Study of New Trends in Precision Agriculture

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Abstract The precision agriculture field is evolving towards the Industry 4.0 era, which will help to increase production in agriculture field with the use of limited resources available. This evolution is resulting in greater varieties and yield of crops. In recent agriculture development, the advancement in various technologies such as the Internet of things and artificial intelligence has played a major role in data-driven and automated agriculture. This article has provided a review on recent development in agriculture technologies and applications as well as research efforts in the context of smart farming. Future direction in precision agriculture is also presented.

Keywords Precision agriculture · Internet of things · Artificial ıntelligence · Cloud computing

1 Introduction

Day by day, the world population is increasing with the rising demands of food. To feed this increasing population, according to the Food and Agriculture Organization, the food production needs to get increased by 70% [1]. The traditional way of increasing the yield of a crop is not going to help, considering all social and environmental challenges faced by this sector. So it is necessary to adopt smart farming techniques since from cultivation of crop to marketing of agri-food.

The Internet of Things technologies is consisting of sensors, actuators, drones, various low power communication technologies such as Bluetooth, RFID, 6LowWPAN, etc., cloud-based data services, decision-making system using various advance algorithms. MQTT is the most widely used M2M communication protocol and used for deployment of IoT network [2]. These technologies have the potential to deal with agriculture-related problems. Hence, nowadays, many countries are using

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the Internet of things in the agriculture sector, precisely this is called as "precision agriculture" or "smart farming". The smart farming helps framers in many ways such as to decide when to cultivate, what amount of water is needed to crop, how much fertilizer needed, the nutrients lacking in the soil, to detect diseases in the crop at initial stages, and avoid the spread of disease, for cost estimation of the yield of a crop, marketing, etc.

The precision agriculture field is evolving towards the Industry 4.0 era, which will help for increasing agriculture production with the use of limited resources available. Giving solution on one of the problems in the Internet of things is like contributing to different fields of knowledge such as telecommunication, informatics, electronics, social science, and public sector. The IoT network consists of different-different kinds of electronic or mechanical devices that are interconnected with each other through different-different communication standards like Zigbee, RFID, Wi-Fi, 6LoWPAN, M2M, etc. Hence, trying to establish an IoT network on existing Internet network as well as trying to focus on agriculture-related issues, has resulted in a lot of many pitfalls. There needs to be development and maintenance of architecture that will concentrate on sensor network integration, naming, addressing location, quality of service, security, battery management, applications, and hardware interfaces, particularly, while establishing IoT network in the agriculture sector as it requires a low-cost framework. The aim of IoT standardization should be the integration of different things into big networks either mobile or fixed and enabling their interconnection with existing Internet network [3].

In agriculture, the IoT applications can be used from the farm to fork, and this whole supply chain requires a large number of execution of IoT-based pilots. Authors Christopher Brewster et al. have given the requirement of a new business model along with security, privacy, and data governance requirement and proposed agricultural information model approach to ensure data interoperability [4]. Related research and development dealing is resulting in commercialization of new products and services to grow fully automated farm [1]. To increase food production effectively, detection of pest and diseases is done using several image recognition, machine learning, and deep neural network-based applications to identify plant type, disease, pest or nutrient deficiency, as well as information about treatment and preventive measures, is also provided. Using image recognition and deep learning algorithms, robotic harvesting technique is used for harvesting the delicate fruits as well as the labour shortage problem is solved. With the help of fixed and movable robots as well as sensors along with decision control algorithms, a multi-robot system is implemented effectively for a highly complex environment in a large area of farm [1].

This article is the study of various approaches, applications, framework, and research which will help farmers to deal with difficulties in improving the efficiency of food production. It is followed with the research gaps in technologies used such cloud computing, machine learning, and artificial intelligence for precision agriculture, as well as the discussion on related research and development work, is also discussed.

