

Big data in smart farming:

Challenges and opportunities

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Smart farming includes application of advanced technology in agriculture to increase the sustained production. It involves various technologies like high resolution satellite data, Global Positioning System, Geographic Information System, field sensors, Artificial Intelligence and, automated machineries, etc. Further, the emerging technologies of Unmanned Aerial Vehicles, Internet of Things, and cloud computing are expected to leverage this development and introduce an Internet of Things of robotic and computer science in farming. Big data is considered as a potential technology for assessment and management of farm-level decisions to increase farm productivity by detecting and overcoming cumbersome practices. Big data has wide range of applications in smart farming, which includes real-time weather monitoring, soil moisture monitoring, automated irrigation systems, inputs monitoring, crop monitoring, pest monitoring, market intelligence, etc. to increase the farm yields. Since both big data and smart farming are relatively new concepts and emerging fields, knowledge and awareness on their applications and implications immensely helps the researchers, farmers and other stakeholders to effectively leverage the potential of these emerging technologies to optimize the farm resources and improve overall farm productivity.

Keywords: Artificial intelligence, Big data, Internet of Things, Smart farming

THE global agriculture sector is facing major challenges of climate change and land degradation resulting from intensive farming practices. Smart farming is a recent and hi-tech system of growing quality food and sustainable for the masses through application of advance technologies to increase the quantity and quality of agricultural products. Smart farming involves technologies like Internet of Things (IoT) and is gateway by which modern technologies are replacing the traditional agricultural practices. Farmers in the 21st century have access to smart phones, Global Position System (GPS), IoT technologies and data management gadgets. As more advanced machines and sensors are involved in farms, farm knowledge grows in both amount and scope with farming processes becoming increasingly data-driven and data-enabled. The

enormous volume, variety, and velocity of data generated from sensors and real-time platforms in smart farming systems leads to an ecosystem termed as 'Big data'. Big data requires a set of techniques and technologies with new forms of integration to reveal insights from datasets that are numerous, complex, and of a massive scale. Big dataset represents the knowledge assets characterized by high volume, speed and selection to need specific technology and analytical strategies for its transformation into equivalent information. Big data applications help analysts, data scientists, professionals and progressive farmers to understand the rapidly increasing volume of data generated by various transactions and other forms of data that are often left untapped by conventional data analytics programs. Big data technologies include smart machines,

which are equipped with all kind of sensors to capture various data, which assigns instruction for further machine behaviour. Advantages of big data are: high speed transaction, access to large amount of data and user can perform several operations simultaneously. Combination of smart farming and big data are emerging concepts viz. knowledge on their applications, challenges and opportunities.

Big data and its components

Big data are being used to provide predictive insights in smart farming operations, drive real-time operational decisions, and redesign business processes for game-changing farm operations. Big data represents the information assets characterized by high volume, velocity, variety, veracity, variability and value to require specific technology and analytical methods for its

transformation into value (Fig.1). Big data consists of large datasets (volume), which have different type of datasets. For handling such a vast amount of data, a strong and flexible framework like Hadoop is required. Data can be collected from different data sources like web application, Application Programming Interface (API), and many more. Velocity consists of the speed at which the information moves through the system, where data flows into the system from multiple sources. Big data is continuously modified, and new data is being added to the dataset simultaneously.

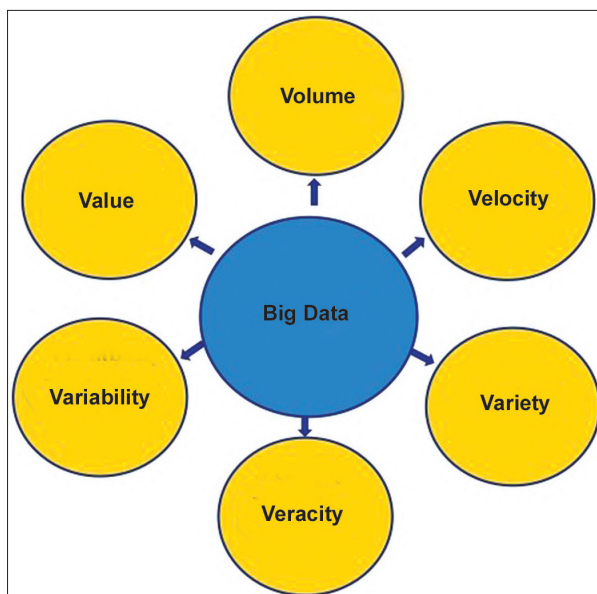


Fig. 1. Big data and its components.

