Automating Warehouse Inventory Management

By
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Abstract

Efficient inventory management is crucial for the smooth operation of warehouses in large retail and chain stores, where traditional methods of manual barcode scanning are often labor-intensive and prone to errors. This project addresses these challenges by developing an automated system that utilizes QR codes and computer vision techniques for inventory tracking. By implementing OpenCV to detect QR codes from images captured within Walmart's warehouse environment, the system processes and categorizes the data to identify warehouse sections and product details. Comprehensive reports are generated to facilitate accurate inventory management, and visualizations are created to provide clear insights into inventory distribution. This approach significantly enhances the accuracy and efficiency of inventory processes, reducing labor costs and improving decision-making and resource allocation.

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1. Introduction

Warehouse Inventory Management is the process of managing the storage, movement, and handling of goods within a warehouse or distribution center. It plays a critical role in supply chain management by ensuring that inventory is accurately.

Early inventory management practices were entirely manual, relying on simple tools like tally sticks and clay tokens to track goods. Tally sticks, essentially pieces of wood, were used by merchants to count items in inventory, while clay tokens represented different types of goods and were often used by accountants to monitor the movement of inventory within organizations. As businesses expanded and became more complex, the limitations of these rudimentary methods became apparent, leading to the development of more advanced systems.

The early 20th century marked a significant turning point in the history of inventory management with the introduction of mechanical systems. These early systems utilized punch cards and other mechanical devices to track inventory levels, marking the beginning of automation in inventory management. The advent of computers in the 1950s further revolutionized the field, enabling businesses to implement electronic inventory management systems that offered greater efficiency and the ability to track inventory in real time. By the 1980s, the introduction of relational databases allowed for the integration of inventory management with other key business functions, such as accounting and customer relationship management (CRM), creating more flexible and scalable systems.

The 1990s and 2000s saw the rise of web-based and cloud-based inventory management systems, which further transformed the field. The Internet made it possible for businesses to access inventory data from anywhere, facilitating collaboration with suppliers and customers on a global scale. Cloud computing took this evolution a step further by offering cloud-based inventory management systems that are hosted online, making them more affordable, accessible, and easier to use than traditional on-premises systems. Today, businesses of all sizes

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can choose from a wide range of inventory management systems tailored to their specific needs and budget, continuing the legacy of innovation in the field.

Inventory management in retail stores, especially large chain stores, presents significant challenges. Traditional methods of tracking inventory often involve manual scanning of product barcodes, which can be time-consuming and prone to human error. This process is particularly cumbersome in large warehouses such as Walmart, where the volume of products and frequency of stock changes require constant monitoring. Inefficiencies in inventory management can lead to issues such as stockouts, overstocking, and inaccurate inventory records, ultimately affecting overall operational efficiency and customer satisfaction. This project aims to address these challenges by developing an automated system that utilizes QR codes and computer vision techniques for inventory tracking.

Each QR code encapsulates a Universal Product Code. When the QR code is detected and processed, the embedded unique code is precisely extracted and identified, facilitating accurate product tracking and management.

QR codes present several key advantages over traditional barcodes, making them particularly well-suited for an automated inventory management system in large warehouses, like Walmart.

Firstly, QR codes have a significantly higher data storage capacity compared to barcodes. While a typical barcode might only hold a product's Universal Product Code (UPC), a QR code can store extensive information, including the product name, production date, expiration date, and more. This expanded capacity allows for more detailed and comprehensive tracking within the inventory management system. Additionally, QR codes offer the benefit of multi-directional scanning. Unlike barcodes, which must be precisely aligned with the scanner, QR codes can be scanned from any angle. This flexibility enhances the speed and efficiency of scanning processes, particularly in the fast-paced environment of a large warehouse. Moreover, QR codes integrate seamlessly with computer vision technologies and other automated systems, enabling real-time tracking and automatic updates to inventory records. This integration is vital for achieving the automation and accuracy improvements highlighted in this thesis. Finally, QR codes are versatile in size, allowing them to be printed compactly while still retaining their higher data capacity. This versatility makes them ideal for labeling a wide range of items and sections within a warehouse.

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By leveraging these advantages, QR codes enhance the efficiency, accuracy, and scalability of inventory management systems, effectively addressing the limitations of traditional barcode scanning methods.

By replacing traditional barcodes with QR codes and installing cameras in each section of a warehouse, images can be captured and analyzed to detect and decode QR codes using computer vision algorithms provided by the OpenCV library. The decoded information is then used to update inventory levels and generate comprehensive reports, significantly reducing the need for manual scanning and enhancing the accuracy and efficiency of inventory management processes.

The proposed system involves creating specific QR codes for warehouse sections and individual products, integrating these QR codes into the warehouse environment, and utilizing computer vision techniques to process images captured by the camera. This approach aims to reduce labor costs, improve decision-making, and enhance resource allocation, ultimately leading to more efficient inventory management in large retail stores.

This document outlines the development and implementation of this automated inventory management system, including the methodologies used, the challenges addressed, and the benefits achieved. The following sections provide a detailed overview of the project's goals, methodologies, and outcomes, offering a comprehensive understanding of the system's impact on improving inventory management processes in large retail warehouses.

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2. The Problem to be Solved

2.1. Challenges with Traditional Methods

2.1.1. Labor-Intensive Processes

At Walmart's extensive warehouse facilities, the traditional method of manual barcode scanning involves physically scanning each product. This process demands significant human effort and time, becoming increasingly cumbersome and inefficient as inventory volume grows. Such labor-intensive practices lead to delays in inventory updates and elevated labor costs.

