Integration of Artificial Intelligence and IoT on Agricultural Applications

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1 Introduction

The global food production is extended to rise by 70% by 2050 (according to "Food and Agriculture Organization of the United Nations n.d."). Indian farmers suffer from a lot of difficulties like water management, different crop diseases, natural disasters, climatic changes and lack of knowledge regarding their soil that degrades crop productivity rate. As the population of world increases gradually, the demand for the food production also increases in the agricultural field. Therefore, the artificial intelligence, machine learning, IoT and deep learning are used in the agricultural area for maximizing the food production with less manpower by detecting the crop diseases at an early stage and also by managing the soil and water for crop yield. Now-a-days, IoT and deep learning [1] are majorly used in the agriculture due to the automatic prediction of climatic changes and sensor-based applications. The IoT sensors facilitate several features to enhance the agriculture, which is depicted in Fig. 1.

IoT performs well in several other applications like security, traffic control system, health, transportation, supply chain, smart city and so on [2]. IoT is also utilized in agricultural areas for enhancing the quality of crop production outcomes. IoT sensor

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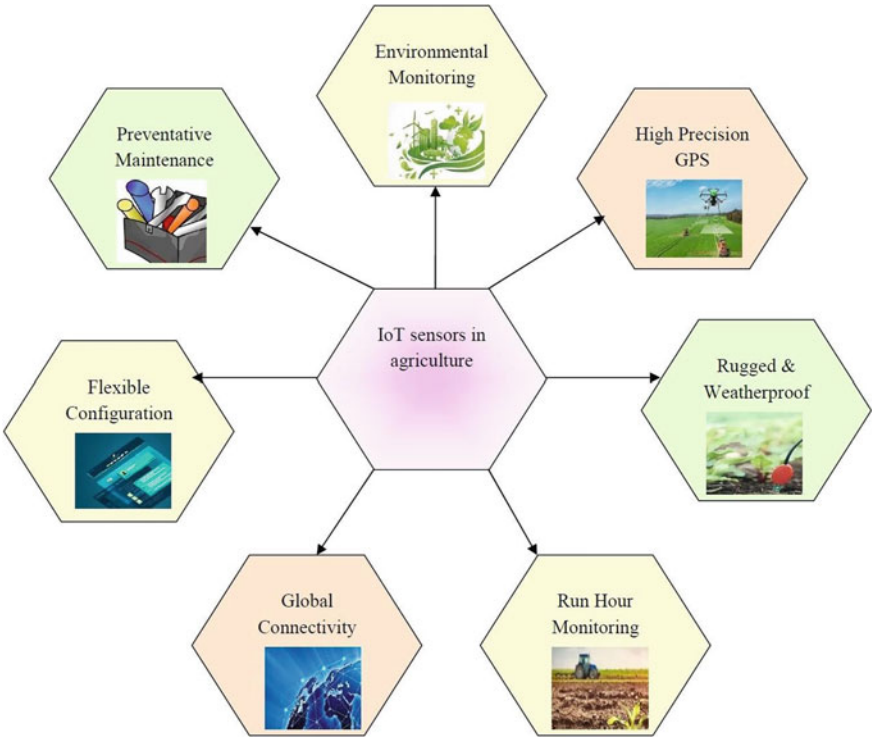

Fig. 1 IoT sensor features in agriculture

devices provide numerous amounts of data that may be unstructured, semi-structured and structured. Further, these data will undergo analytics for predicting the future and determining the present information. Analyzing these data is complex because of its huge quantity. Anyway, these data are much essential when it produces an action and also it can be possible to process with a smart learning mechanism. The main attention is to identify the way for analyzing huge amount of information from the complex data of IoT [3]. Here, the deep learning technology is utilized and also employed in different IoT applications due to its capacity on achieving the efficient results in shorter time. It is observed that the deep learning approaches are much efficient in resolving the problems related to real-time applications.

The huge amount of data are collected mostly in the form of images through remote sensing, in which the collected images represent numerous challenges in the agricultural environments. The agricultural domain is mainly dependent on the imaging analysis for identifying and detecting the anomaly through these images, and also the intelligent data analytics is also applied for different applications of agricultural areas [4]. The major objective of this chapter is to determine the applicability of the deep learning techniques in the agricultural field along with the IoT for enhancing the capacity of the sensor-based applications. Moreover, machine learning and artificial

intelligence are also enriched the various agricultural domains such as analytics of environmental prediction, automated agricultural growth, precision farming, etc. [5].

