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IOT AND CLOUD-BASED TECHNOLOGIES FOR EFFICIENT USE OF RESOURCES IN ALMONDS CROP

THE VERATECH PROJECT

Keywords:

Internet of Things, Precision Agriculture, Smart Agriculture

Abstract:

Efficient use of resources is a critical factor in almond crops. Technological solutions can significantly contribute to this purpose. The VeraTech project aims to explore the integration of sensors and cloud-based technologies in almond crops for efficient use of resources and reduction of environmental impact. It also makes available a set of relevant and impactful performance indicators in agricultural activity, which promote productivity gains supported by efficient use of resources. The proposed solution includes a sensor network in the almond crops, the transmission of data and its integration in the cloud, making this data available to be consumed, processed, and presented in the monitoring and alerts dashboard. In the current state of the development, several data are collected by sensors, transmitted over LoRaWAN, integrated using AWS IoT Core, and monitored and analysed through a cloud business analytics service. This project is implemented on a farm located in the Beira-Baixa region of Portugal and involves a partnership between Vera Cruz (owner of the farm), Veratech, and the Polytechnic Institute of Castelo Branco.

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1. INTRODUCTION

The competitiveness of today's global economy is increasing, which is also reflected in the agricultural sector. There is, however, a concern about the use of natural resources that cannot be neglected. As far as Portugal is concerned, the hydric resource is one of those that have been most debated, not only because of the current scarcity but also because of the forecasts for the future (Silva, 2021). The evolution of technology provides a new vision regarding how to monitor, control and increase production, making the most of available resources. Precision agriculture combines the use of technological innovations, the promotion of better working techniques, and the protection of the environment (Blasch et al., 2020; Thompson et al., 2019; Torbett et al., 2007). In this context, the Internet of Things (IoT) can play a very important role. It is a technology that offers solutions for the modernization of several areas, including agriculture, through the automatic management of production with less human intervention. This technology is associated with the use of various types of sensors, cloud computing, analysis of collected information based on intelligent and forecasting systems, as well as information provided by drones. This grants greater control of cultivated areas, and respective crops, having access to real-time monitoring, thus allowing early detection of problems, increasing production performance, reducing costs, and maintaining resources (Madakam, S. , Ramaswamy, R. and Tripathi, 2015; Singh et al., 2022).

Creation of a sensing network that encompasses plant status and vegetative evolution, soil nutrients, incorporation into critical farm machinery, data from weather stations complement the information to be collected, which are the goals of this project. Currently, multiple suppliers of monitoring and data generation systems, agricultural machinery, and image capture are in operation on many farms in the Beira Interior region. However, such systems operate in a non-integrated way, so that the potential of extracting intelligence from different sources is not exploited. In the market, there isn´t the desired level of integration, as well as the facility to group multiple and distinct types of sensors and generation of insights through the crossing of information and the storage of data, which by its complexity and multiplicity, is not being accompanied by processes that lead to decision support by farmers.

The almond tree is of great economic importance in Portugal. The consumption of almonds has been increasing, resulting from a healthy lifestyle habit and as food with many beneficial properties, that contributed to an increase in the production of around 34 % between 2009 and 2019 in Portugal. Due to favorable climate conditions, it is estimated that the production area will double by 2025, in line with the growth from 300-500 hectares to 10 thousand hectares from 2010 to the present day (agroportal, 2022; RTP Madeira - Economia, 2022).

Thus, a partnership between the Polytechnic Institute of Castelo Branco (IPCB), the company Veratech and the company VeraCruz, was formed to develop the VeraTech project, a technology that enhances production efficiency, sustainability, and the quality of the almonds produced. The VeraTech project aims to develop a set of relevant and impactful performance indicators (KPI) in agricultural activity, which promote productivity increases thanks to the correct rationalization of resources. The technology makes it possible to analyze unforeseen occurrences, helping to manage production more effectively based on information collected in real-time.

2. THE FARM - "HERDADE DO CARVALHAL"

The company VeraCruz produces almonds of Mediterranean varieties in the region of Beira-Baixa, Portugal. It promotes sustainable agricultural production and the efficient management of resources, based on Smart Farming. It has an area of 1,300 ha, divided into 5 farms in the municipalities of Fundão and Idanha-a-Nova, in Portugal. On these farms, VeraCruz has invested in technologies associated with precision agriculture, intending to make efficient use of resources and avoid waste. This study describes the implementation of the VeraTech project, which is being developed and implemented in the farm "Herdade do Carvalhal" (see Figure 1), in a partnership between VeraCruz, Veratech, and the IPCB.

