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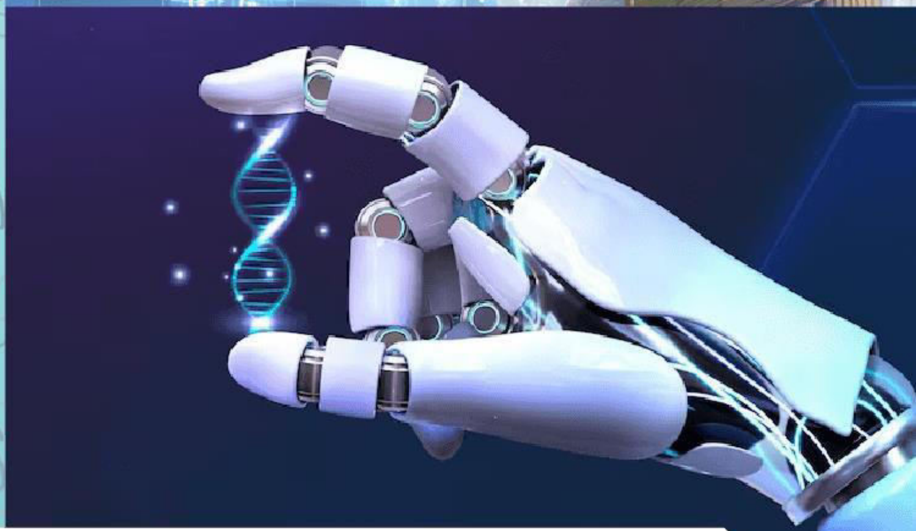

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Smart IOT Temperature Regulation System for Food Storage Containers

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ABSTRACT: This project presents an integrated system for temperature automation and location tracking designed for maritime and food container applications. The system combines deep learning techniques with a YOLO (You Only Look Once) model for recognizing and categorizing various food items using images. Real-time location monitoring is facilitated through GPS technology, enabling users to track the container's movements throughout its journey.The deep learning component, powered by YOLO, plays a pivotal role in automating the identification and categorization of food items within the container. YOLO's efficiency in object detection allows for rapid and accurate recognition, ensuring that different types of food products are appropriately classified. Temperature regulation is achieved through a PID controller, a widely used control loop feedback mechanism known for its effectiveness in maintaining desired setpoints. The PID controller continuously adjusts the Peltier device's operation, ensuring that the container's interior remains within the specified temperature range. This not only preserves the quality of the food items but also prevents spoilage and waste during transportation.The inclusion of GPS technology adds an additional layer of functionality to the system by providing real-time location tracking. Users can monitor the container's precise location at any given time, facilitating efficient logistics management and enhanced security. This feature is particularly valuable in the maritime industry, where container ships traverse vast distances, and in the food industry, where the timely delivery of perishable goods is crucial.

KEYWORD: Temperature automation, YOLO model, GPS location tracking

I. INTRODUCTION

In today's interconnected world, the transportation of perishable goods via maritime and food containers presents a significant logistical challenge. The preservation of these goods' quality and safety hinges on precise temperature control and efficient monitoring of their whereabouts. To tackle these challenges head-on, this project introduces a pioneering system that seamlessly combines cutting-edge technologies to automate temperature regulation and provide real-time location tracking for maritime and food containers.

The foundation of this innovative system lies in the integration of advanced technologies, namely deep learning with the YOLO (You Only Look Once) model, a Proportional-Integral-Derivative (PID) controller, and GPS technology. This powerful combination not only streamlines operations but also enhances the reliability and efficiency of transporting diverse food items across vast distances.

At the heart of the system is the YOLO model, which serves as an intelligent tool for recognizing and categorizing various food items within the container. By leveraging deep learning capabilities, the YOLO model ensures that each food product receives tailored temperature control measures, thereby optimizing storage conditions and minimizing the risk of spoilage. This aspect of the system addresses a critical need in the food industry, where maintaining the quality and freshness of perishable goods is paramount.

Complementing the deep learning component, the PID controller takes center stage in regulating the container's internal temperature using a Peltier device. Known for its precision and effectiveness, the PID controller continuously adjusts

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the temperature to remain within the desired range. This not only safeguards the integrity of the transported goods but also minimizes waste and enhances overall efficiency in the transportation process.

