Recent Advancements in Multimedia Big Data Computing for IoT Applications in Precision Agriculture: Opportunities, Issues, and Challenges

Shradha Verma, Anshul Bhatia, Anuradha Chug and Amit Prakash Singh

Abstract This chapter aims to present a survey on the existing techniques and architectures of Multimedia Big Data (MMBD) computing for Internet of Things (IoT) applications in Precision Agriculture, along with the opportunities, issues, and challenges it poses in the context. As a consequence of the digital revolution and ease of availability of electronic devices, a massive amount of data is being acquired from a variety of sources. On one hand, this overwhelming quantity of multimedia data poses several challenges, from its storage to transmission, and on the other, it presents an opportunity to provide an insight into the business trends, intelligence and render rich decision support. One of the key applications of MMBD Computing is Precision Agriculture. The chapter focuses on major agricultural applications, cyber-physical systems for smart farming, multimedia data collection approaches, and various IoT sensors along with wireless communication technologies employed in the field of Precision Agriculture.

Keywords Multimedia Big Data (MMBD) · Internet of Things (IoT) · Precision agriculture · Digital revolution · Sensors · Data analytics · Data collection in agriculture · Smart farming · Plant pathology

S. Verma (✉) · A. Bhatia · A. Chug · A. P. Singh
USICT GGSIP University, New Delhi, India
e-mail: verma.shradha@gmail.com; shradha.usict.122164@ipu.ac.in

A. Bhatia
e-mail: anshul.usict.127164@ipu.ac.in

A. Chug
e-mail: anuradha@ipu.ac.in

A. P. Singh
e-mail: amit@ipu.ac.in

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1 Introduction

With the advent of the digital revolution and constant generation of user content online through a plethora of electronic gadgets and social media, there arises a challenge on how to deal with such vast amounts of Multimedia Big Data (MMBD) [1]. From collection to storage, processing, analysis, and presentation, it comprises of a cumbersome task. Conventional data processing tools are insufficient to process these complex datasets as the data scale reaches up to petabyte levels. Due to its unstructured and heterogeneous nature, we face additional problems, viz., compression, analysis, interpretation, transmission, and distribution as well as the issues of scale and complexity. Nevertheless, MMBD can be utilized to provide greater opportunities and insight into the context. With the analysis of such huge amount of data, we can build better computational models leading to better decision-making, further applicable to a multitude of real-life domains, agriculture being one of the crucial fields. Precision agriculture necessitates the use of automated and innovative technologies for data collection and analysis in plant pathology. Research work spanning more than a decade has led to several algorithms and techniques that apply the advancements in the computing technologies to the field of agriculture. Given the restricted access to resources and limited expertise, there is a dire need for automated processes for smart farming. Agriculture is dependent on several factors such as soil quality, climate, temperature, humidity, rainfall, irrigation, fertilizers, etc [2]. Internet of Things (IoT) sensors can be used to create an intelligent system in which various environmental parameters such as temperature, humidity, pressure, CO_2, water level, etc., along with images, can be observed and acquired for analysis. Data clustering and data mining techniques can be exploited to discover patterns in the dataset. IoT allows the unification of various communication technologies, IP protocol and embedded devices, to create a smart system that interacts constantly with both real as well as digital worlds simultaneously. It imbibes daily objects with intelligence that can acquire and share information, as well as control the physical aspects of the world. Analysis and interpretation of the MMBD collected from these pre-configured IoT sensors can be employed to optimize the production and quality of the crops.

The major contributions of this chapter are enlisted as follows: (a) broad review of the existing literature on generation of multimedia data in the field of precision agriculture, (b) exploration of the role of IoT devices/sensors for agricultural data collection along with big data analytics, (c) interpretation of the MMBD computing paradigm and its applications in smart farming, (d) presenting the relevant agricultural applications, IoT sensors and communication modules (summarized in Table 2) and (e) listing the opportunities, issues and challenges along with future directions in the context.

1.1 Research Objectives

This chapter aims to present a survey on the existing techniques and architectures of MMBD computing for IoT applications in precision agriculture, along with the opportunities and challenges it poses in the context. Initially, 103 research articles were picked out for this study. Out of these, papers pertaining to specifically precision agriculture were selected along with a few papers on MMBD Computing, published in peer-reviewed, reputed journals and conferences. Remaining papers were not included on the basis of applications, relevance, and quality. The study presented in this chapter attempts to answer the following research questions:

RQ1: What are the sources of data collection for precision agriculture?
RQ2: With the use of IoT sensors and big data, what applications in precision agriculture are being worked upon?
RQ3: What are the commonly used IoT devices for precision agriculture?
RQ4: What kind of MMBD is being acquired for precision agriculture?

Rest of the chapter is organized as follows: Sect. 2 presents the conceptual framework of MMBD Computing, Sect. 3 introduces the Cyber-Physical Systems for precision agriculture, Sect. 4 lists the data collection techniques in precision agriculture, Sect. 5 presents the role of MMBD and IoT in precision agriculture, Sect. 6 enlists various techniques studied and their usage distribution, Sect. 7 drafts the opportunities and challenges of MMBD and IoT in precision agriculture, Sect. 8 draws a conclusion and Sect. 9 stages the future direction.

2 Conceptual Framework: Multimedia Big Data Computing (MMBD)

With the proliferation of cheap electronic devices such as cell phones, equipped with high-end cameras and unlimited internet usage, it is quite easy for a daily user to produce and exchange data with multimedia content [3]. Sharing of personal data, messages, images, videos, etc., on social networking sites, viz., Facebook, Instagram, Twitter, etc., is a common occurrence.

