout EU project**

| Work package number | WP4 | Start Date or Starting Event | | Month 1 | |
|---|---|---|---|---|---|
| Work package title | Software refinement, optimization, and market preparation | | | | |
| Participant number | 1 | 2 | 3 | 4 | 5 |
| Short name of participant | UPV | WALL | SUN | UDLR | SYM |
| Person/months per participant: | 36 | 6 | 0 | 6 | 9 |

The activities planned for this WP have the first task, T4.1, taking place the whole first year as can be seen in the table 12.

**Table 12. Activities planned for Work Package 4 in VineScout EU project**

| | 2016 Dec 1 | 2017 Jan 2 | Feb 3 | Mar 4 | Apr 5 | May 6 | June 7 | July 8 | Aug 9 | Sep 10 | Oct 11 | Nov 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WP4- Softwre refinemnt, opt & preparat | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| T4.1 Analysis navigation & safeguarding | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| T4.2 Analysis & enhan mapping algorithm | | | | | | | | | | | | |
| T4.3 User-centered graphic interface | | | | | | | | | | | | |

**Summary of work for WP4** (Lead partner: UPV)

- **T4.1 – Analysis and expansion of navigation and safeguarding algorithms** *(M1-M24)*. This task is focused on analyzing and enhancing the algorithms for navigation and safeguarding. Special attention has been paid to the complex maneuver of headland turning. UPV has analized the current software and considered the following tests:
  - Enhance the modular integration of ancillary applications by introducing object-oriented approaches, in particular for the integration of GPS, monitoring sensors, navigation sensors, and processors.
  - Review and meliorate the navigation algorithm, especially for complex environments.
  - Expand the safeguarding capabilities.

**Development of the work for WP4: UPV monthly report**

- **Related information: UPV monthly report**

Along this first year of the project, the mechanical system of the robot has been improved. The first version of the prototype arrived in Valencia on 21 August, so the preceding months VineRobot second platform were used. This fact was not a delay in any case, because the platforms (or prototypes) are built taking into account the previous version. Then, the philosophy for building the three prototypes consists of improving the immediate previous one, either changing some mechanical elements, or changing the specific system if the consortium finds another mechanism that works better. This philosophy works with the software development especially. It has been observed that navigation programming is closely linked to the robot mechanical system, what means that, as long as the prototype changes, there will always be modifications in the software, even small adjustments, to adapt the mechanics in the prototype to a smooth field navigation. The first navigation tests took place in June 2017. UPV was in a vineyard field in Quinta do Ataíde, Portugal (41° 14' 56.0" N, 7° 06' 40.1" W), during two weeks (from 12 June to 24 June, 2017); the vineyard field belongs to SYM, who was also assisting in the field tests. The tests revealed possibilities of change in some physical systems, as well as in navigation. After those tests, UPV fixed mechanical systems and reprogrammed navigational issues (headland turns and safeguarding). With the goal of improving the algorithms for the headland turn, and also de safeguarding, different kinds of ultrasonic sensors for the robot were studied. The ultrasonic sensors model HC-SR04 that the previous robot carried, have been usually used in clean and protected environments, however, in the case of a field robot like VineScout, as it must perform the work in a dirty environment with high temperatures, it is better to install sensors with higher quality and endurance. Therefore, the Arduino ultrasonic sensors that the robot carried (left on Figure 28), were changed to Maxbotix (MaxBotix Inc., Brainerd, MN, USA) sensors (right in Figure 28). As in the Figure 28, both ultrasonic sensors were installed together in order to compare measures.

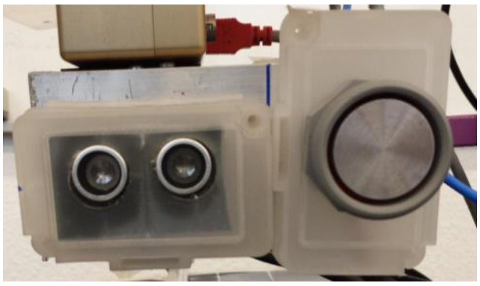


**Figure 28. Ultrasonic sensors: Arduino (left) and MaxBotix (right) installed together to be tested for VS-1**

Maxbotix resulted in more accurate measurements for VineScout application, so those sensors were installed, and several positions (and programming) were tested to determine the best working position. Table 13 shows the different configurations, where configuration 1, for example, was the same that there was in VineRobot.

**Table 13. Several configurations for the ultrasonic sensors to check the best performance in VS-1**

| Sensors configuration | |
|---|---|
| 1 | Initial configuration (same as for Arduino sensors) |
| 2 | Chain configuration |
| 3 | Front invert triangle |
| 4 | Three in-line configuration (with different separation) |
| 5 | Two in-line configuration (with different separation) |
| 6 | Different ground distance (ground effect) |

A LIDAR-based technology sensor (Pepperl+Fuchs, Twinsburg, OH, USA) has been acquired (Figure 29) as an improvement for the detection system and support for headland turns, despite it has not yet been tested in field.

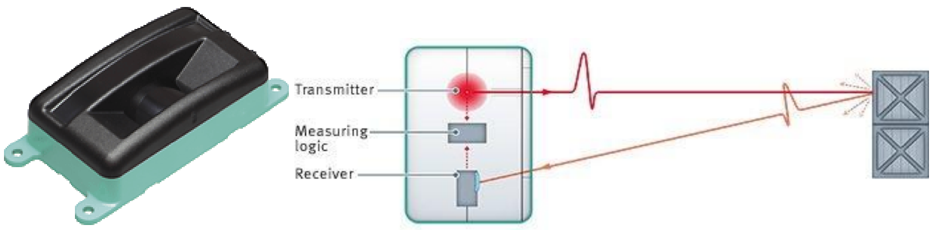



**Figure 29. LIDAR- based technology sensor**

The related technical data of the lidar sensor is displayed in table 14.

**Table 14. Technical data of the LIDAR sensor**

| Technical data<br>Model: OMD8000-R2100-R2-2V15 p/n 264888 SCANNER | |
|---|---|
| Measurement range | 0.2 m to 8 m |
| Measuring method | Pulse Ranging Technology (PRT) |
| Scan rate | 50 s-1 (1 scan = 11 measurements) |
| Scanning angle | 88° |
| Resolution | 1 mm |
| Operating voltage | Range: 10 - 30 V DC |
| No-load supply current | ≤120 mA / 24 V DC |
| Time delay before availability | < 3 s |
| Interface type | RS 232 |
| Protocol | P+F R2100 115k, 8N1 |
| Degree of protection | IP67 |
| Connection | 5-pin, M12x1 connector, standard (RS 232; grey color; shielded) |

UPV did a study with the robot including the MaxBotix ultrasonic sensors and the 2D LIDAR sensor, resulting in the sensory area of the Figure 30, which seems a very promising result for using them in the field. In the Figure 30, the robot is the black outlined box in the center, the robot front is on the right-hand side of the page, which is where the biggest area monitored, while the robot flanks are the top-side in the Figure (left side of the robot), and the bottom-side in the Figure (right side in the robot). The robot senses also on the back (left-hand side in the Figure), as it carries ultrasonic sensors in case it needs to go back when turning in the headlands. UPV will continue with this tests.

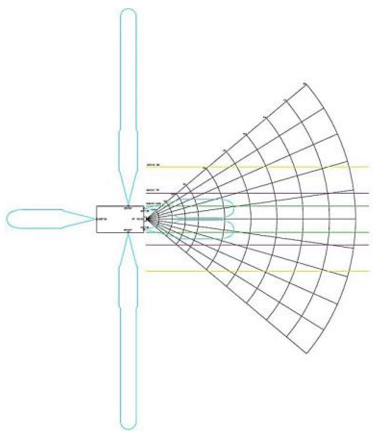


**Figure 30. Area monitored by the robot when VS-1 is using the ultrasonic sensors together with the lidar**

On the other hand, UPV observed during some tests, that the bumper (when activated) performed a continuous rebound effect due to its own slack. For that reason, a new front bumper with programmable timing relay was designed. This issue will be positive not only in terms of safety, but also regarding commercialization. Thus, Figure 31 shows the current relay to control the bumper system in this prototype.

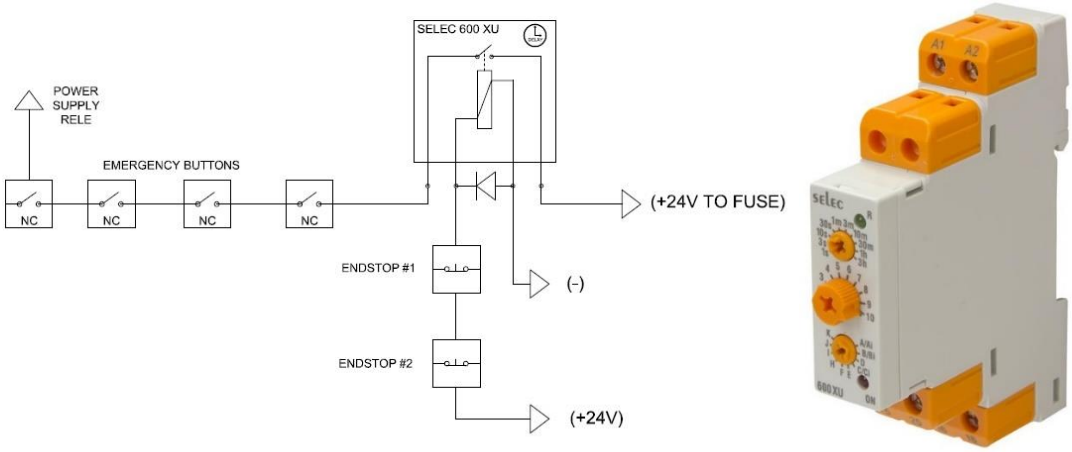



**Figure 31. Block diagram (left) for the new design of the bumper, and its programmed relay (right)**

UPV, assisted by UDLR, tested the navigation algorithms of the robot in Logroño, Spain, in the experimental vineyards of the UDLR (42° 27' 57.1" N, 2° 25' 16.2" W), where the row space in the vineyards is around 3 meters, considered very wide. These tests verified the straight guidance, revealed the need of modifying the headland turn programming for wider vineyard rows, and tested the safety bumper characteristics. Apart from the steering system, the suspension system was checked, as well.

### 1.2.5 Work package 5: Demonstration

Table 15 shows a summary of the work package 5, demonstration, for which SYM, as the final user partner, is the leader. The main objective of WP5 is to set a number of demonstration actions to favour product excellence as an active way to reach TRL 9 and progress beyond. This work package has the purpose of demonstrating on the final market-ready prototype the capabilities of the overall support tool in different settings. This WP will prove that the maps carry valuable decision support knowledge, that end-users will be able to operate the robot as any other farm equipment, and that the resulting wines are different and related to the original field maps.

**Table 15. Highlights and person-month for Work Package 5 in VineScout EU project**

| | | | | | |
|---|---|---|---|---|---|
| **Work package number** | **WP5** | **Start Date or Starting Event** | | Month 10 | |
| **Work package title** | **Demonstration** | | | | |
| **Participant number** | 1 | 2 | 3 | 4 | **5** |
| **Short name of participant** | UPV | WALL | SUN | UDLR | **SYM** |
| **Person/months per participant:** | 9 | 3 | 0 | 12 | **18** |

As shown in table 16, demonstration activities can take place either in September, October, or November (or even, sooner as happened in 2017), depending on the vineyard status.

**Table 16. Activities planned for Work Package 5 in VineScout EU project**

| | 2016 Dec 1 | 2017 Jan 2 | Feb 3 | Mar 4 | Apr 5 | May 6 | June 7 | July 8 | Aug 9 | Sep 10 | Oct 11 | Nov 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WP5- Demonstration** | | | | | | | | | | | | D |
| T5.1 Suppor value of Nit & Anth maps | | | | | | | | | | | | |
| T5.2 Agronomy days | | | | | | | | | | | | |
| T5.3 Decision-making conseq: *technowine* | | | | | | | | | | | | |

**Summary of work for WP5** (Lead partner: SYM)

- **T5.1 – Support value of temperature robot-generated maps** *(M10-M26)*. The objective is to demonstrate the added value carried in data-rich crop maps. The data have been already gathered with the robot, retrieved and processed by UPV, and will be analyzed by UDLR in cooperation with SYM.

**Development of the work for WP5**

- **Related information: D5.2-a, Agronomy Day questionnaires**

The Agronomy Day took place in a field called *Coleçao de Castas* or Symington Grape Variety Library. Symington established an experimental grape variety field known as the Symington Grape Variety Library in the spring of 2014 at its Quinta do Ataíde in the Vilariça Valley (Douro Superior). There, the company has planted 53 Vitis vinifera varieties (29 red and 24 white), comprising indigenous varieties from the Douro, varieties from other regions of Portugal, and varieties from other countries. The underlying objective is to make a significant contribution to the knowledge base of Douro and other Portuguese grape varieties. Among other aspects, the collection is also noteworthy for the number of plants per variety - 200 of each - occupying a total area of 2.25 hectares. This plant population will enable realistic comparative studies in the winemaking of the corresponding wines.

