AnnaMrita: An IoT and AI-Based Solution for Reducing Food Waste and Ensuring Food Safety in India

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Abstract:

Food waste is a pressing global issue contributing to environmental degradation and food insecurity, particularly in India. This paper presents AnnaMrita, an innovative IoT and AI-based system designed to minimize food waste and ensure food safety through real-time spoilage detection and optimized food redistribution. The system utilizes an MQ-135 sensor to monitor volatile organic compounds (VOCs) and moisture levels, enabling precise classification of food as “fresh” or “spoiled” using Support Vector Machine (SVM) and Random Forest algorithms. A web-based platform facilitates coordination between food donors (Informers) and NGOs (Responders), ensuring seamless and timely food distribution. Additionally, an integrated route planner optimizes the delivery process by identifying the fastest and most efficient transportation routes, providing estimated travel times for different modes of transport to help NGOs reach the needy more effectively. Experimental results demonstrate high classification accuracy (SVM: 92%, Random Forest: 95%), real-time monitoring capabilities, and effective alert mechanisms, reducing spoilage and enhancing food donation efficiency. The proposed system is scalable, cost-effective, and aligns with United Nations Sustainable Development Goals: 12 (Responsible Consumption & Production). Future enhancements include integrating blockchain for transparency, deep learning for improved spoilage prediction, and a mobile application for better accessibility. AnnaMrita represents a significant step toward building a sustainable, technology-driven food waste management ecosystem.

Keywords: Food Waste, IoT, Sensor, AI, Machine Learning, Route Optimization, Food Safety, Sustainable Development, Real-time Monitoring.

1. Introduction:

Food waste is a global crisis, with approximately 1.3 billion tons of food wasted annually, amounting to one-third of all food produced (FAO, 2022). This wastage leads to severe environmental, economic, and social consequences, including excessive greenhouse gas emissions, loss of valuable resources, and exacerbation of food insecurity. In India alone, nearly 40% of food produced goes to waste, while over 190 million people remain undernourished (UNDP, 2021).

To tackle this issue, AnnaMrita introduces an IoT and AI-powered system for real-time food spoilage detection, efficient redistribution, and optimized logistics. By integrating sensor-based monitoring, machine learning-based classification, and route optimization algorithms, the system ensures that surplus food is safely and promptly delivered to those in need.

2. Problem Statement and Motivation:

2.1 Problem Statement

Food wastage remains a severe socio-economic and environmental challenge, with inefficiencies in food donation and distribution systems contributing to substantial losses. In India, where over 194 million people suffer from malnutrition, a significant portion of surplus food is discarded due to inadequate storage conditions, lack of real-time monitoring, and inefficient logistical networks. Existing food donation systems face several limitations:

- Food Safety Risks – No real-time monitoring mechanisms ensure the quality of donated food, leading to concerns over spoilage and contamination.
- Logistical Inefficiencies – A lack of optimized transportation planning delays food deliveries, increasing the likelihood of spoilage before reaching the beneficiaries.
- Data Gaps in Food Shelf Life – Current donation systems do not leverage predictive analytics to assess food freshness, resulting in premature disposal of edible food.

2.2 Motivation

The increasing adoption of IoT and AI in smart agriculture and food supply chains presents an opportunity to revolutionize food donation practices. AnnaMrita is designed to tackle food waste through intelligent, real-time monitoring and efficient last-mile delivery optimization. The system aims to:

- Ensure Food Safety – Implement IoT sensors to monitor food spoilage indicators, ensuring that only safe food is redistributed.
- Enable Proactive Decision-Making – Utilize AI-driven classification (SVM, Random Forest) to predict spoilage trends and prevent waste.
- Optimize Logistics with Route Planning – Integrate an AI-based route optimization system to help NGOs identify the fastest and most efficient transportation options, reducing transit time and ensuring food reaches the needy before spoilage.
- Promote Sustainability – Align with Sustainable Development Goal (SDG) 12, emphasizing responsible consumption, food waste reduction, and efficient resource allocation.

3. Related Work:

Numerous studies have explored IoT-based food monitoring, AI methodologies for spoilage detection, and blockchain applications for transparency in food systems. However, the unique amalgamation of IoT, AI/ML, and blockchain in AnnaMrita distinguishes it from existing solutions. This innovative platform not only focuses on spoilage detection but also ensures secure and transparent food donation processes, thus enhancing food safety and reducing waste more effectively than prior efforts.

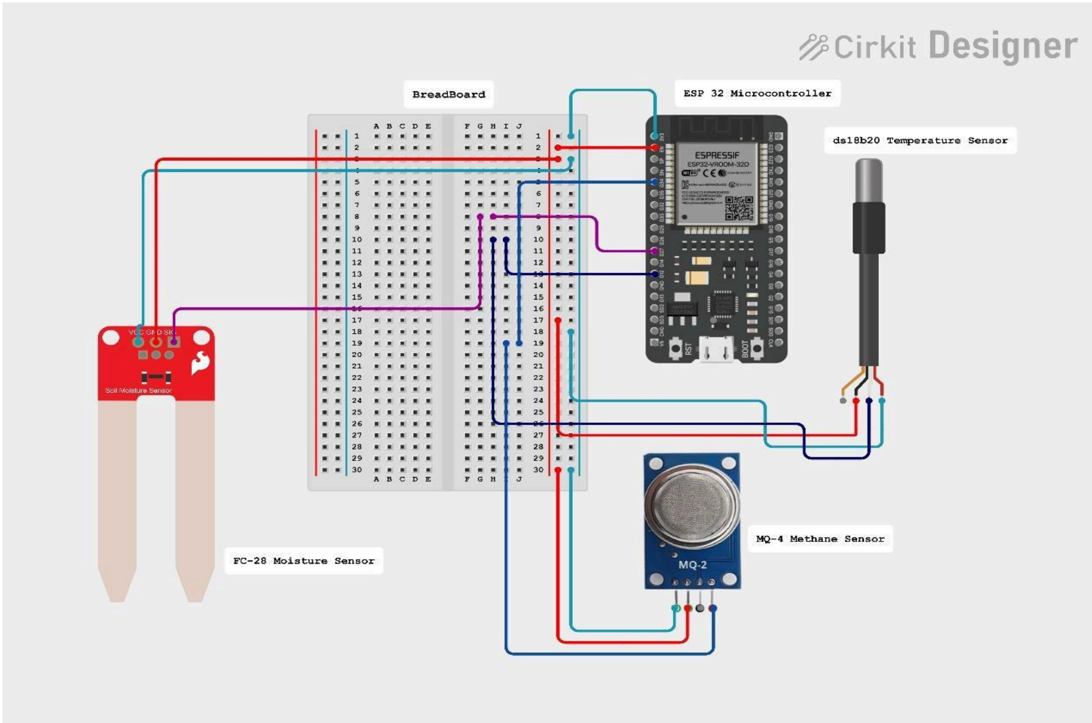
Sr. No	Title	Year	Author(s)	Technology Used	Work Done	Gap
01	Freshness of Food Detection using IoT and Machine Learning, 2020 International Conference on Emerging Trends in Information Technology and Engineering (ic-ETITE)	2020	Nachiketa Hebbar	**IoT:** Node MCU, oxygen sensor **Machine Learning:** Logistic Regression, SVM, Linear Regression	✔ Integration of IoT ✔ Integration of Machine Learning ✔ Real-Time Monitoring	1. Limited Dataset Dependency 2. Less number of sensors used
02	Spoilage detection and shelf life prediction of food using Internet of Things and Machine Learning, 2022 JETIR May 2022, Volume 9, Issue 5	2022	Madhuri Borawake, Aradhana Sharma, Ulfat Shaikh, Sejal Barkade, Putuja Paturkar	**IoT:** Arduino Uno, Wi-Fi module ESP8266, sensors (pH sensor, oxygen sensor, ammonia sensor, moisture sensor) **Machine Learning:** K-Nearest Neighbors (KNN) algorithm	✔ Integration of IoT ✔ Implementation of Machine Learning model with 98% accuracy ✔ Real-Time Monitoring	1. Limited Parameters 2. Machine Learning Model Training