Privacy, confidentiality, and authentication are the keys factors to be considered in order to provide a secure environment for numerous crucial applications, viz., banking, health care [4, 5], defense, etc. Installed for security reasons, even the surveillance cameras generate an immense amount of continuous video content, not to mention the data generated by the biometric systems for identification purposes [6, 7]. Also, video lectures and demonstrations for educational purposes are growing day-by-day. The sheer volume and heterogeneity of this big data from various multimedia devices requires pertinent storage, processing, and analyzing capabilities from the current systems, both in terms of hardware and software. Analyzing MMBD, which is essentially big data with several media types, requires complex algorithms,

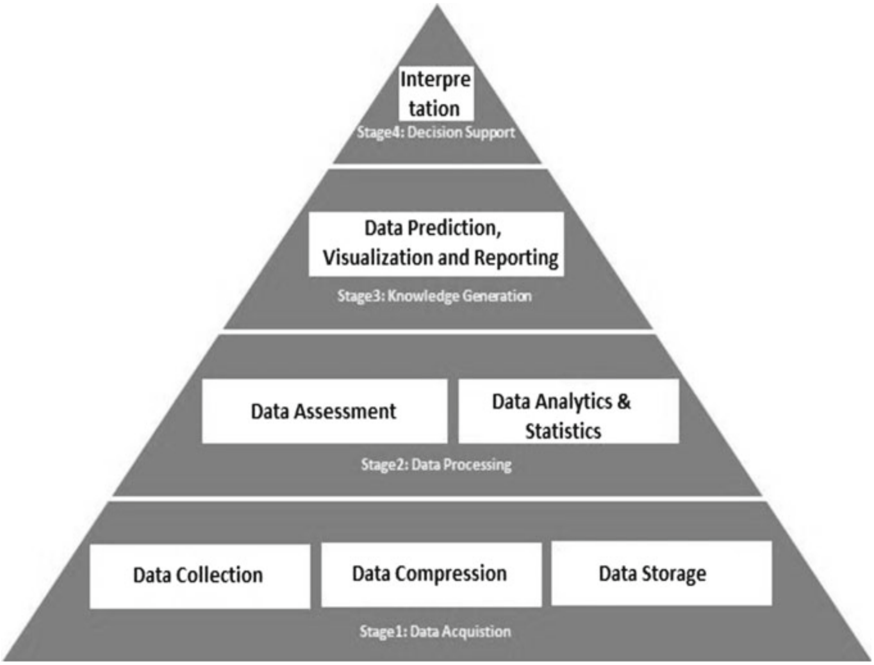

Fig. 1 Basic framework of Multimedia Big Data Computing (MMBD)

parallel and distributed computing, Graphics Processing Units (GPUs), etc., to come into play [8]. MMBD is a useful tool for human perception and understanding but poses several challenges in the context of a machine. Data acquisition from multiple and heterogeneous sources such as cameras, IoT sensors, social media, etc., adds to the unstructured nature of big data, rendering it difficult to model. Hence, there arises a need for data preprocessing that encompasses data cleaning, data transformation, compression and reduction, which is a time consuming task. In addition to voluminous storage, it requires fast processing for real-time computing. Figure 1 shows the basic framework of MMBD computing and its essential processes, divided into four stages namely, data acquisition, processing, knowledge generation and decision support. Raw and unstructured data from multiple sources is collected, preprocessed, stored, and analyzed using novel big data analytics tools, to derive conclusions, and interpretations, for improved decision support.

In spite of the large datasets, researchers are unable to utilize them efficiently, due to the lack of annotations. In recent times, data annotation in itself has emerged as a research area, whereby manual, as well as machine learning based annotation, has been studied with promising results. Understanding and analyzing MMBD via data mining techniques and feature extraction methods can be exploited to uncover patterns and enhance decision-making abilities. With the advent of big data techniques such as MapReduce, Hadoop, RapidMiner, Spark, and platforms for data science such as R Studio, research has accelerated in this direction.

3 Precision Agriculture and Its Cyber-Physical Management

Cyber-Physical Systems (CPS) are a milestone in the development of computational technologies, having achieved widespread success in applications, viz., automotives, healthcare, manufacturing, entertainment, military, etc., precision agriculture being one of the most significant applications. With the projected population growth of around 9 billion by the year 2050, Food and Agriculture Organization (FAO) of the United Nations, has estimated a need for nearly 60% increase in the agricultural production [9]. From irrigation systems to monitoring crop vegetation and smart pest control, CPS-based architectures for precision agriculture have been proposed in various research articles. A CPS encapsulates the physical elements along with the computational components, integrated and interacting in the real world at every level of complexity and scale, with the help of extensive networking capabilities. With the collaboration of computation, communications, and control (3C) technology, real-time sensing and dynamic control of information can be realized effectively [10].

Figure 2 demonstrates the basic model of a CPS along with its governing factors, i.e., the three Cs, communication, computation and control. IoT and Wireless Sensor Networks (WSN) have a lot in common with the CPS, all comprising of a 4-layered architecture (sensing, networking, analyzing, and application) but CPS dominates the degree of integration and interactions between the physical and computational elements. To analyze the environmental variables, data from multiple sources such as IoT sensors, satellite networks as well as advanced remote sensing techniques, viz., multispectral cameras, hyperspectral cameras, IR cameras, etc., is being captured for smart farming applications, to enhance the quality of the crop yield and early prediction of plant diseases [11].

Rad et al. [12] have presented a CPS-based crop status monitoring system for potato vegetation, whereby multispectral data is captured to compute the vegetation indices, which are helpful in detecting the nutrient content, soil type, water content, etc., for a particular area of the field. This could prove to be beneficial in identifying the profitability of the field and in turn improve decision-making for better economic results. Fresco and Ferrari [13] have emphasized on the correlation between sustainable agriculture and public health, agriculture and biodiversity, and the need for digital dimensions and solutions based on CPS architectures. Also, CPS along with the pre-established paradigms can bring about a revolution in the precision agriculture arena.

