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Development of an Intelligent Decision Support System for Smart Viticulture

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Abstract**—**The Internet of Things (IoT) represents the best option for smart vineyard applications, even if it is necessary to integrate the technologies required for the development. This article is based on the research and the results obtained in the DISAVIT project. For Smart Agriculture, the project aims to provide a trustworthy, intelligent, integrated vineyard management solution that is based on the IoT. To have interoperability through the use of a multiprotocol technology (being the future connected wireless IoT) it is necessary to adopt an agnostic approach, providing a reliable environment to address cyber security, IoT-based threats and traceability through blockchain-based design, but also creating a concept for long-term implementations (modular, scalable). The ones described above represent the main innovative technical aspects of this project. The DISAVIT project studies and promotes the incorporation of better management tools based on objective data-based decisions, which are necessary for agriculture adapted and more resistant to climate change. It also exploits the opportunities generated by the digital services market for smart agriculture management stakeholders. The project's final result aims to improve decision-making, performance, and viticulturally infrastructure and increase real-time data accuracy and interoperability. Innovative aspects such as end-to-end solutions, adaptability, scalability, security and traceability, place our product in a favorable situation over competitors. None of the solutions in the market meet every one of these requirements by a unique product being innovative.

Keywords**—**Blockchain, IoT, smart agriculture, vineyard.

I. Introduction

AGRICULTURE represents one of the essential roles in people's lives and well-being; it is a process of producing food and a food source for both population and domestic animals. Over time, the climate has undergone changes that people have had to adapt to and implicitly adopt the solutions used to ensure food or water quality, both irrigated and used daily. [1] The health of soils and crops is essential, as it affects the quality and quantity of agricultural products. [2]

In 2018 the smart agriculture market [3] was evaluated to be worth USD 7.53 billion. By 2023 this is estimated to reach around 13.50 billion dollars at a Compound Annual Growth Rate (CAGR) of 12.39% between 2018-2023. The important factors that have a role in increasing the smart agriculture market include the adoption of advanced technologies in distinct agriculture applications such as precision farming and smart greenhouse.

Farmers or growers worldwide are increasingly adopting high-quality farming devices and equipment such as guidance and steering, sensors, yield monitors, display devices, and farm management software. Agricultural plants are sensitive to climate change because higher temperatures and changes in the rainfall area increase the chance of disease occurrence, leading to crop damage. The current advances of the IoT and Cloud Computing have led to the development of new, highly innovative and scalable service-based applications, including disease detection and pesticide management and detection in a variety of agricultural environments.

The IoT solutions have great potential in assuring the quality and safety of farm products. In the yield monitoring process, GPS devices and sensors contribute to measuring various yield parameters. Increasing demand for automation and control devices, the monitoring and sensing devices are the major factors that are likely to contribute to the growth of the smart agriculture market for hardware. IoT and AI- like methods are helping farmers and growers optimize crop yields and promote livestock health through remote monitoring and data-driven decision-making. Technologies like machine learning, satellite imagery, variable rate technology, and advanced analytics empower vine farmers to grow their income through higher crop yield and greater price control.

IoT platforms for precision agriculture can enhance the quality of the crops by real-time data acquisition, processing, and decision making [4].

The DISAVIT solution is a product for better environmental sustainability addressing a market featured by emerging technologies. DISAVIT will deliver an innovative IoT end-to-end solution for Smart Viticulture covering all phenological stages and most relevant strategic and operational applications for vineyards: plant health, pesticide detection, resource efficiency, grape quality, and maturation and global production. The system will integrate a good number of different sensors (climatic platform), satellite images, artificial intelligence techniques, machine learning, and blockchain technologies, for the processing and modeling of the collected data and their conversion in useful knowledge through the specific proposed intelligent applications.

This article aims to monitor weather conditions, agriculture parameters and air quality necessary for irrigation and detecting pesticides in Smart Agriculture and a Smart Platform to manage and operate the vineyard quality.

The rest of the paper is organized as follows: Section II

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presents the related work in IoT-based smart agriculture. In Section III, the technology used in this article is presented. Section IV outlines the proposed system. Finally, Section V concludes the paper.

II. Related Work

In [5], it was found that two different events occur so that during the day there is a much higher variability than during the night. A number of data reading sensors are used, which causes a significant decrease in battery power. In the above statements, smaller battery drops can be observed during the night compared to the day. Even if many sensors are used, they must be correlated with the needs of each client. It has been shown that during the winter the vine suffers due to the drop in temperature, especially at night, so it is necessary to have sensors that read the temperature permanently in order to be able to notify the grower. In vine crops the most important parameter is the creation of a map for growers and the installation of sensors for air quality, temperature, humidity, etc. to permanently monitor the condition of the crops. This map, in order to have as much accuracy as possible, should be divided into smaller areas, so the intervention time, in case of a natural disaster, would be quite short.

