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AI Based Radiation Emission Risk, Environmental Impact, and Mitigation Planning System

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Abstract: *Radiation estimation plays an important role in understanding radiation levels and supporting effective environmental monitoring and risk assessment. This project presents a Radiation Estimation System using Machine Learning and the Internet of Things (IoT), integrating Random Forest Regression with real-time sensor data collection and web-based monitoring. An ESP32 microcontroller collects environmental parameters and transmits the readings to the ThingSpeak cloud platform. A machine learning model processes relevant environmental parameters to estimate radiation levels, while a Flask-based web application provides prediction results, historical records, and visual analysis. SQLite is used to store predictio n history for further reference. By combining environmental data collection, machine learning-based estimation, and accessible web monitoring, the proposed system aims to support radiation assessment, environmental safety, and informed decision-making. The project contributes to Sustainable Development Goal 3 (SDG 3): Good Health and Well-being, by promoting data-driven radiation monitoring and supporting awareness of potential radiation risks to human health and the environment.*

Keywords: *Radiation Estimation, Machine Learning, Internet of Things (IoT), Random Forest Regression, ESP32, ThingSpeak, Flask Web Application.*

I. INTRODUCTION

Radiation estimation is important for understanding radiation levels and supporting environmental monitoring. However, estimating radiation from environmental parameters can be challenging because multiple factors, such as temperature, humidity, location, and time, may influence the input data. Accurate data processing and model evaluation are essential for obtaining reliable estimates.

Conventional radiation measurement requires suitable calibrated instruments, which may not always be available in student projects. Machine learning and Internet of Things (IoT) technologies provide an approach to estimating radiation using environmental data and connected sensors. These technologies enable data collection, cloud communication, prediction, and web-based visualization.

The proposed AI Based Radiation Emission Risk, Environmental Impact, and Mitigation Planning System combines Random Forest Regression with an ESP32 microcontroller, ThingSpeak cloud integration, and a Flask-based web application. The system processes environmental parameters to estimate radiation levels and uses SQLite to store historical prediction records. It provides dashboard views, historical data, and model analysis to support radiation estimation and accessible monitoring.

Problem Statement

Estimating radiation levels using environmental data can be challenging without suitable instruments and proper data analysis. Collecting sensor readings alone may not provide clear radiation estimates or easy access to previous records. Manual analysis can also make it difficult to monitor and compare data. Therefore, this project aims to use machine learning to estimate radiation levels from environmental parameters. IoT technology is used to collect and transmit sensor data. A web application provides prediction results and historical records for easy monitoring.

Objectives

The main objectives of the Radiation Estimation System are: (1) Todevelop a machine learning-based system for estimating radiation levels using environmental and geographical parameters. (2) To implement a Random Forest Regression model for predicting radiation levels. (3) To collect and process relevant input parameters, including temperature, humidity, atmospheric pressure, UV index, latitude, longitude, altitude, and time of day. (4) To integrate an ESP32-based IoT system for collecting environmental sensor readings and transmitting data to the cloud. (5) To use ThingSpeak for storing and retrieving sensor data for radiation estimation. (6) To develop a web application using Python and Flask for displaying

predicted radiation levels and related information. (7) To use an SQLite database for storing prediction records and maintaining historical data. (8) To evaluate the system using appropriate regression metrics, including Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), and the coefficient of determination (R^2), along with functional testing of the implemented system.

Scope

The project focuses on estimating radiation levels using machine learning and environmental parameters. It includes IoT-based sensor data collection using ESP32, cloud data transmission through ThingSpeak, and radiation prediction using Random Forest Regression. The web application displays prediction results and stores historical records. The system is intended for estimation purposes and does not replace certified radiation monitoring instruments.

II. MATERIALAND METHODS

Existing System

Conventional radiation estimation and monitoring methods rely on radiation measurement instruments and sensor-based monitoring systems. Some systems collect environmental data for monitoring radiation levels, while estimating radiation levels using multiple environmental and geographical parameters may require additional data processing and prediction techniques.

The major limitations addressed by the proposed system are:

- Dependence on specialized radiation measurement instruments for direct monitoring.
- Difficulty estimating radiation levels using multiple environmental and geographical parameters.
- Need for integrating sensor data collection with machine learning-based prediction.
- Limited integration of IoT-based data transmission, radiation prediction, and historical data storage in a single platform.
- Dependence of prediction performance on data quality, sensor calibration, and the accuracy of the trained model.
- These are the identified problem areas addressed by the proposed system; specific comparisons with existing radiation monitoring systems require verified research evidence.