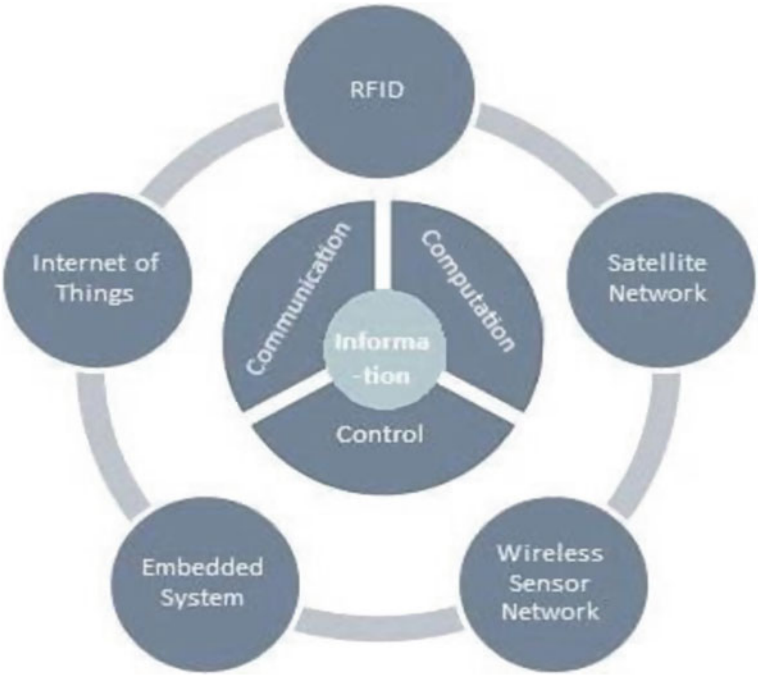

Fig. 2 Basic model of a Cyber-physical System (CPS)

4 Data Collection in Precision Agriculture

As mentioned earlier, data from various sources is being acquired for smart farming applications. There are a plethora of sensors available, to be put to good use for the monitoring of environmental factors dominating the plant growth, along with the imaging and remote sensing techniques utilized for monitoring plant health with minimum human intervention. The humongous amount of data being generated via these techniques can prove to be overwhelming, hence huge database storage and fast and efficient processing is essential. Table 1 lists the data collection techniques studied. These sensors can be installed in the field, on robotic vehicles and/or Unmanned Aerial Vehicles (UAVs).

5 MMBD Computing and IoT in Precision Agriculture

Collaboration of Big Data with Cloud Computing and IoT has transpired a new range of applications spanning multiple domains. But lack of automated processes is a major hindrance in the area of agriculture. Fog computing, a recent technologi-

Table 1 Multimedia Big Data (MMBD) collection methods

Data collection and communication tools	List of available sensors	Type of MMBD
IoT Sensors	Air Humidity and Temperature sensor, Soil Humidity and Temperature Sensor, Light Sensor, pH Sensor, Gas Sensor, Electric Conductivity Sensor, Wind Speed/ Direction Sensor, Pressure Sensor, Liquid-Level Sensor, Water-Level Indicator Sensor, Smoke Sensor, Passive InfraRed (PIR) Sensor, URD Sensor, Thermocouple Sensor, Leaf Wetness Sensor, Rain Volume Sensor, PPFD Sensor	Text, Audio
Imaging and Remote Sensing	Digital Cameras, IR Cameras, Multispectral Cameras, Hyperspectral Cameras, Depth Cameras	Audio, Images (Spatial data as well as Spectral Data), Video
Microcontrollers	Arduino, Raspberry Pi, Atmega 128L, S3C2440, CC2420, STM85103F3.	–
Wireless Communication Technologies	ZigBee, WiFi, RFID, Multi-hop, UART, SMS	–

cal progression, similar to cloud computing, is already being studied in the field of healthcare, providing uninterrupted services to the customers. It supports real-time data acquisition and analysis [14], which can be applied to agricultural applications as well. Gill et al. [15] have proposed a cloud-based service for agriculture known as Agriculture-as-a-service (AaaS), whereby the data captured via several pre-configured IoT sensors is sent to the cloud for processing with the help of big data analytics. The processed result reaches customers simultaneously and automatically. With respect to agriculture, the decision-making trends have been passed down through generations of farmers, but now, with the advent of advanced computational technologies and complex data processing capabilities, the massive data being captured daily, can be exploited to establish a Decision Support System (DSS) for smart farming [16]. Similar to health care, agriculture is a broad area that encapsulates several distinct markets from farmers, traders to retailers and customers. In their paper, Pham and Stack [17] have discussed the similarities and differences between conventional and precision agricultural practices, and explained how with the aid of Global Positioning Systems, sensor data and communication systems, precision agriculture is leaps and bounds ahead. Data is the most significant resource with respect to precision agriculture. Big data has led to the emergence of positions, viz., data scientists, data holders, data analysts, etc. In addition, various firms have sprung up focusing on data collection, storage, and processing, along with providing agricultural prescription services. Carolan [18] has drawn conclusions on the use of big data in precision agriculture on the basis of interviews conducted in Iowa, with several farmers, big data analysts, and entrepreneurs in the local food industry. The discussion on feeding the future generations and flourishing possibilities of exploiting the technology was evident.

