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SMART FEAST ML-POWERED FOOD QUALITY DETECTION AND MANAGEMENT

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Abstract— Smart Feast is an innovative AI-powered food waste management system designed to monitor and reduce food waste in real-time. Utilizing a Raspberry Pi as the central processing unit, the system integrates a variety of sensors, including the DHT11 for temperature and humidity monitoring, the MQ3 for detecting bad odors, and the LDR for light condition assessment. The ADC module ensures accurate sensor data collection. In the event of abnormal conditions, the GSM module sends timely alerts, while a buzzer provides an immediate auditory warning. The system employs a Random Forest machine learning algorithm to analyze sensor data and make intelligent decisions regarding the status of food waste.

Keywords - Food Quality Detection, Machine Learning (ML), Artificial Intelligence (AI), IoT-enabled Sensors, Predictive Analytics, Food Safety Management, Real-time Monitoring.

I. INTRODUCTION

Food waste (FW) is one of the world's major crises in both developed and developing countries. Up to 1.3 billion tons of food across the globe is thrown away each year, accounting for one third of all food produced for human consumption and presenting tremendous social, economic, and environmental challenges [1]. Rapid urbanization, population growth, and economic development have increased waste generated worldwide in recent years. According to the latest statistics, 2.01 billion tonnes of municipal solid waste was generated globally in 2016. This figure is expected to increase to 3.4 billion tonnes by 2050 (Kaza et al. 2018). Unfortunately, 33% of solid waste is managed correctly and disposed of in illegal dumpsites or unmonitored landfills (Kaza et al. 2018). Improper waste disposal poses many environmental and health risks, such as groundwater contamination, land degradation, increased cancer incidence, child mortality, and congenital disabilities (Triassi et al. 2015). In the past, waste management practices were more rudimentary, with a small group of individuals collecting garbage from the streets and depositing it in designated areas (Brancoli et al. 2020). Once the trucks were full, the waste was left in these designated areas. However, with the advent of artificial intelligence, the waste management industry is experiencing significant transformation toward achieving sustainability and profitability [2]. The system uses advanced data analysis techniques combined with machine learning algorithms, specifically the Random Forest algorithm, which is widely known for its high accuracy and ability to handle complex datasets efficiently. By analyzing historical trends, current environmental conditions, and spoilage patterns, the algorithm can predict and identify optimal storage conditions for various types of food items, ensuring they remain fresh for a longer duration. This predictive capability allows Smart Feast to generate insights on whether food items should be consumed soon or if storage adjustments are needed to maintain their quality. Additionally, to ensure that users are alerted without any delays. This review article is based on a comprehensive analysis of the existing literature on food waste, the circular economy, and the use of AI in the food industry. The literature search includes academic and industry publications, reports, and other relevant sources. The findings of this literature review are organized into specific sections that cover the potential applications of AI for addressing food waste and circular economy challenges [3]. However, none of these approaches

combines both techniques within a single IoT device for real-time meat freshness and species classification. This study uniquely integrates camera-based image analysis and gas sensor readings, utilizing a dataset of approximately 9,928 images and multiple classification models to assess freshness and species. In addition, a comparative analysis was conducted between traditional machine learning models such as k-NN and SVM and deep learning models, including a custom CNN and ResNet-50 [4].

II. PROPOSED TECHNOLOGY

The proposed Smart Feast system presents a highly advanced and intelligent AI-powered solution aimed at tackling the critical issue of food waste management by leveraging a seamless combination of cutting-edge sensors, machine learning algorithms, and automated processes. Food waste has become an alarming global challenge, leading to not only financial losses but also severe environmental degradation, resource wastage, and increased greenhouse gas emissions. The Smart Feast system addresses these concerns by ensuring real-time monitoring and predictive decision-making, helping to minimize food spoilage and improve food storage efficiency. By integrating various high-precision sensors, such as DHT11, MQ3, and LDR, the system is capable of continuously tracking key environmental parameters that significantly influence the shelf-life of food items, ensuring that they remain in an ideal storage environment. These sensors play an essential role in detecting temperature variations, fluctuations in humidity levels, exposure to light, and the presence of odors or gases that indicate food degradation, all of which are crucial indicators of food spoilage the system's reliability under prolonged operation.