II. LITERATURE REVIEW

Literature research is the most important step in the software development process. Before creating a tool, it is important to determine the time factor, profitability, and company strengths. With these in place, the next 10 steps are to decide which operating systems and languages you can use to develop your tools. Once programmers start building tools, they need a lot of external support. This support can come from experienced programmers, books, or websites. The above evaluations will be considered in the development of the proposed system before building the system.

Gilal, N.U., Al-Thelaya, K., Al-Saeed, J.K., Abdallah, M., Schneider, J., She, J., Awan, J.H. and Agus, M., 2023. Evaluating machine learning technologies for food computing from a data set perspective. Multimedia Tools and Applications, pp.1-28.
Food plays an important role in our lives that goes beyond mere sustenance. Food affects behavior, mood, and social life. It has recently become an important focus of multimedia and social media applications. The rapid increase of available image data and the fast evolution of artificial intelligence, paired with a raised awareness of people's nutritional habits, have recently led to an emerging field attracting significant attention, called food computing, aimed at performing automatic food analysis. Food computing benefits from technologies based on modern machine learning techniques, including deep learning, deep convolutional neural networks, and transfer learning. These technologies are broadly used to address emerging problems and challenges in food-related topics, such as food recognition, classification, detection, estimation of calories and food quality, dietary assessment, food recommendation, etc. However, the specific characteristics of food image data, like visual heterogeneity, make the food classification task particularly challenging. To give an overview of the state of the art in the field, we surveyed the most recent machine learning and deep learning technologies used for food classification with a particular focus on data aspects. We collected and reviewed more than 100 papers related to the usage of machine learning and deep learning for food computing tasks..

Kakani, V., Nguyen, V.H., Kumar, B.P., Kim, H. and Pasupuleti, V.R., 2020. A critical review on computer vision and artificial intelligence in food industry. Journal of Agriculture and Food Research, 2, p.100033.
Emerging technologies such as computer vision and Artificial Intelligence (AI) are estimated to leverage the accessibility of big data for active training and yielding operational real time smart machines and predictable models. This phenomenon of applying vision and learning methods for the improvement of food industry is termed as computer vision and AI driven food industry. This review contributes to provide an insight into state-of-the-art AI and computer vision technologies that can assist farmers in agriculture and food processing. This paper investigates various scenarios and use cases of machine learning, machine vision and deep learning in global perspective with the lens of sustainability. It explains the increasing demand towards the AgTech industry using computer vision and AI which might be a path towards sustainable food production to feed the future. Also, this review tosses some implications regarding challenges and recommendations in inclusion of technologies in real time farming, substantial global policies and investments. Finally, the paper discusses the possibility of using Fourth Industrial Revolution [4.0 IR] technologies such as deep learning and computer vision robotics as a key for sustainable food production.

Konstantakopoulos, F.S., Georga, E.I. and Fotiadis, D.I., 2023. A review of image-based food recognition and volume estimation artificial intelligence systems. IEEE Reviews in Biomedical Engineering.
The daily healthy diet and balanced intake of essential nutrients play an important role in modern lifestyle. The estimation of a meal's nutrient content is an integral component of significant diseases, such as diabetes, obesity and cardiovascular disease. Lately, there has been an increasing interest towards the development and utilization of smartphone applications with the aim of promoting healthy behaviours. The semi – automatic or automatic, precise and in real-time estimation of the nutrients of daily consumed meals is approached in relevant literature as a computer vision problem using food images which are taken via a user's smartphone. Herein, we present the state-of-the-art on automatic food recognition and food volume estimation methods starting from their basis, i.e., the food image databases. First, by methodically organizing the extracted information from the reviewed studies, this review study enables the comprehensive fair assessment of the methods and techniques applied for segmenting food images, classifying their food content and computing the food volume, associating their results with the characteristics of the used datasets. Second, by unbiasedly reporting the strengths and limitations of these methods and proposing pragmatic solutions to the latter, this review can inspire future directions in the field of dietary assessment systems.

