Internet of Things-Based Devices/Robots in Agriculture 4.0

Gulbir Singh and Kuldeep Kumar Yogi

Abstract Agriculture 4.0 focuses majorly on precision agriculture. Precision agriculture can be achieved in several ways such as refinement of cultivation practices, choices of crops, reduction of risk and volatility, water management, optimized use of pesticides, land/crop monitoring with minimal environmental impact. The best way to achieve precision agriculture through the Internet of Things-based devices in agriculture. The rapid developments on the Internet of Things-based devices have impacted every industry including "Agriculture." This revolutionary change in agriculture is changing the present agricultural methods, and creating new opportunities, and challenges. The Internet of Things-based devices and communication techniques along with wireless sensors are analyzed in this chapter in detail. The specific sensors available for precision agricultural applications like the preparation of soil, checking the status of the crop, pest, and insect identification, and detection, irrigation, spraying of fertilizers are explained. The use of Internet of Things-based devices helps the farmers through the crop stages i.e., sowing to harvesting is explained. At last, this chapter concludes and provides the challenges faced while implementing Internet of Things-based devices in agriculture.

Keywords Internet of Things · Internet of Things-based devices · Sensors · Communication technology · Agriculture 4.0 · UAVs

1 Introduction

The economy of the world majorly depends upon the agriculture. The world's population depends upon agriculture for its survival, and agriculture is the major source to fulfill human needs. Agriculture has a major role in the economic development of countries. The major roles are listed below:

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P. Karrupusamy et al. (eds.), *Sustainable Communication Networks and Application*,
Lecture Notes on Data Engineering and Communications Technologies 93,
https://doi.org/10.1007/978-981-16-6605-6_6

- Agriculture contributes to the national income of a nation.
- It is the major source of the food supply chain to the humans and the industry.
- It is the major source of raw materials for different industries.
- It is very helpful to reduce inequality.
- It is a source of foreign exchange for the nations.
- It contributes to the capital formation.

Precision agriculture is an approach to achieve smart farming. Smart farming refers to a farm management technique that makes use of advanced technologies intending to increase the quantity and quality of agricultural products. This technique includes the usage of Internet of Things-based devices, data management, soil and crop preparation, crop sowing, irrigation, pest/yield monitoring, and last cultivation.

Over the past years, the smart farming has become more useful to farmers as it grants access to farmers to modern technologies and devices that help in the increase in the agricultural product's quantity and quality, which this technique helps in reduction of farming cost.

The benefits of smart farming in agriculture include the high rate of crop production, the decrease in the use of fertilizers, pesticides, and water, reduce environmental pollution, and the increase in the safety of farms and farmers.

Recent researches suggested a vast range of smart devices to fetch and monitor the information related to crop and field status. Many manufactures now providing a vast range of the Internet of Things-based sensors, communicating devices, agricultural robots, unmanned aerial vehicles (UAVs), and other heavy agricultural machinery.

The Internet of Things-based technologies are used in agriculture to retrieve information about the crop field through a variety of sensors for monitoring, trespassing, and controlling the field area [1]. The Internet of Things-based technologies with the use of remote sensing devices provide a way to sense an object in a controlled environment. It helps to reduce the gap between the computer-oriented system and the real world. The main advantage of introducing Internet of Things-based devices in agriculture is to maximize accuracy and efficiency with a low human intervention.

According to a report published by Business Insider Intelligence, the usage of Internet of Things-based devices which are used in smart agriculture is continuously increasing day by day. The following Fig. 1 shows the rapid growth of the Internet of

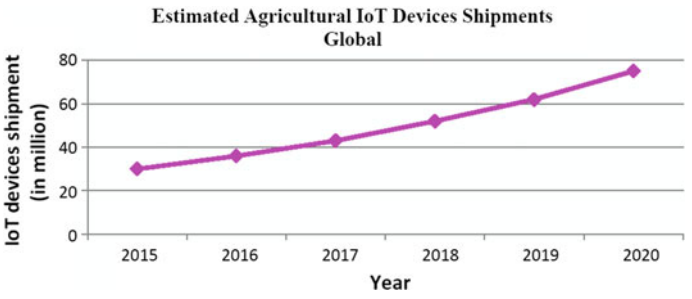

Fig. 1 Growth in the usage of Internet of Things-based devices from 2015–2020

Things-based devices from 2015–2020. The graph shows that the growth is enhanced up to 150% [2].