03	Machine Learning Enabled Food Contamination Detection Using RFID and Internet of Things System, J. Sens. Actuator Netw.	2021	Sharif, A.; Abbasi, Q.H.; Arshad, K.; Ansari, S.; Ali, M.Z.; Kaur	**IoT:** RFID Tag, TagoPerformance setup **Machine Learning:** XGBoost	✔ RFID Tags: Sticker-type inkjet printed RFID tags used. These tags are attached to food samples and capable of backscattering signals when interrogated by an RFID reader. ✔ XGBoost algorithm, implemented in Python, used for training with 90% accuracy	1. Limited Scope of Contaminants 2. Performance Metrics and Model Limitations
04	IoT and Machine Learning based Model for Food Safety and Quality in Handling a Pandemic Situation, International Journal of Food and Nutritional Sciences Journal Volume 11, Issue 12, Dec. 2022	2022	Upendra Singh, Dr. Lokendra Singh Songera	**IoT:** Sensors and RFID **Machine Learning:** Convolutional-LSTM	✔ Utilization of IoT sensors ✔ Real-Time Monitoring ✔ Implementation of LSTM Algorithm	1. Incomplete Data Gathering 2. Lack of Immutable Data Record

4. Methodology:

IoT Setup:

The *AnnaMrita* project employs a simplified yet effective IoT setup to monitor and predict the shelf life of perishable food. This setup integrates an ESP32 microcontroller with select sensors that provide key data to detect spoilage trends, with real-time monitoring accessible via a personal website. Details of the setup include:

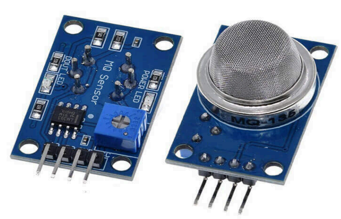


Hardware Components

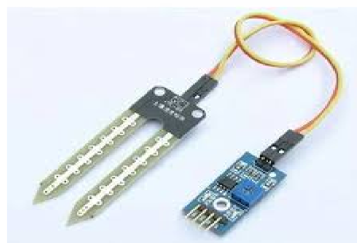
This circuit is designed to monitor environmental parameters including air quality, soil moisture, and temperature. It utilizes a set of sensors interfaced with an ESP32 microcontroller, which is responsible for reading sensor data and potentially sending it to a server. The sensors include the MQ-2 and MQ-135 for air quality measurement, the SparkFun Soil Moisture Sensor for detecting soil moisture levels, and the DS18B20 1-Wire Temperature Sensor for temperature readings.

Component List

1. **MQ-2 Sensor**
   - **Description**: A gas sensor used for detecting LPG, i-butane, propane, methane, alcohol, hydrogen, and smoke.
   - **Pins**: VCC, GND, A0 (Analog Output), D0 (Digital Output)
2. **MQ-135 Sensor Air Quality**
   - **Description**: A sensor for monitoring air quality, detecting a wide range of gases, including NH3, NOx, alcohol, benzene, smoke, and CO2.
   - **Pins**: VCC, GND, A0 (Analog Output), D0 (Digital Output)
   - **MQ-135 Sensor**: This sensor detects volatile organic compounds (VOCs) such as ammonia, which increase as food decomposes. By capturing VOC levels, the MQ-135 provides critical indicators of spoilage.



3. **SparkFun Soil Moisture Sensor**
   - **Description**: A sensor for measuring the volumetric content of water in soil.
   - **Pins**: VCC, GND, SIG (Signal Output)
   - **Moisture Sensor**: Measures the moisture level around the food items. High moisture often accelerates spoilage, especially in perishable foods. Monitoring moisture levels helps provide context for VOC readings.



4. **ESP32 (30 pin)**
   - **Description**: A powerful microcontroller with Wi-Fi and Bluetooth capabilities, suitable for a wide range of applications.
   - **Pins**: EN, VP, VN, D34, D35, D32, D33, D25, D26, D27, D14, D12, D13, GND, Vin, D23, D22, TX0, RX0, D21, D19, D18, D5, TX2, RX2, D4, D2, D15, 3V3
   - **ESP32 Microcontroller**: The core of the system, ESP32 receives data from connected sensors, processes it, and transmits it to a locally hosted XAMPP server. The ESP32's wireless capabilities facilitate seamless data communication for real-time monitoring.

5. **DS18B20 1-Wire Temperature Sensor Probe Cable**
   - **Description**: A digital temperature sensor that provides temperature readings over a 1-Wire interface.
   - **Pins**: Shield, GND, DQ (Data), VDD (Power Supply)

- **DSB1820 Temperature Sensor**: Measures temperature and humidity, environmental conditions that significantly affect food freshness. Maintaining a record of these metrics helps model food spoilage patterns.

Wiring Details

1. **MQ-2 Sensor**
   - VCC: Connected to 3V3 on ESP32
   - GND: Connected to GND on ESP32
   - A0: Connected to GPIO 34 (D34) on ESP32

2. **MQ-135 Sensor Air Quality**
   - VCC: Connected to 3V3 on ESP32
   - GND: Connected to GND on ESP32
   - A0: Connected to GPIO 32 (D32) on ESP32

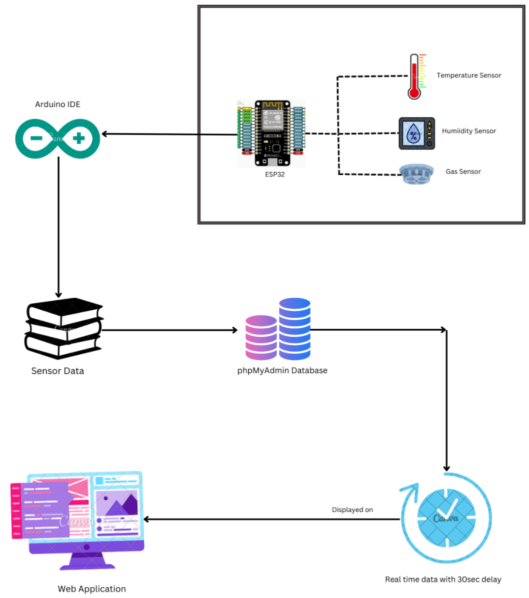
3. **SparkFun Soil Moisture Sensor**
   - VCC: Connected to 3V3 on ESP32
   - GND: Connected to GND on ESP32
   - SIG: Connected to GPIO 35 (D35) on ESP32

4. **ESP32 (30 pin)**
   - 3V3: Power supply for sensors
   - GND: Common ground for all components
   - D35: Connected to SIG on SparkFun Soil Moisture Sensor
   - D4: Connected to DQ on DS18B20 Temperature Sensor
   - D32: Connected to A0 on MQ-135 Sensor Air Quality
   - D34: Connected to A0 on MQ-2 Sensor

5. **DS18B20 Wire Temperature Sensor Probe Cable**
   - VDD: Connected to 3V3 on ESP32
   - GND: Connected to GND on ESP32
   - DQ: Connected to GPIO 4 (D4) on ESP32

Data Transmission and Processing:

- The ESP32 microcontroller, programmed using Arduino IDE, collects sensor readings at specified intervals. These readings are sent to a local XAMPP server, where they are temporarily stored for easy access and further analysis.