In essence the goals of having the grape variety library are: to establish a grape variety library (red and white grapes) in order to preserve and gain greater knowledge of the vines planted in the Douro (indigenous and foreign), both for their viticultural and their oenological potential; to study the phenological aspects, viticultural parameters, dynamics of maturation and winemaking potential; to share the findings of this study, with a view to broadening the knowledge of the most widely planted varieties, but also to provide guidelines for the planting in the Douro of some less well-known varieties; to establish research and development protocols with national and foreign institutions (universities and others) to further the knowledge of these grape varieties, which is what SUN is doing within the VineScout context.

<u>First Agronomy Day on a glance</u>

The First Agronomy Day of the VineScout project took place on 30 August, 2017, in Quinta do Ataíde the commercial vineyard owned by SYM. This event is officially programmed to be part of the annual steering weeks. The First Steering Week (SW1) was initially planned for month 10, i. e. September 2017, but it actually took place earlier than scheduled for weather-induced reasons, as it occurred between 28 and 31 August, 2017. Our initial objective is to synchronize the steering weeks with the harvesting season at the testing site. The average temperatures in the summer of 2017 were unusually high. The climate data collected by SYM, with an automatic weather station in the field, gave a GDD

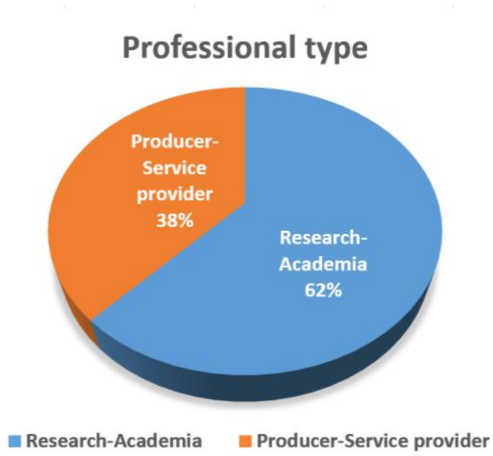
(Growing Degree Days, which is a climate-based indicator for assessing crop development, and it is the sum of the daily temperatures above 10 ºC) of 2466 ºC·Days for 2017, respect to 2190 ºC·Days in 2016, which resulted in a two-weeks anticipation of the harvesting time at Quinta do Ataíde.

According to the agenda set for this first edition of agronomy days, the activities began at 9.30 and continued until approximately 5 pm, with the survey to end-users as the final event. Overall, there were 28 attendees distributed as follows: eight people coming from academia, two attendees from governmental institutions, and 18 people from private companies. The following sections of this document provide a visual narrative of the activities carried out during the first Agronomy Day, analyze the results of the official surveys filled by the attendees, and propose a set of amendments to improve the following editions of this already successful event.

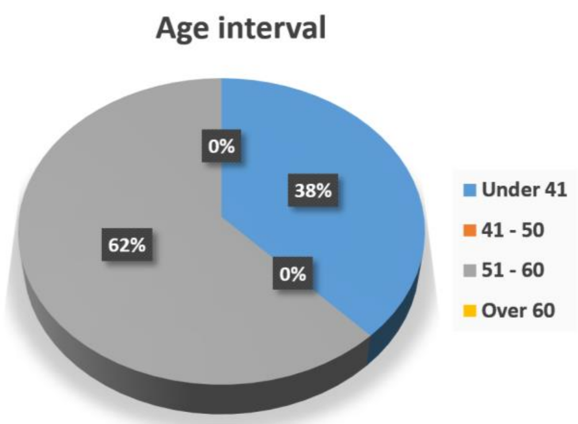
Analysis of the end-user questionnaire

Even though the number of attendees was 28, only eight managed to fill the complete questionnaire at the end of the day. This analysis of the results focuses on the features that are more valuable for the design and construction of the second prototype, which will be tested and validated during the Second Agronomy Day. The characterization of the sample group who filled the survey is based on two aspects: their **age** and the type of **professionals**. These are two sensitive features at the time of studying technology adoption. In terms of robot external design, we look at how users perceive its **physical endurance** and the easiness of **maintenance**. During the field demonstration, the robot was running in straight guidance, and we asked attendees to pay attention to the **stability of straight navigation**, the working **speed**, and the **safety** systems embedded in the robot. Data processing and handling was also explained in the Agronomy Day, but it will be more important for the next prototypes, and therefore it will not be analyzed in this first edition. We ended the survey with two crucial questions for launching a commercial robot: the perception of the user about the estimated **retail price** of 18,000 €, and what they foresee to become the **main barriers** to adapt this technology worldwide. In addition to answer the items included in the questionnaires, several attendees provided their recommendations in a free-text box. Figures from Figure 32 to Figure 35 illustrate the results obtained in the questionnaires for these sections.

- **Population statistics**



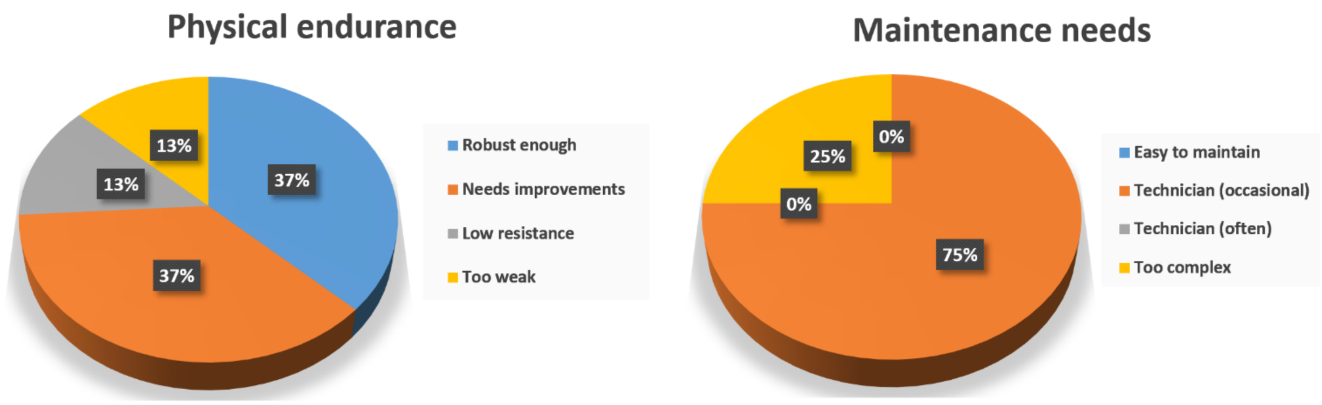

(a)




(b)

**Figure 32. Population statistics regarding Professional type (a) [% of participants], and Age interval (b) [% of participants]**

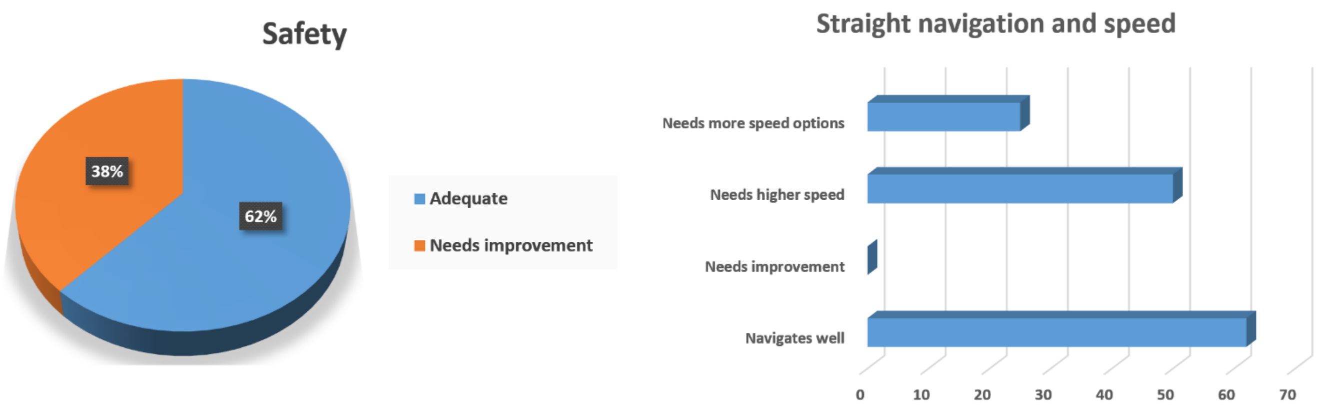
- **Robot external design**




(a) (b)

**Figure 33. Robot design statistics regarding Physical endurance (a) [% of participants], and Maintenance needs (b) [% of participants]**

- **Robot intelligence**




(a) (b)

**Figure 34. Robot intelligence statistics regarding Safety features (a) [% of participants], and Straight navigation and monitoring speed (b) [% votes]**

- **Other aspects**


(a) (b)

**Figure 35. Statistics of the questionnaire regarding Retail price of robot (a) [% of participants], and Main barriers to adapt this technology (b) [% votes]**

End-user recommendations

The following suggestions were written down by the attendees at the end of the questionnaire:

- Add a multispectral camera with single lens (recommended twice).
- Get 3D images with a stereoscopic camera.
- Compatibility with GIS systems.
- The screen monitor needs higher contrast.
- Improve end-of-row detection.
- Contact emergency stop in manual mode.

Conclusions of the Agronomy Day questionnaires

Before analyzing the answers given by the attendees who completed the survey, it is important to describe the characteristics of the group providing an opinion. According to Figure 32a, only one third of the group was formed by producers or personnel coming from companies providing data services to agriculture. The other **two thirds** were **researchers**. This trend should be inverted in upcoming events in order to get more feedback from the final user side. It was not easy to mobilize the wine-producing sector in the beginning of 2017 harvesting season (30 August), whereas researchers and academic staff had more flexibility at the end of the summer. As for the age of participants, the group was polarized; one third was under 41 years old while the rest belonged to the **interval 51-60** (Figure 32b). These Figures make obvious that a much **greater group is needed** to cover the whole spectrum, and as a result, to find more significant evidences of the next steps for the robot's production.

A key objective for the First Agronomy Day was to extract information about a primal prototype of the robot with basic functionality from a group of stakeholders with little –or none– previous experience with agricultural robots. In particular, we looked at two complementary areas of the robot design: the **external structure** and the artificial **intelligence** embedded in the central processor. Figure 33a evidences that approximately one third of the participants believes that the early version was strong enough to endure the typical environmental conditions of vineyards, another third concluded that the current design needs some improvements, and the last third thought that endurance was not sufficient at all, and great improvements were needed. Overall, most of the participants thought that the robot needs to **improve its physical resistance** before it can be released. In terms of maintenance, 75 % of the people believed that a **technician** should be **occasionally providing assistance**, whereas only 25 % found the system too complex for average end-users no literate in digital technologies, especially with potential issues caused by the robot electronics and computing systems (Figure 33b). After running the robot in autonomous mode over several rows of approximately 100-m length, Figure 34a proves that two thirds of the participants felt that the **safety** features of the robot are **adequate**, although the other third concluded that they **need improvements**. Yet the robot did not suffer any incident under automatic guidance along the rows. In the demonstration, only **straight guidance** between rows was evaluated. According to Figure 34b, 62 % of those polled said that autonomous navigation **was correct**, and nobody answered that it needed improvements. However, 50 % of the surveys stated that the robot needs moving faster, and 25 % found that more speed options will be necessary in the future for the practical use of robots. The prototype tested possesses a strong torque in the wheels to climb and roam over rough terrain, but its average speed is 1 km/h, which was considered **too slow** for the expectations of the attendees. Figure 34b also illustrates the opinion of the participants about straight navigation and monitoring speed of the prototype used in the Agronomy Day.

