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Farmer Advisory Report Generator using Soil, Weather & Crop Data using GenAI

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Abstract: Agriculture is increasingly affected by climate variability, unpredictable weather conditions, and crop diseases that reduce productivity and threaten food security. Farmers often rely on fragmented tools for monitoring weather, soil conditions, and disease detection, which leads to inefficient decision making. To address these challenges, this research presents a web-based Farmer Advisory Report Generator that integrates soil data, weather information, and crop disease detection using Artificial Intelligence (AI) and Generative Artificial Intelligence (GenAI).

The proposed system collects real-time environmental data from IoT-based sensors such as NodeMCU, soil moisture sensors, and DHT11 temperature–humidity sensors. In addition, the system retrieves real-time weather and forecast data from the Open-Meteo API. Farmers can also upload crop leaf images, which are analyzed using a Convolutional Neural Network (CNN) to detect plant diseases. The detected results are processed through a Generative AI Large Language Model (LLM) such as Gemini to generate comprehensive advisory reports including disease diagnosis, treatment suggestions, and irrigation recommendations.

The system integrates multiple data sources into a unified decision-support platform, enabling farmers to receive accurate, real-time, and actionable agricultural insights. The proposed approach improves early disease detection, enhances crop management, and supports data-driven farming practices for sustainable agriculture.

Keywords: Smart Agriculture, Generative Artificial Intelligence, Machine Learning, Internet of Things, Crop Disease Detection, CNN, Large Language Models, Precision Farming.

I. INTRODUCTION

Agriculture today faces major challenges due to climate change, unpredictable weather patterns, limited water resources, and the increasing spread of crop diseases. These factors directly affect agricultural productivity, food security, and farmers' income. Traditional farming methods mainly depend on manual observation and farmers' past experiences to make decisions about irrigation, pest control, and crop management. However, with rapidly changing environmental conditions, these conventional approaches are often insufficient for making accurate and timely decisions. Recent technological advancements have introduced several digital tools to assist farmers, including weather forecasting systems, soil monitoring sensors, and plant disease detection models. Although these technologies are useful, most of them operate independently. Farmers often need to use multiple platforms or applications to access information about weather conditions, soil health, and crop diseases. This fragmented approach can make decision-making complicated and may lead to inefficient farm management and delayed responses to agricultural problems.

To address these challenges, this research proposes an integrated web-based platform called the Farmer Advisory Report Generator. The system combines multiple data sources such as real-time weather information from the Open-Meteo API, environmental data collected from IoT sensors, and plant disease detection using deep learning techniques. Convolutional Neural Networks (CNNs) are used to analyze leaf images uploaded by farmers to identify crop diseases with high accuracy. Additionally, Generative Artificial Intelligence (GenAI) models, such as Large Language Models (LLMs), are used to generate detailed advisory reports that include disease explanations, treatment suggestions, and irrigation recommendations. By integrating IoT, machine learning, computer vision, and generative AI into a single platform, the system aims to provide farmers with accurate, real-time, and easy-to-understand agricultural guidance for better decision-making and improved productivity.

A. Objectives

The primary objectives of the proposed system are:

1) To develop a unified web-based platform that integrates weather data, soil sensor data, and crop disease detection for farmer advisory services.
2) To collect real-time environmental data using IoT sensors such as NodeMCU, soil moisture sensors, and DHT11 temperature and humidity sensors.

3) To implement a Convolutional Neural Network (CNN) model for detecting plant diseases from leaf images uploaded by farmers.
4) To integrate Generative Artificial Intelligence (GenAI) models such as Gemini to generate natural-language advisory reports including treatment suggestions and crop management strategies.
5) To improve agricultural productivity and reduce crop losses through intelligent data-driven decision support.