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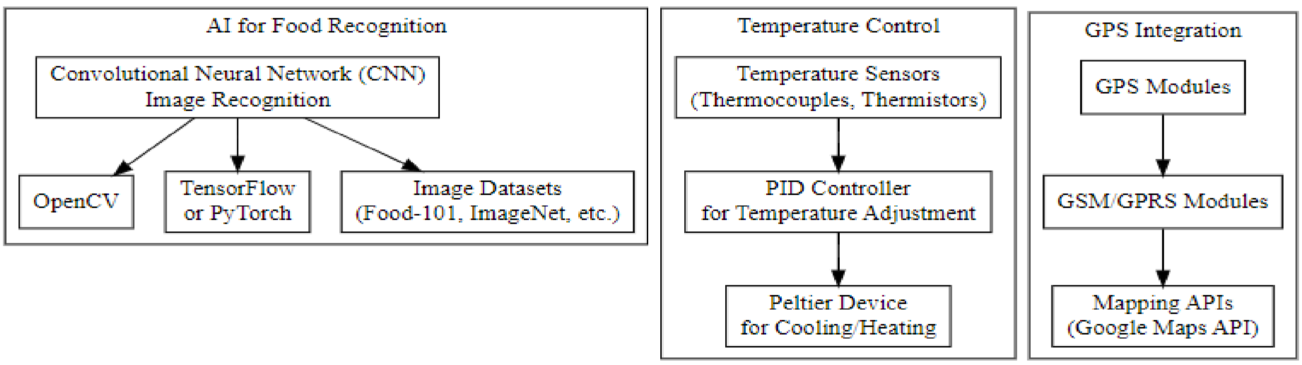
Choi, H., Baek, Y. and Lee, B., 2012. Design and implementation of practical asset tracking system in container terminals. International Journal of Precision Engineering and Manufacturing, 13, pp.1955-1964.
A container terminal plays an important logistical role in handling transshipping containers. Therefore, location information regarding vehicles that carry containers in a port is critical to cost- and time-efficient management for harbor automation. In terms of scalability, cost, and energy efficiency, an active radio-frequency-identification (RFID) based real-time locating system (RTLS) is an appropriate technology for obtaining location information. In general, an RTLS estimates locations using the transmission time of wireless signals. Accurate distance measurement depends on not only time measurement but also guaranteed line-of-sight (LOS) communication. However, in a container terminal environment, the performance of existing system can be seriously degraded because of densely deployed obstacles, e.g., containers and vehicles. Furthermore, places that readers can be installed in a terminal are limited, and thus a sufficient number of readers cannot be installed to provide reliable communication. To overcome these problems, this paper presents a novel and practical approach to overcoming non-line-of-sight (NLOS) RF propagation problems in asset tracking systems for container terminals. In proposed system, we have considered practicable methods from unit experimentsin real world as well as theoretical methods: the system tries to reducerange estimates obtained under NLOS conditions, and estimate the tag locations using vehicles' range estimates and route information. For evaluation, the proposed method has been implemented at a real container terminal in South Korea, and experimental tests demonstrated its validity.

Cil, A.Y., Abdurahman, D. and Cil, I., 2022. Internet of Things enabled real time cold chain monitoring in a container port. Journal of Shipping and Trade, 7(1), p.9.
Seaports are regarded as significant actors in global logistics and supply chains since a large part of the cargoes carried over the globe are being processed there. When the cold chain broken down during transport and storage in the ports, the humidity, nutrition, temperature and time conditions to be required for the growth of the bacteria occur, and rapid reproduction occurs and the properties of the products are rapidly deteriorating. It is imperative that especially medicines, some chemical substances and foodstuffs need to be transported without breaking the cold chain in the logistics. The monitoring and control of the temperature and humidity level is important in the time period between the loading of these containers in special areas in ports, the loading of freight in open areas, or the loading of freight on roads and railway carriages. For this reason, precise monitoring and control of the system is vital in the port logistics management.

III. METHODOLOGY

The approach to our envisioned system centers on the seamless integration of state-of-the-art technologies aimed at transforming the landscape of maritime and food container transportation. The implementation begins with the establishment of the system's basic structure by the systems architect. Here, a Hash code Solomon algorithm is proposed to optimize the distribution of data across various storage platforms, including local machines, fog servers, and cloud storage. This algorithm, rooted in computational intelligence, computes the distribution proportion stored in each platform, ensuring both efficiency and privacyprotection.



The architecture of the proposed system

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To achieve data deduplication and encryption, the proposed scheme utilizes a combination of encryption algorithms and data transformation techniques. Cloud users encrypt their messages using the MLE algorithm to generate ciphertexts, which are then transformed into packages using CAONT. Bloom filter-based location selection method is employed to choose random locations for data storage, enhancing security and efficiency. The process also involves concatenating selected packages and generating gathered packages using file keys for re-encryption. By outsourcing duplicated packages to the Cloud Service Provider (CSP), the scheme achieves ciphertext deduplication, minimizing storage redundancy and optimizing data management.

