**Problem Statement**

Traditional freshness detection is manual, subjective, and unfit for large-scale supply chains. Automated systems are needed to classify freshness, estimate shelf life, and provide nutritional insights to cut food waste and guide better dietary choices. **ABSTRACT**

In perishable conditions, fruits present deterioration and quality loss caused by microbial actions, enzymatic deterioration, or sometimes even adverse environmental conditions affecting their nutritional values, ultimately leading to wholesale wastage. Conventional methods for assessing freshness are subjective and inconsistent and are even awkward to implement on a larger scale. To tackle such problems, we propose an AI system for the automatic classification of fruit freshness using image data. The model specifies three stages of fruit freshness: fresh, semi-rotten, and rotten, thereby giving a more in-depth consideration than binary methods. Using two deep-learning architectures, EfficientNet and MobileNet that are compact and very efficient, classification is accomplished with real-time and accurate consideration. The system also includes nutritional analysis where the established fruit categories are linked to the USDA FoodData Central Database to retrieve nutrient content information: macronutrients, micronutrients, and calories, along with simulating nutrient degradation across freshness stages. To make it further useful and accessible, this system is implemented as a mobile application.

**Index Terms**— Mobile Application, Deep Learning, EfficientNet, MobileNet, Image Classification.

**INTRODUCTION**

Essential for a healthy diet, fruits provide nutrients, vitamins, and minerals. Yet, each has a strange tendency to perish very quickly after harvest due to microbial activity, enzymatic reactions, and unfavorable environmental conditions. Their defects formlessly reduce nutritional values and bring about inanities of food wastage. Traditional means to ensure freshness-the human eye-were subjective, inconsistent, and non-functional for huge capacity operations. Going by recent advancements in AI and deep learning, a relatively automated, reliable, and real-time freshness assessment procedure is now available. Under an image-based classification system, fruits can be classified into various stages of freshness levels, thus doing away with manual inspection. An AI-based system is therefore proposed in the study for fruit classification into three categories: fresh, semi-rotten, and rotten fronts of lightweight architectures-EfficientNet and MobileNet. The system also combines nutritional analysis; i.e., once a fruit is classified, it is linked to the USDA FoodData Central Database; then, it retrieves information on macronutrients, micronutrients, and calories while simulating nutrient degradation across freshness stages.

**Project Objectives & Plan**

1. To develop a multi-class classification model capable of identifying the freshness level of fruits and vegetables (Fresh, Semi-rotten, Rotten) along with their estimated shelf life (time span prediction).

2. To map food items with the USDA FoodData Central database and simulate nutrient degradation across fresh stages, providing calorie and nutrient insights.

3. To build a user-friendly application (web/mobile app) where users can upload images of fruits/vegetables and instantly get freshness classification, estimated shelf life, and nutritional analysis.

**LITERATURE SURVEY**

Fruit freshness detection has now become important in lowering postharvest wastage and preserving nutritional quality. Various deep learning and machine learning manipulations have been brought into this domain for automation. A multi-task CNN considerably improved the accuracy of detection in terms of fruit type and freshness as opposed to single-task models [1]. CNNs and transfer learning techniques also appeared to work well for freshness detection despite non-availability of sufficient dataset [2]. PCA, along with CNN features, was used to perform dimensionality reduction with the aim of efficient classification but at the cost of losing some critical information [3]. AI-based frameworks were also put into pretreatment of fruits and vegetables, facilitating sorting and processing automation [4]. Optimization schemes were proposed for drying systems concerning energy efficiency and nutrient retention [5]. Later works extended AI for preservation and postharvest monitoring [6], introduced explainable models like ForestSHAP [7], while also improving robustness in freshness classification through data augmentation [8]. Hybrid models have been detailed such as CNN–BiLSTM, which supersedes sequential feature extraction for better accuracy [9]. Object detection techniques like YOLO and SSD worked toward ripeness detection in real time [10], while SmartRipen used LST

### ****Methodology****

The proposed methodology begins with **dataset acquisition**, where a large collection of fruit and vegetable images — both fresh and rotten — is gathered from reliable sources such as Kaggle. The data is organized into labeled folders for supervised learning. Next, **data preprocessing** is applied, including resizing, normalization, and data augmentation (rotation, flipping, zooming) to enhance model robustness.