IoT has the ability to alter and guide the world in a positive direction. Security alert systems for smart homes [19], smart cities, connected cars, health sector, etc., are the most common applications of IoT in today's scenario. Nevertheless, IoT technologies have a special impact on the field of agriculture. There is an assumption that global population is going to touch the estimated magical number of 9.6 billion till 2050. Therefore, it is a matter of serious concern for the agricultural industry. They must be able to provide sufficient and quality food for the upcoming generations without unnecessary wastage of the essential resources. So, the use of IoT based smart technology named 'Precision Agriculture' will help out the farmers to decrease the wastage of resources and enhance the quality and productivity of crops and food respectively. Precision agriculture refers to a number of unique tools and techniques that are necessary for the precise evaluation of farming requirements. These tools and techniques basically accentuate on the variations of natural components in the farm field, including the amount of water, soil components, drainage, runoff, chemical leakage, etc. The primary goal of the precision agriculture is to use new technologies like sensors, RFID (Radio-Frequency Identification) tags, remote sensing, WiFi, ZigBee, satellites, etc., to precisely measure the variations in a field. Consequently, agronomic activities like pesticide management, irrigation, fertilizer management, seeding, and pest control can be programmed independently based on the evaluation of a farm field. The following section is going to explain these IoT based technologies in detail.

5.1 Sensor-Based Technology

A sensor is a device that senses and reacts to a special type of input from the nearest environment. Sensors are the eyes and ears of IoT, that's why no one can imagine the existence of IoT without the use of sensors. Today, sensors are widely used in the field of precision agriculture in various applications like monitoring of crops, threat detection in the field, monitoring of soil conditions, observing the climatic condition near the farming field, etc. Till date, various sensors have been employed in the field of precision agriculture like air humidity and temperature sensors, soil moisture sensors, pressure sensors, gas sensors, soil pH sensors, PIR (Passive Infrared) sensors, etc. Figure 3 demonstrates a few of the several sensors available for use in precision agriculture.

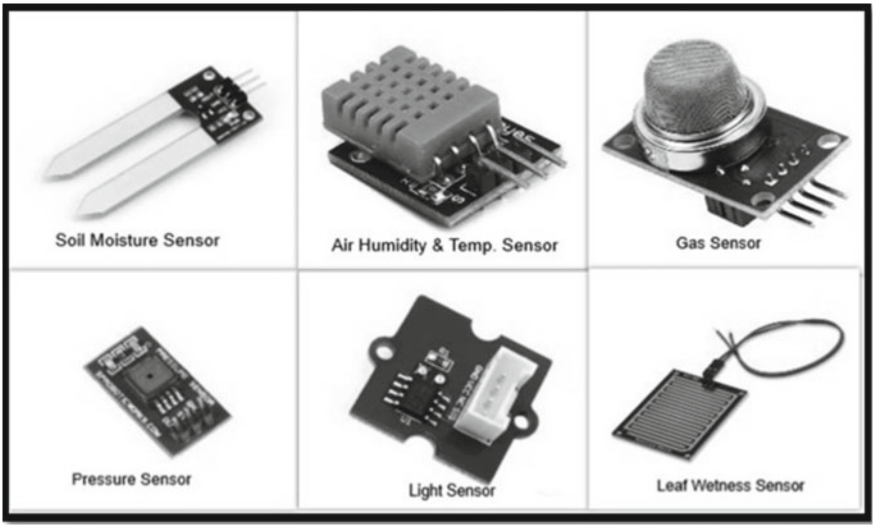

Fig. 3 List of a few sensors used in precision agriculture

5.2 RFID-Based Technology

RFID is an acronym for "Radio-Frequency Identification". The RFID technology is very much similar to the barcode technology in which digital data from a smart label is captured by a special device and stored into the database. It is basically used for object identification and tracking. The reader present in the RFID tagging system captures the digital data from the RFID tag, attached to the object which has to be identified or tracked. The RFID technology has one main advantage over the barcode technology, that the data of RFID tag can be captured by the reader outside the view of the tag, but in barcode technology, the barcode must be associated with an optical reader for capturing the data. The in-depth integration of RFID technology and Global Positioning System (GPS) can be used for monitoring and controlling the object intelligently. There are various RFID products available in the market, but only a few of them can be used in the precision agriculture applications.

5.3 Wireless Communication Technology

With the rapid increase in the field of information technology, wireless communication technology has also grown gradually. Today, wireless communication has become an essential mode of information exchange among remote users. Wireless communication technologies can be classified into various categories on the basis of the type of devices, range of data and distance of communication. ZigBee, WiFi, Bluetooth, General Packet Radio Service (GPRS), radio communication, satellite communication, etc. are the most common wireless communication technologies being used currently. ZigBee technology has a monopoly over other communication technologies because of its unique characteristics like low cost, unified standard, less power consumption and versatility. ZigBee, WiFi and GPRS technologies are widely used in the field of precision agriculture because of their cheap and sustainable behavior.

5.4 Automation-Based Technology

Precision agriculture depends on automation based technologies for monitoring and controlling farming related activities. Automation technology is electromechanical in nature; a decision-making framework along with the controller is the main part of the automation technology. Numerous scientists have been working in the field of agriculture automation since the past 8–10 years. Automated irrigation system, crop monitoring system, plant disease detection system, fertilizer and pesticide control system, are some example of agricultural-automation technologies developed by the scientists, mentioned in their research work. These agricultural-automation technologies not only precisely utilize the resources, but also improve the quality of crops and food.