Proposed System

The proposed Radiation Estimation System combines machine learning-based radiation prediction with IoT-based sensor data collection and a web-based interface. Environmental and geographical parameters are collected and processed by the system. The Random Forest Regression model estimates radiation levels based on the input parameters. The application displays the predicted radiation values and stores historical prediction records for future reference .The system uses Random Forest Regression for radiation estimation, ESP32 for sensor data collection, ThingSpeak for cloud-based data transmission, Python and Flask for web application development, and SQLite for storing prediction records.

System Architecture

The system can be described using three logical layers. The presentation layer uses HTML, CSS, and JavaScript to provide a web interface for displaying radiation prediction results. The application layer uses Python and Flask to process environmental and geographical parameters, integrate the Random Forest Regression model, and generate radiation estimates. The IoT and cloud layer uses ESP32 to collect sensor readings and ThingSpeak to transmit and retrieve data, while SQLite stores prediction records and historical data for future reference.

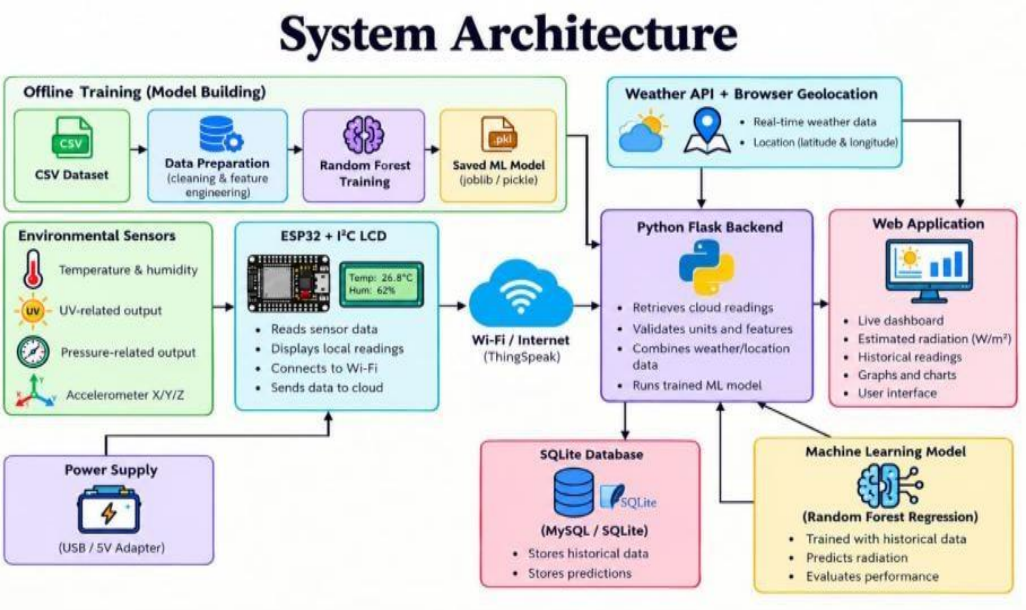

Fig. 1. System Architecture

Technologies Used

Technology	Purpose
Python	Application development and integration of the machine learning model.
Random Forest Regression	Machine learning-based radiation level estimation.
ESP32	Collection of environmental sensor readings and transmission of data.
Flask	Web application development and handling prediction requests.
ThingSpeak	Cloud-based storage and retrieval of sensor data.
SQLite	Storage of prediction records and historical data.
Environmental Sensors	Collection of environmental parameters such as temperature, humidity, and other relevant readings.
HTML, CSS, JavaScript	Development of the web interface for displaying radiation prediction results.

Implemented Modules

- **Sensor Data Collection**: Collects environmental readings such as temperature, humidity, wind speed, and UV-related values using the available sensors connected to the ESP32.
- **Data Transmission:** Uses ESP32 Wi-Fi connectivity to transmit collected sensor readings to the server through the internet.
- **Data Preprocessing:** Processes and validates environmental and geographical parameters into the required format before providing them to the machine learning model.
- **Radiation Estimation:** Uses the Random Forest Regression model to estimate radiation levels based on the input parameters.
- **Web Application:** Provides a user-friendly interface developed using Python and Flask to display sensor readings and estimated radiation values.
- **Historical Data Management:** Maintains radiation prediction records and related information for future reference.
- **Database Management:** Uses SQLite to store prediction records and retrieve historical data.
- **Data Visualization:** Displays radiation estimates, sensor readings, and historical information using graphs and charts, as supported by the implemented application.
- **Cloud Data Integration**: Uses ThingSpeak to store and retrieve sensor data collected through the IoT system.

