The use of smart sensors in viticulture

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Abstract

Over time, agriculture has gone through a series of changes and had to provide food for a growing population. The same can be said for *viticulture; production and standards have increased significantly. Climate change is causing crops to be repositioned and resized. These environmental changes also mean that new diseases are appearing, leading farmers to use different substances to save crops and achieve the desired yields. The study of smart viticulture in this paper aims to implement methods that will bring improvements in quality standards and production yield. This paper aims to present the research realised in the DISAVIT project, which uses agricultural, meteorological and air quality sensors along with data processing and modelling technologies. In the experimental part, sensors were positioned on plants, soil or machinery to collect and monitor data. These are then processed to extract useful information. Analysis of results is done to optimise the process, grow and cure the crop. Data is sent generating MQTT messages using Libelium Smart Agriculture Pro and an IoT device. In this study, an experimental part is also carried out to monitor essential parameters in viticulture. Data on air humidity, soil temperature and humidity, and solar radiation were analysed. It was found that most of the time the studied environment was optimal for crop growth. The presented study differs from other research due to the architecture presented and the experimental data interpreted in a different way. The architecture aims at both data collection, using appropriate sensors and stations, and communication of the data with a platform for storing and creating solutions for diseases.*

Keywords: *Smart Viticulture, IoT, sensing, vineyard*.

1. Introduction

Vineyards are an important economic factor in most countries. Geographically speaking, regions with temperate climates have the most vineyards. Europe is the continent with the largest area under vines (approx. 40%), with Italy, Spain and France contributing most [1]. Vineyards are mostly located in areas where water scarcity is a real problem. This is because of people's desire to grow necessary food in suitable areas [2]. Climate is a significant factor for yield, crop phenology and grape composition. In recent decades, several studies have shown that climate change has a significant impact on crops. For this reason, these changes are increasingly researched in order to find solutions. These changes can easily be monitored using crop models, which allow the consequences of changes in temperature, water supply or CO_2 levels to be visualised [3].

Soil microbiology can also be affected, involving the drought resistance of vines. Temperatures may change in relation to climate change, but this is not true in all regions. Temperatures have started to be higher during the ripening period, which can be significant in phenology and harvest quality. Evaporative demand contributing to vine transpiration and soil evaporation is increased by higher temperatures. Therefore, the soil water balance will be increasingly negative throughout the season.

This paper proposes a new IoT platform for viticulture. It is retrieved data on air humidity, solar radiation, and soil humidity and temperature. The data are interpreted to realize whether the environment is conducive to vine growth. With this data, new solutions for viticulture can be implemented and it can be monitored if it develops properly. The architecture of the project uses some of the most advanced technologies, consisting of several sensors and specially developed equipment for vineyard maintenance.

This study is structured in sections: Section II presents the state-of-the-art on IoT monitoring platforms and technologies for viticulture. In Section III, an architecture based on IoT technology for smart viticulture is proposed, highlighting the components used. In Section IV it is presented the experiments conducted and their final results. Section V summarizes the conclusions and remains open to new experiments related to monitoring.

2. Related work

For vineyard condition monitoring, remote sensing and proximal sensing sensors have become widely used. With their help, it can be observed plant health, water supplies, pathogens and environmental changes. This process is used to capture information that is needed in the process of growing and improving crops.

Vineyards face many environmental constraints, and climate change is exacerbating them. Lately, studies have focused on numerous experiments on the response of grapevines to biotic and abiotic stresses and it has been concluded that there is a certain tolerance. Marker Assisted Selection (MAS) [4] is an advanced technique to characterise this tolerance in detail. MAS can identify genomic portions that have resistance genes in vineyards. Using this method, pathogen resistance genes have been recorded in several varieties of genetic backgrounds as well as hybrids. Introducing genes from the wild into the cultivated environment vineyards is also possible using the MAS technique.

Wireless Sensor Network (WSN) [5] technologies are widely used in viticulture because they help to monitor the crop. They are a method for real-time monitoring of various parameters needed in wine production, but also for processing and transmitting data and alerts to farmers. In this study, the aim is to implement a WSN in which field images are captured by each sensor node. Then it uses image analysis to detect various leaf changes, which can indicate a range of diseases, pests or other deficiencies in the soil or air. When the symptom is identified, the farmer receives a notification.

A study [6] proposes an architecture for an M2M telemetry system. This architecture brings very low power consumption, is easy to handle, has a high life expectancy, is implemented for radio communications and integrates GSM, GPRS, 3G and UHF technologies. The software of this system is designed on an architecture that takes data from the Adcon gateway and then processes or visualises it. The system allows the user to measure, send and process parameters over large distances or specific areas for agriculture or meteorology.