This article provides knowledge that can help different engineers and researchers for the implementation of Internet of Things-based technologies to obtain desired smart agriculture. This article also provides an overview of the major applications of the Internet of Things in the agriculture field. The use of different Internet of Things-based devices/sensors is also discussed followed by a conclusion and challenges arise in implementing the Internet of Things in the agriculture.

2 Literature Review

Many research centers and software as well as software industries focus on the impact and usage of Internet of Things-based technologies and suggested major concerns in this field. The section focuses on the past work done by authors/researchers that can use the Internet of Things-based devices in agriculture.

In Fig. 2, the usage and application of Internet of Things-based devices in agriculture are shown, and Table 1 shows the research work done by different researchers in agriculture using Internet of Things-based technologies.

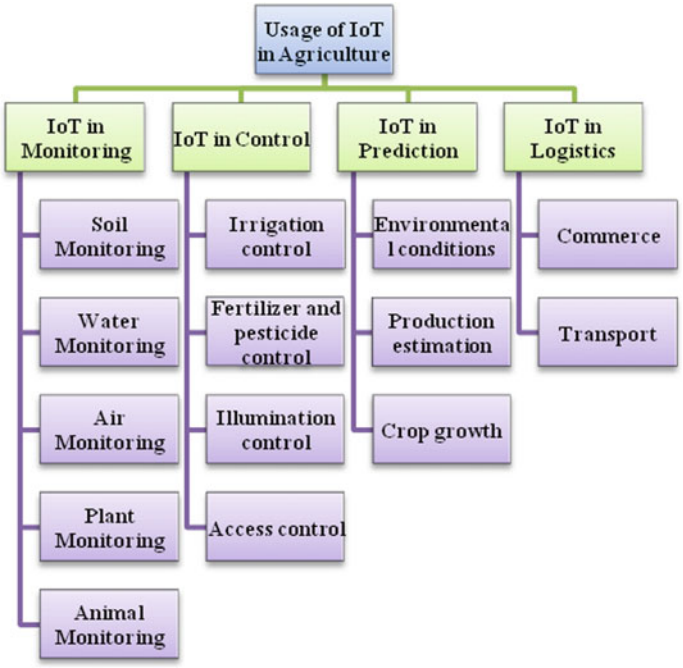

Fig. 2 Usage of Internet of Things-based devices in agriculture

Table 1 Past research which was done by the researcher using Internet of Things-based technologies in agriculture

Authors and Year	Subdomain	Observations
Cheng-Jun [3]	Monitoring of field	The author proposed a system for crop monitoring, and using an online tool, it captures multiple variables like soil moisture, pH levels of water, humidity, temperature, etc. The proposed system consists of three levels of architecture first, the perception layer using WSN support; second, the network layer for data communication, and the last layer as an application layer Web server to analyze the data
Mafuta et al. [4]	Monitoring of soil	The authors have suggested an Internet of Things-based system with WSN to monitor the soil temperature, and moisture. The proposed system uses communication technology like ZigBee, GPRS, and the Internet
Singh et al. [5]	Air pollution monitoring	The authors have proposed a system with the help of Adriano and a variety of gas sensors. The authors have developed a Web application to store and process the processed data
Singh and Yogi [6]	Crop disease monitoring	The authors have a critical review on crop/plant disease detection using Internet of Things-based devices. They also focus on the use of machine learning and Artificial Intelligence for plant disease detection
Jain et al. [7]	Animal monitoring	The authors have proposed a system for animal monitoring, where the Internet of Things-based system is responsible for monitoring the Swamp Deers. The proposed system collects the data of animals' behavior and climate at the same time
Shuwen and Changli [8]	Irrigation control and monitoring	The authors have suggested a solar power-based irrigation monitoring system that uses the ZigBee protocol for data communication