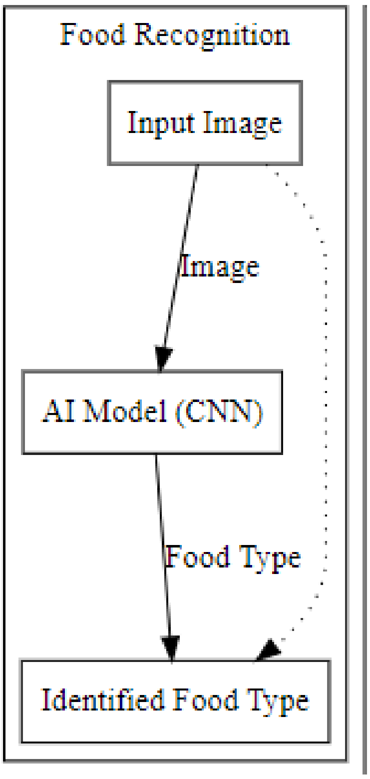
Performance evaluation of the proposed system focuses on key aspects such as location generation, gathered package generation, and computational overhead. The Bloom filter-based location selection method is assessed for its efficiency in choosing random locations, with varying bit lengths tested to optimize performance. Additionally, the cost computation time for generating gathered packages is analyzed, considering factors like chunk size and processing overhead. Through theoretical safety analysis and experimental validation, the feasibility and effectiveness of the proposed scheme are demonstrated, offering a robust solution for enhancing data storage and security in maritime and food container transportation.

IV. RESULTS AND DISCUSSION

The proposed system aims to develop an integrated smart food storage solution by leveraging advanced technologies for food recognition, temperature regulation, and real-time location monitoring. The overarching goal is to efficiently manage and preserve perishable food items during transportation and storage, ultimately enhancing food preservation, minimizing losses, and ensuring the quality and safety of stored goods.

MODULES IDENTIFIED:
Food recognition module, Temperature control module, GPS monitoring module.

1. FOOD RECOGNITION MODULE
Convolutional Neural Network (CNN): Recognizes and categorizes various food items using images.
OpenCV: Image processing and feature extraction for the CNN.
TensorFlow or PyTorch: Framework for building and training the CNN.
Image Datasets: Such as Food-101, ImageNet, or custom datasets for training the CNN.



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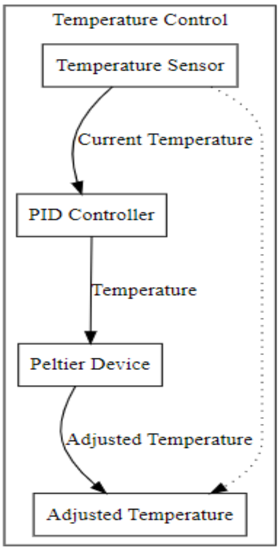
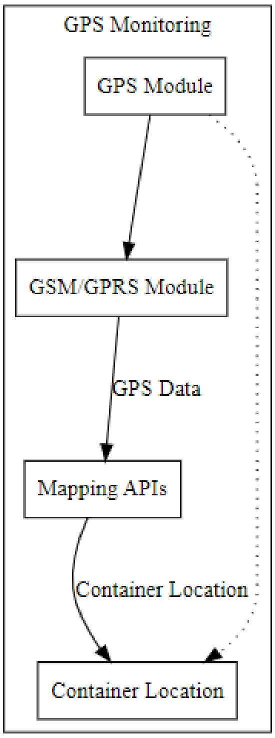
2. TEMPERATURE CONTROL MODULE
Temperature Sensors: Thermocouples or thermistors for real-time temperature monitoring.
PID Controller: Adjusts the temperature based on input from the food recognition module.
Peltier Device: Acts as a cooling/heating element controlled by the PID controller.



3. GPS MONITORING MODULE
GPS Modules: Provide real-time location data of the shipping container.
GSM/GPRS Modules: Enable cellular communication to transmit GPS data.
Mapping APIs (like Google Maps API): Used for visualization of container location in real-time.