- PHP scripts on the XAMPP server manage the backend, storing data in a MySQL database for consistency and reliability.

- **Visualization and Monitoring**
  - Sensor data is displayed on a custom website, enabling remote monitoring. Graphical visualizations aid in understanding food quality trends, while threshold-based alerts notify users if food conditions suggest spoilage.
  - The thresholds for "fresh" and "spoiled" states are pre-defined based on initial sensor data analysis from fresh and decayed samples, enhancing detection accuracy.

AI/ML Models:

1. **Support Vector Machine (SVM)**
   - **Purpose**: SVM is employed to classify food as "fresh" or "spoiled" based on VOC and moisture levels. Given that spoilage is influenced by precise environmental thresholds, SVM's strength in binary classification makes it ideal for separating fresh and spoiled states with high accuracy.
   - **Advantages in AnnaMrita**: SVM works well with high-dimensional data, allowing it to effectively use features derived from sensor readings to delineate the freshness boundary. The model identifies the hyperplane that best separates fresh and spoiled food based on historical data, providing a reliable decision boundary even with limited data samples.
   - **Application in Prediction**: By training SVM on data labeled as fresh or spoiled, the model learns to detect subtle shifts in VOC and moisture levels. This capability enables the system to alert users of spoilage onset at an early stage.
2. **Random Forest**
   - **Purpose**: Random Forest is utilized for feature importance and to increase prediction robustness by analyzing decision trees built on sensor data patterns. It serves as an ensemble method that evaluates multiple decision pathways, increasing model stability and accuracy.
   - **Advantages in AnnaMrita**: Given that food spoilage can vary with multiple interacting

factors, Random Forest's ensemble of decision trees helps account for complex relationships between VOC levels, moisture, and time. The model identifies critical thresholds and feature importance for each sensor reading, highlighting which indicators are most predictive of spoilage.

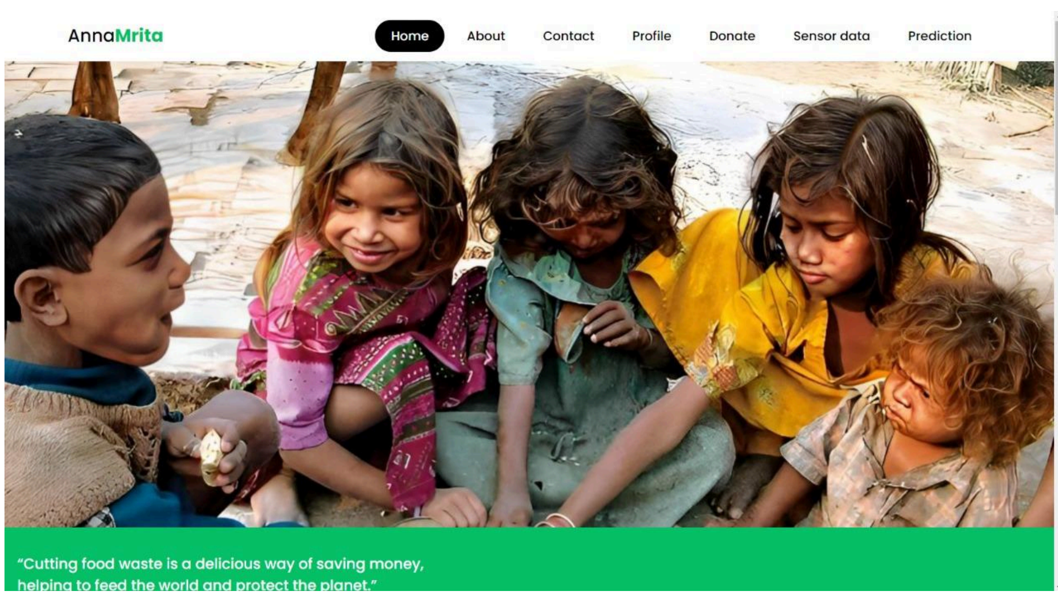
   - **Application in Prediction**: The model's collective decision approach enhances generalizability, reducing the risk of overfitting and making it versatile across various food types. By implementing Random Forest, *AnnaMrita* can adapt its spoilage predictions to account for variability in food properties and storage conditions.

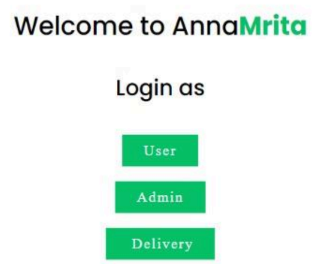
➢ **Why SVM and Random Forest?**
The combination of SVM and Random Forest in *AnnaMrita* allows for both precise classification (fresh vs. spoiled) and adaptive learning of spoilage indicators, maximizing model accuracy. SVM's robustness in classification complements Random Forest's strength in capturing complex, multi-feature relationships, offering a comprehensive approach to food spoilage prediction. This hybrid approach enables *AnnaMrita* to provide consistent, reliable alerts for food quality, aiding in timely interventions and reducing food waste effectively.

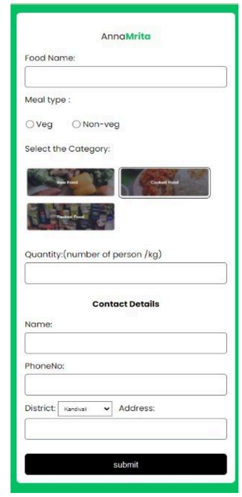
Web Application:

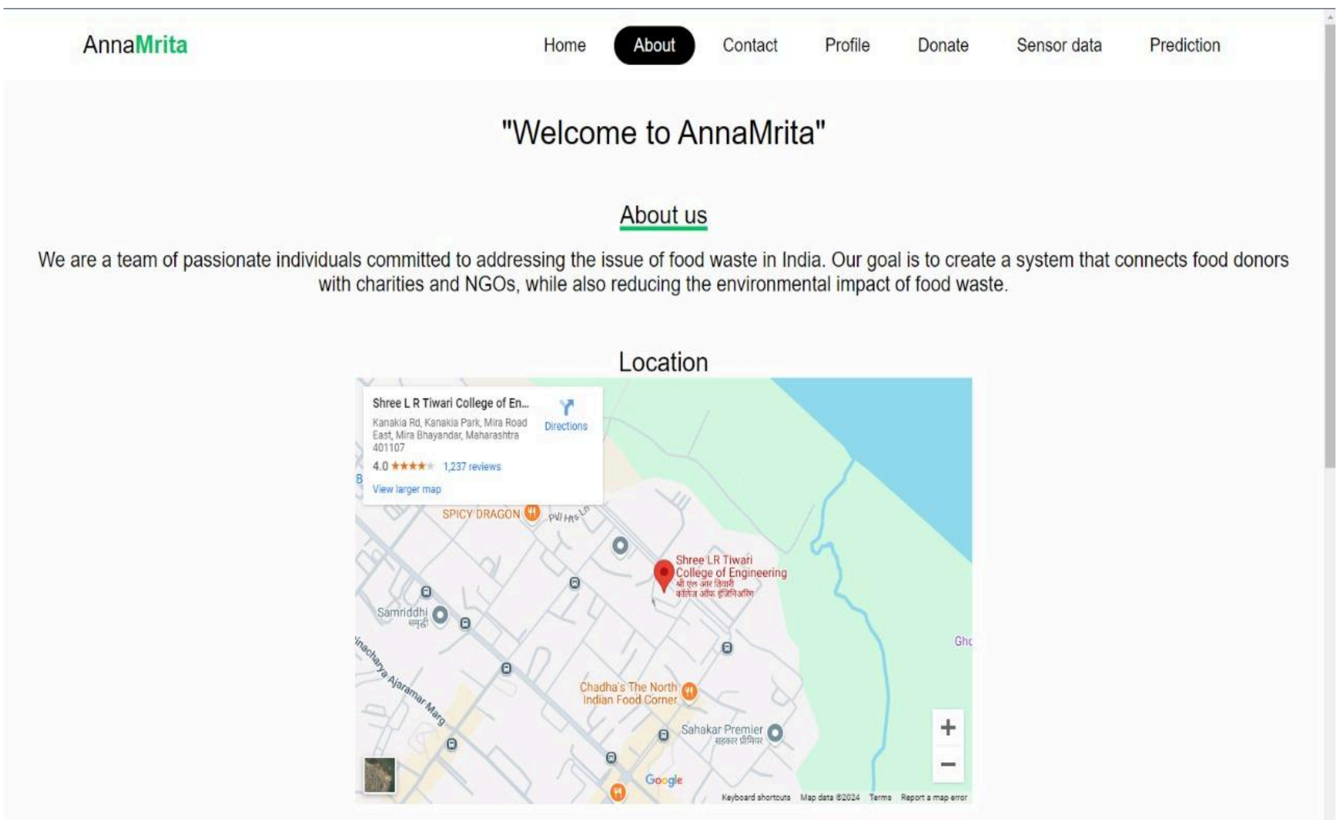
The *AnnaMrita* web application is a versatile platform that not only monitors food quality but also facilitates timely food donations, making it an essential tool in reducing food waste. The application serves two primary user roles: *Informers* (food outlets) and *Responders* (NGOs and volunteers). Together, these roles ensure the seamless flow of information on food availability and quality, allowing for efficient food redistribution.

