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Farm 4.0: Mobile manipUlation in agriculture For precision FarmINg

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Executive summary

The objective is the realization of a Precision Viticulture technology and the design of a service that, based on this technology, is able to help winegrowers in the vineyard health monitoring.

The first part of the project consisted in a preliminary analysis of agriculture and technology, with a specific focus on the Italian panorama. Through surveys and interviews it was possible to understand needs and expectations of the farmers as well as the difficulties in the introduction of new technologies. Based on the outcome of this phase, a feasible service architecture was developed: it consists in an autonomous rover provided with a series of cameras able to analyse the vigour of the vines through the NDVI indicator. Thanks to the data provided, the user can have a record of the historical behaviour of the field, see the health situation of each plant and plan future actions in order to prevent diseases and increase productivity. The technology has to be cheap and easy to use in order to ease the adoption.

The development of the technological part has been divided into two parallel branches, the rover and the sensor and data analysis. For what concerns the rover the best design solutions has been investigated in order to produce a machine able to work in a harsh environment as the vineyard. A sizing of the fleet based on the autonomy and the average traveling speed was made. About the choice of the sensors, a low-cost solution was developed obtaining data with two cameras (Pi and PiNoIR) with the support of GPS localization. Also, a user-friendly interface was developed to control data acquisition. All the considerations made resulted in the production of 1:5 scale prototype, which was tested at Azienda Agricola Pecchenino, the main stakeholder of the project.

At last, a business model was developed using the Business Model Canvas methodology, representing how this technology can be profitably sold in the Italian market, and the Net Present Value of the proposal was computed.

Key Words

Precision viticulture; Precision farming; Agriculture4.0; Rover; Sensors; Plant vigour monitoring

Project description written by the Principal Academic Tutor

Agriculture is facing many challenges, such as the growth in the world population, resource shortages, the increasing demand for energy, dietary changes and the increase in competition on world markets. Traditional agricultural methods are not able to sustain all these changes, so technology comes to the rescue. Precision agriculture (PA), or precision farming, is a modern farming concept which exploits digital techniques to optimize agricultural production processes. PA practices are the most effective way to significantly reduce the negative impact of farming on the environment while still producing enough food to satisfy a growing demand. The introduction of advanced sensing capabilities allows monitoring at plant level, spotting problems before they spread. The introduction of advanced perception and action capabilities brings in a leading-edge technological approach to farming, allowing for observing, measuring and acting. In the last years it has entered successfully the market, but, because of the high cost, it has been applied only on very large farms and valuable productions.

The objective of the project is the design and demonstration of a service for precision farming, including drone technology (UGV (unmanned ground vehicle) first, but UAV (unmanned aerial vehicle) also can be considered as well), mobile robotics, Internet of Things and Software Platforms. The main result of the project is the definition of a new way of thinking in agriculture, introducing typical approaches/technologies that already proved to be successful in other industrial environments. In particular, the ability to sense, collect and analyze data through IoT platforms and Bigdata methodologies offers the opportunity to introduce a new approach in agriculture, based on fleet of ground and/or air autonomous vehicles and mobile manipulation techniques. Considering the competences available within the team, the service had to be set up considering both a technological and an economical perspective.

The solution has to be suitable to the Italian agriculture context, made of small farms, and in particular focusing on the most exclusive and celebrated production in Italy, wine grapes. Wine is an international market characterized by growing competition. Consequently, winegrowers need to achieve high standards of quality in their vineyards. The reduction of inputs as fertilizers, pesticides, energy, water and the increase in the wine quality and its production sustainability are the objectives of new agricultural techniques. Indeed, the objective is the realization of a Precision Viticulture technology and the design of a service that, based on this technology, is able to help winegrowers in the vineyard health monitoring, in the identification of potential problems and in the application of chemicals, fertilizers, pesticides with high precision, just when needed and in the smallest necessary amount.

Team description by skill

- Turin sub-team:

The sub-team was in charge for software development and testing activities for which programming competences, held by Adrian Sernaque being a mechanical engineer, and data analysis competences, held by Chiara Ghio as an environmental engineer, are necessary.

- Milan sub-team:

The sub-team was characterized by two management engineers (Silvia Beggio and Martina Rontini) and one mechanical engineer (Tania Simon). The main activities were studying needs and users requirements, prototyping and building the business model.