ALGORITHM
YOLO, or **You Only Look Once**, revolutionizes object detection with its streamlined approach, combining classification and bounding box prediction into a single neural network. This integration enables YOLO to achieve

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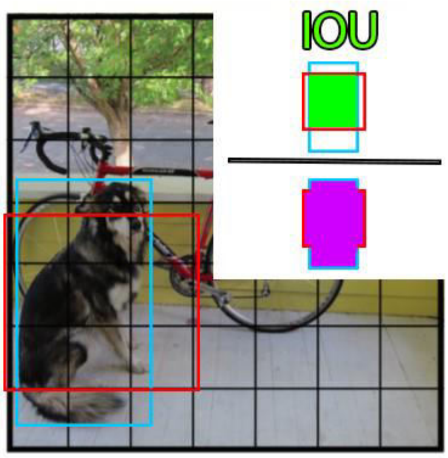
remarkable speeds, performing real-time object detection at 45 frames per second. By analyzing the entire image at once, YOLO captures contextual information, reducing false positives compared to traditional methods. Its ability to generalize object representations enhances its adaptability to different environments, making YOLO a versatile choice for applications requiring rapid and accurate object detection.

The following illustration highlights how YOLO works:

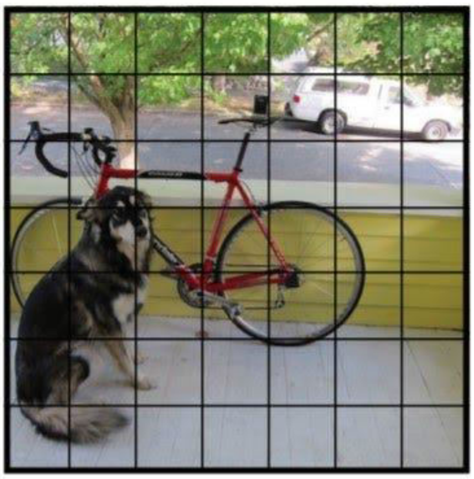
How it works

YOLO is based on the idea of segmenting an image into smaller images. The image is split into a square grid of dimensions S×S, like so:



S × S grid on input

The cell in which the center of an object, for instance, the center of the dog, resides, is the cell responsible for detecting that object. Each cell will predict B bounding boxes and a confidence score for each box. The default for this architecture is for the model to predict two bounding boxes. The classification score will be from `0.0` to `1.0`, with`0.0` being the lowest confidence level and `1.0` being the highest; if no object exists in that cell, the confidence scores should be `0.0`, and if the model is completely certain of its prediction, the score should be `1.0`. These confidence levels capture the model's certainty that there exists an object in that cell and that the bounding box is accurate. Each of these bounding boxes is made up of 5 numbers: the x position, the y position, the width, the height, and the confidence. The coordinates `(x, y)` represent the location of the center of the predicted bounding box, and the width and height are fractions relative to the entire image size. The confidence represents the IOU between the predicted bounding box and the actual bounding box, referred to as the ground truth box. The IOU stands for Intersection Over Union and is the area of the intersection of the predicted and ground truth boxes divided by the area of the union of the same predicted and ground truth boxes.



