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Monograph

Ag-Internet of Things for Crop and Environment Monitoring: Present and Future

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Introduction

Crops are essential for human life because they provide food, animal feed, fuel, and raw materials for clothing and shelter. Crop yield has to be doubled in 2050 compared to 2009 in order to meet the demand of a growing population while increasing the food quality and reducing production inputs. Potential solutions to enhance global food security include closing crop yield gaps, reducing food waste, changing dietary habits, and reducing inefficiencies in resource use. Reducing inefficiencies in input resources (such as water and nitrogen) can be achieved by continuously monitoring crops, soil, and microclimate, and then properly controlling inputs without sacrificing the yield and quality of the crop. Internet of Things (IoT) becomes a key technology that enables continuous monitoring and control in the present scenario. There has been a boom in IoT application development in agriculture. Ag-IoT has evolved in the last two decades, particularly in the crop, soil, and microclimate monitoring. However, the application of Ag-IoT at the commercial scale is still at its early stage. A deeper and more holistic understanding of the existing IoT system development is important for various stakeholders to sketch the future landscape of Ag-IoT. Though Ag-IoT is proliferating in both crop and animal monitoring and management, IoT platforms for livestock production, as well as other sectors of agriculture (such as postharvest) are included. In the future, these technologies will allow improving productivity through the sustainable cultivation of food, as well as to take care of the environment, efficient use of water and the optimization of inputs and treatments. IoT technologies allow developing systems that

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support different agricultural processes. Some of these systems are remote monitoring systems, automated irrigation systems, frost protection systems, fertilization systems and decision support tools etc.

IoT Applications in Agriculture

The main applications of IoT technologies in agriculture are found in precision agriculture whose architecture includes IoT techniques for urban agriculture and precision agronomy in smart cities. Another area of IoT application is the intelligent greenhouses which includes hydroponic and small-scale aquaponic systems. Intelligent greenhouses are progressively more common in urban areas because they allow monitoring several parameters of nutrient solutions, as well as to improve the growth, yield, and quality of plants. Other applications of the IoT are the agricultural drones which are relatively cheap drones with advanced sensors that give farmers new ways to increase yields and reduce crop damage, among other things. These improvements contribute significantly to the achievement of smart cities with infrastructures that allow automating, optimizing and improving urban agriculture and precision agronomy. Another area in which IoT technologies are practically applied is the vertical agriculture, which allows controlling soil moisture and water content by means of computers or mobile devices such as tablets and smartphones. Finally, there are applications that combine IoT technologies with Artificial Intelligence such as Malthouse, which is an Artificial Intelligence system that allows prescribing configurations and schedules in precision farming and food manufacturing areas.

IoT-Based Software Applications Used in Agriculture

IoT-based technologies have been successfully adopted in various contexts. Due to this fact, several companies are investing in IoT-based software development for agriculture. Nowadays, there are a number of software products available in the market focused on supporting different agricultural processes. For instance, AG-IoT is an unmanned aerial vehicle that locates and assists IoT-based devices available on the ground to form groups for the transmission of data. On the other hand, Agro 4.0 implements high-performance computational methods, a sensors network, cloud computing, connectivity between mobile devices and analytical methods to process large volumes of data and provide decision support systems. Agro-Tech records, stores, and updates the data obtained from various sensors accessible in a specific area of the crop. Also, this software allows farmers to access this information aiming to monitor their crop. There are many agricultural monitoring systems that transmit live video to carry out such process remotely through IoT-based devices that integrate cameras and Raspberry Pi cards. On the other hand, Cropx is an adaptive irrigation software tool that allows farmers to boost crop yields at the lowest cost possible, as well as saving energy and water. Farmlogs is a farm management software that allows registering activities related to the conservation of crop

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through images and Mbegu Choice is an application that allows farmers to select the best drought tolerant seed suppliers.

Why invest in IoT for agriculture?

IoT agricultural applications already exist in the market places which are enabling farmers and ranchers to virtually connect their operations, collect meaningful data, reduce costs, and increase production. New technology like sensors require these wireless networks to operate, enabling farmers to collect data and analyze it to operate more efficiently and effectively. Additionally, drones are being deployed to assess crops and fields, collecting and transmitting additional data, in real time.

- Agriculture in urban and rural areas taking advantage of hardware and software resources and large amounts of data.
- Logistic and qualitative traceability of food production that allows reducing costs and the waste of inputs through the use of real-time data for decision making.
- Generation of business models in the agricultural context that allow establishing a direct relationship with the consumer.
- Crop monitoring that allows reducing costs as well as the theft of machinery.
- Automatic irrigation systems that work according to temperature, humidity, and soil moisture values that are obtained through sensors.
- Automatic collection of environmental parameters through sensor networks for further processing and analysis.
- Decision support systems that analyze large amounts of data to improve operational efficiency and productivity.

Artificial intelligence in Ag-IoT

Techniques that facilitate machines to mimic human behavior are artificial intelligence (AI), while a subset of AI that gives machines the ability of learning without being explicitly programmed is machine learning. Deep learning techniques are a subset of machine learning techniques with multilayer neural network feasibility. The data generated from the Ag-IoTs are often used to train machine learning models for specific agricultural use cases such as yield forecast, crop stress detection, and pest spreading prediction. To be more specific, for the agricultural IoT applications, raw sensing information such as field and weather conditions

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and crop status can be collected and used for model training locally or in the remote end that has more computational resources. These trained models can later be used to control actuators for variable rate irrigation and site-specific pesticide/ herbicide applications. Deep learning techniques are heavily used with image processing applications in agriculture. Trained deep learning models are available for crop type detection, fruit, flower, plant phenotyping, and leaf detection and weed detection for herbicide applications. Artificial intelligence becomes an integral part of IoT due to its capability of using it as a data analytics tool.

Ag-IoT for farming systems analyses and management

Modern Ag-IoTs take measurements at hourly and sub-hourly intervals. This high temporal resolution data allows us to observe the crop responses to environmental cues at finer time steps, and enhance our understanding on how basic plant physiological processes such as transpiration and photosynthesis vary due to short-term environmental fluctuations. Process-based crop and soil models, which are widely used to evaluate the economic and environmental consequences of farming practices, usually experience from the lack of site-specific data to parameterize and calibrate them, especially in-seasonal crop data and data related to soil moisture. These data are exactly what Ag-IoT sensors are good at generating and therefore would improve the accuracy of these models for farm-level management assessment. Networked sensors and actuators of Ag-IoT, along with the real-time data processing, transmission, and modeling, would significantly improve the decision-making cycle of farm-level management practices. Ag-IoT has the potential to transform farm-level decision-making by enabling multi- inputs, multi-outputs decision strategies, powered by real-time data processing and relevant models run in the cloud to shorten the latency. For example, soil, crop and microclimate sensors can simultaneously measure the crop water and nitrogen status, soil moisture content and nitrate content, and weather variables. These multi-source inputs can be fed into the models to output two variables: a water sufficiency index and a nitrogen sufficiency index.

Conclusions

Ag-IoT is a promising technology that would increase resource use efficiency in agricultural systems and is an indispensable tool for digital agriculture transformation. Furthermore, crop macro and micronutrient demand analyses are still at the infant stage due to the non-availability of sensors that can measure nutrients in real-time. Therefore, it is essential to improve the sensor and actuator applications in crop monitoring and controlling. In addition, heterogeneity of the system parameters is a major challenge to the Ag-IoT systems implementation, to which the improvement of the context- awareness could be a answer. Power harness options for Ag-IoT nodes require more exploration as there are limited options available and it would be a big advantage for the perennial crop monitoring.

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