(continued)

Table 1 (continued)

Authors and Year	Subdomain	Observations
Pahuja et al. [9]	Pesticides and fertilizers monitoring	The authors have proposed a microclimate monitoring system for the greenhouse. They have used the WSN system to collect and process the data
Cozzolino et al. [10]	An infrared sensor in the field	The authors have done a critical review of the usage of infrared sensors in the agriculture field. They have used infrared sensors to monitor the harvesting of cereal crops
Bhatnagar et al. [11]	Internet of Things devices in agriculture	The authors have analyzed the usage of Internet of Things-based devices in the agriculture field. They have suggested the challenges faced in the implementation of these devices in agriculture
Unold et al. [12]	Internet of Things-based health monitoring system for COW	The authors have proposed a framework composed of hardware, cloud system, and user interface. The proposed system was tested in real-time, and has proved more effective for monitoring animals
Gadre and Deoskar [13]	Challenges, transformation, and benefits of Industry 4.0	The paper covers the strategic role that can help manufacturers as a guide for industry 4.0
Nejkovic et al. [14]	A semantic approach for RIoT autonomous robots	The authors have proposed a semantic approach for an autonomous robot of RIoT
Singh and Gupta [15]	Secured and optimized ad-hoc on-demand distance vector protocol for secured and optimized communication for disaster-response applications	The authors proposed a new secured and optimized ad-hoc on-demand distance vector protocol for secured and optimized communication for disaster response applications. With the help of IoT-based devices, the proposed protocol is reflected the better outcome in disaster response and prevention applications like climate and weather observation for agriculture

(continued)

Table 1 (continued)

Authors and Year	Subdomain	Observations
Manocha and Gupta [16]	Satellite image enhancement technique	The authors suggested a new satellite image enhancement framework (SIE-EVD) to reduce the blur or noise of an image of agricultural land captured by IoT-based devices without losing high-frequency details of the image

3 Application of Internet of Things-Based Devices in Agriculture

The traditional framing can be changed or transformed to modern/smart/precise farming by the implementation of Internet of Things-based devices, latest sensors. The solution to the traditional farming issues can be solved by following the practice of smart farming. Figure 3 lists all the major applications of Internet of Things-based devices in smart agriculture.

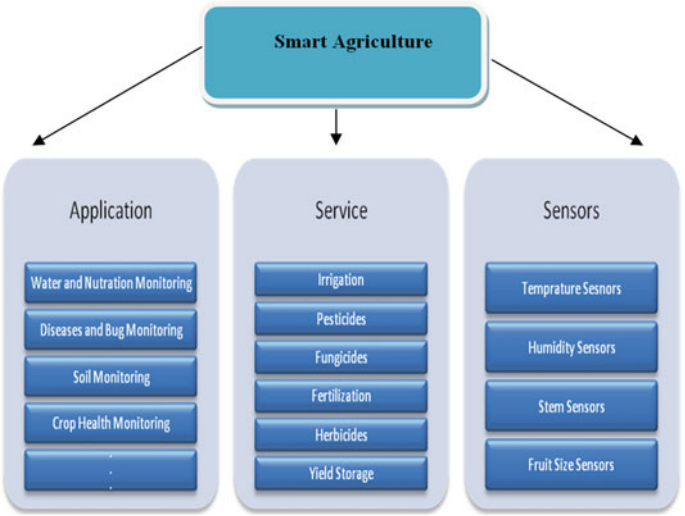

Fig. 3 Major application of Internet of Things-based technologies in smart agriculture

3.1 Soil Monitoring

Soil is the major building block for plants as soil provides all the nutrients and water supply to the plant that helps in plant growth. The first step of soil monitoring will be done through soil sampling, as the sampling process examines the field-specific details for farming. The major objective of soil analysis is to provide information on the nutrients status, so that the corresponding measures or actions can be taken when the crop faces issues related to nutrients deficiency.