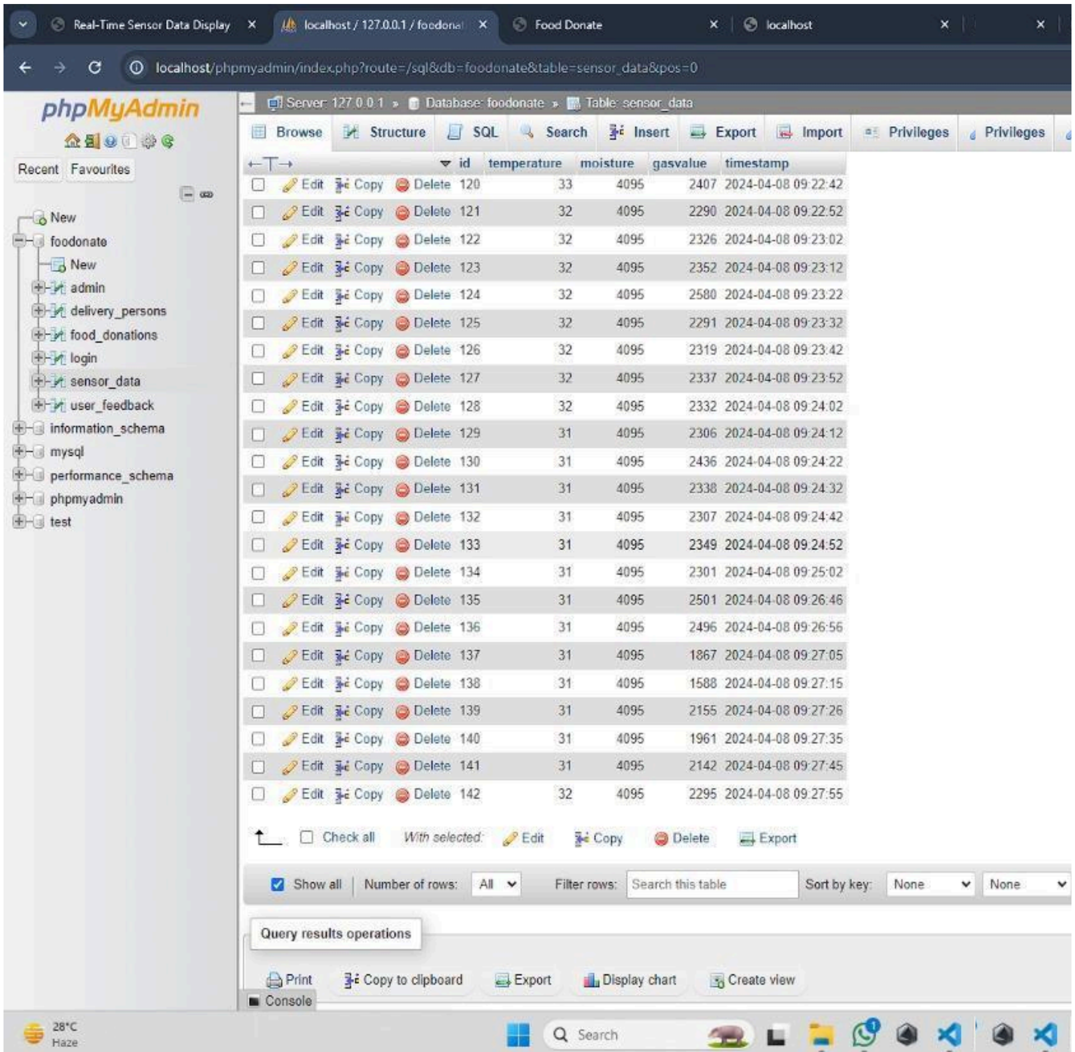
1. **User Interface Design**
   - **Dashboard View**: The main dashboard provides Informers and Responders with real-time sensor data, displaying the VOC levels from the MQ-135 sensor and moisture readings, which indicate food freshness.



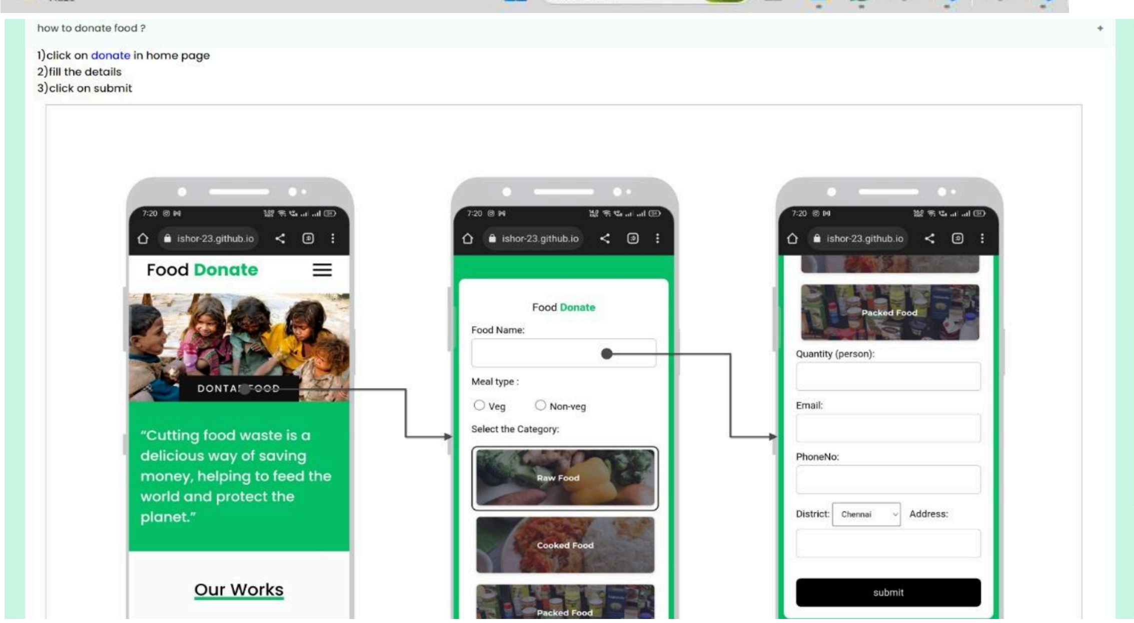

Welcome to AnnaMrita
Login as
User
Admin
Delivery


AnnaMrita
Food Name:
Meal type :
Veg
Non-veg
Select the Category:
Quantity:(number of person /kg)
Contact Details
Name:
PhoneNo:
District:
Address:
submit