6 Comparative Analysis of Various Techniques

Till date, numerous IoT applications have been proposed in the field of precision agriculture, where automated irrigation system, plant/ crop monitoring system, climate monitoring system, plant disease detection and removal, monitoring and evaluation of soil, fire detection system, weed detection system are the most common applications. A precise and robust architecture is required for the implementation of such applications. Anurag et al. [20] have proposed a wireless sensor network based architecture for precision agriculture applications which senses environmental and meteorological parameters and propagate them to a central repository for further intimation to the farmers and end users. Similarly, Khattab et al. [21] have also developed and implemented a cloud-based three-layered architecture for smart farming applications. Their proposed architecture was intended to collect the required data from the sensing nodes, present on the front-end layer and to propagate it to a gateway layer. Further, the gateway layer propagates the collected data (most probably the manipulated data) to the cloud servers in the back-end layer where this data is stored, processed and analyzed. The required feedback actions that are uncovered from the data analysis and processing are sent back to front-end nodes for the implementation. These types of architectures are the fundamental units for the implementation of any precision agricultural application. Precision agriculture is a science of using

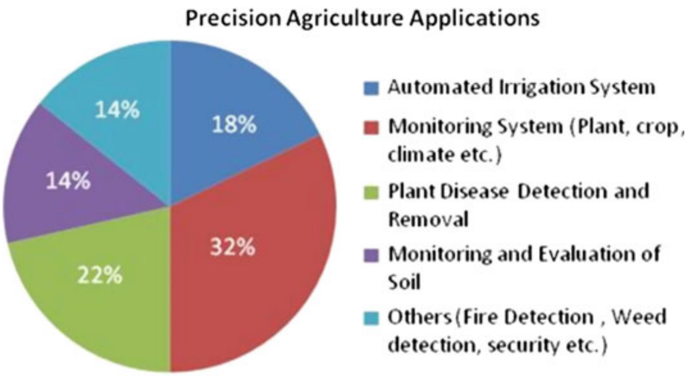

Fig. 4 Distribution as per various precision agriculture applications

IoT technology to improve the production of a farm field. This can be achieved by real-time monitoring and controlling of various agricultural parameters like crops, plants, climatic conditions, etc. We have gone through a number of research papers on IoT applications in the field of precision agriculture and found that 32% of the researchers have focused primarily on monitoring and controlling systems, 18% of them focused on automated irrigation systems, 22% researchers emphasized on plant leaf disease detection and removal, another 14% talked about soil monitoring and evaluation, and remaining 14% focused on emergency systems like fire detection, weed detection, security system etc. in their research papers. Figure 4 depicts the distribution of research papers as per various precision agriculture applications.

Mohanraj et al. [22] have proposed an application named "e-Agriculture" to monitor several meteorological parameters based on a knowledge base. They also provided a mechanism for controlling these parameters in order to increase farm production. Further, a livestock monitoring system has been developed by Tanmay et al. [23], near the field and grain store, without any human intervention. Similarly, [24–29] also used IoT technologies for monitoring various agricultural parameters as crops, plants, climatic conditions, etc. in their research. The main objective of precision farming is the efficient utilization of the agricultural resources like water, pesticides, and fertilizers, etc. To this effect several researchers [22, 30–33] have focused on the proficient utilization of water resources by giving the concept of an automated irrigation system. In precision agriculture, diseases and pests cause excessive monetary loss to farmers by reducing the quality and quantity of crops. Even the pesticides and fertilizers used for controlling these pests and pathogens are very costly, which leads to increased financial pressure on the farmers. So for the detection and removal of plant diseases, many researchers [25, 28, 34–37] have developed various inexpensive and accurate automation techniques, so that they can guide the farmer through providing high security to the farm fields, with minimum cost.

Agricultural productivity is directly and/or indirectly dependent on the soil present in the farm field. Soil improves the growth of plants by mediating the organic, bio-

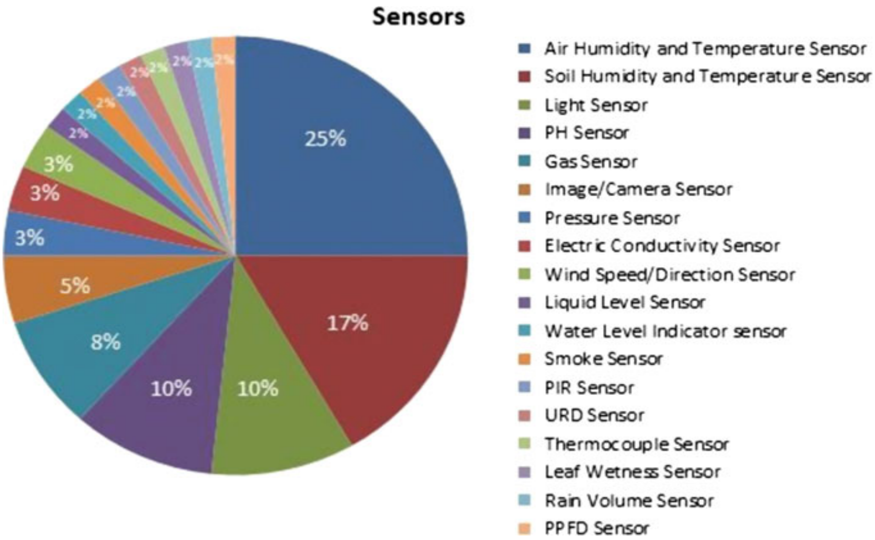

Fig. 5 Distribution as per the type of sensors used

chemical, and physical processes that supply plants with nutrients, water, and other elements. That's why observation and evaluation of soil is very important for the improvement of agricultural land. Till date, several researchers [22, 30, 34, 38, 39] have focused on the exogenous variables derived from soil monitoring and their subsequent evaluation.