Figure 1
Almonds crop - Herdade do Carvalhal.

At Herdade do Carvalhal, 4 varieties of almonds are produced (Soleta, Laurane, Penta and Isabelona) in a total of 330 ha (Planted area: 267.18 ha; Number of plants: 490,000 trees).

VeraCruz recently obtained GlobalGAP certification[1] (Which demonstrates food safety and sustainability in the production unit), being an important stage for its expansion in foreign markets. The company's objective is to reach export levels of around 80 %, with a strong focus on the English, German, French and Italian markets.

3. GOAL AND REQUIREMENTS

The VeraTech project aims to explore the integration of sensors and Business Intelligence in almond plantations for efficient use of resources and reduction of environmental impact. The research and development will focus on the establishment of indicators that generate higher productivity with lower consumption of resources, for a comparative almond plantation area. On the farm, there are 2 types of experimental fields: a 6 ha test plot and a 6 ha sample sensing plot, providing a greater soil and climate variability and, at the level of almond varieties, for research work.

1. https://www.globalgap.org/uk_en/

Another line of research is the evaluation of sensors and image capture formats that make up the set of probes that will be part of the project. That includes testing possible sensors for evaporation measurement, soil moisture sensors, flow measurement in drip irrigation pipes, drones for aerial image capture, smartphone, or mini-PCs for ground image capture, as well as meteorological sensors. Another goal is to promote the integration of this IoT sensorial universe, integrating them through a set of APIs, with the formation of a Big Data for the storage of sensorial data that generates intelligence reports, and feeds operational indicators with alarms.

It is also intended to develop a set of dashboards displaying all the indicators generated by the sensors in real-time. Also, historical data, in such a way that a group of administrators can analyze unforeseen occurrences and possibly feed the agricultural planning system so that actions can be adjusted according to the alarms generated.

The final goal is to validate the application in the almonds crop, answering questions currently being asked by the agricultural community of the Beira Interior region (and which in fact is transversal to the agricultural community in general), regarding the recent wave of digitalization of the sector:

1. Does the increased use of sensors impact productivity? Does it increase the quality of the almond trees?
2. Can the cross-referencing and correlation of indicators and use of business intelligence bring information that is relevant to the almond farm under consideration? Which are they? What new KPIs should be developed from these findings?
3. Do the experimental almond fields under study become more productive compared to the other blocks on the farms? And compared to patterns of almond trees in other regions?
4. Does intensive sensing and "real time" monitoring reduce the number of occurrences/interventions in unscheduled events? What about the same study with sampling sensing?
5. How much is saved in man-hour usage with this VeraTech Solution?
6. How much is saved in water resources use with the project? And how much is saved in the remaining externalities (production factors, energy, diesel, time, ...)?

It is intended to develop a model for capturing multiple data from different sources, so that, through Smart-farming, Precision agriculture, Real-Time Monitoring, and Business Intelligence can instill increases in productivity and optimization of resource use in the almond crop.

For the identification of operational requirements and needs, different criteria were considered. An important factor is the needs identified by the partners (VeraCruz and Veratech) since they will be the end-users and takers of the project's results. The partners' extensive experience was also considered. In addition, a series of requirements was carried out at the priority level, which makes it possible to establish, in the first phase, the main functionalities of the system. Based on the demands and needs for this specific target of application, for this system the functional requirements identified are:

- The system should allow registering of users and editing their personal data;
- The system should allow creating and validating indicators (KPI);
- The system should allow building of dashboards with direct and/or parameterized consultation, with the option to produce reports and the respective consultation;
- The system should generate alerts and allow users to consult them.

Under this system, the non-functional requirements are:

- Portability - Limitations regarding hardware and software on which the system will be implemented to promote ease migration;
- Security – blocking unauthorized access;
- Usability – Ease and accessibility in using the system.

After identifying these functional and non-functional requirements, a solution was designed to meet the intended objectives. In the following section, aspects related to the design of this solution are presented.

4. VERATECH SOLUTION OVERVIEW

The functional and non-functional requirements, identified in the previous section, and the characteristics of the farm, were considered for the specification of the solution to be developed. Thus, the technical requirements that must be satisfied by the solution were identified, as well as its architecture and main components.

4.1 Technical Requirements

Technical requirements were identified according to 4 main levels: sensing devices; communication infrastructure; integration, organization, and storage; and visualization and decision-support.