II. LITERATURE REVIEW

The integration of Artificial Intelligence (AI), Internet of Things (IoT), and data analytics has transformed traditional agriculture into intelligent and data-driven farming systems. These technologies help farmers monitor environmental conditions, detect crop diseases, and receive predictive recommendations to improve productivity and farm management. Talie and Oladele [1] studied IoT-based sensor networks for smart agriculture and showed that sensors such as soil moisture, temperature, and humidity sensors can continuously monitor field conditions and support efficient irrigation management. Similarly, Kumar et al. [2] proposed a machine learning-based weather prediction system that helps farmers plan agricultural activities using climate forecasts, improving decision-making and reducing risks caused by climate variability.

Deep learning techniques have also been widely applied in plant disease detection. Several researchers [3][5] demonstrated that Convolutional Neural Networks (CNNs) can effectively identify plant diseases from leaf images by analyzing visual features such as colour patterns, textures, and lesion structures. Popular CNN architectures like VGG, ResNet, and MobileNet have achieved high accuracy when trained on agricultural datasets such as PlantVillage. These models allow early disease detection and help farmers take preventive measures. However, most existing disease detection systems focus mainly on classification and often lack detailed treatment recommendations or advisory support.

Recent developments in Generative AI and Large Language Models (LLMs) have introduced new possibilities for generating intelligent agricultural recommendations. Bhatia et al. [10] discussed the use of Natural Language Processing (NLP) in agriculture to generate automated advisory reports based on environmental and crop data. Similarly, studies such as Shaikh et al. [7] and Singh et al. [8] highlighted the benefits of IoT-enabled soil monitoring and AI-based disease detection systems. Although these technologies improve crop monitoring and environmental analysis, most existing systems focus on individual functionalities rather than integrating IoT monitoring, disease detection, and weather forecasting into a single unified advisory platform.

A. *Research Gap and Contribution of the Present Work*

The proposed system, Farmer Advisory Report Generator using Soil, Weather, and Crop Data with Generative Artificial Intelligence**,** addresses these limitations by integrating multiple technologies into a single platform. The system combines real-time weather information obtained from the Open-Meteo API, environmental data collected through IoT sensors such as NodeMCU, soil moisture sensors, and DHT11 temperature–humidity sensors, and crop disease detection using Convolutional Neural Networks (CNNs).

Feature	Existing Systems	Proposed System
IoT-Based Environmental Monitoring	✔	✔
Weather Forecast Integration	Partial	✔
Disease Detection using CNN	✔	✔
Generative AI Advisory Reports	✖	✔
Integration of Multiple Data Sources	Limited	✔
Real-Time Sensor Data Processing	Partial	✔
Natural Language Advisory Generation	✖	✔

Table I. Comparative Analysis between Existing Systems and Proposed System

III. SYSTEM ARCHITECTURE

The application is a secured web application that is developed in Python to manage the user accounts, read/process data, and conduct AI supported analysis.