2.1.2. Error-Prone Operations

Manual inventory management at Walmart is susceptible to human errors, including incorrect data entry, missed scans, and misidentification of products. These errors can cause inaccuracies in inventory records, resulting in stockouts, overstocking, and discrepancies between physical and recorded inventory levels.

2.1.3. Inaccurate Inventory Records

Dependence on manual scanning and data entry at Walmart often leads to inaccurate inventory records. This inaccuracy impacts operational efficiency, causing stock imbalances and complicating inventory level management.

2.1.4. Lack of Real-Time Updates

Traditional inventory management methods used by Walmart do not provide real-time updates of inventory levels. Consequently, inventory records may not reflect the current state of stock, leading to delayed decision-making and suboptimal resource allocation.

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3. The New Approach and Solution

3.1. Integration of QR Codes

Traditional barcodes used in Walmart’s inventory management are replaced with QR codes, which offer enhanced capacity for storing information and perform better under various scanning conditions. Each product and warehouse section within Walmart's warehouse is assigned a unique QR code, enabling precise and detailed identification of items and their locations.

3.2. Computer Vision Techniques

The system leverages advanced computer vision algorithms to detect and decode QR codes from images captured within Walmart’s warehouse environment. OpenCV, a leading computer vision library, is employed to ensure accurate and reliable detection and decoding of QR codes from warehouse images.

3.3. Automated Image Processing

Strategic placement of cameras throughout the warehouse allows for continuous capture of images of warehouse sections. These images are processed in real-time to identify and decode QR codes, thereby automating the inventory tracking process and eliminating the need for manual scanning by warehouse staff.

3.4. Data Handling and Reporting

Upon detecting and decoding QR codes, the system processes the data to update Walmart’s inventory records. It produces detailed and comprehensive reports and visualizations, including processed products report, unread products report, unread sections report, and inventory count charts. This automated reporting system enhances transparency in inventory management and provides valuable insights into inventory distribution and status.

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3.5.Impact and Benefits

Implementing the automated inventory management system is expected to deliver the following benefits:

Reduced Labor Costs: Automation decreases the need for manual labor, leading to significant cost savings.
Improved Accuracy: By minimizing human errors associated with manual scanning and data entry, the system ensures more accurate inventory records.
Increased Efficiency: The automated process accelerates inventory management, reducing the time required for stock tracking and updates.
Enhanced Decision-Making: Real-time updates and comprehensive reports provide valuable insights for better resource allocation and inventory management.
Integration with Other Systems: Integrating the automated inventory management system with various other systems can greatly enhance its functionality and effectiveness. By connecting with Enterprise Resource Planning (ERP) systems, the inventory system can achieve real-time data synchronization and automate reordering processes, streamlining workflows and maintaining optimal inventory levels. Integration with Warehouse Management Systems (WMS) will improve warehouse operations and tracking accuracy. Linking with Customer Relationship Management (CRM) systems provides real-time inventory updates to sales and customer service teams, enhancing customer service and offering valuable sales insights. Synchronizing with Point of Sale (POS) systems ensures immediate updates to inventory levels and facilitates detailed sales analytics. Integrating with e-commerce platforms helps prevent overselling and streamlines order fulfillment. Additionally, connecting with Supply Chain Management (SCM) and Transportation Management Systems (TMS) improves supply chain visibility and logistics efficiency. Financial Management Systems integration supports accurate financial reporting and cost analysis, while Human Resource Management (HRM) systems integration aids in effective labor management and compliance. Lastly, incorporating Analytics and Business Intelligence (BI) tools allows for advanced data analysis and customized dashboards, supporting better decision-making and strategic planning.

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4. Methodology

4.1. Implementation Steps

4.1.1. Setup Environment

- **Purpose**: Ensure the necessary software and libraries are installed and the project directory is structured correctly.
- **Activities**:
  - ❖ Install required Python libraries (pandas, matplotlib, opencv-python).
  - ❖ Organize the project directory into logical folders (e.g., initialDataset, results, reports).

4.1.2. Image Processing

- **Purpose**: Detect and decode QR codes from warehouse images.
- **Activities**:
  - ❖ **Image Collection:** Gather and place all relevant images in the initialDataset/images/ directory.
  - ❖ **QR Code Detection:**
    - Load each image using OpenCV.
    - Detect and decode QR codes using OpenCV's QRCodeDetector.
    - Differentiate between section QR codes and product QR codes.
    - Store the detected information in a structured format.

4.1.3. Data Handling

- **Purpose**: Load and manage the data necessary for report generation.
- **Activities**:
  - ❖ **Load JSON Data:**
    - Load product details from productsList.json.
    - Load warehouse section details from warehouseSections.json.
  - ❖ **Save JSON Data:**

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- Save the processed QR code data into results/imageProcessingResult.json.

4.1.4. Report Generation

- **Purpose**: Analyze the processed data and generate reports on inventory status.
- **Activities**:
  - ❖ **Generate Processed Products Report:**
    - Match detected product QR codes with the product list.
    - Save the matched product details to an Excel file (reports/processed_products.xlsx).
  - ❖ **Generate Unread Products Report:**
    - Identify products in the product list that did not exist in the warehouse sections.
    - Save the details of unread products to an Excel file (reports/unread_products.xlsx).
  - ❖ **Generate Unread Sections Report:**
    - Identify warehouse sections that were not detected in any image.
    - Save the details of unread sections to an Excel file (reports/unread_sections.xlsx).

