IOT SOFTWARE ARCHITECTURE ON AGRICULTURE: A LITERATURE REVIEW

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ABSTRACT

Context *– Internet of Things (IoT) interrelates computing devices, machines, animals, or people and things that use the power of internet usage to utilize data to be much more usable. Food is one of the mandatory human needs to survive, and most of it is produced by agriculture. Using IoT in agriculture needs appropriate software architecture that plays a prominent role in optimizing the gain.* ***Objective and Method*** *– Implementing a solution in a specific field requires a particular condition that belongs to it. The objectives of this research study are to classify the state-of-the-art IoT solution in the software architecture domain perspective. We have used the Evidence-Based Software Engineering (EBSE) and have 14 selected existing studies related to software architecture and IoT solutions to map to the software architecture needed on IoT solutions in agriculture.* ***Result and Implications*** *– The results of this study are the classification of various IoT software architecture solutions in agriculture. The highlighted field, especially in the areas of cloud, big data, integration, and artificial intelligence/machine learning. We mapped the agriculture taxonomy classification with IoT software architecture. For future work, we recommend enhancing the classification and mapping field to the utilization of drones in agriculture since drones can reach a vast area that is very fit for fertilizing, spraying, or even capturing crop images with live cameras to identify leaf disease.*

Keywords*: agriculture, artificial intelligence, evidence-based software engineering, internet of things, machine learning*

ARSITEKTUR PERANGKAT LUNAK IOT PADA PERTANIAN: TINJAUAN LITERATUR

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ABSTRAK

Konteks *- Internet of Things (IoT) menghubungkan perangkat komputasi, mesin, hewan, manusia atau suatu benda dengan menggunakan internet. Makanan merupakan salah satu kebutuhan utama manusia dan sebagian besar diproduksi dari hasil pertanian. Penerapan IoT di bidang pertanian membutuhkan arsitektur perangkat lunak yang tepat yang memiliki peran penting guna mendapatkan hasil yang optimal.* ***Tujuan dan Metode*** *- Penerapan solusi dalam suatu bidang memiliki kekhususan dalam bidang tersebut. Tujuan dari penelitian ini adalah untuk mengklasifikasikan solusi IoT dalam perspektif domain arsitektur perangkat lunak. Kami menggunakan metode Evidence-Based Software Engineering (EBSE) dan memilih 14 studi penelitian yang ada, terkait dengan arsitektur perangkat lunak dan solusi IoT dan memetakan pada arsitektur perangkat lunak solusi IoT di bidang pertanian.* ***Hasil dan Implikasi*** *- Hasil penelitian ini adalah mengklasifikasikan berbagai solusi arsitektur perangkat lunak IoT di bidang pertanian. Bidang yang disorot, terutama di bidang cloud, data besar, integrasi, dan kecerdasan buatan / pembelajaran mesin. Kami memetakan klasifikasi taksonomi pertanian dengan arsitektur perangkat lunak IoT. Untuk pekerjaan di masa depan, kami sarankan untuk mengembangkan klasifikasi dan pemetaan pada pemanfaatan drone di bidang pertanian karena drone dapat menjangkau area yang luas yang sangat cocok untuk pemupukan, penyemprotan, atau pengambilan gambar tanaman dengan kamera langsung untuk mengidentifikasi penyakit daun.*

Kata Kunci*: evidence-based software engineering, internet of things, kecerdasan buatan, pertanian, machine learning*

I. INTRODUCTION

Food is one of the basic needs in human life that is mostly produced by agriculture. Smart agriculture is one of the IoT automation technologies that is implemented in agriculture and proposed to promote the modernization of agriculture increasing food production. In smart agriculture, many things can be monitored and controlled. Such as temperature, turbidity, soil pH, moisture, can be collected by using the Internet of Things (IoT) platform, equipped with related sensors and wireless communication system [1]. That is the reason why smart farming is essential since it makes it easier to control and monitor crops growth.

In planting cycles, vital parts that need proper treatments in farming are seeding, irrigation, fertilizer, disease handling, pest handling, and monitoring the growth of crops. The primary purpose of appropriate treatment in seeding is to determine the quality of crops and the value of planting. The quality of seeds also affects how the plant will resist disease. To ensure the plant grows appropriately, we must provide enough water for plants implemented by managing irrigation. Besides that, plants need enough nutrients for their growth. Natural nutrients get from soil or supplied with fertilizer. Other challenges on the growth of crops are diseases and pests. Pests and diseases can hamper plant growth if we pay less attention to them. We must monitor the crops from the seeding phase until the harvesting phase.

