Product Detection in Retail Environments

Internship Project # 4 Report

Deep Learning Team Epsilon

A project submitted in partial fulfillment of the

Deep Learning Internship

At

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Project Registration

Type (Nature of project)		[*] **D**evelopment [] **R**esearch [] **R**&**D**	
Area of specialization		Deep Learning (AI)	
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Introduction

Abstract:

In the dynamic and competitive retail environment, efficient inventory management is critical for enhancing customer satisfaction and operational efficiency. Traditional manual methods for tracking products on retail shelves are **labour-intensive** and often prone to errors, leading to stockouts, misaligned restocking efforts, and increased shrinkage. This project aims to develop an automated product detection system using advanced computer vision techniques to address these challenges. The system will detect and classify products on shelves in real-time, providing retailers with accurate insights into product availability, shelf organization, and restocking needs. By integrating this technology, retailers can streamline inventory management, reduce stockouts, improve restocking efficiency, and mitigate losses due to theft or misplaced items. The proposed solution has the potential to significantly enhance inventory practices, ultimately improving both operational performance and the customer experience.

Project Requirements

- A functional product detection model that accurately identifies and classifies products on retail shelves.
- Improved inventory management practices, leading to reduced stockouts and enhanced customer satisfaction.
- Insights into product performance, enabling retailers to make data-driven decisions regarding restocking strategies.
- A user-friendly interface that provides actionable insights based on real-time product detection data.

Objectives

The objective of this project is to develop a real-time, automated product detection and classification system using advanced computer vision techniques to optimize inventory management in retail environments. The system aims to:

1. Automate Product Detection: Accurately detect and classify products on retail shelves, reducing reliance on manual tracking methods.
2. Monitor Shelf Inventory in Real-Time: Provide continuous, real-time insights into product availability to prevent stockouts and enhance inventory accuracy.
3. Improve Restocking Efficiency: Facilitate data-driven restocking by identifying low-stock items and restocking needs more effectively.
4. Reduce Shrinkage: Minimize product loss due to theft or misplacement through consistent monitoring and detection of inventory discrepancies.

5. Enhance Customer Satisfaction: Ensure that products are readily available for customers, leading to fewer stockouts and a better shopping experience.

Problem Strategy

The strategy for solving the problem of automated product detection on retail shelves using the YOLOv11 (You Only Look Once) model can be divided into several key steps:

1. Data Collection and Preprocessing:

- **Image Dataset**: Collect a comprehensive dataset of images representing various retail shelf layouts and products. This dataset should include diverse lighting conditions, angles, and different product arrangements.
- **Labelling**: Each image in the dataset will need to be annotated with bounding boxes around the products, including their class labels (product categories).
- **Preprocessing**: Normalize the images, resize them to the input size expected by the YOLOv11 model, and augment the dataset (e.g., rotation, scaling, flipping) to improve generalization.

2. Model Selection and Training:

- **YOLOv11 Architecture**: YOLOv11 will be used for this project due to its fast detection speed and ability to handle object detection in a single forward pass. The network will be trained to predict both bounding box coordinates and class probabilities simultaneously.
- **Loss Function**: The model will use a loss function that combines:
    - **Localization Loss**: For predicting accurate bounding box coordinates.
    - **Confidence Loss**: To predict the likelihood that an object is present in a grid cell.
    - **Class Probability Loss**: For classifying detected objects correctly.
- **Training**: The model will be trained using the collected dataset. It will learn to detect and classify products in various configurations on the retail shelves.

3. Real-Time Detection:

- **Single-Pass Detection**: YOLOv11 divides the image into a grid and predicts bounding boxes and class probabilities in a single forward pass, making it highly efficient for real-time use in retail environments.
- **Real-Time Monitoring**: The system will be designed to process video feeds or images from cameras monitoring store shelves, providing real-time data on product availability and arrangement.

