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Precision Agriculture Using (IoT) and Machine Learning

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The world's population is growing at a rapid pace and is estimated to reach 9 billion by 2050. This puts an immense responsibility on the agriculture sector to enhance crop production and increase yield per hectare (FAO, 2021). For the last few years, agriculture is continuously challenged by climate change and other environmental problems and they create a huge hurdle in achieving enhanced productivity. Two possible options to tackle the food shortage are increasing land usage and practicing farming in large area or adapting best practices and technology support to enhance productivity.

Considering the case of developing countries with highly populated areas where increasing the land area is merely impossible, the only way is to go smarter with the help of cutting-edge technologies like the Internet of Things (IoT) and allied technologies like Artificial Intelligence (AI). The recent advancement in ICT (Information and Communication Technology) and associated research have identified the 'Internet of Things' and 'Artificial Intelligence' as key technologies for revolutionizing modern agriculture practices (Hari *et al.*, 2015).

By incorporating the use of digital technologies like artificial intelligence and Internet of Things, better insights can be formed effectively from data gathered from the field and allowing farming practices to be planned systematically with minimal manual labour. Over the decades, the agriculture sector has realized the importance of precision farming.

Precision agriculture

Precision agriculture technology adoption is attracting more attention as a solution in food production to feed a growing population (Godfray *et al.*, 2010). The history of agricultural development shows that the adoption of innovative technologies has been one of the essential factors in the growth of agricultural production systems (Basso *et al.*, 2017). Precision agriculture is the science of improving crop yields and assisting management decisions using high-technology sensors and analytical tools. It involves managing spatial and temporal variability in fields using Information and Communications Technologies (ICT) (Sasse *et al.*, 2016).

Precision agriculture is defined as the practice of doing the right thing at the right place and time with the right intensity (Khosla *et al.*, 2008). It aims to optimize field-level management concerning crop farming, enhancing productivity, efficiency, and sustainability.

The Cycle of Precision Agriculture

Data Collection: This is the foundation of the entire cycle. Various tools and techniques are used to gather information about the field and crops like sensors, satellite imagery, weather stations.

Data Analysis: The raw data collected needs to be processed and transformed into usable insights using data integration and spatial analysis.

Decision Making: Once the data is analyzed, it's time to make informed choices using Variable Rate Application (VRA) and Crop Selection & Planting.

Taking Action: Finally, the decisions made based on data analysis are put into action. Precision application equipment: Modern tractors and farm machinery can adjust application rates of resources based on VRA maps (Loures *et al.*, 2020).

Components of Precision Farming

GPS - Super accurate navigation system.
GIS - Digital filing cabinet for geographical information.
Autosteer - Automatic steering or guidance.
Wireless communication technology - collect and transmit data.
VRT - Application of inputs such as fertilizers, pesticides, or seeds at variable rates. AI - Analyze large datasets and make predictions.
Remote sensing - Collects data about field from a distance.

Data Collection and Analysis - Advanced technologies - sensor networks, satellite imagery, and automated machinery.

Yield Monitoring - Process - Quantifying and analyzing crop yields

Internet of Things (IoT)

The Internet of Things (IoT) refers to a system of interrelated computing devices, mechanical and digital machines that transfer data over a network without human-to-human or human-to-computer interactions. The term was proposed by Kevin Ashton in 1999.

Being connected to the internet, the main goal of the IoT device is to generate real-time data. Algorithms have the capability to handle and derive meaningful insights from the data which can lead to high-quality decision-making. Problem solving and automation have been made quite simple by the introduction of new logic and methods such as Machine Learning,

Natural Language Processing, Machine Vision, Artificial Neural Network (ANN) etc. Out of all these, Machine learning and ANN are the most widely applied methods in researches related to automation in agriculture (Jha *et al.*, 2019).

Need for IoT in Agriculture

IoT is essential in agriculture to improve efficiency, maximize yields, and ensure sustainability. IoT enhances data collection and monitoring, supports precision agriculture, enables remote farm management, and promotes improved sustainability.

Structure of IoT

Things: Devices such as sensors (temperature, power, humidity, etc.) that collect data.