2 Challenges

In past, whenever there was more demand for food supply, the forest is simply reduced into agriculture field to acquire more land to get more production. But nowadays, it is very difficult to acquire more land as its increased cost due to urbanization and industrialization. Also, due to excess use fertilizers, the available land is not yielding much. Hence, it is a bit challenging to use available land effectively using new technologies without causing soil pollution much and to get more production of food.

One of the major concern of agriculture is water and its use. Total 70% of the world's usable water is used by agriculture field only. As the population is growing continually, the competition for water will also increase in all sectors, presenting a key challenge to increasing the yield of a farm with limited use of water.

The third challenge for farmers is environmental challenges, sometimes unnecessarily rains too much, sometimes water will be scarce due to lack of rain which leads to decreasing the crop production. This affects the net income of farmers. Further, due to social and financial condition of agriculture, farmers are experiencing very less profit in an uncertain market environment.

To change this face of the agriculture industry, it is necessary to adopt new techniques, tools, and practices that will help the farmers in increasing farm yield with effective use of land and water, giving solution to uncertain climatic conditions and market environment (Fig. 1). This will lead the agriculture industry to transform into a new era of data-driven management and automation sector [1].

3 Related Research and Development

To bring automation and data-driven management in agriculture, Internet of things play a major role where the network of various devices are embedded with electronic devices, software, and Internet connectivity that gather, process, and share information for monitoring and control [1]. The automation in agriculture is due to the use of various techniques, approaches, and services used, which are based on machine learning, cloud computing, and artificial intelligence, etc. This section is all about the study of those techniques.

3.1 Machine Learning Approaches

In machine learning, the data from various sensors deployed are collected and analysed and based on analysis and a decision support system is built for different purposes such as optimized use of water, optimized use of fertilizers, perdition

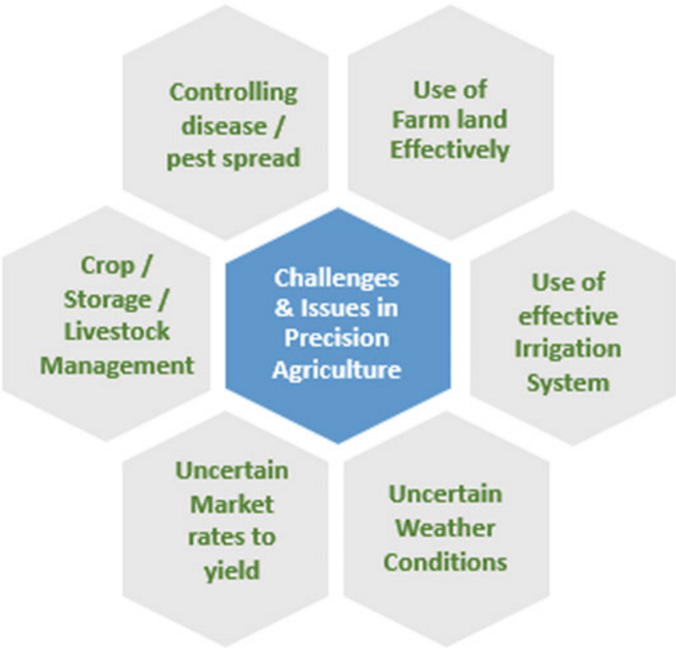

Fig. 1 Challenges and issues in precision agriculture

of diseases in the plants and estimation of crop yield. Various machine learning approaches are explained here:

Authors Anat Goldstein, et al. have given weekly irrigation plan for jojoba orchards, which is based on different machine learning algorithms on different subplots under the same environmental conditions. The data collected from sensors deployed in the subplots and from the meteorological station is cleaned and transformed to the required schema and then uploaded to flat tables. The regression models applied on datasets are linear regression model, simple decision tree, and gradient boosted regression tree (GBRT). Similarly, the optimal classification model obtained that is boosted tree classifier is compared with other classification models such as decision tree, support vector machine, logistic regression, and Bayesian procedures. By comparing these algorithm results, the best regression model obtained is gradient boosted regression model which 93% accurate and the best classification model obtained is boosted tree classifier model with 95% accuracy. This study helps to guide the decision-making process to automate irrigation process [5].