The implementation of IoT solutions [7] in precision viticulture is strictly linked to the implementation of a WSN. The deployed application contains certain requirements, and for this, the structure, number and location of nodes must be done accordingly. The sensors will be installed in each node, but this is conditioned by climatic parameters. The sensor network must meet certain conditions to ensure the reliability and cost-effectiveness of the data.

A study [8] proposes an IoT solution that relies on DIY and open hardware. This method is very low cost and aims to monitor how IoT nodes are forming. The architecture of IoT nodes is introduced to describe logical and physical aspects. It aims to implement a modular design at the software and hardware level. 3G connectivity gives more control when the node is configured and allows it to adapt to other IoT scenarios. This IoT node is implemented in an IoT management platform, SEnviro connect. This generates alerts on vineyard diseases. It offers a self-contained solution in terms of connectivity and energy.

In precision viticulture, a study [9] has implemented a new method of crop monitoring. This experiment involved the installation of three platforms onboard a ship to take NDVI images of Italian vineyards using multispectral sensors. A spectral framework was used to determine similarity. It was found that in heterogeneous crops, low-resolution images do not capture the variability in the vineyard. Following the financial analysis, the Unmanned Aerial Vehicle (UAV) remote sensing platform was found to have the most advantages for areas up to five hectares. UAV is a technology that is increasingly used in viticulture because of the results it delivers. Its costs are low, it is very flexible in use, and it has a high spatial resolution.

3. Project solution

The DISAVIT project aims to provide an easy-to-use and low-cost solution for intelligent viticulture systems. It covers all phenological stages and provides strategic and operational applications for vineyards.

3.1. Architecture

The advancement of vineyard monitoring methods and the resolution of emerging The study is accomplished on specific conditions and sizes, location and technical data sets are taken into account. deficiencies is the main goal of the project.

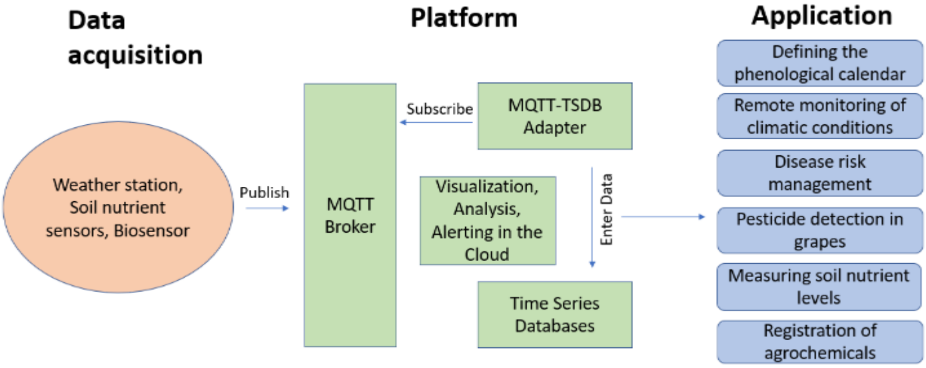

Fig. 1. Architecture of DISAVIT project

Data on water resources, air quality and soil condition will be carefully analysed. The platform will monitor diseases and create solutions to cure crops also, treatment plans will be created. Fig.1 presents the DISAVIT project architecture, which comprises three fields: Data Acquisition, Platform and Application. Their importance and composition will be described below. The project has been designed for both producers and consumers. The creation of crops with the highest standard is ideal in this study.

3.2. Device layer and targeted parameters

The sensing devices used in this project are based on the Smart Agriculture Pro platform, which includes various sensing probes.

This station is equipped with a probe that provides temperature, humidity and pressure sensors. The BME280 is a combined sensor for these parameters, and its detection is proven. The humidity sensor offers both high overall accuracy over a wide temperature range and a very fast response time. In the pressure sensor, the drastic noise is quite low. It is an absolute barometric pressure sensor that has extremely high accuracy and resolution.

The temperature sensor is also used in the experiments, as its output is used to compensate the temperature of the pressure and humidity sensors. When the sensor is deactivated, current consumption drops to 0.1 μA.

The station also features a leaf moisture sensor. Its resistance has an infinite resistance behavior, when condensation is missing. The output voltage can be observed at the analog input of the Waspmote ANALOG3, which is inversely proportional to the humidity on the sensor. The sensor can be powered on or off using the switch controlled by the ANALOG7 digital pin.

