Exploring the advances in computer applications with the Internet of Things (IoT) for optimized agricultural farm management

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Abstract- The Internet of Things or the IoT is the label IT people have now assigned to the world's billions of Internet-linked devices. Not only can these instruments gather data, they even exchange information. Via wireless networks and cheap processors, many physical artifacts can now be converted into an IoT computer. The competitiveness of farming and agriculture processes must be improved, such that emerging innovations, such as the Internet of Things, boost yield and cost performance (IoT). In particular, by reducing human interaction by automation, IoT will make agriculture and agriculture more effective. This research aims at analyzing IoT applications in the agriculture and agricultural industries that have recently been launched to include an analysis of sensor data collection and innovations and sub-verticals such as water control and seed safety. This research can be used as a benchmark to enhance and expand IoT usage to maximize agricultural output productivity. This research review also presents suggestions for potential research, including scalability of IoT structures, heterogeneity dimensions, the design of the IoT framework, methods for data analysis, agricultural domain, or land size, IoT protection and protocols or solutions for the challenge of IoT, operating infrastructure, data management, cloud platforms, and energy sources.

Index Terms- IoT, Agricultural Farm Management, Smart Agriculture, Innovation

I. Introduction

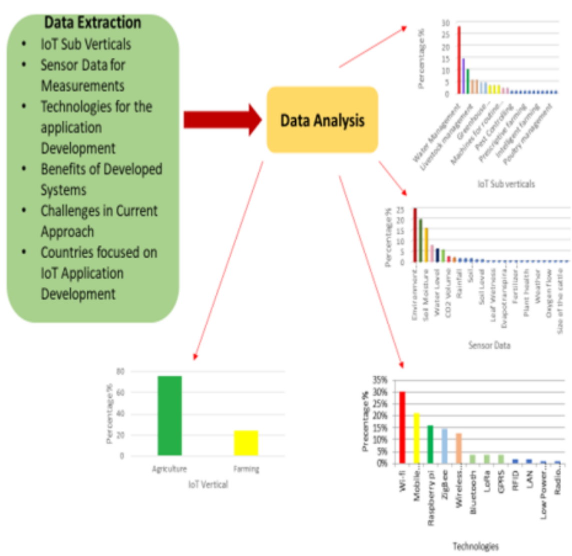
In recent years, agriculture has experienced the fourth revolution by incorporating ICT in conventional agricultural activities. Fascinating innovations such as; "Internet of Things (Internet of Things) (IoT), Unmanned Aerial Vehicles (UAVs), Big Data Analytics, and Machine Learning (ML) [1]." Agriculture is progressing by introducing many emerging core innovations into a modern and exciting age of food cultivation, known as; "Agri-Food 4.0., IoT, Smart Sensors, Remote Sensing, UAV, Low Power Large Area Networks and Wireless Sensor Networks, Long Range Wide Area Access Networks (LoRAWAN)" all have their origins. This intelligent farming technology can be separated into data processing and measurement and application technology. Different variations of the above-mentioned innovative product in smart agriculture in Australia and Europe, particularly India, Brazil, Ireland, and Italy, have proven successful [1].

High precise agricultural metrics can be used to maintain crop production, cost savings, and optimization of process resources, such as temperature, environmental conditions, soil quality, and water sources. We can control insects and fertilizers, and we can control weeds and greenhouse through the use of these advanced farming and tracking methods.Smart agricultural practices are a green technology solution since they lower conventional farming's environmental footprint. Precision cultivation will further avoid the risk of leaching and pollution and the effects of the global climate through smart irrigation, the least use of pesticides and fertilizers on farm crops [2].

Precision cultivation will further avoid the risk of leaching and pollution and the effects of the global climate through smart irrigation, the least use of pesticides and fertilizers on farm crops. In new wireless networking, IoT is one of the most innovative technology. The underlying principle is that a set of physical entities or objects communicate to be linked to the Internet with a single addressing scheme. IoT technology may be implemented in several market industries, such as; industrial, transport, fitness, car, smart home, and agriculture [3]. IoT instruments offer valuable knowledge on a large variety of physical criteria in an agricultural setting to strengthen cultural practices. In IoT, the role of "wireless sensor networks (WSNs)" technology is critical because wireless data processing is the basis for most IoT applications in different markets.

