Smart Refrigerator Shelf with Spoiled Food Detection

Jagadish M
Assistant Professor, Department of ECE, Acharya Institute of Technology, Bengaluru, Karnataka, India

Shivam Garg Shukla
UG Student, Department of ECE, Acharya Institute of Technology, Bengaluru, Karnataka, India

Vignesh HP
UG Student, Department of ECE, Acharya Institute of Technology, Bengaluru, Karnataka, India

Utkarsh Kumar Karn
UG Student, Department of ECE, Acharya Institute of Technology, Bengaluru, Karnataka, India

Abstract

This paper presents the design and implementation of a Smart Refrigerator Shelf with Spoiled Food Detection system that integrates embedded sensing, Internet of Things (IoT) connectivity, and multimodal artificial intelligence for real-time freshness assessment. The system employs an ESP32- CAM node for image capture, an MQ135 sensor for volatile organic compound (VOC) detection, and a DHT11 sensor for temperature-humidity monitoring. Sensor data undergoes pro- cessing through a Python-based gateway that leverages the Google Gemini multimodal API for intelligent analysis, delivering human-readable explanations, confidence scores, and estimated shelf-life via Telegram bot notifications. Practical implementation overcomes hardware challenges including ADC-WiFi conflicts through external I2C-based ADS1115 converter and power sta- bility issues using dedicated power banks. Results demonstrate accurate spoilage detection with reduced false positives through multimodal fusion logic, achieving 92-96% accuracy with only 6-12% false positive rate. The system achieves deployment readi- ness suitable for households, retail refrigerators, and commercial kitchens, contributing to waste reduction, improved food safety, and sustainable resource management across the food value chain.

Keywords

IoT, Food Spoilage Detection, Machine Learning, Computer Vision, Gas Sensors, Edge Computing, Multi-modal AI, Smart Refrigeration, ESP32-CAM, Gemini API.