Finally, we can argue vital parts that need proper treatments in farming are seeding, irrigation, disease handling, pest handling, fertilizer, and monitoring. They have significant effects on crop production. In this literature review, the topics cover various technologies including choosing the best seed, irrigation systems, handling pests and diseases, monitoring soil, and fertilizing. For a better overview of this research study, we classify the literature studies in this paper to those parts. The classification description also gives summaries regarding research that utilize IoT that integrates with other technologies such as cloud, big data, artificial intelligence.

II. Related Work

The main objective of implementing smart farming is to get optimal yield. Research [2] studies IoT adaptation motivated by the need to determine application areas, trends, architectures. It opens challenges on the agricultural, environmental fields and classifies topic studies into four (4) taxonomical areas. They are monitoring, control, logistics, and prediction. The result of the research [2] analyzes a few difficulties and limitations described in SLR papers that give a few insights to contribute to the adoption of IoT for agricultural and environmental field solutions. Stronger standardization to improve compatibility among different vendors and ensure stronger measures on security in the entire IoT stack, better power management to increase the endurance of IoT solutions. Security is the major challenge for the realization of IoT in agricultural problems. The research [2] also concluded that most of the solutions for agricultural and environmental issues relied on heterogeneous components and wireless sensors networks.

Another research of multiple case studies [3] about agri-food stakeholders affected the needs of food productions. There are 5 main concerns of the agri-food area, such as arable farm, dairy, fruit, vegetable, and meat. Since they are daily consumption needs, it makes many stakeholders implement IoT infrastructure for improvement in farming, agri-processing, logistics, and consumption. The research proposed a general method for IoT implementation and development that supports communications between producers and stakeholders in the agri-food area.

The agriculture data is analyzed for optimization, giving information about the environment, and predicting crops water needs. Data mining is applied to extract the best value from precise measurements with automatic computerized devices monitoring plants, land, and climate. Once the devices are connected to a server, all the data and devices can be monitored and controlled anywhere and everywhere. Since IoT can get a large volume of data, data science can also be applied to analyze data patterns and make predictions. The collected data is analyzed with various data mining algorithms and artificial intelligence models in the cloud layer [4]. An excellent research study related to architecting software for IoT based systems [5] has a useful classification taxonomy.

III. Methodology

We referenced the taxonomy classification in the agriculture implementation shown in Figure 1. This paper focuses on several fields based on Evidence-Based Software Engineering (EBSE) [5] that are cloud-based software ecosystems, big data systems, the agent-based system, and mapped to the taxonomy of agriculture fields. The topics most commonly fit in agriculture implementation. We have 14 selected existing studies related to software architecture and IoT solutions to map a software architecture that are needed in IoT solutions in agriculture.

Table I shows the research area and research topic in this review. The research field refers to the research context of agriculture. Meanwhile, the research topic relates to the topic context in software architecture. Total studies refer to the count of the research topic. A quick description, advantages, and disadvantages of each study reference shown in Table II. Table II gives us information about the short description, advantages and disadvantages topic, concern, and discussed issues in each paper. It also classifies based on taxonomy areas that are the seed, irrigation, fertilizer, disease, pest, and monitoring. The following discussion will give us more detail regarding concerns in each taxonomy area.

3.1 Seed

Quality of seed determines the value of planting. Since seed has a significant impact on yield, we must pay attention to the quality of seed before planting. Research that focuses on seed testing [6] is present to present the development of an integrated system consisting of hardware, middleware, and application to continuously monitor and record the performance of seed testing equipment from the beginning to the completion of each test in seed testing laboratories. The research focused on CoIoT middleware (Context + IoT), which provides mechanisms for managing IoT devices and context awareness mechanisms to monitor and record the equipment functions, throughout the seed testing processes.