Understanding the problem

Precision agriculture is a way to apply the right treatment in the right place at the right time. Precision Viticulture (PV) consists mainly in the identification and management of the variability within vineyards. Its aim is to increase productivity and/or quality while at the same time reducing the cost of inputs and the environmental impact.

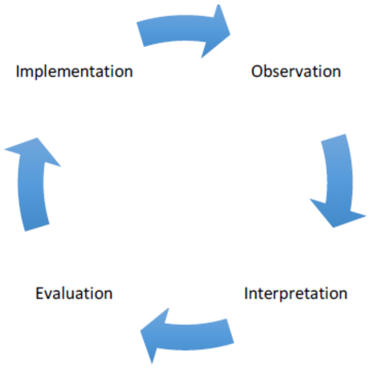

Figure: The process of precision viticulture

The understanding of the problems started with the exploration of the existing technologies in the field of agriculture and the investigation of several case studies demonstrating the profitability of such solutions. The visit of the Milan sub-team to the Agritechnica Fair in Hannover, the biggest fair about agricultural machines, was also useful to enrich the analysis. A panoramic of the structure and the properties of a typical vineyard (Veronesi, 2011-2012) was performed for understanding the challenges to overcome. For example, we understood that the small trees develop mostly on the vertical plane, allowing the detection of a greater amount of information using a ground vehicle instead of airborne one. Furthermore, the disposition of the rows (e.g. ritocchino and girappoggio) and, consequently, the slope can be fundamental factors in the choice of the level of mechanization.

Then, the literature on the matter was studied in order to have an insight on the reasons that lead to the diffusion or to the rejection of such technologies. What emerged is that the main drivers towards adoption are increases in productivity and reductions in the costs of the inputs, advantages whose importance is even bigger considering the current competition in the markets. Diffusion is delayed due to the need of costly investments and to the lack of an innovation culture in agriculture. For these reasons, adoption is limited to medium and big producers. However, diffusion is broader in viticulture more than in other kind of cultures due to the higher margins and to the high importance given to quality.

After this general overview about the market, the specific needs of the vine growers were identified by means of questionnaires and interviews. It was confirmed that the features that would make adoption easier are easiness of use and low investment cost.

Exploring the opportunities

Different technologies have been studied to maximize the quality, the sustainability and the efficiency of vineyards. According to Matese (2015), a wide range of sensors is applied in the two ways of monitoring: remote and proximal monitoring. The first alternative collects reflectance information from satellites or airborne systems (e.g. UAV platforms) using optical sensors such as hyperspectral or multispectral cameras. These cameras allow the acquisition of different electromagnetic spectral bands that can be combined for detecting the vigour and the photosynthetic activities of the plants. The second alternative allows the collection of detail information near the surface by a vehicle or an operator. Due to the development of low cost and open source technology applicable, this opportunity has become more and more common. The proximal monitoring includes: mechanical and electrical sensors that can detect properties of the soil, directly connected to the quality of the wine; optical sensors such as multispectral cameras and LIDAR sensors; fruit dendrometer to perform a non-destructive analysis of the percentage of sugar in the grape.

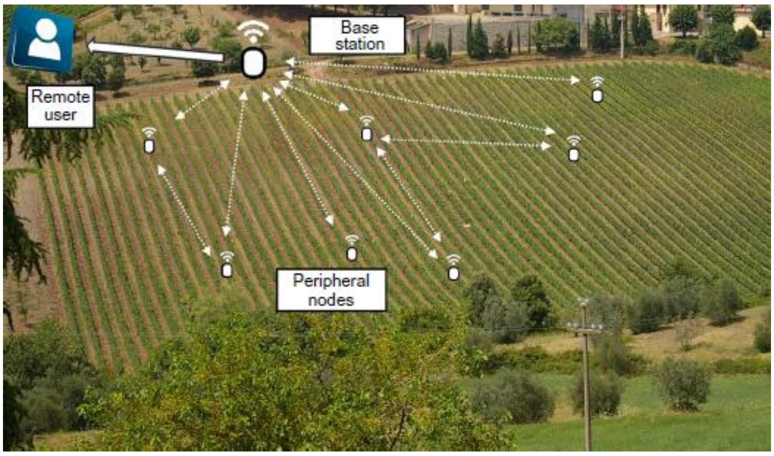

Figure: Wireless network sensors

In the last years, vehicles have been automatized and equipped with monitoring sensors to perform site-specific operations without human help. Even if the use of robotics in viticulture is still at the beginning of its life, new prototypes are on their way to become reality because of more investments on PA. However, the greatest limitation is still linked to the high cost of this technology.