Researchers have concentrated on intelligent agriculture and integrated agricultural networks utilizing IoT to solve the current problems. IoT is a network of items that recognize software knowledge, sensors, and universal internet access. The data obtained from the Internet include gadgets, sensors, and actuators in IoT. Many scientists concentrated on intelligent systems to track and manage farming parameters by enhanced productivity and performance. Smart devices gather calculation data, which may contribute to effective measures to obtain correct performance. Agricultural systems are being implemented that use specific incredibly "smart" methods like weather monitoring sensors, remote sensors, and various other technical developments to gather data regarding the atmosphere, weather, and soil. Researchers have developed smart agricultural systems that use different sensors in order to collect detailed sensor information. Using this data allows the farmer to create more valuable products. The research's key objective is to render processes automated by decreasing human involvement, prices, electricity, and water use, like water control, crop management, and smart agricultural practices [4].

Besides, fertilizer plays an essential role in agriculture by its contribution to improving plant productivity. Using IoT, farmers can more efficiently and at less cost control the soil condition by controlling it everywhere. This study's fundamental aim is to merge IoT and technology with emerging developments in water conservation, fertilizers, and electricity in the agricultural industry. This benefits both the economic growth of the countries and the welfare of the citizens. IoT can monitor and take care of all the related manufacturing aspects and minimize waste, failure, and costs by incorporating sophisticated hardware and software techniques. The required knowledge to make informed choices can only be accessed by mobile devices. The IoT is enabling farmers to turn into more effective, affordable, and environmentally safe farms. Innovative technologies and applications might resolve the quality, quantity, sustainability and cost-effectiveness of agricultural production [1]. In addition to the optimization of prices as well as the growth in dairy production, and the improvement in certain livestock over the breeding period through the detection of the estrus cycle and enhanced sources of revenue from wastes, IoT provides further advantages for the agriculture sector by improving the health of livestock through better food and environment [1].



This study has explored IoT technologies in agriculture and farming that have recently been introduced to resolve present-day challenges, such as excessive labor activity resulting in increased labor costs, excessive water use, potential water savings steps, higher energy use, and the future energy-saving initiatives and, crop control problems. The research shows that irrigation and crop management and water is a vertical business that can be categorized inside the vertical demographic [2]. The research also emphasizes work and stream data from a range of fields relevant to agriculture to recognize IoT technologies' discrepancy in an area that least obtained data. IoT produces massive data (high volume and different data rates) with varying data quality, so-called big data. To advance smart IoT use, the study of the IoT framework and its main attributes is essential. Therefore, our paper's fundamental purpose is to discuss newly developed IoT applications, such as crop and water management, in farming and agriculture to obtain a more profound knowledge on sensor data processing, used technologies, and sub-verticals. The second aim of my research is to establish and analyze the possible issues of the future, such as improved interaction between citizens, high labor costs, increased water use, water shortage for the coming years, increased energy use, potential power savings and, crop tracking challenges for irrigation and agriculture [4].

II. SMART AGRICULTURE IOT PROTOCOLS

"Network sensors, gateways, the server, and, of course, the network" are the essential components of the smart agricultural infrastructure. Network sensors, a series of detectors in a farm, i.e., a square meters of land and relay data over the Internet as per the specified schedule, interact with the gateway. The gateway stores information on a local scale. The transmission controller protocol (TCP/IP), associated with most network hardware elements, could link the server's network sensor. It is important to note that, due to software, hardware, and interface compatibility concerns, the incorporation of diverse data from different sensors used in smart agricultural production is a demanding job [5].

CONNECTION STANDARDS FOR WIRELESS COMMUNICATION

The significant standards that can be used are the following; "IEEE 802.11 (Wireless Fidelity - Wi-Fi), IEEE 802.201, IEEE 802.15.4 (Low-rate LR-WPAN) and 2nd/3rd/4th generation of cell networks (2G/3G/4G), IEEE 802.15.1 (Bluetooth), LoRaWAN R1.0, Wireless Networking Protocols for physical communication and connecting layers". The two promising innovations that contain many technological variations are LoRA and NB-IoT. The contact protocol will be chosen based on the optimal consumption of resources, distance, cost of implementation, etc. The 3GPP communication technology standard NB-IoT is intended to support a wide variety of mobile devices and services [1] [4]. NB-IoT is a 3GPP radio technology standard. However, LoRaWAN provides shallow energy usage (20 miles) and high coverage, but small data speeds, i.e., 0.3-50 kbps. Indeed, the transmission of calculation data from the most conventional agricultural sensors is satisfactory. For knowledge purposes, the IEEE 802.15.4 protocol was suggested to correspond between the sensor nodes and the gateway. For RTU's server communications, usage of the "General Packet Radio Service (GPRS) or the Global Mobile Communication Networks Enhanced Data Rates GSM Evolution (EDGE)" has also been suggested. The following table offers a comparison of these protocols [1].