Gateway: Facilitates data transfer from sensors to the cloud or central system.

Internet: Provides connectivity via Wi-Fi, fiber, or other means.

Services: Data analysis and visualization services that process and interpret the collected data (He *et al.*, 2015).

Generalized architecture of AI powered IoT ecosystem for agriculture

An IoT based agriculture automation system comprises multiple technologies glued together for achieving the intended task. At the lowest level of the system, it has the IoT sensors deployed on the targeted site. This could be fields for soil monitoring, ear tag for cattle, or sensors deployed in a greenhouse, farm machines, and so on. An IoT device used in the agricultural site has multiple components. Raspberry Pi, Arduino, and Beagle Bone are some of the most commonly used devices, which normally have limited processing memory but can communicate effectively to outside using the communication module. They can send/receive signals from the external environment. Any changes in the environment are captured by the sensors on a real-time basis and will be sent to a remote server or cloud through an IoT Gateway. The remote server/cloud server is responsible for data management. Data are normally stored in the database. Since the data are huge and unstructured, traditional relational databases are not preferred for storing this sort of data. NoSQL databases are mostly adopted across the cloud and found to be the best fit for the unstructured data and faster accessibility. Features like auto-scaling, availability, and security make cloud servers a good choice for IoT based applications.

Sensors in IoT

Sensors act like electronic eyes and ears, collecting data on various aspects of the farm environment and the crops themselves. This data is then used by farmers to make more informed decisions about their crops, leading to increased yields, better resource management, and improved sustainability (Wasson *et al.*, 2017)

LM393 Soil Moisture Sensor: Calculates the amount of moisture present in the soil.

Soil NPK Sensor: Detects the levels of nitrogen, phosphorus, and potassium (NPK) in the soil. (Patil *et al.*, 2023). Typically, the measurement range of soil NPK sensors varies based on the nutrient being measured.

✓ Nitrogen (N): 0-2000 mg/kg

✓ Phosphorus (P): 0-1000 mg/kg

✓ Potassium (K): 0-2000 mg/kg

DHT 11

measures humidity and temperature. This sensor employs a thermistor with a capacitive humidity sensor to analyze the ambient air (Sundaresan *et al.*, 2023).

✓ Temperature range - 0°C to 50°C

✓ Humidity - 20% to 90%RH

S12SD Sensor: Measures UV range of 240 nm to 370nm. This helps in monitoring crop health and growth (Sushanth and Sujatha, 2018).

FC-37 Rain Sensor: Track precipitation allowing for hands-free control of watering schedules. Farmers may use this intelligent device to automatically irrigate their crop upon constant rainfall data (Patil *et al.*, 2023).

MPL3115A2: Measure pressure in the range of 20 kPa to 110 kPa.

Role of IoT in Agriculture

Crop Management

Crop monitoring is a whole process until the crop is yielded from the land. The process includes the appropriate use of seeds, the moisture needed for a crop, and the number of pesticides and insecticides for that crop.

Smart Irrigation

Smart irrigation systems tailor watering schedules and run times automatically to meet specific landscape needs. These controllers significantly improve outdoor water use efficiencies (Fig. 5). It is based on real-time data, controlled by mobile phones, and store data in cloud-based systems. Benefits include water conservation, improved crop yields, reduced labor, and minimized environmental impact.

Soil Health

Various sensors are deployed in the field to gather real-time data on crucial soil parameters on soil pH, EC, fertility, salinity problems in soil.

Weather Monitoring

These remote sensing satellites are in space to convey data on weather phenomena. Different meteorological institutions are working in the field of weather forecasting. Advanced knowledge on weather forecasting as well as warnings on upcoming natural hazards such as floods, droughts, cyclones, etc., are based on the success of weather forecasting.

Integrated and Judicious Disaster Management Procedure Such as cyclonic, flood and drought forecasting and mitigation. Rapid Information Processing, and Disbursal also now trying to solve using IoT technique for easy, fast, and error free.