One of the most widely used methods of monitoring external factors is to use a libelium station that contains a waspmote. In addition to the sensors used by air temperature, humidity, atmospheric pressure, solar radiation, ultraviolet radiation, wind direction and speed, soil temperature, water supply from the soil, on this board can be installed certain sensors to help in the industry of wine such as: sensors for monitoring the fermentation process such as sugar level, alcohol, must temperature. What brings an advantage to this board is the fact that its charging is done through solar energy, using a photovoltaic panel. The centralization of data through a network of wireless sensors is done through nodes that permanently transmit data to a centralized server. The communication between the sensor network and the web server is based on the TCP/IP communication model that has a certain number of well-defined ports. All protocols and messages are encoded in C/C ++ language. These messages are changed to binary format, so security issues are avoided. [6]

One of the most common problems with vine crops is hail storms. Thus, in [7] an automatic umbrella is used to protect the culture from these catastrophic events. The system is divided into three sections. The first of these is represented by the electronic part for opening the umbrella, the second is the ability of the system to open only in case of a storm, being connected to the first part through a telecommunications network made by ZigBee Devices and the third part to the internet connection made with a WiMAX subsystem if we do not have a GPRS connection.

Previous studies have shown that digital technology and IoT sensing devices have a great impact on agricultural sectors. Reference [8] presents an open platform used to monitor the mildew disease for vineyards. The low-cost platform is designed to measure the parameters related to humidity, temperature and the amount of rainfall, which are involved in Goidanich’s model.

The Sense of Our Environment (SEnviro) platform [8] is an efficient and autonomous solution that uses the IP protocol for connection. The hardware part of the platform consists of: Sensors, Core (micro-controller, connectors, clock and memory), communication and power supply. Using all the sensors, the platform is able to make observations periodically, observations that are published to SensorThings API services, for example, through the Sensor Data Management (SDM). A good characteristic of the platform is that it can adapt to a new behavior following the received configuration. The main objectives of the platform are represented by taking and sending all the observations at every ten minutes and calculating the Goidanich model.

The model used to follow the mildew disease is the Goidanich model [8] which is based on the three phenomena (temperature, humidity and rainfall). The prediction of the infection is made following the “rule of three ten” that is useful to know the time when the plant starts to be affected. In order to apply this model to each SEnvio node, it used the fog computing paradigm. The first step of the algorithm is to estimate the amount of rainfall. When this quantity rises above 10 mm, the system calculates the humidity and temperature means, following to be used to define the percentage of mildew. Also, the system sends an alarm when the mildew percentage reaches the value of 100. The warning message is sent through the SMS-based service: SMS notification on the mobile phone. By using this type of service, the information reaches to destination.

III. Technologies

A. Cloud Computing

A smart vineyard system is designed to collect meaningful and actionable data about the humidity, temperature, leaf wetness, pressure, and different types of pollutants. The sensors are connected to the system, the system collects the data from sensors by a predefined interface, analyses the data and displays the results on a serial port terminal. The data are stored in the Cloud and it is uploaded to social media, where a private page is created on IoT. Cloud Computing supports applications with the necessary infrastructure, for example storage, platform, services, database and data analytic tools over the Internet to offer faster innovation, flexible resources, and economies of scale.

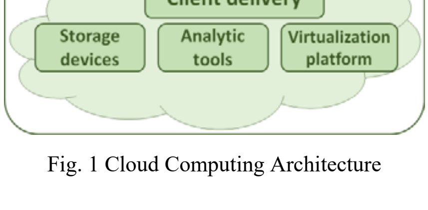

Fig. 1 Cloud Computing Architecture

In Cloud Computing Architecture (Fig. 1) many types of necessary applications and tools must be provided:

- Awareness application: to make the user aware about water quality. A smartphone may be used to notify the user when the water quality has exceeded a threshold.
- Control and management application: allow the water staff to control and change the rules of pumping according to the analyzed information about each zone.
- Big data analytic tool: analyze the collected data. The data will be collected for a period of time established by the end-user and analyzed in order to get better quality of water. This huge amount of data needs to be stored and analyzed, the IoT Cloud will provide the system with an efficient and solid infrastructure for the collected data.

