Smart Agriculture: Continuous Plant Health Monitoring and Pathogen Detection with IoT and AI

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***Abstract*—The project, managed by the University of Messina, consists of an AI and IoT-based solution to provide farmers with cutting-edge tools and sensors capable of early identification of diseases and deficiencies (nutritional, water, etc.). Agrigeos's Plantarray is an innovative high-throughput phenotyping system designed to generate datasets on plant growth, both in the presence and absence of pathogenic contamination. SmartMe develops the specific sensors for this application. Data processing occurs at the edge level, where AI modules are deployed for prompt identification of phytopathological issues by analyzing growth data collected in the field, with specific reference to tomato cultivation. This important sector of the Made in Italy brand will be represented and managed by the partner Consorzio Ortofrutticolo Sud Est Sicilia, recognized as a productive district by the Sicilian Region (DOSES).**

Keywords—artificial intelligence, internet of things, plant health monitoring, pathogen detection, smart agriculture.

I. Introduction

The project is situated in a crucial context and addresses a diverse audience of businesses, focusing carefully on various key aspects. Italy represents 14.8% of the world's tomato production and 56.5% of Europe's, holding the top position after Spain, Portugal, and Turkey, with 6.6 million tons and over 6 billion euros in revenue. Italian tomatoes stand out in the international market for their quality and uniqueness, particularly the peeled tomatoes, an excellence of Made in Italy. The geographical location of the target enterprises has been strategically identified.

Fig. 1. Greenhouse tomato cultivation.

The decision was made to concentrate on greenhouse tomato cultivation (Figure 1), particularly involving the southeast Sicily area, which contributes about 30% of the entire national production. According to data provided by DOSES (Southeast Sicily Fruit and Vegetable District), tomato cultivation has been specifically affected by pathogens such as late blight (P. infestans), which alone reduced production by over 5% in 2022, having a significant negative impact on the southeast region of Sicily. This area is particularly important for fruit and vegetable production, generating a business volume of 200 million euros and representing a key sector of Made in Italy. The types of target enterprises include farmers, fruit and vegetable producers, and agri-food companies. These businesses play a fundamental role in the agri-food industry and face challenges related to plant disease management, with direct impacts on both the quality and quantity of production. Regarding the sector, the initiative primarily focuses on agriculture and the agri-food industry, where the presence of diseases can cause significant economic damage. The objectives of this initiative are closely connected to the needs of the target businesses, located in disadvantaged and relatively marginal areas. Agricultural companies, in particular, need advanced tools and innovative solutions to monitor the health of their crops. In southern Italy, over 60% of companies that cultivate tomatoes have an average revenue of 300,000 euros (Source CREA 2023). The need to promptly identify diseases and adopt preventive measures is crucial to ensuring the sustainability of agricultural operations and the quality of the products.

II. Case Study

The project aims to provide farmers with advanced tools to monitor plant health in real-time. A key objective is to develop a **predictive system** through the application of machine learning algorithms trained on the extensive dataset generated/generated by Agrigeos's Plantarray system. In this way, we intend to meet the critical need for timely and reliable information for managing diseases and deficiencies, contributing to the sustainability of agricultural operations. Specifically, the Plantarray can derive the following parameters: Normalized daily transpiration, Normalized stomatal conductance of the canopy, Water use efficiency, Stress level, Resilience rate, Theta crit (Volumetric water content in the pot where the plant begins to show stress), Air temperature, Relative humidity,

Photosynthetically active radiation, Barometric pressure, Vapor pressure deficit. Another crucial objective is the creation of customized artificial intelligence models for different crops and agricultural environments. This addresses the need for adaptable and specific solutions for various types of crops and environmental conditions, ensuring a personalized approach to plant disease management. The project objectives can be summarized as follows:

1. Study the growth of plants (particularly tomatoes) using Agrigeos's Plantarray to collect datasets related to the above-mentioned parameters with and without pathogens (late blight P. infestans).
2. Develop and train AI models capable of identifying the health status of tomato plants, with particular reference to late blight P. infestans.
3. Develop, with the support of SmartMe, next-generation sensors (Figure 2) based on Arancino [1] architecture capable of running AI models directly on board for the immediate identification of P. infestans attacks in greenhouse tomato crops.
4. Test the proposed solution in several companies in the Ragusa area specialized in tomato cultivation, among those gathered in the Consorzio Ortofrutticolo Sud Est Sicilia.
5. Extend and publicize the experimental results to a broad set of greenhouse tomato and wine grape cultivation companies operating in Italy.

III. Open Source Strategy

We adopt a policy of distributing our solutions based on open source principles. Making research results available under open models promotes transparency, accessibility, and widespread innovation. The open source strategy adopted is structured as follows:

- Publishing datasets related to tomato growth, with and without the late blight pathogen.
- Publishing hardware schematics of the sensor board.
- Publishing evolution of the Stack4Things [2] software and management system.
- Publishing AI modules.

Fig. 2. SmartMe next-gen sensor for the indoor monitoring of air parameters.

IV. AI Solutions

The project includes an artificial intelligence (AI) solution for monitoring and diagnosing diseases in tomato crops, based on the integration of advanced sensors and machine learning algorithms. This system will distinguish itself from traditional solutions by its ability to learn and dynamically adapt to environmental variations and the specific needs of the crops.

- **Objectives in Sensing and Data Collection**

1. **Implementation of IoT Sensors:** IoT sensors to monitor crucial parameters such as humidity, temperature, light intensity, and soil composition, in addition to specialized sensors for analyzing plant conditions.
2. **Advanced Data Processing:** The collected data are processed both at the edge and in a centralized system, allowing continuous monitoring and effective surveillance of the crops.

- **Objectives in Machine Learning Algorithms**

6. **Algorithms for Analysis and Interpretation:** We aim to create advanced machine learning algorithms capable of detecting patterns indicative of diseases or stress in plants.
7. **Innovation in Early Diagnosis:** The AI algorithms are designed to identify early signs of diseases, allowing for rapid and targeted interventions.
8. **Adaptability and Continuous Learning:** The algorithms will be continuously improved and adapted based on the collected data, increasing their accuracy and reliability.

- **Federated Learning**

The project adopts a Federated Learning approach to avoid centralizing all training data on a single server, as in traditional machine learning. Federated Learning allows training models directly on devices or distributed nodes, keeping the data local. This enables different agricultural companies to collaborate on model training without sharing sensitive data. Each company trains its AI model independently, sharing only parameters (not specific data). The updated parameters are then redistributed to the companies to further refine their AI models. This approach promotes greater diversity in training data, enhancing the system's robustness and effectiveness.

V. Conclusions

In this paper we presented and discussed the Smart Agriculture Project in Sicily managed by the University of Messina, Agrigeos and SmartMe. The project innovates the agriculture sector through advanced integration of AI technologies and sensor technology, contributing to setting new standards for efficiency, precision, and sustainability in the industry. Tangible objectives include: Customized Machine Learning Algorithms, Continuous Learning and Adaptation, Integration of Advanced Multispectral Sensors, Environmental Impact Reduction, Promotion of Plant Health and Biodiversity, Versatility and Scalability, Data-Driven Decision Making.

References

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