Testing Methodology

The Radiation Estimation System should be tested against its functional requirements. Testing should cover sensor data collection using ESP32, data transmission through ThingSpeak, preprocessing of environmental and geographical parameters, radiation estimation using the Random Forest Regression model, display of prediction results, historical data management, and database operations. Each test case should record the input, expected outcome, actual outcome, and pass/fail status. Model performance should be evaluated separately using a documented test dataset. Metrics such as Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), and the coefficient of determination (R^2) should be reported only after they have been calculated and verified.

III. RESULTS

Functional Testing

The Radiation Estimation System should be evaluated using test cases covering ESP32 sensor data collection, data transmission through ThingSpeak, environmental parameter preprocessing, radiation estimation using the Random Forest Regression model, display of prediction results, historical data retrieval, and database operations. Actual test outcomes must be verified before final results can be reported. The model's prediction performance should be evaluated separately using a test dataset and verified regression metrics, including MAE, RMSE, and R^2.

Test ID	Scenario	Expected outcome	Actual result
TC01	Sensor Data Collection	Environmental sensor readings are collected through ESP32.	verified
TC02	Data Transmission	Sensor data is transmitted to ThingSpeak successfully.	verified
TC03	Cloud Data Retrieval	Data is retrieved from ThingSpeak correctly.	verified
TC04	Input Data Validation	Invalid or missing input parameters are handled appropriately.	verified
TC05	Data Preprocessing	Input parameters are converted into the required format for prediction.	verified
TC06	Radiation Estimation	Random Forest Regression generates a radiation estimate.	verified
TC07	Prediction Display	The estimated radiation value is displayed on the web application.	verified

TC08	Historical Data Storage	Prediction records are stored in the SQLite database.	verified
TC09	Historical Data Retrieva	Previously stored prediction records are retrieved correctly.	verified
TC10	Weather Data Integration	Available weather data is retrieved and processed correctly.	verified
TC11	Geographical Data	Latitude, longitude, and available altitude data are processed correctly.	verified
TC12	Dashboard Functionality	The dashboard displays available readings and prediction information.	verified
TC13	Model Performance Evaluation	MAE, RMSE, and R^2 are calculated using a suitable test dataset.	verified

Table I. Representative functional test cases

Results Summary

The final testing results of the Radiation Estimation System should include the total number of test cases executed, passed, failed, and retested, where applicable. Testing should cover ESP32 sensor data collection, ThingSpeak data transmission and retrieval, environmental parameter preprocessing, radiation estimation, prediction result display, historical data management, and database operations. The pass rate should be calculated using the formula: Pass Rate = (Number of Passed Test Cases / Number of Executed Test Cases) × 100. The verified test counts and calculated pass rate should be reported only after the test cases have been executed and their outcomes documented. The machine learning model's performance should be evaluated separately using a suitable test dataset, with metrics such as Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), and the coefficient of determination (R^2) reported only after they have been calculated and verified.

Observed Application Functionality

The implemented Radiation Estimation System integrates IoT-based sensor data collection, cloud data transmission, machine learning-based radiation estimation, and web-based visualization. Insert actual screenshots of the ESP32 sensor readings, ThingSpeak data dashboard, radiation prediction interface, AI analysis page, historical prediction records, and main web application dashboard. Include only screenshots of features available in the working application and ensure that the displayed sensor readings and prediction results correspond to the implemented system.

