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Food Fresh Vision – AI-Powered Freshness Checker

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Abstract:
Food spoilage is a big problem in the world today, which leads to economic, health-related, and food waste problems. The traditional way to identify the freshness of food products was through the use of human senses, which was not efficient. This paper proposes a system to identify the freshness of food products through the use of Artificial Intelligence, Computer Vision, and IoT technologies. The system is referred to as "Food Fresh Vision." The system uses a Convolutional Neural Network to identify the freshness of the food product as either fresh or spoiled. For the case of liquid food products, the system uses pH sensors and gas sensors known as MQ-135 sensors. sensors then send its readings to a web application through the use of the ESP32 microcontroller. The proposed system can be able to identify the freshness of the food product with an accuracy rate of 92%.

Index Terms— *Food Freshness Detection, Computer Vision, Convolutional Neural Network (CNN), Internet of Things (IoT), ESP32, pH Sensor, MQ-135 Gas Sensor, Deep Learning, Smart Food Monitoring.*

I. Introduction

Food safety and quality monitoring have become a crucial aspect that needs to be considered in the modern world because of the increasing rate of food spoilage and waste. It is estimated that a significant percentage of the food produced is being wasted every year because of the inability to monitor the spoilage of the food at the correct time. Spoiled food may lead to health hazards like food poisoning and infection.

In the conventional method of food freshness detection, the food freshness is detected using the human senses like smell, touch, and vision. However, the usage of the human senses is quite inaccurate because the food may seem to be fresh from the outside, but it may be spoiled from the inside.

In the case of liquid food products like milk and juice, the spoilage is invisible and needs to be analysed using chemicals, which is done in the laboratory.

In the modern world, the use of Artificial Intelligence (AI) and Internet of Things (IoT) technologies is becoming popular as tools to help solve problems in the world. For instance, the use of computer vision technique of Artificial Intelligence can be applied to analyze the image of the food item and determine the pattern of spoilage, while the use of IoT technique can be applied to analyze the chemical composition of the food item using pH sensors and gas sensors to determine the spoilage of the food item. However, the use of the above approaches is usually limited to the use of either the computer vision technique or the IoT technique.

In order to overcome the challenges, the authors propose the use of a hybrid system to monitor the freshness of the food item, which is referred to as the "Food Fresh Vision."

The system uses the computer vision technique to analyze the image of the food item such as fruits and vegetables, while the use of the IoT technique is applied to analyze the chemical composition of the food item such as milk and juice using pH sensors and gas sensors to determine the spoilage of the food item. The system uses the ESP32 microcontroller to process the data from the sensors to the web-based system.

II. LITERATURE SURVEY

In addition to the above-mentioned techniques, Artificial Intelligence (AI), image processing techniques, and Internet of Things (IoT) technologies are also included in recent research works on food freshness detection technology. Generally, in practical implementation, the freshness of food items is checked by manually inspecting them. However, while checking the freshness of food items manually, errors are possible. To avoid errors, many recent research works on food freshness detection technology have included Convolutional Neural Network (CNN) techniques to classify fruits and vegetables as fresh or spoiled based on the features of the images of food items. Regarding the implementation of Convolutional NeuralNetwork (CNN) techniques, many recent research works on food freshness detection technology have shown high accuracy and efficiency while implementing the MobileNet model and ResNet model.

In addition to the above-mentioned image processing techniques, Internet of Things (IoT) technologies are also included in recent research works on food freshness detection technology by implementing pH sensors and gas sensors to check the changes in the chemistry of food items. Regarding the implementation of Internet of Things (IoT) technologies, many recent research works on food freshness detection technology have shown that the MQ series of gas sensors can be implemented to check the presence of gases such as ammonia, methane, and ethanol, as these gases are strong indicators of spoiled food items. In addition to the above-mentioned gas sensors, pH sensors can also be implemented to check the changes in pH levels in liquid food items such as milk and juice.

In addition to the above-mentioned techniques, recent research works on food freshness detection technology have also included a system that combines image processing techniques and Internet of Things (IoT) technologies to check the freshness of food items more accurately. Regarding the implementation of the proposed system, many recent research works on food freshness detection technology have shown that the proposed system, which combines image processing techniques and Internet of Things (IoT) technologies, will give higher accuracy compared to other techniques. However, many recent research works on food freshness detection technology still face problems in terms of cost-effectiveness and user-friendly interfaces. Thus, a cost-effective and portable system can be implemented using the proposed system to check the freshness of both solid food items as well as liquid food items.