3.2 Irrigation

Water is a mandatory need for the crop. Water can be from rain or irrigation. Unfortunately, rain does not occur each season. The emergence of persistent drought, population growth, and consequences of climate is the main factor for improvement, such as increasing water supply and reducing water demand. To enhance irrigation, we can increase water supply and decrease water consumption. An IoT framework proposed for data acquisition associated with the use of water. IoT uses sensors to collect data about soil moisture and nutrients [10] [12]. Besides sensors, image processing [7] can identify soil conditions. Soil condition and other environment variables stored in the database. They utilized it for forecasting future conditions [8] [10]. Real-time monitoring in irrigation is useful in agriculture to ensure adequate water supply [7] [8] [9] [11].

3.3 Fertilizer

One of the primary reasons for low yield is the improper use of fertilizers by the farmers. Research about fertilizer addition based on soil nutrients like Nitrogen-Phosphorus-Potassium (NFK) is proposed [12]. The sensed data is classified into fuzzification value to determine its deficiency. The collected data then analyzes using the Mamdani fuzzy rule to decide its nutrients edge level, they can give information to the farmer about its soil nutrient level and using the fertilizer at the right time.

3.4 Disease

The disease has become one of the main problems in agriculture that affected production. Many kinds of prevention against disease proposed using IoT architecture. One of the major conditions that is found in crops is mildew [13] [16] and late blight disease [15]. The research discusses preventing disease in agriculture by using sensors to gather information from farmlands. It also talks about climate and weather data based on its historical data to receive more precise climatic details [14] [15]. Meanwhile, meteorological data phenomena that initialized and periodically gathered information [16]. The collected data can be forwarded by Internet connection to be processed by Decision Support System [15], Artificial Intelligence [14], to make an option and suggestion to the farmers. Another research is making a simulation model give an early warning system that can give a prediction about the disease detection by lighting conditions [13], and by reducing the implementation of fungicides that can be harmful to the environment [14]. The benefits of these results are early warning detection systems [13] finding a solution for disease problems [14] [15] [16] to increase the quality and quantity of their production.

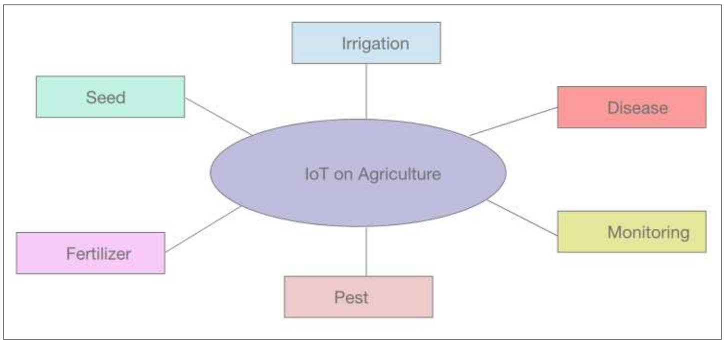

Figure 1. Taxonomy classification in the agriculture implementation.

Table I Research Area and Theme.

No	Research Area	Research Topic	Total Studies
1	Seed	Distributed System [6]	1
2	Irrigation	Image processing [7] Machine learning [8][9][10][11]	1 4
3	Fertilizer	Cloud Computing [12]	1
4	Disease	Image processing [13] Artificial Intelligence [14] Cloud Computing [15] Machine Learning [16]	1 1 1 1
5	Pest	Cloud computing [17]	1
6	Monitoring	Machine Learning [18][19]	2

Table II Description, Advantages, and Disadvantages of Literature Studies Contents.