Sensing devices:

- Must have the ability to communicate using wireless technologies;
- Must have autonomy, without wires, longer than the duration of a harvest cycle (more than 1 year).

Communication infrastructure:

- Must allow coverage greater than the size of the homestead (a radius not less than 5 km);
- Must allow autonomy for several years;
- Must be robust and have strong interference protection;
- Must support at least 100 nodes and be scalable;
- Must ensure the protection and privacy of the data that is transmitted;
- Must ensure the transmission of data between sensor devices and the server.

Integration, organization, and storage:

- Must allow interconnecting devices and applications;
- Must allow the integration of hundreds of devices and must be easily scalable;
- Must support policies with individualized access permissions to devices and applications;
- Must support MQTT and HTTPS protocols;
- Must allow configuration of alerts and warnings;
- Must allow the integration of data from existing platforms, namely via HTTP;
- Must allow storage of at least 1TB;
- Must be scalable, in size and supported devices;
- Must provide access to the data using APIs.

Visualization and decision-support:

- Must allow creating and embedding graphs and dashboards in applications;
- Must support Business Intelligence and Machine Learning algorithms;
- Must provide predictions based on Machine Learning.

4.2 Proposed Architecture and Main Components

Considering the goals and requirements previously identified, a set of guidelines was identified for defining the architecture of the solution. The architecture must support the implementation of the solution that was specified in the previous section. Thus, it must include the installation of a sensor network in the almond's plantation, the transmission of data and its integration in the Cloud, and make this data available to be consumed, processed and presented in a monitoring, recommendation, and alerts dashboard and analyzed using Business Intelligence algorithms. Four main modules were identified, each of which includes several components (see Figure 2): sensoring, integration, KPI identification and generation and visualization and decision support dashboards.

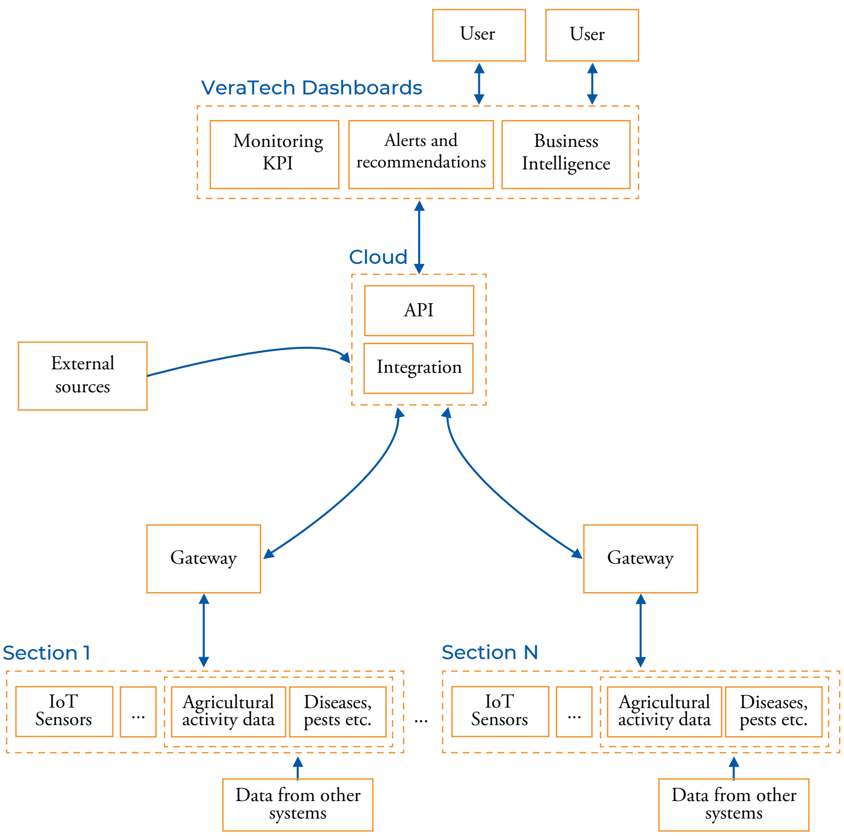

Figure 2

General architecture of the VeraTech solution (block diagram).

Sensoring: Develop a sensor system suitable for almond farms, but which, due to their versatility, can be extended to other agricultural crops. This module includes the evaluation of several distinct sensors and image formats. This includes, but is not limited to: evaporation measurement sensors, tree stem measurement sensors, light, soil humidity and temperature sensors, air humidity and temperature sensors, lux over the canopy and lux below canopy sensors, soil moisture measurement sensors, soil electrical conductivity sensors, flow measurement sensors in irrigation pipelines, aerial images captured using drones, and weather sensors. Regarding sensors and gateway, the architecture must allow the organization of equipment by sections of the farm. The specifications of the equipment to be used must guarantee communication compatibility with the infrastructure and with the integration layer.

