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IoT and Data Analytic in Smart Agriculture

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Abstract: *The research explores the use of IoT in agriculture, focusing on its potential applications in rural development and the agrarian sector. It discusses IoT equipment categorization, platforms, standards, and network solutions. The Internet of Things (IoT) is a network of devices that communicates machine-to-machine (M2M) based on wired and wireless Internet. It is widely used in agriculture for management systems, monitoring, control systems, and unmanned machinery. Wireless communication technologies like Wi-Fi, LoRa-WAN, ZigBee, and Bluetooth are also used. With advancements in communication technologies like 5G, IoT will be applied to various agricultural processes, contributing to automation, increased crop quality, and reduced labour. The system consists of three components: hardware, cloud and mobile application. The hardware collects crop data using sensors & electronic components while the cloud is mediator that transfer data. The mobile application controls Device, allowing automatic or manual control. The system sends notifications via the LINE API for the LINE application.*

Keywords: Internet of Things (IoT), Data Analytics, Agriculture, Technologies, Sensors

I. INTRODUCTION

Technology like the Internet of Things (IoT) and data science is totally changing agriculture and farming. IoT means connecting equipment like tractors and sensors in the fields to the internet. This allows farmers to monitor their fields from afar using their smartphones! Sensors can measure things like soil moisture and how the crops are growing. This data helps farmers make better decisions to increase yields and profits. Industrial IoT (IIoT) applies this connectivity to the whole agricultural supply chain. That means connecting complex systems across the farm, processing plants, and logistics. Artificial intelligence analyzes all of the data from the field sensors, weather forecasts, equipment, etc. This gives insights to optimize irrigation, fertilizer use, harvest time, and more.

Data science uses fancy algorithms to unlock useful info from agricultural data. By looking at historical data on crop yields, weather, and prices, data scientists can build models to predict the future. These models can forecast the best planting dates, disease outbreaks, and commodity prices. This enables precision agriculture to improve productivity. Data-driven insights also optimize the supply chain by coordinating production, processing, and distribution.In a nutshell, technologies like IoT, IIoT, and data science are enabling a digital revolution in agriculture. By collecting and analyzing data at large scale, farmers can make smarter decisions and supply chains can be more efficient. This has huge potential to feed the growing population in a world impacted by climate change and limited resources.

II. LITERATURE SURVEY

Traditional methods of agriculture monitoring and control rely heavily on manual labour to regularly check fields and crops. Tools like soil thermometers, moisture meters, pH tests are used to test soil conditions. Pest traps, manual counting of pests is used to estimate infestation levels. [6] However, these methods are time-consuming, inaccurate and do not provide comprehensive real-time data.

Recent advancements in IoT, sensors, wireless connectivity and cloud computing have enabled remote, continuous and automated monitoring of agricultural fields. Smart agriculture systems like WSNs, real-time pest detection using computer vision, automated irrigation control using soil moisture data have emerged (Pathak et al., 2019).

The Internet originally was controlled only by the user. Machine-to-machine (M2M) technology based on wired and wireless Internet with the development of intelligent communication technology was then developed. M2M is a passive concept that collects information by installing sensors and networks, functions on all objects, exchanges data through communication functions, and finally provides information to the user. IoT technology evolved in M2M means technology that communicates among various objects without human intervention and then provides services. The functions of IoT are widely known as data collection and processing, planning and decision-making, and prescriptions and services [1].

The use of IoTs leads to a large-scale or big data that provides valuable information. For this reason, many studies have attempted to turn such data into useful information and knowledge, as surveyed in developed an online microclimate monitoring and control system for greenhouses. The system was supported by a WSN for gathering and analysing plant related sensor data to provide control of climate, fertilization, irrigation, and pests. Tripathy et al. (2014) used data derived from WSN to discover knowledge by data mining. This study focused on leaf spot disease assessing the crop-weather-environment-disease relations, based on wireless sensors and field level surveillance. A classifier was trained to predict the disease. Kehua Xian (2017) proposed a new convenient online monitoring system for IoTs, based on cloud computing.[2]

III. IOT & IIOT TECHNOLOGIES IN AGRICULTURE

Sensors - IoT sensors monitor soil moisture, crop growth, equipment telemetry, weather conditions, and more. Sensors for temperature, humidity, light, and other environmental factors provide data to optimize growing conditions.