4.1.5. Data Visualization

- **Purpose**: Create visual representations of the inventory data to facilitate analysis and decision-making.
- **Activities**:
  - ❖ **Generate Inventory Count Chart:**
    - Load the processed products data from the Excel file.
    - Use Matplotlib to create a bar chart showing the count of product boxes by section.
    - Save the chart as an image file (reports/inventory_count_by_section.jpg).

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5. Initial Dataset

5.1. Products List

The `initialDataset/ProductsList.json` file contains detailed information about 514 products at Walmart. Each product record includes essential attributes such as Product Title, Unit Cost, UPC. The product title denotes the name of the item, while the unit cost indicates the price per individual unit. The UPC, or Universal Product Code, serves as a unique identifier for each product. These details are essential for generating QR codes and facilitating accurate identification within the inventory management system. This information is pivotal in ensuring that each product is efficiently tracked and managed throughout the inventory process.

Sample product


```
[
	{
		"Vendor Stk Nbr": "116113",
		"Item Status": "A",
		"Acct Dept Nbr": 92,
		"Item Nbr": 30364361,
		"UPC": "00884282229 62",
		"Product title": "ALOOATTA DIWALI NUTS GIFT PACK",
		"Size Desc": "390",
		"WHPK Qty": 20,
		"Unit Cost": 7.25,
		"Unit Retail": 7.97,
		"MU %": 0.090339,
		"WHPK Cost": 145
	},
	...
]
```


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5.2.Warehouse Sections

The `initialDataset/warehouseSections.json` file enumerates various sections within Walmart's warehouse, each identified by a unique section code. These sections are structured as an array of JSON objects, where each object contains a "section" key specifying the section code. The sections are organized sequentially from "S101-001-001" to "S101-001-062".

The use of these unique codes enables systematic organization within the warehouse, facilitating the precise location and identification of specific areas. By segmenting the warehouse into distinct sections, these codes ensure a structured and orderly environment. This level of organization is critical for efficient inventory management, as it allows for the rapid and accurate identification of various warehouse zones. Consequently, this dataset is integral to maintaining smooth and efficient warehouse operations.

Sample Section

```
[
	{
		"section": "S101-001-001"
	},
	...
]
```

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5.3.Images folder

The `initialDataset/images` folder contains 58 image files documenting various sections of Walmart’s warehouse. Each image captures a specific warehouse section, featuring QR codes used for automated identification and tracking. These images are crucial for the system's ability to detect and decode QR codes, ensuring accurate and efficient real-time updates to warehouse records without manual scanning.

Figure 1. Sample Image

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6. Project Code Overview

6.1. Main Code

```
# main.py
from imageProcessing import process_images
from jsonHandling import load_json_data
from reportGeneration import (
   generate_read_products_report,
   generate_unread_products_report,
   generate_unread_sections_report,
   generate_inventory_count_chart
)

# Step 1: Process images to detect QR codes and save data to JSON
process_images('initialDataset/images', 'results/imageProcessingResult.json')

# Step 2: Load the saved QR code data and JSON data for products and warehouse
sections
image_processing_result = load_json_data('results/imageProcessingResult.json')
products_list = load_json_data('initialDataset/productsList.json')
warehouse_sections = load_json_data('initialDataset/warehouseSections.json')

# Step 3: Generate reports
generate_read_products_report(image_processing_result, products_list)
generate_unread_products_report(image_processing_result, products_list)
generate_unread_sections_report(image_processing_result, warehouse_sections)

# Step 4: Generate inventory count chart
generate_inventory_count_chart()
```

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6.2.The main steps

6.2.1. Step 1: Process Images to Detect QR Codes

Code: imageProcessing.py
Function: `process_images(image_folder, output_json)`
Goal: Detect QR codes in images stored in a specified folder and save the data to a JSON file.
Process:

- **Image File Collection:** The glob library is employed to retrieve a list of all image files with the .jpg extension from the specified folder. This allows for batch processing of images stored in the designated directory.
- **QR Code Detection:** For each image file, the detect_qr_codes function is invoked. This function processes the image to identify and decode QR codes present in it.
- **Data Categorization:** Detected QR codes are organized into two categories:
  - **Section Code:** Represents the section of the warehouse or storage area where the image was taken.
  - **Product QR Codes:** Represents the unique QR codes associated with products.
- **Data Storage:** The results for each image are compiled into a list of dictionaries. Each dictionary includes:
  - **image_file:** The filename of the processed image.
  - **section:** The section code extracted from the image.
  - **qrcode**: A list of decoded QR codes found in the image.
- **Saving Results:** The compiled data is saved to a JSON file using the save_to_json function. This JSON file contains all the detected QR codes, categorized by their corresponding image files and sections.