The main factors that need to analyze in the soil are soil type, fertilizers/pesticides application, cropping history, topography and irrigation level, etc. This factor gives detailed information related to the physical, chemical, and biological status of the soil. Soil mapping helps in solving many issues related to sowing different varieties of the crop in specific farmland.

The Internet of Things-based technologies like sensors and vision-based devices can be used to identify the depth and distance for sowing the seeds. To perform the sowing activity in farmland, the robots can be taken into consideration, as they can be implemented at every location of the farm and can use global and local map generated from the vision-based and GPS-based system is connected to a computer.

3.2 Farm Irrigation

Irrigation can be done by various methods like sprinkler irrigation, drip irrigation and can be recommended to solve the issues of water wastage issues in farmlands. While in traditional farming, the irrigation methods such as furrow irrigation and flood irrigation were used that can badly affect the quality and quantity of the crop. It would be a tough job to determine the water requirement of field crops where other factors are involved such as soil moisture, crop irrigation methods, and crop type.

The current condition of irrigation can be enhanced by embracing the Internet of Things-based technology. Rapid growth is expected in crop production and efficiency with the help of the Internet of Things-based technologies like CWIS-based irrigation management systems. The CWIS is a wireless sensor-based system for monitoring irrigation where other field sensors are used to collect the field data from the farm.

3.3 Fertilizers Spraying

Fertilizers provide nutrients to plants for their fertility and growth. The plants need three major micronutrients nitrogen for the growth of the leaf, phosphorus for the flowers, fruits, and root development, and potassium for the water movement and stem development [17]. The shortage of the nutrients and applying them wrongly

may affect the harmfully of the plants. The use of fertilizers in excessive amounts may harm financial losses but also harm the crop, soil, and the environment.

The fertilization is done with the help of Internet of Things-based technologies in smart agriculture to help inaccurate estimation of the required amount of nutrients, and this also minimizes the negative effects on the crop and the environment. The Internet of Things-based fertilization technique helps in identifying the nutrients requirements by crop with high accuracy and minimum labor requirement. In smart farming, Internet of Things-based technologies like geo-mapping, GPS accuracy, VRT technology, and autonomous vehicles are used for the fertilization process.

3.4 Pest and Crop Disease Management

According to a report generated from FAO (Food and Agriculture Organization) estimated that 20 to 40% of global crops are lost annually due to disease and pests. To control a huge loss, the use of agrochemicals and pesticides was taken into consideration to reduce the loss in past years.

The use of Internet of Things-based devices like wireless sensors, drones, and robots helps the farmers to reduce the use of pesticides in fields or only used when they are required with the precise amount. These pesticides are very harmful to humans, environment and even sprayed in huge amounts also harmful to crops. The advanced Internet of Things-based technologies help in pest/disease management in real-time, provide live monitoring, forecasting of pests and diseases, and hence are proved more efficient [18]. The advanced pest and disease detection techniques depend upon three levels such as sensing, evaluation, and treatment. The image processing technique is a method where the real-time pictures have been captured from the farm and using advanced tools and techniques the pest and disease forecasting can be done.

Techniques like VRT chemigation [19] and vehicle precise spray are used in smart farming and also can be utilized for disease and pest treatment.

3.5 Harvesting, Forecasting, and Yield Monitoring

To monitor agriculture yield, the yield monitoring mechanism can be used to analyze the different aspects related to agriculture like harvested grain quality, moisture content, and grain mass flow.

Crop forecasting is the technique used for the prediction of yield and production before the harvesting of the crop. This forecasting helps the farmers to plan the near future and decisions making. The yield monitoring contains several development stages, and it uses the fruit conditions such as color, size, etc.