COMPARISON OF WIRELESS COMMUNICATION PROTOCOLS

	Frequency band	Data rate	Range	Energy consumption	Cost
WiFi	5 - 60 GHz	High	Medium	High	High
WiMAX	2 - 66 GHz	High	High	Medium	High
LR-WPAN	868/915 MHz, 2.4 GHz	Low	Low	Low	Low
Cellular	865 MHz, 2.4 GHz	Flexible	High	Medium	Medium
Bluetooth	2.4 GHz	Medium	Low	Very low	Low
LoRa	868/900 MHz	Low	High	Very low	High
SigFox	868/902/920 MHz	Low	High	Very low	Medium
NB-IoT	800/900/1800 MHz (EU)	Low	High	Low	High

CLOUD NETWORKING

Cloud Networking may collect and evaluate data shared by the remote client and then reveal the information straightforwardly. Data analysis involves visualizations, decision-making, and others. Cloud service models may be divided into three subcategories: "Technology as a Service, Network as a Service, and Software as a Service." If one is interested in creating an intelligent farming method, many problems need to be addressed. The data was taken from peer-reviewed research articles (2016-2018) based on IoT-sub-verticals and compilation of sensory data for detailed decision-making measurements [5].

III. METHODS AND MATERIALS

In research papers regarding agriculture incorporating the Internet of Things (IoT) and industrial technologies, the data collection includes defining relevant parameters. Peer-reviewed scientific IoT literature released in scientific newspapers in agriculture and agriculture between 2016 and 2018 was specific.

RAW DATA COLLECTION

Data from peer reviews (2016-2018), obtained from the IEEE database, was gathered for this analysis. Many of these journals include numerous data implementations examined and evaluated in this survey. The comparative features included sub-verticals, data processing calculation, equipment employed, new problems, advantages, countries, and IoT drivers.

REQUIREMENTS FOR DATA INCLUSION

A comparative table was drawn up to provide the following attributes for the study of data inclusion criteria: "creator, sub-vertical, calculation data set, technology, advantages, challenge, response, and IoT controls." In our analysis, however, publications were omitted if the attributes chosen did not occur [1] [6]. This research did not involve the number of sensors, the volume of data gathered, the hardware behind it, sensor topology, and other intermediate portals. No data can be identified for all the publications checked by the peers (2016-2018).

REVIEW OF DATA

Findings were clustered and summarized according to the data obtained in peer-reviewed papers and on new topics in a table. Data sets incorporated sub-vertical characteristics, data processing measures, infrastructure, gain, difficulty, solution, and countries based on agricultural advance automation and IoT drivers [6]. Considering the findings from 2016 to 2018, the analysis's descriptive specifics depending on the publishing year have been analyzed.

IV. RESULTS

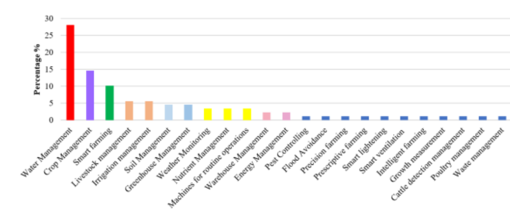
The purpose of this research is to examine the inclusion of IoT in agricultural and agricultural applications growth. The analysis focuses on sub-verticals and the gathering of data for agricultural measurements and innovations across the Internet of Things (IoT) to boost production and quality. This IoT analysis in agriculture and agriculture aims to establish an approach to criteria using agricultural, environmental parameters and technology, and IoT steps [7]. Several environmental parameters in agriculture need to be considered to boost crops, minimize water use, and human participation. Besides, various sub-verticals may be found based on the method variations.

We also collected papers in this study based on sub-verticals for cultivation and agriculture in 2016-2018. As Fig 1 reveals, 23 sub-verticals were identified in line with the findings, and water conservation was the main priority (28.08 percent) [1].

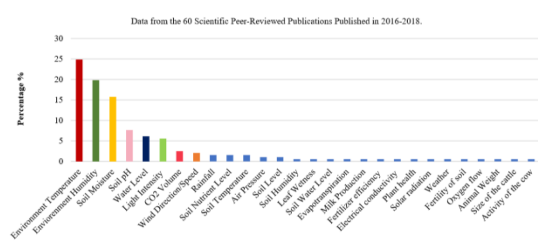
IoT relies on sensor data collections. To classify or forecast correct outcomes, a broad range of data must be obtained. "This analysis reveals that more studies concentrated on ambient measures of environmental temperature (24.87%), humidity (19.79%) and soil moisture (15.73%)." As Fig 2 reveals, 28 data forms were gathered to be deemed the most critical criteria for cultivation and agriculture for measurements of ambient temperatures and moisture.