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Sample Output


```
[
    {
        "image_file": "initialDataset/images/48.jpg",
        "section": "S101-001-048",
        "qrcode": [
            "0890115512211",
            "0890115514422",
            "0890115510921",
            "0890115540631",
            "0890115511021",
            "0890115541431",
            "0890115530144",
            "0890115511521",
            "0890115511821",
            "0890115511521",
            "0890115512211",
            "0890115542731",
            "0890115530144",
            "0890115544131",
            "0890115541431",
            "0890115512211",
            "0890115541431",
            "0890115511621",
            "0890115510811",
            "0890115511521",
            "0890115530144",
            "0890115511621",
            "0890115511521",
            "0890115511621"
        ]
    },
    {
        "image_file": "initialDataset/images/49.jpg",
        "section": "S101-001-049",
        "qrcode": [
            "0890115510522",
            "0890115548441",
            "0890115548341",
            "0890115510221",
            "0890115511121",
            "0890115511121",
```


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```
            "0890115511411",
            "0890115510421",
            "0890115511311",
            "0890115510721",
            "0890115510621",
            "0890115548441"
        ]
    },
        ...
]
```

This output demonstrates the successful processing of images to detect and categorize QR codes, which are then systematically saved in 'results/imageProcessingResult` a JSON format for further analysis and integration. This includes the image file, section code, and UPC. The image file shows the directory address of the images. The section code identifies the specific warehouse section where the products are located, and UPCs show the product's unique codes to identify each specific product box. This structured format makes it easier for further analysis and integration into the system. The process ensures that the data is organized and ready for the next steps. This organized data can be used to improve the overall inventory management system.

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6.2.2. Step 2: Load JSON Data

Code: jsonHandling.py
Functions: `load_json_data(json_path)`
Goal: Load JSON data from files for further processing.
Process: The function reads: 'results/imageProcessingResult.json`, 'initialDataset/productsList.json' and 'initialDataset/warehouseSections.json', and returns them as a Python dictionary.

6.2.3. Step 3: Generate Reports

Code: reportGeneration.py
Function 1: `generate_read_products_report(image_processing_result, products_list)`
Goal: Generate a report of read products and save it as an Excel file.
Process:

- For each QR code entry, match the product QR codes with the product list.
- Create a list of matched products, including their section codes and other relevant details.
- Save it as an Excel file.

Function 2: `generate_unread_products_report(image_processing_result, products_list)`
Goal: Generate a report of unread products and save it as an Excel file.
Process:

- Identify products that were not matched with any QR code.
- Create a list of these unread products.
- Save it as an Excel file.

Function 3: `generate_unread_sections_report(image_processing_result, warehouse_sections)`
Goal: Generate a report of unread sections and save it to an Excel file.
Process:

- Identify sections that were not detected in any image.
- Create a list of these unread sections.
- Save it as an Excel file.

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6.2.4. Step 4: Generate Inventory Count Chart

Code: reportGeneration.py
Function: `generate_inventory_count_chart()`
Goal: Create a bar chart visualizing the count of inventory by section.
Process:

- Load the read product data from the Excel file.
- Use `pandas` to count the number of products in each section.
- Plot the data using `matplotlib`.
- Save the chart as an image file.

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7.Project Functions

7.1.detect_qr_codes(image_path)

Description: This function uses computer vision techniques to detect QR codes within an image. It reads the image specified by image_path, applies QR code detection algorithms, and returns decoded information from any QR codes found.
Libraries Used:

- **cv2 (OpenCV):** Provides functions for image loading (cv2.imread()), QR code detection (cv2.QRCodeDetector()), and geometric transformations (cv2.polylines()).

```
import cv2              # Computer Vision library for image processing

def detect_qr_codes(image_path):
    """
    Detect QR codes in an image using OpenCV.

    Parameters:
    image_path (str): Path to the image file.

    Returns:
    list: Decoded information from QR codes found in the image.
    """
    # Load the image
    image = cv2.imread(image_path)

    # Initialize the QRCodeDetector
    qr_detector = cv2.QRCodeDetector()

    # Detect and decode QR codes in the image
    retval, decoded_info, points, _ = qr_detector.detectAndDecodeMulti(image)

    if len(decoded_info) > 0:
        for i in range(len(decoded_info)):
            qr_points = points[i]

            # Draw a rectangle around the detected QR code
            cv2.polylines(image, [qr_points.astype(int)], True, (255, 0, 0), 2)
    else:
```

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```
        return []

    return decoded_info
```

7.2.process_images(image_folder, output_json)

Description: This function processes a folder of images (image_folder) to detect QR codes in each image. It compiles the results into a structured JSON format and saves them to the output_json file. It handles each image file individually, detecting QR codes and storing relevant data such as the image file path, section code, and QR codes detected.

Libraries Used:

- **cv2 (OpenCV):** For image processing and QR code detection.
- **glob:** For file path handling and iterating through image files (glob.glob()).

```
import os               # Operating system functions
import cv2              # Computer Vision library for image processing
import glob             # File path management
from jsonHandling import save_to_json

def process_images(image_folder, output_json):
    """
    Process images to detect QR codes and save data to a JSON file.

    Parameters:
    image_folder (str): Path to the folder containing images.
    output_json (str): Path to the output JSON file.
    """
    image_files = glob.glob(os.path.join(image_folder, '*.jpg'))
    qr_data = []

    for file_path in image_files:
        try:
            # Detect QR codes in the image
            qr_codes = detect_qr_codes(file_path)

            if qr_codes:
                section_code = ""
```

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```
            product_qr_codes = []

            # Identify section and product QR codes
            for code in qr_codes:
                if code.upper().startswith('S') and not section_code:
                    section_code = code
                else:
                    product_qr_codes.append(code)

            qr_data.append({
                "image_file": file_path,
                "section": section_code,
                "qrcode": product_qr_codes
            })
        else:
            print(f"No QR Codes detected in {file_path}")

    except Exception as e:
        print(f'Error processing file {file_path}: {e}')

save_to_json(qr_data, output_json)
```

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7.3.save_to_json(data, file_path)

Description: Saves data provided in the data parameter to a JSON file specified by file_path. It formats the data as JSON and writes it to the file for later retrieval or analysis.

Libraries Used:

- **json:** Standard Python library for encoding and decoding JSON data (json.dump()).