Finally, we focus on two crucial aspects that affect the future **exploitation** and **commercialization** of the robot: its final selling cost and the main barriers that may block the generalized adoption of scouting robots for grape and wine production. Despite the fact that the targeted **retail price of the robot**, currently 18,000 €, was not explicitly mentioned in the questionnaire, the cost of the robot raised several questions and discussions along the field day, and therefore these discussions were the base for answering the price question of the survey. Figure 35a represents the results, which indicate that nobody thought that the price was low; on the contrary, 37 % of the people assured that the retail price was **too high** and another 38 % declared they were not sure about the price, which makes sense because most of the attendees were not familiar with field robots. Interestingly, 25 % of those polled affirmed that the price was reasonable. The discussion on the **price of the robot** resulted to be of **great importance**. As a matter of fact, among the main **barriers to put this technology in the market**, chosen by the participants as illustrated in Figure 35b, the **major obstacle** is actually the **selling price** of the robot, selected by 50 % of the surveyed. The **second barrier**, mentioned by 37 % of the polls, is **reliability**, which was *a priori* expected to be the highest. **Complexity** was also considered a barrier by 25 %, as well as **uncertainty returns** (12 %) and the **lack of a trained staff** in robotics and automation. Surprisingly, nobody thought that the need of a specialist to carry out maintenance tasks might become a barrier, probably because most of the attendees indicated (Figure 33b) that the needs of a technician would likely be occasional.

The specific recommendations made by the attendees that filled the questionnaire also resulted helpful for the planning of the second year, although not all of them were aligned with the main objectives of the project. The fact that two surveys mentioned the benefits of adding **multispectral perception** is significant, because we had already arrived to such conclusion, and consequently the second prototype VS-2 is expected to incorporate a multispectral camera. The collection of 3D images, on the contrary, is not currently a priority task for the end-user (SYM), focused on water status assessment. Nevertheless, it would not imply a big modification of the robot architecture because it already implements a stereoscopic camera for straight navigation. The compatibility of local-based flat east-north maps (generated by the robot mapping engine) with conventional GIS systems raised an intense discussion on the round table of the afternoon session. This issue is going to be considered in future versions of the mapping algorithm, probably for VS-3, given that it could improve the marketability of the robot. The observation made on the insufficient **contrast of the control screen** is important from a practical standpoint, as the robot is designed and made to work in the field, and most of the times in the summer when sun radiation is strong. Constructive comments like this that come from external observers are very helpful, because developers somehow get so used to work with the robot that do not realize of practical inconveniences like a weak contrast or the unfortunate location of a switch. One of the participants realized that the robot did not stop at the end of the row by itself. The turning routine at the headlands is under review, and was not activated in the tests. This will be one of the key features to evaluate in the next field event. The addition of a contact emergency stop in manual mode demands more thoughts, but one of the possibilities under consideration for VS-2 is the upgrade of the **joystick** with a more ergonomic grip that could additionally incorporate an emergency stop.

Feedback-induced actions for the second prototype VS-2

The objectives –both ideological and practical– of the Agronomy Days were satisfactory met in its first edition, as the robot was tested by a group of stakeholders who filled a survey at the end of the day, providing feedback on their experience in a real environment. This feedback was intended to power the iterating design of the robot in such a way that convergence between the solution proposed by the consortium and the needs claimed by the actual producers is continuously increasing until the deployment of a final model, properly industrialized and ready for production. The following actions, straightly derived from the experiences lived in the First Agronomy Day, will be taken into account for the design of the second prototype, which is expected to be ready for the Mid-project meeting, scheduled for May 2018 in Valencia.

- The **external cover** of the robot and its design are going to improve in order to increase the physical resistance to potential impacts and weather influence (moisture, sun radiation, overheating), and also to increase the durability. The new body will be more **compact** and the computing components will be optimally ventilated. The new suspension design with four independent springs will include **shock absorbers** to palliate the effects of vertical accelerations caused by terrain irregularities. Intense testing to **evaluate fatigue** in the structure, body, steering, and electronics will be conducted between May and August 2018.
- To diminish the need of regular assistance from maintenance specialists, which has been reported as an important concern by users (Figure 33b), an effort will be made to make **components easily exchangeable** by operators in the field. New batteries that are easily accessed and replaced, and a novel design of the electronic network are intended to expand the time between maintenance visits.
- Although 62 % of the participants in the survey declared that the safety features were good enough, we did not challenge the robot in headland turnings or with rows of highly irregular shape, and therefore **safety** remains an important **source of work** for the coming months. The sonar network, in particular, is currently been redesigned with the goal of enhancing obstacle detection, and intense developments are expected in the spring 2018 to improve the routine for **headland turning**.
- There was a consensus during the field tests on the needs for doubling the forward velocity of the robot. The VS-2 will be equipped with a different gearbox for the four-wheel motors in such a way that **more speed options** are available without affecting the torque needed to traverse rough terrain.
- The majority of attendees believed that a retail price of 18,000 € is too high, and it may become the principal barrier preventing the adoption of robotic scouting in commercial vineyards. Deliverable D6.1-a will analyze the possibility to **reduce the selling price significantly**. One of the proposals under consideration will consist of launching **two versions** of the VineScout; a **basic robot** with simple functionality at a very competitive cost, and a **premier version** with more sophisticated set of functionalities.
- A **new** touchscreen **monitor** manufactured by National Instruments with higher contrast and better protection options will be installed in VS-2 in January 2018. Other options for the joystick are being studied as well.
- The monitoring of nitrogen content in vines will be carried out with a **hyperspectral camera** with simultaneous perception in three spectral bands located in the green, red (edge) and

infrared spectra. SUN and UDLR are negotiating with camera manufacturer JAI the assembly of a **customized** camera for measuring spectral vegetation indices.

<u>Visual narrative of the activities</u>

| | |
|---|---|
| **9h30** | Welcome address and purpose of Agronomy Days within the VineScout project Francisco Rovira-Más (Coordinator) / Symington Family Estates; Translation by SYM team |
| **9h45** | How the VineScout robot works: hardware and software<br>Francisco Rovira-Más (UPV); Simultaneous translation by SYM team |


| | |
|---|---|
| **10h00** | Good practices and current limitations to assess vineyard status; what the robot can measure María Paz Diago (UDLR) and Fernando Alves (SYM) |


| | |
|---|---|
| **10h30** | Coffee break |


| | |
|---|---|
| **10h45** | Hands-on experience with the robot: measuring runs and data gathering.<br>*All attendees* |


| | |
|---|---|
| **12h45** | Lunch and wine tasting social with invited end-users |


| | |
|---|---|
| **14h00** | Brief introduction of all attendees: consortium, Project Officer, Advisory Board members, and group of invited end-users who will explain their current activities and interests |
| **14h30** | Mapping techniques and interpretation of the robot data taken in the morning session Verónica Saiz-Rubio (UPV); Simultaneous translation by SYM team |


| | |
|---|---|
| **15h00** | Agronomical decisions based on field data: evidence versus intuition<br>María Paz Diago (UDLR); Simultaneous translation by SYM team |
| **15h30** | End-user-driven round table discussion: lessons learned and upcoming steps.<br>Moderated by Pedro Leal da Costa (SYM) |
| **16h30** | Official questionnaire to end-users Administered by UPV & SYM teams |

## 1.2.6 Work package 6: Exploitation and market strategic plan

Table 17 contains the summary of work distribution for WP6, where the partner WALL is the leader. This WP objective is to establish the exploitation and business plan for the exploitation and use of the project results, paving the way for a wide exploitation in Europe and boosting innovation, as well as managing the IPR rights among consortium members.

**Table 17. Highlights and person-month for Work Package 6 in VineScout EU project**

| Work package number | WP6 | Start Date or Starting Event | | Month 3 | |
|---|---|---|---|---|---|
| Work package title | Exploitation and market strategic plan | | | | |
| Participant number | 1 | 2 | 3 | 4 | 5 |
| Short name of participant | UPV | WALL | SUN | UDLR | SYM |
| Person/months per participant: | 3 | 12 | 9 | 3 | 3 |

Table 18 highlights that the work related to the first task of the work package is studied during seven months in the second part of the first reporting period.

**Table 18. Activities planned for Work Package 6 in VineScout EU project**

| | 2016 Dec 1 | 2017 Jan 2 | Feb 3 | Mar 4 | Apr 5 | May 6 | June 7 | July 8 | Aug 9 | Sep 10 | Oct 11 | Nov 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WP6- Exploitat & market strategic plan | | | | | | | | | | | | D |
| T6.1 Product cost-efficiency | | | | | | | | | | | | |
| T6.2 Dynamic business mod & explot plan | | | | | | | | | | | | |
| T6.3 Innovation & IPR management | | | | | | | | | | | | |

**Summary of work for WP6 (Lead partner: WALL)**

- **T 6.1 – Product cost-efficiency** *(M6 - M36)*. Task 6.1 has the goal of steadily reducing the final cost of the robot to enhance market penetration. Partners WALL and SUN have been cooperating to iteratively select the best components with a reasonable price and quality standards. The idea of this task is to reduce costs along the project duration until finding the best trade-off at the end of the action.

- **T 6.2 – Dynamic business model and exploitation plan** *(M3 - M36)*. The Exploitation Manager, WALL, has supervised and completed the VineScout business plan. The exploitation and business plan evolves in parallel to the development of the project, and that evolving exploitation plan has been reported in D6.2, which has been elaborated by UPV, and according to the guidelines provided by both the exploitation (WALL) and innovation (SUN) managers.

**Development of the work for WP6**

- **Related information: D6.2**

Update on user needs

The need for objective measurements that allow winemakers produce premier wine consistently, season after season, continues being the main drive behind the adoption of robotics and ICT applications. However, the steady increment of average temperatures in combination with uncertain water availability is re-shaping user needs. According to Symington Family States (SYM), the most critical parameter at present for wine production is the unambiguous assessment of vine water status, which must be monitored several times along the growing season, typically from May to September. The consequences of a poor assessment of the plant water status, in addition to its nitrogen content, may result in catastrophic yields, and therefore in important losses, both from an economic point of view and in terms of reputation.

The VineScout monitoring robot is being designed to provide the spatial variation of the nitrogen content and water status of the vines in real time. This will allow end-users to track these two key parameters as often as they deem appropriate for the management of their vineyards. The nitrogen content is going to be estimated through a customized multispectral camera sensing in three spectral bands simultaneously (green, red, and NIR), in order to calculate a spectral vegetation index, which can be well correlated with the nitrogen content in leaves. The assessment of water status in vines, with especial focus on the early detection of water stress, will be carried out from the real-time recording of canopy temperature as the robot scans the vineyard every two rows. The measurement of canopy temperature on-the-fly will be practically executed with an infrared radiometer mounted onboard the robot. The availability of nitrogen content and water status at a resolution that approaches plant-specific precision, leads to unique data-supported assistance in vital decision-making for common vineyard operations, such as irrigation scheduling, fertilization rating, or the strategic sampling of grapes for optimized harvesting logistics.

New advances of the competitors

The following tables (from Table 19 to Table 23) describe the potential direct competitors found during the first year of the project in conferences, tradeshows, commercial catalogues, scientific journals, and dissemination magazines in the farm machinery or wine production sectors. Every product analyzed also includes a subjective assessment of its potential risk to the VineScout project, together with a technical justification of the risk it represents.

**Table 19. Non-contact Nitrogen estimators**

| Graphical information | Technical information | |
|---|---|---|
|   | Product 1: | **CropCircle ACS-470** |
| | Manufacturer: | Holland Scientific |
| | Country | USA |
| | Product 2: | **Green Seeker RT 200C** |
| | Manufacturer: | Trimble |
| | Country | USA |
| | Development status: | Commercially available |
| | **Estimated RISK** | **L O W** |

<table>
<tr><td></td><td>Justification of Risk</td><td>This solution is not fully automated as it needs an operator (walking or driving). Only provides one parameter (NDVI) and acquisition cost ranges between 7,000 € and 11,000 €. These sensors are quite a different product from the VineScout concept, thus they are not straight competitors.</td></tr>
</table>

**Table 20. Project Romovi**

<table>
<tr><th>Graphical information</th><th colspan="2">Technical information</th></tr>
<tr><td rowspan="6"></td><td>Product:</td><td>Romovi</td></tr>
<tr><td>Design & construction:</td><td>Tekever; INESC TEC; ADVID</td></tr>
<tr><td>Country</td><td>Portugal</td></tr>
<tr><td>Development status:</td><td>Project in progress 2017-2020</td></tr>
<tr><td>Estimated RISK</td><td>L O W</td></tr>
<tr><td>Justification of Risk</td><td>The project only focuses on the specific environment of terraces with only one row, envisioning a localization solution based upon a full-custom wireless positioning system. Romovi robot features an off-the-shelf robotic platform from Clearpath whose price and IP rights impede the commercialization of a robot with similar specs to VineScout.</td></tr>
</table>

