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INTERNET OF THINGS IN SMART AGRICULTURE: APPLICATIONS AND OPEN CHALLENGES

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Abstract

Purpose of Study: The IoT is an emerging field nowadays and that can be used anywhere in automation, agriculture, controlling as well as monitoring of any object, which exists in the real world. We have to make use of IoT in Agriculture to increase productivity. Agro-industry processes could be more efficient by using IoT. It gives automation to agro-industry by reducing human intervention. In the current scenario, the sometime farmer doesn't know the current status of the soil moisture and other things related to their land and don't produce productive results towards crops. The purpose of this research study is to explore the usage of IoT devices and application areas that are being used in agriculture.

Methodology: The methodology behind this study is to identify trends and review the open challenges, application areas and architectures for IoT in agro-industry. This survey is based on a systematic literature review where related research is grouped into four domains such as monitoring, control, prediction, and logistics.

Main Findings: This research study presents a detailed work of the eminent researchers and designs of computer architecture that can be applied in agriculture for smart farming. This research study also highlights various unfolded challenges of IoT in agriculture.

Implications: This study can be beneficial for farmers, researchers, and professionals working in agricultural institutions for smart farming.

Novelty/Originality of the study: Various eminent researchers have been making efforts for smart farming by using IoT concepts in agriculture. But, a bouquet of unfolded challenges is still in a queue for their effective solution. This study makes some efforts to discuss past research and open challenges in IoT based agriculture.

Keywords: *Internet of Things, IoT, Agricultural, Sensor data, Smart farming, Crop Residue, QoS, Challenges, Applications.*

INTRODUCTION

Internet of Things (IoT) is a mechanism in which objects (living and nonliving) are mapped with some unique metadata or identifiers. The significance of this mapping is the transmission of data over the internet without any intervention of humans with computers or humans with humans or vice-versa. IoT is an emerging field nowadays and that can be used anywhere in automation, agriculture, controlling as well as monitoring of any real object, which exists in the real world. As per Juniper Research, more than 13.4 billion IoT devices were used in different domains of the real world and approximately 185% of expected growth to 38.5 billion IoT devices will be connected to society by 2020. IoT devices are being used in almost every field of modern society. The main aim of IoT is generally unify everything that exists in this real-world under a common infrastructure. It will give us not only controlling over such objects, but it will also inform us about the current state of these objects.

IoT also being used in agriculture to get to know the crop-field by utilizing sensors for monitoring, controlling, and any trespassing by the field (Sales, Nelson, Orlando Remédios, and Artur Arsenio (2015)). IoT provides a mechanism to sense an object in a controlled environment by introducing a remotely accessed network infrastructure. It creates opportunities to overcome the bridge-gap between the physical world and computer-based systems. The main benefit of introducing the IoT in agriculture is to improve the efficiency and accuracy with low-level human-intervention. IoT in agriculture includes agricultural practices with the adoption of IoT, sensors, and others, to increase the productivity of the farm. In the current scenario, IoT plays a vital role in the agriculture sector. It transforms the agriculture industry and enabling the farmers for facing and handling the big challenges. For enhancing the productivity of farmers, IoT agricultural sensors can have a tremendous impact. IoT agricultural sensors are capable of providing the crop-yields related information, forecasting of rainfall, soil nutrition, and pest infestation, and other valuable information to the farmers. Agricultural sensors can be used to measure various parameters of the field such as temperature, humidity, soil moisture, etc. The conditions of the field can be viewed by farmers from anywhere and analyze the data accordingly.

The world will need to produce 70% more food in 2050, as per the United Nations Food and Agriculture Organization (FAO). But, the critical challenge for producing more food will be a lack of agricultural land. The reason behind this is agricultural lands are shrinking due to the expansion of the concrete jungle. The tremendous reduction in the availability of natural resources such as water and cultivable land, the production of staple crops, has provoked this challenge.

According to Business Insider Intelligence, the shipment of IoT devices used in agriculture is increasing at a rapid speed. The following figure-1 illustrates the growth of shipment of IoT devices during the last 6 years (2015-2020). As per figure-1, the line chart clearly shows that the growth is increased by 150%. (Putjaika, Narayut, et al (2016))

