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# The Impact and Implementation of LED-Based Inventory Spotting Platform

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**Abstract**: Implementing a cost effective LED light system for inventory picking in retail stores can significantly enhance restocking efficiency. By motorizing an LED Light system to illuminate specific inventory items using a LED spotlight in the warehouse, associates can swiftly locate and pick items, reducing time and effort. This system eliminates the need for smartphones or apps, providing a straightforward visual cue for restocking needs and out-of-stock items. The LED-based inventory spotting system addresses the challenges of stock delays, customer dissatisfaction, and operational inefficiencies in inventory management. It offers a hands-free and clearer way to display pick suggestions, enhancing picking accuracy and efficiency. With its potential to minimize stocking delays and increase customer satisfaction, this system represents a significant advancement in retail inventory management practices.

**Keywords**: Ecommerce, Artificial Intelligence, Robotics, Image recognition, AR, Inventory management

## 1. INTRODUCTION

The efficient management of inventory is a critical aspect of success for retail businesses. Timely restocking of shelves is paramount to meeting customer demands and maintaining high levels of customer satisfaction. However, the traditional methods of inventory picking and restocking often face challenges such as inefficiencies, delays, and inaccuracies. These challenges not only impact the bottom line of businesses but also affect the overall customer experience.

In a retail environment where every minute counts, out-of-stock items can result in lost sales opportunities and erode customer trust. The average daily sales per store represent a significant revenue stream, and even a slight out-of-stock rate can lead to substantial financial losses. Additionally, the operational inefficiencies caused by stocking delays can tarnish a business's reputation and affect its standing in the competitive market. Thus, there is a pressing need for innovative solutions that streamline inventory management processes and optimize operational efficiency.

The introduction of a LED-based inventory projection pick system presents a promising solution to the challenges faced in traditional inventory management. By leveraging motorized LED light systems and Camera, the system aims to revolutionize the way inventory is picked and restocked in retail stores. This introduction will delve into the intricacies of this system, highlighting its benefits, functionalities, and potential impact on improving the overall efficiency of inventory management in retail settings.

## 2. BACKGROUND

An effective warehouse inventory management system is critical to the operational efficiency of a retail business. Delays in stocking will result in failure to make products available to customers in a timely manner, leading to loss in sales, reduction in business reliability, and increased costs.

These days warehouses are currently equipped with either Barcodes/ QR / AR code (Aruco Marker). When associates use an inventory software to scan any of these codes attached to catonbox/inventory on the shelves, usually pick suggestions will be displayed on screen.

Existing warehouse integration with inventory applications allows associates to scan multiple packs/carton boxes or packs in the warehouses by pointing their smartphone cameras. This has introduced an increased stocking efficiency in replacement of scanning labels one by one. However, the scanning range is still limited by the field-of-view of smartphone cameras or multi barcode scanners[6]. Store associates are required to constantly walk around the warehouse, holding their smartphones or barcode scanners up for label scanning, and making back-and-forth switching between smartphone and case packs when they need to pick items.

This constant distraction embedded in store associate's daily workflow not only becomes potentially safety concerns, but also increases the cost in store operations as the time of store associates is not fully utilized: around 10000 item pick operations[7][8] are happening in a typical big Retail stores on each day, assuming every time there is an extra second taken for store associates to pick item while holding their smartphones.

Warehouse associate time wasted = Time wasted in scanning each item * number of items to pick

Hours wasted = Warehouse associate time wasted * number of stores

Its costing retail companies hours wasted billable hours across all retail stores per day, which accounts to massive daily losses in wages.

To remediate the problem in stocking efficiency, the LED-based inventory spotlight picking system purposed in this paper optimizes the picking flow by:

1) Freeing both hands of store associates by installing cameras to track inventory status in the warehouse, instead of having associates constantly interacting with their smartphones for pick suggestions, so the store associates are refrained from distractions while performing picking operations.

2) Providing a clearer and brighter indication of pick suggestion signals by projecting LED Spot light directly onto case packs, so any store associate can have a quick overview of real-time inventory status as soon as they walk into the warehouse.

3) Displaying pick suggestions for potential out-of-stock items based on inventory status change patterns, so store

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associates can take actions to restock items to the sales floor proactively, further reducing the chance of failing to make products available to customers on time.