A **Convolutional Neural Network (CNN)** forms the backbone of the system. To achieve higher accuracy and reduce training time, **transfer learning** is employed using pre-trained models like **MobileNetV2** and **EfficientNetB0**, which are fine-tuned on the fruit and vegetable dataset. The model extracts deep spatial and color features and performs classification using a softmax layer.

The system is trained and validated using the augmented dataset to minimize overfitting. Post-training, performance metrics such as accuracy, precision, recall, and F1-score are computed to evaluate model performance. Finally, the trained model is integrated into a **mobile or web-based application** using TensorFlow Lite or Flask, allowing users to capture or upload an image and instantly get the freshness classification along with estimated nutritional information.

### **Existing and Proposed System**

In the existing system, the freshness of fruits and vegetables is generally determined through **manual visual inspection** or by using **traditional machine learning techniques** that rely on handcrafted features such as color, texture, and shape. These approaches are often inconsistent and subjective, as they depend heavily on human judgment or limited image descriptors. Moreover, traditional classifiers like Support Vector Machines (SVM) and K-Nearest Neighbors (KNN) struggle to maintain accuracy when faced with variations in lighting, background, or the natural diversity of fruits and vegetables. As a result, existing methods are often inefficient, less scalable, and unsuitable for real-time or large-scale applications.

The proposed system overcomes these limitations by introducing a **deep learning–based approach** using **Convolutional Neural Networks (CNNs)** and **transfer learning models** such as MobileNetV2 and EfficientNet. Instead of manually extracting features, CNNs automatically learn complex spatial and texture patterns that distinguish fresh items from rotten ones. The system performs multi-class classification, identifying not only the type of fruit or vegetable but also its freshness level. Additionally, data augmentation techniques are applied to improve model generalization under different lighting and background conditions. This deep learning-driven approach achieves higher accuracy, robustness, and automation, making it a reliable and scalable solution for real-world freshness detection and quality assessment.

### ****Models Used****

To achieve efficient and accurate classification, two state-of-the-art **transfer learning models** — **MobileNetV2** and **EfficientNetB0** — were utilized. **MobileNetV2** is a lightweight CNN architecture optimized for mobile and embedded devices. It uses depthwise separable convolutions and inverted residuals to deliver high accuracy with minimal computational cost, making it suitable for real-time freshness detection. **EfficientNetB0**, on the other hand, scales network depth, width, and resolution using a compound scaling method, enabling a better balance between performance and efficiency. By fine-tuning these pre-trained models on our dataset, the system achieves robust feature extraction and improved generalization for multi-class fruit and vegetable classification.

**Our workflow**

he proposed architecture for the **Fruit and Vegetable Freshness Detection System** follows a structured, flow-based approach consisting of sequential stages. The process begins with **Dataset Acquisition**, where images of both fresh and rotten fruits and vegetables are collected from reliable sources such as Kaggle. These images are then passed through the **Data Preprocessing** stage, which involves resizing, normalization, and data augmentation (like rotation, flipping, and zooming) to enhance model robustness. Labels are assigned to each image based on the fruit type and freshness class.

Next, in the **Model Development** phase, a convolutional neural network is built using pre-trained architectures such as **MobileNetV2** and **EfficientNetB0** through transfer learning. The top layers are replaced with customized dense layers and regularization techniques like dropout and batch normalization. This model is then trained and validated using the processed dataset in the **Model Training and Validation** stage, where performance is evaluated through metrics such as accuracy, precision, recall, and F1-score, and the best model weights are saved.

After successful training, the model is deployed through either **TensorFlow Lite** for mobile devices or **Flask** for web applications in the **Deployment** phase. The **User Interface** allows users to upload or capture an image, after which the system predicts the fruit or vegetable type, classifies it as fresh or rotten, and displays its estimated nutritional information. Finally, a **Feedback and Improvement** module collects misclassified samples and continuously retrains or fine-tunes the model to improve accuracy over time. This entire pipeline ensures a scalable, accurate, and efficient real-time food freshness detection system.

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