Food Spoilage Detection & Expiration Tracking System

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Abstract: **Food spoilage and contamination pose serious risks to households and the food industry, leading to health hazards, financial losses, and increased waste. This project introduces a food spoilage and expiration tracking system that detects spoilage early and provides real-time alerts. Using IoT, machine learning, and computer vision, the system monitors food quality based on gas emissions, temperature, humidity, and visual indicators. It integrates MQ-135 and DHT11 sensors with an ESP-32 camera module to collect data, which is analysed using a YOLOv8 model for visual inspection. A user-friendly mobile and web application allows users to track freshness, receive alerts, and access recipe suggestions to minimise waste. Designed for seamless integration with smart home devices, this cost-effective and scalable solution enhances food safety. By leveraging advanced technology, the system aims to reduce food loss, improve consumer awareness, and promote sustainable food management.**

Index Terms: **IoT, machine learning, Computer Vision, Food Spoilage.**

I. INTRODUCTION

Food spoilage and contamination are major concerns that affect both individual households and the commercial food industry. Ineffective monitoring of food quality results in health risks, economic losses, and increased food waste. The demand for reliable food monitoring systems has grown significantly as people become more aware of food safety and the importance of proper storage conditions. Inadequate systems for detecting food spoilage often rely on manual inspection or single-sensor technologies, which are prone to inaccuracies and inefficiencies. In addition, traditional monitoring techniques do not consider multiple factors that contribute to spoilage, such as gas emissions, temperature, humidity, and visual indicators. Addressing these limitations requires a comprehensive and efficient approach that ensures accurate detection of food quality. This project aims to develop a food waste and expiration tracking system that integrates various sensors and machine learning techniques to provide real-time alerts on food freshness. By offering a user-friendly solution with enhanced monitoring capabilities, this system is intended to reduce food waste, improve food safety, and promote efficient food storage practices.

The primary goal is to improve food spoilage detection accuracy and efficiency. Existing systems are often limited by time-consuming, error-prone manual inspection or single-sensor methods and lack multi-parameter monitoring. The proposed system addresses these issues with gas, temperature, and humidity sensors, along with visual inspection and machine learning (YOLOv8), to provide timely alerts, enhance food safety, and improve storage management.

II. LITERATURE SURVEY

The field of food spoilage detection and prevention has seen significant advancements, with researchers exploring various methodologies. Saini et al. [1] reviewed emerging technologies for detecting food contaminants, highlighting innovations such as nanobiosensors, DNA biosensors, and smartphone-based biosensors for rapid and sensitive detection. Green et al. [2] developed an electronic nose system combined with neural networks to analyse food odours, demonstrating the potential of real-time odour monitoring for early spoilage detection in smart homes.

Shan et al. [3] provided a comprehensive review of on-site food safety detection methods, emphasising portable devices that enable rapid identification of pathogens and toxins, facilitating timely intervention. Hassoun et al. [4] introduced the concept of Food Processing 4.0, discussing how Industry 4.0 technologies enhance food quality. safety, and cost-efficiency while reducing waste through automation and intelligence.

Wei et al. [5] proposed an IoT-based framework for food traceability, utilising optimised classifiers to improve supply chain transparency and food quality monitoring from production to consumption. Anjaiah et al. [6] developed a food quality auditing and surveillance system leveraging IoT for continuous assessment of food safety parameters. Das and Mishra [7] reviewed advancements in sensor technologies, including fluorescence, colorimetric, biosensors, and electronic nose sensors, which enhance food safety assessment accuracy and speed.

These studies collectively highlight the significant role of IoT, machine learning, and sensor innovations in food safety and spoilage detection. However, integrating these technologies into a cohesive, real-time monitoring system remains a challenge. This project addresses this gap by combining IoT devices, machine learning models, and user-friendly applications to develop a comprehensive food spoilage and expiration tracking system, contributing to improved food safety and reduced waste.

III. SYSTEM ARCHITECTURE

The food spoilage detection and monitoring system is designed to ensure real-time food quality assessment by integrating IoT sensors, AI-based image analysis, and a user-friendly dashboard. The data acquisition module consists of an ESP32-CAM for capturing food images, an MQ135 gas sensor for detecting volatile organic compounds (VOCs) released during spoilage, and a DHT11 sensor for monitoring temperature and humidity levels. These components collect real-time data, which is transmitted to the backend via ESP32 WiFi.