```
import json            # JSON file handling

def save_to_json(data, file_path):
    """
    Save data to a JSON file.

    Parameters:
    data (list): Data to be saved.
    file_path (str): Path to the JSON file.
    """
    with open(file_path, 'w') as file:
        json.dump(data, file, indent=4)
```

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7.4.load_json_data(json_path)

Description: Loads JSON data from a file specified by json_path and returns it as a Python dictionary. This function is used to retrieve previously stored JSON data for further processing or analysis.

Libraries Used:

- **json:** Standard Python library for reading JSON data (json.load()).

```
import json            # JSON file handling

def load_json_data(json_path):
    """
    Load JSON data from a file.

    Parameters:
    json_path (str): Path to the JSON file.

    Returns:
    dict: JSON data loaded as a Python dictionary.
    """
    with open(json_path, 'r') as file:
        return json.load(file)
```

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7.5.generate_read_products_report(qr_data, products_list)

Description: Generates a report of products for which QR codes were detected in the images. It matches QR codes found in qr_data with products from products_list and creates a detailed report including image file paths, section codes, UPCs, product titles, and costs. This report is then saved as an Excel file (processed_products.xlsx).

Libraries Used:

- **pandas:** For creating and manipulating DataFrames (pd.DataFrame()).
- **matplotlib.pyplot:** For data visualization, specifically for creating bar charts to visualize inventory counts by section.

```
import pandas as pd    # Data manipulation and analysis

def generate_read_products_report(qr_data, products_list):
   """
   Generate and save the read products report.

   Parameters:
   qr_data (list): QR code data.
   products_list (list): List of products.
   """
   read_products = []
   for entry in qr_data:
       section_code = entry["section"]
       product_qr_codes = entry["qrcode"]

       if section_code:
           matched_items = [item for item in products_list if item.get("UPC") in
product_qr_codes]

           if matched_items:
               for item in matched_items:
                   product_obj = {
                       "image_file": entry["image_file"],
                       "section_code": section_code,
                       "UPC": item["UPC"],
                       "Product title": item["Product title"],
                       "Cost": item["Unit Cost"]
                   }
                   read_products.append(product_obj)
```

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```
    # Convert the matched products list to a DataFrame
    df_processed_products = pd.DataFrame(read_products)

    # Save the DataFrame of matched products to an Excel file
    df_processed_products.to_excel('reports/processed_products.xlsx', index=False)
```

7.6.generate_unread_products_report(qr_data, products_list)

Description: Generates a report listing products for which did not exist in the warehouse section images. It compares QR codes found in qr_data with products from products_list to identify unmatched products. This report includes UPCs, product titles, and costs of products that do not exist in the warehouse and is saved as an Excel file (unread_products.xlsx).

Libraries Used:

- **Pandas:** For creating and manipulating DataFrames (pd.DataFrame()).

```
import pandas as pd    # Data manipulation and analysis

def generate_unread_products_report(qr_data, products_list):
    """
    Generate and save the unread products report.

    Parameters:
    qr_data (list): QR code data.
    products_list (list): List of products.
    """
    read_products = []
    for entry in qr_data:
        section_code = entry["section"]
        product_qr_codes = entry["qrcode"]

        if section_code:
            matched_items = [item for item in products_list if item.get("UPC") in
product_qr_codes]

            if matched_items:
                for item in matched_items:
                    read_products.append(item["UPC"])
```

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```
    unread_products = []

    processed_upcs = {upc for upc in read_products}
    for product in products_list:
        if product["UPC"] not in processed_upcs:
            unread_products.append({
                "UPC": product["UPC"],
                "Product title": product["Product title"],
                "Cost": product["Unit Cost"]
            })

    # Convert unread products list to a DataFrame
    df_unread_products = pd.DataFrame(unread_products)

    # Save unread products data to an Excel file
    df_unread_products.to_excel('reports/unread_products.xlsx', index=False)
```

7.7.generate_unread_sections_report(qr_data, warehouse_sections)

Description: Generates a report listing sections in the warehouse for which no QR codes were detected in the images. It compares sections from warehouse_sections with section codes found in qr_data to identify unread sections. This report is saved as an Excel file (unread_sections.xlsx).

Libraries Used:

- **Pandas:** For creating and manipulating DataFrames (pd.DataFrame()).

```
import pandas as pd    # Data manipulation and analysis

def generate_unread_sections_report(qr_data, warehouse_sections):
    """
    Generate and save the unread sections report.