**Table 21. Vinobot robot**

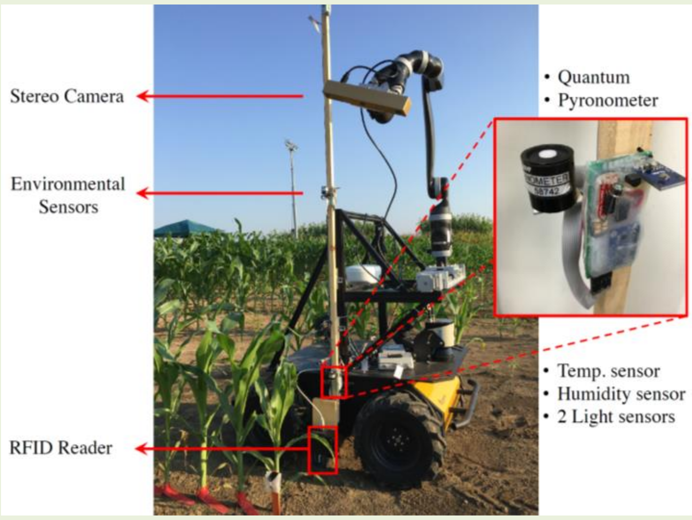
<table>
<tr><th>Graphical information</th><th colspan="2">Technical information</th></tr>
<tr><td rowspan="6">
</td><td>Product:</td><td>Vinobot</td></tr>
<tr><td>Design & construction:</td><td>University of Missouri, MO</td></tr>
<tr><td>Country</td><td>USA</td></tr>
<tr><td>Development status:</td><td>Research; proof of concept</td></tr>
<tr><td>Estimated RISK</td><td>L O W</td></tr>
<tr><td>Justification of Risk</td><td>The objective of this project is plant phenotyping, and they are not looking at a commercial solution. The robot carries many sensors whose integration is far from industrialization. They use the platform from Clearpath, which limits its potential for the market for the same reasons exposed in table 2.</td></tr>
</table>

**Table 22. VitiBot robot**

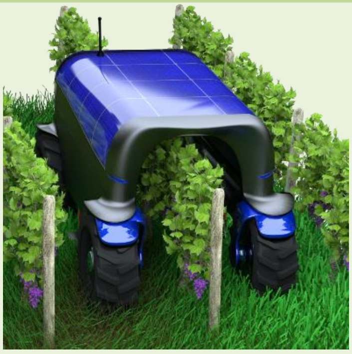
| Graphical information | Technical information | |
|---|---|---|
|  | Product: | **VitiBot** |
| | Manufacturer: | Vitibot |
| | Country | France |
| | Development status: | Prototype |
| | **Estimated RISK** | **M E D I U M** |
| | Justification of Risk | Autonomous, solar and electric are features that compete with VineScout, but the fact they still have no physical prototype puts them several months behind. |

**Table 23. TED Robot**

| Graphical information | Technical information | |
|---|---|---|
|   | Product: | **TED** |
| | Manufacturer: | Naïo Technologies |
| | Country | France |
| | Development status: | Prototype |
| | **Estimated RISK** | **M E D I U M** |
| | Justification of Risk | Ted probably represents the most direct competitor. It is made by a European company that just started selling agricultural robots. This platform is nice and robust to withstand farm environments, and can operate at 4 km/h. However, the following features create a significant breach between Ted and VineScout, with clear advantages to the second:<br>▪ Ted's weight is 800 kg<br>▪ It requires 12 lithium batteries that already cost 15,000 €<br>▪ Guidance is achieved with RTK GPS. That requires farmers pre-recording maps and an extra cost of 15,000 €<br>▪ The total cost is 80,000 €<br>▪ Ted design does not seem to be driven by end-users |

<u>Conclusions on competition risks</u>

The fact that the robotics market is beginning to bloom together with the advent of a multiplicity of crop sensors at competitive cost is rising the interest of viticulturist and vineyard-owning wineries to implement digital technologies in their management strategies. The nitrogen sensors described in Table 19 are currently being used with bulk crops to determine the nutritional status of plants and apply a precise amount of fertilizer, but the advantages found by large-scale row crops are now being claimed by specialty crops producers. At present, there is an interest to measure spectral vegetation indices (such as NDVI) from terrestrial platforms, and therefore VineScout can yield the first autonomous solution. As far as we have investigated, on-the-fly contactless nitrogen estimators have rarely been used in commercial vineyards. The solutions represented by Romovi (Table 20) and Vinobot (Table 21) show a continuous interest in farm robotics, but these solutions are just proof of concepts where the hard task of machine design and construction has been circumvented by using a commercial all-purpose robotic platform; these robots are tools for gathering data rather than integral robotic solutions.

VitiBot (Table 22) and Ted (Table 23) confirm the idea that for a vineyard robot to be successful, it has to be specifically designed for the environment it is going to work on. VitiBot is not intended to monitor the vineyard collecting relevant parameters; rather, it is supposed to remove weeds with a tilling disk and spray, using for that only electrical power. The fact that a working prototype still has not been validated in the field for such complex tasks provides competing advantages to VineScout. Likewise, the high weight and overprice of Naïo's Ted situate the VineScout robot in a good position to be the first in hitting the market, with a weight around 100 kg, user-suggested operational features, and a price initially set at 18,000 €, with a commitment of significant reductions in cost after the industrialization stage is completed.

The VineScout also introduces a unique and powerful computing platform equipped with an embedded application processor (ARM Cortex A53), a real-time processor (ARM Cortex R5), a graphics processor (ARM Mali 400MP2), and a field-programmable gate array (FPGA). All of these units will be highly integrated in the Xilinx ZU4EV device, which has shown evidence of high performance in latency, safety, and power consumption when compared to conventional processor-based platforms (https://goo.gl/Aj8W2x). Recently, NVIDIA has announced[8] their NVIDIA Jetson TK1, which is an embedded platform for accelerating Artificial Intelligence (AI) algorithms, and was specially designed for RAS. However, the NVIDIA platform is only equipped with a GPU and CPU integrated in the same chip. Despite the fact that the NVIDIA Jetson has been designed for accelerating AI algorithms, the NVIDIA Jetson TK1 does not have a real-time unit (required for meeting critical time goals) or a programming logic unit (for performing hardware acceleration). Another downside of the NVIDIA Jetson TX1 is that it is not compatible with the PCI/104 Type 3 architecture, or FMC-LPC, which are desirable for high-speed sensors such as cameras. There also exists a wide range of alternative embedded processing solutions (e.g. Raspberry Pi, Intel NUC, etc.), but all of these solutions lack real-time capabilities, programmable logic units, or graphic processing units. At the time of writing this deliverable 6.2-a, SUN is not aware of any other commercial off-the-shelf (COTS) solution able to deliver such a flexible computing platform as the proposed ARM Cortex.

Revisiting the three-stage market uptake

*Monitoring efficiency under review*

The monitoring of both nitrogen content and water status, according to vineyard managers, can be achieved by collecting data every two rows, as local changes are not as acute to require scanning every single row. At an average speed of 2.5 km/h and the typical row spacing of 2 m, the VineScout can easily cover one hectare in one hour. The workload requirement for the robot was initially 6 hours of monitoring per day, which required batteries of 6-h autonomy. However, the flexible design we are

[8] Retrieved from http://www.nvidia.co.uk/object/jetson-tk1-embedded-dev-kit-uk.html on the 23/12/2017

introducing in VineScout-2 (VS-2) with easily exchangeable low-weight lithium batteries may expand the working day to 8 or 9 hours, and consequently the area covered by a robot may reach 8 or 9 ha per day. The VineScout-3 (VS-3) will even try to go beyond and introduce night monitoring, which, in addition, will provide new data insights as temperature monitoring and plant status will be quite different between day and night. With this updates in the agenda, it is clear that the robot does not need to increase speed to be more efficient, which is a convenient way to lower the risks associated to high speeds in autonomous mode.

In terms of area coverage and robot sharing, if we assume (as confirmed by end-users) that a weekly monitoring is more than sufficient, and the VineScout robot will at least cover 6 ha daily, one single robot will easily cover 30 ha. As the European average vineyard has an area of 2.6 ha, ten growers may share a robot for monitoring, which obviously implies dividing the cost by ten for every end-user. As the daily area grows, the robot total coverage will grow accordingly, and consequently the cost assigned to each farmer with a robot in share will go down. In conclusion, the VS-2 with a target velocity of 2-3 km/h and a flexible procedure for battery replacement in the field is designed to increase workload efficiency.

<u>Three-stage strategy to penetrate the market</u>

The initial market uptake strategy through three consecutive stages was envisioned as follows:

- Stage 1: promote the VineScout among wine-producing agents that already have links, either commercial or technical, with project partners.
- Stage 2: sponsor the project throughout wine-producing countries in Europe.
- Stage 3: expand the results to wine-producing countries outside Europe.

After the first year of the project, we can conclude that stage 1 only occurred with Portuguese stakeholders related to SYM through attendance to the First Agronomy Day (deliverable D5.2-a). Stage 2 occurred with the project promotion at the Global Robot Expo in Madrid (UPV) and SITEVI in Montpellier (UPV). Stage 3 included Australia (UDLR), Argentina (UDLR) and the USA (UPV). It is clear that these three stages did not occurred sequentially, as expected, but concurrently. However, the promotion involved in stages 2 and 3 majorly involved agents related to research and technology, instead of the most-desired growers who could acquire the VineScout product in the near future. For the second year of the project, an effort will be made to reinforce stage 1, and a measure to do so will include a greater diversity of attendees in the Second Agronomy Day to be held in September 2018. Based upon the robot performance and attendees response in this event, extra non-scheduled field demonstrations might be offered as a promotional tool to spread the word of this new technology for the vineyard.

<u>The robotics market</u>

- Service robots market

There exist many information sources on economic data that prove that robotics is clearly a growing economy. Figure 36 is such an example provided by the Japanese Robotic Association, where the growth of service robots is expected to sky-rise in the next decade. The autonomous vacuum cleaner of Figure 37a has already seen several generations over the last ten years, and their sales have been growing since the first machine was manufactured. Its success roots in the competitive price, which is comparable to regular vacuum cleaners, and the fact that it offers a technology that easily merges with daily life. Of course, the hazard posed by a small robot like this is practically inexistent, and taking an autonomous machine to the outdoors where the environment is harsh, unpredictable, and typically of large dimensions, is something radically different. Nonetheless, expectations are high, and there already exist solutions for open spaces. Of course, these are limited, totally controlled spaces such as private courtyards, but they imply a step ahead in automation and artificial intelligence. Figure 37b shows the autonomous mower Tango, commercialized by a major manufacturer of agricultural equipment.

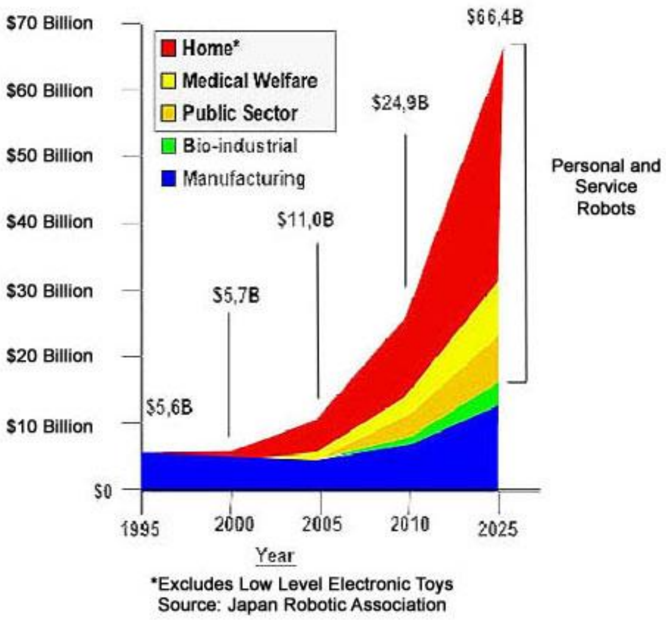



**Figure 36. Sharp growth of service robots market from 1995 to 2025**


a b

**Figure 37. Service robots: a) vacuum cleaner Roomba by iRobot; b) Tango autonomous mower by John Deere**

The UK government has recently announced that it will invest £500 billion[9] on high quality infrastructure projects by 2020-21 and £160 M for accelerating innovation by UK food and farming[10]. Such infrastructures will have to be maintained via both humans and robots working side by side. The utilization of robots is mostly desirable in resilient environments that represent health or live treats to

[9] Retrieved from https://www.gov.uk/government/publications/national-infrastructure-and-construction-pipeline-2016 on the 23/12/2017
[10] Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/227259/9643-BIS-UK_Agri_Tech_Strategy_Accessible.pdf on the 23/12/2017

humans and animals (e.g. nuclear power plants, pipelines, high voltage power lines, etc). Also, the European Commission created in 2016 the partnership for robotics in Europe, SPARC, with a joint investment that is expected to reach €2.8b with €700m in financial investments coming from the EC H2020[11].