As discussed earlier, there is a multitude of sensors which have been used in the field of precision agriculture like air humidity and temperature sensors, soil moisture sensors, pressure sensors, gas sensors, soil pH sensors, PIR sensors, etc. Figure 5 demonstrates the distribution of research papers on the basis of the type of sensors used in them.

Sensor outputs are basically fed as inputs to the microcontrollers and they represent the electrical equivalent values of any physical quantity. They generally measure physical quantities like light intensity, distance, acceleration, etc., essentially as continuously varying values. So no one can use the sensors without interfacing it with a specific type of microcontroller. There are various microcontrollers available in the market like Raspberry Pi, Arduino, Atmega 128L, etc. Figure 6 shows the distribution of research papers on the basis of types of microcontrollers employed.

Figure 7 shows the distribution of research papers on the basis of sources of data collection. As per our study, we found that 70% of researchers have used sensors for collecting the data. 25% of researchers focused on only images in their research work and 5% of them have used both images and sensors as the data source.

Figure 8 shows the distribution of research papers on the basis of wireless communication technology. As per our study, we found that 45% of researchers have used ZigBee for wireless communication. 25% of them focused on WiFi, RFID tags

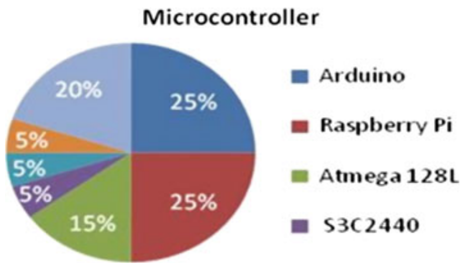

Fig. 6 Distribution as per the type of microcontroller

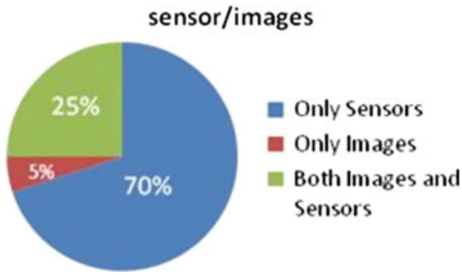

Fig. 7 Distribution as per the sources of data collection

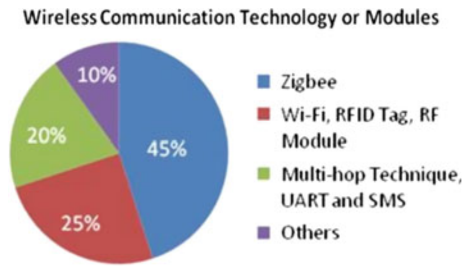

Fig. 8 Distribution as per the used wireless communication technology

and RF module for communication purpose. Another 20% have used UART, SMS, and multi-hop technique for wireless transmission of the data. Remaining 10% have shifted their focus towards some wireless modules like nRF24L01 ultra-low power transceiver wireless communication module. Table 2 lists the names of sensors, applications, communication technologies, etc., employed in the printed literature. Table 3 lists the pros and cons of the wireless communication technologies used in the literature and Table 4 presents a comparison of the most commonly used microcontrollers, as per our study (but not limited to it).

7 Opportunities, Issues, and Challenges

Advanced computational technologies such as machine learning, cloud computing, big data, etc., have brought about a revolution in various fields like healthcare, business, entertainment, and are now being employed to transform the agricultural

Table 2 List of Agriculture applications, sensors and communication modules used

Ref, year	Precision agriculture application(s)	Sensors or images used	Name of sensors	Communication Technology/module	Microcontroller used	Crop/Plant
Reference [34], 2018	• Detection of Disease affected plant • Recognition of weeds • Checking the fertility of soil • Fire disaster detection	Both images and sensor	• Soil Moisture Sensor EC-5 • Soil Temperature Sensor THERM 200 • Soil pH Sensor • Soil Electric Conductivity WET-2 • Humidity Sensor STDS75 (STM) • Temperature Sensor HIH-4000–001 (Honeywell) • Light Intensity Sensor BH1750FVI(DLI) • Carbon Monoxide Sensor GGS-200T (UST) • Atmospheric Pressure sensor MS5540B (Interseema) • Smoke Sensor EC01000 (Honeywell)	Multi-hop technique	–	–

(continued)

Table 2 (continued)

Ref, year	Precision agriculture application(s)	Sensors or images used	Name of sensors	Communication Technology/module	Microcontroller used	Crop/Plant
Reference [35], 2018	Plant Leaf Disease Detection	Images and camera as a sensor	Camera as a sensor	WiFi (inbuilt in Raspberry Pi3 board)	Raspberry Pi3 board	Pomegranate, Brinjal, Tomato
Reference [38], 2018	Soil monitoring system	Sensors	SHT15 Humidity and Temperature sensor	ZigBee, GPRS Module	S3C2440 microcontroller	NA
Reference [32], 2017	Automated irrigation system	Sensors	• Temperature and humidity Sensor • Soil Moisture Sensor • Light Intensity Sensor • CO_2 sensor	ZigBee	–	NA
Reference [25], 2017	• Plant Disease Detection • Plant Monitoring	Both images and sensor	• DHT22 Temperature and humidity sensor • MQ-2, MQ-135, MQ-136 Gas sensors • LDR (Light Dependent Resistor Sensor)	UART communication	Arduino and Raspberry Pi	–

(continued)

Table 2 (continued)