    Parameters:
    qr_data (list): QR code data.
    warehouse_sections (list): List of warehouse sections.
    """
    read_sections = {entry["section"] for entry in qr_data}
```

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```
    unread_sections = [{'section': section['section']} for section in warehouse_sections
if section['section'] not in read_sections]

    # Convert unread sections to a DataFrame
    df_unread_sections = pd.DataFrame(unread_sections)

    # Save unread sections data to an Excel file
    df_unread_sections.to_excel('reports/unread_sections.xlsx', index=False)
```

7.8.generate_inventory_count_chart()

Description: Creates a bar chart to visualize inventory counts by section based on the processed data. It reads the data from processed_products.xlsx (generated by generate_read_products_report()), calculates the number of product boxes in each section, and visualizes this information using a bar chart. The chart is saved as an image file (inventory_count_by_section.jpg).
Libraries Used:

- **Pandas:** For reading data from Excel (pd.read_excel()).
- **matplotlib.pyplot:** For data visualization, specifically for creating bar charts (plt.bar()).

```
import matplotlib.pyplot as plt  # Data visualization

def generate_inventory_count_chart():
    """
    Generate a bar chart to visualize inventory counts by section.
    """
    df_processed_products = pd.read_excel('reports/processed_products.xlsx')
    inventory_counts = df_processed_products['section_code'].value_counts()
    inventory_counts.plot(kind='bar')
    plt.xlabel('Section Code')
    plt.ylabel('Number of Boxes')
    plt.title('Inventory Count by Section')
    plt.savefig('reports/inventory_count_by_section.jpg')
    plt.show()
```

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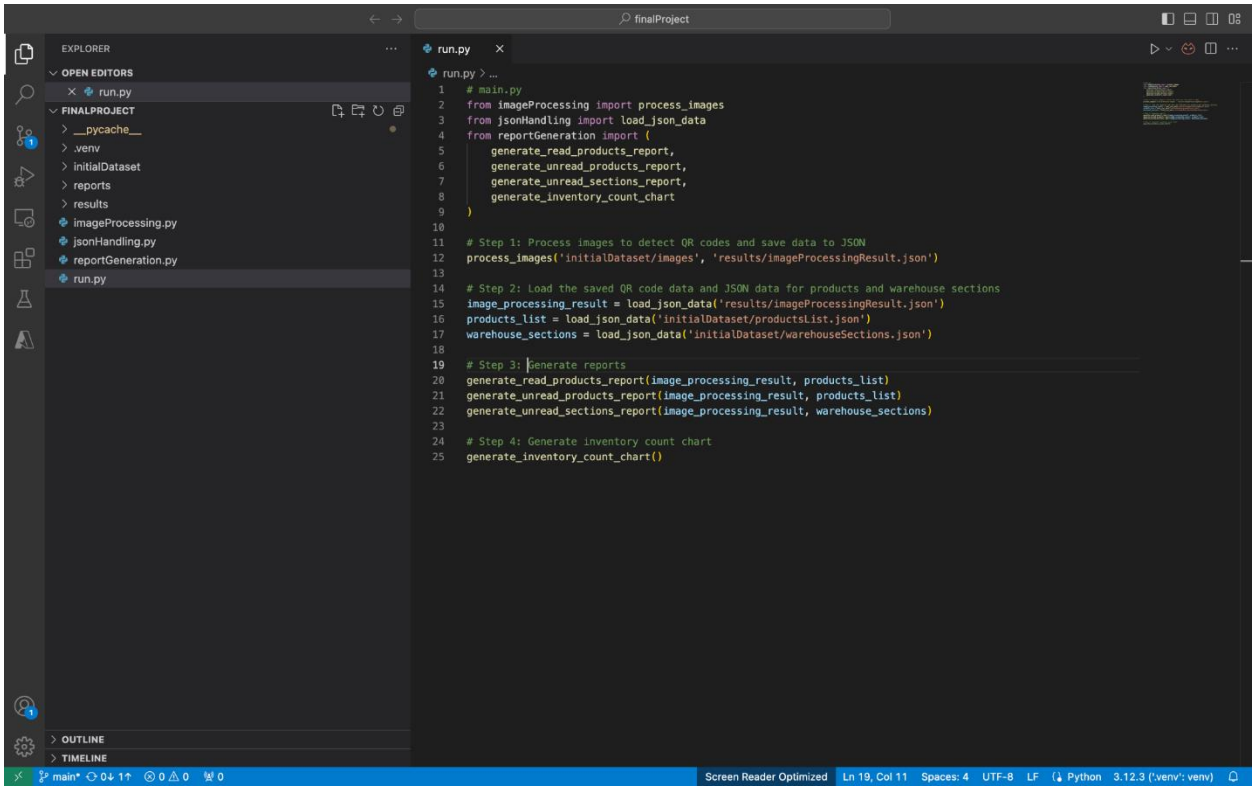
8. Code Execution

To execute the project, simply run the `run.py` script. This script orchestrates the entire process in a systematic manner. The execution of `run.py` ensures a seamless flow from image processing to comprehensive report generation and visualization.

Figure 2. `run.py` script



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9. Analysis and Comparisons

9.1. Analysis

9.1.1. Performance of QR Code Detection

The use of OpenCV for QR code detection in Walmart's warehouse proved effective, with a high success rate in detecting and accurately decoding QR codes. The system performed well across varying image qualities and lighting conditions, though some challenges were noted in extremely low-light environments or when images had significant obstructions.

9.1.2. Data Processing and Reporting

The pipeline for data processing, from QR code detection to report generation, was efficient and accurate. Walmart's JSON data handling and Excel report generation functions performed reliably, ensuring correct inventory data matching and reporting. However, processing very large volumes of images may require additional optimization for improved performance.