- Agricultural robots market

According to the *Global Agricultural Robots Market Professional Survey Report 2017* [12], the major field robotics players in the global agriculture market are Harvest Automation Inc. (USA), Clearpath Robotics (Canada), PrecisionHawk Inc. (USA), Naïo Technologies (France), SenseFly SA (Switzerland), and Shibuya Seiki (Japan). Under the generic category of "Agricultural Robots", the following possibilities are typically included: unmanned aerial vehicles (UAV), driverless tractors, milking robots, automated harvesting machines, and unmanned ground vehicles (UGV). Figure 38 shows the global market share according to Research Nester, considering therefore all kind of robotic platforms. However, for the VineScout project, we are only interested in UGV, which interestingly include half of the companies mentioned by the 2017 survey report. Following this report, automated solutions can be classified on the basis of end-user applications as field farming, dairy management, indoor farming, horticulture, and other applications. For this project, only field farming is to be considered, although certain operations in horticulture could benefit from the technology developed in the VineScout project. The market share illustrated in Figure 38 shows a portion for Europe that should be quite larger according to its scientific influence and economic development; the modest contribution of this project will try to overturn this negative trend.

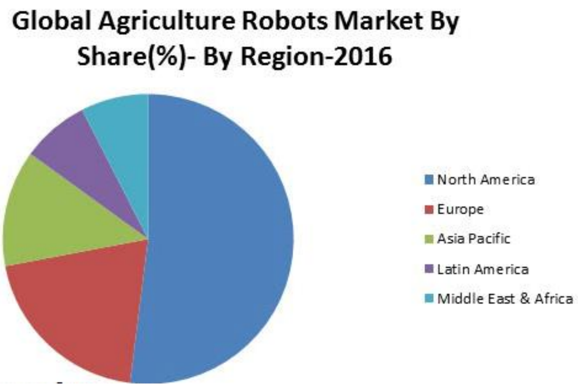



**Figure 38. Agricultural robots global market (Source: Research Nester)**

<u>Investors and venture capital agencies</u>

In spite of being within the first year of the project, the following investors and venture capital companies have shown their interest in VineScout:

- GTAI, Germany Trade & Invest
- NAGARES, Powerful Solutions
- BLUE OCEAN ROBOTICS

[11] Retrieved from http://ec.europa.eu/programmes/horizon2020/en/h2020-section/robotics 23/12/2017
[12] This information is extracted from a pre-purchase sample of the actual report, whose acquisition was rejected by both the Exploitation and Dissemination Manager (SUN) and the Innovation Manager (WALL) due to its cost of $3,500.

Future developments that could impact sales

The combined assessment of water status and nitrogen content is currently one of the major concerns for the wine-producing sector, and as a result, the highest priority measurements for an autonomous monitoring robot. However, taking advantage of the agility and versatility of VineScout, there are other applications of agronomical interest that could be implemented at a reasonable cost, thus empowering the usability of the robot. Among these complementary functionalities, it is worth mentioning:

- **Soil monitoring**. The availability of water in the soil, its physical properties, and the presence of accessible nutrients are complementary information to the water and nutritional status measured in the canopy. The spatial monitoring of soil conductivity (or resistivity), in particular, can be instrumental to understand and assess water stress in a holistic way. To achieve these measurements, some contactless sensors are being developed at present, and if end-users show a real interest in this type of maps, the addition of a soil sensor could be a good market drive for the top version of the robot.

- **Smart crop protection**. The problem of removing weeds and fighting pests with a minimum use of chemicals is especially significant in Europe. France, for instance, has embarked in a crusade against glyphosate that other countries may follow soon. In this context, there is a growing interest in the use of small tilling machines to remove weeds between vines, and the site-specific application of fungicides and insecticides. Taking advantage of the robot's enhanced rolling capacity and safe navigation system, the addition of some of these implements would majorly depend on the availability of electrical power in the robot. Each particular application will obviously require a specific energy study before reinforcing the onboard battery pack, but a multiplicity of expanding options are in the agenda. Autonomous spraying reduces the risk of intoxication, and therefore represents a valuable welfare feature for field operators.

Barriers and obstacles to widespread exploitation

*Feedback from the First Agronomy Day*

One of the questions formulated to the First Agronomy Day attendees through the official survey focused on the potential barriers to introduce VineScout technology in the market with a reasonable success rate. Figure 35b reproduces the results found in the questionnaire carried out in August, where the **retail price** of the robot is the most important, followed by **reliability** and **complexity**. The need of occasional maintenance by a dealership was not considered a problem at all, and the need of users well trained in these technologies as well as the questionability of early returns raised some concerns among those surveyed.

According to Figure 39, available in the *Global Agricultural Robots Market Professional Survey Report 2017*, and released by KMI Agriculture Robots Research Center in September 2017, there is a clear trend in the sales price of agricultural robots, which has significantly fallen after 2013. This trend is well aligned with the VineScout objective of analyzing the target retail price of the robot with the goal of lowering its price by one third.

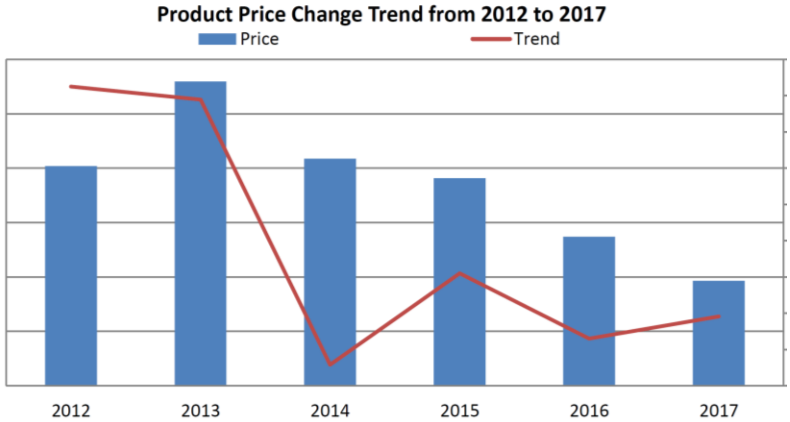



**Figure 39. Agricultural robots sales price in 2012-2017 (Source: KMI Ag. Robots Res. Center)**

*Other barriers foreseen and consortium counteraction*

The two main barriers identified in the questionnaires, namely the selling price and reliability, are going to be intensely studied and improved until the end of the project, and significant progress is therefore expected. Other difficulties not explicitly mentioned in the survey are:

- Data is not relevant enough to justify investment.
  - Counteraction: intensify data analysis and correlation, proposing meaningful decision-making actions. Increase field work with the robot.
- Data-based field actions impact not demonstrable in the 3-year duration of the project. The new field practices derived from the data collected by the robot must be noticeable in the grapes, which will have to be transformed in wine. Even though we will try to accelerate the process, it takes some minimum time to age the wine, and therefore the complete picture of VineScout will likely be available after the end of the project.
  - Counteraction: over the season 2018, the VineScout robot is going to register maps of temperature and a spectral vegetation index, which will allow SYM to carry out micro-vinification experiments leading to distinct wine options to be tasted in late 2019.
- Resistance to technology by traditional growers.
  - Counteraction: active intensification by ALL partners of communication, dissemination, web-based, and demonstration activities.
- Regulations and standards. Nothing has been released so far regarding regulations for the fabrication and use of farm robots, and for the time being, their commercialization is legal. Nevertheless, things might change in the short run due to the growing interest and economy of the robotics market.
  - Counteraction: periodic review of new regulations by the Innovation Manager (SUN) and the Exploitation Manager (WALL).

## 1.2.7 Work package 7: Dissemination and promotion

WP7 is focused on spreading the commercial potential of the project, so a number of communication and dissemination activities have been carried out for an optimal visibility of the project outcomes. The ultimate objective is to reach the general public with the support of the H2020 program and taking advantage of the massive growth that the robotics sector is having at present. Table 24 highlights some characteristics of this WP and its leader, UDLR.

**Table 24. Highlights and person-month for Work Package 7 in VineScout EU project**

| | | | | | |
|---|---|---|---|---|---|
| **Work package number** | **WP7** | **Start Date or Starting Event** | | Month 1 | |
| **Work package title** | **Dissemination and promotion** | | | | |
| **Participant number** | 1 | 2 | 3 | **4** | 5 |
| **Short name of participant** | UPV | WALL | SUN | **UDLR** | SYM |
| **Person/months per participant:** | 5 | 3 | 4 | **7** | 3 |

Table 25 shows that tasks 7.1 and 7.4, which are related with VineScout's promotion and press releases, take the whole year, while dissemination activities start later, when data begins to be ready.

**Table 25. Activities planned for Work Package 7 in VineScout EU project**

| | 2016 Dec 1 | 2017 Jan 2 | Feb 3 | Mar 4 | Apr 5 | May 6 | June 7 | July 8 | Aug 9 | Sep 10 | Oct 11 | Nov 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WP7- Dissemination and promotion** | D | | | | | | | | | | | |
| T7.1 Project info, promotion & visibility | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| T7.2 Industrial dissemination | | | | | | | | | | | | ■ |
| T7.3 Scientific dissemination | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| T7.4 Press and audiovisual releases | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |

**Summary of work for WP7** (Lead partner: UDLR)

- **T7.1 – Project information, promotion, and visibility** *(M1-M36)*. The news about the VineScout project is intended to reach the major producers of grapes and wine, especially in Europe. This task included the creation and maintenance of a creative website for the entire duration of the project (and additional years after its end). As a support action, schematic fliers with the key information of the project have already been widespreaded due to the Agronomy Day. Also, a roll-up has been presented in all official meetings and demos scheduled in the work plan. The specific actions comprising Task 7.1 are: Creation and maintenance of the project website, or promotional material: fliers, roll-up, logo…, among others.
- **T7.2 – Industrial dissemination** *(M12-M36)*. Partners identified strategic tradeshows where the project was promoted, such as the Global Robot Expo, or SITEVI.
- **T7.3 – Scientific dissemination** *(M6-M36)*. The deployment of agricultural robots commercially produced is, by itself, a remarkable success from the scientific standpoint. T7.3 regulates the scientific publications derived from the research and development of the project. In particular, two categories may be identified: the oral presentations, posters, and conference papers presented in scientific congresses on one hand; and the publications in peer-reviewed journals on the other. This first year the focus has been centered on conferences with oral presentations, mainly, despite emphasis will be made to publish in open access as much as possible for journals of high impact. Relevant conferences where the consortium has participated has been: CIGR, GiESCO, and ASABE, as non-EU events.

- **T7.4 – Press and audiovisual releases** *(M1-M36).* The velocity at which information is exchanged through the internet, especially in audiovisual format, offers excellent ways to promote the project and its outcomes. Task 7.4 is focused on the information released to the press, which was first discussed with the Management Board (specially during the Steering Week), and approved.

**Development of the work for WP7**

- **Related information: logo, D7.1, roll-up, Agronomy Day flier, conference research articles, press releases**

<u>Project information, promotion, and visibility</u>

*Logo*

VineScout logo is shown in Figure 40. The two black-orange dots want to simulate the eyes of a hawk, while the purple part simulates the body. The hawk has a very good vision, and it is fast detecting preys, the same as VineScout robot when scouting the vineyard. Depending on where the logo will be located, the sentence below (Intelligent decisions fro vineyard robots) will be displayed or not.

VineScout

Intelligent decisions from vineyard robots

**Figure 40. VineScout logo**

*Roll-up*

The roll-up shown in Figure 41 was displayed in various meetings and tradeshows, where the VineScout was present and promoted.


**Figure 41. Roll-up for dissemination activities or meetings**

*Webpage*

The goal behind the VineScout webpage is to keep the robotics community –especially for agricultural applications–, the farm machinery industry, researchers on automation, engineers, students, technology lovers, and wine production stakeholders aware of the progress made in the project. The web will narrate how obstacles appear in the way, the approach to handle them, and the milestones achieved in the complex process of transforming a prototype into a market-ready product. The sections organized in two menu bars will help to deliver all the key information. Figure 42 shows the Home page that appears when visiting the project webpage: [www.vinescout.eu](http://www.vinescout.eu).