Integration: The architecture must allow the integration of all data from the sensors and devices included in the "sensing network" in the farm. It should also allow the integration of various parameters from external data sources, such as data from farm machinery, data from weather stations, data from and pest and disease detectors, and data about the use of resources and on the characterization of production. This data must be integrated into a data model on the Cloud to allow scalability. Data is later accessed through API by the various application modules of the solution. This data model must be able to store the data and must allow continuous evolution.

KPI identification and generation: Develop a set of KPI with relevance and impactful on the almond's agricultural activity, that is, that promote productivity increases with a correct rationalization of resources.

Visualization and decision-support dashboards: Provide dashboards that allow displaying the values generated by the sensors in real-time. Also analyzes of historical data, so that unforeseen occurrences can be analyzed and possibly feed the agricultural planning system so that actions are changed according to the alarms generated. Build a correlation of multiple data, with real-time monitoring, creating decision support dashboards, with the incorporation of an alarm system with the occurrence of deviations. Using Business Intelligence tools, data will be prepared for analysis, so that reports, dashboards, and data visualizations can be created. These tools will support decision-making, helping to increase operational efficiency, identifying trends, KPI, and possible new opportunities for improvement in the almond crop process.

Validation: The proposed solution will be validated in an operational environment, by means of a comparative analysis between 3 types of experimental fields (a core plot, a sampling plot with sampling sensing and another plot with extended sensing). The KPI will be evaluated and validated in the almond fields throughout the cultural cycle, establishing a cause-effect relationship, an innovative and differentiating fact insofar as the multiple data derived from multiple sensors will be available in real time and correlated with each other.

4.3 Implementation Plan

The implementation of the VeraTech project includes five main activities:

- AT1: Requirements and specifications;
- AT2: Sensoring integration and Business Intelligence;
- AT3: Test and Validation;
- AT4: Project communication and dissemination;
- AT5: Project management and coordination.

Each activity is coordinated by one of the consortium partners, although the other partners also participate in its elaboration. Figure 3 illustrates the relationship between the activities and the partner responsible for their coordination.

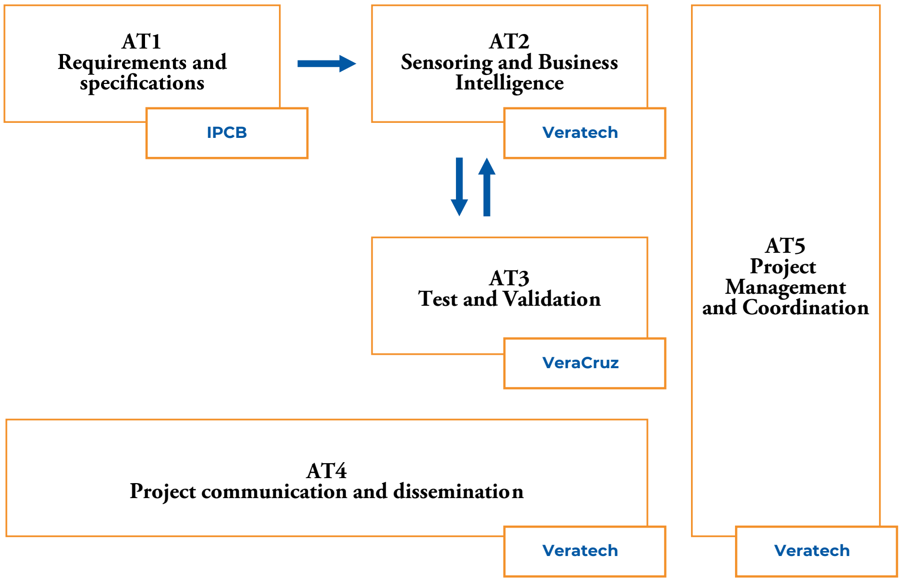

Figure 3

Implementation - Main activities.