4 Equipment and Technologies Used in Smart Agriculture

The major tasks in modern agriculture can be done by the use of large-scale heavy and urban tools like harvesters, robots, tractors, etc., which fully or partially supports remote sensing, and other related communication technologies. In smart agriculture, the task is majorly performed by vehicles equipped with GIS and GPS technologies, so that they can perform precisely, independently, and accurately. Figure 4 shows the major applications of Internet of Things-based devices in smart agriculture.

4.1 Wireless Sensors

Wireless sensors play a major role in collecting information regarding crop conditions and their related data. The wireless sensors can work standalone when required and also integrated into every advanced tool of agriculture. In the following, the major sensors type have been discussed according to their working purpose and procedure.

Fig. 4 Major technologies used for smart agriculture

4.1.1 Optoelectric Sensors

Optoelectric sensors are generally used to differentiate plants, and they can be used for the detection of herbicides, weeds, and other unwanted plants in crops flew [20]. The optoelectric sensors are combined with location information, and it helps in mapping weeds and resolution. Optoelectric sensors use reflection spectra to differentiate the vegetation and soil.

4.1.2 Airflow Sensors

The airflow sensors can be used for measuring the moisture percentage and soil air permeability. They are also used to detect the structure of the soil to identify the different types of soil. The measurements are done at singular or dynamic locations while in motion, fixed location, or in the mobile node. It pushes the desired quantity of air required by the ground at a predefined depth in the soil. It can identify the different soil properties like soil compaction, moisture level, soil structure, etc.

4.1.3 Electromagnetic Sensors

These sensors can be used to find the electrical conductivity, electrical response, and electromagnetic responses in the actual situation. Electromagnetic sensors use electric circuits to evaluate the capacity of soil particles to accumulate or conduct electric charge that is carried by the following techniques: contact or non-contact. The electromagnetic sensors are also capable to measure the nitrates and organic matter in the soil [21].

4.1.4 Optical Sensors

The light reflection phenomena are used by optical sensors to determine the soil organic substances, soil color, soil moisture, and minerals in the soil. The optical sensors reflect light on different portions of soil for testing the soil. These sensors are also used for crop assessment, especially to monitor fruit maturation. The optical sensors are combined with microwave scattering, then they can help distinguish grove canopies such as olives and similar crops [22].

4.1.5 Acoustic Sensors

Acoustic sensors are used for various in the agriculture applications like soil cultivation, weeding, fruit harvesting, etc. The main benefit of these sensors is that they are low cost and have a fast response when considering mobile equipment. These

sensors compute the changes in noise as they connected with other materials, e.g., soil particles [23].

4.1.6 Electrochemical Sensors

These sensors have a major role in agriculture as they help in measuring soil features and identify the nutrient levels like pH levels. Normal soil chemical examination is a very costly and time-taking process and can be easily exchanged with electrochemical sensors.

4.1.7 Mechanical Sensors

The mechanical sensors are used to measure the soil compaction (resistance). The mechanical sensor can be put into the soil to get the information of the force assessed using a strain gauge. The pressure unit is used to identify the soil's mechanical compaction level.

4.1.8 Mass Flow Sensors

The mass flow sensors are used to monitor yield as they provide the yield information to compute the quantity of grain flow. The yield monitoring system contains server modules such as grain moisture sensors, hardware for data storage, and dedicated software to analyze data collected from the agriculture field.

4.2 Internet of Things-Based Tractors

Due to the growth in the agriculture industry, the rural labor resources have come under heavy stress and pressure as a result of which the tractors and other heavy machinery start to enter agriculture to provide efficient and progressive efforts. To fulfill the rising demand of farmers, the major agriculture-based industries have started to provide better solutions to farmers' requirements. The self-driving tractors are now available in the market and provide the ability to reduce the revisiting of the same row/area of field by reducing the overlap. These Internet of Things-based tractors provide a better precision along with the reduced error, mainly when spraying pesticides and other related tasks which are unavoidable when a human operator the machine.