9.1.3. Visualization and Insights

The inventory count charts generated by the system provided clear and actionable insights into inventory distribution. These visualizations helped identify sections with high or low inventory levels, supporting better resource allocation and decision-making for inventory management.

9.2. Comparisons

9.2.1. Traditional Manual Inventory Management vs. Automated System

Accuracy: Traditional manual inventory management is prone to human errors such as incorrect data entry and missed scans. The automated system significantly reduces these errors through precise QR code detection and processing.

Efficiency: Manual methods were time-consuming and labor-intensive. The automated system enhances efficiency by quickly processing images and updating

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inventory records, resulting in substantial time savings and a more streamlined workflow.

Cost: Manual inventory management involves ongoing labor costs. The automated system reduces these costs by minimizing manual labor, making it a more cost-effective solution in the long run.

9.2.2. Automated Systems vs. Other Automated Technologies

Barcode Systems: While traditional barcode systems offer some automation, they still require line-of-sight scanning and are less versatile than QR codes, which can store more information and be read from various angles.

RFID Systems: RFID systems offer similar benefits in automation and data accuracy but are typically more expensive to implement than QR codes. The choice between QR codes and RFID depends on specific needs and budget considerations, with QR codes offering a more cost-effective solution while still providing robust functionality.

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10. Final Reports and Result

10.1. Processed Products Report

The Processed Products Report for Walmart identifies and records products whose QR codes have been successfully detected and decoded in the warehouse images. It lists the products along with their corresponding section codes, UPCs, product titles, and costs. The product list and image processing results serve as the primary data sources for this report. The product list offers comprehensive details about the items, while the image processing results identify the specific products detected within various warehouse sections. By integrating these data sources, the report facilitates a thorough analysis and comparison of the information, ensuring the accuracy and currency of inventory data within the Walmart store.

This report provides critical insights into the correct mapping of products to their corresponding warehouse sections. Such mapping is essential for maintaining accurate inventory records. Furthermore, the report aids in strategic decision-making by identifying products that may be understocked in the warehouse. It offers actionable insights that support decisions regarding product reordering.

By leveraging the findings of this report, inventory levels can be more effectively managed, thereby minimizing the risk of stockouts. The report, therefore, plays a pivotal role in enhancing planning processes and optimizing overall inventory management.

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Table 1. Processed Products

image_file	section_code	UPC	Product title	Cost
images/48.jpg	S101-001-048	0890115544131	GITS PANEER MAKHANI.	2.05
images/48.jpg	S101-001-048	0890115540631	GITS PAV BHAJI.	1.5
images/48.jpg	S101-001-048	0890115512211	GITS RABDI.	1.3
images/48.jpg	S101-001-048	0890115511021	GITS RAVA DOSAI MIX	1.1
images/48.jpg	S101-001-048	0890115510921	GITS RAVA IDLE MIX	1.1
images/48.jpg	S101-001-048	0890115514422	GITS ROSE FALOODA.	1.42
images/48.jpg	S101-001-048	0890115510811	GITS SAMBHAR.	1.1
images/48.jpg	S101-001-048	0890115511621	GITS UPMA 200G	1.1
images/48.jpg	S101-001-048	0890115511821	GITS UTTAPAM - 200G	1.1
images/48.jpg	S101-001-048	0890115541431	GITS VEGETABLE BIRYANI.	1.5

This report identifies and records products with successfully detected and decoded QR codes in warehouse images, listing their section codes, UPCs, product titles, and costs.

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10.2. Unread Products Report

The Unread Products Report lists products that didn't exist in the warehouse images. This report was created using the product list and the image processing results. It aims to identify products that are in the product list but do not appear in the image processing results.

The report includes key details such as Universal Product Codes (UPCs), product titles, and costs. This information is instrumental in identifying products that are currently out of stock. Prompt reordering of these out-of-stock items is essential for maintaining optimal inventory levels and ensuring that the warehouse is adequately supplied.

The Unread Products Report is vital for effective inventory management, as it helps prevent stockouts by ensuring that all necessary products are available in the warehouse. By facilitating timely reordering, the report plays a crucial role in sustaining a well-stocked inventory and supporting the overall efficiency of warehouse operations.

Table 2. Unread Products

UPC	Product title	Cost
0040050134525	BIKAJI SOAN PAPDI	3.75
0088428211018	SUGRAIN GOLDEN YELLOW SUGAR	2.25
0088428211009	SUGRAIN ICING SUGAR	2.35
0008464394005	TEA INDIA 216 CLUB PACK.	7.81
0008464394102	TEA INDIA CARDAMOM CHAI	4.5
0008464393289	TEA INDIA CARDAMON CHAI	3.92

This report lists products that did not exist in the warehouse sections, including their UPCs, titles, and costs.

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10.3. Unread Sections Report

The final report is the Unread Sections Report, which identifies warehouse sections that were not detected by QR codes in the images or where image capture was problematic. This report was generated by analyzing the warehouse section data in conjunction with the image processing results. It highlights areas where QR code detection may have failed, assisting in identifying sections that may require new images to be captured. Additionally, the report pinpoints areas where the camera encountered difficulties, providing valuable information for assessing and rectifying potential issues with the camera equipment.

This report is crucial for ensuring comprehensive monitoring of all warehouse sections. By identifying sections that may not be fully covered, the report supports efforts to maintain complete and accurate inventory tracking.