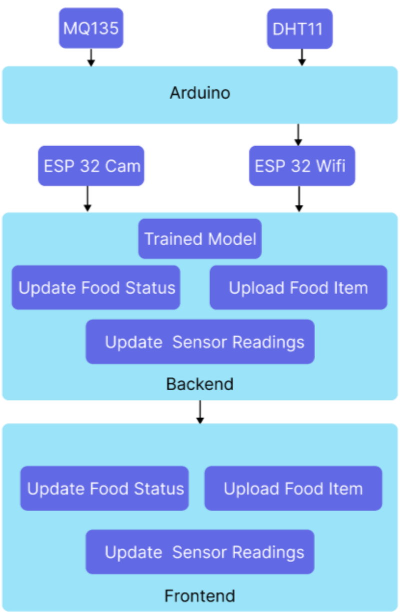

Fig. 1: System Architecture

The data processing module utilizes a YOLOv8 model to analyze food images for spoilage indicators such as discoloration and mold. Simultaneously, sensor data is processed to detect abnormal environmental conditions that could impact food freshness. The processed results are sent to the decision and alert module, which evaluates food quality by combining AI-based detection with sensor readings. If spoilage is detected, the system generates alerts and notifications through the web and mobile application.

The communication module facilitates seamless data transfer between hardware and software components, ensuring efficient backend processing. A database stores sensor readings, processed results, and food inventory records. The web and mobile dashboard module presents real-time food freshness updates through visual indicators such as fresh, caution, and spoilt. This scalable and cost-effective system provides an intelligent approach to monitoring food quality, reducing spoilage, and promoting sustainable food management.

IV. COMPONENTS DESCRIPTION

The different mechanisms used in this project are as given below:

1. ESP32-CAM
2. MQ135 Gas Sensor
3. DHT11 Temperature and Humidity Sensor
4. ESP32 WiFi Module
5. Arduino Uno
6. YOLOv8 Model for Image Processing
7. Flask (Backend)
8. Next.js (Frontend)
9. Firebase (Database)

1. ESP32-CAM

The ESP32-CAM module is a compact, low-power microcontroller with an integrated camera, which is utilized for capturing images of stored food items. These images are processed using a trained YOLOv8 model to detect spoilage indicators such as discoloration, mold, and texture changes. The module also supports WiFi communication, enabling seamless data transmission to the backend.

2. MQ135 Gas Sensor

The MQ135 gas sensor is employed to detect volatile organic compounds (VOCs) released during food spoilage. It measures the concentration of gases such as ammonia, carbon dioxide, and methane, which are key indicators of food degradation. The sensor provides real-time data that, when combined with image analysis, enhances the accuracy of food spoilage detection.

3. DHT11 Temperature and Humidity Sensor

The DHT11 sensor is used for monitoring environmental conditions such as temperature and humidity, which significantly influence food freshness. The data collected helps in predicting potential spoilage conditions and assists users in maintaining optimal storage environments for different food items.

4. ESP32 WiFi Module

The ESP32 microcontroller is responsible for data transmission between various system components. It collects sensor readings and image data from the ESP32-CAM and sends it to the backend over WiFi. Its low power consumption and wireless communication capabilities make it a suitable choice for IoT-based applications.

5. Arduino Uno

Arduino Uno serves as the primary microcontroller for this system, responsible for collecting sensor data from gas and environmental sensors. It processes and transmits data to the ESP32 module, ensuring seamless communication between hardware components. The Arduino Uno is chosen for its simplicity, compatibility with multiple sensors, and efficient power management.

6. YOLOv8 Model for Image Processing

A YOLOv8 deep learning model is implemented to analyze food images and detect spoilage characteristics. This model classifies food items based on visual features such as color changes, mold formation, and structural degradation. The AI-powered approach enhances real-time decision-making and improves spoilage detection accuracy.

7. Flask Backend

Flask is a lightweight Python web framework used to build web applications and APIs. Flask backend receives the image from ESP-32 cam and sensor reading from the Arduino Uno and processes it correspondingly. Flask also serves as an API that allows the Next.js frontend to fetch real-time information about food spoilage conditions. The frontend continuously requests updates from Flask, ensuring that users receive immediate alerts when spoilage is detected. By integrating these components, Flask plays a central role in enabling the seamless operation of your AI-powered food spoilage detection system.

8. Next.js

Next.js is used for developing the front-end of the web dashboard, providing users with an interactive and responsive interface. It allows real-time display of food freshness status, alerts, and historical data visualization, enhancing user experience and usability.