B. Blockchain – Smart Viticulture Model

The proposed architecture [9] for the Smart Viticulture System is presented in Fig. 2. It will have the ability of Blockchain security. And each transaction made by the system will be tracked during the processes. This ability will not only provide security but it will also give privacy features. The smart devices are acting as nodes and each node has into its build a copy of the blockchain. If a user of the system wants to use it, then each node has to be verified before a transaction occurs (electronic voting). If the majority is considered valid, then each one of them will be recorded with a hash code in the blockchain structure. And each copy is sent further so it can be used in the system. The proposed system will be updated every 15 minutes, thus it will be impossible to be hacked and to forge the security system. Henceforth the requests of the received data from each device will be secured via Blockchain.

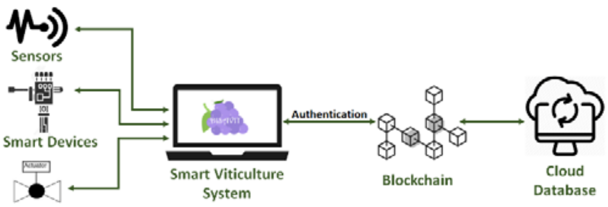

Fig. 2 Blockchain-based IoT Model for the smart viticulture system

C. IoT Devices

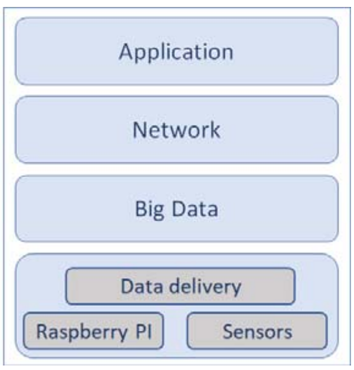

Fig. 3 IoT Architecture

The system is based on monitoring the grapes production, air and weather conditions for irrigation in Smart Viticulture by managing, operating the grape quality, and improving the operation of the smart agriculture network. The sensors network is connected to a cloud platform by means of a reconfigurable wireless transceiver and integrates several low-cost sensors that can measure different parameters.

IV. The Proposed System

In order to reduce the effects of disease on grapes and increase production in agriculture, irrigation is required for the controlled supply of soil with additional water quantities compared to those received under natural conditions, to ensure high and constant agriculture production. The system is based on monitoring the parameters for smart agriculture (leaf wetness, humidity of soil, temperature of soil), air and weather conditions for irrigation in Smart Agriculture by managing, operating the grapes quality. The sensors network is connected to a cloud platform by means of a reconfigurable wireless transceiver and integrates several low-cost sensors that can measure different parameters such as soil temperature, pressure, humidity of soil, pollutant from air (PM_{10}, $PM_{2.5}$, NO_x, SO_2, CO) and meteorological parameters. The measured parameters will be transferred through an operational communication node, which should be capable of ensuring reliable communication with timing and variation delay constraints.

The sensors must be able to perform self-configuration and calibration, and they have to adapt to these environment conditions. All this information is available in a cloud platform responsible for the collection of environmental data.

For the DISAVIT system architecture, the produced assets were used, such as conceptual model, specification, components interfaces and the design of the architecture, for guidance in the implementation of the techniques, methods and protocol. In Figs. 4 and 5 are presented the system architecture, respectively the functional diagram, including the Big Data based architecture and conceptually integrating the interoperability, security (IoT-based) and traceability supporting mechanisms.

The proposed methodology will move wine farming one step ahead in the efficiency and technification of wine production. The concern about the presence of pesticide residues in water, soil, and food has prompted the search for alternative methods able to detect low levels of these compounds in a simple way. Biosensors offer great advantages over conventional analytical techniques, including high specificity for real-time analysis in complex mixtures, high sensitivity, simple operation without the need for extensive sample pre-treatment, and low cost. Immunobiosensors which can provide concentration-dependent signals, appear to be appropriate for identification of a single pesticide or, in some cases, small groups of similar pesticides in environmental monitoring, as they are rapid, specific, sensitive and cost-effective analytical devices.

DISAVIT system integrates a good number of different sensors (climatic platform, satellite images, UAV, biosensors as well as an advanced analytical engine, including cutting edge artificial intelligence techniques, as machine learning, and blockchain technologies, for the processing and modeling of the collected data and their conversion in useful knowledge through the specific proposed intelligent applications.