2 IoT and Artificial Intelligence in Agriculture

IoT plays a major role in different real-world applications. Similarly, a new framework is introduced in the smart agriculture by employing different sensors such as "temperature sensor, water level sensor and soil moisture sensor" for the purpose of observing the agricultural activities like plant, crop and irrigation monitoring. So, it is easy for the farmers to monitor the agricultural activities from any place. While comparing the ordinary farming like reaping, manual tilling, and planting with the IoT-based smart farming, it provides better performance to increase the agricultural productivity rate by utilizing several sensors in field. Smart agriculture is one among streams in the IoT [6]. It produces numerous data through the sensors that bring out the notion of big data, which is considered to be huge amount of data from different sources such as "sensor, social networking and business". The challenges are occurred during the data recording, storing, analyzing and searching the data from the IoT devices. The analytics process of agricultural data [7] is given in Fig. 2.

Additionally, these data were obtained from different varieties of sensor systems, and so, it has shown the heterogeneity nature in the attained information. This creates the primary challenges while analyzing the real-world IoT data that affect the retrieval of useful information. To overcome these issues related to IoT big data, enormous analytical solutions are introduced for determining the valuable information of big data through IoT devices. Smart farming based on IoT is essential in providing several benefits like offering appropriate fertilizer and controlling of water optimum usage [8]. The IoT applications in the agricultural field are described in Fig. 3.

3 Overview of Deep Learning

Deep learning works on the basis of computational frameworks or Artificial Neural Networks (ANNs), in which the functions of deep learning are similar with the working of the human brain. Some of the deep learning applications are driverless cars, voice control in phones, hands-free speakers and tablets, automatic game playing and also in natural language processing, where these models are trained with the images, text or speech for the classification. It includes a huge quantity of training data that are obtained from the neural networks with numerous hidden layers. Most of the deep learning methods include the neural networks for training the data, and so, it is termed as deep neural networks. The neural networks get the support of several learning algorithms for enhancing the information quantities, and thus, it provides the effective training process [9]. While utilizing the huge dataset, the processing of the model will be more efficient.

