Integration of Information and Communication Technologies in Agriculture for Farm Management and Knowledge Exchange

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***Abstract*—The demographic growth of the last centuries has been followed by a demand for higher productivity of agriculture activities and an increase in the quality of farming products. Modern consumers seek quality by selecting foods containing high concentrations of healthy nutrients (e.g., antioxidants, vitamins, minerals) while also valuing eco-friendly practices and sustainable consumption. In line with the modern social needs, integrating Information Communication Technologies (ICT) solutions could assist in different levels of the agriculture lifecycle, such as crop monitoring, animal production, food safety, and farm management. Two aspects that are often neglected from many ICT solutions are the compilation of different data sources into the proposed software architecture and the facilitation of knowledge exchange between domain experts. In order to fill the gap of knowledge accumulation in this paper we take into consideration the PestNu architecture, as defined in section V that illustrates the different steps that are required for a complete data analysis life cycle into the development and deployment of the OpenHub platform. The OpenHub aims to cover the knowledge hub between experts with different backgrounds and promote the best practices from different users with hands-on experience.**

***Index Terms*—Green Deal, Farm-to-Fork, Education material, Knowledge exchange, Information systems, Information Communication Technologies, Smart Farming, Precision Agriculture**

I. Introduction

In the year 1800, the total population was 1 billion. In comparison, today has reached 7 billion [1] . The anticipation of farming products' demand rises to 70%, and will be doubled by 2050 [2]. Precision agriculture can address this challenge for the massive production of livestock products more sustainably [3]. The Green Deal and the Farm-to-Fork Strategy are two flagship initiatives from the European Commission aiming to improve animal productivity and the quality of products. However, the lack of available farmland, the limited access to water, the climate change, and, as mentioned earlier, the overpopulation jeopardize the overall sustainability of food production. To provide enough food for the growing population, producers have to enhance crop productivity per field unit. The agrotechnical landscape needs to be reshaped, including current agriculture systems and solutions. The introduction of modern technologies in agriculture brings new methods and practices to deliver innovative changes into cultivation and reform the typical procedures.

Traditional Decision Support Systems (DSS) often fail to efficiently visualize the incoming information [4] and offer enough data evidence, and integrity [5] indicating the need for complex data management tools and novel software approaches. This work presents the latest trends in precision agriculture, livestock production, and farm management. In contrast, it presents the PestNu software architecture, which combines data from different sources and the SmartRoot OpenHub, that has as a target to improve the interaction of experts with different technical backgrounds.

II. Trends in Precision Agriculture

Systematic crop monitoring can boost the transition from conventional farming practices to eco- friendly, flexible and practical solutions that will allow for carbon reduction. The later is in alignment with the Green Deal Strategy that remains a challenge for the agricultural sector. The strategy adopts an eco-friendly approach by utilizing renewable energy, circular economy, stopping climate change, reducing biodiversity losses, and cutting pollution. Adopting mixed farming systems that combine farming, livestock, and forestry could become a viable solution due to their low reliance on external inputs, enhanced nutrient cycling, and increased natural resource use efficacy [6]. Farming systems, irrigation practices, and soil analysis are the three innovation pillars in precision agriculture.

An **eco-friendly farming system** that gains popularity is the Conservation Agriculture (CA) [7] that promotes three primary principles:

- Continuous minimum mechanical soil disturbance with direct seeding, which fights against soil erosion and preserves soil organisms.
- Permanent soil organic cover with crop residues and cover crops, which allows the retention of a protective layer of vegetation on the soil surface to suppress weeds and protect the soil from the impact of weather and avoid soil compaction.
- Plant species diversification fosters a diverse range of soil flora and fauna that contribute to nutrient cycling and plant nutrition and prevent many diseases.

Similar, Regenerative Agriculture (RA) [8] aims at helping the soil heal from excessive production; as soil health improves, input requirements may decrease, and crop yields may increase as soils become more resilient against extreme weather events and harbor fewer pests and pathogens.