III. PROPOSED SYSTEM

The proposed system, named "Food Fresh Vision," is an intelligent hybrid framework that utilizes the combined power of Artificial Intelligence (AI) and Internet of Things (IoT) technologies to carry out the task of detecting the freshness of food items, whether they be in a liquid or a solid state. The proposed system aims to deliver a comprehensive and reliable evaluation by overcoming the limitations of traditional single-method approaches.

In the case of solid food items, the proposed system utilizes a Convolutional Neural Network (CNN) model for the classification task. The images of the food items are captured by the proposed camera module, and the images are then subjected to a preprocessing task that includes resizing, normalization, noise reduction, and background adjustment.

These steps ensure the uniformity of the input images and therobustness of the proposed model. The proposed model extracts high-level features, such as the distribution of colors, texture, deformation, and the appearance of decay patterns, to identify the spoilage characteristics, such as discoloration, bruising, and fungal growth.

The deep learning model is trained on a labeled dataset containing fresh as well as spoiled food samples. This allows the model to learn the patterns of differentiation effectively. Lightweight architectures like the MobileNetV2 can be used for efficient computation on embedded systems. The CNN model provides a probability score indicating the likelihood of the food being fresh or spoiled.

In the case of liquid food items, the proposed system includes sensor-based analysis using a pH sensor and an MQ-135 gas sensor. The pH sensor measures the level of acidity or alkalinity of the sample.

During spoilage, the level of acidity increases due to the action of microorganisms. Similarly, the MQ-135 gas sensor detects the gases produced during spoilage, like ammonia, ethanol, and carbon dioxide. These gases are produced during the decomposition of the food items. These sensor readings provide the internal quality of the food items, which cannot be obtained through image analysis.

The ESP32 microcontroller acts as the core of the proposed system. It interfaces with the camera module as well as the sensor module. It processes the data obtained from the sensor module. Due to the Wi-Fi and Bluetooth capabilities of the ESP32 microcontroller, it is possible to transmit the data obtained from the sensor module to a cloud server.

For the purpose of increasing the accuracy of the decisions made, the proposed system incorporates a data fusion method. This method combines the results obtained from the CNN model and the sensors. Instead of using a single source for the purpose of data input, the proposed system uses multiple parameters for the purpose of evaluation. This helps in reducing the false predictions made by the proposed system.

The proposed system can be mathematically represented as follows:

$$F = f(I, S_p, Sg)$$

where F represents the freshness score, I represents the image used for the purpose of input, S_p represents the pH sensor data, and Sg represents the gas sensor data. The proposed system uses a threshold mechanism for the purpose of decision-making. The food item is classified as Fresh or Spoiled using the proposed system.

The results obtained from the proposed system are presented on a web-based dashboard. The proposed system displays real-time data, which includes the results obtained from the proposed system. The proposed system is scalable, cost-effective, and portable.

Therefore, the proposed system can be used for a wide range of applications. The proposed system combines AI and IoT.

Therefore, the proposed system provides a smart solution for the purpose of food quality monitoring. The proposed system has the potential to reduce food wastage. The proposed system improves the food safety standards.

IV. METHODOLOGY

The proposed Food Fresh Vision system utilizes a structured framework for the assessment of the freshness of food items based on computer vision, sensor-based analysis, and IoT communication. The proposed system is capable of evaluating the freshness of both liquid and solid food items based on image processing, feature extraction, sensor data, classification, and data visualization, thus ensuring the accuracy and efficiency of the proposed approach for the assessment of the freshness of food items.

1. *Image Acquisition*

The images of the solid edible items, which are mainly fruits and vegetables, are acquired through a camera module or a mobile device. The images are then transmitted to a processing unit for analysis. To improve accuracy, images can be acquired under different illumination conditions. The input can be represented as:

$I = \{Img\}$, where Img represents the acquired images.

2. *Image Preprocessing*

The acquired images are preprocessed to improve their quality, making them suitable for feature extraction. The images acquired through the camera device or mobile device might be noisy, and there might be disturbances in the background. The preprocessing includes resizing the images, normalization, removal of noise through filters, and background segmentation.

3. *Feature Extraction*

In this process, significant features such as color, texture, and pattern are extracted using a Convolutional Neural Network. These features will be helpful in detecting spoilage characteristics, which include color, texture, and pattern changes. The extracted features can be represented as:

$V = \{C, T\}$, where C represents color, and T represents texture features.