9. Firebase (Database)

Firebase is used as the database solution for real-time data storage and retrieval. It stores sensor readings, image analysis results, and user data, ensuring efficient synchronization between the backend and frontend. Firebase provides scalability, real-time updates, and secure data management, making it ideal for handling continuous monitoring and notifications in the system.
By integrating these components, the system provides an intelligent, real-time food spoilage detection solution that helps reduce food waste and ensures food safety.

V. METHODOLOGY

1. Data Acquisition:
A pre-existing dataset from Kaggle was used to train the YOLOv8s model. The dataset, sourced from Kaggle, provided the foundational image data necessary for training the object detection model. However, the data was initially unlabelled, necessitating subsequent processing to make it suitable for the intended machine learning task. This step underscores the importance of data collection in machine learning projects and the need to source data that, while relevant, may require further preparation.

2. Data Preprocessing:
The acquired dataset wasn't labelled and required manual annotations. Bounding boxes were drawn and

labelled to distinguish between fresh and rotten food items. Since the initial dataset lacked annotations, a crucial step involved manual annotation. This process entailed a person carefully examining each image in the dataset and drawing bounding boxes around the food items, labelling them as either "fresh" or "rotten." This labor-intensive process is essential for supervised learning, where the model learns to associate specific features within the image with the provided labels.

3. Data Processing:
Images received from the ESP32-cam need to be enhanced to achieve better accuracy. The YOLO model then processes the food item, and a corresponding message is generated. The images captured by the ESP32-cam undergo processing to improve their quality before being fed into the YOLOv8s model. This enhancement step is critical for ensuring the model can accurately detect spoilage in real-world scenarios. The YOLO model then analyzes the enhanced image to identify and classify the food item, and the system generates an appropriate message based on the model's output.

4. Monitoring System:
The system is designed such that the user is notified if either one of the conditions is true: if the model detects visible spoilage of the food item or if the sensors pick up a value below the threshold. The system also shows the current temperature and humidity. The system employs a dual-pronged approach to monitoring food spoilage. First, the YOLOv8s model analyzes images to detect visual signs of spoilage. Second, data from sensors (temperature, humidity, and gas) are evaluated against predefined thresholds. The user is alerted if either of these conditions is met, and the system also provides current temperature and humidity readings.

5. User Notification:
The frontend presents the analysis results to the user. Users receive warnings and recommendations to take appropriate actions. The results of the spoilage analysis from both the YOLOv8s model and the sensor are presented to the user through a frontend interface. This interface provides warnings when spoilage is detected and offers recommendations on what actions the user should take, such as discarding the food item or adjusting storage conditions.

VI. WORKING

The system acquires data from two primary sources: visual input and environmental sensors. For visual spoilage detection, images of food items—specifically bananas and apples—are captured using either a standard camera or an ESP32-cam, depending on the implementation. A pre-existing dataset from Kaggle provided the foundational image data necessary for training the YOLOv8s model. The captured images undergo processing to enhance their quality, ensuring that the YOLOv8s model can accurately detect spoilage in real-world scenarios. Trained to identify signs of spoilage such as discoloration and spots, the model analyzes the images to classify the food item, and the system generates an appropriate message based on the model's output.

Simultaneously, non-visual indicators of spoilage are monitored using an Arduino Uno microcontroller connected to a DHT11 temperature and humidity sensor and an MQ135 air quality sensor. The DHT11 sensor measures ambient temperature and humidity, while the MQ135 sensor detects volatile organic compounds (VOCs) such as ammonia and sulfides, which are indicative of microbial activity. The Arduino Uno reads data from these sensors at regular intervals, converts the raw readings into meaningful units, and transmits this data to a PC via serial communication. The system notifies the user if either the model detects visible spoilage or if the sensors pick up a value below the threshold. The web application presents the analysis results, displaying real-time sensor readings and the YOLOv8's image analysis results, including bounding boxes around detected food items and labels indicating whether the item is fresh or rotten. Users can also manually enter food items and their expiration dates, which are stored in a database.

VII. CONCLUSION

The proposed system represents a significant advancement in food spoilage detection and expiration tracking. By integrating multiple sensor technologies with machine learning and computer vision, the system provides a more accurate, efficient, and reliable solution than traditional methods.

The user-friendly interface, coupled with real-time alerts and smart home integration, enhances its practical applicability for both residential and commercial settings. The system’s ability to monitor a wide range of spoilage indicators, from gas emissions to visual changes, ensures comprehensive food quality management.

VIII. REFERENCE

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