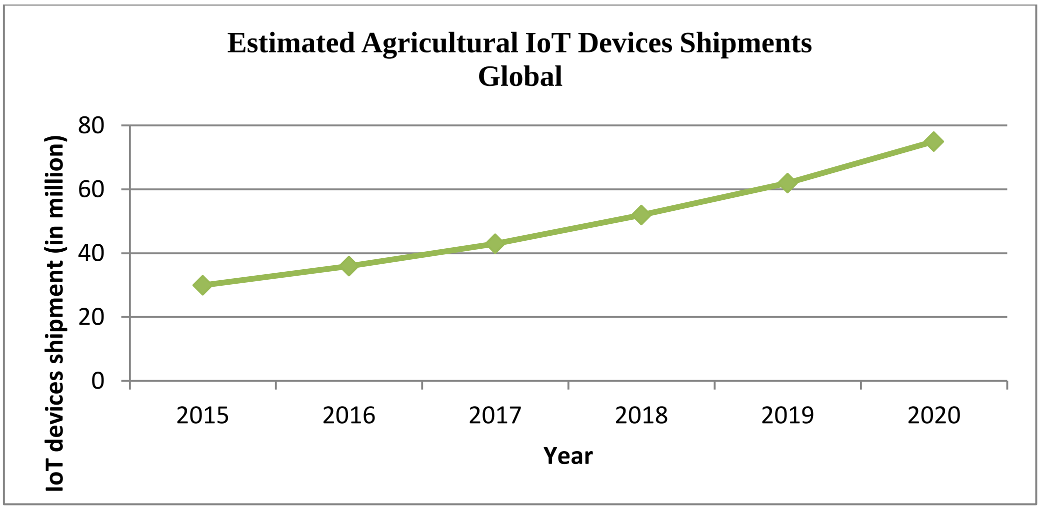

Figure 1: Growth of shipment of IoT devices during the last 6 years (2015-2020)

Usage of IoT devices in agriculture is a vast opportunity for farmers to monitor, control their crops and enhance productivity. In this research study, the main aim is to explore the usage of IoT devices and application areas that are being used in agriculture.

LITERATURE REVIEW

Various software industries and research centers are working hard towards the usage and impact of the Internet of Things (IoT) in agriculture and explore the major research issues in this domain. The review in this section highlights the work of eminent researchers and designs of computer architecture that can be applied to IoT in agriculture. (Alexandratos, N. and J. Bruinsma (2012))

The hierarchical structure of the study is illustrated in figure-2 that contains the four domains of study and their sub-domains.

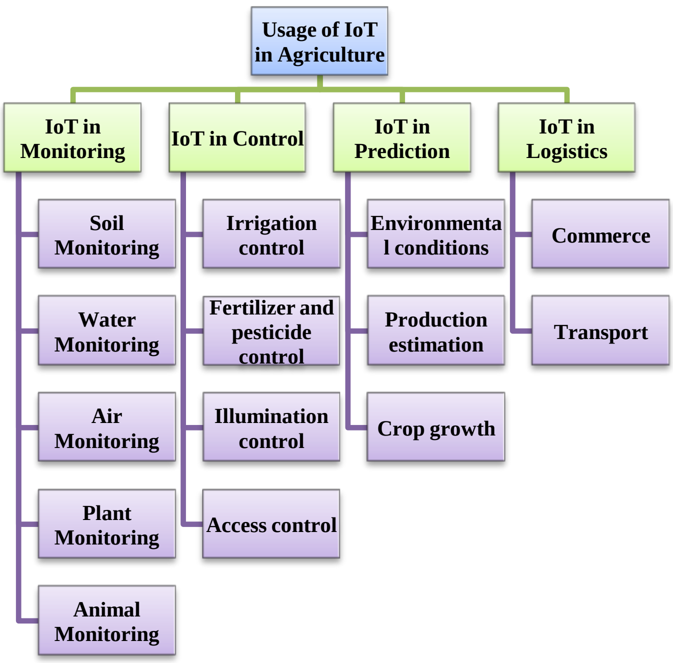

Figure 2: Hierarchical structure of usage of IoT in Agriculture

In a developing country such as India, IoT interventions and applications are mostly confined to sectors other than agriculture (Athani, S. and Tejeshwar, C. H. (2017)). The changes in the environmental conditions are the biggest issue in the agricultural paradigm. These climate changes directly affect every factor associated with farming. Quick solutions are needed for handling this issue. IoT uses multiple sensors that are embedded in the fields, which collect real-time information regarding soil moisture weather information, temperature, dampness, precipitation, soil composition, soil temperature, leaf wetness, air quality, predicting pests, crops, water level, etc. Such analytical statistical data provides helpful information to the cultivator in a smarter way that helps to get the decision very precisely. (Srinidhi Siddagangaiah (2016))

1. IoT in Monitoring

Moreover, in this section IoT solutions are related to the monitoring of different physical variables depending on the subdomain to which it belongs. Identified subdomains are soil monitoring, water monitoring, air monitoring, plant monitoring, and others which includes animal monitoring. (Liping, W., (2012))