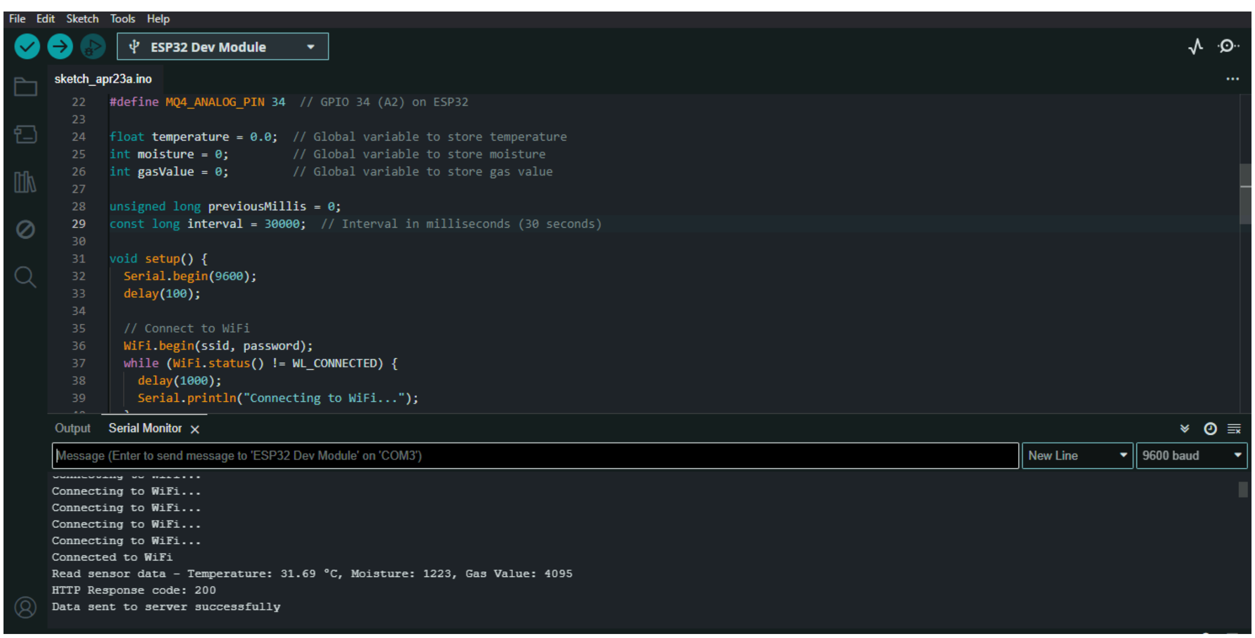

AnnaMrita
Home
About
Contact
Profile
Donate
Sensor data
Prediction
"Welcome to AnnaMrita"
About us
We are a team of passionate individuals committed to addressing the issue of food waste in India. Our goal is to create a system that connects food donors with charities and NGOs, while also reducing the environmental impact of food waste.
Location
Shree L R Tiwari College of En...
Kanakia Rd, Kanakia Park, Mira Road East, Mira Bhayandar, Maharashtra 401107
Directions
4.0
1,237 reviews
View larger map
SPICY DRAGON
Shree LR Tiwari College of Engineering
Samriddhi
Chadha's The North Indian Food Corner
Sahakar Premier
Google
Keyboard shortcuts
Map data ©2024
Terms
Report a map error