In farm management information systems (FMIS), retrospective case study on wheat crop and prospective case study on tomato crop is done. In a retrospective study, by analysing the existing study, the features of smart wheat production are provided, which is used in FMIS and this system is integrated with external weather forecast system as well. Unlike the retrospective study, in a prospective study, the application architecture is analysed by carrying out post-interviews. Based on these approaches, three architecture views are chosen including decomposition view, layered view, and deployment view for developing new applications of FMISs. This process is effective and practical [6].

Agri-IoT is a semantic framework developed for huge data analytics and event detection, ensuring without seam interoperability among part of IoT network including sensors, services, processes, operations, farmers, and other relevant actors. In this framework, according to agriculture need, the data is processed with the help of RDF stream processing standard. Detection of fertility and its management for cows is carried out by static discovery for relevant stream identification and dynamic query processing. While to detect soil fertility, the query processing is done differently [7].

Flavescence doree is a vineyard disease which symptoms got detected after one year; hence, it is very difficult to detect infected area on crops. To detect vegetation indices (VI) and successive projection algorithm (SPA)-based techniques are implemented which have given promising results. When crop got infected, it will change the leaf colour, for red grape, leaves become reddish, and for white grape variety, leaves become yellowish. These changes in colour in leaves which differ by cultivar help to identify disease. Hence, it is possible to detect infectious spots in plants at early stages only using VI and SPA-based techniques [8].

In smart farming, for crop yield estimation, various remote sensing techniques with high spatial resolution images are taken are used. These techniques are suitable for only large area homogeneous crop fields, otherwise, it will not give accurate results because of data loss due to climate condition. Author Mohamad M. Awad has designed a new optimization model of crop yield estimation which compensates missing data by using the energy balance equation. The data extracted from the satellite is called biomass data, which is calculate using Monteith model and satellite images with different acquisition dates. This data is used as input to a new optimization model developed using trust-region methods for nonlinear minimization [9].

Smart water development platform (SWAMP) is a five layer IoT-based architecture in precision irrigation domain of agriculture. Layer 1 is for IoT services, layer 2 is for the virtual entity and data storage, layer 3 is for data analytics and machine learning, layer 4 is for water data management, and layer 5 is for water application services. This project includes data acquisition from sensors, decision making using various algorithms and flexible system nature by sending commands to both automatic and human actuators. This whole project is monitored with four pilots locate at different regions of Europe and Brazil. Finally, this project estimated water requirements of each farm by analysing sensor data and relevant information designs irrigation recommendation map and send this to users [10].

3.2 Artificial Intelligence Approaches

In artificial intelligence, devices adapt its environment and take action which increases the chances of getting successful. This is done by interpreting the given data, learning from it and the machine tries to take decision based on interpretation. In agriculture, these AI-based algorithms can be used for detection features of flowers, fruits, plant, etc., to predict the yield of the crop. Some AI-based algorithms are studied here as:

It is very difficult to forecast crop yield when the problem nonlinear and complicated. Author Mohammad Saleem Khan et al. have monitored the biomass and yields using artificial neural network (ANN) technique with the help of LNADSAT data that is a spectral band and spectral indices as well as derived biomass equation for crop yield estimation. The ANN algorithm used is a multi-layer perception (MLP) to estimate mint menthol crop. Multiple linear regression algorithm is used to find the relation between the dependent variable (field biomass) and independent variables (remotely sensed spectral variables) for more accuracy in menthol crop estimation [11].

In rice canopy scattering model (RCSM) and a genetic algorithm optimization tool (GAOT), the rice yield parameters considered are ear length, ear diameter, and ear density, and the algorithm is simulated in MATLAB with a parallel computing model to improve available computation efficiency for speedy application or task processing. The results obtained are compared against the measured data at sampling sites. Use of quad polarized Radarsat-2 SAR image resulted in expected results while assigning initial values to parameters considered need to be instigated to get stable and optimal solution by genetic algorithm [12].