Table 1: IoT in Agricultural Monitoring

Authors and Year	Sub-domain	Observations
Zou (2014)	IoT in Monitoring	Authors suggested a system for online crop monitoring and it captures different variables such as soil moisture, humidity, pH of water, temperature, luminosity, CO2 and images. The proposed system is having three layers: (a) a perception layer with WSN support; (b) a network layer for data transmission by using different protocols and gateways, and (c) an application layer that includes a web server for analyzing the data to produce information and a database to store data.
Mafuta et al., 2012	Soil monitoring	The researchers have proposed an IoT system using WSN for monitoring moisture and soil temperature of arable land. These systems support various technology for communication such as GPRS, ZigBee, and Internet, where a web application is used to handle user interaction with the system.
Xijun et al., 2009	Water monitoring	The authors have proposed a WSN system for monitoring rainfall and water levels in irrigation systems.
Postolache et al. (2013)	Water monitoring	The authors presented a system for monitoring water quality and pollution by sensing pH, temperature, and chemicals. In this IoT system water quality measured through the assessment of temperature, conductivity, and turbidity.
Watthanawisuth et al. (2009)	Air monitoring	Authors discussed an IoT based framework for evaluating and determining environmental factors or pollution to stop adverse and damaging effects. Forecasting of possible changes in the environment is also included in the system. This is a real-time WSN based IoT monitoring system including temperature and relative humidity sensors (SHT15) that operates on solar power. It uses ZigBee communication technology.
Singh et al. 2019	Air monitoring	The proposed system is a pollution management system having MQ135 gas sensors to sense the air quality.
Langendoen et al., 2006	Plant monitoring	The authors were suggested a plant or crop monitoring system named LOFAR-agro. In the system, a WSN based solution was used for monitoring the microclimate (humidity and temperature) to protect a potato crop against phytophthora (a genus of Oomycota or water molds). It was deployed to frame a policy based on sensors data to protect the crop against the disease.
Fourati et al. (2014)	Plant monitoring	The authors proposed a Web-based Decision Support System with WSN for irrigation in Olive fields. Here, authors have used sensors for measurements of humidity, temperature, rain, solar radiation.
Siddagangaiah 2016	Plant monitoring	The researchers have proposed a system having DHT11 and YL-38 + YL-69 sensors as Temperature and Humidity monitoring sensor and soil moisture sensor to detect the humidity of the soil that helps to monitor the soil moisture.
Jain et al. (2008)	Animal monitoring	Researchers have presented an animal monitoring system, where an IoT system has responsibility for migration, behavior, and monitoring of Swamp Deers, collecting data of the climate and positions of animals at the same time.
Ehsan et al. (2012)	Animal monitoring	Authors proposed a necklace that gathers data about horses' position and speed at time instance, and send it to fixed nodes when they are in the

		coverage area. It was a delay-tolerant WSN for the monitoring and tracking of six horses. The research was related to animal tracking for both animal husbandry and wildlife activities.
R. Shanmugasundaram 2017	Animal monitoring	Authors proposed an IoT based animal tracking and monitoring system in Zoo.
Singh, G., Kumar, G., Bhatnagar, V., Srivastava, A., & Jyoti, K. (2019)	Environment Monitoring	The authors proposed a framework for the monitoring of surrounding using IoT.

2. IoT in Controlling

IoT control systems use a bi-directional information channel, unlike monitoring system, where the user has unidirectional information channel for data transmission over WSAN (Wireless Sensor and Actuator Network)for controlling a group of actuator devices to change the state of the process, which was being controlled by the IoT system. A new communication method was added, and instructions could be sent back to the device deployed in the agriculture field. This system helps the farmer by reducing water consumption and by providing the facilities for optimum usage of pesticides and fertilizers. Overall, solutions with control systems could save money to the farmers by providing mechanisms based on data sensors for the consumption of water, fertilizers, pesticides, and electricity. In this paper, the following sub-domains are considered: irrigation, fertilizers, pesticides, illumination, and access control.