4. *Classification*

These features are then fed into the trained deep learning model to obtain the classification results. A CNN-based model such as MobileNetV2 is utilized to classify the food item as fresh or spoiled. The classification function can be represented as:

$$F_1 = f(I)$$

5. *Sensor Data Acquisition*

For the case of liquid food items such as milk or juice, sensor-based analysis is performed. A pH sensor is utilized to measure the acidity level of the food item, while an MQ-135 gas sensor is used to measure the gases such as ammonia, ethanol, and carbon dioxide released due to spoilage. The sensor data can be represented as:

$$S = \{S_p, Sg\}$$

6. *Sensor Data Processing*

The sensor data is then processed to obtain the results using predefined thresholds to classify the food item as fresh or spoiled. The sensor-based output can be represented as:

$$F_2 = g(S_p, Sg)$$

7. *Data Fusion and Final Decision*

Finally, the results from the image-based output F_1 and sensor-based output F_2 can be fused to obtain the final output F as fresh or spoiled using the data fusion technique as follows:

$$F = w_1 \cdot F_1 + w_2 \cdot F_2$$

where w_1 and w_2 are the weighting

factors.

8. *Data Transmission and Visualization*

All the data obtained from the proposed approach is transmitted to the dashboard via the ESP32 microcontroller, and the data is transmitted via Wi-Fi or Bluetooth.

IV SYSTEM ARCHITECTURE

The architecture of the proposed Food Fresh Vision system defines the integration of hardware, communication, and AI processing techniques for real-time detection of food freshness. The architecture integrates image acquisition, sensor data acquisition, cloud computing, and visualization in a single framework.

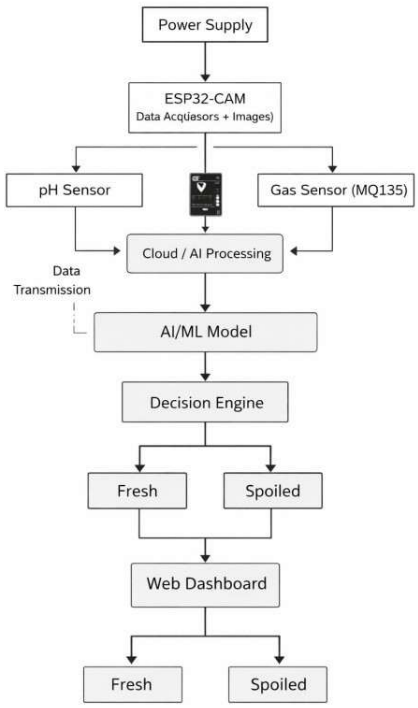

Fig 1: System Architecture

1. ***Image Acquisition Layer***

The role of this layer is to obtain images of solid food items, such as fruits and vegetables, through a camera module, which can be ESP32-CAM or a mobile camera. The images, which are obtained with high resolution, are then passed to the processing unit for analysis. The images obtained through this layer provide a reliable source of information regarding the condition of the food items under analysis, irrespective of the environmental conditions.

2. ***Sensor Acquisition Layer***

The role of this layer is to collect information from the sensors that are used for the analysis of liquid food items. The pH sensor measures the acidity level, whereas the gas sensor, which is an MQ-135 gas sensor, measures the amount of gas, which includes ammonia, carbon dioxide, and ethanol, released from the food items.

3. ***Preprocessing Layer***

The images obtained from the image acquisition layer and the information obtained from the sensors are passed through this layer, which performs preprocessing. The preprocessing of images includes resizing, normalization, removal of noise, and enhancement. The preprocessing of the information obtained from the sensors includes filtering and calibration, which remove the noise from the information obtained from the sensors.

4. ***Feature Extraction Layer***

In this layer, the salient features are obtained from the images and the sensors. The CNN model extracts the features from the images, which include color, texture, and decay, whereas the sensors provide the chemical features.

5. ***Classification Layer***

In this layer, a pre-trained deep learning model is used to analyze the extracted features. For image classification, a CNN model (MobileNetV2) is used, while thresholds are used in the analysis of the sensors. The model will produce a result indicating whether the food is fresh or spoiled, as well as the level of spoilage.

6. *Data Fusion Layer*

In this layer, the results obtained from the analysis of images as well as the analysis of the sensors are fused together. This allows the model to be more accurate compared to using single approaches.

7. *Communication Layer*

In this layer, the ESP32 module is used as a transmitter of the processed data via Wi-Fi or Bluetooth connectivity, allowing the results to be monitored remotely via the cloud server or web portal.

8. *User Interface Layer*

In this layer, the results obtained from the model are presented via a web portal, showing the freshness of the food as well as the results obtained from the analysis of the images and the sensors.

9. *Optional Cloud Integration Layer*

For the large-scale usage of the model, integration with cloud services can be used to store the data and update the model remotely. This model can be used to update the model continuously.

V. RESULTS AND DISCUSSION

The proposed system of Food Fresh Vision was assessed using a dataset containing images of fruits and vegetables, as well as sensor readings from liquid food samples like milk and juice. Freshness evaluation was carried out through image classification and sensor-based evaluation, with the fusion of the two for better accuracy.