Bigdata ecosystem is capable of withstanding high-speed transactions. Variety of data can be found in bigdata, which are often unique because of wide range of both the sources being processed and their relative quality. It includes traditional data type like text file, log file, other heavy data type like images, video and audio recording. Veracity helps to evaluate the quality of data and processing quality of result analysis. Data veracity score and ranking for a particular dataset is used to assign to avoid making decision based on analysis of uncertain data. Variability includes variation in the data which leads to wide variation in quality, where additional resources can be used to identify, process, or filter low quality data to make it more useful. To measure the value of data, big data ecosystem deals with boundless processes and approaches both in structured or unstructured data.

Big data ecosystem in smart farming

The convergence of multiple technologies such as AI, IoT, big data and cloud computing have a significant impact on various operations and applications in smart farming. In smart farming there are several processes, which demand higher energy input and markets require products of high quality. Such process can be classified according to the requirement, technology and applications. AI has the ability to

augment automation, cost reduction and enhance revenue. Machine learning (ML) is a core part of AI and demonstrated widely in various fields like smart farming, crop monitoring, yield prediction, disease detection, prediction of soil properties, soil and water management, etc. ML algorithms have the ability to overcome human limitations in terms of speed, accuracy, reliability, consistency, and transparency in performing the assigned tasks. Robotics associated with AI need intelligence to handle tasks like object manipulation and navigation in conjunction with sub-problems of localization, motion planning and mapping. IoT is used mainly for the automation of the equipment and application development using data analytics. In IoT-based smart farming, monitoring crop field with the help of sensors and automating the irrigation systems are possible, where farmers can monitor and control the farm conditions from remote. IoT enables farmers to take a data-driven approach to collect vast amounts of information from instrumented sensors about the status of their farms to improve farm yield and mitigate risks from weeds, pests and diseases. In addition to data collected from traditional sensors, more advanced sensing techniques, which are being increasingly deployed for smart farming include proximal,

airborne and satellite-based sensors. Information and Communication Technology (ICT) includes devices, networks, mobiles, services and applications; these range from innovative internet-era technologies and sensors to other pre-existing aids such as fixed telephones, televisions, radios and satellites. The use of mobile and smartphone technologies in smart farming is becoming increasingly popular especially in harnessing the full potential in communication space. Several smartphone apps are available for agriculture, horticulture, and farm machinery to make farm operations smarter and

easier.

Potential applications of big data in smart farming

In smart farming, geospatial technologies like high resolution remote sensing, Geographical Information System (GIS), GPS and field sensors play an important role in reorganization of spatial variations at individual farm level and to address them using appropriate strategies. The important big data applications in smart farming are real-time weather monitoring, soil moisture monitoring, automated irrigation systems, inputs monitoring, crop monitoring, pest monitoring, market intelligence and are briefly summarized below (Fig. 2).

Weather monitoring: In smart farming, farmers need accurate information on weather forecasts and farm inputs. A number of earth observation platforms are used to collectively enable real-time observation and dynamic monitoring of accurate, comprehensive, continuous, and diverse information on weather parameters. Automatic Weather Station (AWS) provides information on various meteorological parameters, soil moisture and soil temperature for better informed decision on irrigation scheduling. The poly-house monitoring systems also create automatic SMS alerts for any change in temperature, humidity, and soil

moisture in the farms.

Soil moisture monitoring:

Smart irrigation system is an automated irrigation system based on sensors, which are interfaced to the microcontroller unit. In smart farming, large farms are divided into number of small sectors; which are easy to handle and helps in managing the resources easily. Soil moisture monitoring sensors, either stationary or mounted on equipment, collect data on soil temperature, moisture, pH, NPK, for automatic irrigation and to provide appropriate nutrients.

Automated irrigation systems:

Wise use of water for crops needs understanding of evapo-transpiration processes and use of efficient irrigation methods. Automated irrigation system does the work without involvement of much manual operations by using computer and sensors. A rule-based expert system helps to save a lot of water, where field sensors collect and analyse data by automated program and accordingly required water is supplied to required part of the farm. An IoT-enabled, remotely controlled cross-platform system equipped with big data analytics and intelligent irrigation scheduling can be accessible through web and mobile applications, which are hosted on enterprise cloud. These systems control the execution of operation and helps in crop field assessment for irrigation, applying fertilizers and pesticides.