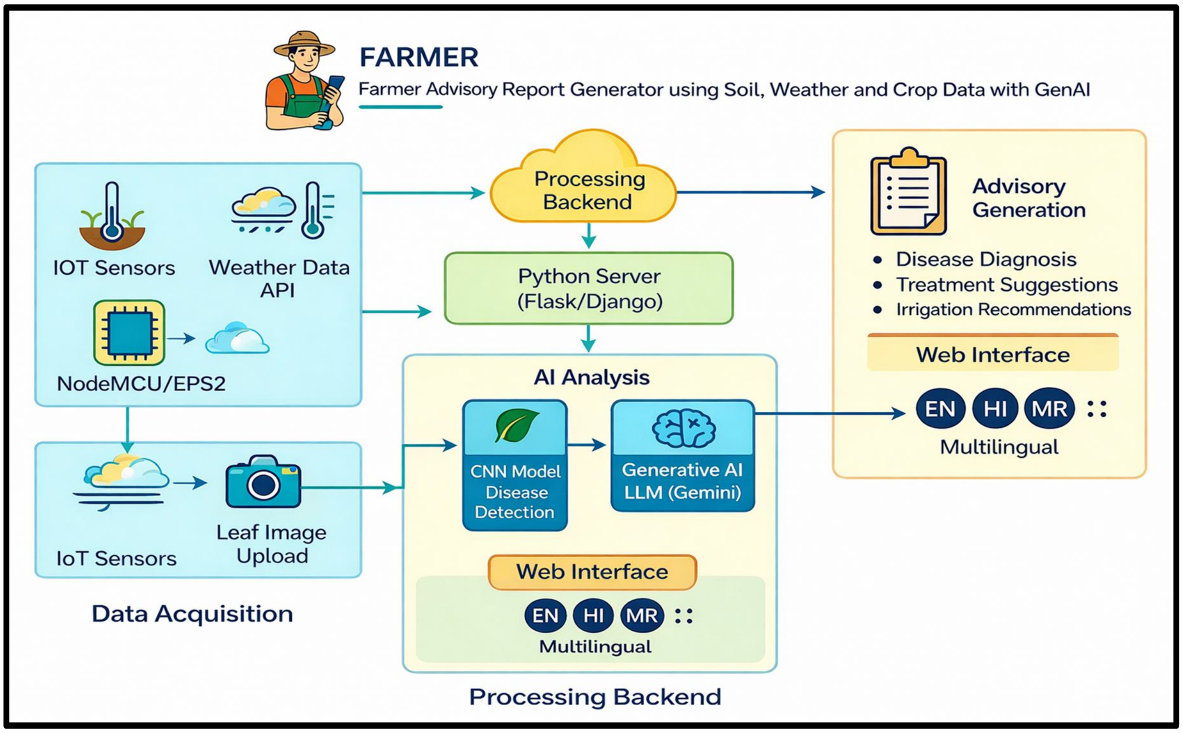

Fig. 1. System Architecture

A. System Overview

The proposed system architecture is organized into four major layers—Data Acquisition Layer, Communication Layer, Processing Layer, and Application Layer. These layers work together to collect environmental data, analyse agricultural conditions using Artificial Intelligence, and generate advisory reports for farmers.

1) Data Acquisition Layer: This layer is responsible for collecting real-time agricultural data from multiple sources. IoT sensors such as soil moisture sensors and DHT11 temperature–humidity sensors are connected to a NodeMCU (ESP8266/ESP32) microcontroller to capture environmental parameters from the field. In addition to sensor data, the system retrieves real-time weather information from the Open-Meteo Weather Data API. Farmers can also upload crop leaf images through the web interface, which are used for disease detection using computer vision techniques.
2) Communication Layer: The communication layer enables data transfer between the data acquisition components and the backend processing system. Sensor data collected by the NodeMCU is transmitted to the backend server through Wi-Fi connectivity using HTTP requests or API endpoints. Similarly, weather data is fetched from the Open-Meteo API through internet-based requests. This layer ensures seamless communication between the IoT devices, APIs, and the processing server.
3) Processing Layer: The processing layer consists of a Python-based backend server implemented using frameworks such as Flask or Django. This server manages incoming data, processes user requests, and integrates various AI models. Environmental sensor data and weather information are analyzed to generate contextual insights. Leaf images uploaded by users are processed using a Convolutional Neural Network (CNN) model that detects crop diseases by analysing visual features. The outputs of these models are further passed to a Generative AI model, such as Gemini, which interprets the results and prepares meaningful advisory information.
4) Application Layer: The application layer provides a user-friendly web interface that allows farmers to interact with the system. Through this interface, users can upload crop images, view sensor readings, check weather conditions, and receive advisory reports generated by the system. The advisory module provides recommendations including disease diagnosis, treatment suggestions, and irrigation guidance. The platform also supports multilingual output, allowing farmers to view recommendations in multiple languages such as English, Hindi, and Marathi, thereby improving accessibility for regional users.

