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A Systematic Literature Review of Internet of Things Applications in Agriculture

Ahmed Tawfiq Jamil

Ministry of Education Republic of Iraq, General Directorate of Education, Najaf, Iraq

alahmedtawfiq@gmail.com

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Abstract: The digital divide between agricultural farmers and IOT technology has narrowed in recent years. In the future, these technologies will allow for increased production via sustainable food growing, as well as environmental protection through effective water usage and input and treatment optimization. IOT technology enables the creation of systems that assist various agricultural activities. Remote monitoring systems, decision support tools, automated irrigation systems, frost protection systems, and fertilization systems are examples of these systems. Given the above facts, it is critical to offer farmers and researchers a comprehensive picture of IOT applications in agriculture. In this regard, this paper gives a thorough evaluation of the literature on IOT-based tools and applications for agriculture. The goal of this paper is to provide an overview of IOT applications in agriculture by discussing topics such as IOT-based software applications for agriculture that are currently available on the market, IOT-based devices used in agriculture, and the benefits provided by these types of technologies.

Key words: Smart agriculture, IOT system, Cloud computing, Food technology, and IOT applications

1. INTRODUCTION

The enables farmers to remotely supervise agricultural fields using sensors and to have autonomous watering systems[1]. More precise information on the crop, the soil, and the climate may be collected via the use of computer programs based on sensors than through more conventional approaches. This trait contributes to the higher quality of the goods, procedures, and raw materials employed in the process. Because of these factors, smart agriculture based on IOT is more efficient than conventional methods [2]. Smart agriculture technologies based on the Internet of Things may also aid the success of organic and family farms [3]. The digital divide between agricultural farmers and IOT technology has narrowed [4]. These tools will help farmers increase output in the future by growing food in a more environmentally friendly way, all while minimizing their impact on the planet by conserving water and minimizing wasteful treatments and inputs[5]. Smart farming practices include things like automatic irrigation systems, frost prevention, fertilizing, and remote monitoring[6]. These activities may be carried out with the assistance of intelligent applications including devices [7], intelligent machines, integration platforms, monitoring processes, systems, and cloud computing [8–10]. It's possible that the

Internet of Things (IOT) and cloud computing may combine to form something called the Cloud of Things (Cloud of Things), which will help realize the IOT and Internet aims[11,12]. Furthermore, the Internet of Things must assist society in achieving information openness [13, 14]. In this study, a comprehensive analysis of the research on Internet of Things (IOT) technologies and applications for agricultural purposes is presented. The purpose of this article is to provide an overview of these fields by discussing topics like Internet of Things (IOT) software applications for agriculture that are currently available on the market, Internet of Things (IOT) devices that are used in agriculture, and the benefits that are provided by these technological advancements.

2. IMPLICATIONS OF IOT TECHNOLOGIES FOR AGRICULTURE

This section describes the three parts of the literature review approach utilized in this work. question formulation, search strategy, and research selection. This review explores research activities and projects related to the use of digital applications to agriculture in order to provide direction for their usage in urban agriculture, precision agriculture, and industrial agriculture were shown.

3.1. Questions and Motivation Relating to Research

The underlying research issues and rationale for the work are provided as follows below.

***RQ1**:* Where precisely might Internet of Things technologies be seen being used in the agricultural sector? What types of technologies based on the Internet of Things are now being used in the field?

RM1: The goal is to identify the most prominent applications of internet of things technology in agriculture and to compile a list of the most significant internet of things technology-based instruments used in this industry.

RQ2: What potential benefits may the Internet of Things (IOT) have for farmers, and what sort of software would be required for them to take advantage of them?

RM2: Through the study, the types of IOT software that are created and how they are used in agriculture are recognized.

3.2. Plan for Searching

During the investigation for primary research, the following online resources were utilized: IEEE, Elsevier, ACM Digital Library, and Science Direct. After that, we compiled a list of phrases related to the subject matter of our investigation, which included the following: environment, applications, devices, Internet of Things, intelligent agriculture, cloud in agriculture, and analytics data in agriculture. In the end, the search string was made by combining the keywords that were supplied before with the connectors "AND" and "OR." As a consequence of this, the search chain that we make use of may be seen in Table 1.

Table 1. List of Keywords of data sets in Scientific web sources.