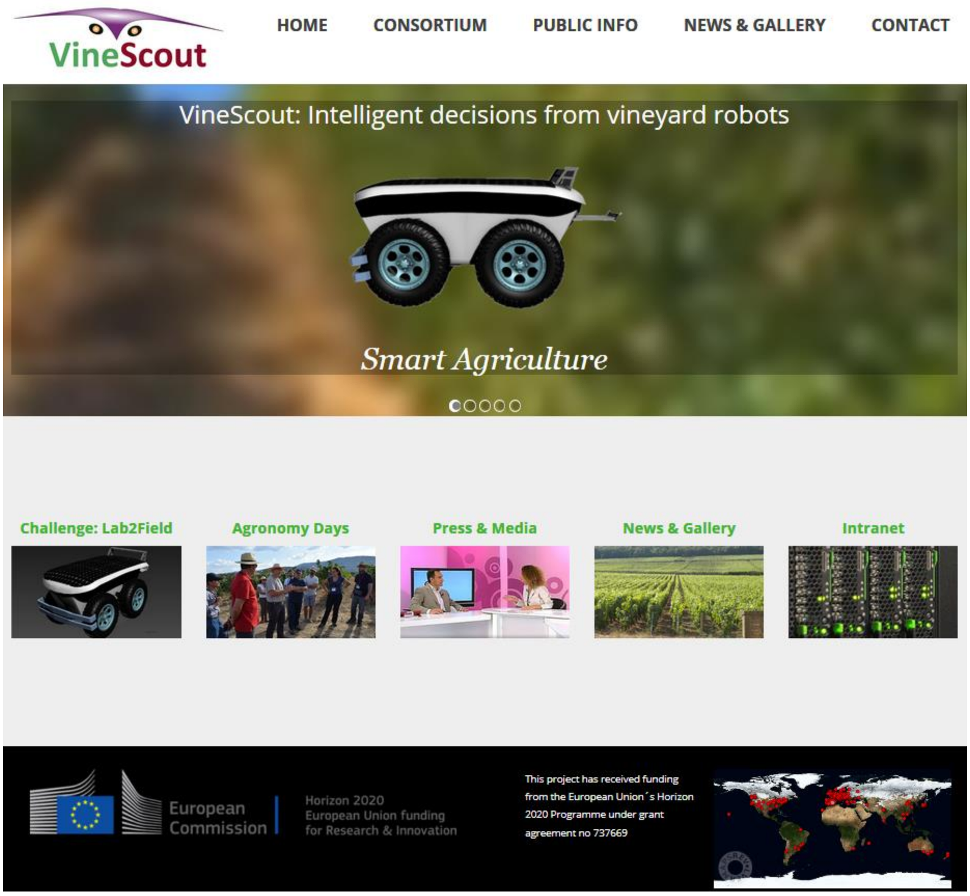



**Figure 42. Home page of the VineScout website**

***Webpage General Menu***

When accessing the webpage, two potential alternatives can be followed; a general menu placed below the opening scene and divided into five sections represented by a reference image, and a conventional menu bar located at the web's top on the right side of the VineScout logo.

The Webpage General Menu consists of the following sections:

**Challenge: Lab2Field**

This section describes some specific challenges faced in VineScout when moving from a functional prototype to a commercial solution in less than three years. The idea behind this page is to relate our experience in overcoming certain shortcomings that turned out to be significant for the success of the project, even though they initially did not appear to be very relevant. In brief, this section was conceived as a *hint & tips* window with the purpose of helping other researchers in the field of agricultural robotics be more efficient in their designs by avoiding those solutions that eventually did not worked out as expected, mainly after intense testing in the field.

## Agronomy Days

This section gravitates around the end-user, and is devoted to cover the special event called *Agronomy Days*. These events will be one-day gatherings with actual users, potential buyers, and interested stakeholders that express their willingness to learn about the project and contribute to it with their practical "ground-based" experience. The execution of each Agronomy Day will be aligned with the philosophy of a user-centered design. *Agronomy Days* will take place within the annually-planned Steering Weeks, which represent the central meeting of all the partners of the consortium with the Advisory Board members available, and even the VineScout Project Officer. The structure of a typical Agronomy Day will include field hands-on experience, classroom-based instruction, and the administration of a voluntary questionnaire from which the consortium will retrieve ideas for upcoming designs. As a result, the partners will get together every year with producers from different origins in actual vineyards, where the robotic prototypes in progress will be explained by the project team, and handled by future end-users, who ideally will pose operational challenges *in vivo* and through the written questionnaires. This page also provides a link where potential users of the robot from other areas or countries can apply to participate in upcoming Agronomy Days events. The Agronomy Day are scheduled to coincide with the beginning of the harvesting season every year of the project. The flier prepared for the first Agronomy day is displayed in Figure 43.

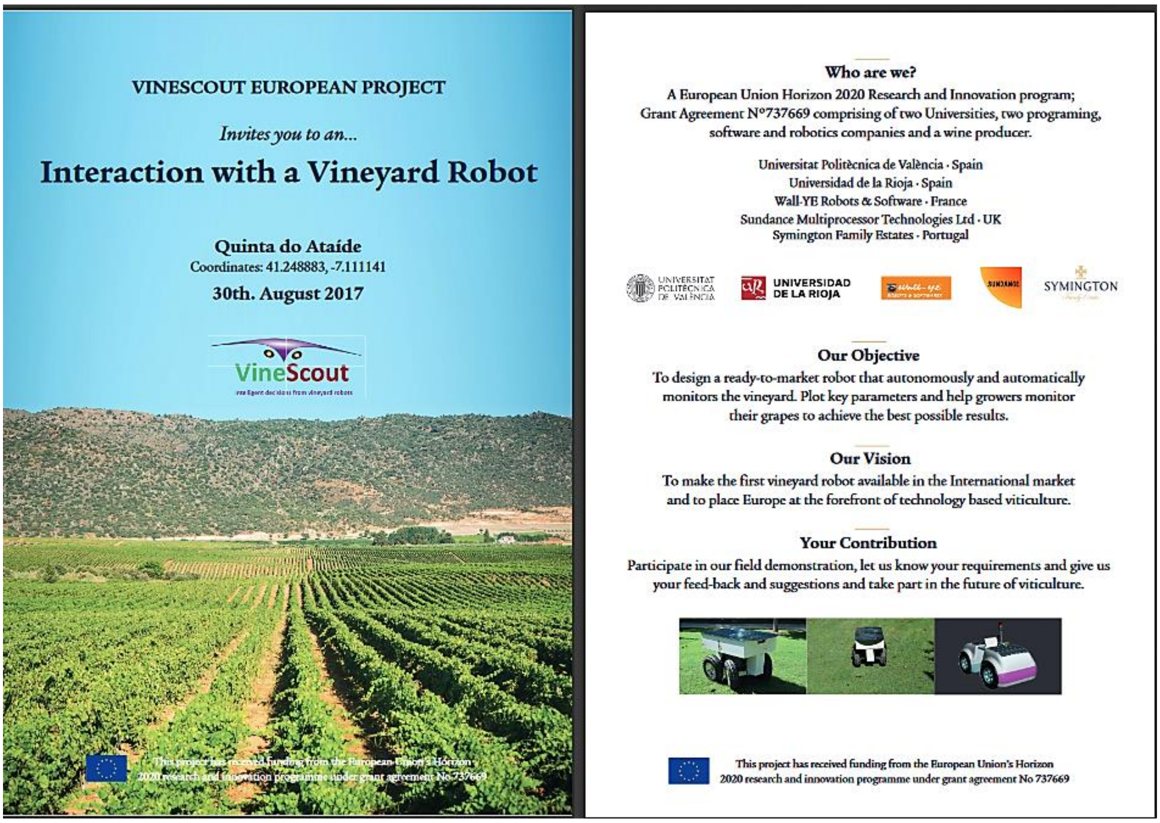



**Figure 43. Flier prepared for the first Agronomy Day on August 30, 2017**

### Press & Media

This section is the communication area, and it will contain the main press releases derived from the promotion of the VineScout project. The format of these articles can vary from digital to paper, or even to short promotional videos or partner's interviews.

### News & Gallery

This area intends to keep project followers updated with all the activities related with the project. It will consists of short articles informing about project meetings, technical conferences, field tests and demos, attendance to tradeshows to promote the project, and every project event carried out by one or several partners.

### Intranet

The content in the Intranet section is password protected. It is intended to be used by the partners of the project and authorized European Commission members that request it. Typical material posted here will comprise project-customized templates for deliverables, oral presentations, and meeting minutes, as well as the documents themselves, both public and confidential.

## *Webpage Top bar Menu*

### Home

This tab takes the user to the Home page shown in Figure 42.

### Consortium

The Consortium section lists all partners in the project and the key personnel of every institution involved in the project. It contains a brief description of each partner and the role played by each member.

### Public Docs

This part is divided into two subsections: *Deliverables* and *Publications*. The *Deliverables* section (

Figure 44) provides a list of all the deliverables, highlighting the release date of due documents and providing a link to download those documents labeled as public (PU). The section *Publications* entails the dissemination area, which will contain all the open access technical publications released during the project.

| Deliv. | Deliverable name | Related WP | Lead Partner | Dissemination level | Delivery date | Download |
|---|---|---|---|---|---|---|
| D1.1-a | Deployment of prototypes (1/3) | 1 | WALL | PU | 5 Dec 2017 | PDF |
| D1.1-b | Deployment of prototypes (2/3) | 1 | WALL | PU | M22 | PDF |
| D1.1-c | Deployment of prototypes (3/3) | 1 | WALL | PU | M34 | PDF |
| D2.1-a | Construction and assembly of the electronic systems (1/3) | 2 | SUN | PU | 1 Dec 2017 | PDF |
| D2.1-b | Construction and assembly of the electronic systems (2/3) | 2 | SUN | PU | M22 | PDF |
| D2.1-c | Construction and assembly of the electronic systems (3/3) | 2 | SUN | PU | M34 | PDF |
| D3.1 | Mapping algorithms for basic maps | 3 | UDLR | CO | M24 | CONFIDENTIAL |
| D3.2 | Algorithms embedded in advanced operative maps | 3 | UDLR | CO | M36 | CONFIDENTIAL |
| D4.1 | Software generated in format of closed libraries | 4 | UPV | PU | M36 | PDF |
| D4.2 | Operator manual | 4 | UPV | PU | M36 | PDF |
| D5.1 | Report on decision support value of robot-generated maps | 5 | UDLR | CO | M27 | PDF |
| D5.2-a | Testimony of *Agronomy Days* (1/2) | 5 | SYM | PU | 22 Dec 2017 | PDF |

**Figure 44. List of some Deliverables in Public Docs tab under the Deliverables subsection**

## News & Gallery

This tab provides an alternative access to section *News & Gallery* of the Webpage General Menu. Figure 45 depicts some articles already published in this section.

## FIRST VINESCOUT STEERING WEEK

**Quinta do Ataíde, 28-31 August, 2017**

The First Steering Week took place at the end of August in Symington's Quinta do Ataíde (Portugal). On 30 August, 2017, VineScout partners held the first **AGRONOMY DAY**, where invitees from different backgrounds enjoyed a beautiful field day interacting with the robot, learning its basic features and asking all they wanted to know about the project and the robot. After the open-air lunch, technical sessions focused on data acquisition and interpretation took place, wrapping up this successful day with a round-table discussion and the official survey to participants.

For more details on the first Agronomy Day, visit the special section from the home page.

## FIELD TESTING IN PORTUGAL

**Quinta do Ataíde, 12-24 June, 2017**


UPV, SUN, and SYM teams joined in the vineyards of Quinta do Ataíde (SYM) to test the navigation algorithms of the robot, draft the new electronic system, and challenge robot components at temperatures around 40 ° C.

**Figure 45. Articles published in the News & Gallery section of the VineScout website**

## Contact

The contact form printed in Figure 46 is supplied in order to contact the Project Coordinator via email.

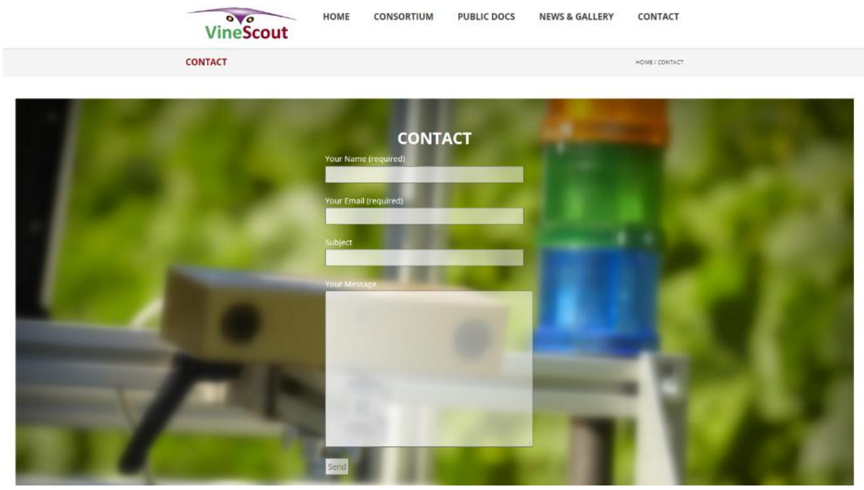



**Figure 46. Contact form to easily reach the Project Coordinator**

### *Webpage bottom stripe*

Figure 47 contains a static stripe that is common to all sections and subsections of the webpage, appearing constantly regardless of the sections currently in view. This stripe comprises the European

Commission logo followed by the official and mandatory sentence "*This project has received funding from the European Union's Horizon 2020 Programme under grant agreement no. 737669.*"


**Figure 47. Band at the bottom of the webpage**

The right side of the bottom stripe includes a worldwide map locating the geographical origin of the visits since the website was publicly released. Figure 48 pops up when the map is clicked, showing the live statistics of the webpage visits. These statistics provide the number of times the webpage is accessed and the place from where it was accessed. When the tab *2D map* from Figure 48 is clicked, Figure 49 appears, showing a two-dimensional map indicating visitor's locations with yellow dots.