B. Data Flow

The system processes data from three primary sources: IoT sensors, weather APIs, and crop leaf images. Environmental data collected by the NodeMCU sensors is transmitted to the backend server where it is stored and analysed. Simultaneously, weather data is retrieved from the Open-Meteo API and integrated with the sensor data to provide a comprehensive understanding of field conditions.

When a farmer uploads a leaf image through the web interface, the image is first pre-processed using image processing libraries such as Pillow and NumPy. The image is resized to the required input dimensions (typically 224 × 224 pixels) and normalized before being passed to the CNN model for disease classification. The predicted disease label, along with environmental data and weather conditions, is then sent to the Generative AI model. The model generates an advisory report that includes disease explanation, treatment recommendations, and irrigation suggestions, which are displayed on the user dashboard.

C. Security and Reliability

The system incorporates several mechanisms to ensure secure and reliable operation. All data communication between IoT devices, APIs, and the backend server is performed using secure HTTPS protocols to maintain confidentiality and data integrity. The web application uses session-based authentication to manage user access and protect user accounts. Additionally, system logs and timestamped data records are maintained to ensure traceability of sensor readings and advisory outputs. These mechanisms enhance system reliability and ensure that farmers receive accurate and trustworthy recommendations.

IV. METHODOLOGY

A. IoT Data Acquisition System

The hardware module is designed to collect environmental data from the agricultural field and transmit it to the backend system for analysis. It consists of a NodeMCU (ESP8266/ESP32) microcontroller, which acts as the central communication unit between sensors and the cloud server. The system integrates multiple sensors to monitor field conditions and support data-driven agricultural decisions.

1) Soil-Moisture Sensor: Measures volumetric water content in the soil to determine irrigation necessity.
2) Temperature and Humidity Sensor (DHT11/DHT22): Monitors atmospheric conditions affecting evapotranspiration.
3) Relay Module and Water Pump: Executes ON/OFF operations based on AI-generated decisions.
4) Power Supply Unit: Provides regulated power to the microcontroller and sensors.

All hardware components are assembled to enable continuous data collection and automated actuation.

B. System Software Framework

The software component forms the analytical core of the system, integrating IoT communication, artificial intelligence models, and web-based visualization. The backend server is implemented using Python frameworks such as Flask or Django to manage system operations.

1) Python Backend Server: Handles user requests, processes sensor data, and manages communication between different system modules.
2) Weather Data API: The system retrieves real-time and forecast weather information from the Open-Meteo API to provide environmental context for agricultural decision-making.
3) CNN Model for Disease Detection: Uploaded leaf images are processed using a Convolutional Neural Network (CNN) model to classify crop diseases based on visual patterns.
4) Generative AI Model: Large Language Models such as Gemini analyse outputs from the CNN model and environmental data to generate advisory reports for farmers.
5) Web Interface: Developed using HTML, CSS, and Bootstrap, the interface allows farmers to upload images, view environmental data, and receive advisory recommendations.

C. System Logic Flow

1) Environmental data from IoT sensors is collected by the NodeMCU microcontroller and transmitted to the backend server.
2) The system simultaneously retrieves real-time weather information from the Open-Meteo API.
3) Farmers upload crop leaf images through the web interface, which are preprocessed and analyzed by the CNN model for disease detection.

4) The outputs from sensor data, weather information, and disease detection are combined and analyzed using Generative AI models.
5) The system generates an advisory report that includes disease diagnosis, treatment recommendations, and irrigation guidance, which is displayed on the user dashboard in real time.

V. RESULTS AND DISCUSSION

The proposed Farmer Advisory Report Generator was evaluated using real-time sensor data, weather API inputs, and crop leaf images. The system performance was assessed based on disease detection accuracy, advisory generation quality, and overall system responsiveness.

A. Environmental Data Processing Performance

The system successfully collected environmental data from IoT sensors such as soil moisture and DHT11 temperature–humidity sensors through the NodeMCU microcontroller. Sensor readings were transmitted to the backend server in real time and integrated with weather data obtained from the Open-Meteo API. The system demonstrated reliable data acquisition and processing, enabling continuous monitoring of agricultural conditions.