The solution uses the Watermark sensor, which is a resistive sensor consisting of two electrodes. These are embedded in a granular matrix and are highly resistant to corrosion. The resistance of the sensor is proportional to the soil water voltage. Three sockets for the Watermark sensors and the equipment required to power and condition the signal have been placed in the electronic board so that soil moisture can be measured at three different depths.

The soil temperature sensor requires a 3.3V power supply. The DS18B20 digital thermometer manages to record 9-bit Celsius temperature measurements. It requires a single data line for communication with Waspmote.

The Pt-1000 sensor has a resistance that varies between 920Ω and 1200 Ω. This can result in voltage variations that are too small for the Waspmote's analog-to-digital conversion resolution.

The SQ-110 sensor is specially calibrated to detect solar radiation. The output voltage is directly proportional to the intensity of light in the visible range of the spectrum.

For best readability, the output is via a 16-bit analog-to-digital converter, which communicates with the motor microcontroller.

The radiation sensor provides an output voltage proportional to the intensity in the ultraviolet range of the spectrum. The power supply is 5V and is controlled by a digital switch, which can be internally turned on and off by the library.

The brightness sensor is a light-to-digital converter that converts light intensity into a digital output signal. The device contains a broadband photodiode and an infrared photodiode, both on a single circuit. The photodiode currents are converted by two ADC integrators to a digital output representing the irradiance measured on each channel [10].

In addition to sensors, dendrometers are used in the data collection process. These are very precise instruments, an ideal tool for observing how much the plant is growing.

3.3. Network and Protocol layer

MQTT is a communication protocol that uses M2M connectivity because it is energy efficient. The main feature of this protocol is that it uses less energy than the HTTP protocol. This is very important in IoT applications, as the number of devices increases. This protocol was chosen for the DISAVIT project because, with its tools it can process and analyse data in real time, ensure reliability and robust energy efficiency in IoT devices [11].

3.4. Cloud layer

The system designed for DISAVIT collects data via sensors attached to the device, and the results are sent to the internet system. The information is to be processed in the Cloud, and the IoT provides a private web network. The Cloud architecture includes three main applications: Data analysis, configuration (sensor parameters can be changed), and monitoring (notifications are sent about the state of the crop and the environment) [12].

3.5. Application layer

The system designed for the DISAVIT project will monitor vine crops in real time in order to observe the health of the plants and prevent potential problems. An advanced dashboard was used to visualise and analyse the data, which also plays an important role in decision-making by sending alerts and notifications.

4. Experimental results

To obtain the data to be processed, a case study was carried out on a vineyard in the vicinity of Beia Consult International. Detection devices were installed in the soil and near the grapes. Sensors were used for this process, together with Libelium Smart Agriculture Pro hardware. The aim of this experiment was to detect the soil quality, but also the climatic changes that can affect the crops. Next, the evolution of the vines and the problems that can occur in the stem, root or fruit are monitored.

The variation of solar radiation is shown in Fig. 2. Solar radiation heats the ground as it reaches the surface. 30% of extraterrestrial solar radiation is reflected back into space, but about 51% is absorbed by the Earth's crust and waters, and another 19% is absorbed by clouds and the atmosphere. The Sun heats the Earth, conditions the evaporation of water, the formation of air currents and weather variations. In summer, direct radiation is higher, but in winter, when the sky is cloudy, diffuse radiation is higher [13]. The annual daily average is 2.75 kWh/m^2, so the soil was favorable for crop development most of the time.

Vineyards should not be planted in narrow valleys where cold air collects and stagnates. It yields well in areas with annual rainfall of 500-650 mm and air humidity of 60-70%. Observing that in Fig. 3, the air humidity has an average value of more than 50%, resulting that the development of the grapes was optimal [14].