The DHT11 sensor monitors temperature and humidity levels, ensuring that perishable food items, such as dairy products, fruits, and vegetables, are kept in an optimal environment. Sudden temperature spikes or drops can accelerate the spoilage process, making it essential to have a continuous monitoring system that alerts users to take necessary action. Additionally, humidity levels play a crucial role in preserving food, as excess moisture can lead to mold growth and bacterial contamination, while low humidity levels can cause dehydration and loss of freshness. The MQ3 sensor specializes in detecting gases such as ethanol and other volatile organic compounds (VOCs) that signal food decomposition. The presence of these gases is often associated with microbial activity, indicating that food is beginning to spoil. By catching these signs early, Smart Feast helps users take action before the food becomes completely inedible, thereby reducing unnecessary waste. Furthermore, the LDR sensor ensures that food storage conditions are protected from excessive light exposure, which is particularly important for items like oils, dairy products, and certain packaged goods that degrade when subjected to high-intensity light over prolonged periods. To enhance the efficiency of food waste management, Smart Feast is powered by an advanced machine learning algorithm—Random Forest—which is renowned for its high accuracy and reliability in analyzing complex datasets. This algorithm processes vast amounts of sensor data, identifying patterns and trends in food spoilage while continuously improving its accuracy over time.

The self-learning capability of this machine learning model ensures that the system becomes more refined and efficient in identifying optimal storage conditions for various types of food, ultimately leading to better decision-making and significantly reducing food wastage. Smart Feast also integrates a real-time alert system to ensure that users receive instant notifications whenever unfavorable storage conditions are detected.

If any abnormal variations in temperature, humidity, or gas levels are observed, the system triggers immediate alerts through the GSM module, sending SMS notifications directly to users' mobile devices. This feature is particularly beneficial for commercial kitchens, supermarkets, and food storage warehouses where large quantities of perishable goods are stored, as it enables quick responses to prevent financial losses due to spoilage. In addition to mobile notifications, the system is also equipped with a buzzer system, which provides local audible alerts, ensuring that users present in the vicinity are immediately informed about potential food spoilage risks. The dual notification system ensures that no critical alert goes unnoticed, allowing timely interventions and reducing food waste effectively. With Smart Feast's automated approach, food waste is handled proactively rather than reactively, allowing food establishments to optimize their inventory usage, extend the shelf-life of perishable items, and improve overall operational efficiency. Moreover, by preventing food from being discarded unnecessarily, Smart Feast contributes to environmental sustainability by reducing landfill waste, lowering methane emissions, and promoting responsible food consumption practices. The system's ability to provide predictive analytics for better decision-making further enhances its practicality and usability. Rather than relying on estimations, users gain data-driven insights into how environmental factors are affecting their food storage, enabling them to adjust their storage conditions accordingly.

III. COMPONENTS

The Raspberry Pi -it is a small, affordable single-board computer developed by the Raspberry Pi Foundation, aimed at promoting computer science education.

Raspberry Pi models typically include a CPU, RAM, USB ports, HDMI output, and GPIO pins for hardware projects. They run various operating systems, with Raspbian (now called Raspberry Pi OS) being the most common.

The device can be used for a wide range of applications, from learning programming and building DIY projects to powering home automation systems and creating media centers. Its community support and extensive resources make it an ideal starting point for anyone interested in technology and programming.

Fig 1. Raspberry Pi

The MQ3 sensor – it is one of the most widely used in the MQ sensor series. It is a MOS (Metal Oxide Semiconductor) sensor. Metal oxide sensors are also known as Chemi resistors because sensing is based on the change in resistance of the sensing material when exposed to alcohol.

Fig 2. MQ3 sensor

Power supply - A step-down transformer converts the 230V AC into12v. The bridge rectifier is used to change AC to DC. A capacitor is used to filter the AC ripples and gives to the voltage regulator. Finally, voltage regulator regulates the voltage to 5V and finally, a blocking diode is used for taking the pulsating waveform.

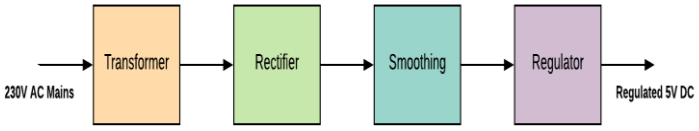

Fig 3. Power supply

GSM Module - SIM900A GSM Module is the smallest and cheapest module for GPRS/GSM communication. It is common with Arduino and microcontroller in most of embedded application. The module offers GPRS/GSM technology for communication with the uses of a mobile sim. It uses a 900 and 1800MHz frequency band and allows users to receive/send mobile calls and SMS. The keypad and display interface allows the developers to make the customize application with it. Furthermore, it also has modes, command mode and data mode. In every country the GPRS/GSM and different protocols/frequencies to operate. Command mode helps the developers to change the default setting according to their requirements.