4) Sending signals to the stocking team whenever there is a need to pick items from the warehouse, so the LED Light system will operate only when there are store associates in the warehouse checking for pick suggestions. Excess power costs for operating the system can be saved.

Details of the proposed inventory pick system is discussed in the next section.

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## 3. The LED projection System with Camera

### 3.1 The setup

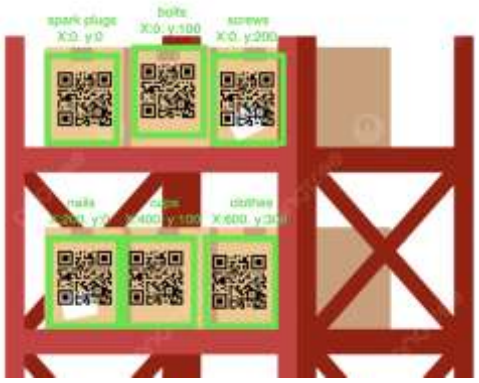

The LED based inventory projection pick system requires a combination of hardware and backend. In this section, we discuss both hardware setup and backend dataflow.

The hardware setup for the LED-based inventory projection pick system consists of 2 major components: the camera and the LED spot light mounted on 2 axis gimbals made of 2 servos. The camera captures and recognizes QR Codes that are attached to Inventory, which will help to map its position on the shelves and to identify the contents inside the inventory using the inventory software.

With the combinations of Camera and LED Light system projects LED spot light onto the Inventory that needs to be picked one at a time and keep on repeatedly showing what needs to be picked in regular intervals of time

As shown in Figure 1, both the camera and the LED Light system are required to be mounted at a height that is able to cover at least multiple warehouse shelves within their field-of-view.

### 3.2 Scanning barcode using QR code libraries




The camera within the LED-based inventory projection pick system is designed with advanced capabilities to detect and scan multiple QR codes printed on inventory items placed on shelves in the warehouse. Using sophisticated imaging technology and algorithms, the camera can accurately identify and read multiple QR codes simultaneously[3]. As it scans the warehouse shelves, the camera maps the XY coordinates of each QR code it detects in its view creating a digital inventory map that provides a precise location for each item within the warehouse. This mapping of XY coordinates enables efficient inventory location tracking and management, allowing store associates to quickly locate specific items and streamline the restocking process. By leveraging the camera's ability to scan multiple QR codes and map their coordinates, the system enhances inventory visibility and facilitates proactive inventory management strategies in retail environments.

### 3.3 Image processing POC

Here's a version of the code that sends real-time updates and location data of different inventory items to an inventory software system. Additionally, it simulates a 2-axis servo system controlling LED spotlights based on demand, although the actual hardware implementation of the servo system would require specific hardware and libraries. The code POC uses Python and computer vision library to find the barcode on the video feed which is scanning the inventory.

In this code, the inventory_locations dictionary stores the XY coordinates of each inventory item, and the inventory_demand dictionary simulates the demand for each item. The code simulates a 2-axis servo system controlling LED spotlights based on demand, printing the activation of the LED spotlight for illustrative purposes. In a real implementation, you would replace the simulated servo control with actual hardware control and integrate the code with the inventory software system to send real-time updates and location data.

By leveraging this example code, one can implement sophisticated system integrating with one’s retail inventory software system to achieve the goal

```
import cv2
from pyzbar.pyzbar import decode

# Initialize camera capture

cap = cv2.VideoCapture(0)
```

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```
# Initialize variables for inventory location and demand
inventory_locations = {}
inventory_demand = {}

while True:
    # Read a frame from the camera
    ret, frame = cap.read()

    # Convert the frame to grayscale
    gray = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)

    # Detect QR codes in the frame
    qr_codes = decode(gray)

    # Loop through detected QR codes
    for qr_code in qr_codes:
        x, y, w, h = qr_code.rect
        qr_code_data = qr_code.data.decode('utf-8')
        print(f"QR Code Data: {qr_code_data}")

        # Update inventory location and demand data
        inventory_locations[qr_code_data] = (x, y)  # Store XY coordinates
        inventory_demand[qr_code_data] = True  # Simulated demand for illustration

    # Simulated servo control based on demand
    for item, demand in inventory_demand.items():
        x, y = inventory_locations[item]
        if demand:
            # Simulated servo control: Activate LED spotlight on demand
            print(f"Activate LED spotlight for item {item} at coordinates ({x}, {y})")