Water distribution methods play a crucial role in the adoption of eco-friendly practices. The most popular ones are drop-by-drop (drip irrigation) [9], [10], field-surface, and furrow irrigation [11], [12]. The field-surface method involves applying water on the entirety of the plot of land, while the furrow irrigation method applies water to the field from ditches or pipes. Finally, in drip irrigation, the water is placed on the roots of the individual plants, which automatically renders this method the most water-efficient one.

Soil analysis is the foundation for quality farm management, aiming to eliminate doubts about soil, farm, and crop management. Soil analysis is the practice of sampling soil that determines the exact amount of available crop nutrients, the overall chemical makeup of the soil, and its physical and biological properties. It provides accurate information such as the content of nitrogen, phosphorus, potassium, and other nutrients, average soil pH, organic matter, and the overall chemical, physical, and biological soil properties and makeup. State-of-the-art eco-friendly farm practices aim to improve soil organic matter by leaving crop residue on the soil surface, performing crop rotation with legumes, conserving tillage practices, adding organic materials such as manure, compost, sewage sludge manually, and avoiding soil compaction.

III. Livestock Production and Revised Practices

The conditions in which animals live and how animal products are manufactured affect the animal's quality of life. Healthy livestock can reach total production and becomes a nutritious and safe food supply for human consumption. Technological advances and the development of intelligent farming can enable vast strides in the efficient and economical generation of higher-quality animal foods and fiber products.

Precision livestock farming is a domain of agriculture that leverages technologies such as Artificial Intelligence (AI) in conjunction with Computer Vision (CV) and remote sensing techniques [13], [14] to elicit data to boost production, increase food quality, and enhance animal wellness. There has been a significant swift towards more efficient management and eco-friendly technologies. More specifically, IoT devices have shown conceivable concessions in dairy cattle farming for extended and trustworthy service since they have established a low cost in the market compared to traditional equipment (GSM, Radio Frequency). Considering that farms are extremely complex physio-chemical systems with highly interdisciplinary data sources, incorporating irrigation, fertilizers, diseases, drugs and invasions, livestock, feeding, watering, and disease management, accurate and timely data collection is required essence in terms of successful livestock management.

Modern Good Veterinary Practices (GVPs) recommend that all animals should be inspected and handled correctly before and after slaughter and use various temperature controls, storage, shipping maintenance, and meat handling to avoid post-slaughter contamination. The adherence to GVPs in the production of primary food crops allows for a level of assurance that the consumers' food meets the quality and safety standards at the time of the slaughter.

IV. Farm management

Farm management brings a fresh perspective on all types of farm machinery, from soil management sensors and sowing machines to satellite imagery and farm management software [15], [16]. In other words, while growing crops, a farmer should manage farm production according to recommended farm activities and regularly record them for all crops and farm materials. In the last two decades, the agricultural sector has encountered multiple challenges. However, the majority of farmers utilize traditional practices that cannot cover modern challenges. Blind trust in the traditional methods is possibly not the best practice, which means high-production losses and low business opportunities. The continuously discerning of neglect or even descending profits lead farmers to minimize or give up their businesses.

The farmer must complete several farm activities to bring the most satisfactory results. These activities include: soil preparation, crop planting or sowing, plant care management, harvest, and post-harvest management. Because farming is a complex process in which each activity contributes to achieving a shared objective, all activities must be appropriately managed. Therefore, a farmer should manage farm production according to recommended farm activities and keep track of farm activities for all crops as well as the use of farm materials while growing crops. Certain farming practices are required for each crop. Following and recording these practices offers a farmer a detailed picture of his crop's production.

Leveraging ICT systems, such as farm management systems and knowledge hubs, is feasible to connect and communicate with people with different backgrounds and expertise. This action leads to inter-connectivity between farmers, veterinarians, chemists, and agronomists to share information, comment on issues, and give possible solutions. The aggregation of individual solutions provides the chance to discover the most optimized solution to support their economic sustainability and confidence for continuous improvement.