Fig 4. GSM Module

The DHT11 is a basic, low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed). It's fairly simple to use, but requires careful timing to grab data. The only real downside of this sensor is you can only get new data from it once every 2 seconds.

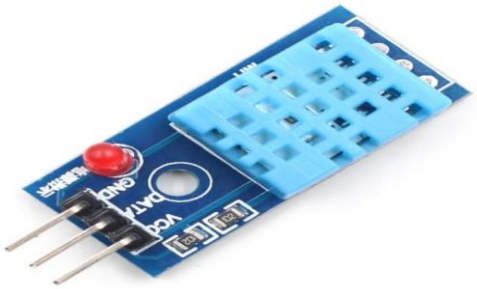

Fig 5. DHT11

LCD is Liquid Crystal Display - it is a passive device, which means that it does not deliver any light to display characters, animations, videos, etc. LCD uses fluorescent tubes to lighten the picture, but can't provide a clearer picture as LED delivers. It consists of millions of pixels made of crystal and arranged in a rectangular grid. In LCD it has backlights that provide light to each pixel. Each pixel has a red, green, and blue (RGB) sub-pixel that can be turned on or off. When all of the sub-pixels are turned off, then it's black and when all the sub-pixels are turned on 100%, then it's white.

Fig 6. LCD

A Light Dependent Resistor (also known as a photoresistor or LDR) is a device whose resistivity is a function of the incident electromagnetic radiation. Hence, they are light-sensitive devices. They are also called as photoconductors, photoconductive cells or simply photocells. They are made up of semiconductor materials that have high resistance. There are many different symbols used to indicate a photoresistor or LDR, one of the most commonly used symbols is shown in the figure below. The arrow indicates light falling on it.

Fig 7. Light Dependent Resistor

Buzzer The piezo, also known as the buzzer, is a component that is used for generating sound. It is a digital component that can be connected to digital outputs, and emits a tone when the output is HIGH. Alternatively, it can be connected to an analog pulse-width modulation output to generate various tones and effects.

Fig 8. Buzzer

IV. BLOCK DIAGRAM

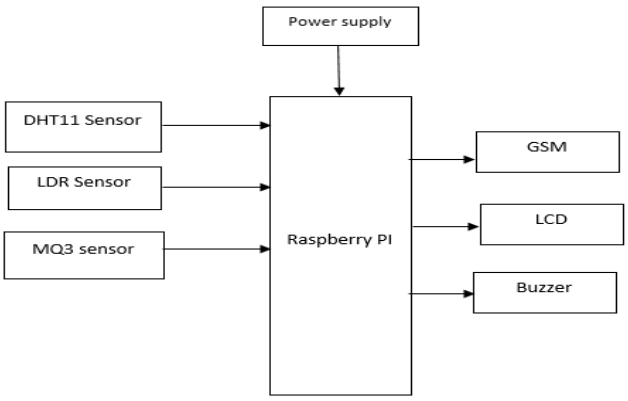

Fig 9. Block Diagram

V. Random Forest Algorithm in Machine Learning

Random Forest is a **supervised learning algorithm** used for both **classification and regression tasks**. It builds multiple decision trees and merges them to get a more accurate and stable prediction. A Random Forest is an **ensemble learning technique** that combines multiple **Decision Trees** to make predictions. It operates by constructing several decision trees during training and outputs the mode of the classes (classification) or the mean prediction (regression) of the individual trees.

Functions of Random Forest

Feature Selection: Identifies the most important features for prediction by observing which features contribute most to splitting nodes in decision trees. **Classification & Regression:** Can be used for predicting categorical outputs (classification) and continuous outputs (regression). **Handling Missing Values:** Random Forest can maintain accuracy even if a large proportion of the data is missing. **Outlier Detection:** It can be used to detect anomalies by analyzing the model's prediction errors. **Overfitting Prevention:** The averaging of multiple decision trees helps to reduce the risk of overfitting.

