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Smart Agriculture: Multi-Sensor IoT System integrated with Drone for Crop Monitoring

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Abstract- Agriculture has been a cornerstone of human civilization, in recent years smart farming became one of the most important revolutions in the agriculture industry. India currently holds the position as the world's second-largest producer of agricultural goods. Present climate and socioeconomic issues would threaten the global food and environmental security. Multi-sensor IoT systems integrated with drone technologies are revolutionizing smart agriculture by providing a promising approach that supports efficient, sustainable, and profitable crop production. Studies have been conducted across the world that satisfactorily demonstrated the implication of integrated IoT-smart sensors in monitoring environmental factors such as moisture, humidity, temperature, and soil composition that are critical for crop growth [1] . SEDA is used to define the boundaries of plant structures and potential disease symptoms in aerial images. This method allows for precise analysis of CH and helps identify the affected areas. Spanning Tree Optimization (STO) is used to enhance the efficiency of data transmission.AI/ML models then process that data to make decisions. Experimental activities show that the smart agriculture architecture helped farmers effectively plan the different stages of planting and harvesting.

The future of intelligent farming is through drone-based image processing, IoT, and AI/ML integration, which will help in accurate disease prediction, sophisticated environment and soil monitoring, and autonomous agriculture equipment. These tools provide farmers with real-time information, predictive analytics, and automation to increase productivity, minimize losses, and ensure sustainable agriculture.

Keywords- Internet of Things, AIML, Drone, Sensor, Smart Agriculture, monitoring.

I. INTRODUCTION –

Agriculture is integral part of the human community. It has been upgraded with time to increase agricultural yields [1] . This sector has a big impact on its GDP. The need for increased productivity in agriculture is a result of the growing world population. However, there will be times when supply and demand are out of balance. To improve agricultural productivity, maintaining and managing capital and labor remains a very difficult task and also due to environmental changes, food production is insufficient, and resources must be conserved. To overcome this situation people are working on modern farming techniques. The advancement of information technology in recent years, brought light into the

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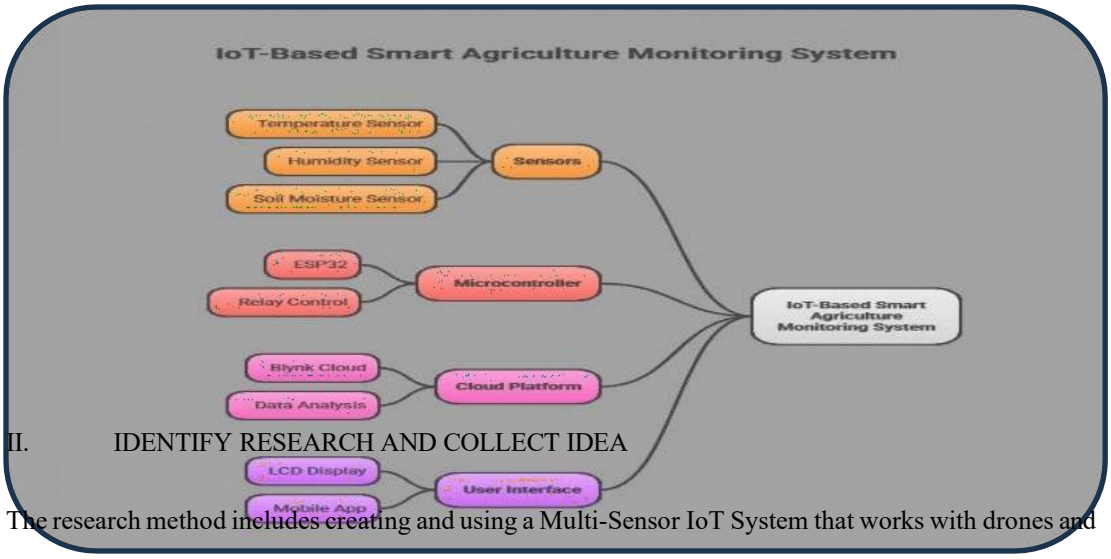
area of robotics with the development of Unmanned Ariel Vehicles (UAV) [2] . They can increase crop quality and productivity without requiring a lot of labor. The Internet of Things (IoT) combined with Artificial Intelligence and Machine Learning (AI/ML) can be used to develop devices that accelerate agricultural processes through automation technologies. The main idea is to use drones for capturing crop images and sensors for monitoring crop health. This data can then be processed by a Machine Learning model trained to classify and analyze the crops. This idea will be extremely helpful towards farmers and agricultural experts as they will be able to keep track of real time data of their farms and save a lot of time for better utilization. The system has one main part, a detection system that includes a temperature sensor, a humidity sensor, and a soil moisture detector. The second part is system control; it monitors and controls everything using a smartphone app.