- Connectivity - Cellular, Wi-Fi, and satellite connectivity allows IoT devices in remote fields to transmit data to the cloud. Standards like NB-IoT and LoraWAN enable long-range, low-power connectivity.
- Embedded systems - Smart irrigation systems, GPS-guided tractors, automated greenhouse environments, and livestock tracking tags are examples of embedded systems with internet connectivity.
- Cloud platforms - The aggregation, management, and analysis of agricultural data requires scalable cloud storage, computing, and IoT platforms like AWS IoT Core.
- Automation - IoT-enabled automation improves efficiency via smart irrigation, precision fertilizer application, autonomous tractors, drone crop monitoring, and robotics.
- Asset tracking - RFID tags and GPS tracking provide real-time visibility and condition monitoring of farm equipment and livestock.
- Farm management software - Integrates data from field sensors, equipment, weather services into one platform to optimize growing and business operations.
- Predictive analytics - Machine learning on agricultural big data enables forecasting models for crop yields, pest/disease outbreaks, commodity pricing, and more.
- Blockchain - Enables traceability across the supply chain from farm to fork, helping comply with food safety regulations.

By connecting the physical and digital worlds, IoT and IIoT allow complete visibility and data-driven intelligence for modern, high-tech agriculture.

IV. INTERNET OF THINGS HARDWARE, PLATFORMS AND SENSORS IN AGRICULTURE

Hardware:

- Smart irrigation controllers - Automatically adjust watering based on weather, soil moisture sensors, crop needs, etc.
- Self-driving tractors - Use GPS, radars, cameras and farm management software to automate poling, seeding, spraying.
- RFID tags - Track livestock location and health; RFID readers scan tags automatically.
- Smart greenhouses - Control temperature, humidity, lighting, irrigation, nutrient levels to optimize growing conditions.
- Farm robotics - Robots for tasks like pruning, weed control, harvesting, increasing automation.

Platforms:

- Farm management systems - Centralize operational data from field, equipment, weather, and enterprise systems to optimize production.

- Asset management systems - Track location and condition of farm equipment using telematics and predictive maintenance tools.
- Irrigation management systems - Remotely control irrigation hardware based on data like soil moisture, weather, crop water needs.

Sensors:

- Soil sensors - Measure moisture, nutrient levels, temperature, electroconductivity, pH levels for irrigation, fertilizer decisions.
- Crop sensors - Assess plant health, growth rate, stress levels based on spectral reflectance or thermal imaging data.
- Weather stations - Capture rainfall, wind speed, temperature, humidity to inform crop management.

Livestock sensors - Track animal location, health metrics like body temperature and heart rate.

V. IOT & DATA ANALYTICS IN SMART AGRICULTURE

With the help of the Internet of Things (IoT), farmers can now gather and evaluate data from a variety of sensors and devices placed across their fields, revolutionising the agricultural industry. This information may give farmers helpful insights to boost yields, cut expenses, and streamline processes. Among the principal applications of IoT data analytics in smart agriculture are:

- Soil monitoring: Real-time sensors can track temperature, nutrient levels, moisture content, and other characteristics. This enables farmers to spot possible problem areas and water and fertilise their crops more effectively.
- Crop health monitoring: Drones and satellites using computer vision and spectral images may identify crop stress and forecast yields. Plant-level sensors on agricultural machinery may also track the health of crops.
- Weather monitoring: Schedules for irrigation, pesticide application, and harvesting can be influenced by hyperlocal meteorological data obtained from on-farm weather stations as well as external meteorological data.
- Monitoring of equipment: Tractors and cultivators, for example, include sensors that track performance and identify possible maintenance problems before they become serious. The use of equipment may be optimised using telematics data.
- Monitoring livestock: Wearable technology, video analytics, and ambient sensors can monitor the health and behaviour of animals and provide insights into early disease identification, ideal feed rates, estruses notifications, and other topics.

farm workflow optimisation: By combining automated sensors with sophisticated analytics on temporal data, it is possible to provide insights that may be used to improve operational effectiveness throughout the farm system.