Scientific web sources	Search Keywords
Science Direct	((“Agriculture environment with IOT” OR “Apps of Agriculture ” OR “Smart Devices in Agriculture”) AND (‘‘IOT Agriculture’’ OR “Internet of Things Data in the Agriculture’’ OR ‘‘Intelligent Agriculture’’ OR ‘‘Cloud in the Agriculture’’)) .
Elsevier	
IEEE	
ACM digital library	

3.3. Researches Selection

Methods for selecting research included electronic databases while keeping in mind predetermined search parameters and other inclusion criteria. This method is divided into two steps, detailed below. The studies in digital libraries in Table 1 for the first research question (QR1) were (283, 1500, 1059, 920, respectively). As for the second research question (QR2), the tests that were carried out in this study were (39, 88, 125, and 317), respectively.

3. THE GATHERING OF INFORMATION

This part gives an overview of all the studies that were chosen because they attempted to address the research questions that were stated at the beginning of this piece of work.

3.1. Implementing IOT Technologies in Agriculture

The most common applications of IOT technology in agriculture are in the realm of precision agriculture[15], which employs these techniques to improve urban agriculture and precision agronomy in smart cities. These days, cyber-physical systems (CPS) and software-defined networks (SDN) are essential components of many "smart cities" [16].Agricultural drones are another example of how the Internet of Things is being put to use; these low-cost aircraft are equipped with sophisticated sensors

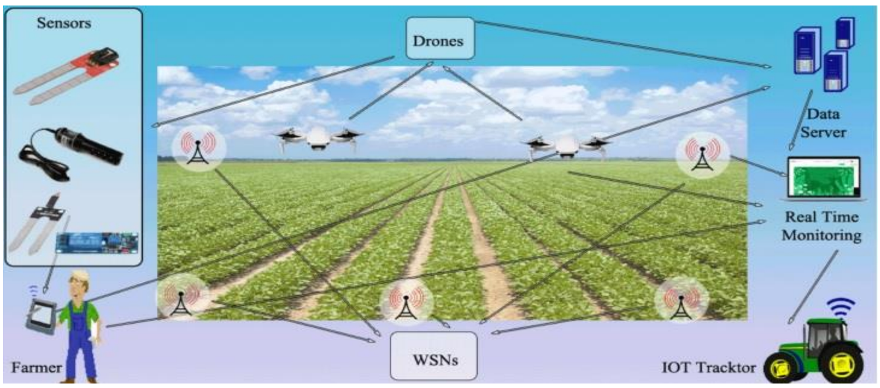

Fig. 1. Smart farm monitoring system based on the internet of things [17]

that may help farmers enhance crop yields and decrease instances of crop damage as shown in Fig. 1[17].

Hydroponic and small-scale aquaponics systems [18] are another area where the Internet of Things is being put to use, in addition to "intelligent greenhouses"[19]. Smart greenhouses are becoming more widespread in metropolitan areas due to their ability to promote plant growth, production, and quality via the monitoring of many parameters of fertilizer solutions [20]. These enhancements are crucial in realizing the vision of smart cities equipped with the infrastructure necessary to automate, optimize, and improve urban agriculture and precision agronomy. IOT technologies are also used in vertical agriculture [21], where they enable the regulation of water and moisture levels in soil through desktop or handheld computers and mobile devices. Last but not least, there are applications that merge IOT technology with AI, such as Malthouse [22], an AI system that prescribes settings and schedules for use in precision farming and the food production industry.

3.2. Agricultural Tools Based on IOT

Many sectors and markets have embraced IOT-enabled gadgets. In this regard, agriculture is one sector that stands to gain immensely from Internet of Things innovations. For instance, LoRa, for instance, has become a popular network radio in Indiana because of its many useful features, including its low power requirements, extended range, and inexpensive initial cost. Internet of Things (IOT) cameras are another kind of device used to examine food for quality [23]. However, various approaches to manage agricultural data using Big Data technologies exist, such as cloud computing and wireless sensor networks (AaaS, Agriculture-as-a-Service) [24]. For example, Phytec's PlanIOT platform can monitor plants, evaluate data, and make recommendations without human intervention.

