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Intelligent Machine for Food Quality and Safety Assessment

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Abstract

This paper presents the development of an intelligent fruit and vegetable classification system aimed at reducing food waste and infections caused by spoiled items. Using artificial intelligence and sensor data, our system classifies items into three categories: ripe, unripe, and rotten, and employs servo motors to sort them into respective baskets. The classification process utilizes real-time temperature, humidity, and image data captured by the camera and processed by the laptop. Additionally, the nutritional information of the ripen fruits are provided after classification. The system employs DC motors for conveyor belt movement, IR proximity sensors for item detection, and DHT11 sensors for environmental monitoring and are controlled by an Arduino Uno R3 microcontroller. Our work demonstrates the potential of such a system in reducing food waste, aiding in diet control, and assisting farmers in agricultural sorting tasks. Overall, this research contributes to the development of intelligent systems for efficient food management, benefiting both consumers and agricultural stakeholders.

Keywords: Artificial Intelligence, Nutritional information, Diet control, Food management, DC motors.

INTRODUCTION

Even in this 21st century, food spoilage is a crucial problem as the consumption of spoiled food can be harmful to health. In India, food commodities are wasted due to spoilage. Consuming spoiled food can cause food poisoning. Hence the detection of freshness of food or food quality is needed. Manual detection of freshness through smell, taste, or visual cues is time-consuming and prone to human errors. Thus, it's necessary to develop a device that can detect food spoilage without human intervention. In response to the challenges in various industries including agriculture and food processing, our research endeavors to develop an intelligent machine that automates the classification process using artificial intelligence (AI) and innovative mechanical design.

The primary objective of this work is to design and implement an intelligent machine capable of classifying fruits and vegetables into three distinct categories: ripen, unripe, and rotten. The machine utilizes AI algorithms to analyze real-time data, including temperature, humidity, and visual inputs captured by a laptop camera. These inputs are with the AI model in the laptop by using Arduino Uno R3 and is tested against the trained model. By integrating servo motors as a mechanical arm, the machine efficiently separates items into different baskets based on their classification. Additionally, the machine provides users with real-time information on the nutritional values of ripe fruits, aiding in dietary control decisions.

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A major part of our research involves the development and training of an AI model using a dataset comprising temperature, humidity, and image inputs. We employed convolutional neural networks (CNNs) to analyze visual data and make classification decisions based on predefined criteria. Experimental validation was conducted using a prototype system consisting of Arduino Uno R3, servo motors, DC motors, and various sensors, enabling real-time classification and sorting of fruits and vegetables. Our approach utilizes a laptop as the processor, offering a cost-effective solution with comparable performance.

LITERATURE SURVEY

Dr. D. Baswaraj and Sankirti Shiravale (2024) present a comprehensive framework for accurately recognizing fruits and vegetables using machine learning techniques [1]. By employing various feature descriptors for color and texture extraction from images, the study aims to categorize fruits and vegetables efficiently. The framework evaluates the performance of different classifiers like C4.5 decision trees and KNN to determine the optimal combination of features and classifiers for image recognition. While the paper offers a systematic approach to fruit and vegetable classification, potential limitations include dataset relevance and complexity variations in the fruits and vegetables being classified, as well as challenges related to high-dimensional feature spaces and imbalanced data. Overall, the framework provides valuable insights into fruit and vegetable recognition, highlighting the need for further research to address these limitations and enhance the system's effectiveness.

Zheng Zhou and Umair Zahid (2023) [2] attempted to explore the application of AI in on-farm fruit sorting and transportation to enhance efficiency and reduce labor costs. It emphasizes the use of AI models for data acquisition, sorting, and potential autonomous systems. However, limitations include the need for optimization to function effectively in field conditions, dataset quality, and diversity challenges leading to potential biases and overfitting, and the requirement for reliable operation in environments with vibrations and uneven terrain. Overcoming these limitations is essential for improving the accuracy and practicality of AI technology in on-farm fruit sorting and transportation.

Bin Yu and Ping Zhan (2020) [7] proposed a Food Quality Monitoring System for fruit juice production that utilizes smart contracts, machine learning, and blockchain to automate quality assessment throughout the production process. However, this system does not involve physical sorting mechanisms limiting its applicability to sorting tasks, and lacks real-time sensing capabilities. Furthermore, the focus on fruit juice production may not directly address the broader issue of food waste and infections caused by spoiled fruits and vegetables in various contexts beyond juice production.

Miaomiao Zheng and Shanshan Zhang (2021) [4] focus on enhancing public health through a food safety traceability system utilizing RFID, big data, and IoT technologies for real-time monitoring of rice production. However, IoT and RFID technologies may limit their scalability and real-time tracking capabilities.