Inputs monitoring:

The fertilizer requirement of crops is highly dependent on the soil test value of nutrient, amount of soil organic matter, and yield goal, among other factors. Using high resolution satellite images, soil moisture and surface temperature can be acquired. Fusion of images from different sensors help in providing image with both high spatial and high temporal resolutions. Soil and crop nutrition status can be mapped with high resolution satellite/drone images and

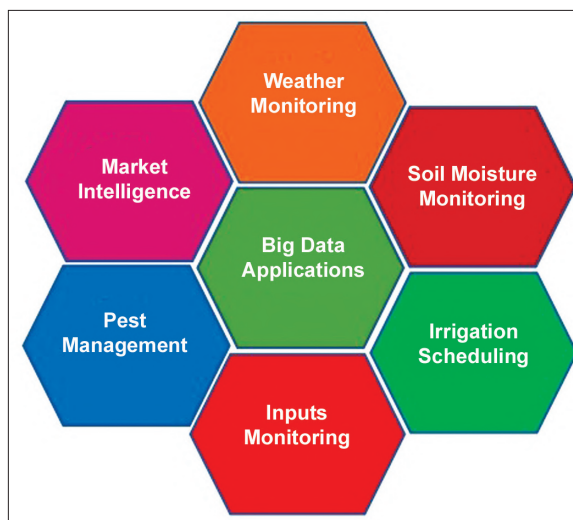


Fig. 2. Potential applications of big data in smart farming

then transferred to field to field/pixel fertilization prescription.

Crop monitoring: High resolution satellite (Fig.3) and drones are capable of collecting crop data that helps in analysing the current crop condition based on which crop health can be monitored. Drones equipped with various types of high frequency sensors are capable of capturing and transmitting the data on the go. Drones can i) identify the crop growth by comparing time-series images taken by the satellite, and ii) can assist farmers to reduce

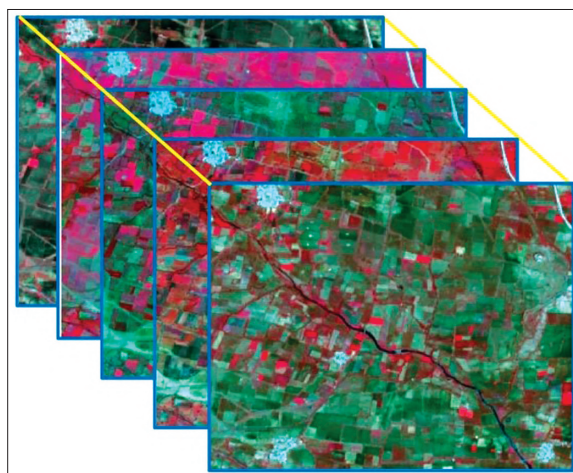


Fig. 3. Crop monitoring through temporal high resolution Sentinel-2 satellites data.

excessive use of water and reduce the chemical load on the environment by spraying on the plant that require attention.

Pest monitoring: An automatic insect identification system with various sensors can be built for insect and pest detection on crop through image analysis. The low power image

sensors can be used to capture images of the trap contents and send them remotely to a control station, which helps in significant reduction of pest monitoring costs, low maintenance cost, real time insect's pest monitoring. Drone can be helpful in spraying of fertilizers and pesticides with remote control. By using alerts on crop infestation, farmers can click an image of their crop and use their resolution to grasp the pests, diseases, and foreign plants (weeds) growing on their farms. The solution uses deep learning and image process

models to identify any crop diseases or pest infestation within the crops.

Market intelligence: In smart farming, AI can help in deploying correct grain storage techniques by maintaining the appropriate temperature, air pressure, and humidity conditions, by adjusting its analysis according to different kinds of crop products. It can also provide real-time information to the warehouse manager if there's any change in set parameters within the grain storage. To improve supply chain efficiencies, many companies are using real-time data analytics on data-streams coming from multiple sources for an efficient and smart supply chain. The agricultural product grading system used, to automate quality analysis of images of food products, is an accurate and reliable method for grading fresh products characterized by colour, size and shape. Their solution reads the image that a farmer has taken on his phone and determines the product quality in real time, with minimum manual intervention.