    # Simulate sending real-time updates to inventory software
    # Here, you would typically send data to the inventory software system
 # Display the frame with detected QR codes
    cv2.imshow('QR Code Scanner', frame)

    # Exit the loop if 'q' is pressed
    if cv2.waitKey(1) & 0xFF == ord('q'):
        break

# Release the camera and close all windows
cap.release()
cv2.destroyAllWindows()
```

## 3.4 Deployment in storage facility

Deploying a 2-axis servo system with a camera in a store warehouse to scan real-time inventory and spotlight based on demand involves several steps:

1. Hardware Setup:

- Install a camera in the warehouse with a clear view of the inventory shelves. Set up a 2-axis servo system with LED spotlights. The servo system should be capable of moving the LED spotlights along two axes (e.g., pan and tilt) to target specific inventory items.

2. Connect Hardware to System: Connect the camera and servo system to a computer or microcontroller board capable of processing image data and controlling servo movements. For example, you might use a Raspberry Pi or Arduino board for this purpose.

3. Software Implementation: Write software code to capture real-time video from the camera and process it for QR code detection using libraries like OpenCV and pyzbar[4].

- Implement logic to identify QR codes representing inventory items and track their locations in the warehouse based on the camera's perspective.

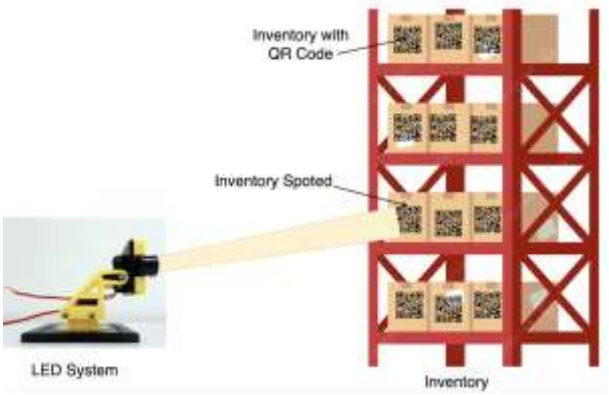
4. Inventory Management Integration: Integrate the software with your inventory management system to receive real-time updates on inventory status and demand. This may involve using APIs or communication protocols to exchange data between systems.

5. Demand-Based Spotlight Control: Develop algorithms that analyze inventory data to determine demand levels for different items. For example, you might consider factors like sales trends, restocking schedules, or customer requests to assess demand. Implement control logic for the 2-axis servo system to move the LED spotlights and illuminate inventory items based on demand. The servo movements should align the spotlights with the QR-coded items identified by the camera.

6. Testing and Calibration: Conduct thorough testing of the system to ensure accurate QR code detection, precise servo movements, and effective spotlight illumination. Calibrate the camera, servo system, and spotlight movements as needed to optimize performance and minimize errors.

7. Deployment and Maintenance: Install the deployed system in the store warehouse according to safety guidelines and operational requirements. Regularly monitor and maintain the system to address any issues or updates needed for continued functionality and reliability.

This deployment process combines hardware setup, software development, integration with inventory management systems, and testing to create a functional and efficient solution for real-time inventory scanning and spotlight control based on demand in a warehouse.



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### 3.5 Integration with Inventory software system


The Inventory spotting system integrates with existing inventory software systems and inventory demand calculation systems[2] to enhance inventory management processes. The camera communicates with the inventory software system to update the inventory supply information in real time by scanning the QR codes, ensuring that the items are available in the warehouse for restocking in the sales floor. This enables accurate tracking of inventory levels and ensures that the system reflects the most up-to-date information regarding stock availability.

Additionally, the LED spotting system plays a crucial role in highlighting inventory demand. Using spot light using the LED torch, It illuminates specific items or areas on the shelves, indicating the demand for those items in the sales floor. This visual cue helps store associates quickly identify which items need to be picked and restocked, streamlining the restocking process and reducing the chances of out-of-stock situations. Overall, the integration of cameras for inventory detection and the LED system for demand highlighting enhances the efficiency and accuracy of inventory management in retail environments.

## 4. CONCLUSION

This paper proposes a LED based inventory spotting system to optimize the operational efficiency of the current inventory management system.

The proposed system uses LED spotlight and to project pick suggestions directly onto warehouse shelves, minimizing the distractions, safety concerns, and time waste that are currently existing in the picking flow, while also being cost-effective.

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