Author Bedogni et al. have proposed an architecture for detection of features strawberry flower in multiple scale images using deep-level region-based convolutional neural network (R-CNN) for predicting strawberry yield. First, features of selected images were extracted using CNN, then it is classified region using support vector machine (SVMs). Then, the gradient descent algorithm is used for optimizing network parameters which minimize backpropagation error of training datasets. The results of all datasets of R-CNN, Fast R-CNN and Faster R-CNN are then compared in which Faster R-CNN has given better results [13].

3.3 Cloud Computing Approaches

The main advantage of cloud computing is the adoption of hardware virtualization and providing scaling of services according to customer needs. Since it offers on-demand access to the shared pool of resources, it is beneficial to provide flexible services and decision making in agriculture. Cloud-based frameworks for precision agriculture are explained here:

Author N. Pavon-Pulido, et al. has designed cloud-based architecture to offer deployment and validation services in agriculture using Google App Engine. The deployed sensor nodes are enabled with GPRS communication and used to measure soil and plant parameters, and these nodes directly send information to the cloud. And UAV mobile node is used to read visual information of crop. The performance of the proposed precision agriculture system is measured in terms of standard runtime instances, outgoing network traffic, incoming network traffic, quotas related to data store, and the accordingly monthly cost of an application can be calculated, which is still very low. The major benefit of this system is that stakeholders can retrieve information and create, update, and delete the entities, and also devices can monitor the crop and transparently can share the information to cloud backend by sending HTTPs request [14].

SWAMP project is for a high precision smart irrigation system for agriculture with water reserve, water distribution, and water consumption. For performance analysis of SWAMP, FIWARE-based IoT testbed was designed which includes collection sensor data values deployed in the different cloud and fog configuration. While experimenting, increased response time and memory leak problem are crashing the IoT agent. Thus, reengineering of some components is required for higher scalability with less computational resources, and also the replacement for MongoDB as it affects CPU performance affecting overall system performance [15].

Author Tomo Popovic, et al. has developed an architecture based on server and cloud technologies for precision spraying and irrigation, assessment of the marine environment and monitoring fish farm in precision agriculture and aquaculture. This architecture implements analytic prototype, modelling, and predictive functions needed to add, describe, and modify various IoT sensor nodes based on Arduino, Rasberry Pi, and PC, and their quick integration into communication network [16].

Agro-info is autonomic QoS and cloud-based information system built using Internet-based technologies which manage various types of agriculture services. This system collects information from various IoT devices and analyses it using fuzzy logic with fuzzy rules which are stored in cloud repository for future decision, and these rules automatically respond to user queries and allocate resources automatically based on QoS requirements of different requests. The automatic resource manager works on SCOOTER technique [17].

Cloud computing is also used for fruit detection where cloud segmentation for fruit images applied to obtain accuracy in fruit recognition for harvesting robot [18].

3.4 Other Approaches

Using some linear and fundamental mathematical models and equation, agriculture frameworks are designed for land levelling, an energy-saving mechanism in the network, optimal irrigation technique, to detect soil properties, etc. They are explained here as:

Land levelling is helpful in irrigation water saving for better use of land for crop cultivation. There are traditional manual land levelling methods are available for land levelling. These manual land levelling methods are less accurate and the cost of operation is more. Author Manpreet-Singh has reviewed some manual land levelling methods and based on this study has developed automatic land leveling method which more accurate, less cost of operation with improved land uniformity coefficient. But fuel consumption is more in automatic land levelling method [19].

Authors Luca Bedogni, et al. have addressed three issues, first design and implementation of wake-up nodes with energy-saving mechanism, second proved that optimal policy depends upon application requirements, and third designing centralized orchestration algorithm to select an optimal set of wake-up nodes and energy-saving wake-up modes for each wake-up node in the network. The orchestration algorithm is consisting of two parts clustering algorithm and scheduling algorithm. The clustering algorithm is used to cluster wake-up IoT nodes (WuN) to minimize the maximum intracluster correlation. While scheduling algorithm is used to maximize the network lifetime by optimal wake-up node and mode selection [13].