The heterogeneity of the available resources, from aerial images to ground temperatures, and the plethora of the crops that are cultivated create a challenging environment for farm

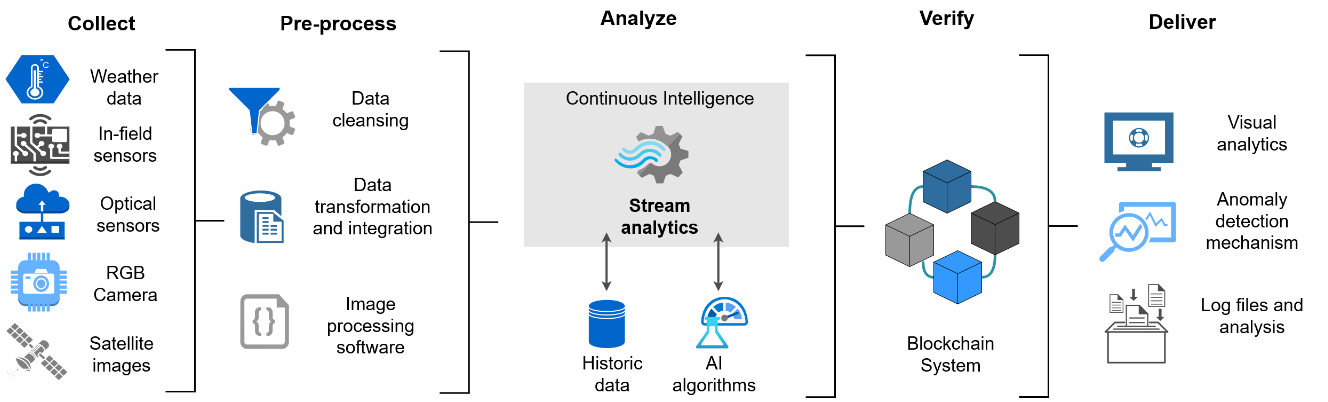

Fig. 1. PestNu data stream conceptual architecture

management systems. There is the need for both end-to-end farm management pipelines and the need to develop collaboration platforms where stakeholders with different backgrounds can cooperate having a mutually beneficial relationship.

V. Proposed Solutions for Smart Farming

Agricultural and veterinary experts possess domain expertise, but they lack the technical knowledge to automate their tasks and accelerate their business using ICT solutions to monitor animals or farmlands, make decisions based on aggregated data and accelerate decision-making processes. Decision-making is vital in improving productivity and ensuring food safety, animal welfare, and efficient use of resources. ICT for agriculture (ICTA) has grown considerably over the past decade and now plays an essential role in developing new farming techniques, precision agriculture, and improving existing processes. The PestNu architecture illustrates the integration of different data sources into one DSS, while the OpenHub knowledge exchange platforms bridges the knowledge gap between ICT experts and agriculturists.

A. *PestNu Architecture*

The PestNu architecture aspires to address the modern challenges that the climate change brings and proposes an end-to-end scheme covering every step of the farm management from data collection to the visualization of helpful information. PestNu core concepts are based on reducing the use of fertilizers and pesticides while aiming towards zero pollution of water, soil, and air, following the Farm-to-Fork and Green Deal strategies. More specifically, it combines an eco-friendly pesticide management system, novel digital and space-based technologies, and agro-ecological and organic practices.

Figure 1 illustrates the PestNu conceptual architecture. It is divided into five zones, data collection, pre-processing operation, continuous analysis, data and models verification, and presentation of the results. The proposed architecture has the capabilities to collect data from different resources, including AI robotic traps, autonomous self-navigating robots for pesticide monitoring, satellite images, and in-site solar radiation sensors. The pre-processing component follows a distributed architecture with edge nodes processing the different types of data locally, including data cleansing, transformation and integration, and image processing. The core processing component is a user-centric cloud-based farm management system enabling different AI algorithms and exploiting historical data into the stream analytics engine to achieve continuous intelligence on the status of the farm management system. An innovative approach that is followed in PestNu is the integration of a blockchain component to verify the integrity of the incoming data. Finally, the results of the deployed algorithms are presented, while the visual analytics offers an overview of the system's status.