S × S grid on input

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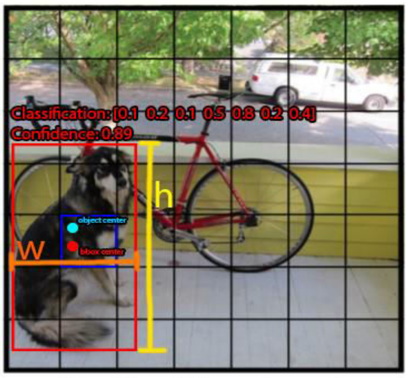
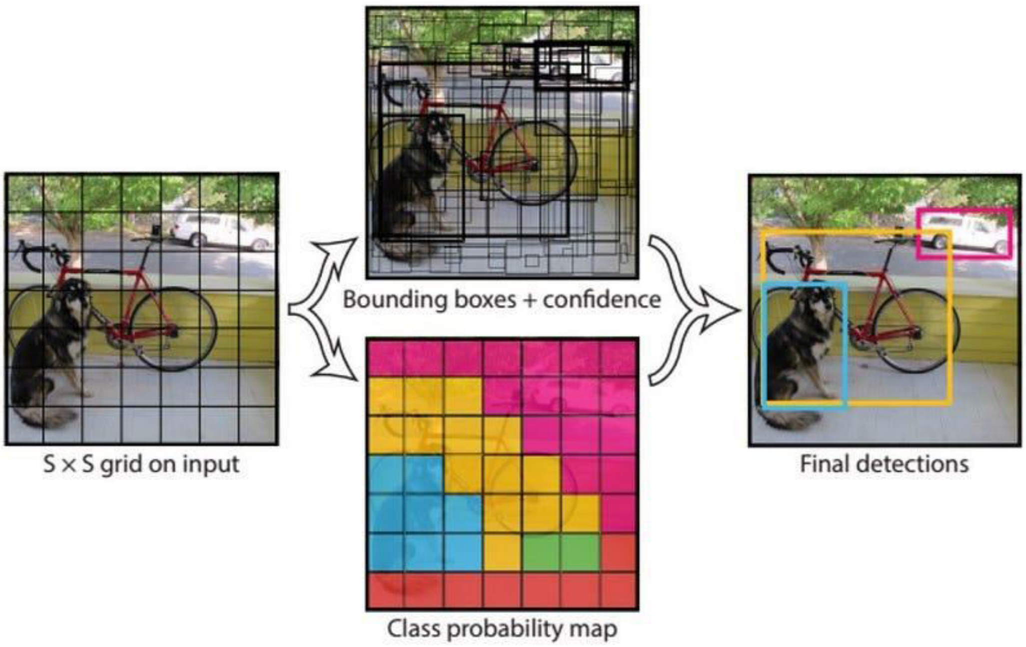
In addition to outputting bounding boxes and confidence scores, each cell predicts the class of the object. This class prediction is represented by a one-hot vector length C, the number of classes in the dataset. However, it is important to note that while each cell may predict any number of bounding boxes and confidence scores for those boxes, it only predicts one class. This is a limitation of the YOLO algorithm itself, and if there are multiple objects of different classes in one grid cell, the algorithm will fail to classify both correctly. Thus, each prediction from a grid cell will be of shape **C + B * 5**, where **C** is the number of classes and **B** is the number of predicted bounding boxes. **B** is multiplied by 5 here because it includes **(x, y, w, h, confidence)** for each box. Because there are **S × S** grid cells in each image, the overall prediction of the model is a tensor of shape **S × S × (C + B ∗ 5)**.



S × S grid on input

Here is an example of the output of the model when only predicting a single bounding box per cell. In this image, the dog's true center is represented by the cyan circle labeled 'object center'; as such, the grid cell responsible for detecting and bounding the box is the one containing the cyan dot, highlighted in dark blue. The bounding box that the cell predicts is made up of 4 elements. The red dot represents the center of the bounding box, **(x, y)**, and the width and height are represented by the orange and yellow markers respectively. It is important to note that the model predicts the center of the bounding box with widths and heights rather than top left and bottom right corner positions. The classification is represented by a one-hot, and in this trivial example, there are 7 different classes. The 5th class is the prediction and we can see that the model is quite certain of its prediction. Keep in mind that this is merely an example to show the kind of