3.3. Applications Based on IOT Used in Agriculture

Technologies built on the IOT have found widespread use. For this reason, many businesses are pouring resources into creating agricultural software that takes advantage of the Internet of Things. There are already a number of software packages available that are specifically designed to aid with various agrarian procedures. As an example, consider the unmanned aerial vehicle AG-IOT [25], which can locate and assist ground-based IOT-based devices in banding together to send data in groups. In contrast, Agro 4.0 [26] makes use of high-performance computational tools, a sensor network, mobile-to-mobile communication, cloud computing, and analytical methodologies to manage enormous data sets and provide decision support systems. The information collected by the numerous sensors in a given region of the crop is recorded, stored, and regularly updated by Agro-Tech [27]. Additionally, the program provides access to this data with the intent of helping farmers keep tabs on their crops. Precision agriculture and the food industry may both benefit from Malthouse [28]. AI system that prescribes configurations and timetables. The Internet of Things (IOT) has made it possible to remotely perform such an operation, with equipment like cameras and Raspberry Pi cards being used in agricultural monitoring systems that can stream live footage as shown in Fig. 2[29]. Cropx, on the other hand, is an adaptive irrigation software tool that assists farmers in optimizing crop yields while simultaneously reducing water and power consumption. Using Farmlogs, a piece of farm management software, you may keep a photographic record of your efforts to protect your crops. Using the Mbegu Choice app, farmers can locate reputable dealers of drought-resistant seed.

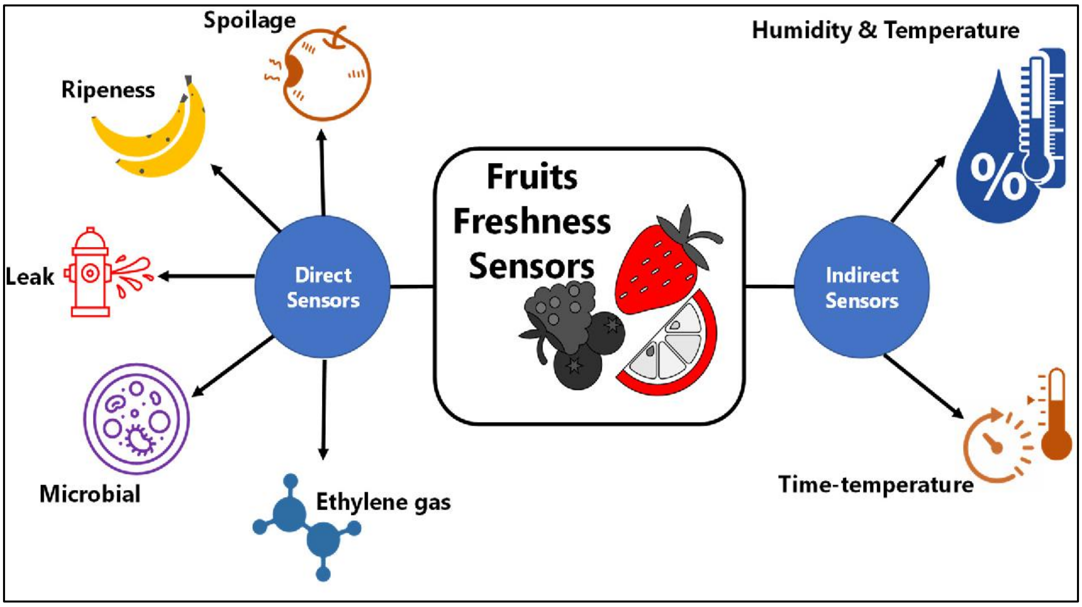

Fig. 2. The overarching design of IOT based fruit identification and harvesting system[29] .

3.4. The Advantages of IOT in Agriculture

The following is a synopsis of the primary literature review findings about the advantages of IOT in agriculture.

I. Making use of readily available equipment, software, and massive amounts of data to improve agricultural practices in urban and rural communities.

II. The capacity to track the quantity and quality of food produced in real time, which will help cut down on waste and save money.

III. The development of agriculturally relevant business models [30] that promote consumer engagement.

IV. This includes crop monitoring, which helps cut down on expenses and equipment theft.

V. Sensor-based automatic irrigation [31] that responds to changes in soil moisture, air temperature, and humidity.

VI. Sensor networks allow for the automated collection of environmental characteristics for further processing and analysis.

VII. After analyzing huge datasets, decision support systems boost productivity and efficiency in the workplace.

4. The most important successful experiences in smart agriculture

4.1. The United States

The United States, which has the world's largest electronic information economy, supports smart and precision agriculture through the Internet of Things. The United States has led the research and deployment of agricultural IoT in recent years. 75% or more of US farms with annual sales of $450,000 or more use IoT in agriculture, and 41% of small farms do as well. In agriculture, IoT can be used to find out what nutrients are in the soil, prevent and control diseases of crops and aquatic animals, save water through irrigation, and track quality and safety[32]. By creating the IoT infrastructure for agriculture, manufacturers can monitor, learn from, and interact with their surroundings. Intelligent irrigation combines soil moisture, air moisture, and other components to manage the frequency of irrigation and water use and prevent waste. When the Internet of Things is used to integrate real-time information on livestock and poultry diseases, crop diseases, pests, and other elements, it could save time and money, reduce pesticide use, and increase agricultural accuracy. US Farming System Simulation and Forecasting has helped US agriculture avoid pests, diseases, natural disasters, and diseases of livestock and poultry. The fact that American farms are using the Internet of Things more and more shows how forward-thinking they are about technology[33].