**Figure 48. Live statistics for the VineScout webpage showing recent visits and their geographical locations**


**Figure 49. Two-dimensional map showing the places where the webpage was accessed**

### *Webpage Conclusions*

The VineScout website has been designed to display and inform about the progress of the project in a dynamic and interactive way. From it, other researchers may learn what decisions will not help their designs, end-users might register to participate in Agronomy Days, documents of interest can be quickly downloaded, such as deliverables or journal papers, and all the news related to the project can be easily tracked by project followers.

Industrial dissemination

The tradeshows that partners considered strategic for enhancing the visibility of the project were:

- **Global Robot Expo: 2 - 4 February 2017, Madrid (Spain)**. In their webpage they announce that there were more than 2,200 appearances in media, a total of 11,000 visitors, more than 140 brands presented, more than 8,000m$^2$ of exhibition, media impact of 45 million euros, and global audience of 400 million people. In Figure 50 is shown different moments in the tradeshow when the coordinator was interviewed by different press media.


**Figure 50. VineScout coordinator being interviewed by two different press media**

- **SITEVI: 27-29 November 2017, Montpellier (France).** SITEVI is the international equipment and expertise exhibition for the vine-wine (mainly), olive, and fruit-vegetable productions. In their website they say that SITEVI has confirmed its status as the imperative business & innovation event for all producers, with more than 1,000 companies exhibiting, 54,000 registrations/entries, and with visitors from 52 different countries.

- Other forums, where UPV members were invited to talk about the project: **Bayer Digital Farming Day** (23 May 2017, Seville, Spain), organized by the company Bayer, **VineScout: FTI project success story** (27 September 2017, Valencia, Spain), organized by Universitat Politecnica de Valencia, and **CIGR Next Leaders meeting**: 13-15 July 2017, Chicago (Illinois, USA). The CIGR is the International Commission of Agricultural and Biosystems Engineering. From their webpage, it is an international, non-governmental, non-profit organization consisting of a network of Regional and National Societies of Agricultural Engineering as well as private and public companies and individuals worldwide. They manage different kinds of resources, such as the CIGR Journal, conference proceedings, newsletters, a CIGR Handbook, as well as Working Groups. The coordinator of VineScout is involved in Section III of CIGR, Plant Production, as the secretary. This meeting brought an opportunity to introduce the VineScout project to the international community represented by the CIGR.

<u>Scientific dissemination</u>

Three research articles have been writen during 2017:

- **ASABE Annual International Meeting: 16 – 19 July 2017, Spokane (Washington State, USA)**. The American Society of Agricultural and Biological Engineers (ASABE) holds the Annual International Meeting (AIM) every year. The ASABE conference is the most important meeting for Agricultural Engineers worldwide. This year, the number of people attending the conference according to ASABE publication magazine "Inside ASABE" (article named Speaking of Spokane: Wrapping up the 2017 Annual International Meeting) was more than 1,700 people, one among the highest attendance in the recent years. During this meeting, VineScout project was presented in a parallel session called Automation and Robotics for fruit, vegetables and other specialty crops - Part 2. That session took place in a room with about 60 people attending. The article presented was ***Performance Improvement of a Vineyard Robot through its Mechanical Design***, by Veronica Saiz-Rubio (UPV), Francisco Rovira-Más (UPV), and Christophe Millot (WALL) - DOI: 10.13031/aim.201701120. In

Figure 51, there is a copy of the conference program announcing the oral session presentations. The presentation given by UPV is highlighted. Figure 52a shows UPV member presenting the project to the audience, and Figure 52 shows the increase in visits to VineScout webpage during UPV stay in USA: the aquamarine dots are visits before the meeting, and red dots are the visits after the conference. There were also seven visits from Spokane, where the conference took place.

Wednesday, July 19 – 10:15AM-12:15PM

**SESSION 331** **AUTOMATION AND ROBOTICS FOR FRUIT, VEGETABLES AND OTHER SPECIALTY CROPS - PART 2**
– Sponsored by MS-48
Moderator: Manoj Karkee, Washington State Univ

**Location: 203**

| Time | Paper# | Title/Author |
|---|---|---|
| **10:15AM** | | **Introduction** |
| **10:20AM** | **1700662** | **Development of a new dry bin filler for apple harvesting and infield sorting with a review of past and existing technologies** Zhao Zhang, Michigan State University, East Lansing, MI United States (Presenter: Renfu Lu) (Zhao Zhang, Anand Pothula, Renfu Lu) |
| **10:35AM** | **1700160** | **Designing and evaluating the use of crop signaling markers for fully automated and robust weed control technology** Thuy Nguyen, University of California Davis, Davis, CA United States (Presenter: Vivian Vuong) (Thuy Nguyen, David Slaughter, Steven Fennimore, Vivian L. Vuong) |
| **10:50AM** | **1700587** | **Evaluation of a new apple in-field sorting system for fruit singulating and imaging** Anand Pothula, USDA Sugarbeet and Bean Research Unit, East Lansing, MI United States (Anand Pothula, Renfu Lu, Zhao Zhang) |
| **11:05AM** | **1700871** | **An Automated System for Crop Signaling and Robotic Weed Control in Processing Tomato** Vivian Vuong, University of California Davis, Davis, CA United States (Vivian Vuong, David Slaughter, Thuy Nguyen, Steve Fennimore, D Ken Giles) |
| **11:20AM** | **1701288** | **Stereo Vision for Computational Bird Detection and Deterrence** Shivam Goel, Washington State University, Pullman, Washington United States (Shivam Goel, Santosh Bhusal, Matthew Taylor, Manoj Karkee) |
| **11:35AM** | **1701420** | **Automated high-throughput machine vision-guided waterjet knife strawberry calyx removal system** Yang Tao, University of Maryland, College Park, MD United States (Yang Tao, John Lin, Robert Vinson, Maxwell Holmes, Xuemei Cheng, Gary Seibel) |
| **11:50AM** | **1701120** | **Performance Improvement of a Vineyard Robot through its Mechanical Design** Veronica Saiz-Rubio, Universitat Politecnica De Valencia, Valencia, Spain (Veronica Saiz-Rubio) (Veronica Saiz-Rubio, Francisco Rovira-Mas, Christophe Millot) |

**Figure 51. ASABE Program announcing UPV presentation about VineScout**


a b

**Figure 52. Presentation of VineScout European Project**

After ASABE meeting, members of UPV visited some laboratories in Washington State University to disseminate the H2020 European Project VineScout. They were to two different campuses: Prosser (CPAAS: Center for Precision & Automated Agricultural Systems), and Pullman (Department of Biological Systems Engineering).

- **ECPA** (European Conference on Precision Agriculture): **16-20 July 2017, Edinburgh (UK)**. The conference welcomes papers about all aspects of precision agriculture related to any cropping system–from soil and crop sensing, to data management, information systems and spatial decision support systems. The paper presented was titled ***On-the-go thermal imaging for water status assessment in commercial vineyards***, by S. Gutiérrez, M. P. Diago, J. Fernández-Novales, and J. Tardaguila (all members from UDLR).

- **GiESCO: 5 – 10 November 2017, Mendoza (Argentina).** GiESCO stands for "Group of international Experts of vitivinicultural Systems for Cooperation". In their webpage they announce GiESCO as one of the most important scientific and techonogical meeting related to viticulture. GiESCO Meetings are organized every two years and about 300 people assist to them. Scientific and technological subjects are presented during the meeting as talks or posters, and there are also field visits to local research and commercial vineyards and wineries. One day of the meeting, the Professional Day, is usually targeted to the local audience of professionals and growers. The research article presented was ***Vineyard water status assessment by non-destructive, proximal, NIR spectroscopy***, by Juan Fernández-Novales, Salvador Gutiérrez, and Maria Paz Diago (all members from UDLR) - DOI:10.1017/S204047001700108X.

- Another minor conference, where UPV members where invited to talk about the project: **Agrichains workshop** (6-8 November 2017, Vila Real, Portugal).

Press and audiovisual releases

- Many VineScout press releases have been launched due to the start of the project (kick-off meeting), and the Agronomy Day during the Steering Week. The figures below show some selected examples. The first press releases were launched coinciding with the kick-off meeting (Figure 53). There were also some news in digital newspapers due to the Steering Week (Figure 54 and Figure 55). Also, a French blogger contacted UPV to release a piece of news (Figure 56, top left), and so did Wine Expectator to release its news (Figure 56, top right) Figure 56 (below) also shows an article from Decanter, self-proclaimed as the world's best wine magazine. Finally, Figure 57 shows a press released launched from PTV (Plataforma Tecnológica del Vino – wine technologic platform), an association that wrote a letter of intent for VineScout.

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

VineScout

**La UPV lidera un proyecto para facilitar la gestión de los viñedos aprovechando el potencial de la robótica y la inteligencia artificial**

[ 19/12/2016 ]

Facilitar a los viticultores europeos la gestión de los viñedos aprovechando todo el potencial que la robótica y la inteligencia artificial ofrecen al sector. Este es el objetivo fundamental de VineScout, un proyecto europeo liderado por la Universitat Politècnica de València (UPV) en el que participan también la Universidad de La Rioja (UR), las empresas tecnológicas Wall-Ye y Sundance Multiprocessor Technology, y Symington Vinhos, una de las bodegas portuguesas de mayor prestigio internacional.

VineScout toma el relevo de VineRobot, proyecto que ya contó con la participación de la UPV, la UV y Wall-Ye, y en cuyo marco se desarrolló un avanzado prototipo de robot vitícola. Ahora, el objetivo es mejorar tanto su movilidad como su sistema de monitorización -incluyendo nuevos parámetros de mayor interés para la gestión de viñedos europeos- con el objetivo de, finalmente, proceder a su comercialización.

**Una herramienta de gestión sin precedentes**

LA RIOJA 20 años

**Robótica e inteligencia artificial para mejorar la gestión de los viñedos**

Valencia, 19 dic (EFEAGRO).- El proyecto europeo VineScout, liderado por la Universitat Politècnica de València (UPV), facilitará a los viticultores europeos la gestión de los viñedos aprovechando todo el potencial que la robótica y la inteligencia artificial ofrecen al sector.

La iniciativa, en la que participan también la Universidad de La Rioja; las empresas Wall-Ye y Sundance Multiprocessor Technology, y Symington Vinhos, una de las bodegas de mayor prestigio de Oporto, toma el relevo de VineRobot, han informado fuentes de la UPV en un comunicado.

En el marco del proyecto anterior, los investigadores desarrollaron un avanzado prototipo de robot vitícola, y el objetivo ahora es mejorar su movilidad y su sistema de monitorización -incluyendo nuevos parámetros de mayor interés para la gestión de viñedos europeos- para, finalmente, llevarlo al mercado y comercializarlo.

Agrodigital.com La web del campo

Agricultura | Ganadería | Política agraria | Desarrollo rural | Medio Ambiente | Alimentación | CC.AA. | Legislación

**Robótica, visión artificial y monitorización vía satélite para mejorar la gestión y calidad de los viñedos europeos**

20/12/2016

Facilitar a los viticultores europeos la gestión de los viñedos aprovechando todo el potencial que la robótica y la inteligencia artificial ofrece al sector. Este es el objetivo fundamental de VineScout, un proyecto europeo liderado por la Universitat Politècnica de València y en el que participan también la Universidad de La Rioja; Wall-Ye y Sundance Multiprocessor Technology como empresas tecnológicas; y Symington Vinhos, una de las bodegas de mayor prestigio de Oporto.

Este proyecto toma el relevo de VineRobot, en el que también participaron tanto la UPV como la Universidad de La Rioja y la empresa francesa Wall-Ye. En el marco de dicho proyecto, los investigadores desarrollaron un avanzado prototipo de robot vitícola; el objetivo ahora es mejorar su movilidad y su sistema de monitorización -incluyendo nuevos parámetros de mayor interés para la gestión de viñedos europeos- para, finalmente, llevarlo al mercado y comercializarlo.