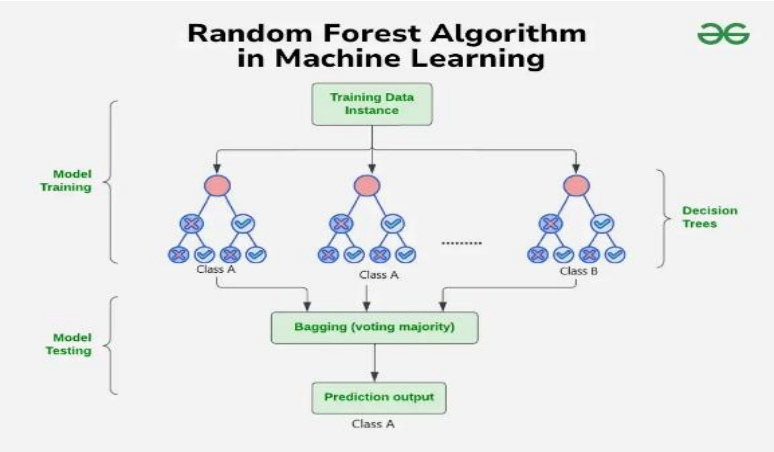

Fig 10. Random Forest Algorithm

Process of Random Forest Algorithm

Data Preparation:

- Gather and preprocess the dataset (handling missing values, encoding categorical data, feature scaling, etc.).

Bootstrap Sampling (Bagging):

- Randomly select subsets of data (with replacement) from the original dataset to create several datasets.
- Each dataset is used to train an individual decision tree.

Building Decision Trees:

- For each subset, build a decision tree using a random subset of features.
- Unlike normal decision trees, not all features are considered for splitting at each node (a random subset is selected).

Prediction:

- The final prediction is determined based on aggregation results (majority voting or averaging).

Evaluation:

- Measure performance using metrics like Accuracy, Precision, Recall, F1-score (for classification), or Mean Squared Error, R^2 score (for regression).

VI. FLOWCHART

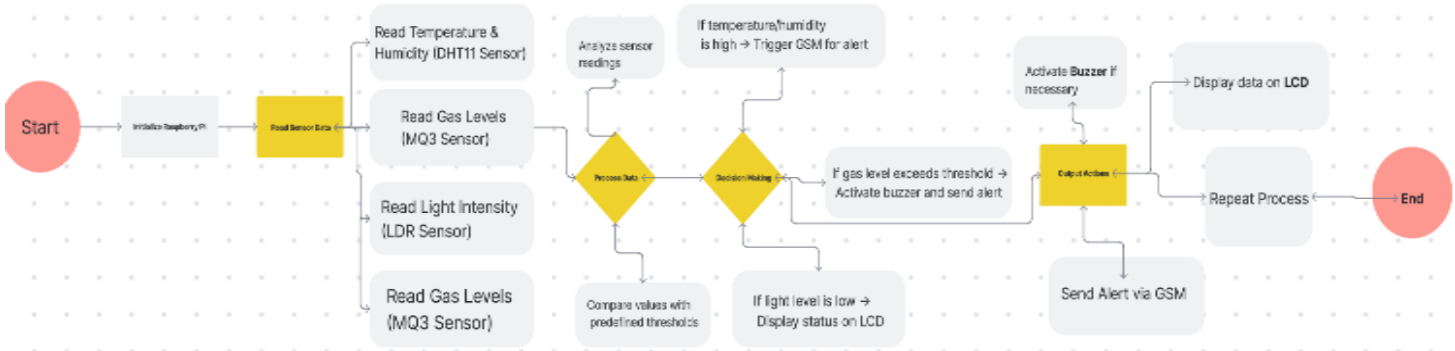

Fig 11. Flowchart

VII. FUTURE USE

Advanced Analytics and Data Integration

With the growing availability of data and the increasing sophistication of analytics tools, we can expect to see more advanced AI algorithms that can process and analyze large volumes of data from various sources, providing more accurate and comprehensive insights into food waste generation and prevention.

Integration with Other Technologies

AI food waste management technologies can be integrated with other technologies such as blockchain and IoT to enable more seamless and efficient tracking of food waste throughout the supply chain. This can enhance transparency and traceability while also improving waste reduction strategies.