B. Disease Detection Results

The Convolutional Neural Network (CNN) model was tested on multiple crop leaf images representing different disease categories and healthy leaves. The model analyzed visual features such as color variation, lesion patterns, and texture to classify diseases accurately. Experimental results indicate that the CNN model achieved an average classification accuracy of approximately 94%, successfully identifying plant diseases and providing diagnostic information. This capability enables early detection of crop infections and supports farmers in taking preventive measures.

C. Advisory Generation Performance

The system integrates Generative Artificial Intelligence models to convert analytical outputs into natural-language advisory reports. Based on environmental data, weather forecasts, and disease detection results, the AI model generates recommendations including treatment suggestions, crop management guidance, and irrigation advice. The advisory reports were generated quickly and presented through the web interface in a user-friendly format.

D. Summary of Performance Metrics

Parameter	**Value / Result**
Disease Detection Accuracy	~94%
Environmental Data Processing Accuracy	~92%
Advisory Generation Response Time	Less than 2 seconds
Data Sources Integrated	IoT Sensors, Weather API, Image Upload
AI Models Used	CNN + Generative AI
Language Support	English, Hindi, Marathi

Table II. Summary of Performance Metrics

E. Discussion

The experimental results demonstrate that the proposed system effectively integrates IoT sensing, computer vision, and Generative AI technologies to support intelligent agricultural advisory services. The high disease detection accuracy and fast response time allow farmers to receive timely recommendations for crop management. Furthermore, the system's multilingual interface and user-friendly dashboard make it accessible to farmers from different linguistic backgrounds. Overall, the integration of environmental monitoring, AI analysis, and automated advisory generation provides a scalable and efficient solution for modern precision agriculture.

VI. CONCLUSION

The proposed Farmer Advisory Report Generator integrates Artificial Intelligence (AI), Internet of Things (IoT), and Computer Vision to support intelligent agricultural decision-making. The system collects environmental data from IoT sensors, retrieves weather information through APIs, and analyzes crop leaf images using a CNN model.

By combining these technologies, the system provides farmers with accurate and real-time insights related to crop health, soil conditions, and weather forecasts. The integration of Generative AI enables the automatic generation of advisory reports that include disease diagnosis, treatment suggestions, and irrigation recommendations.

Experimental results show that the system achieves around 94% accuracy in disease detection with a fast response time. Additionally, the multilingual web interface improves accessibility, making the platform a practical and scalable solution for modern precision agriculture.

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VII. EXTENDED RESEARCH AND FUTURE INNOVATIONS

A. Expansion of Crop Disease Detection Models

Future development of the system can include expanding the dataset to support a wider variety of crops and plant diseases. By training the CNN model on larger and more diverse agricultural datasets, the system can improve detection accuracy and provide advisory services for multiple crop types across different regions.

B. Mobile Application for Farmer Accessibility

A dedicated mobile application can be developed to improve accessibility and usability for farmers. The mobile platform would allow users to upload crop images, view environmental data, and receive advisory reports directly on smartphones, even in areas with limited computer access.

C. Integration of Advanced Data Analytics

The system can be enhanced by incorporating historical data analysis and predictive analytics. By analysing past sensor readings, weather patterns, and crop health data, the platform could generate predictive insights and long-term crop management strategies for sustainable precision agriculture.

D. Augmented Reality (AR) for Crop Diagnosis

AR technology can allow farmers to point their smartphone camera at crops and see real-time overlays showing disease symptoms, nutrient deficiencies, or treatment suggestions directly on the plant.

E. Holographic Farm Advisory Assistant

Future systems could include a 3D holographic AI assistant that visually explains crop diseases, irrigation plans, and farming strategies in an interactive way.