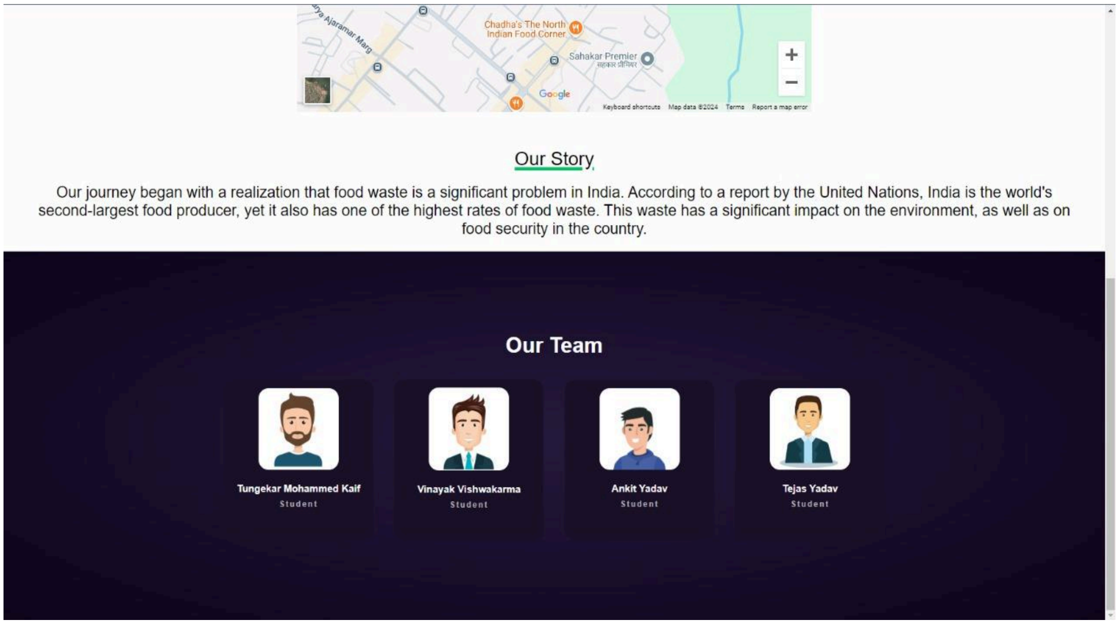


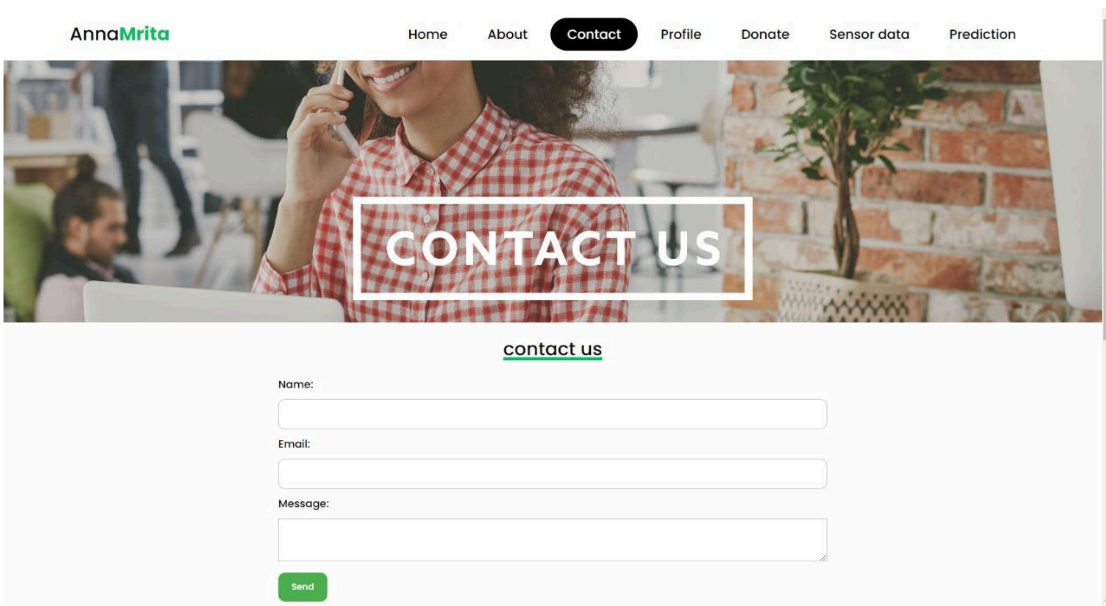
id	temperature	moisture	gasvalue	timestamp
120	33	4095	2407	2024-04-08 09:22:42
121	32	4095	2290	2024-04-08 09:22:52
122	32	4095	2326	2024-04-08 09:23:02
123	32	4095	2352	2024-04-08 09:23:12
124	32	4095	2580	2024-04-08 09:23:22
125	32	4095	2291	2024-04-08 09:23:32
126	32	4095	2319	2024-04-08 09:23:42
127	32	4095	2337	2024-04-08 09:23:52
128	32	4095	2332	2024-04-08 09:24:02
129	31	4095	2306	2024-04-08 09:24:12
130	31	4095	2436	2024-04-08 09:24:22
131	31	4095	2338	2024-04-08 09:24:32
132	31	4095	2307	2024-04-08 09:24:42
133	31	4095	2349	2024-04-08 09:24:52
134	31	4095	2301	2024-04-08 09:25:02
135	31	4095	2501	2024-04-08 09:26:46
136	31	4095	2496	2024-04-08 09:26:56
137	31	4095	1867	2024-04-08 09:27:05
138	31	4095	1588	2024-04-08 09:27:15
139	31	4095	2155	2024-04-08 09:27:26
140	31	4095	1961	2024-04-08 09:27:35
141	31	4095	2142	2024-04-08 09:27:45
142	32	4095	2295	2024-04-08 09:27:55

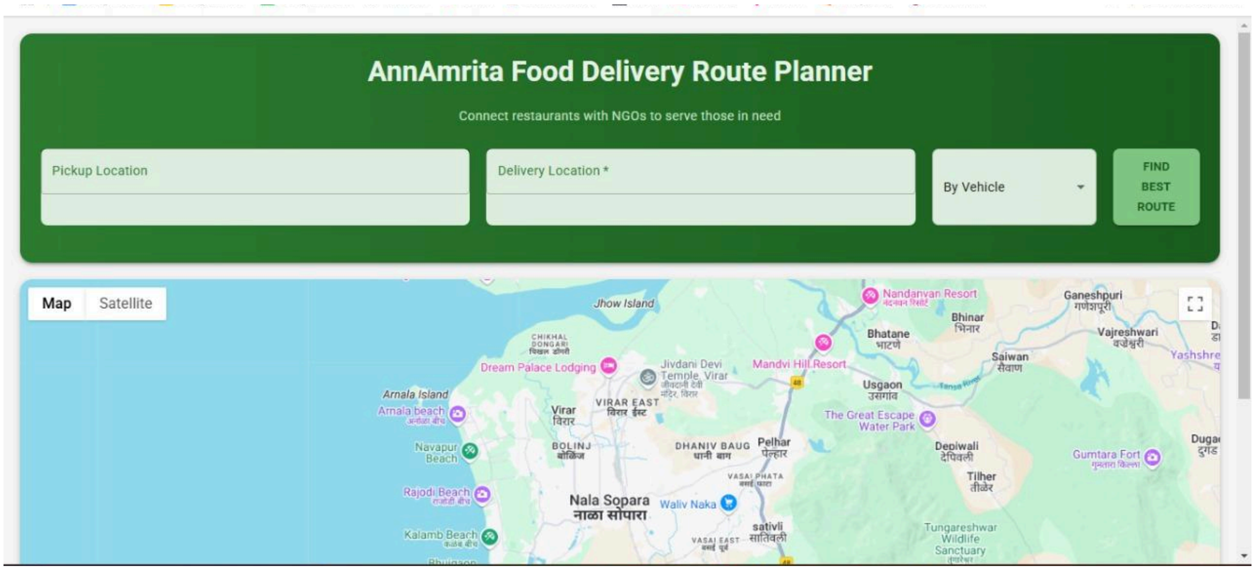


Sensor	Latest Value
Temperature	31 °C
Moisture	3316 gm3
Gas Value	1829 ppm
Spoilt Status	Not Spoilt
Last Updated	2024-10-11 20:19:14




Chadha's The North Indian Food Corner
Sahakar Premier
Google
Our Story
Our journey began with a realization that food waste is a significant problem in India. According to a report by the United Nations, India is the world's second-largest food producer, yet it also has one of the highest rates of food waste. This waste has a significant impact on the environment, as well as on food security in the country.
Our Team
Tungekar Mohammed Kaif
Student
Vinayak Vishwakarma
Student
Ankit Yadav
Student
Tejas Yadav
Student


AnnaMrita
Home
About
Contact
Profile
Donate
Sensor data
Prediction
CONTACT US
contact us
Name:
Email:
Message:
Send



2. **User Roles and Functionalities**
    - **Informers (Food Outlets)**: These users, primarily food donors, can log in to provide details about available food and monitor spoilage status in real time. The application helps food outlets manage donations by notifying them if food conditions are nearing spoilage, promoting timely distribution.
    - **Responders (NGOs and Volunteers)**: Responders receive alerts regarding food availability and can view data on food freshness, allowing them to prioritize collection efforts. This role's main functionality is centered around receiving notifications and acting on donation opportunities, creating an efficient response mechanism.

AI-Powered Route Optimization:

- The system integrates a **route planner** that calculates the **fastest and most efficient path** for food pickup and delivery.
- It provides **estimated travel times** for different transportation modes (bike, car, public transport) to **help NGOs optimize their collection efforts**.
- This feature **reduces transit delays**, ensuring food reaches its destination in a safe and timely manner.

3. **Backend and Data Management**
    - **Server and Database**: A XAMPP server hosts the backend, where sensor data is stored in a MySQL database managed by PHP scripts. Data from the ESP32 microcontroller is stored and classified using machine learning models for spoilage prediction.
    - **Integration of Machine Learning**: SVM and Random Forest models process sensor data to classify it as "fresh" or "spoiled," based on learned patterns. Classification results are saved in the database and visualized on the dashboard, aiding users in making timely decisions.
    - **Data History**: The application stores historical data, allowing both Informers and Responders to analyze spoilage trends. This feature also supports machine learning model retraining, further improving prediction accuracy over time

5. Experimental Setup and Results:

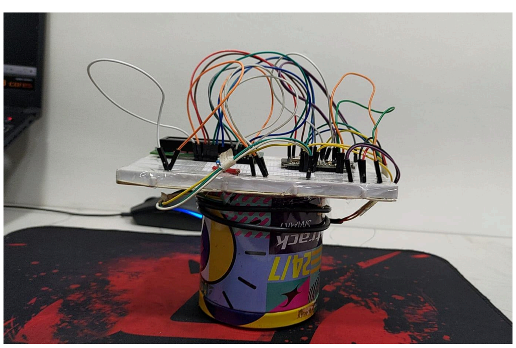
The experimental phase of *AnnaMrita* aimed to validate the effectiveness of the IoT-based system in monitoring food quality and accurately predicting spoilage. This involves setting up sensor configurations, calibrating machine learning models, and conducting real-time tests on various food items to observe spoilage patterns. The collected data provides insights into the system's reliability, enabling refinements and improvements for practical applications.