Increased Use of Robotics

Robotics technology can be used to automate certain processes such as food sorting, reducing the need for human intervention and improving efficiency. AI algorithms can be used to optimize these processes, improving overall performance.

Expansion of Food Waste Reduction Programs

As public awareness of food waste continues to grow, we can expect to see an expansion of food waste reduction programs at the local, national, and international levels. AI-based technologies can play a key role in supporting these initiatives, providing data-driven insights into food waste generation and prevention.

Increased Collaboration and Partnerships

Collaboration and partnerships between businesses, organizations, and governments can help drive the development and adoption of AI food waste management technologies. These collaborations can enable the sharing of data, resources, and expertise, resulting in more effective and sustainable solutions. As AI food waste management technologies continue to evolve and improve, we can expect to see significant advancements in the way we manage food waste. With the potential to improve efficiency, reduce costs, and promote sustainability, these technologies will play a critical role in creating a more sustainable and resilient food system.

VIII. DISCUSSION

Food quality detection and management is a crucial aspect of ensuring public health and reducing food wastage. Traditional methods of quality assessment rely heavily on manual inspections, chemical tests, and sensory evaluation, which are often time-consuming, costly, and prone to human errors. With advancements in artificial intelligence and machine learning (ML), automated food quality detection systems have emerged as a reliable alternative. Smart Feast is an ML-powered system designed to enhance food quality monitoring and management through real-time data analysis, predictive modelling, and automated decision-

making. By leveraging image processing techniques, the system can detect spoilage patterns in food products, analyze texture variations, and identify potential contaminants. One of the primary advantages of Smart Feast is its ability to provide continuous monitoring and instant feedback. IoT-enabled sensors collect real-time data, which is transmitted to cloud-based ML models for analysis. The system can detect deviations from ideal storage conditions and alert users through mobile applications or automated notifications.

The ML algorithms utilized in Smart Feast include convolutional neural networks (CNNs) for image classification, support vector machines (SVMs) for quality grading, and recurrent neural networks (RNNs) for predictive analysis. Another essential feature of Smart Feast is its application in supply chain management. By integrating blockchain technology, the system ensures traceability and transparency in food distribution. Each food item is assigned a digital identity, and its quality status is recorded at every stage of the supply chain. This prevents fraudulent practices, enhances consumer trust, and ensures compliance with regulatory standards. By combining ML, IoT, and blockchain technologies, it offers a scalable and efficient solution to minimize food wastage, enhance safety, and optimize storage conditions. Future developments may include integrating AI-powered robotics for automated quality inspections and expanding the system's capabilities to detect emerging contaminants.

IX. CONCLUSION

The Smart Feast system represents a paradigm shift in food quality detection and management, leveraging ML-driven automation to enhance food safety, reduce wastage, and optimize storage conditions. The ability to integrate IoT sensors, real-time monitoring, and predictive analytics makes Smart Feast an invaluable tool for multiple industries. By ensuring a proactive approach to food quality assessment, businesses and regulatory bodies can minimize contamination risks, ensure compliance with safety standards, and optimize inventory management.

A major advantage of Smart Feast is its ability to adapt and evolve. The use of deep learning and reinforcement learning models allows the system to continuously refine its predictive capabilities. As new threats to food quality emerge, such as novel bacterial strains or chemical contaminants, the system can be updated with new training data to maintain accuracy and reliability. Additionally, the integration of blockchain technology enhances traceability, ensuring that every stakeholder in the supply chain has access to transparent and tamper-proof food quality records.

The scalability of Smart Feast also makes it ideal for future advancements. Emerging technologies such as edge computing and 5G connectivity can further enhance its capabilities by enabling faster data processing and reducing reliance on cloud computing. AI-powered robotics can be incorporated into the system for automated inspections in food processing plants, ensuring even greater efficiency in quality control. Additionally, wearable technology could be integrated to provide real-time feedback to food handlers, ensuring adherence to hygiene standards and reducing contamination risks.

In conclusion, Smart Feast is a game-changing innovation that combines machine learning, IoT, and blockchain technology to revolutionize food quality detection and management. By providing accurate, real-time assessments and predictive analytics, it empowers businesses, regulatory bodies, and consumers to make informed decisions about food safety. As technology continues to evolve, Smart Feast has the potential to expand its capabilities, ensuring a smarter, safer, and more sustainable global food supply chain.

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