VIII. ACKNOWLEDGMENT

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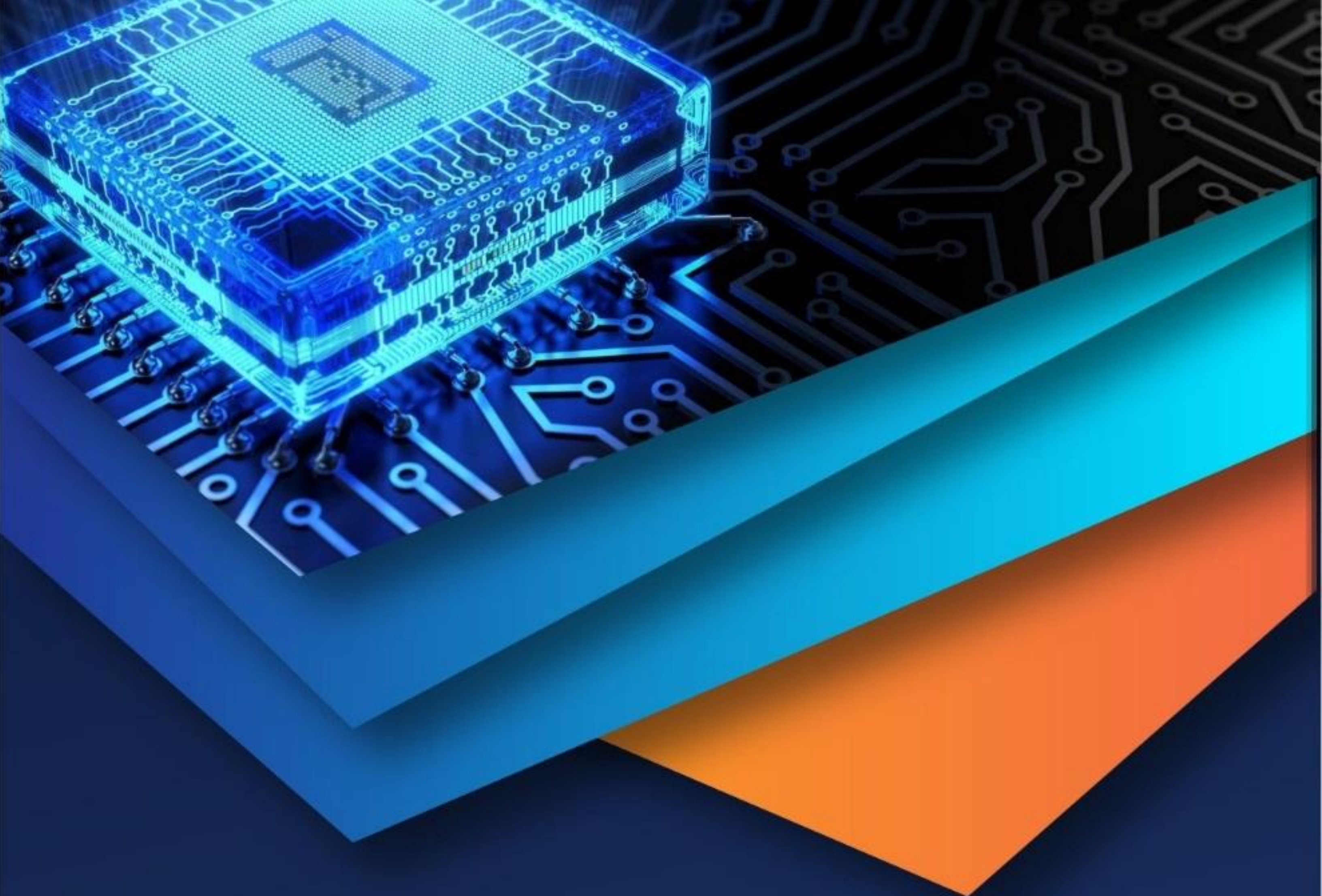

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