As Fig 3 reveals, the innovations included in the papers have been categorized. "This study finds Wi-Fi to be the most used (30.27%) technology, accompanied by mobiles (21.10%) for agriculture and agriculture." ZigBee is still seen, albeit to a smaller degree, as another technology in data transmission.

"As seen in Fig. 4, in agriculture using IoT application was more pronounced than using simple farming methods. (simple farming – 28.3%, IoT agriculture – 76.1%)."



(Fig 1)



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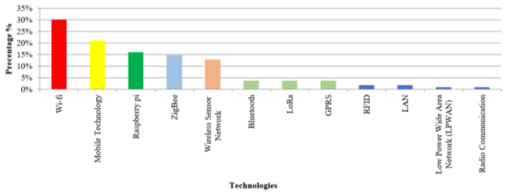

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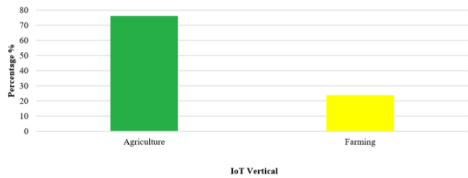

(Fig 4)

V. DISCUSSIONS

In this study, we established core qualities for evaluating research results in farming and agriculture. The above details suggest that water conservation, grain management, and intelligent agriculture are the most studied sub-verticals. In recent years, the most sought-after sub-vertical water control has primarily focused on water supply use due to its inadequate availability in most nations. Irrigation conditions in farming impact crop production, rendering irrigation management a primary priority of efficiency growth [8]. Due to the value of food supply for an increasing global population, the second sub-vertical one is crop management. For sustainable development, it is necessary to administer the standard, quantity, and productivity. While the research addressed that the most utilized sensor data collecting for measurements are pH and humidity conditions. According to our review, the most frequently calibrated values are ambient temperature, accompanied by humidity and moisture content. Besides, IoT can be characterized as the merging of heterogeneous chip networks, which progressively broaden due to rapid growth in Internet applications such as; "logistics, agriculture, the smart society, smart conversion systems, control systems, and trackers." According to researchers' analyses, in the year 2020, IoT artifacts are semi-intelligentsia and an integral aspect of human social lives [9]. Mobile devices are technologies with a broad range of agricultural and irrigation standards compared with other technology solutions to track soil and water supply, as examined in the Wi-Fi study.

While the outcome has been seen in this manner, a report examined the RFID usage, a technology utilized by the Wireless Sensor Network (WSN), to improve crop development to satisfy increasing population needs efficiently. The other IoT systems that use "Low Capacity Shorten IoT Networks, Low Range PAN and Low Power and Wide Area networks in developed countries with low Internet speed rather than Wi-Fi [10]."

Further studies have shown that WSN is used for various purposes such as health regulations, environment, agriculture surveillance, and commercial applications. In contrast, this research shows the usage of IoT in agriculture and IoT in engineering. We note that in developed countries, agriculture is, for example, the principal source of income, as compared with others, India, with a broad geographical region. Many experiments on water resources were undertaken by measuring environmental parameters such as temperature, moisture, and humidity. Most of the outcomes were based on optimizing water usage, reducing inhuman activity and manufacturing costs.

Future studies should concentrate mainly on automating current waste treatment, intelligent lighting, and sub-vertical control processes by reducing established disadvantages since it gained the least research publicity during the period. In future IoT research, Fog Computing could be viewed as a cross-boundary breakthrough between remote data centers and IoT computers [11]. While IoT has addressed several problems pertaining to agriculture and agriculture, we must take note of limitations. Any of the drawbacks to being discussed in future studies include lack of interoperable and system consistency, network flexibility problems as more systems link, and sensors' durability.

This research found that industry 4.0 emphasizes IoT aspects in agriculture, which turn the growth and agriculture fields. This research has taken into account the soil quality, irrigation level, temperature, pest and insect presence as sensors details. The drivers' assistance in optimizing roads and shortening harvesting and care, thereby minimizing fuel usage, is among the fundamental ways they have been examined. Sufficient food is a massive problem for the whole planet since the global population changes quickly, climate change, and the lack of jobs. Researchers are currently working on robotics to fix these concerns. A growing number of researchers and businesses have concentrated on weeding by decreasing farmers' herbicides in robotics and artificial intelligence (AI) [12].