Ref, year	Precision agriculture application(s)	Sensors or images used	Name of sensors	Communication Technol-ogy/module	Microcontroller used	Crop/Plant
Reference [37], 2017	Disease Detection and removal	Sensors	• DHT11 Humidity and Temperature Sensor • Soil Moisture Sensor • Soil pH value Senor • Nitrogen Sensor	ESP8266 WiFi Module	Arduino	Rice crop
Reference [22], 2016	• Plant Growth Monitoring • Irrigation schedule planner • Identification of soil type and soil deficiency	Sensors	• DHT11 Temperature and Humidity Sensor • Soil Moisture Sensor (KG003) • Ball Float Liquid level Sensor • Magnetic float sensor (for water level Indicator) • BH1750 Module digital light intensity sensor/ LDR Resistor	–	T1 CC3200 launch pad and 1.6.8 Arduino Uno board	–
Reference [23], 2016	Monitoring and smart security of the field and grain stores	Sensors	• PIR sensor • Web Cameras • URD (Ultrasonic Ranging Device) Sensor	SMS	Raspberry Pi 2 Model B+	–

(continued)

Table 2 (continued)

Ref, year	Precision agriculture application(s)	Sensors or images used	Name of sensors	Communication Technology/module	Microcontroller used	Crop/Plant
Reference [21], 2016	General cloud-based architecture for precision agriculture applications	Sensors	• Air temperature SHT11 • Air Humidity HTU21D • Soil Moisture Sensor SEN0114 • Leaf Wetness FC-37 • Wind Speed/ Direction SEN -08942 • Rain Volume Sensor SEN-08942	nRF24L01 ultra-low power trans-receiver wireless communication module	Raspberry Pi	NA
Reference [31], 2015	Automated irrigation system	Sensors	• Soil Moisture Sensor VH400 • Temperature Sensor DS1822	ZigBee, GPRS Module	PIC24FJ64GB004 Microcontroller	NA
Reference [26], 2015	Monitoring and controlling the connected farm	Sensors	• Compound sensor for temperature, humidity, and CO_2 • Photosynthetic photon flux density (PPFD) sensor • Soil Moisture Sensor	ZigBee	Raspberry Pi	NA

(continued)

Table 2 (continued)

Ref, year	Precision agriculture application(s)	Sensors or images used	Name of sensors	Communication Technology/module	Microcontroller used	Crop/Plant
Reference [27], 2015	Greenhouse monitoring system	Sensors	• Temperature Sensor • Pressure Sensor • Light Sensor • Humidity sensor • Wind speed & Wind Direction sensor • CO_2 sensor	ZigBee	STM85103F3 microcontroller	• Carnation Plants • Gerberas Plants • Anthurium plants • Tomato • Roses
Reference [28], 2015	• Monitoring climatic parameters for a better quality of plant • Plant leaf disease detection	Both images and sensor	• Temperature Sensor • pH sensor • Humidity sensor • Soil Moisture Sensor	ZigBee	Arduino 1.0.6	Grape plant
Reference [29], 2015	Monitoring of agricultural parameters	Both images and sensor	• Temperature Sensor • pH sensor • Humidity Sensor • Soil Moisture Sensor	ZigBee	Arduino	NA

(continued)

Table 2 (continued)

Ref, year	Precision agriculture application(s)	Sensors or images used	Name of sensors	Communication Technology/module	Microcontroller used	Crop/Plant
Reference [30], 2013	• Soil monitoring • Automated irrigation system	Sensors	• Soil Moisture Sensor (capacitance sensor ECH2O, EC-5 Decagon Devices) • Temperature Sensor (Sensirion Sensors)	Multi-hop technique	–	Apple tree orchard
Reference [40], 2011	Crop Monitoring and security	Sensors	• Soil pH sensor S8000 • Hydra Probe-II sensor (conductivity, salinity, soil moisture and temperature) • MTS-420 Board (ambient light sensor) • EC-10 HS soil moisture sensor • Camera sensor	ZigBee	Atmega 128L Microcontroller	–
Reference [24], 2011	Crop Monitoring	Both images and sensor	• Image Sensor OV7640 • Temperature Sensor • Humidity Sensor	RF Module CC1101	Atmega 128L Microcontroller	NA

(continued)

Table 2 (continued)

Ref, year	Precision agriculture application(s)	Sensors or images used	Name of sensors	Communication Technology/module	Microcontroller used	Crop/Plant
Reference [33], 2008	Automated irrigation system	Sensors	• Watermark soil moisture sensor • Thermocouple Sensor	RFID Tag	–	Cotton crop
Reference [20], 2008	General Architecture for precision agriculture applications	Sensors	• Soil pH Sensor • Soil Moisture Sensor • Soil Temperature Sensor	ZigBee	CC2420, Ti (Texas Instruments) bases board	NA
Reference [36], 2006	Plant Disease Detection	Sensors	Sensirion SHT75 Digital Humidity and Temperature sensor	WiFi	Atmega 128L Microcontroller	Potato plants

Table 3 Pros and cons of wireless communication technologies employed

Wireless Communication Technology	General description	Pros	Cons
WiFi	• Mostly used to connect various electronic devices with a wireless local area network • Standard—IEEE 802.11 • Uses 2.4 GHz and 5.8 GHz frequency radio bands. • Data Rates—11 to 105 Mbps • Range—10–100 m	• Simple Installation • Inexpensive • Easily Accessible • Scalable	• Highly Vulnerable • Security issues • Restricted Range • The devices working in the same band can interfere
ZigBee	• Connect a number of electronic devices with personal area network • Standard—IEEE 802.15.4 • Frequency Bands—868/915 MHz—2.4 GHz • Data Rates—250 Kbps • Range—10–to 300 m	• Less Power Consumption • Nodes can be accessible with small configuration • Support many topologies like One to One, Star, Mesh etc.	• Expensive • Data Rate is low • Frequencies other than 2.4 GHz requires licensing in many countries.
Bluetooth	• Used in short distance communication • Standard—IEEE 802.15.1 • Frequency Bands—2.4–2.485 GHz • Data Rates—25 Mbps • Range—0–10 M	• Inexpensive • Less energy utilization • Highly Secure • Low power consumption	• Low Range • Less Data Rates
RFID	• Uses electromagnetic field and store information electronically • Used to detect and track the object through tag attached to it • Standard—EPC global standards and ISO RFID standards • Frequency Bands—120 kHz–150 kHz, 13.56 MHz, 433 MHz, 865–868 MHz and 902 to 928 MHz • Data Rates—10–100 Kbps • Range—10 CM—100 M	• Easy Installation • Does not need any power • Highly secure	• Invasive Technology • If tags installed in fluids or metals than RFID reader find difficulty to read them • Incompatible with smartphones