Drones, being a component of IoT-based smart agriculture, are one of the most efficient techniques for precision farming. They not only take aerial photographs for crop monitoring in large fields but also feed into IoT systems to provide actionable information . Data from drones as well as IoT sensors can be stored and managed through cloud-based solutions, while AI/ML models process this data to extract patterns, anomalies, and predictions .

By combining IoT sensors with AI/ML methods, we are able to develop a Smart Agriculture System (SAS) that enhances crop observation, maximizes irrigation, and enhances overall crop production. Studies have demonstrated that Machine Learning (ML) and Deep Learning (DL) have been extensively used to enhance crop yields, create agriculture advisory systems, identify crop diseases, identify pests, classify plants, and identify weeds. For example, Zeynep et al. have given a comprehensive literature review for DL applications in intelligent agriculture with prominent use cases like the detection of disease, pest identification, smart irrigation, and weed identification.

When we Integrate IoT sensors and smart technologies like machine learning, we can build a farming system that makes it easier to keep an eye on crops and improve how they grow.



II. IDENTIFY RESEARCH AND COLLECT IDEA

The research method includes creating and using a Multi-Sensor IoT System that works with drones and

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radar technology to gather and study data on crop health and growth.

TYPES OF SENSORS

Temperature, humidity sensors and soil moisture sensors are used in the field. Multiple IoT sensors are placed over the farmland which is continuously measure soil condition and environmental parameter like temperature, humidity, soil moisture and also nutrient level.

(A) SOIL MOISTURE SENSOR - Soil moisture sensor measures the amount of water in the soil. It also helps farmer that when and how much to irrigate that means it helps to do the crop selection and scheduling. So, these sensors are able to collect the real time environmental data and soil data. (Fig .1).

(B) TEMPERATURE SENSOR - The temperature sensor monitors air and soil temperature of crops, it also affects growth rate, pest activity etc. Temperature helps to determine the crop planting time and it protects crops from heat stress .(Fig.2)

(C) HUMIDITY SENSOR - Humidity sensor measures the moisture level of air. It affects crop transpiration and Greenhouse climate control. On the other hand, it helps to predict fungal and bacterial infections. In a word it helps in weather based decision making.(Fig. 3)



Fig1: Soil Moisture Sensor

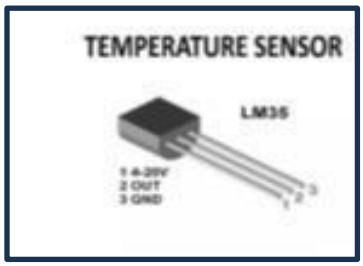

Fig2: Temperature Sensor



Fig3: Humidity Sensor

(II) SENSOR COMMUNICATION

(A) ROLE OF ZIGBEE - In smart agriculture, Zigbee functions by enabling sensors like soil moisture, temperature, and humidity sensors to transmit their data wirelessly through a mesh network. It also provides the highest scalability (5-20K nodes) but low data-rates of about 100Kb/sec [3]. The data is received by a gateway (Zigbee coordinator), which sends it to a farmer mobile app for it to be monitored. If really action is needed then commands are returned over the Zigbee network to actuators.

(B) ROLE OF LORAWAN - It gathers various kinds of data by Sensor Node, such as soil moisture, humidity and temperature etc. and transmits it through LoRA signal. Then through LoRA gateway, it gets the signal and then next it will be routed. So, by server the data handles safely and then next will be saved on a mobile app. And if the action is indeed necessary then cloud sends the messages back through the gateway . supports a communication range of up to 0.5Km and data-rates of up to 100Kb/s for up to 65K nodes [3].

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(III) SENSOR AND ACTUATOR COORDINATE

In smart agriculture , microcontroller-based platforms popularly used by researchers in IoT based SAS include ATMEGA328P [4]. Sensors collect data from crop's farm and actuator works based on that data what are received. Sensor like humidity, temperature and light sensor detect measure climate and sunlight levels. Then the data processing starts and by the help of IoT gateway , it analyzes sensor readings . Then actuator starts operation like water height of the plant (in cm) with respect to time pump, heater from relief of too hot etc. After actuators action sensor monitor the environment to fix the changes**.**

(IV) ROLE OF DRONE

In smart agriculture Drone plays vital role also. Though it is already used in agriculture process, but i can say that it improves agriculture day by day By the help of camera in Drone, it captures all over images in the field. Farmer can detect crop's nutrient efficiency or deficiency and as well as pest attacks. So, drones are actually help in crop monitoring and imaging in agriculture process**.**