In the image classification method, a Convolutional Neural Network (CNN) model was used, which was trained on a corpus of about 1,200 images containing fresh and spoiled versions of fruits and vegetables. High accuracy was obtained in the detection of spoilage through the appearance of discoloration and texture changes. In the context of liquid food items, the pH sensor and the MQ-135 gas sensor were used to detect the chemical changes and gas emissions that occur during spoilage.

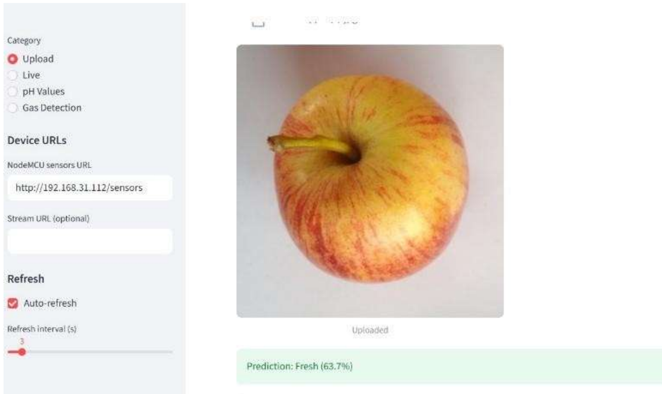

Fig 2: Fresh food classification result (Apple – Fresh, 63.7%)

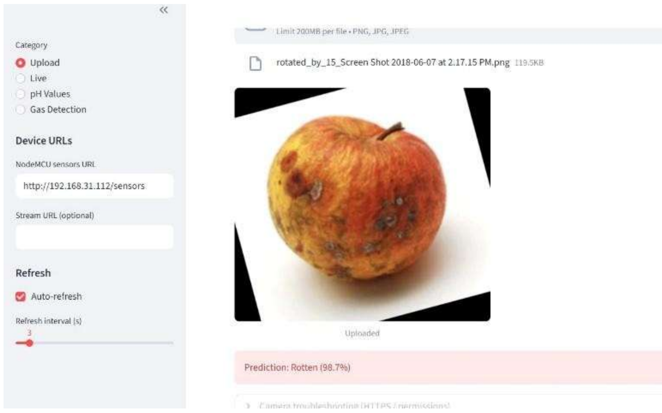

Fig 3: Spoiled food classification result (Apple – Rotten, 98.7%)

The performance of the system can be represented in Table I.

Table I
Performance Evaluation of the Proposed System

Model/System	***Accuracy***	***Precision***	***Recall***	***F1-Score***
CNN Model	92.3%	0.93	0.92	0.92
Sensor-Based System	90.1%	0.89	0.91	0.90
Hybrid System	95.1%	0.95	0.95	0.95

From the results shown in Table I, it can be concluded that the proposed system performs better compared to other approaches by incorporating both visual and chemical techniques. The proposed Convolutional Neural Network (CNN) model performs well in recognizing external spoilage. At the same time, the sensor system performs well in recognizing internal and chemical changes.

The proposed system was tested in real-time conditions and was able to classify food items and provide results through a web dashboard. The system response time was also less than 5 seconds. However, system performance may vary depending on lighting conditions and image quality. Improvement can be done by increasing the data set and improving sensor accuracy.

VI CONCLUSION

In this article, a novel intelligent and integrated system, namely Food Fresh Vision, for the detection of food freshness in real-time using Artificial Intelligence and Internet of Things technologies is proposed. The proposed system combines computer vision techniques with sensor-based analysis, which can be applied to both solid and liquid food items.

The Convolutional Neural Network model is applied to classify fruits and vegetables according to their attributes, whereas pH and MQ-135 gas sensors can be applied to identify chemical changes and gas emissions in liquid food items. The experimental results show that the proposed approach can achieve significant improvements in accuracy and reliability for detecting food freshness.

The inclusion of an ESP32 microcontroller enables the system to perform real-time data acquisition and communication, whereas a web-based interface can be applied for a more efficient interface.

The proposed system is intended to be cost-effective, portable, and easy to deploy, thus ensuring its usability in different applications, such as residential, supermarkets, restaurants, and storage facilities. The proposed system has the potential to minimize wastage, ensure the quality and safety of food, and help users make informed decisions about the consumption of food products. It is evident that the proposed system is effective, but like all systems, the proposed system has some disadvantages, such as the quality of images, lighting, and calibration. The proposed system may be improved by the use of large and diverse datasets, the use of deep learning, and the integration of sensors. Moreover, the proposed system may be improved by the integration of cloud computing for better efficiency. In conclusion, the proposed system for monitoring the freshness of food products is a smart, efficient, and effective solution to the development of intelligent food quality management systems.

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