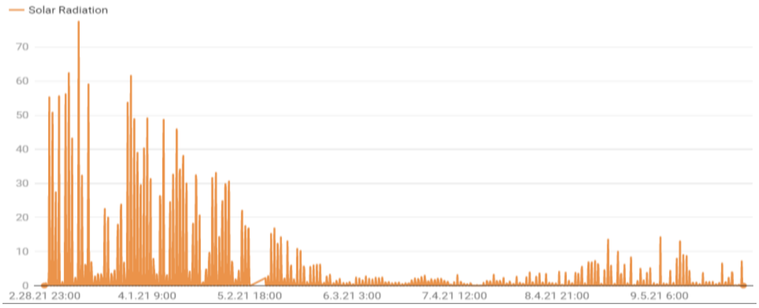

Fig. 2. Solar Radiation evolution between 28.02.2021 - 30.09.2021

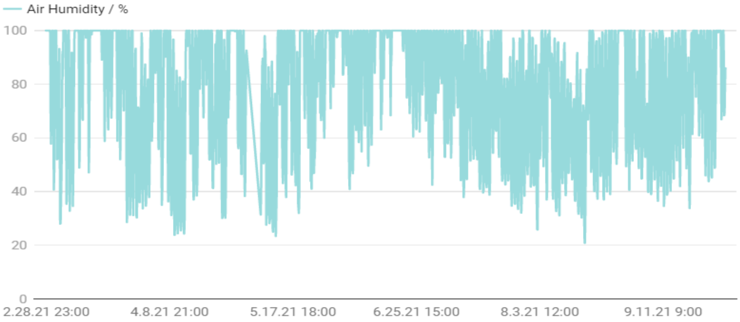

Fig. 3. Air humidity evolution between 28.02.2021 - 30.09.2021

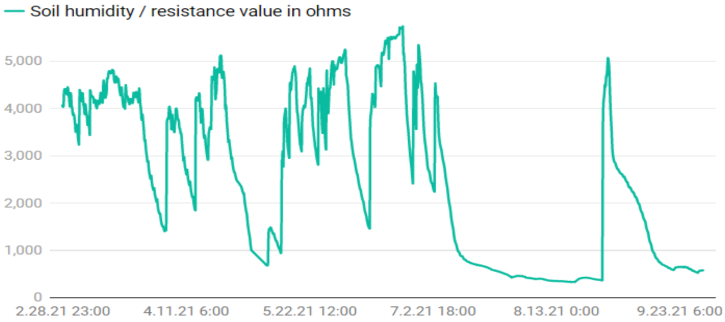

Fig. 4. Soil humidity evolution between 28.02.2021 - 30.09.2021

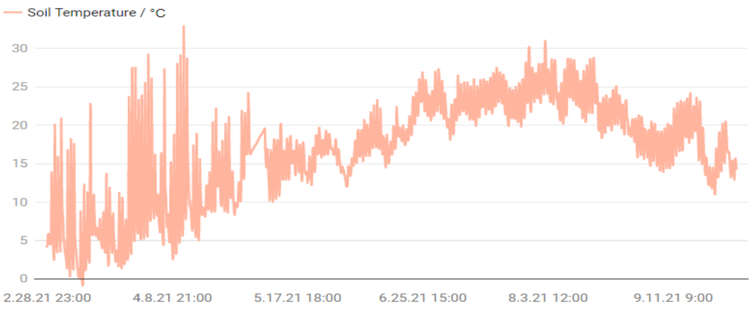

Fig. 5. Soil temperature evolution between 28.02.2021 - 30.09.2021

Fig. 4 shows the evolution of soil humidity. Soil and substrate moisture is the amount of water physically bound to the soil-substrate. Soil moisture is an essential parameter in crops. The optimum soil moisture for grapevines is between 50% and 80% of the active moisture range, with lower values considered favorable for berry ripening and higher values for shoot growth. Analysing Fig. 4, it can be observed that in the range of active humidity, values above 50% were recorded. However, there were also much lower values for grapes ripening.

The temperature determines the area under vineyards, the cropping system, the onset and timing of the growing phases, the quantity and quality of production. In general, vineyards are planted in spring as early as possible, when the soil temperature is 9-10ºC. Fig. 5 shows the soil temperature from February to September [16]. By analysing these experimental data, the paper can build a preliminary basis for vine crops. These values are useful in the process of increasing yield and quality.

5. Conclusions and future work

Viticulture has always been affected by climate change. Requirements and standards have also increased, and growers must therefore comply to stay in business. New technologies are being implemented to support the evolution of viticulture. The DISAVIT project aims to offer the possibility to implement cost-effective and efficient solutions to produce superior crops. Based on IoT technology, new methods of monitoring vineyards are proposed so that crops will be more protected, diseases can be prevented early, and grapes will be of higher quality.

In terms of devices, the proposed architecture is different from other solutions, using Smart Agriculture Pro devices, hardware platform and sensors from Libelium. At the network level, the Meshlium Gateway is used, which has storage capabilities, using an internal database, when the communication link cannot be achieved.

The experimental data was accomplished using the Libelium Smart Agriculture Pro station, mounted in a vineyard. The research team investigated and interpreted the data obtained. The performance of the devices used was also tested, but some of the sensors need to be integrated into the test bench for further case studies.

The future work proposes to develop an algorithm for the correct identification of events. The system should be self-configurable and autonomous. An accessible platform for people who are not in the specified field is also a consideration.

Acknowledgements

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