The ability to transition from reactive to prescriptive farming, where farmers can predict results and proactively reduce risks, is the main advantage of IoT analytics in agriculture. These technologies have the potential to drastically alter agricultural production, profitability, and sustainability when used correctly.

VI. APPLICATIONS OF THE INTERNET OF THINGS IN AGRICULTURE.

Management Systems

Until recently, farmers lacked the resources necessary to manage their farms using a profitability, benefit, and cost analysis. Though it is now simpler to gather and store data for agriculture thanks to advancements in sensor and communication technology, it is crucial to carefully handle and employ diverse categories of gathered information. The management system in agriculture is utilised for several elements, including farms, energy, water, and agricultural machinery; the following serves as an illustration of them. Displays the networks and sensors used in smart management. Method utilised in the earlier research.

Agriculture Machinery

Agricultural machinery management involves monitoring and maintaining complex fleets of tractors, harvesters, sprayers, and other farm equipment. IoT connectivity and fleet telemetry allows remote monitoring of equipment

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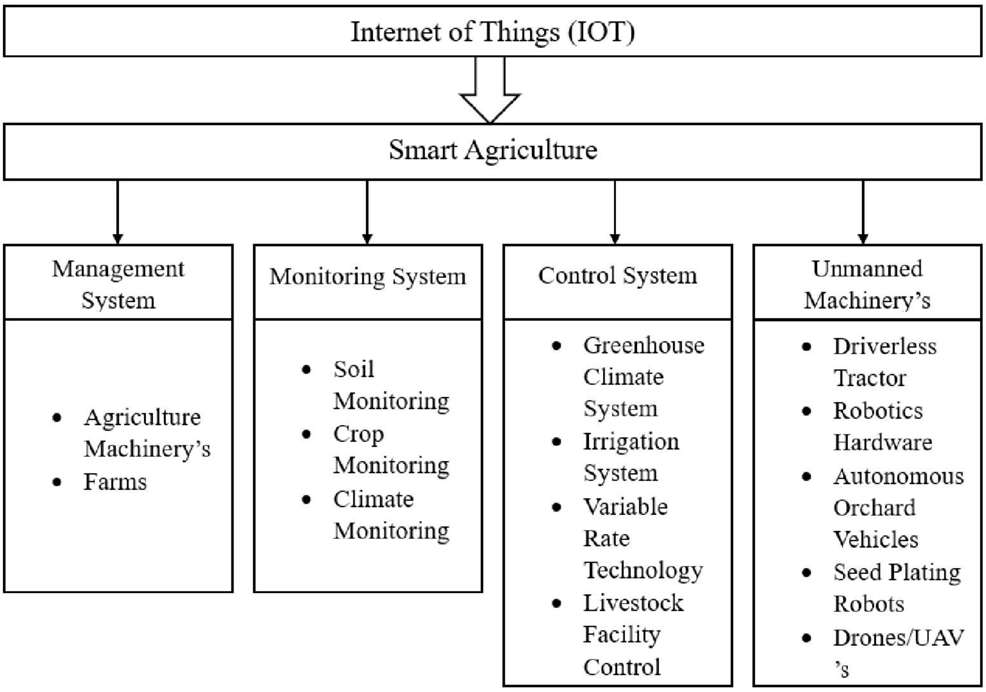
location, hours of operation, fuel/fluid levels, and diagnostic codes. This data is used to optimize fleet usage and routing. Sensors on equipment provide real-time data like soil compaction, crop yield, speed, and efficiency for each implement. This identifies optimization opportunities. Predictive maintenance uses data from sensors and machine learning algorithms to forecast maintenance needs, minimize downtime, and prevent costly breakdowns. Automated service scheduling utilizes telemetry data to intelligently schedule preventative maintenance when needed. This reduces human effort. Asset management software centralizes insights from all equipment sensors, condenses it into user-friendly dashboards and reports. Provides overview of fleet. Driver assists technologies like auto-steering, headland management, implement control automation, reduce driver fatigue and human error for safer operation. Software can generate optimized routes between fields for each piece of equipment, minimizing non-productive time on roads. Remote disable/enable allows managers to shut off equipment access remotely in case of theft or unauthorized usage. Integration with farm management information systems allows two-way data flow between machinery, ERP software, and agronomic planning.