Cloud computing requires a fast Internet link to send and retrieve data from the cloud compared to edge computing. The method includes the transmission and retrieval of data from the cloud. Because its bandwidth is more extensive than its power, data must often be stored locally rather than sent to the cloud. The edge computing mechanism is more effective than the cloud since the bandwidth doubles as the power. Because IoT uses sensor data collection to make choices, the cloud or the edge-based data may be used according to device specifications to process the collected information. However, IoT device implementation also poses several difficulties. After the lack of technological expertise amongst farmers in the future, the link of too many machines to IoT is the greatest obstacle [13]. Today's unified infrastructure promoting IoT systems is less progressive than network development, and central systems would become the bottleneck. Besides, as IoT device deploys, battery sensor power and lifetime and data storage are both far more oriented. Smart agriculture is a synthesis of modern technological developments and various digital crops and animals, cultivation and agriculture. Intelligent cultivation will add farmers' benefits to agriculture. The reduced production resources save capital and labor for farmers and thus improve reliability and market results. To turn the Internet of things (IoT) into the potential dominant technology, it may be exciting to research a range of methods for a machine framework, decision-making through inference or trend analysis large data databases [14].

This research would fill the void by defining the numerous IoT sub-verticals and data sets for industrial and agricultural measurements. Results indicate that most significant sub-verticals and data sets for agricultural and farming measures are considered. Our analysis also reveals the technology used for the production of IoT applications for the time reviewed.

In brief, this research has a broader view of IoT technologies built for agriculture and agricultural automation. This study demonstrates the most relevant sub-verticals, collected sensor data, and IoT-based applications in agriculture and the agricultural sector for substantial market development.

The table below indicates other requirements for information collection that were not used in all research [1].

TABLE II. IMPORTANT DATA INCLUSION CRITERIA FOR FUTURE IOT STUDIES

Criteria	Information to be Collected in IoT Domain	Addressed in this Review	To be Addressed in Future Research
IoT Sub Verticals	What are the sub-areas addressed?	✓	✓
Measures (Data Collection)	What sort of sensor data collected for measurements?	✓	✓
Technologies Used	Used technologies to develop or to solve problems.	✓	✓
Benefits of Proposed System	Advantages of having the system to address existing issues.	✓	✓
Challenges in Current Approach	Existing issues and problems in the current systems and methods.	✓	✓
Solution for Current Issues	Proposed solution to solve the issues in the current problems.	✓	✓
Drivers of IoT Countries	What are the novelty and future aspects of the proposed systems and methods?	✓	✓
IoT systems' Scalability	Number of sensors are deployed, a variety of sensors, amount of data collection (volume), speed (velocity) of data collection (days-hours, hours-minutes, seconds-microseconds)	x	✓
Heterogeneity Aspects	Are sensors and underlying technologies uniform or heterogeneous in the system?	x	✓
System Architecture	Complex is the adopted IoT architecture, sensors topology, information about intermediate gateways	x	✓
Data Analysis Methods	Business intelligence, Artificial Intelligence, learning algorithms (machine Learning algorithms, Deep learning), big data technologies (Hadoop, Spark) and other protocols	x	✓
Observed System	Size or scale of the observed land or agricultural domain	x	✓
Access to Natural resources	Water resources and weather condition	x	✓
IoT Security and Threat Solutions / Protocols	Encryption techniques for IoT data access, Vulnerable identity (change default passwords), self-error detection and possible cyber attacks	x	✓
Operational Technology	Control and automation hardware, controllers, sensors and actuators	x	✓
Data Storage and Cloud Platform	Public Cloud, Private Cloud, Hybrid Cloud, Cloud (data at rest and centralized data center), Fog (data in motion and distributed data center) or Edge computing	x	✓
Power Supplies	Battery, AC power, and other protocol to optimize energy savings	x	✓

VI. CONCLUSION

From the peer reviews (2016-2018), water management had been the highest estimated IoT sub-vertical led by crop management, smart cultivation, livestock management, and irrigation management with the same percentage when addressing the possible Internet of Things applications. According to the observation, the most critical sensor data set for the calculation is ambient temperature, environmental moisture, and even other sensor data collected for IoT-applications such as soil moisture and soil pH. There are fewer uses of different livestock and agriculture technologies such as; "Zigbee, RFID, Raspberry, pi, WSN, Bluetooth, LoRa and GPRS [15]." The food business uses IoT to automate, as opposed to the agricultural field, a lower proportion. The automation method could become more reliable and competitive. The findings for successful companies may help investigators find new ways and solutions to the current agricultural period.

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