Tri Tran Minh Huynh and Tuan Minh Le (2022) [3] highlighted a sophisticated approach utilizing Adaptive Particle-Grey Wolf Optimization (APGWO) for feature selection in fruit recognition using camera images. This system relies solely on camera images which would interrupt efficient classification and sorting. The paper discusses advancements like Improved Grey Wolf Optimization (IGWO) but it makes the system more complex for the users.

Fu Yuesheng and Song Jian (2021) conducted a study using the GoogLeNet network for classifying fruits and vegetables, achieving high accuracy and addressing training speed issues [6]. It compares the optimized GoogLeNet with other CNN models and highlights a 2% accuracy improvement. Limitations include the focus on a specific set of produce, potentially limiting generalizability, and the study does not extensively discuss scalability to larger datasets or different produce types. The findings underscore the effectiveness of GoogLeNet for classification tasks but acknowledge limitations in model applicability and scalability beyond the studied fruits and vegetables.

Christiena and Dhanushitha H.S (2020) [8] focuses on addressing food wastage through a Food Quality Monitoring System (FQMS) based on IoT technology. By monitoring and controlling parameters like temperature, humidity, and light, the FQMS strives to maintain optimal storage conditions for fruits and vegetables, thus mitigating spoilage risks. However, the proposed system's reliance on IoT technology may pose limitations in terms of accessibility and affordability, particularly in rural areas with limited internet connectivity and infrastructure.

Dr. Keshavamurthy and Mariyam Steffi J (2019) demonstrate an automated system for detecting and processing food quality that uses convolutional neural networks (CNN) and computer vision to evaluate food quality [9]. By integrating a microcontroller, sensors, camera, and conveyor belt setup, the system efficiently segregates fruits based on their quality. However, while the system emphasizes non-destructive and cost-effective food quality assessment, its reliance on IoT technology could pose limitations for certain setups, particularly those operating in areas with limited connectivity or resources.

Nachiketa Hebbar (2020) [5] utilizes a combination of sensors, IoT, and machine learning to detect spoiled food items effectively in various settings, ranging from industrial to household environments. However, a limitation lies in the reliance on IoT technology, which may pose connectivity challenges in certain environments or regions lacking robust internet infrastructure.

Naveed Shahzad and Usman Khalid (2018) proposed a device named eFresh which is an innovative solution equipped with biosensors capable of measuring crucial parameters like pH, moisture, and ethanol levels in food items [10]. By integrating an Android mobile application, users can easily input the food to be analyzed, triggering commands to the Arduino Uno via a Bluetooth module. While the device provides valuable real-time insights into food freshness, its reliance on predefined algorithms may limit its adaptability to varying food types and conditions, potentially affecting its accuracy and reliability in certain scenarios.

By examining the earlier publications, surely, the development of an intelligent machine capable of classifying fruits and vegetables offers promising results with profound implications. By providing real-time nutritional information, the machine offers added value to consumers and promotes healthier dietary choices. In agricultural settings, our system can streamline sorting processes, enabling farmers to optimize yield and minimize losses. Beyond consumer benefits, this system holds great potential for reducing food waste contributes to sustainable public health, and enhances efficiency and sustainability throughout the food supply chain. Overall, this approach offers a cost-effective and scalable solution with comparable performance, paving the way for broader adoption in diverse applications.

METHODOLOGY

Our project aims to develop an intelligent machine that employs artificial intelligence and a combination of sensors, including the DHT11 sensor for monitoring environmental conditions, an IR-based proximity sensor for item detection, and a camera for capturing images. The Arduino Uno R3 serves as a crucial component in the circuitry. Additionally, the system employs DC motors for conveyor belt movement. The real-time values are communicated with the laptop through a USB serial drive. The machine learning model uses a trained AI model for intelligent classification. The system efficiently categorizes fruits and vegetables into three groups: ripe, unripe, and rotten. A mechanical arm driven by servo motors facilitates the physical separation of these items into designated baskets. Furthermore, the system offers real-time nutritional insights into ripened fruits, aiding individuals in making informed dietary choices. Also holds promise in agricultural settings, assisting farmers in streamlining produce sorting processes (Figure 1)