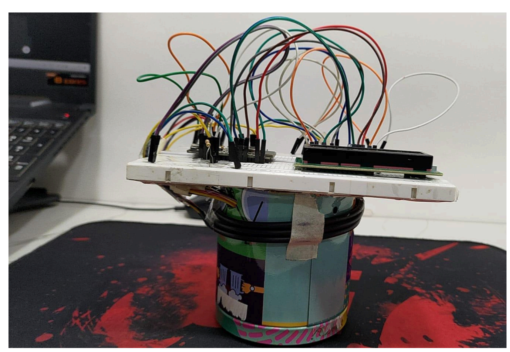
1. Experimental Setup

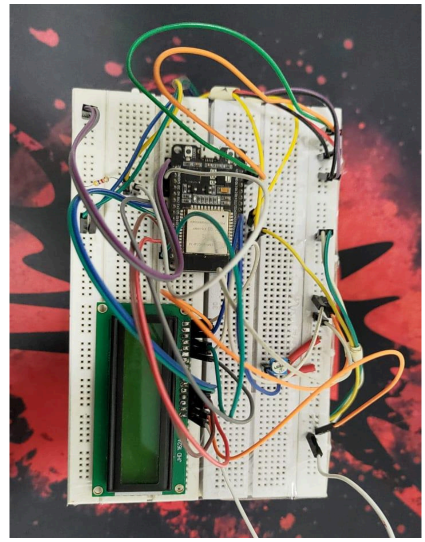
- ***Sensor Configuration***: The ESP32 microcontroller was connected to two key sensors: the MQ-135 sensor for monitoring VOC levels, particularly ammonia and other gases emitted during food decomposition, and a moisture sensor to assess environmental moisture levels around the food. Each sensor was calibrated based on data from fresh and spoiled food samples to establish baseline and threshold values for accurate classification.
- ***Data Collection***: The setup included an isolated testing environment where common perishable items, such as dairy products, fruits, and grains, were placed. Sensor data was recorded at regular intervals over several days, capturing VOC and moisture changes as spoilage progressed. This data was then sent to a local XAMPP server and stored in a MySQL database for processing and analysis.
- ***Machine Learning Model Calibration***: The SVM and Random Forest models were trained on a dataset comprising labeled instances of fresh and spoiled states based on sensor readings. The models were fine-tuned to classify data from the IoT sensors accurately. SVM, chosen for its binary classification capability, was particularly effective in drawing a boundary between fresh and spoiled states, while Random Forest added robustness by analyzing feature importance, making the system adaptable to variations in food spoilage behavior.

2. Results

The experimental setup yielded promising results, validating *AnnaMrita*'s ability to reliably detect food spoilage and alert users in a timely manner. Key findings from the testing phase are summarized below:







A. Sensor Data Collection and Visualization

To assess food spoilage in real-time, methane gas levels, humidity, and temperature were monitored overnight for different food items—Rice, Dal, and Samosa. The collected data was stored in a database and later visualized through graphs. The following subsections discuss the trends observed and their implications.

B. Analysis of Methane Gas Levels, Humidity, and Temperature

Figures **X, Y, and Z** present the variations in methane gas levels, humidity, and temperature for Rice, Dal, and Samosa, respectively.

1) Rice Dataset Analysis

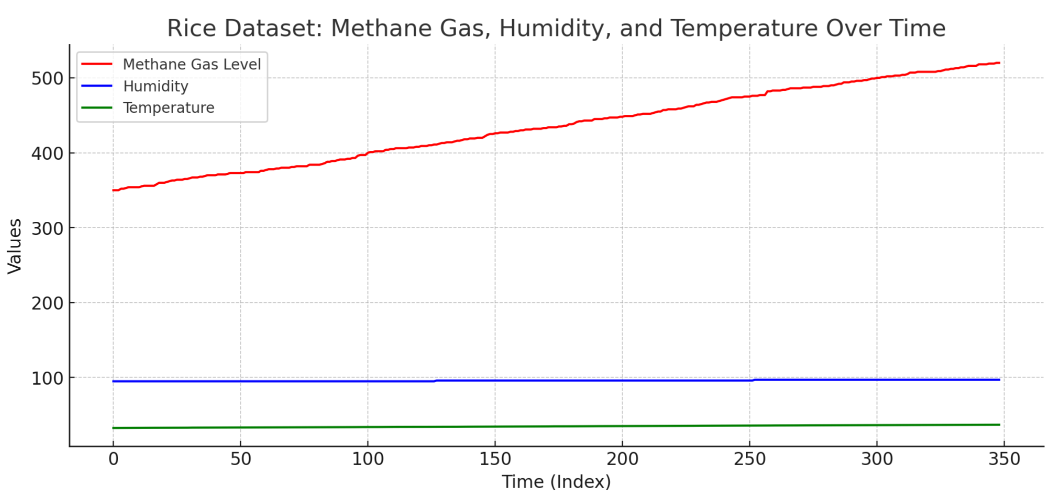


Figure 5.2.B.1 (X)

As depicted in **Figure X**, the methane gas levels (red) show a steady increase over time, indicating gradual spoilage. The humidity (blue) and temperature (green) remain relatively stable. This suggests that the primary contributor to spoilage is the buildup of methane due to bacterial activity rather than significant environmental fluctuations.

2) Dal Dataset Analysis

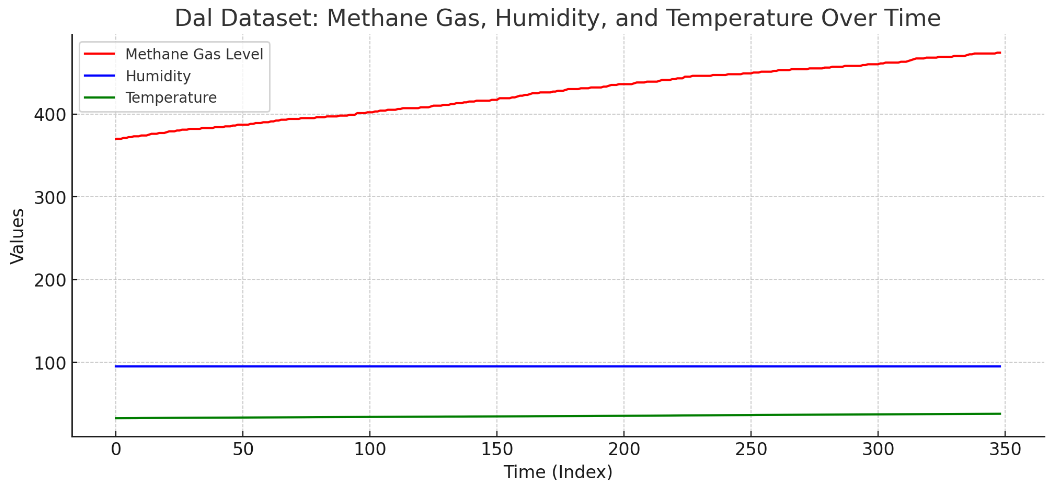


Figure 5.2.B.2 (Y)

Figure Y demonstrates a similar trend in methane gas accumulation for Dal. However, the humidity levels appear slightly higher than those observed in the Rice dataset, which may suggest increased moisture retention, potentially accelerating spoilage.