Smart Greenhouse

A green house is a glass house and all its activities can be controlled well by the use of remote sensing. It is also designed in an integrated manner with a wireless sensor network (WSN) with a decision-making support system (DMSS). It uses 3S such as remote sensing (RS), GIS, and GPS or geometrics causes more greenery to agriculture as well as greater sustainable environment.

Pest Management

IoT offers a more targeted and sustainable solution through smart pest management systems. Insect traps equipped with sensors that detect pest presence and even identify specific species (Alagumariappan *et al.*, 2020). Microbial sensors that can signal the presence of diseases even before visible symptoms appear.

Agriculture Drones

Agricultural drones are a class of Unmanned Aerial vehicles (UAVs) considered as aircraft without a human pilot aboard. The drone device consists of actuators and motors for performing necessary operations, a set of sensors such as laser, radar, camera, gyroscope, accelerometer, compass, GPS receiver for reading the environment information and a central processing unit. To communicate with this, the remote control is used and communication is done in the radio frequency range. UAVs are capable of monitoring hectares of fields in a single light using the thermal and multi-spectral cameras mounted on them. The cameras can capture the bands with different wavelengths and based on the reflectance values, indices such as Normalized Difference Vegetation Index (NDVI) can be calculated.

Data Analytics

It uses algorithms and statistical models to analyze agricultural data, make predictions, and support decision-making. The beauty of this field of study is that it makes computers capable to learn without programming. It is one of the most electrifying tools that one would have ever encountered. The name reflects that it makes the computers analogous to humans: the ability to learn.

Applications in Agriculture - Machine learning, combined with IoT data analytics, can increase production quantity and quality to meet growing food demand. It involves collecting, managing, analysing data, and deriving insights to optimize farming practices.

Applications of Data Analytics in Agriculture

➢ ML techniques namely Cubist regression model, partial least squares regression, ELM and LSSVM for predicting pH and Soil Organic Matter of paddy soil. They concluded that extreme learning machine with genetic algorithm for band reduction produced best result and is very helpful in prevention of paddy soil degradation (Hua *et al.*, 2019).

➢ Mohapatra *et al.* (2021) have employed SVM, DNN and ANFIS for forecast of seasonal groundwater levels. The usefulness of these techniques was assessed using suitable graphical and statistical indicators. The conclusion was that DNN technique worked most proficiently in forecasting seasonal groundwater levels.

- Crop management includes farming techniques for management of physical, chemical and biological crop environment having the objective of achievement of both the qualitative and quantitative targets (Yvoz *et al.*, 2020).
- Karadag *et al.* (2018) used three ML algorithms namely Naive Bayes, K-nearest neighbour and ANN for classification to detect fusarium diseased peppers from the leaf reflections and concluded that the method was useful in detection of disease using leaf reflections.
- Sujatha *et al.* (2021) paralleled the ML algorithms and DL algorithms in terms of citrus plant disease detection. They concluded that in comparison to ML algorithms, the performance of DL algorithms was much better.

Advantages

- Optimized Resource Use
- Improved Crop Yields
- Early Detection of Problems
- Reduced Environmental Impact
- Improved Decision Making

Remote Monitoring Limitations and Challenges

- Land Holdings
- Technological Challenges
- Privacy and Security
- Connectivity Issues
- Awareness and Investment
- Environmental Impact

Conclusion

Precision agriculture, powered by IoT and machine learning, offers significant potential for enhancing agricultural productivity and sustainability. By addressing the limitations and challenges, these technologies can revolutionize farming practices, ensuring food security for the growing global population. The integration of IoT devices and machine learning algorithms enables farmers to make data-driven decisions, optimize resource usage, and improve crop yields. As technology continues to advance, the agricultural sector must embrace these innovations to meet the increasing demand for food and achieve sustainable development goals. Machine learning in agriculture is one of the rapid growing areas. It is extensively used to solve complicated problems in agriculture and thus, helping the farmers in their economic growth. It has been observed that machine learning based models have gained significant outcomes in solving the problems related to agriculture. The need of time is to develop customized and precise ML models which can automatically analyze bigger, perform fast with complex data and be helpful in optimization of processes like predictions and classifications in agriculture.

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