Area	Reference	Description	Advantages	Disadvantages	Citation	Reader	H-Index
Seed	[6]	Presenting the development of an integrated system consisting of hardware, middleware, and application that continuously monitor and record the performance of seed testing equipment from the beginning to the completion of each test in seed testing laboratories.	• Graphically can visualize seed progress and condition • Accessible anywhere	• Possible miscommunications between the Edge Server and the Context Server	3	207	104
Irrigation	[7]	Proposing an automation of drip irrigation in which the smartphone initially captures soil image, calculates its wetness level and transmits the data onto the microcontroller through GSM module intermittently. The microcontroller decides the irrigation and sends the status of the field to the Farmer's mobile phone. The status about the irrigation process is updated periodically to farmer's mobile through SMS	• Fast notification to farmer since the system sends irrigation status to farmer's mobile phone	• The information can't be graphically displayed since it sent through via SMS	15	52	55
	[8]	Build smart irrigation management that can control irrigation motor, predict soil moisture, data acquisition via a sensor, transport data via web service REST API, collect public weather data and visualize in web application	• The novel algorithm developed for soil-moisture prediction improved accuracy and less error • Modularizing into separate modules/layers i.e data collection and transmission layer, data processing & intelligence layer and application layer of IoT • Service oriented • Rich user interface with bootstrap API for real-time monitoring and scheduling of irrigation activities	• Possible loss connection between standalone sensor and centralize web service	52	419	104
	[9]	Developing smart irrigation that can estimate schedule, neural-based decision making for intelligent support, and remote data monitoring. The neural network provides required intelligence to the device that considers current sensor input and masks the irrigation schedule for efficient irrigation. The system uses MQTT and HTTP to keep the user informed about the current crop situation even from a distant location.	• Realtime based system.	• Need learning model	15	249	104
	[10]	Designing an autonomous network of sensors that collect data about soil moisture and concentration of dissolved contaminants, assimilate these data together with forecast precipitation into predictive models of soil moisture dynamics and contaminant migration and use these data-driven models to optimize	• Forecasting soil moisture dynamics and optimizing irrigation practices.	• Not include crop parameters such evapotranspiration	10	136	105

		the irrigation practices while minimizing their environmental impact.					
	[11]	Presenting intelligent Smart Watering System (SWS) that is assisted with an Android application for small consumption of water.	• Capturing real time data. • Securing with block chain	• Researched for medium-scale garden and field.	11	105	20
Fertilizer	[12]	Analyzing Nitrogen-Phosphorus-Potassium to giving alert message to the farmer about nutrients of the soil so the fertilizer can be added appropriately	• Detect deficiency of soil nutrient • Fertilizer can be determined	• Fuzzy is biased by its thresholds range	5	53	104
Disease	[13]	modeling forecast condition for disease identification in strawberry plants. by using camera, kinematic GPS	• Reduce time of day and labour cost of disease identification	• Reducing human for manual disease identification can affect to social psychology in it	3	44	104
	[14]	implementation data from fields sensor and AI to reduce harmful against environment and also reduce cost by using precision time of fungicides in potato and tomato crops	• Can handle different plant disease model • Can suggest an option to protect the crops	• Atmospheric instability in wide area	1	89	99
	[15]	climate based sensors for prevention against late blight disease in potato crop	• Notification to the producer when thresholds of attack is reached	• Implemented in potato crop only	19	267	20
	[16]	meteorological data-based phenomenon to give an alert for downy mildew disease in vineyard. proposed a platform called SEnviro.	• The platform can be used to provide recommendation on another vineyard for the same disease detection	• Implementation in another vineyard must be based on the first implemented vineyard	5	117	99
Pest	[17]	Developing experimental Cloud-IoT based late blight decision support system on potato farms.	• Early alert for Late Blight disease after calculating humidity and temperature in crops. The alerts are sent via SMS to the farmer	• Image processing as enhancement is not implemented, so when crops show no change in humidity and temperature, the disease cannot be early detected.		23	99
Monitoring	[18]	CLAY-MIST Measurement (CMM) is developed to comprehend issues in existing monitoring techniques to determine comfort level based on dew-point-humidity data that gives a false decision with time and energy consumption.	• The system has accurate calculation with little to no error rates.	• Does not include specific types of crops	16	115	81
	[19]	Combining cloud and fog computing environment to increase data calculation to obtain faster measurement	• Reduces computational cost and accelerates calculations that reflect shorter response time.	• Software developing might be harder and needs longer codes.	4	80	20

3.5 Pest

Pests play significant roles in delaying or interrupting crop growth and harvest yields. Research [17] explicitly explains one of the pest-caused crop problems on potatoes, which is a blade disease as critically damaging, threatening both production quantity and quality. [17] proposed a novel method using an experimental decision support system (DSS) using Cloud-IoT based framework to help farmers detect blight disease early and give early precautions or even treatment. The proposed method allows farmers by early alerting for Late Blight disease after calculating humidity and temperature in crops. The alerts are sent via SMS to the farmer. Farmers then can take precautions by looking at measurements given by the system. The proposed prototype consists of 3 main blocks: collections of sensor nodes to gather micro-climate information such as temperature and humidity, the gateway to provide connection, and Cloud-IoT. The research focuses on using climate sensors, while possible future works adding image processing could help detect symptoms that might not be detected with temperature and humidity sensors.