The PestNu architecture is based on the concept of systematic innovation, combining existing tools and solution into an end-to-end architecture that removes existing technical barriers. The data fusion mechanisms alongside with the visualisation dashboard provides a comprehensive view for the status of both the farm and the network while covering security and privacy aspects with the deployment of security middleware and blockchain system. The proposed architecture will be deployed in different production systems, such as aquaponics and semi-closed hydroponic greenhouses. Additionally, under different conditions, soils, and crops, open-field vegetable cultivation will also be tested. Overall, its component-based architecture allows the system to be modified and extended according to the needs of the different use cases.

B. *OpenHub Knowledge Exchange Platform*

The SmartRoot OpenHub (https://openhub.smartroot.eu/) is a knowledge exchange platform aiming to motivate and connect people to exchange their valuable knowledge in the context of mixed farming systems. The platform intends to foster collaboration between experts such as software engineers, farmers, agronomists, and veterinaries through a modern and straightforward web interface.

More specifically, the platform includes administrators and regular users; administrators are selected users who have unique privileges within OpenHub. They are responsible for monitoring all of the activities within this platform and per-

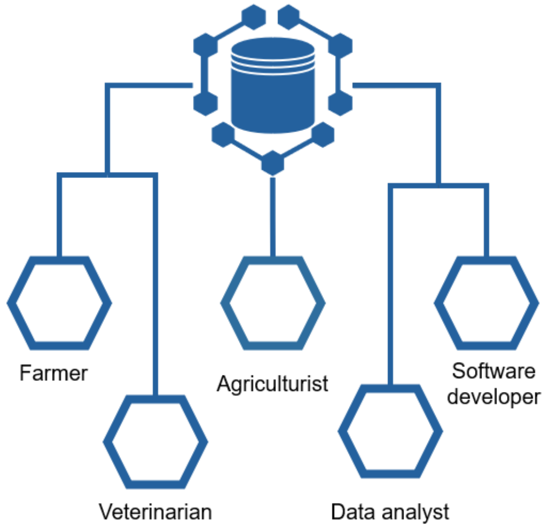

Fig. 2. SmartRoot OpenHub concept

forming actions to ensure that OpenHub offers high-quality, up-to-date information and educational material. Regular users are separated into two categories: experts and stakeholders. The capabilities of each regular user subcategory are equivalent due to the social media-like nature of OpenHub. The expert user is an individual who joins OpenHub for problem-solving and knowledge-sharing purposes. According to their profession and expertise, experts may fall under the ICT, agronomist, or veterinarian category, and they desire to contribute to the community with their knowledge. On the other hand, a stakeholder user is an individual who joins the platform to gain knowledge, ask questions, and receive domain-expert support. For example, stakeholders may be farmers or breeders seeking help and information about good practices in mixed farming systems. The platform's features include access to wiki pages, information search capabilities, and participation in the platform's forum.

Additionally, the OpenHub platform offers social media capabilities allowing them to join groups, add friends, and chat in real-time using the built-in messaging feature. The user's engagement with the platform will result in a more tailored news feed and, eventually, a personalized experience. All users can update their profiles and change their personal and contact details.

Figure 2 illustrates the concept of the platform exchange platform. The expert users contribute according to their knowledge to the hub while also having access to the information that could expand their knowledge.

VI. Conclusion

The rising challenges in the field of agriculture require a cross-discipline approach while they dictate the use of ICT tools in every step of the agriculture process, from data collection and manipulation to visual analytics and AI algorithms. However, with the deployment of new advanced equipment, more and more farmers require a scheme of guidelines to reach maximum profit and productivity. The solution to this problem is ICT platforms, which facilitate farmers to ask and learn more about their problems from experts. More research and innovation are needed to maintain our learning level while still supporting the agricultural needs of our economy. Knowledge exchange is imperative to improve the agriculture sector and enhance farmers.

