INTEGRATING IOT INTO AGRICULTURAL OPERATIONS TOWARDS THE INDUSTRY 4.0 AND SUSTAINABILITY

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Abstract. Industry 4.0 is a trend that is expected to have major impact on the transformation of all industrial sectors. Since agriculture is probably the most essential sector of the primary industry, facing the challenge of ensuring food security with regard to sustainability, it is significant to integrate the technological advancements that emerged in the context of Industry 4.0 within the agricultural operations. This paper presents an approach of facilitating agricultural operations by employing an IoT based system, capable of delivering a variety of operational services.

1. Introduction

The Industry 4.0 concept, which was originally introduced by the German National Academy of Science and Engineering [1], represents a prominent trend expected to significantly affect the modernization of all industrial sectors [2] by promoting a framework for the integration of the entire production process into a "smart" digitalized environment. In this sense, since agriculture is a major sector of the primary industry, it is essential to launch the Industry 4.0 technological advancements into agricultural operations, in order to address the excessive challenge of ensuring food security for the constantly increasing world population with regard to the climate change effects and the imperative necessity for long-term sustainable usage of environmental resources.

Provided that the Industry 4.0 concept is considered to be a "collective" term through the establishment of a digitalized environment wherein physical and virtual objects can interconnect and interact autonomously along the entire value chain [3], it is strongly tied to the technology of the Internet of Things (IoT). In all industrial sectors, among which is agriculture, the IoT integrates the concepts of "Internet" and "thing" offering some key features such as heterogeneity, interoperability, high scalability, interconnectivity, object-related services as well as dynamic changes [4].

This paper is keen to present an approach of employing a responsive and adaptive IoT based system, capable of delivering a wide variety of services in order to facilitate agricultural operations. To this end, the proposed approach adopts a layered hierarchical structure consisting of a farming facility at the lower level and two higher levels involving cloud components. It is considered that such an approach constitutes an alternative solution for overcoming computational and storage challenges by using the resources offered into the cloud in order to facilitate the process, analysis and storage of sizeable amounts of raw data acquired remotely in multiple agricultural environments, and support the control of infrastructures as well as the making of critical decisions related to the optimization of agricultural production. In such manner the framework acts in the backend as a DSS providing finally intelligent services which optimize agricultural production, minimize the cost and assist all agricultural stakeholders in making decisions for the benefit of sustainability.

2. Operational Overview of the System

According to the suggested IoT operational framework, the raw data, which are acquired by the sensors of a Wireless Sensor and Actuator Network (WSAN) located in a farming facility, are transmitted to a context-aware middleware cloud wherein they are modified accordingly to context. These generated contextual data are additionally managed inside the middleware cloud, along with incoming rules that are provided by the services cloud, so as to result in monitoring information, control actions and services. Subsequently, the context-aware middleware cloud responds back to the actuator nodes of the farming facility's WSAN triggering the proper equipment infrastructures in order to perform the required agricultural operations. Additionally, end-users, such as farmers, agronomist engineers and food commodities merchants, are provided with real-time monitoring information and context-aware services, mostly but not exclusively via suitable mobile apps, so as to undertake further assistive actions. In this sense, end-users can manage agricultural operations remotely by means of the cloud services. It is worth noting that that this framework, may be easilyapplied to more than one farming facilities. Within the proposed system, the IoT serves as the

enabling technology for efficient farm management ensuring maximum agricultural output of optimum quality and increase the profitability of various agricultural production schemes.

3. Implementation and Performance Evaluation

In order to study the functionality of the operational framework, a model was developed by employing the Python programming language for prototyping and a cloud platform for computing infrastructure and services. The performance of the system has been validated by conducting a number of trials both in simulated and actual conditions in a farming facility in Greece.

Testing the system allowed its proper analysis and evaluation in terms of health, operation, and performance. In general, according to the outcomes provided by the metrics obtained during the tests, the system performs fairly satisfactory for controlling one agricultural facility environment since sensory data could be adequately acquired, processed, stored in the knowledge base, retrieved and disseminated to the applications of interest, resulting consequently into the proper actions. Nevertheless, the performance of the system is intended to be more thoroughly tested by evaluating additional parameters and integrating multiple agricultural environments for various cultivations and in distinct locations as part of future research.

Conclusions:

In conclusion, it is strongly believed that the proposed system framework may support the integration of agricultural operations toward the Industry 4.0 concept. It is in that regard that the introduced approach, based on the integration of WSANs into the IoT, has the benefit of being effortlessly adaptable, modifiable, and extendable for any application in any agricultural system environment no matter how complex it is.

Future work on the subject is intended to include an in-depth performance evaluation of the model through the integration of multiple agricultural facility environments with various cultivations and in distinct locations, in order to improve the interoperability and standardization of the proposed framework. For what is more, since the involvement of smart mobile devices and social networking was not taken into much consideration, these features are going to be included as part of the ongoing work.

References:

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