3) Samosa Dataset Analysis

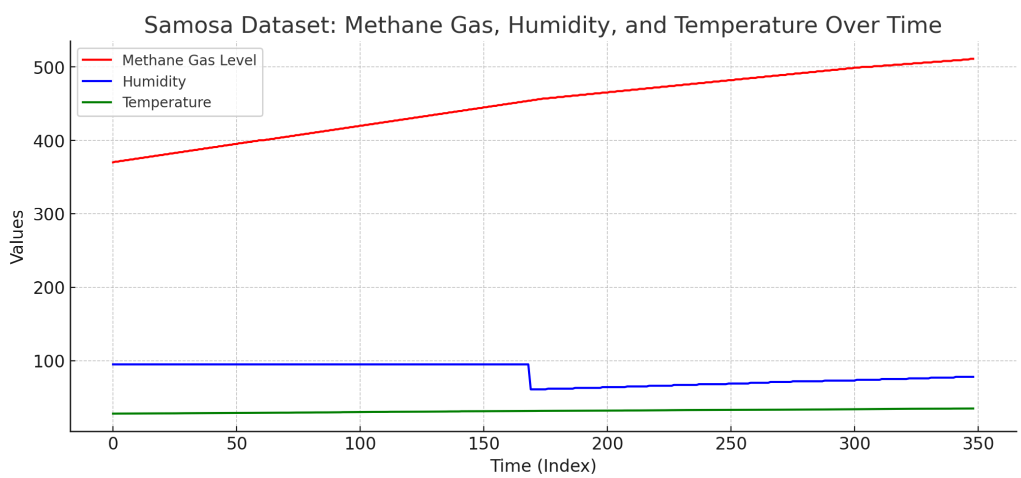


Figure 5.2.B.3 (Z)

In **Figure Z**, methane levels continue to rise, but an unusual fluctuation in humidity is observed around the midpoint of the time series. This sudden increase could be attributed to external environmental factors or condensation inside the storage container, influencing the spoilage rate.

C. Comparative Insights and Implications

The analysis indicates that methane gas levels are the most consistent indicator of spoilage progression across different food types. Humidity variations were more pronounced in fried food items like Samosa, potentially affecting preservation strategies. These findings can guide NGOs in optimizing food storage and transportation to minimize wastage.

- ***Accuracy of Classification***:
  - ***SVM Model***: Achieved a classification accuracy of approximately 92% in distinguishing fresh from spoiled states. The SVM model performed consistently in identifying spoilage based on VOC levels alone, which correlated well with early stages of decomposition.
  - ***Random Forest Model***: Demonstrated an accuracy of 95%, benefiting from its ensemble approach and the inclusion of moisture data. By ranking feature importance, Random Forest enabled the system to adapt classification criteria based on the food type and environmental conditions, enhancing the model's overall accuracy.
- ***Response Time***: The setup effectively monitored sensor readings in real time, updating the web dashboard with a delay of under 5 seconds. This rapid response allowed users to view real-time data and receive alerts promptly, critical for food that is nearing spoilage.
- ***Effectiveness of Alerts***: Alerts generated by the system were tested with Responders (NGOs and volunteers) under simulated conditions. The system successfully sent notifications when readings neared spoilage thresholds, facilitating timely response by alerting NGOs about food availability before spoilage occurred.

6. Use Cases:

1. ***Reducing Excess Food Waste***
   AnnaMrita enables food outlets, restaurants, and organizations to proactively manage and donate excess food items before they reach spoilage. By continuously monitoring food quality through VOC and moisture levels, the system alerts food handlers when food is nearing spoilage, allowing them to initiate donation processes. This proactive approach minimizes waste and promotes efficient use of excess food resources.
2. ***Food Quality Assurance***
   Ensuring food safety is crucial throughout the donation cycle, from the moment food is offered for donation to the point it reaches beneficiaries. *AnnaMrita* supports food quality assurance by continuously monitoring and classifying food status as "fresh" or "spoiled." This feature ensures that only safe, high-quality food is distributed, protecting recipients from potential health hazards and building trust in food donation efforts.
3. ***Data-Driven Decision Making***
   By utilizing real-time sensor data, *AnnaMrita* provides actionable insights for food donation organizations and handlers. The system's machine learning models predict spoilage patterns based on collected data, helping users make informed decisions about food handling, storage, and distribution timing. This data-driven approach optimizes the entire donation process by prioritizing food that requires immediate attention, ensuring timely action.
4. ***Real-time Food Safety Monitoring***

AnnaMrita empowers NGOs and volunteers with instant access to the status of donated food. Through the web application, Responders (NGOs and volunteers) can view real-time VOC and moisture readings and receive immediate alerts if food approaches spoilage thresholds. This functionality is crucial for maintaining food safety, especially in situations where timely redistribution is essential.

5. ***Smart Food Donation and Redistribution***
   The system streamlines food donation processes by connecting Informers (food outlets) with Responders (NGOs and volunteers) through a centralized web application. Informers are promptly notified of food nearing spoilage, and Responders receive alerts regarding food availability, enabling them to respond efficiently. This seamless communication improves engagement between food outlets and NGOs, making food redistribution faster and more reliable, and ultimately maximizing the impact of donated food.

7. Feasibility and Viability Analysis:

An operational and economic feasibility study indicates that AnnaMrita can be implemented effectively using cost-effective IoT components and open-source AI tools. Addressing operational challenges, such as technology integration and user training, will be essential. Strategies for overcoming these hurdles include continuous system testing, user education programs, and diversification of funding sources.

8. Potential Challenges and Risks:

- ***Technological Integration*****:** Ensuring reliable data transmission and AI prediction accuracy.
- ***Operational Resistance*****:** Educating stakeholders about the effective use of the technology.
- ***Funding and Scaling*****:** Acquiring necessary resources to expand the initiative.

9. Conclusion:

The *AnnaMrita* project presents a transformative approach to addressing the critical issue of food waste while enhancing food safety and security. By integrating IoT technology with advanced machine learning algorithms, *AnnaMrita* presents a novel IoT and AI-driven approach to minimizing food waste by integrating real-time spoilage detection, AI-powered classification, and smart logistics optimization for food donations. The project has demonstrated high accuracy in spoilage detection, facilitating timely alerts that empower NGOs and volunteers to respond efficiently. Through its innovative web application, *AnnaMrita* not only streamlines the food donation process but also fosters collaboration between food outlets and charitable organizations along with route planner which significantly improves food donation logistics, ensuring that surplus food reaches the needy before spoilage occurs. While challenges remain in terms of scalability, user adoption, the potential impact of *AnnaMrita* on reducing food waste and supporting vulnerable communities is significant. Future enhancements, including the integration of additional sensor technologies and mobile accessibility, promise to further strengthen the system's effectiveness. Ultimately, *AnnaMrita* serves as a crucial step toward building a more sustainable food ecosystem, promoting responsible consumption, and contributing to global efforts in combating food insecurity.

10. Future Work :

Looking ahead, the *AnnaMrita* project aims to enhance its capabilities and expand its impact through several key initiatives. One primary focus will be on improving sensor accuracy and reliability by exploring advanced sensor technologies and integrating additional sensors to monitor temperature and humidity levels, further refining spoilage predictions. Additionally, expanding the machine learning models to incorporate more diverse datasets will enhance the system's predictive analytics, allowing for more accurate classifications across various food types. The project will also explore mobile application development to improve accessibility for users in the field, ensuring that both Informers and Responders can access real-time data on their smartphones. Collaboration with local NGOs and food outlets will be pursued to facilitate broader adoption of the system and gather user feedback for continuous improvement. Finally, addressing scalability challenges is essential; thus, *AnnaMrita* will work on optimizing backend processes to manage larger datasets and a growing user base efficiently. Through these efforts, *AnnaMrita* seeks to not only minimize food waste but also foster a more sustainable and responsive food donation ecosystem.

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