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References

[1] M. Roser, H. Ritchie, and E. Ortiz-Ospina. World population growth. [Online]. Available: https://ourworldindata.org/world-population-growth
[2] G. Kakamoukas, P. Sarigiannidis, A. Maropoulos, T. Lagkas, K. Zaralis, and C. Karaiskou, "Towards climate smart farming—a reference architecture for integrated farming systems," in *Telecom*, vol. 2, no. 1. Multidisciplinary Digital Publishing Institute, 2021, pp. 52–74.
[3] A. Lytos, T. Lagkas, P. Sarigiannidis, M. Zervakis, and G. Livanos, "Towards smart farming: Systems, frameworks and exploitation of multiple sources," *Computer Networks*, vol. 172, p. 107147, 2020.
[4] A. Protopsaltis, P. Sarigiannidis, D. Margounakis, and A. Lytos, "Data visualization in internet of things: tools, methodologies, and challenges," in *Proceedings of the 15th International Conference on Availability, Reliability and Security*, 2020, pp. 1–11.
[5] K. Demestichas, N. Peppes, T. Alexakis, and E. Adamopoulou, "Blockchain in agriculture traceability systems: A review," *Applied Sciences*, vol. 10, no. 12, p. 4113, 2020.
[6] G. Kakamoukas, P. Sariciannidis, G. Livanos, M. Zervakis, D. Ramnalis, V. Polychronos, T. Karamitsou, A. Folinas, and N. Tsitsiokas, "A multi-collective, iot-enabled, adaptive smart farming architecture," in *2019 IEEE International Conference on Imaging Systems and Techniques (IST)*. IEEE, 2019, pp. 1–6.
[7] P. R. Hobbs, K. Sayre, and R. Gupta, "The role of conservation agriculture in sustainable agriculture," *Philosophical Transactions of the Royal Society B: Biological Sciences*, vol. 363, no. 1491, pp. 543–555, 2008.
[8] L. Schreefel, R. Schulte, I. De Boer, A. P. Schrijver, and H. Van Zanten, "Regenerative agriculture–the soil is the base," *Global Food Security*, vol. 26, p. 100404, 2020.
[9] S. Dasberg and D. Or, "Practical applications of drip irrigation," in *Drip irrigation*. Springer, 1999, pp. 125–138.
[10] FMS. Drip irrigation: The pros and cons. [Online]. Available: https://farmmanagementsystem.com.au/2020/02/03/drip-irrigation-the-pros-and-cons
[11] E. Holzapfel, J. Jara, C. Zuniga, M. Marino, J. Paredes, and M. Billib, "Infiltration parameters for furrow irrigation," *Agricultural Water Management*, vol. 68, no. 1, pp. 19–32, 2004.
[12] L. Krutz, "Pipe planner: The foundation water management practice for furrow irrigated systems," *Mississippi State University Extension Service: Starkville, MS, USA*, 2016.
[13] A. Triantafyllou, P. Sarigiannidis, S. Bibi, F. Vakouftsi, and P. Vassilis, "Modelling deployment costs of precision agriculture monitoring systems," in *2020 16th International Conference on Distributed Computing in Sensor Systems (DCOSS)*. IEEE, 2020, pp. 252–259.
[14] A. Triantafyllou, P. Sarigiannidis, and S. Bibi, "Precision agriculture: A remote sensing monitoring system architecture," *Information*, vol. 10, no. 11, p. 348, 2019.
[15] G. Amponis, T. Lagkas, P. Sarigiannidis, V. Vitsas, and P. Fouliras, "Inter-uav routing scheme testbeds," *Drones*, vol. 5, no. 1, p. 2, 2021.
[16] G. A. Kakamoukas, P. G. Sarigiannidis, and A. A. Economides, "Fanets in agriculture-a routing protocol survey," *Internet of Things*, p. 100183, 2020.