4. Deployment and Integration:

- **Edge/Cloud Processing**: The system could either run on edge devices (for in-store cameras) or be deployed in the cloud, depending on the hardware capabilities and network infrastructure.
- **Integration with Retail Systems**: The detection outputs will be integrated with the store's inventory management system to trigger alerts for low-stock products, out-of-stock situations, or misplaced items.

5. Post-Detection Processing:

- **Stock Alerts**: The system will automatically notify staff when stock levels are low or when shelves need restocking based on the detection results.
- **Anomaly Detection**: By comparing detected products with inventory data, the system can identify potential shrinkage (theft or misplaced items).
- **Restocking Optimization**: The system will generate reports on product availability and shelf organization, helping optimize restocking efforts.

6. Evaluation and Continuous Improvement:

- **Performance Metrics**: Measure the model's performance using standard metrics such as precision, recall, F1-score, and mean Average Precision (mAP) to ensure that it is accurately detecting and classifying products.
- **Model Optimization**: Fine-tune the YOLOv11 model to improve detection accuracy, especially for small or overlapping objects, and reduce false positives/negatives.
- **System Feedback Loop**: Continuously improve the model by retraining it with new data, adapting it to store-specific layouts, product variations, and environmental changes (e.g., lighting, shelf arrangement).

Team Details

Ahmed Islam: Data Collection

Rida Abid : Data Preprocessing

Tauseef Ahmed: Model Training and Evaluation + Documentation

Muhammad Hamza Khattak: Model Testing and Interface development

Arham Khan : Model training and Interface development with **Tauseef Ahmad and Muhammad Hamza**