The structure and organization of the VeraTech project activities are outlined in Figure 3. It includes two industrial research activities (AT1 and AT2). AT2 involves installing the sensor network on the VeraCruz farm, collecting, processing, and interpreting the data, and integrating it into a data model. AT3 involves testing and validating dashboards, implementing decision-support models, and comparative analysis between the 3 plots: one without any type of sensors, another with the installation of sensors by sampling, and a last one with extended sensing. Comparative tests will also be carried out with data from the region (regardless of the culture in question), as well as data and parameters of the almond culture in other geographical locations that may allow to obtain important relationships such as the relationship between productivity and the consumption of resources such as water, energy, production factors, pests and diseases, etc. This central work cannot exist without the prior development of requirements for the systems to be developed (AT1). AT4, transversal to the entire project, deals with the exploration, dissemination of results, and extensive communication of the project. The AT5 activity, also transversal to the entire project, encompasses the technical management tasks to guarantee formal cohesion and the good continuation of the project as planned.

4.4 Architecture and Technologies

Based on the system's block diagram (Figure 2) and considering the functional requirements (Section 3) and the identified technical requirements (Subsection 4.1), the services/technologies necessary to implement a solution were identified.

Data communication can be a challenge since farms are often located far from communication antennas, but LoRaWan (Long Range Wide Area Network) technology can be used to monitor farm assets and crop and livestock conditions. This technology is an example of the IoT or Smart Farming for agriculture and is used for a long-range wireless network to communicate and uses a license-free radio frequency that enables long-range transmissions with low power consumption. The LoRa gateways communicate with the nodes, receiving the data from the sensor devices and transmitting signals back to the sensor devices so they can be managed remotely, also to provide the data to the Internet. Thus, for the sensor network and for communication it was decided that:

- The sensor devices must have a LoRa interface that will allow them to communicate directly with the gateways using RF.
- The Things Network (TTN) will be used, a network communication infrastructure that allows the connection of LoRaWAN devices and gateways.

After a comparative analysis of the characteristics of various IoT cloud platforms, the AWS IoT Core platform was selected due to aspects of existing knowledge, market share and system sustainability in the medium and long term. AWS IoT Core is a managed cloud service that lets connected devices easily and securely interact with cloud applications and other devices. AWS IoT Core can support billions of devices and trillions of messages and can process and route those messages to AWS endpoints and to other devices reliably and securely (Amazon Web Services, 2022). Figure 4 presents the services proposed for the sensor network, communication, and integration.

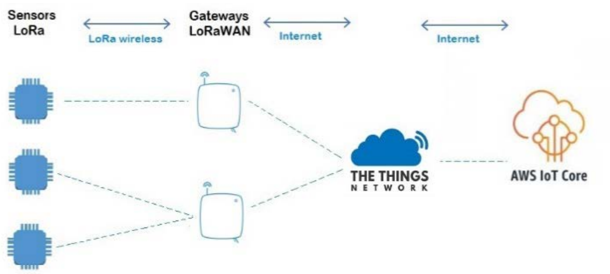

Figure 4

Integration of sensor devices, LoRaWAN and AWS IoT.

Figure 5 focuses on the technologies to support information integration and organization, visualization, monitoring, and decision support.IoT core rules and Node.js Lambda functions are used to process the data and insert it in an Aurora relational database management system.

Figure 5

AWS IoT Analytics to prepare data for QuickSight.

Amazon QuickSight is a cloud business analytics service. It is used to build dashboards and perform ad-hoc analysis. Datasets can be created from the Aurora DB to build personalized dashboards.

5. CONCLUSIONS AND FURTHER RESEARCH

This paper presented a case study that is under development in the scope of precision agriculture that combines the use of state-of-the-art technological innovations to support the decision-making for the promotion of better working techniques, promotion of better use of natural resources and the protection of the environment in the Beira-Baixa region of Portugal. This project is being implemented on a farm located in Fundão and involves the partnership of the company Vera Cruz (owner of the farm), VeraTech, and also of the IPCB. The architecture designed to solve the identified requirements, described in this paper, as well as the implementation of the solution is currently being implemented in the field. There are already several data collected by sensors located in the pilot sectors of this study. The results about the collection of data and their transmission over the LoRaWAN are consolidated. In the current stage of implementation, progress is being made with their treatment in the Cloud (AWS IoT) environment and in the design of dashboards that facilitated the activity of decision-makers who guarantee the management of the farm's agricultural activity. With this solution, the goal is to increase the productivity of plants and save important resources, such as water used in irrigation or optimization of fertilizer costs, among others. Since this is an agricultural production sector in expansion in Portugal, as mentioned in the introduction, it is expected that the designed solution can be used later on other farms with this type of crop, or similar, and implement innovative processes to the smart and precision farming industry.

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