Big data in smart farming - Challenges

- Acquisition and creating valuable data involves huge investment to build infrastructure.
- Seamless data collection, quality, storage and integration.
- Involves information influx heavily as in-field sensors create a time series at different frequencies, and

the airborne platforms generate high-resolution multispectral or hyper spectral images. It would need high-performance computing for subsequent data processing and analysis. It demands newer scalable facilities in terms of software and hardware for effective management of big data.

- Availability and quality of the spatial and non-spatial data is often a challenge and prerequisite for applications in smart farming.
- Big data access is a challenge, hence, designing of high-performance systems are essential for easy access to distributed data by different users
- Lack of spatial data integration is an important challenge. Big spatial data computing requires modern computing and analytical methods to analyse the unevenly distributed data originating in real-time from different locations. The innovative open-source cloud platforms can be used to access services to analyse voluminous data.
- In data-driven smart farming, data privacy issues and rights to data usage are quite obvious. Lack of data governance and suitable policies in place hinders data privacy and security. Hence, privileged access to big data and building trust with farmers should be a starting point in developing robust applications in smart farming.
- Since big data is from various sources in the agriculture supply chain, multi-stakeholder collaboration is needed for improved decisions and quick access to right data to evaluate key performance indicators in building successful applications.

Big data in smart farming - Opportunities

The key factors that determine successful smart farming are affordability of technology, ease of access and operations, easy maintenance of systems, timely grievance redressal and appropriate policy support. Some of the emerging opportunities of big data application in smart farming are

briefly discussed below.

- **GPS enabled tractors:** GPS data is used to find out soil quality and quantity of crop from different areas of field and determines how much fertilizer is to be applied in each part of the field. GPS enabled tractors enable farmers to accurately navigate to specific locations within the field to collect soil samples or monitor crop conditions. Crop dusters are equipped with GPS and are designed to follow accurate swaths over the farm and spray fertilizer only on required plant, thus optimizing use of fertilisers, reducing amount of chemicals required, thereby benefitting the environment.
- **Embedded sensors on crops and fields:** As per requirement, different sensors can be established in the field to acquire the required data in real-time. An environmental monitoring system can be implemented for real-time measuring temperature, humidity, illumination of soil moisture by using array of sensors.
- **Smart greenhouses:** Greenhouse equipped with sensors and actuators enable farmers to access the facilities of greenhouse through dashboard or mobile application and operations can be managed by using voice commands. Smart greenhouse is able to monitor temperature, humidity, soil moisture to change the climate conditions according to the requirement of plants for effective growth. These smart greenhouses minimises the human efforts in handling the operations.
- **Robots in agriculture:** There is an ever-increasing awareness of the necessity to develop and apply robotic systems in agriculture, forestry, greenhouses, horticulture, etc. Smart robotic vehicles are capable of working 24×7 round the year in all weather conditions and have the intelligence embedded within them to behave sensibly in a semi-natural environment, unattended, while carrying out many useful tasks in smart farming.
- **Decision analytics:** In smart farming, farmers take final decision

using various strategies and different services. Decision analytics uses the previous results to take the final decision. In this process all the decision are based on the previous result and different algorithm comes in the action to analyse the previous results and enable the user to take the final decision in smart farming operations.

- **Supply chain tracking:** In supply chain, for perishable and sensitive materials such as seeds, plants, and food products, preventing spoilage is a matter of concern, where big data has proven useful at various stages. At the production stage, automated systems handle data to show performance and reveal issues in critical equipment. Big data helps farmers and suppliers optimize fleet management to increase delivery reliability. Big data tracking solutions, smart meters, and GPS-oriented analytics improve routing, cutting transportation costs and offering advanced mapping of the locations.

SUMMARY

Smart farming powered by trending technologies like AI with big data analytics, IoT, AI, ML and DL immensely helps in making farming smarter with good profit margins. In data-driven smart farming, big data access, the availability of quality data, big spatial data computation, spatial data integration, data privacy and rights to use data are some of the important challenges exists. On the other hand, immense opportunities exist in smart farming, which include sensors-based technologies to achieve increasing production or accurate inventories for sustainability. Farmers can access the facilities of greenhouse through dashboard and operations can be managed by using voice commands. In smart farming supply chain, use of big data was found to be immensely useful at all stages.

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