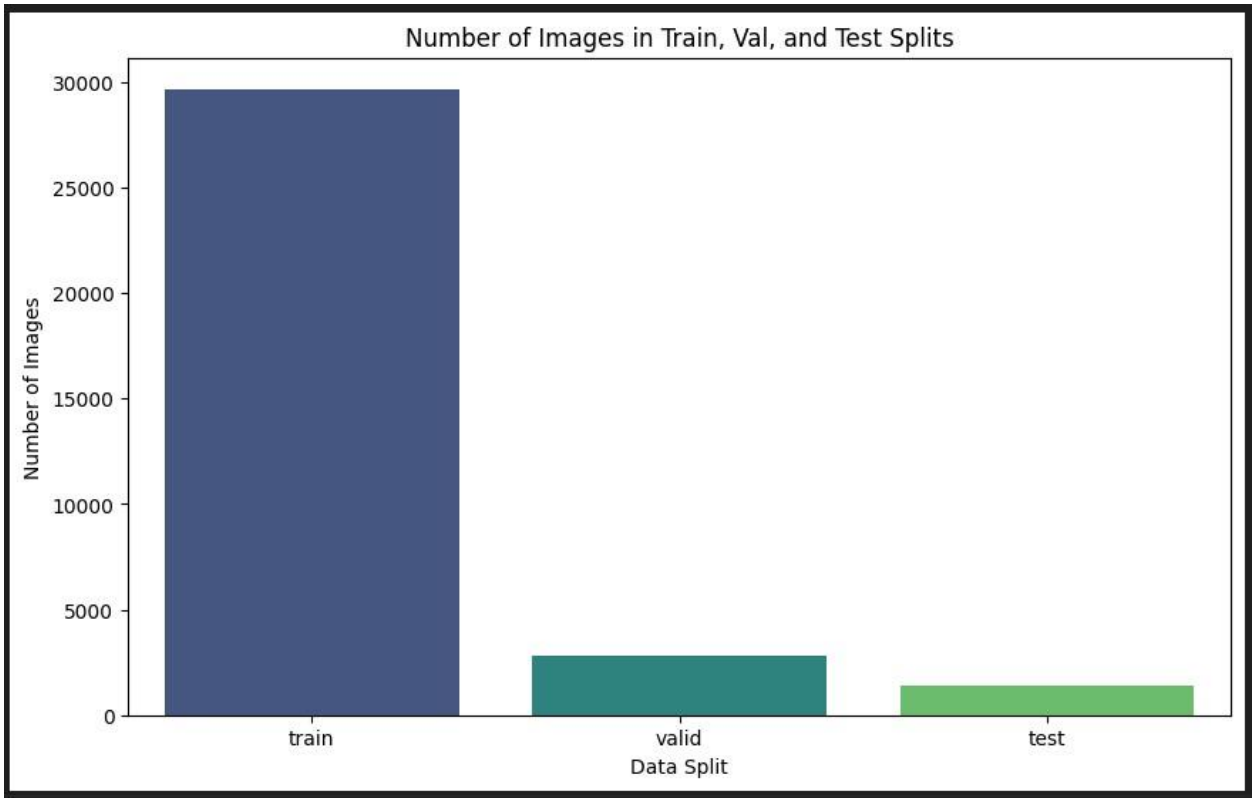
YOLO

The YOLO (You Only Look Once) model is a state-of-the-art, real-time object detection algorithm known for its speed and efficiency. Unlike traditional object detection methods that use a two-stage approach (first proposing regions of interest and then classifying them), YOLO performs detection in a single pass. It divides the input image into a grid and, for each grid cell, predicts bounding boxes and class probabilities simultaneously. This unified approach makes YOLO exceptionally fast, allowing it to process images in real-time while maintaining high detection accuracy. YOLO's architecture is particularly effective for applications requiring real-time performance, such as autonomous vehicles, video surveillance, and retail product detection. Over the years, several iterations of the YOLO model (YOLOv1 to YOLOv5 and beyond) have introduced improvements in accuracy and efficiency, making it one of the most popular choices for object detection tasks. Its ability to detect multiple objects in complex environments with high speed makes YOLO a powerful tool in various industries.

Dataset used:

- Inventory Management system data set is used which is prepared and collected by Arham and Ahmed manually also the data set is annotated manually using roboflow.