3.6 Monitoring

While other areas of taxonomy explained the focus on one or two factors on agriculture, both research [19] and [18] focus on the calculation of data, time, and energy consumption of the field monitoring framework. Research [19] combines both services of cloud and fog computing to increase data calculation, which leads to faster measurement results. It also shows reduced computational cost, and accelerated calculation time, that results in shorter response time. Research [18] used CLAY-MIST Measurement (CMM) to comprehend issues in existing monitoring techniques to determine comfort level based on dew-point-humidity data that gives a false decision with time and energy consumption. The system has accurate calculation while not ignoring the importance of error rates.

IV. Discussion

The farming model is not only limited to open field cultivation but also in greenhouse cultivation. Open field cultivation is a conventional method of farming. We use open land, which has consequences. We have to take care of the soil, sow seeds or plant transplants in traditional ways, and protect them from climate change, disease, pest attack, eroding soil, etc. Meanwhile, the greenhouse model was designed as isolated land instead of open land. In the greenhouse, we have more control over the environment where the crops grow. We can efficiently manage temperature, the irrigation process, the air humidity, and the light. We may use different methods to control all these factors and be able to protect crops from pest attacks and diseases. By having that much power over the development of the plants, we can keep them healthier and can predict how much you will harvest.

After mapping literature studies and categorizing them into taxonomies classification, we summarized that software architecture has an essential role in designing the IoT solution on agriculture. On the other hand, the farming model influences the selection of technology to apply for it. The following items are a technology that mostly we found as a part of the IoT solution in agriculture and needs attention to implementing them.

4.1 Cloud Based

The nature of agriculture is mostly in distributed areas. Cloud-based service is an ideal solution for various functions, such as application deployment, storage, services, and over the internet. It makes it easier to access anywhere and anytime that ensures the availability of service close to 99% of SLA. The service ideally should be available for 24 hours.

4.2 Big Data System

Data acquisition in agriculture is time-based and mostly captured 24 hours. The smaller the sampling duration, the more accurate the data will be. This condition leads us to a high volume of data. Even though the size may need extra storage, it can give us advantages. We can utilize the data with machine learning to profile crop growth, environment, etc. and event forecast the value of data for the future.

4.3 Agent Based System

Based on taxonomic classification on IoT solutions [5], the agent-based system includes interconnected software agents that have primary challenge how to exploit the devices and things in the IoT systems to engineer and develop autonomous and adaptive agents that are interconnected and web-accessible. This condition takes place in data acquisition of crops, soil, irrigation in agriculture. Ideally, all the data should be captured, transmitted, and stored in the cloud. So, it can be analyzed, visualized, and notified to farmers regarding the condition of crops and fields. Finally, we can propose a mapping between standard software architecture stack and agriculture classification taxonomy regarding the IoT solution in agriculture based on the literature studies.