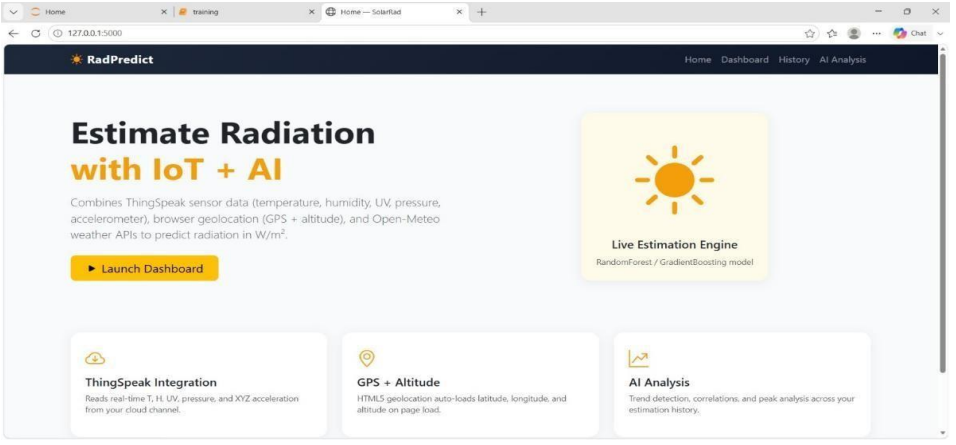

Fig. 1. Home page of the Radiation Predict web application

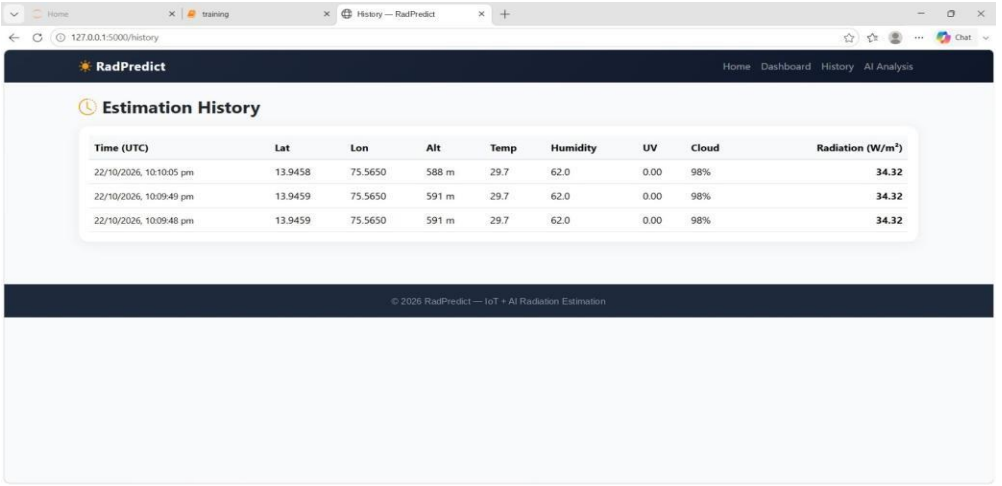

Fig. 2. Radiation Estimation History

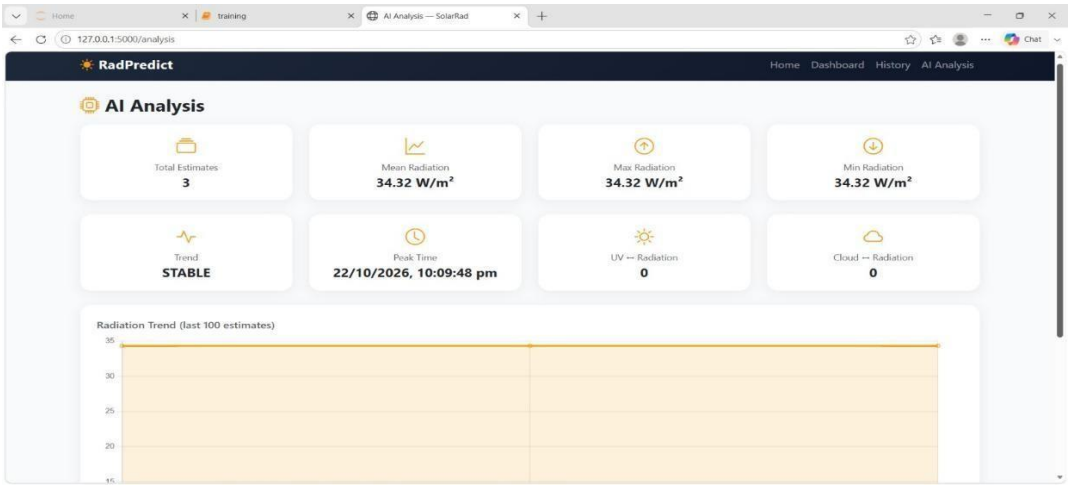

Fig. 3. AI analysis page of Radiation Predict showing radiation statistics, trend and peak time.

IV. DISCUSSION

The Radiation Estimation System integrates machine learning-based radiation estimation with IoT-based sensor data collection. Random Forest Regression performs radiation prediction, while ESP32 and ThingSpeak support sensor data collection and cloud transmission.

The integration of radiation estimation, web-based visualization, and historical data storage provides a centralized platform for analyzing radiation levels. However, system reliability depends on input data quality, sensor calibration, measurement consistency, and model performance.

The predicted radiation value represents an estimate and does not guarantee accuracy. Model performance should be evaluated using an independent test dataset and verified regression metrics. The system is intended for educational and estimation purposes, not as a replacement for certified radiation measurement instruments.

V. CONCLUSION

The Radiation Estimation System is a machine learning-based project designed to estimate radiation levels using environmental and geographical parameters. The system uses Random Forest Regression for radiation prediction and integrates ESP32, ThingSpeak, Python, Flask, and SQLite for sensor data collection, cloud communication, web-based visualization, and data storage.

The project aims to provide an integrated platform for radiation estimation and historical data analysis. Further evaluation is required to establish the model's prediction performance, document functional testing results, and identify system limitations. The system is intended for estimation and educational purposes rather than as a substitute for calibrated radiation measurement instruments.

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