Table 3. Unread Sections

section
S101-001-015
S101-001-021
S101-001-030
S101-001-044
S101-001-059
S101-001-060
S101-001-061
S101-001-062

This report highlights sections not detected by QR codes, providing an overview of areas needing further detecting or verification.

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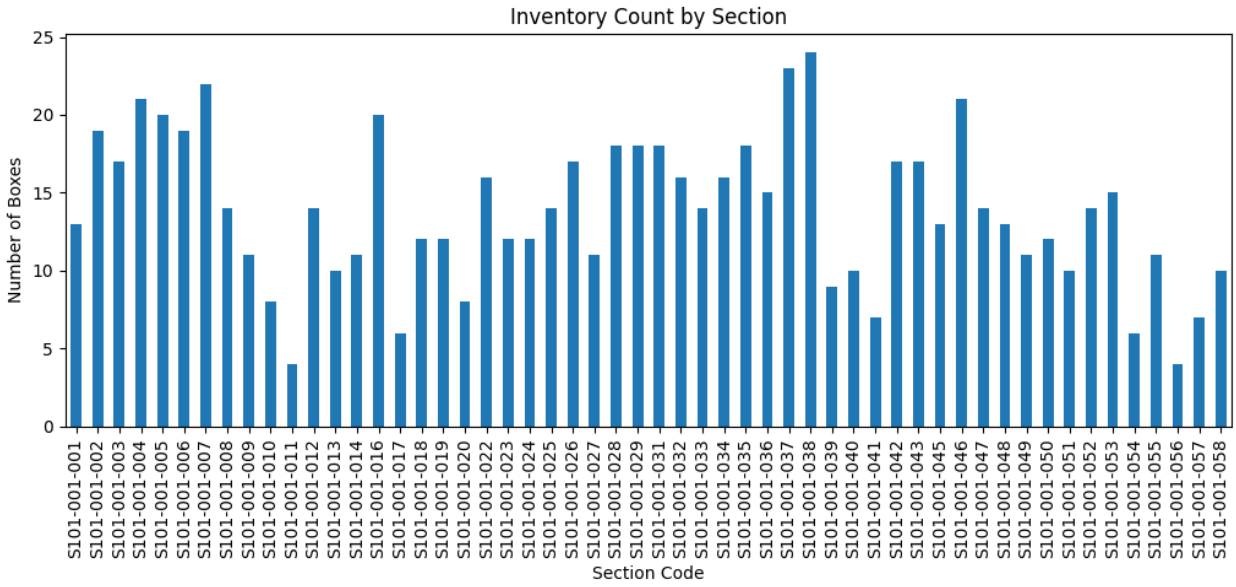
11. Final chart

11.1. Inventory Count Chart

This section discusses the final chart, the Inventory Count Chart, which visualizes the distribution of inventory across various sections of the Walmart warehouse. The chart is presented as a bar chart, where each bar represents the number of inventory boxes per section. The data for this chart is derived from the product list and image processing results.

The Inventory Count Chart provides a clear depiction of the quantity of products stored in each warehouse section. It facilitates the identification of sections with either an excess or a shortage of inventory, thereby supporting more informed resource allocation and enhancing decision-making in inventory management.

Figure 3. Inventory Count Chart



This chart visualizes the distribution of inventory counts across sections, showing the number of boxes per section with a bar chart.

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12. Conclusion

The implementation of an automated inventory management system using QR codes and computer vision significantly enhances the accuracy and efficiency of warehouse operations. Traditional manual methods of inventory tracking are prone to errors and inefficiencies, leading to issues such as stock discrepancies and increased labor costs. By integrating QR codes and utilizing computer vision technology through the OpenCV library, this project addresses these challenges effectively, as demonstrated in the Walmart store where it was implemented.

The system's ability to detect and decode QR codes from Walmart's warehouse images allows for real-time updates to inventory records. This not only reduces the dependency on manual scanning but also ensures that inventory data is more accurate and up to date. The automated approach streamlines the inventory management process, minimizes human error, and provides detailed reports and visualizations that aid in better decision-making.

The project demonstrates that leveraging modern technologies such as QR codes and computer vision can lead to substantial improvements in inventory management practices, not only at Walmart but also in other large retail and chain store warehouses.

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13. Future Work

Advanced Image Processing Algorithms and Machine Learning: Future improvements to the automated inventory management system could focus on integrating more sophisticated image processing techniques, such as convolutional neural networks (CNNs) or deep learning models, the system could achieve higher accuracy in detecting QR codes, even in challenging conditions like low lighting or occlusions. Machine learning algorithms could also be employed to continually improve the accuracy and efficiency of QR code recognition over time by learning from past errors and successes.

Integration of IoT Devices: The incorporation of Internet of Things (IoT) devices, such as smart cameras equipped with advanced imaging sensors and environmental sensors (e.g., temperature, humidity), could greatly enhance real-time monitoring and data collection. Smart cameras would provide high-resolution images and video feeds, enabling more precise inventory tracking, while environmental sensors could monitor the conditions of storage areas, ensuring optimal environments for different types of products.

Real-Time Analytics and Interactive Dashboards: Expanding the system's capabilities to include real-time analytics would allow for immediate analysis of inventory data as it is collected, providing insights into inventory levels, stock movements, and potential issues as they arise. Interactive dashboards could be developed to allow users to customize and visualize data according to their specific needs, making it easier to identify trends, spot anomalies, and make informed decisions quickly.

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