Authors J. A. López-Riquelme, et al. have developed a software architecture based on FIWARE which is open source and free development module, for reducing water use during irrigation task. In this, to provide an online, distributed, scalable, elastic reliable, and secured framework consisting of three modules, first, FIWARE smart agriculture nodes sending information to FIWARE server component, second, a worldwide common database developed using Cosmos and CB GEs, and third, a customized graphical user interface. This architecture provides reusable and easily maintained modules without the use of expensive hardware. This framework is reliable, scalable, optimistic, and cost-effective [20].

Geographical weighted principal component analysis (GWPCA) is based on principle component analysis (PCA) and is used to calculate the covariance between the feature of object and features of its neighbours and also soil properties, based on this relation the decision of data transfer is taken for delineation of management zone. PCM is used to divide the field into homogeneous management zones. In these management zones, soil properties are calculated and farmers are guided accordingly for fertilizer dose. This technique is simple, functional, and cost-effective [21].

4 Future Directions

Agriculture field is moving towards agriculture Industry 4.0, leading towards new opportunities and new business models. In this article, it had a basic version of this new development. Still, it has a lot scope of developments such as developing decision-making algorithms to optimize and automate irrigation process without human intervention, using different cloud and AI-based technologies for detection soil fertility, detection of crop diseases, detecting yield of a crop, etc., designing agriculture frameworks for land levelling, smart spraying and irrigation system, quality of services (QoS) models to manage agriculture services, applications, delineation of management zones in agriculture, etc., are shown in Table 1.

In the recent Internet of things is everywhere, the base of IoT is wireless sensor network with low maintenance and deployment cost which is applicable in many broad areas like agriculture. Hence, the techniques used in WSN can be used in IoT for increasing network lifetime and QoS. Various renewable energy approaches are used in WSN to increase the network lifetime. In IoT application where device to device communication routing protocol is used, energy harvesting techniques are

Table 1 Technologies used in various agriculture application

Applications in agriculture	Techniques used
Land levelling	Automatic land levelling using laser leveller
Smart irrigation	Gradient boosted regression model (GBRT) and boosted tree classifier model (BTC) Smart water development platform (SWAMP) Private IoT enabled cloud-based platform FIWARE
Pest and disease detection	Vegetation indices and successive projection algorithm-based technique
Estimation of crop yield	Using an energy balance equation Artificial neural network with multi-layer perception genetic algorithm optimization tool (GAOT) Region-based convolutional neural network (R-CNN)
Design and management of farm applications	Farm management information system(FMIS) Google app engine-based framework Agro-info
Estimating the fertility of the soil	Agri-IoT Geographical weighted principal component analysis (GWPCA) and probabilistic fuzzy C-means (PFCM) algorithm

capable of increasing lifetime of a network using solar energy with optimized link-state routing with ad hoc on-demand distance vector is being used [22]. Also, in WSN, there exist a lot many algorithms based on clustering technique, out of this there are two popular algorithms LEACH and HEED concept is followed in almost all algorithms as they have used received signal strength for selecting the next node. In order to profit IoT systems in a future network, developing smart clustering strategies is the future direction [23].

5 Conclusion

To deal with the food demands of the growing population, there needs to be a transition in the agriculture sector to get maximum production in fewer resources considering climatic changes in the environment. Also, optimistic and effective use of natural resources such as water, soil, and light to keep balance in the ecosystem is needed. This is possible by bringing data-driven management and automation in the agriculture industry by convergence with various technologies such as artificial intelligence, Internet of things, and robotic.

Interest and a lot of funding in research is the cause of innovations in various big sectors such as agriculture leading to automated farms with various applications and services for pest and disease detection, robotic harvesting, automatic cultivation, and irrigation. When such products and services get commercialized, the agriculture products will have good business deals resulting in good profit in this industry as well as will help to eliminate food shortage problem in the future.

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