This advanced machinery, most farmers are unable to afford due to their heavy cost. To overcome this issue, HELLO TRACTORS has designed a cost-efficient monitoring device that can be mounted to any ordinary tractor and that device

Fig. 5 Internet of Things-based tractor in agriculture field

provides software and analytical tools. Figure 5 shows an Internet of Things-based tractor in the agriculture field.

4.3 Harvesting Robots

The harvesting robots provide a major role in the harvesting of crops. The harvesting of some crops can be done a single time, or in some crops, it is performed several times. Doing harvesting early or late may affect the production of the crop, so it is very critical to perform harvesting of the crop at the right time. To automate to harvesting process, the role of robots raised for achieving precision harvesting. Several scientists and researchers have done their research to increase the capability of fruit detection by its size, shape, color, and localization [24, 25]. The automated harvesting of crops/fruits requires the use of dedicated sensors that are efficient for unambiguous, and precise details of that particular fruit. This process requires very sophisticated and specialized tools to identify the fruit's conditions. Considering this issue, many robots were used for specific crops. Few of the major robots which are used for crop harvestings such as Octinion, SW 6010, and FFRobot. Figure 6 shows different harvesting robots used in agriculture.

Fig. 6 Harvesting robots

4.4 Unmanned Aerial Vehicles Used in Agriculture

The Internet of Things-based devices has developed to higher levels and is used in several industries. In the agricultural field, the communication between the end devices has their own restrictions due to limited range, power, and bandwidth, and also the modern communication systems are taught to implement in the rural areas. Considering these issues, the remote-controlled aerial vehicles (UAVs) area unit the alternative solution to these issues. The UAVs can communicate across the whole field through the wireless sensors spreaded in the field. The UAVs will simply collect the information from the fields for further processing. The UAVs are referred to as drones, and they are equipped with high-resolution cameras and sensors and might fly through thousands of hectares of fields. Figure 7 shows UAVs.

5 Challenges

- Precision agriculture requires the implementation of new technologies for crop production, for a normal farmer the setting up of Internet of Things architecture and sensor networks for his field could be a tough task. So, the lack of knowledge in implementing these technologies can be dangerous.
- The wireless network connectivity in many remote or rural areas around the world can affect smart farming.
- Lack of configuration and scalability problem.
- Energy depletion risk.

Fig. 7 UAVs

- Technical failure and corollary damages.
- Loss of human employment.
- Security of Internet of Things-based devices from natural disasters like heavy rain, storms, fire, etc.
- Mobility and analysis of cost is a critical challenge for smart agriculture.

6 Conclusion

In this research, we have discussed the work of researchers/engineers and the major application areas of Internet of Things-based devices in smart agriculture. This article also discussed the various equipment and technologies used in smart agriculture. Finally, this research highlights various challenges that arise while implementing Internet of Things-based devices in agriculture. This study is very useful and helpful for researchers, agriculturists, and, professionals working in the field of modern agriculture. The usage of the Internet of Things is useful in the advancement of farming and agriculture by introducing new concepts like live tracking, pest control, irrigation control, soil investigation, etc. This paper a critical review of Internet of Things-based devices deployed in the agricultural fields. In the introduction section, we have discussed the growth of the Internet of Things-based devices in agriculture as the graph in Fig. 1 shows it is increased up to 150%. In the next section, we have provided the applications of Internet of Things-based devices in agriculture like IoT in monitoring, IoT in control, IoT in prediction, etc. In the next section, we have discussed the equipments and technologies used in agriculture like various wireless sensors used, IoT-based tractors, harvesting robots, and unmanned aerial vehicles. Then, we have discussed the challenges faced while implementing IoT-based devices in agriculture.

Acknowledgements The authors are very thankful to the Department of Computer Science and Engineering, Banasthali Vidyapith, Rajasthan, India, for their motivation, and support to complete this research.

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