Results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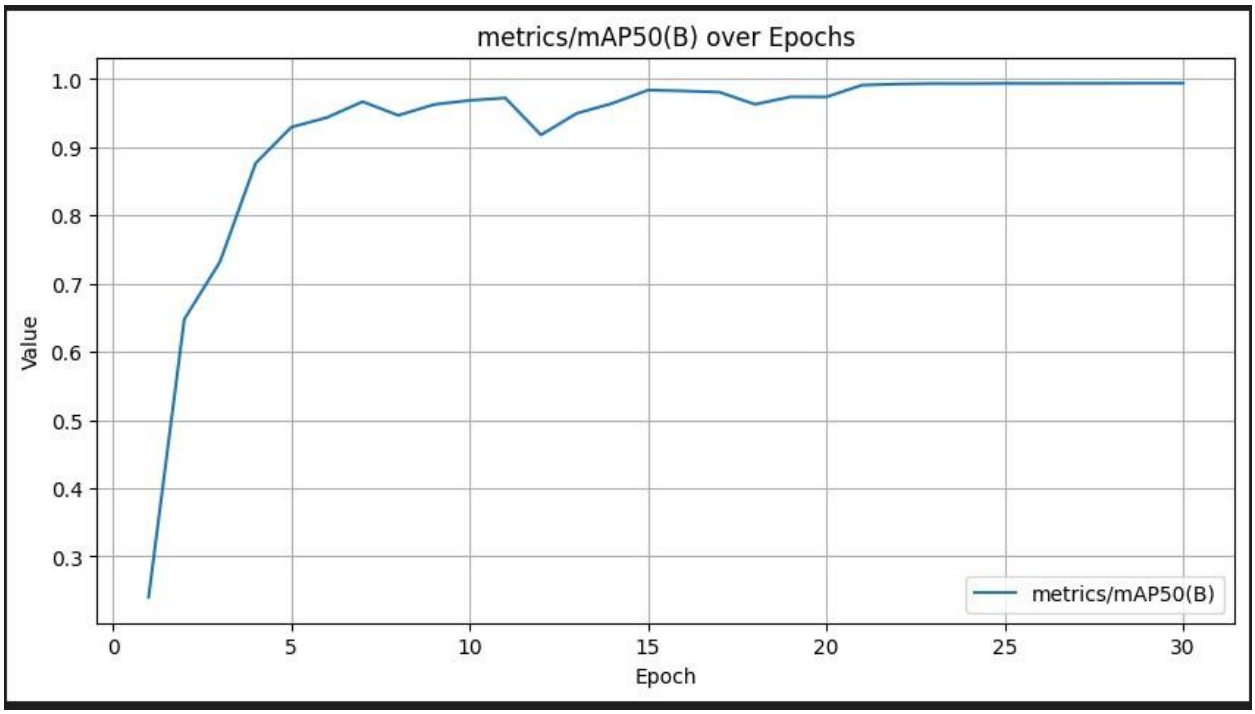
train
valid
test
Data Split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Epoch
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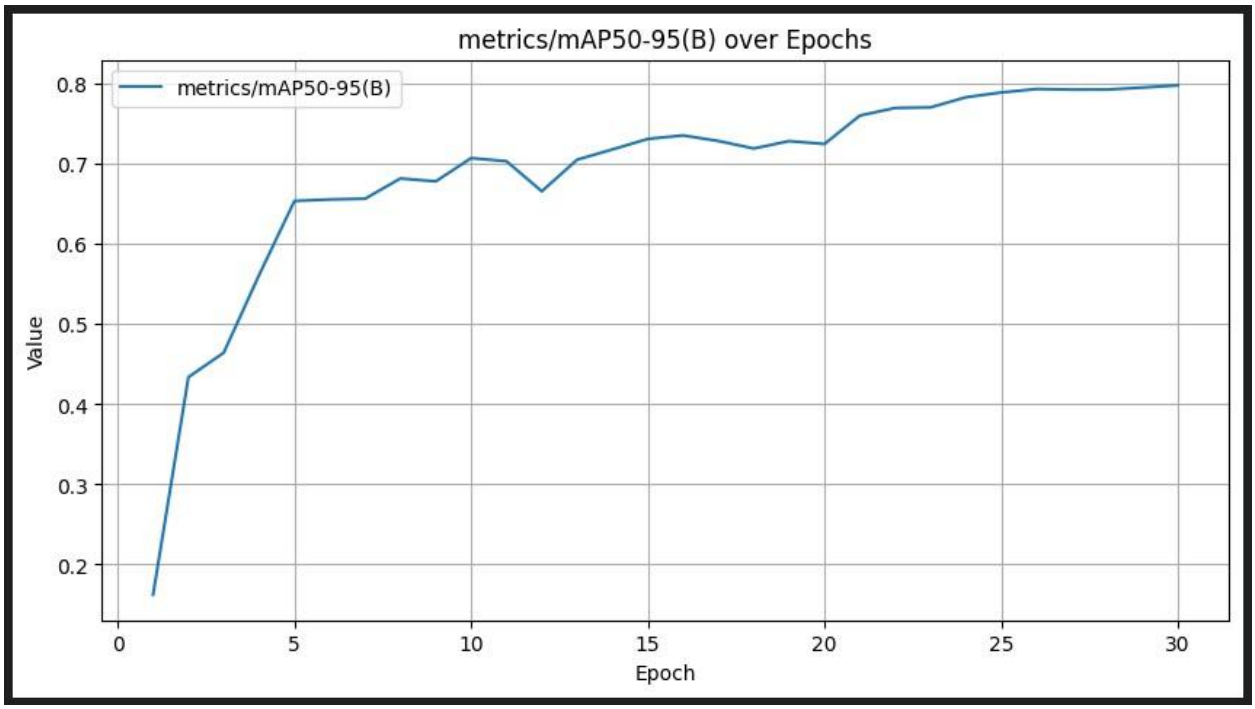
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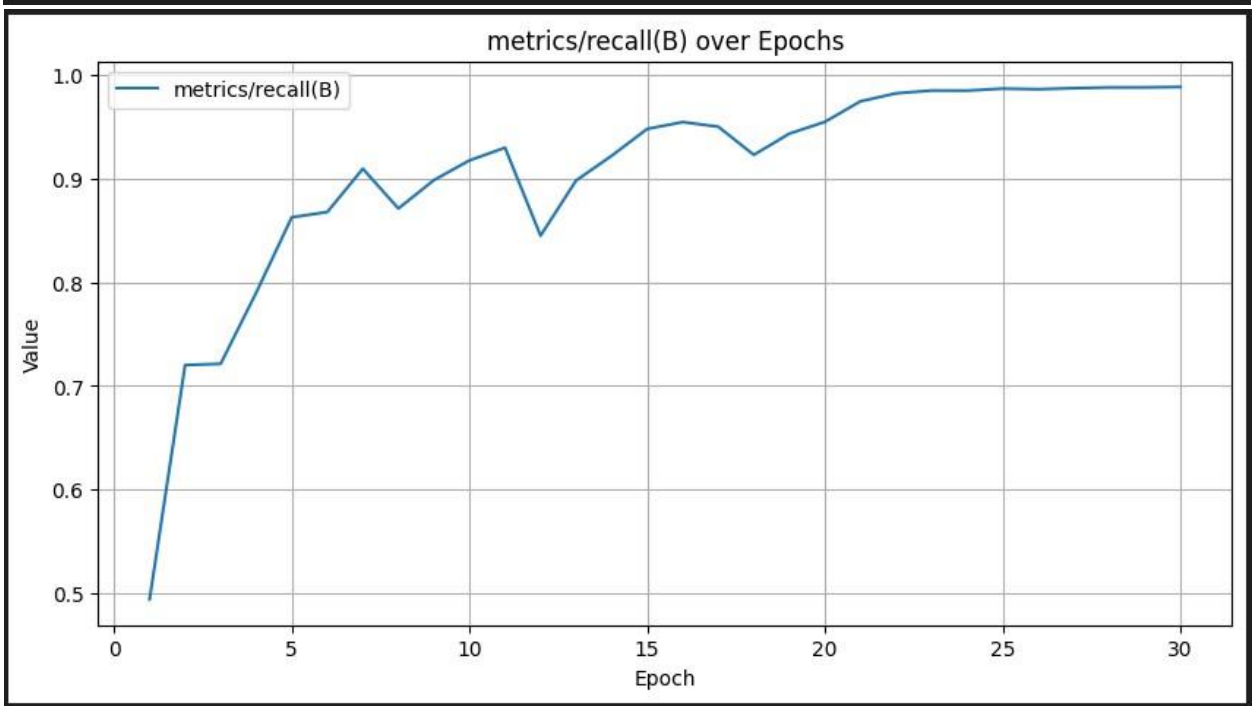