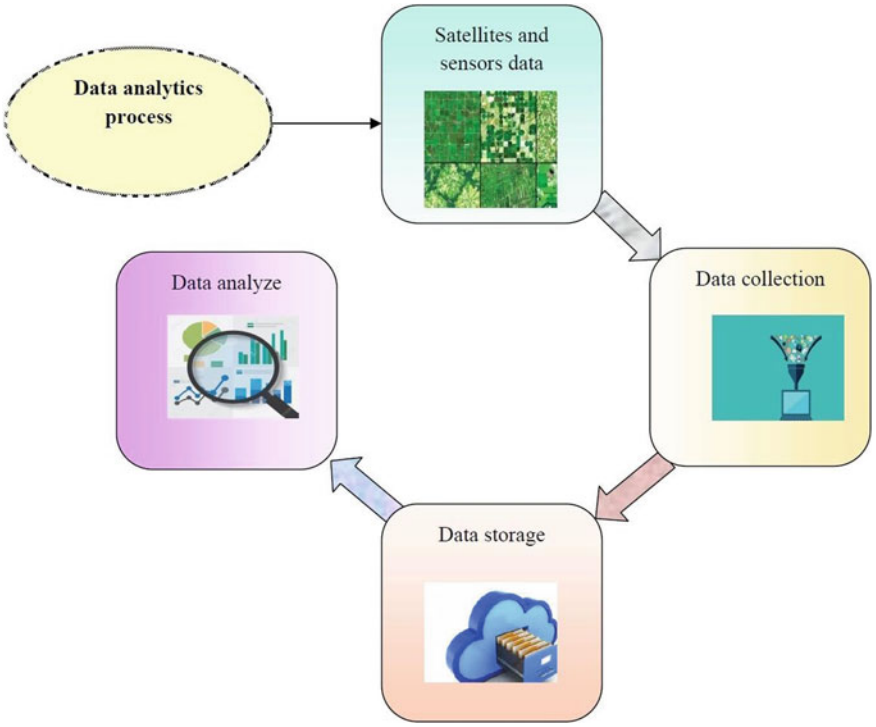

Fig. 2 Data analytics process in agriculture

Deep learning employs various algorithms for information processing and enhances the decision-making ability. This type of invention is utilized in certain sectors like recognition of pictures and voice and self-driving cars. It is more difficult to manage the complex and high-dimensional data in the nature language processing, image translation and image processing techniques. This also leads to complexity in processing these high-dimensional data. These problems related to processing the complex data can be overcome by the deep learning models by utilizing its conceal layer and also produce the subsequent information for predicting and detecting the farming tasks. The main advantage of deep learning takes place in the feature extraction, where the features can be extracted from the raw data and generate the accurate features. The feature extraction is the process of converting the input data into a set of features, which is further utilized for the classification or recognition purposes. Deep learning does not contain any requirements for physically extracting the image features [7]. At the time of training process, the network itself obtains the extracted features and put forwarded towards the network for processing without any manual support, and finally verifies the dataset. The process of deep learning in agriculture consists of gathering of data from sensors and other devices, analysis and extraction of features, make predictions, train, and test model, and makes predictions. These consecutive processes in deep learning approaches help in learning and boost the

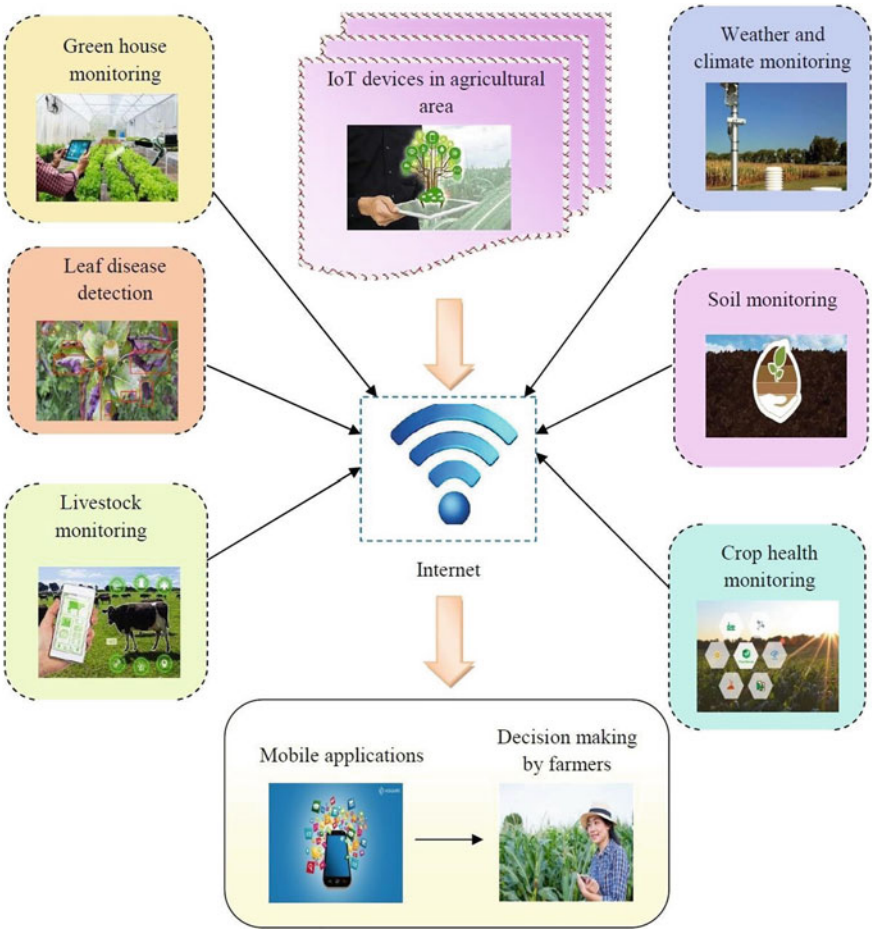

Fig. 3 IoT applications in agriculture

analytics in IoT applications. The deep learning process with IoT sensors for making prediction about the agricultural areas is diagrammatically represented in Fig. 4.