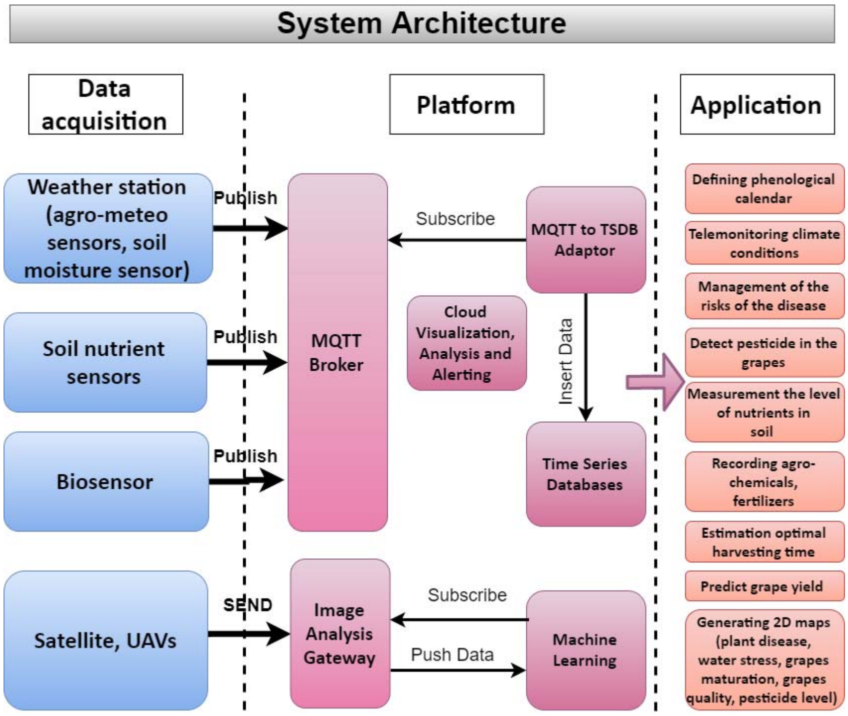

Fig. 4 DISAVIT System Architecture

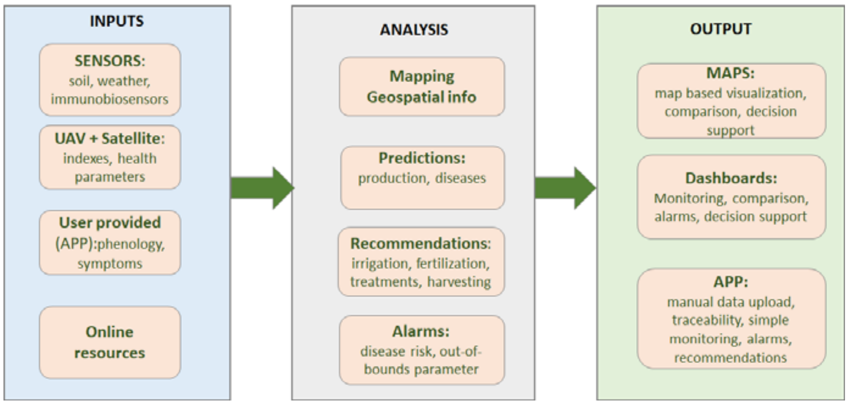

Fig. 5 Functional Diagram of the DISAVIT system

The data capture of the sensors is carried out by technologies linked to the IoT. To this end, data capture buses are implemented in real time to allow the disambiguation of the input data. This is achieved by applying the semantic interpretation to the data and allowing its linkage to the analysis entities to be defined. To achieve this capture, protocols such as MQTT are applied to ensure the entry of messages in the system. This information is routed by the messaging brokers. This messaging broker in combination with the real-time processing systems allows the analysis through the combination of different input variables. This information is stored in repositories which ensure the scalability of the system, allowing the application of distributed analysis techniques in large volumes of data. The analysis layer allows the computer processing implementation through Machine Learning libraries.

V. Conclusion

The article provided a trustworthy, intelligent and integrated water management solution for Smart Agriculture, Smart Viticulture that is based on the IoT. The solution has been demonstrated to be useful for smart environmental management, historical analysis and profiling, monitoring, cost-efficiency management, security considerations and environmental pollution detection.

The Decision Support System (DSS) is a software solution used by the farm manager for actions such as determining accurate spray timing based on Disease Models, performing protective irrigation based on timely Frost Warnings, and determining harvesting dates and insect development based on Growing Degree Days. But such site-specific action requires accurate and site specific data, delivered in near-real time to the farmer's desk.

At the hardware level, DISAVIT advantages are low-cost and reduction of the sensor size for water quality metering and less intrusive (by-pass solution).

To ensure a constant and high agriculture production, it is necessary to reduce the effects of pesticide on crops and increase production in agriculture.

Acknowledgment

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