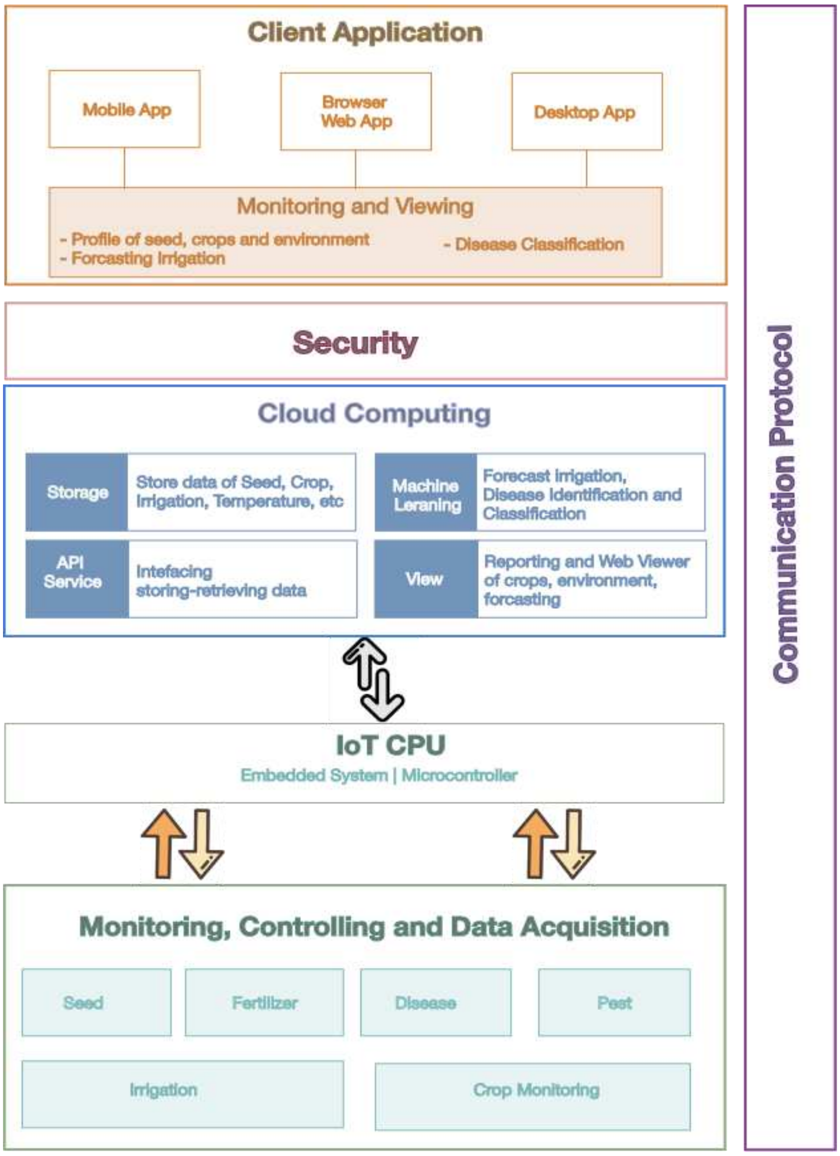

Figure 2 Mapping agriculture taxonomy with IoT architecture stack

The mapping between agriculture taxonomy and IoT architecture stack in Figure 2 showed that the IoT device layer is a layer that interacts directly with crops and environments. IoT CPU represented with an embedded system or microcontroller coupled with a sensor or camera and actuator for control action if any. Sensors and cameras are interfaces that capture data and processed by the controller and transmit to the cloud for further processing. For burdensome process computing, learning-based processes, for example, leaf disease identification, forecasting irrigation water volume, etc., that consume significant CPU and memory, we recommend processing them in the cloud. The controller grabs the result from the cloud via service API if needed. So, the computation in the IoT CPU will be lighter.

The next stack is a cloud computing layer. The cloud computing layer consists of several parts: storage, API service, machine learning, and visualization. Storage is the place to store data. Machine-learning processes data with statistics, artificial intelligence, or any other machine learning algorithm. The result will be useful for analytic, controlling, or monitoring the condition of crops.

We do recommend that data processing on machine learning should have much more attention. Since data processing is the key success of decision making, the computing result of the machine learning part should be stored back to the storage so that clients can consume it for their needs. The clients could be IoT devices, applications, or external clients. The clients that need to consume the data processed in the cloud can access it via API service. They should not have direct access to the storage; that is why we have a security layer stack on top of the cloud stack. Visualization part related to a presentation of the system. It can help stakeholders to analyze data related to the profile of seed, crop, forecasting environment (temperature, the water volume of irrigation), classification (disease, pest).

V. Conclusion

In this paper, we have classified literature studies into the taxonomic research area of agriculture. We have used Evidence-Based Software Engineering (EBSE). We have 24 selected existing studies related to software architecture and IoT solutions to map to the software architecture needed on IoT solutions in agriculture. We propose classification to seeding, irrigation, fertilizer, disease handling, pest handling, and monitoring the growth of crops. We also mapped the taxonomic fields with a typical IoT architecture that can give us information on where the taxonomic areas should place in the IoT architecture. The classification and mapping architecture organized in compact categories and diagrams that provide us with better knowledge and can help us to develop the right IoT solution on agriculture to optimize the farming yield. For future work, we recommend enhancing the classification and mapping field to the utilization of drones in agriculture since drones can reach a vast area that is very fit for fertilizing, spraying, or even capturing crop images with live cameras for leaf disease identification.

References

[1] A. Pathak, M. A. Uddin, M. Jainal Abedin, K. Andersson, R. Mustafa, and M. S. Hossain, "IoT based smart system to support agricultural parameters: A case study," *Procedia Comput. Sci.*, vol. 155, pp. 648–653, 2019.