Farms:

By monitoring all measured data from placed sensors on farms, farm management information systems (FMISs) based on the Internet of Things have been proposed to help farmers make better decisions. This system was designed to give farmers access to financial analysis findings derived from big data analysis as well as data gathered on agricultural products including machinery, seeds, fertiliser, and pesticides. PAMS was created specifically for managing sizable farms that produce agricultural products. In order to provide features like data collecting, data retrieval, data analysis, production monitoring and management, remote control of production processes, and assistance for production choices, this system was developed utilising cutting-edge technologies like WebGIS and IoT. To boost agricultural output and assist farmers in making wise decisions, agricultural management information systems, or AMIS, may be widely used throughout the full agricultural cycle.

Monitoring Systems

Soil Monitoring

Soil monitoring involves deploying wireless sensor networks in fields to collect key parameters. Sensors are installed at different depths depending on the crop. Major parameters monitored include soil moisture, temperature, nutrient levels (nitrogen, phosphorus, potassium), pH, and conductivity. Moisture sensors like tensiometers, gypsum blocks, time

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domain reflectometers (TDRs) measure moisture content. Temperature sensors record subsurface heat. Nutrient level monitoring requires specific ion-selective sensors that measure concentrations of nitrate, phosphate, and potassium ions. pH and conductivity sensors detect changes in acidity and salt levels, important for plant health. Wireless protocols like ZigBee, Bluetooth, LoRaWAN, and Sigfox enable sensor connectivity to IoT platforms. Low power wide area networks (LPWANs) conserve energy. Gateways and routers aggregate and transmit data from soil sensors to cloud platforms for analysis and visualization. Farmers access soil sensor data on desktop or mobile apps to track changes and make data-driven decisions on irrigation, fertilizer application. achine learning algorithms analyze soil sensor data to guide precision agriculture and detect anomalies requiring intervention. Real-time soil monitoring improves crop quality and yields while optimizing water and fertilizer usage for greater efficiency.

Crop Monitoring

Crop monitoring aims to assess plant health, growth stages, stress levels, and yield estimates. Both ground-based and aerial sensing methods are used. Proximal sensors like GreenSeeker use optical sensors mounted on tractors or drones flying low over the crops. Measures vegetation indices like NDVI. Satellite imagery provides occasional snapshots of crop fields. Useful for tracking acreage and large-scale crop patterns. Multispectral and hyperspectral cameras capture high-resolution images across different wavelengths. Detects crop stress and diseases. Thermal cameras measure crop canopy temperature, which correlates to evapotranspiration and soil moisture status. LiDAR sensors measure crop height and 3D structure for growth monitoring and yield prediction. Weather stations in fields track climatic conditions like rainfall, wind speed, humidity that impact crops. Computer vision and deep learning analyze crop images to identify plants, detect pest damage, estimate yields. Data from multiple sources is integrated into dashboard apps to provide growers real-time insights on crop status. Helps guide decisions on irrigation, fertilizer, taking preventative measures against threats.