(V) USE OF AIML [5]

AI determines the soil moisture, temperature and humidity and nutrient level. ML operates on predict the data such as sufficient water amount, fertilizer and pesticides etc. In addition, Ai assisted in detecting the symptoms of disease at the early stages. Ai and MLX both assist in weather prediction and climate forecasting**.**

(A) PLANT DISEASES - Recent developments in the detection of crop diseases are based on image-processing and Deep Learning (DL) instead of the conventional RNA analysis, allowing quicker and more precise results. CNNs are extensively used to extract features from images, which are thereafter classified by ANNs. Diseases can be infectious (fungal, bacterial, viral) or non-infectious (imbalance of soil pH, toxic minerals, nutrient deficiency). Methods like hyperspectral imaging, genetic algorithm, Gabor Transform, and CNN models obtain 85–95% accuracy, with dedicated systems for fruits such as citrus, mango, apple, and rice.

(B) AGRICULTURAL ADVISORY SYSTEMS - A system based on chatbots can assist farmers with quick and precise answers to their queries. It draws on online farming resources to offer advice about the most suitable crops for given areas or the correct application of pesticides and fertilizers. Other knowledge-based resources, such as ADANS and AGRI-QAS, enable farmers to access beneficial information by entering simple questions and answers, simplifying the retrieval of good-quality farming guidance when it is needed.

(C) REAL-TIME PEST DETECTIO - Detection of pests has typically been based on ML models processing crop images, but those are typically run on off-site hardware, leading to latency and restricting

real-time action. To overcome this, a real-time codling moth detection system using AI at the edge was proposed. The system utilizes available and reasonably cost-effective hardware like Raspberry Pi 3, Intel Movidius NCS, and the Intel Myriad X VPU for local vision processing.

(D) WEED DETECTION - Weeds are invasive plants that compete with the crops and reduce farm yields. The latest methods today employ deep learning and computer vision to detect weeds in the fields and even from aerial images taken by drones. Some utilize transfer learning to improve accuracy.

III. STUDIES AND FINDINGS

(A) Temperature Monitoring - Field and air temperature measurement assists in detecting heat stress in crops and tracking microclimates. It aids in more effective irrigation scheduling and management of greenhouses for optimum crop growth. The sensor provides data to Arduino for remote monitoring and automated alerts. Farmers can see real-time data and past trends for immediate response

(B) Soil Moisture Monitoring - Soil moisture monitoring avoids water stress in plants. It also promotes eco-friendly cultivation. Arduino processes the data and stores it for easy remote monitoring. Farmer gets real-time notifications, historical trend analysis, and automatic irrigation management

(C) Humidity Monitoring - Humidity detection enhances quality of crops. It is applicable to greenhouse and open-field cultivation methods. The sensor readings are sent to Arduino for climate control and monitoring. Farmers receive real-time values, past graphs, and prompt warnings.

(D) Drone Monitoring - Drones capture high-up images to spot damaged crops, unwanted plants, or pests early. They assist farmers in field mapping and tracking nutrient or growth differences. Data is calculated in real time to aid precision farming. This allows for targeted spraying and bulk monitoring

(E) AI/ML Integration - AI and ML process sensor and drone data for intelligent decision-making. They forecast yields, identify plant diseases at an early stage, and schedule irrigation. The system gives outcomes via IoT dashboards to farmers. This saves costs, enhances efficiency, and enables sustainable agriculture

IV. CONCLUSION –

The system is very efficient to use for tracking farm parameters like temperature, humidity, moisture in the soil, and so on, and also automatically spray water. This eliminates a great extent of manual labor and man-power demands.

The configuration consists of Arduino UNO, humidity and temperature sensors, soil moisture sensors, an ultrasonic sensor, and an IoT module. A Thing Speak dashboard can be developed to monitor and control the system remotely through a mobile device. By combining these technologies, farmers can minimize crop damage by predators and increase overall productivity.

Moreover, the ultrasonic sensor assists plant health monitoring, while AI/ML-enabled drones provide an

expansion of functionalities by taking aerial shots, inspecting crop health, scanning for initial signs of disease or pest infestations, and even marking areas that need irrigation or fertilization. This gives farmers actionable information to make decisions promptly.

In the future, such innovations as the corn-tending robot show how robotics technology allied with software-based data can fertilize crops, deposit cover seeds, and collect data continuously to maximize yields with minimal waste. IoT and AI-based systems, and drones, provide farmers instantaneous reports on crop development, pest risks, and soil nutrients, making them major assets in precision agriculture and green farming.

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