Según señala Francisco Rovira, director del Laboratorio de Robótica Agrícola de la UPV y coordinador del proyecto, VineScout ofrecerá una "herramienta de gestión vitícola sin precedentes", ya que el robot permitirá la toma masiva de datos por parte de viticultores independientes que no necesitarán adquirir información de empresas externas de servicios, no siempre accesibles física o económicamente.

LAS PROVINCIAS

**Robótica e inteligencia artificial para mejorar la gestión de los viñedos**

Valencia, 19 dic (EFEAGRO).- El proyecto europeo VineScout, liderado por la Universitat Politècnica de València (UPV), facilitará a los viticultores europeos la gestión de los viñedos aprovechando todo el potencial que la robótica y la inteligencia artificial ofrecen al sector.

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Según el director del Laboratorio de Robótica Agrícola de la UPV y coordinador del proyecto, Francisco Rovira, VineScout ofrecerá una

**Figure 53. VineScout kick-off press releases in Spanish**

Diário de Notícias

**Consórcio europeu está a criar um robô que auxilia a produção nas vinhas**

**Um consórcio europeu, do qual faz parte a empresa portuguesa Symington Family Estates, está a desenvolver um robô capaz de medir diferentes parâmetros do estado da vinha, de forma a avaliar precocemente o seu potencial e auxiliar a produção.**

Com o robô VineScout, "acessível, fiável e fácil de operar", vai ser possível monitorizar e mapear os índices de vegetação - que traduzem o estado de saúde da videira -, o estado hídrico e, sobretudo, parâmetros de rendimento e de qualidade, explicou à Lusa Fernando Alves, responsável da Symington para Investigação e Desenvolvimento Viticultura.

"Quando tomamos decisões ao nível da gestão de vinhas, temos que ter ferramentas que nos permitam segmentar as áreas onde pretendemos intervir, visto que o comportamento de uma parcela ou de uma casta não é exatamente o mesmo em todos os terrenos, tendo variações que importam medir", indicou Fernando Alves.

No entanto, segundo referiu, é "extremamente difícil" conseguir medir certos parâmetros através dos métodos tradicionais, que passam por uma avaliação visual do comportamento da vinha.

De acordo com o responsável, existem no mercado ferramentas que avaliam de forma pontual diferentes estados da vinha e da forma como está a evoluir, mas que não possibilitam "uma cobertura global, quase que linha por linha".

A utilização deste robô autónomo, que recorre à propulsão elétrica e à energia solar, vai permitir que as avaliações sejam "mais precisas", possibilitando "segmentar uma parcela no seu todo, nas diferentes partes qualitativas", disse ainda Fernando Alves.

Dessa forma, será possível delimitar zonas homogéneas de qualidade e intervir em áreas específicas, o que permite, por

VIDA RURAL

PRODUÇÃO | AGROINDÚSTRIA | INSIGHTS | VIDEOS

Tecnologia E Máquinas Agrícolas

**'Robot da vinha' já faz ensaios de campo no Douro**

por Ana Rita Costa - 1 Setembro, 2017

**Figure 54. VineScout Steering Week press releases in Portuguese**

SYMINGTON

*Family Estates*

Press Release

**VineScout — Vineyard Robot Field Trials in Douro Vineyards**

The Douro is known for its historic farming methods, but while traditional viticulture remains highly relevant, the region is having to adapt to a serious labour shortage resulting from substantial de-population, with many people moving to the cities or abroad.

With a view to improving Douro viticulture as well as that of other European wine regions, a project for a vine monitoring robot termed VineScout was begun in December 2016 by a consortium of two leading Spanish Universities; Valencia and La Rioja, together with Wall-YE Robots & Software of France, Sundance Multiprocessor Technologies of the UK and Symington Family Estates.

VineScout is funded by the European Union H2020 'Fast Track to Innovation Pilot' with the objective of developing an affordable and reliable vineyard robot. European Union funding accounts for €1.7 million of the total €2 million investment.

VineScout was field-trialled at the Symington's Quinta do Ataíde Grape Variety Project in the week

**Figure 55. VineScout Steering Week official press release in English**


# A month in wine

All the important issues affecting you across the globe, compiled by Laura Seal

## Robot trials: a new dawn for viticulture?

Robot Ted in use at Château Clerc Milon, Pauillac, Bordeaux

ROBOTS MAY SOON be playing a more significant role in some of the world's most prestigious vineyards, following successful trials in Bordeaux and Portugal.

The latest report comes from Château Clerc Milon, owned by Baron Philippe de Rothschild, where trials with a prototype vineyard robot named 'Ted' began in early 2017. Aimed at helping with soil cultivation and weeding, the trials were part of a partnership with French group Naïo Technologies.

'We see robotics as an effective solution for the future,' said Baron Philippe de Rothschild's managing director Philippe Dhalluin.

'As well as helping to make our vineyard work less arduous and respecting the soil, it will reduce our dependency on fossil energies and the harm caused by traditional agricultural machinery.' Baron Philippe de Rothschild said it has been pursuing organic and biodynamic methods more generally in its vineyards, as well as reducing chemical treatments by 30% since 2008.

Dhalluin, who is also managing director at Mouton Rothschild, told *Decanter* that he doesn't anticipate robots replacing humans in the vineyard, particularly when it comes to picking and selecting grapes.

'In the vineyards, we are first and foremost concerned with the wellbeing of our workers. Ted will be able to relieve them of some of the repetitive tasks, but a robot will never replace the human hand, [which is] essential for a perfect, high-quality harvest.'

**Above: VineScout at Agronomy Day in Symington's Quinta do Ataíde, Douro, Portugal**

Port producer Symington Family Estates has also recently trialled a vineyard robot named VineScout, which can monitor vine health and alert winemakers to any problems, such as water stress. It uses GPS tracking to function autonomously among the vines.

The three-year VineScout project started in 2016 and is part-funded by the European Union, together with private institutions.

The trials in Portugal and Bordeaux are the latest examples of automation in vineyard management. Drones are already used in some areas to monitor vine health, as at Château Pape Clément in Bordeaux.

**Figure 56. VineScout press releases in Vitisphere (French), WineExpectator (English above), and Decanter (English below)**


**Figure 57. PTV press release**

## 1.2.8 Work package 8: Project management and coordination

The overall objective of WP8 is to coordinate and supervise all the activities related to the project, such as its general administrative and financial management, the contract with the EC, the supervision of quality and timing of all deliverables, the assessment of potential risks mitigating their impact, and the establishment of an effective internal and external communication among all the partners of the consortium. Table 26 shows the coordinator of the project, UPV, as the leader of this WP.

**Table 26. Highlights and person-month for Work Package 8 in VineScout EU project**

| | | | | | |
|---|---|---|---|---|---|
| **Work package number** | **WP8** | **Start Date or Starting Event** | | Month 1 | |
| **Work package title** | **Project management and coordination** | | | | |
| **Participant number** | **1** | 2 | 3 | 4 | 5 |
| **Short name of participant** | **UPV** | WALL | SUN | UDLR | SYM |
| **Person/months per participant:** | **12** | 2 | 2 | 2 | 2 |

Table 27 highlights the importance of this WP showing how it is involved throughout all the project.

**Table 27. Activities planned for Work Package 8 in VineScout EU project**

| | 2016 Dec 1 | 2017 Jan 2 | Feb 3 | Mar 4 | Apr 5 | May 6 | June 7 | July 8 | Aug 9 | Sep 10 | Oct 11 | Nov 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WP8- Project management & coordinat** | | | | | | | | | | | | D |
| T8.1 Communic, legal & contract manag. | | | | | | | | | | | | |
| T8.2 Organization proj meet, act & report | | | | | | | | | | | | |
| T8.3 Financial & administrat managemnt | | | | | | | | | | | | |
| T8.4 Risk assessment & management | | | | | | | | | | | | |
| T8.5 Quality Assurance | | | | | | | | | | | | |

**Summary of work for WP8** (Lead partner: UPV)

**Description of work:**

- **T8.1 – Communication, legal, and contractual management** *(M1-M36)***.** The first task is centered on communication and exchange with the EC, establishing communication procedures and tools for facilitating the exchange of information among partners.
- **T8.2 – Organization of project meetings, activities, and reporting** (*M1-M36*). This is the organization and follow-up of internal, review, and board meetings among the partners. Monitoring of project activities and work progress has been done on the basis of *monthly* reports from partners. The following meetings have taken place so far:
  - Kick-off meeting: In Valencia (Spain) on M1
  - First Steering Week (SW1): in Quinta do Ataíde (Portugal) on M9. It included testing, internal meeting, and Management Board meeting
  - Progress-based videoconference/phone meetings (no minutes recorded)
- **T8.3 – Financial and administrative management** *(M1-M36)*. The financial and administrative management of the project includes the circulation and check of financial statements and related information. All payments were made in due time.
- **T8.4 – Risk assessment and management** (*M1-M36*). This task analyzes the potential risks associated to the project activities, and identifies preventing measures and contingency plans. The objective of this task is to ensure that project risks are captured, assessed and adequately controlled. The project coordinator also assumes the role of technical manager (Francisco Rovira-Más, UPV), being also in charge of quality monitoring and risk assessment of the project.
- **T8.5 – Quality Assurance** (*M1-M36*). The objective of this task is the permanent monitoring of the activities planned within the VineScout project to guarantee that they are carried out with the highest possible quality.

**Development of the work for WP8**

- **Related information: VineScout webpage [intranet]**

<u>Communication among partners and EC</u>

VineScout project has had three different Project Officers (PO) during the first year: Aurélie Martin-Hidalgo, Chiara Marinai, and Ivan Ginga, (current VineScout PO). The communication between Coordinator and PO has been mainly through e-mail, and occasionally through the Participant Portal.

Due to a misunderstanding in the reporting procedure, and the change in officers, some deliverables were submitted late. The coordinator has informed the consortium of the need of sending documents with the proper time ahead.

<u>Project meetings, activities, and reporting</u>

The monitoring of project activities and work progress of partners has been done through monthly (approximately) reporting, in the format of technical reports requested by the coordinator. These reports are uploaded in the VineScout webpage intranet.

The meetings that have taken place during this first reporting period are listed on Table 28, apart from some videoconferencing and phone calls. There have been no review meetings yet.

**Table 28. General meetings during VineScout first reporting period**

| DATE & PLACE [Month of the project] | MEETING | RECORDS uploaded to VineScout webpage *(Intranet)* |
|---|---|---|
| 20-21 December 2017, Valencia (Spain) [M1] | Kick-off | Attendance sheet, meeting minutes, presentations |
| 8 February 2017, (Online) [M3] | Internal | no minutes recorded |
| 28-31 August 2017, Quinta do Ataíde (Portugal) [M9] | Internal | Attendance sheet, meeting minutes, presentations |
| 31 August 2017, Quinta do Bomfim (Portugal) [M9] | Management Board | Attendance sheet, meeting minutes, presentations |

Financial and administrative management

As soon as the correspondent budget for VineScout first period arrived from the EC to the coordinator, UPV distributed it to the rest of partners.

During internal meetings, not only technical information was shared, but also general financial information. There were reminders about keeping records of the invoices, even five years after the project ends. The project manager encouraged to keep time records neatly; UPV showed how they do their time records for the University, as it goes through very strict regulations, and recording working hours for each specific Work Package.

Risk assessment and management

This part, which analyzes the potential risks associated to the project activities, and identifies preventing measures and contingency plans, is developed in the Participant Portal. There are sixteen foreseen risks, but only risk 11 can be partially considered. The proposed risk-mitigation measure is to *increase perceptual capabilities with additional redundant sensors*. Currently, straight guidance is working reliably, and headland turning algorithms are being reinforced with higher quality sonar and a lidar rangefinder.

## 2. Update of the plan for exploitation and dissemination of result

Dissemination through conferences and trade shows will continue as the first year. However, communication among end-users must include a more international group, in addition to Portuguese growers.

## 3. Update of the data management plan

The robot generates field data in text format. These data will be downloaded by the user or retrieved from mobile terminals. These maps will be used as a decision support tool to make management decisions about the vineyard. The resulting wine will be evaluated by professionals to assess the goodness of the data and the certainty of their interpretation.

For the moment, the **generated project data** that can result interesting have been published in conferences. After the project, when partners will decide about the confidentiality, the data could be at public disposal from a **repository** located in UPV´s Agricultural Robotics Laboratory website, VineScout website, and another repository that can be adequate for that purpose.

## 4. Deviations from Annex 1 and Annex 2

Deviations from Annex 1

- Due to the interest of final users in measuring plant water status, the anthocyanin content that was supposed to be measured when the project was written, has been replaced by the measure of plant water status through their leaves.

- Due to a misunderstanding in the reporting procedure, and the change in officers, some deliverables were submitted late. The coordinator has informed the consortium of the need of sending documents with the proper time ahead.

Deviations from Annex 2

No deviations