Climate Monitoring

Climate monitoring refers to tracking environmental conditions like temperature, humidity, sunlight, airflow that impact plant growth. Used extensively in greenhouses, indoor vertical farms, mushroomb houses and livestock barns. Sensors measure temperature, relative humidity, CO2 levels, light intensity and distribution. Ventilation is monitored using air flow and quality sensors that detect oxygen, ammonia. Actuators and controllers adjust greenhouse parameters based on sensor data to optimize conditions. Irrigation systems integrate moisture sensors with automated watering and fertigation. Smart thermostats, humidistats, lighting adjust based on crop needs and growth stages. Energy curtains, movable insulation panels modify internal conditions. Environmental control systems tie all sensors and actuators together, allowing centralized monitoring. Climate data enables predictive analytics to model plant response and set optimal climates. Remote access allows monitoring and control using smartphones and web dashboards. Helps improve yields, crop quality and resource efficiency in controlled environment agriculture.

Control System

Control systems automate and optimize agricultural processes by coordinating sensors, controllers, and actuators. Enables maintaining optimal growing conditions, precision in crop care, and automation in livestock operations.

Greenhouse Climate Control

Uses sensors for temperature, humidity, CO2, light levels tied to HVAC, fans, shade/insulation curtains. Setpoint controllers run PID algorithms to determine actuator adjustments needed to reach targets. Machine learning applied for predictive climate control based on weather forecasts and crop models.

Irrigation Control

Soil moisture sensors, flow meters, valves allow precise irrigation based on crop water requirements. Weather data and evapotranspiration models inform timing and volumes. Automates fertilizer injection (fertigation) along with water application.

Variable Rate Technology

GPS-guided application machinery adjusts seeding, spraying, fertilizing rates in real-time. Auto-steering systems, headland control automation for efficient navigation. Prescription maps guide adjustments based on soil fertility, topography, yield data.

Livestock Facility Control

Climate control systems maintain temperature, humidity, ventilation levels in barns. Automated feeding systems control ration amounts tailored to each animal. Milk harvesting robots control the milking process including udder prep, pumping, monitoring.

Unmanned Machinery

Unmanned agricultural machinery utilizes robotics and automation to perform tasks without an operator onboard. Enables precision farming and reduces labor requirements.

Driverless Tractors

Use GPS, sensors, and software for navigation, steering, implementing control without a driver. Increase efficiency through continuous operation, data collection, and integration with IoT systems. Tasks include tilling, planting, mowing, spraying, and harvesting.

Robotic Harvesters

Self-driving units automate picking of fruits like strawberries and apples using robotic arms. Have multiple cameras, sensors to detect ripeness, guide gentle picking and placement. Provide labor relief for tedious harvesting tasks.

Autonomous Orchard Vehicles

Specialized units operate in orchards for pruning, thinning, spraying, weed control and data collection. Use LiDAR, computer vision, articulated arms to perform close-proximity tasks. Avoid damage to trees and crops.

Seed Planting Robots

Highly precise automated seed planting reducing waste and improving germination. Can plant multiple seeds per second with exact depth and spacing. Guided by RTK-GPS, grid maps.

Drones/UAVs

Equipped with multispectral sensors and cameras drones can survey crops, monitor livestock. Collect aerial data for crop health analysis, yield forecasting. Used for targeted spraying and granular fertilizer application.

VII. CONCLUSION

The Internet of Things is rapidly transforming the agriculture industry by enabling advanced data collection and analysis. The deployment of various sensors, devices, and monitoring systems allows farmers to gain insights into crop status, soil conditions, livestock health, and farm operations. Key IoT technologies like wireless sensor networks, GPS, robotics, and cloud computing are enhancing data-driven smart farming. Precision agriculture leverages IoT to optimize field variability and automate management. Real-time soil, crop, and climate monitoring improves decision making for irrigation, fertilization, and pest control. Livestock tracking optimizes health and productivity. Fleet management telematics streamline equipment usage. Overall, IoT connectivity provides complete farm visibility for better prediction and control. While IoT technologies hold tremendous potential, some challenges remain. Data security, privacy, and standardization need more focus in the agri-tech industry. The collection of quality data and integration with analytics and machine learning will be critical in realizing the full benefits. With continued innovation in agricultural IoT systems, data science approaches and practical application, the future of farming is poised to be more efficient, sustainable and productive than ever before.

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