4 Deep Learning for Smart Agriculture

Deep learning is much essential in the "automation of predictive analytics". It is useful in certain agricultural areas such as hydroponic agriculture, detection of fruit type, crop or plant classification and fruit counting. In agriculture, it is necessary to have healthy crops for enhancing the quality of the agricultural production. Deep learning [10] has ensured its efficiency in solving the problems like image segmentation, image

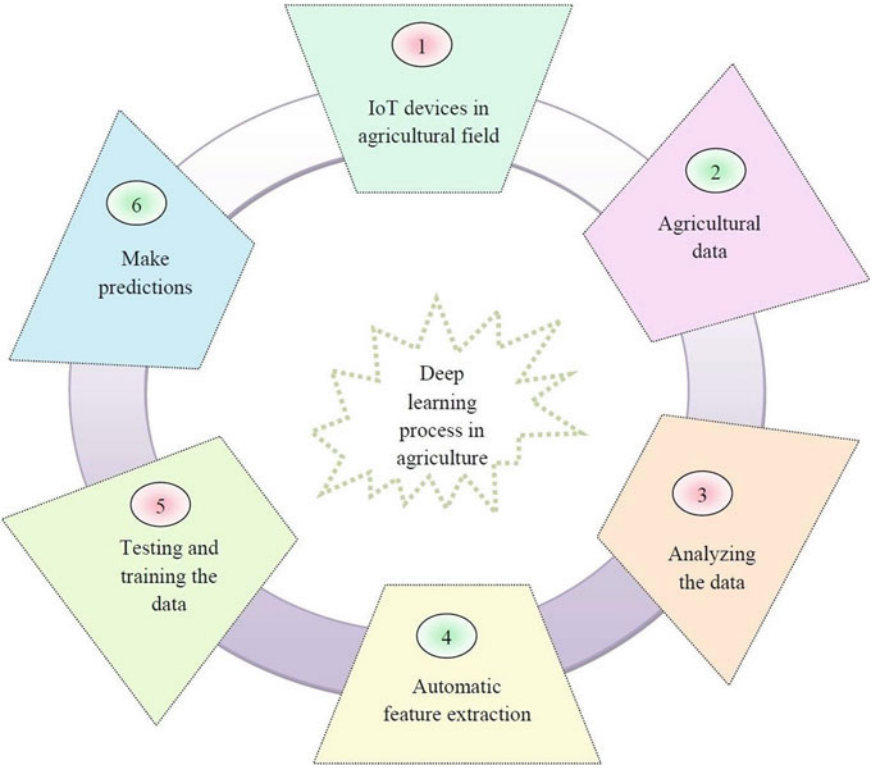

Fig. 4 Deep learning process using IoT sensors in agriculture

classification, object detection, picture recognition and natural language processing. It provides the enhanced accuracy for the classification even in processing the huge quantity of dataset. It is also useful in various functions such as automatic farming detection and forecast.

5 Several Deep Learning Techniques in Agriculture

Different agricultural applications in IoT are detection of plant diseases, forecast of soil moisture content, fruit counting, detection of leaf diseases, crop type classification and plant recognition [11]. To support agriculture, healthy crops should be produced, and so, artificial intelligence plays a major role in solving the challenges like image segmentation and classification, object detection. The existing studies show that the superior classification accuracy is observed by deep learning approaches. Some of the common deep learning approaches are "Convolutional

Neural-Network (CNN), Recurrent Neural Networks (RNN), Generative Adversarial Networks (GAN), Long- Short Term Memory (LSTM)", etc.

Convolutional Neural-Network: It is a set of feed-forward and deep ANN, which is utilized for analyzing the visual images. This network contains numerous numbers of neurons with learnable weights and biases. The input layer is inserted with the input data, which is further given to the several hidden layers, and results are obtained from the output layer. While comparing with other ANN models, CNN has convolutional and pooling layers to extract the features. Here, the convolutional layers perform the feature extraction using the input images, in which the dimensionality of the features will be minimized by the pooling layer. It has the capacity to learn the complex problems at a faster rate because of its complex and weight-sharing model that enables the parallelization. When the large datasets are provided to the CNN, it achieves more accuracy in the classification. So, data augmentation is used to increase the size of the dataset and enhance the CNN accuracy [12]. CNN is independent of illumination, size or translations, and so, continuous random transformations like translation and rotation can be applied to input images for enhancing the dataset. This is more useful in the different areas of farming fields such as "crop and plant leaf disease detection, plant recognition, land cover classification, weed identification, and fruit counting".

Recurrent Neural Networks: It is said to be a multi-temporal network that contains network connections among the direct graphs and its nodes with the temporal sequence. RNN has an ability to allow the temporal dynamic behavior. It has the capacity to utilize the information present in its own internal memory. This indicates that RNN employs previous observation for obtaining the classification output of the current observation.