4.2. Japan

The growth of information technology in Japan's agricultural industry is focused on increasing productivity. Japanese agriculture has become a model of efficiency and sustainability thanks to the Internet of Things (IoT). Agriculture-related IoT growth happened in Japan in 2004, and the Japanese Ministry of Internal Affairs and Communications also suggested U-Japan (JMIAC) [34]. The purpose of this research is to discover the connections between people and goods in agricultural supply networks. Farmers may now build up wireless networks in distributed plastic greenhouses, connecting them to monitoring probes, soil, sunlight, air temperature, carbon monoxide emission sensors, and other equipment thanks to IoT technology[35]. More than half of the farmers in Japan are already using IoT to make up for the lack of workers and grow more crops.

4.3. Arab region

An ecosystem for agricultural technologies built on data analytics, the IoT, and AI has emerged in the Arab region recently. As a result of the efforts of both new businesses and the governments in the Arabian Gulf region, the area has been at the forefront of the agricultural technological revolution. UAE has set aside at least $100 million to fund the creation of an agricultural technology business as part of its National Food Security Strategy [36]. Saudi Arabia gives big subsidies to irrigation projects so that the country can grow more wheat [37]. In Egypt, animal excrement was used to generate plant fertilizers that were subsequently used in agriculture in an effort to increase agricultural productivity and in keeping with the principles of a circular economy [38]. In the meanwhile, Lebanon has implemented an irrigation system that uses both hardware and software to help reduce the amount of water needed for agricultural output [39]. As of late, Jordan is home to the world's first agricultural technology accelerator, which is aimed at helping small and medium-sized firms in the agricultural technology industry [40]. It is of the utmost importance to study ways to enhance agricultural technology because of the Arab world's vulnerability to water shortages and desertification.

5. DISCUSSION

The articles that were chosen provide a synopsis of the research that was considered for this project. You can see that 21 of the articles focus on the use of IOT tools in farming. Twelve of the articles focus on the implementation of IOT-based tools in farming [41]. Some of the most common types of devices that are used in this context include optical sensors, which are used for measuring soil properties; photodiodes and photodetectors, which are used for identifying soils, organic matter, and soil moisture; moisture sensors, which are used for measuring the amount of water that is present in the soil; and geo-positioning devices, which are used for specifying latitude, longitude, and altitude. It is important to note that in order to practice precision agriculture, the use of GPS technology is absolutely necessary [42]. The development of platforms for information collection and analysis also relies heavily on other IOT-based equipment [43], such as cameras and wireless networks, which are commonly employed in the agricultural setting. In contrast, this study identifies a number of software tools that stand out from the crowd: a support system for renewable energy projects; a system that focuses on environmental resources and technologies; a decision support system for precision agriculture [46]; a system that is based on wireless sensor networks; and a smart system for vertical farming [46]. The reviewed literature includes 21 studies on IOT applications in agriculture; 12 studies on IOT-enabled devices used in agriculture; 8 studies on IOT-enabled software applications used in agriculture; 11 studies on the positive effects of IOT on agriculture; and 8 studies on the use of automated control technology in agriculture.

6. CONCLUSIONS

In order to carry out effective remote monitoring of crops, IOT technologies make it possible to collect data on factors such as climate, humidity, temperature, and soil fertility. These advancements in technology have made it possible for farmers to monitor their crops from anywhere at any time. However, wireless sensor networks enable management of the farm's environment and the automation of many tasks. Some of the studies included in this article, for instance, use the use of wireless cameras to monitor the progress of a crop in real time. Drones have been used in other studies to assist with precision agricultural activities, and farmers' cellphones have been used to keep tabs on crop progress and problems. When used to agriculture, IOT may be linked with a number of outstanding technologies, including wireless sensor networks, cloud computing, middleware systems, and mobile applications. In the agriculture sector, Internet of Things technologies have already proven indispensable. For this reason, we conducted a literature analysis to determine the most important agricultural IOT applications, IOT-based software and devices, and agricultural advantages. While the issues discussed here are crucial for the agricultural community as a whole, it is essential to highlight the need to review further studies that focus on finding environmentally friendly solutions to the challenges of growing food sustainably.

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