Table 2: IoT in Agricultural Controlling

Authors and Year	Sub-domain	Observations
Shuwen and Changli (2015)	Irrigation control	The authors proposed a ZigBee based Remote Irrigation Monitoring Solution that controls the irrigation by using solar power.
S, Monisha (2019)	Irrigation control	Authors proposed an advanced automatic irrigation system that can be controlled with and without internet using GPRS/GSM technology pump theft control was also introduced in the system for this an obstacle sensor is used below the soil, an alert message through the android app is sent to the farmer when the pump-set is moved.
Barman A (2020)	Irrigation control	An irrigation system was discussed by researchers. It is an IoT system based on renewable energy i.e. solar energy. This system has some data for different crops regarding moisture level in a database after some time sensor detects the moisture level in the field if it is less than the previously determined standard level in the database controller automatically start the irrigation system.
Pahuja et al. (2013)	Fertilizer and pesticide control	Researchers were proposed an Online Micro-climate monitoring and Controlling System for greenhouses. For gathering and analyzing the sensor data, a WSN system was used. The main purpose of such analysis to produce actions to control irrigation, fertilization, and pesticide.
Yoo et al. (2007)	Illumination control	Here, a wireless sensor network-based system used for monitoring greenhouses' melons and cabbages crop. It was used to monitor the growth process of crops and to control the environment of the greenhouse. Here, the system can control the illumination by changing the light. Other factors measured by this proposed system were humidity, temperature, and light.
Roy et al. (2015)	Access control	The authors proposed an intrusion detection system for agriculture to generate alarms. When an intruder entered into the crop field, a text message is automatically sent to the farmer's mobile as well as another alternative contact.

3. IoT in Prediction

In the prediction domain, eminent research is discussed for providing tools and information to support the decision making of farmers. For these tasks, the system has specific modules in the architecture, and for the system, predicted variables are grouped as environmental conditions, production estimation, and crop growth.

Table 3: IoT in Agricultural Prediction

Authors and Year	Sub-domain	Observations
Luan et al. (2015)	Environmental conditions	Authors were proposed an IoT based system that provides irrigation prediction and integrates drought monitoring and

		forecasting.
Lee et al. (2013)	Production estimation	Authors were developed an IoT based prediction system for the growth and yield of crops. The main purpose of this system was to stabilize the demand and supply of agro-products.
Saville et al., 2015	Production estimation	Using ultrasonic sensors, the authors suggested a real-time estimation system for the fixed net fishery.

4. IoT in Logistics

In the logistic domain, eminent research is discussed for exploring the flow of entities and providing information to support consumer demand. It refers to the related information from producer to consumer. For these tasks, the system has specific modules like agricultural production, transportation, acquisition, storage, packaging, loading and unloading, distribution and other related activities. The concerned research is further categorized in commerce and transport.

Table 4: IoT in Agricultural Logistics

Authors and Year	Sub-domain	Observations
Li et al., 2013	Commerce	Authors suggested an IoT based system for agriculture for tracking as well as tracing of the whole agricultural production. The supporting Information discovery system was designed to capture, manage, locate, standardize, implement and query business data from production. This query-based system is allowed to consumers to verify the quality of products based on the consumer's query.
Pang et al. (2015)	Transport	Authors proposed an IoT based transport system for food production and commercialization. In this system, sensors were used to measure environmental conditions including humidity, temperature, CO2, oxygen and ethylene, etc. For better transportation of melons, mechanical stress such as shocks, vibrations, and tilts, etc. were also discussed in this research.

OPEN CHALLENGES IN IoT BASED AGRICULTURE

Various eminent researchers have worked hard towards the usage and impact of the Internet of Things (IoT) in agriculture. Many research challenges arise in IoT based Smart Agricultural applications. This research study has identified some unfolded IoT based smart agricultural challenges.

1. Protection of electronic circuits of devices used in IoT agricultural system from natural environmental situations (Heavy rain, fire, intolerable winds, extreme humidity, high/low temperature, etc.)
2. Reliable energy-efficient network-based setup for the secure transmission of information to respective stakeholders in a secured manner.
3. Selection of suitable IoT end devices, tools, and technologies for implementing smart farming.
4. Design and implementation of highly scalable and reliable security mechanism for each IoT end devices used in Smart Agriculture.
5. Resource utilization in an optimized manner is a big challenge in IoT agriculture.
6. Cost-analysis and mobility are also huge challenges for smart farming.
7. Maintenance of Quality of Service (QoS) efficiently in IoT based Smart Agricultural System is also an unfolded issue.
8. A proper decision-making system to handle the natural disaster with the latest policies is a part of these open challenges in IoT agriculture.
9. Crop residue for a clean environment is still a major problem.

FUTURE ENHANCEMENT

Nowadays we are using IoT system for smart agriculture management, but the crop residue is still a major problem for environment, for this problem we can develop an IoT System blended with biotechnology that can help to get the information (including climate factor to grow fungi and bacteria for different sites and crops) to resolve the problem of crop residue and provide a solution to decompose the crop residue in filed that will make the land fertile and reduce the pollution.

CONCLUSION

In this research study, we have discussed a detailed work of the eminent researchers and designs of computer architecture that can be applied in agriculture for smart farming. The hierarchical structure of the usage of IoT in agriculture is also discussed. Besides, this research study also highlights various open challenges of IoT in agriculture. This study is very beneficial to agriculturists, researchers, professionals, and decision-makers working with agricultural institutions and other persons who are working on IoT based technologies for smart farming.

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