Generative Adversarial Networks (GAN): GANs are designed by considering two neural network systems like discriminative networks and generative networks, which help in inspecting, interpreting and mimicking from the training dataset. It can be enhanced by using GAN. The combined GAN architecture gives high-quality data.

Long-Short Term Memory (LSTM): It is one of the efficient algorithms, among other deep learning techniques, which process complete data and also process the single information points. Therefore, LSTM is useful for efficient forecasting and classification of time-series data. The LSTM is more eminent in processing agricultural applications.

6 Frameworks in Deep Learning

Certain frameworks of deep learning are enclosed in the agricultural field, such as "Convolution Architecture for Feature Extraction (CAFFE), PyTorch, Theano and TensorFlow".

CAFFE (Convolution Architecture for Feature Extraction)

It is an "open source framework" that ensures different types of deep learning architectures. This framework function utilizes the C++, which elevates the "Compute Unified Device Architecture (CUDA)" for computing the "Graphics Processing Units (GPU)". This ensures the interface for python and MATLAB. This framework has supported numerous deep learning methods for processing image segmentation and classification. This also enforces the fully connected neural network designs such as LSTM and CNN.

PyTorch

It is an "open-source code framework" that helps the machine learning algorithms. It is developed by Torch, which is a scientific computing framework that is utilized for developing and training the deep neural network. It is simple to make the DNN models when using the PyTorch framework. This framework has numerous deep learning algorithms that are constructed based on PyTorch. Due to its clear architectural style, it is easy to process the training and implementing the deep learning for the purpose of learning and execution.

Theano

Theano is "an open source Python language" that works based on the deep and machine learning framework. Theano ensures fast computation, and it can be run on both GPU and CPU. But, it works slower on CPU while comparing the processing time of GPU. It is used for training the deep neural network algorithms.

Tensor Flow

An "open source software library" is Tensor Flow that is used for machine learning and deep learning and also for different deep neural networks. It is very essential for generating the neural networks through the graph representations. Here, the nodes indicate the mathematical operations performed based on the graph, and edges denote the "multi-dimensional data arrays (tensors)" that is located in between the nodes. A set of imaging tools named TensorBoard is implemented by TensorFlow for visualizing the TensorFlow outcomes.

7 Deep Learning Applications in Agriculture

In recent times, IoT and robotics technologies, computer vision, deep learning and image processing are very useful for farmers. These methods are used for visualizing the progress of the crops, which can support the farmers to determine the status of crops whether it can be moved to harvest or not. The deep learning applications in agriculture are unlimited, where some of them are described as follows.

Crop Management: It is the most essential part of agriculture for enhancing the crop quality. The deep learning techniques are utilized in the smart agriculture for

observing the water level and temperature of the crop. Moreover, the farmers can monitor their agricultural land from other areas. Smart agriculture can be effective while performing it with the IoT and artificial intelligence [13].

Water Management: The crop growth depends on the water level, and so, analyzing the water level regularly is much significant for improving the growth of the plant. By considering the soil and crop category, it is very effective in machine learning algorithms for monitoring the level of the water [14]. Further, the artificial neural network model is developed for "smart irrigation system" that ensures the enhanced water management in the agricultural areas.

Soil Management: It is easy to identify the appropriate crops and its suitable fertilizer for the soil by utilizing the machine learning methods. The soil quality is based on its macro, micro and primary nutrients and pH level, which are examined for estimating the soil health condition [15]. The soil management is enhanced by introducing the "artificial neural networks, Bayesian network and Gaussian kernel-based support vector machines".

8 Conclusion

As the population of the world increases every day, the demand for food production also increases. Hence, the food production can be improved by assisting the farmers. The new research deploys IoT devices along with artificial intelligence for improving the investments. The smart farming is improved by adopting the artificial intelligence with IoT for efficient processing and generation of information. The sensors or IoT devices can be installed in IoT applications for making the agriculture efficient one. The gathered information is processed by deep learning approaches, which assists the farmers in the future for smart farming. This chapter has explained the contributions of IoT and artificial intelligence, deep learning in the smart agriculture. Also, some deep learning approaches and frameworks for improving the field of agriculture were explained and also have discussed about the applications of deep learning in agriculture. Artificial intelligence or IoT in agriculture causes the cost inefficiency for buying the robots and requires regular maintenance for its effective working. It also affects the poor farmers due to its high energy cost and maintenance. So, in future, it is necessary to develop the robots at an affordable rate for assisting the farmers.

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