In order to make easier the introduction of precision technologies in the Italian viticulture, the team started focusing on low cost sensors interfaced to a low cost single-board computer such as Arduino or Raspberry Pi. These sensors use the same system of data acquisition as the expensive ones already present in the market, reaching performance similar to theirs. For example, we understood that the same acquisition of multispectral images as done by the multispectral camera can be performed by two different cameras: a normal RGB camera detecting Red, Green, Blue bands and a NIR camera detecting Near InfraRed bands.

Generating a solution

Figure: Architecture of the service

Taking into account the state of the art and the main needs already described in the paragraphs above, we developed our solution for giving to the farmers a greater advantage in terms of quality and crop monitoring. We decided to use a rover travelling across the vineyards and equipped with cameras taking pictures of the vegetation. Images are post-processed to get a visual vertical map of the Normalized Differential Vegetation Index (NDVI) describing the health or the stress of the plants when it is not yet perceived by the human eyes. The first application of this information is to provide immediate alerts to the farmer against diseases or lacks of fertilizers. Moreover, by looking at the historical data, future actions can be planned to prevent the onset of complications.

The team developed a prototype of the rover in model scale 1:5, provided with all the sensors that would be mounted on the real one. The movement of the rover was controlled by Arduino board through an user-friendly interface on a computer or smartphone connected to the rover with a Wi-Fi system. The rover was equipped with rubber belts because of the type of traction needed to travel in irregular and sloped terrain and it was designed in terms of dimensions, positions of the payload and material to use. Moreover, a sizing of the fleet based on the autonomy and the average travelling speed was made. We chose optical sensors that can detect the sunlight reflected by plants in terms of visible bands (RGB Camera Pi) and near infrared bands (PiNoir Camera). Both cameras were positioned in a small box designed ad hoc on the top of a telescopic stick, adjustable to have the right height and inclination, and connected through a Multiplexer to Raspberry Pi board. In order to know exactly the location of each image taken, a GPS device was connected to Raspberry Pi and GPS raw data were post-processed to improve the accuracy in the localization. The GPS and the Raspberry Pi were put in a box designed ad hoc and located at the base of the rover in the back for balancing the weight of the motors in the front. A user-friendly interface was designed to start and stop the measurements.

Figure: The prototype (above) and details: GPS box (down left) and the camera box (down right)

The prototype was tested in a vineyard of Azienda Agricola Pecchenino to verify the ability of the architecture developed. The results satisfied the expectations: despite the harsh terrain and the high slopes the rover managed to overcome all difficulties without rolling over and limited vibrations. The RGB and NIR images of the vegetation were well superimposed and the NDVI mosaic showed values close to the maximum for all the plants, proving they were healthy.

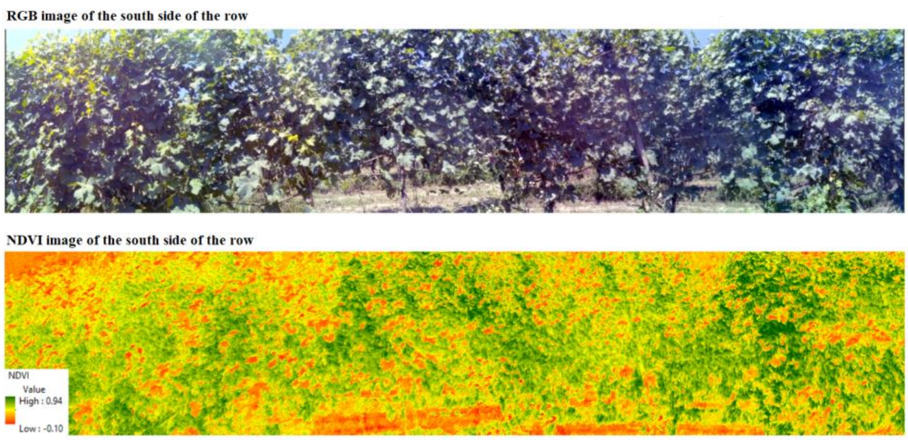

Figure: RGB image of the south side of the row (above) and corresponding NDVI image (below)

At the same time of the realization of the PV technology, the team considered three different business solutions representing how this technology could be sold in the Italian market: selling the rover, renting the rover and selling the service of vigour mapping. Due to the highest Net Present Value for selling the rover, this solution was adopted in the development of the Business Model Canvas.

Main bibliographic references

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