Table 4 Pros and cons of Arduino and Raspberry Pi (microcontroller used)

Microcontroller	Pros	Cons
Arduino	• Easier to get started • Best for real-time applications • No need for high programming language • Easy to extend • Comprises of various libraries and contributed shields	• Can only be programmed using C or C++ • Connection to the internet is complex
Raspberry Pi	• Easily connects to the internet • Entire Linux software stack available with it • Can be programmed using multiple languages	• No real-time access to hardware • Hardware is not open source • Does not contain inbuilt analog-to-digital converter • Insufficient power to drive inductive loads

domain. With larger investments being poured in this arena, it is evident that there is huge excitement over the potential of these technologies to increase the farm output with minimum input, in terms of land, cost, usage of pesticides, and decreased environmental footprint.

Ease of access to a gamut of electronic devices and social networking sites has resulted in the vast amounts of data being generated by the second. On one hand, the MMBD poses the challenge of storage, processing, transmission, and analysis, and on the other, it presents an opportunity to unfold hidden patterns to be utilized for efficient decision-making. Data being generated is useless unless it is administered in the direction of creating better decision support tools for the stakeholders. MMBD has showcased huge potential towards solving future agricultural problems faced due to growing population and reduced resources. Previously, field related data was collected by the farmers and environmental data was acquired by government agencies. But now, with the slumping costs of sensor-based technologies, much better degree of automation, computational abilities for data generation and data analysis is affordable and evolving day by day. This leads to another challenge, i.e., the heterogeneous and unstructured nature of the acquired data from a plethora of sources. However, this data can be the driving factor for profound advances in plant phenotyping, detection of plant diseases, land cover, soil fertility, study of weather statistics, and deploying farm management systems. Data from multiple growers can be integrated to identify the problem areas and improve the decision-making. Current systems are not equipped with dynamic data aligning and processing capabilities. Another major hindrance is the lack of proper training to the farmers to exercise the data collection equipment and tools, not to mention the lack of sound protocols and policies in place, for consolidation and interpretation of collected data.

One of the principal issues is the privacy of the captured data along with its authenticity. Before moving forward, we need to take into account the measures for validation and verification of the acquired data and the ethical factors as well. Enormous data generated poses the challenge of high dimensionality which hampers the process of visualization. Along with visualization, we need data integration capabilities for structured, semi-structured and unstructured multimedia data. These are the few likely factors due to which we have not been able to realize the full potential promised by the novel precision agriculture technologies and reap their benefits.

8 Conclusion

This chapter focused on the applications of MMBD and IoT in the field of precision agriculture. In today's scenario, about two-thirds of the data traffic over the internet comprises of multimedia data. Along with the challenges of handling such heterogeneous and voluminous, structured as well as unstructured data, comes the opportunity of analyzing and utilizing it, in order to respond to real-world situations. Current big data systems are not configured to process multiple data types and execute complex image processing and audio/video analytics algorithms. MMBD Computing is one such area that focuses on multimedia data acquisition, storage, to processing and its visualization. One of its major application areas is precision agriculture that requires decision-making abilities to enhance the crop yield and quality, based on the data acquired via an amalgamation of sensors. IoT sensors can be used to create an intelligent system in which various environmental parameters can be observed and acquired to be analyzed. These sensors along with remote sensing technologies accumulate all types of multimedia data, viz., text, audio, images (RGB, multispectral, hyperspectral) and video.

Over the past decade, agricultural applications such as crop monitoring systems and plant disease detection are dominant and on the rise with multiple technologies being implemented for empirical studies. According to our research, mostly used sensors for precision agriculture were Air humidity and temperature sensors, soil humidity and temperature sensors, light sensors and pH sensors. Majority of the researchers have utilized ZigBee as the wireless communication technology because of its low power consumption and cost. Also, Arduino and Raspberry Pi are the most commonly used microcontrollers with multifaceted applications in smart farming. There has been a huge increase in the use of advanced technologies to precision agriculture for quantifying the shortcomings related to data collection and analysis. While there are numerous concerns, such as reliability, cost, security, deficient procedures, etc., it is expected that in future, with new designs in advanced remote sensing technologies and relevant protocols in place, there will be greater benefits for precision agriculture and its subsequent impact on the ecosystem.

9 Future Direction

In the near future, the agricultural domain will come face to face with several challenges such as water shortage, reduced soil fertility, weeds, use of fertilizers and their negative impact on the environment and human health, growing population, increased cost of seeds, chemicals, etc. Use of advanced computational technologies can heighten the decision-making capabilities and reduce the wastage of resources. The CPS-based agricultural systems can be equipped with advanced functionalities such as tracking capabilities, dynamic data aggregation, multimedia content analysis, data mining methods, detection of faulty sensors, generating yield maps for the field, daily task manager, notifications to be sent to the grower along with suggestions, updates to be sent periodically, remote control of agricultural devices etc. Work needs to be done to make the existing methods reach the farmers effectively, to be user-friendly, secure, and accurate.

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