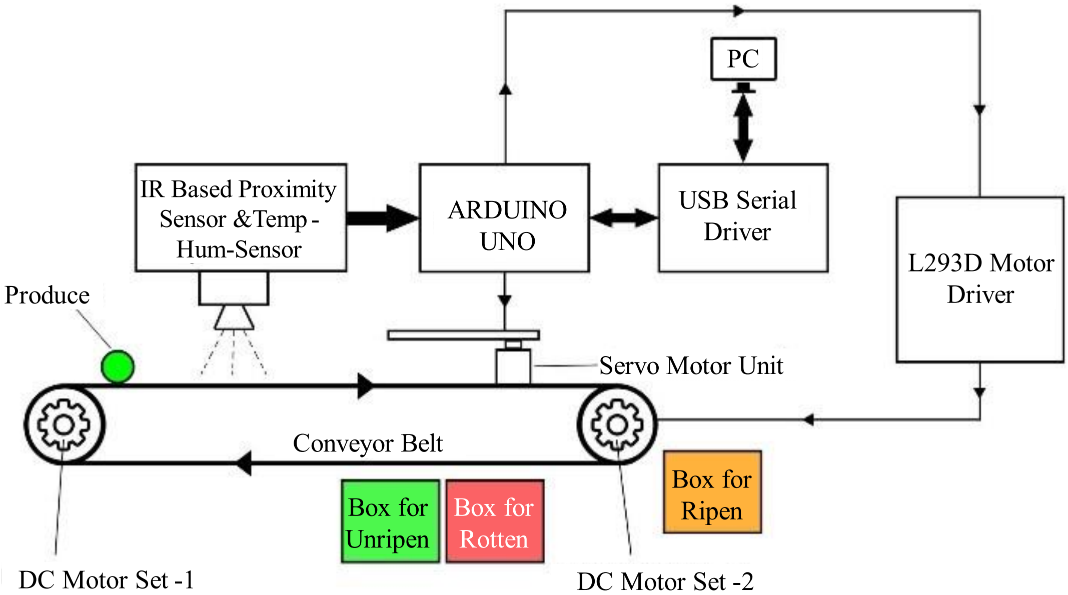

Figure 1. Block Diagram

1. *Arduino Uno R3:* This is a microcontroller board based on the ATmega328P chip clocked at 16MHz, offering 32KB of flash memory, 2KB of SRAM, and 1KB of EEPROM. It has 14 digital and 6 analog input/output pins that can be programmed to interact with sensors, motors, and other devices.

2. *Servo Motor:* A servo motor is a rotary actuator that allows for precise control of angular position. It consists of a motor, gears, and a control circuit. Servo motors are commonly used in applications where precise positioning or continuous rotation is required, such as in robotics and automation.
3. *IR-based Proximity Sensor:* This sensor detects the presence of an object without physical contact by emitting and detecting infrared radiation. It works on the principle of reflection or interruption of the emitted infrared light. IR proximity sensors are used in various applications, including object detection, obstacle avoidance, and proximity sensing.
4. *USB Serial CP2102:* This is a USB-to-serial converter chip that allows microcontrollers like Arduino to communicate with a computer over USB. It converts the serial data from the microcontroller into USB format, enabling serial communication between the microcontroller and the computer.
5. *L293D Driver Module:* It is a popular motor driver IC (integrated circuit) that can drive two DC motors or one stepper motor. It provides bidirectional control of the motors and can handle motor voltages up to 36V. The driver module typically contains the L293D IC along with additional components for protection and ease of use.
6. *DHT11 Sensor:* The DHT11 is a basic digital temperature and humidity sensor. It consists of a capacitive humidity sensor and a thermistor for temperature measurement. The sensor provides digital output and is relatively simple to use, making it suitable for applications such as environmental monitoring and HVAC systems.
7. *DC Motor:* A DC (direct current) motor converts electrical energy into mechanical motion. It consists of a stator, rotor, and commutator, and operates based on the interaction between magnetic fields. DC motors are widely used in various applications, including robotics, automation, and electric vehicles.
8. *IC 7805:* The 7805 is a voltage regulator IC that provides a stable 5V output voltage from a higher input voltage. It regulates the input voltage and ensures a constant output voltage regardless of variations in the input voltage or load. The 7805 is commonly used to power low-voltage electronic circuits and components.

CONCLUSION

Food quality detection and management will be an important factor for healthier dietary choices and a sustainable food supply chain. With a high concern for good quality and safety in food products, the system proposed provides a method of detection by various sensors and Artificial Intelligence. This paper not only aims to assess the quality of food items, but it also provides real-time nutritional values and efficient sorting of items. This eliminates human-prompted errors while sorting. The tedious health issues and food wastage will be reduced.

In the future, we plan to make our system better by improving the AI algorithms for more accurate classification. Additionally, integrating more advanced sensors and technologies could further optimize the efficiency and effectiveness of the machine, expanding its applicability and impact in various domains.

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