[2] J. M. Talavera *et al.*, "Review of IoT applications in agro-industrial and environmental fields," *Comput. Electron. Agric.*, vol. 142, no. 118, pp. 283–297, 2017.

[3] C. Verdouw, H. Sundmaeker, B. Tekinerdogan, D. Conzon, and T. Montanaro, "Architecture framework of IoT-based food and farm systems: A multiple case study," *Comput. Electron. Agric.*, vol. 165, pp. 104939, 2019.

[4] F. Bu and X. Wang, "A smart agriculture IoT system based on deep reinforcement learning," *Futur. Gener. Comput. Syst.*, vol. 99, pp. 500–507, 2019.

[5] A. Alreshidi and A. Ahmad, "Architecting software for the Internet of Thing based systems," *Futur. Internet*, vol. 11, no. 7, 2019.

[6] R. Santos de Souza *et al.*, "Continuous monitoring seed testing equipments using internet of things," *Comput. Electron. Agric.*, vol. 158, pp. 122–132, 2019.

[7] S. R. Barkunan, V. Bhanumathi, and J. Sethuram, "Smart sensor for automatic drip irrigation system for paddy cultivation," *Comput. Electr. Eng.*, vol. 73, pp. 180–193, 2019.

[8] A. Goap, D. Sharma, A. K. Shukla, and C. Rama Krishna, "An IoT based smart irrigation management system using Machine learning and open source technologies," *Comput. Electron. Agric.*, vol. 155, pp. 41–49, 2018.

[9] N. K. Nawandar and V. R. Satpute, "IoT based low cost and intelligent module for smart irrigation system," *Comput. Electron. Agric.*, vol. 162, pp. 979–990, 2019.

[10] G. Severino, G. D'Urso, M. Scarfato, and G. Toraldo, "The IoT as a tool to combine the scheduling of the irrigation with the geostatistics of the soils," *Futur. Gener. Comput. Syst.*, vol. 82, pp. 268–273, 2018.

[11] M. S. Munir, I. S. Bajwa, and S. M. Cheema, "An intelligent and secure smart watering system using fuzzy logic and blockchain," *Comput. Electr. Eng.*, vol. 77, pp. 109–119, 2019.

[12] G. Lavanya, C. Rani, and P. Ganeshkumar, "An automated low cost IoT based Fertilizer Intimation System for smart agriculture," *Sustain. Comput. Informatics Syst.*, no. 2018, pp. 1–12, 2019.

[13] M. Sultan Mahmud, Q. U. Zaman, T. J. Esau, G. W. Price, and B. Prithiviraj, "Development of an artificial cloud lighting condition system using machine vision for strawberry powdery mildew disease detection," *Comput. Electron. Agric.*, vol. 158, pp. 219–225, 2019.

[14] A. Khattab, S. E. D. Habib, H. Ismail, S. Zayan, Y. Fahmy, and M. M. Khairy, "An IoT-based cognitive monitoring system for early plant disease forecast," *Comput. Electron. Agric.*, vol. 166, pp. 105028, 2019.

[15] K. Foughali, K. Fathallah, and A. Frihida, "Using Cloud IOT for disease prevention in precision agriculture," *Procedia Comput. Sci.*, vol. 130, pp. 575–582, 2018.

[16] S. Trilles, J. Torres-Sospedra, Ó. Belmonte, F. J. Zarazaga-Soria, A. González-Pérez, and J. Huerta, "Development of an open sensorized platform in a smart agriculture context: A vineyard support system for monitoring mildew disease," *Sustain. Comput. Informatics Syst.*, no. 2018, pp. 1–11, 2019.

[17] K. Foughali, K. Fathallah, and A. Frihida, "A Cloud-IOT Based Decision Support System for Potato Pest Prevention," *Procedia Comput. Sci.*, vol. 160, pp. 616–623, 2019.

[18] M. S. Mekala and P. Viswanathan, "CLAY-MIST: IoT-cloud enabled CMM index for smart agriculture monitoring system," *Meas. J. Int. Meas. Confed.*, vol. 134, pp. 236–244, 2019.

[19] T. C. Hsu, H. Yang, Y. C. Chung, and C. H. Hsu, "A Creative IoT agriculture platform for cloud fog computing," *Sustain. Comput. Informatics Syst.*, vol. 28, 2018.