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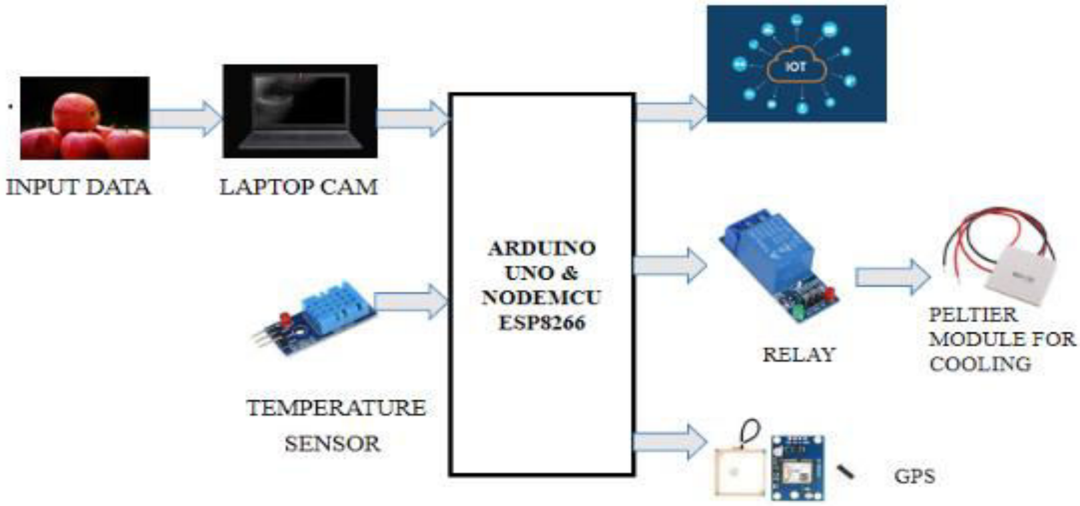
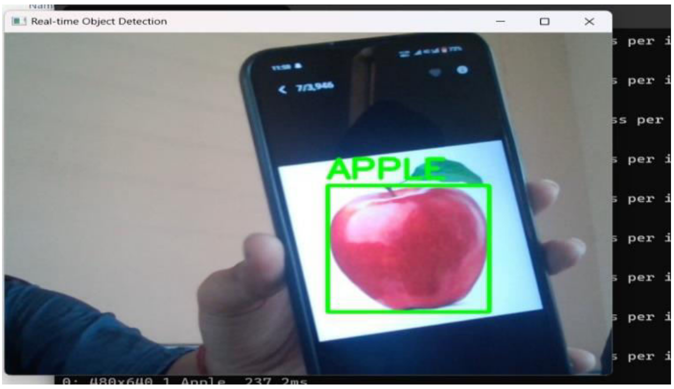
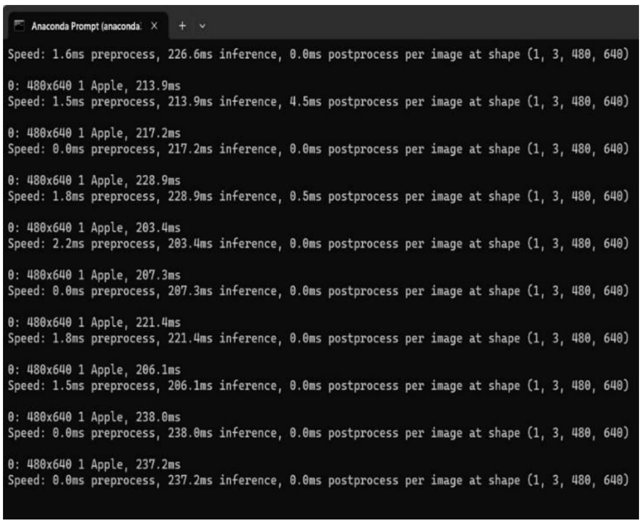
output that is possible and so the values may not be accurate to any real values. Below is another image of all the bounding boxes and class predictions that would actually be made and their final result.

SAMPLE OUTPUT:







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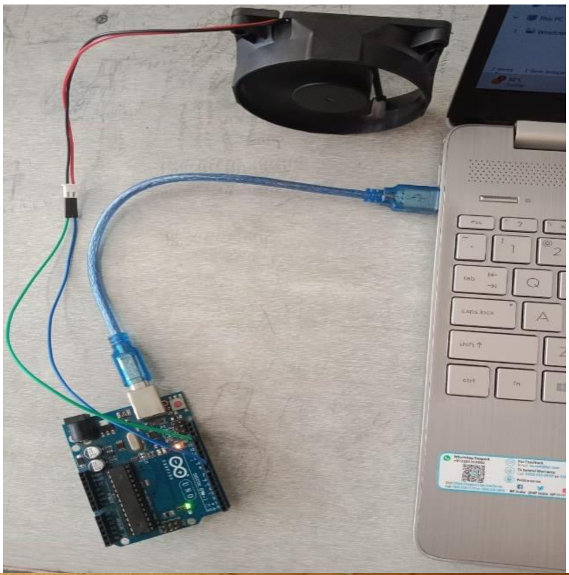

V. CONCLUSION

In this innovative system, the integration of deep learning with YOLO object detection revolutionizes inventory management practices by swiftly and accurately recognizing and categorizing various food items through image analysis. This advanced technology ensures better organization and monitoring of stored products, enhancing food safety and inventory management efficiency. By automating the identification process, the system reduces manual effort and minimizes the potential for errors, thereby optimizing operational efficiency.

Additionally, the precise temperature control enabled by the Proportional-Integral-Derivative (PID) controller in conjunction with a Peltier device plays a crucial role in preserving the freshness and quality of stored food items within the container. The PID controller continuously adjusts the temperature based on predefined setpoints, ensuring optimal conditions tailored to the specific requirements of different types of food. This meticulous temperature regulation not only safeguards perishable goods but also contributes to sustainability efforts by minimizing food waste throughout the transportation process, ultimately improving overall food safety standards.

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