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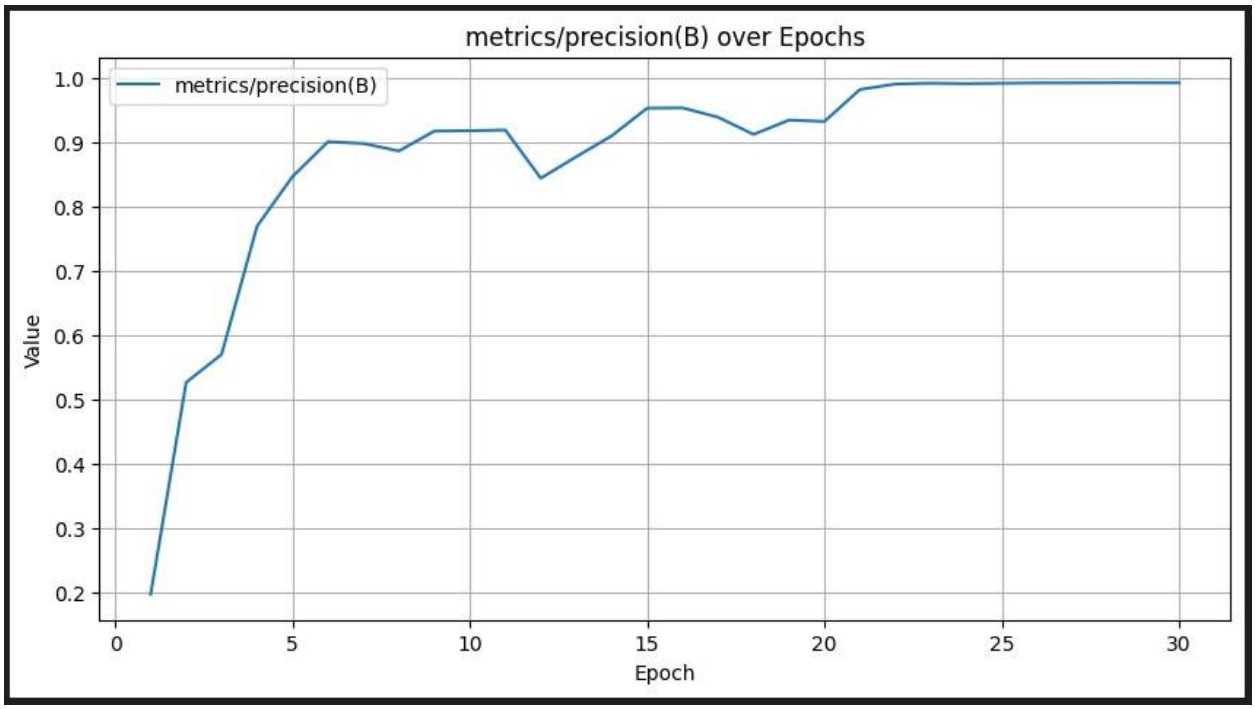
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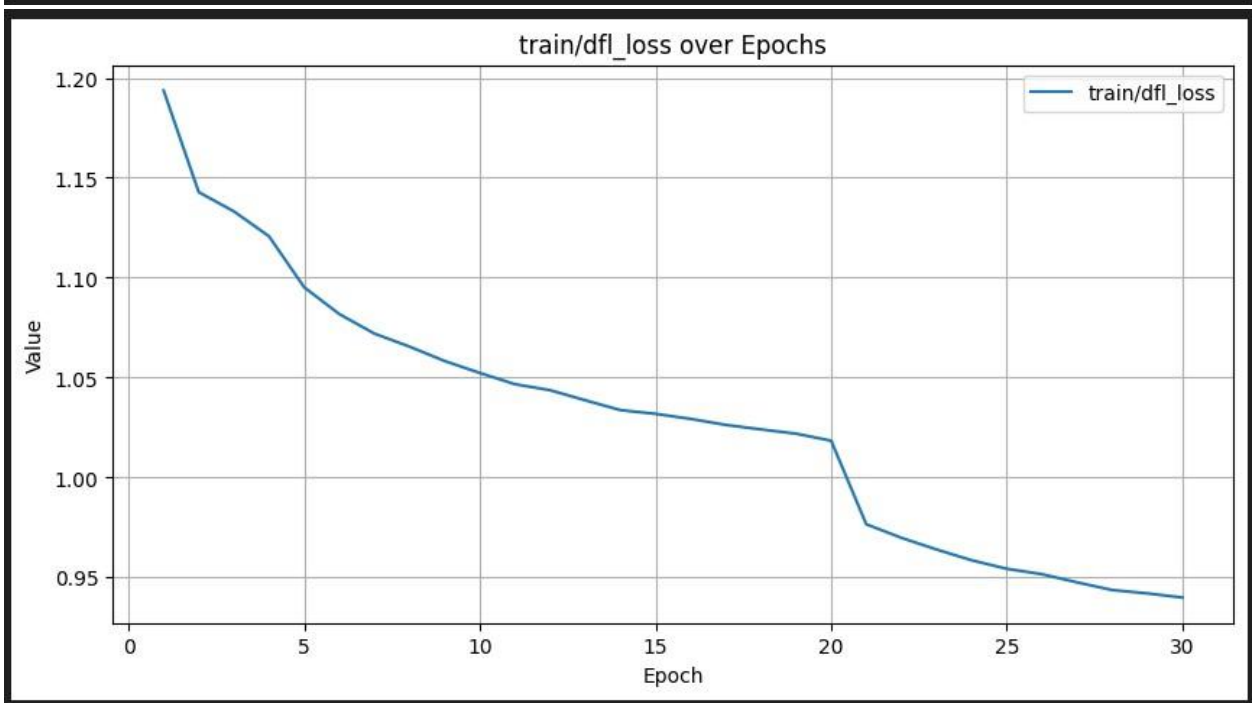
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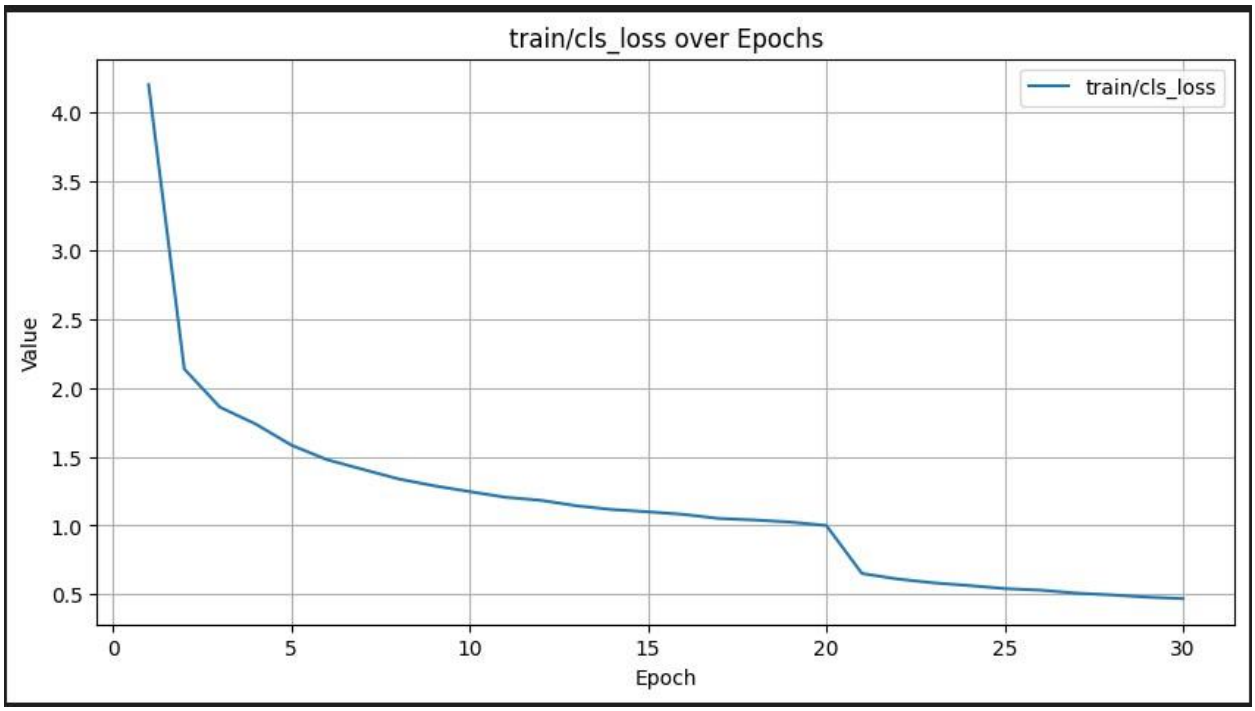
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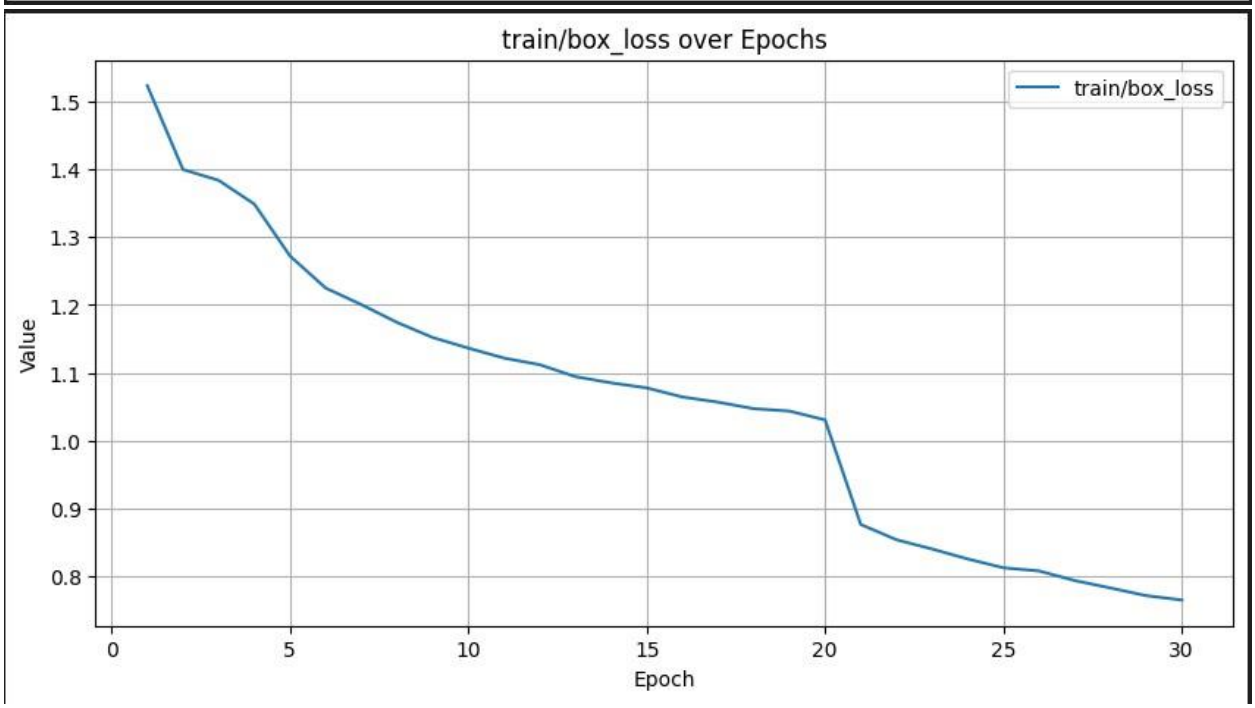
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Summary

This project aims to develop an automated product detection system using the YOLOv111 (You Only Look Once) computer vision model to improve inventory management in retail environments. Traditional methods of tracking inventory on shelves are often manual, time-consuming, and prone to errors, leading to stockouts, inefficient restocking, and potential shrinkage due to theft or misplaced items. By utilizing YOLOv11, which enables real-time object detection, the system will detect and classify products on retail shelves, providing continuous insights into product availability and shelf organization.

The system will automatically monitor inventory in real-time, helping retailers prevent stockouts, optimize restocking efforts, and reduce losses from shrinkage. It will also integrate with existing inventory management systems to trigger alerts and generate reports for better decision-making. The proposed solution leverages the efficiency of YOLOv11 to streamline retail operations, enhance customer satisfaction, and reduce labour-intensive processes in inventory management.