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A Framework for an IoT-enabled Intelligent Inventory Management System

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ABSTRACT:
The rapid advancement of Internet of Things (IoT) technology has opened new frontiers in inventory management by enabling real-time, data-driven decision-making. This paper presents a comprehensive framework for an IoT-enabled intelligent inventory management system (IIMS) that integrates weight sensors, Radio Frequency Identification (RFID), computer vision, and neuro-fuzzy logic for optimizing inventory control. The proposed system aims to enhance inventory monitoring accuracy, automate item identification and placement verification, and optimize reorder levels. Weight sensors track inventory depletion, while RFID tags enable fast and precise identification of items. Computer vision is used to detect correct and incorrect placement of items, ensuring accuracy in warehouse operations. A neuro-fuzzy model is implemented to dynamically adjust reorder points based on inventory levels and demand fluctuations. This framework facilitates seamless, real-time inventory tracking and decision-making, improving operational efficiency, reducing human errors, and supporting timely replenishment decisions. The study underscores the system's potential to transform inventory management practices by integrating IoT technologies, making it highly adaptable to various industries.

KEYWORDS: Internet of Things (IoT), Computer Vision, Inventory Management, Neuro-fuzzy, Sensors

I. INTRODUCTION

The Internet of Things (IoT) has emerged as a technological advancement across various industries in the modern era of technological advancement, transforming operations and improving efficiencies. Inventory management is one such sector where IoT has had a major impact. Conventional inventory management systems have mostly depended on labour-intensive, error-prone human data input, barcoding, and recurring stock-taking procedures (Singh et al., 2020). IoT-enabled intelligent system evolution offers a real-time, automated method that minimizes errors, optimizes inventory control, and decreases the need for human interaction. With an emphasis on current trends and problems, this backdrop describes the major operational and technological developments that have led to the creation of a framework for an IoT-enabled intelligent inventory management system (Madamidola et al.2024).

Inventories management systems with Internet of Things (IoT) capabilities use software, sensors, and networked devices to track and manage inventories in real-time. By enabling constant observation of inventory quantities, locations, and conditions, these systems lessen the need for manual intervention. New techniques to enhance the precision and effectiveness of inventory management systems have been made possible by recent developments in RFID technology, weight sensors, and computer vision (Patil&Patil, 2022). While RFID technology improves the traceability of commodities throughout the supply chain, weight sensors, in particular, have shown effectiveness in monitoring stock levels by detecting changes in the weight of stored objects (Pereira & Silva, 2021). Companies that use IoT technology can incorporate real-time data analytics to predict inventory demands, avert stockouts, and eliminate surplus inventory. This predictive skill allows firms to function more efficiently, resulting in improved supply chain efficiency (Oloruntoba&Oluwaseun, 2023). The use of IoT in inventory management is particularly advantageous in businesses with fast-moving or perishable commodities, where timing and accuracy are crucial to decreasing waste and loss. An intelligent inventory management system automates decision-making processes using modern technologies such as machine learning, artificial intelligence (AI), and neuro-fuzzy logic (Madamidola et al, 2017). Neuro-fuzzy systems, which combine the adaptability of neural networks with the interpretability of fuzzy logic, offer sophisticated solutions for determining reorder levels and managing inventory flow based on historical data and sensor inputs (Rajput et al., 2020). Such systems can analyze large amounts of data to detect patterns, predict demand, and optimize stock levels dynamically.

This framework combines several IoT technologies, including RFID, weight sensors, and computer vision, with adaptive algorithms that adapt to changing situations. RFID tags, for example, track the movement of goods, weight sensors monitor real-time changes in stock levels, and computer vision systems verify that items are properly placed in the warehouse. These technologies, when used in unison, improve inventory visibility, reduce human error, and improve decision-making processes. Despite the obvious advantages, installing an IoT-enabled inventory management system creates difficulties. One of the most pressing concerns is the security of IoT devices. (Madamidola, et al.,2021) These gadgets, which are frequently connected to a large network, are susceptible to cyberattacks, data breaches, and illegal access (Kumar et al., 2021). Another issue is the high cost of implementation, especially for small and medium-sized businesses (SMEs), who may struggle to afford the initial investment required for IoT infrastructure (Jain & Singh, 2021). Furthermore, interoperability across different IoT devices and systems is an issue because not all IoT devices use the same communication standards (Sridhar et al., 2023).

As IoT technology advances, future inventory management systems are anticipated to include increasingly complex AI algorithms, such as deep learning models, to improve automation and decision-making processes. These systems will be more adaptable, using past data to better forecasting and inventory management.(Adeniyi et al, 2024) Furthermore, IoT-enabled systems will continue to promote advances in predictive maintenance, lowering downtime and increasing overall supply chain efficiency (Chaudhary et al., 2022). The creation of an IoT-enabled intelligent inventory management system has exciting possibilities for improving inventory control, lowering costs, and increasing efficiency. Businesses may automate complex decision-making processes, decrease human error, and improve inventory management by integrating real-time data analytics, artificial intelligence, and advanced sensor technology. However, overcoming the difficulties of security, affordability, and compatibility will be critical to the broad adoption of these systems.

II. REVIEW OF RELATED WORKS

Sai et al (2023) worked on an Online stock and inventory management system, the primary objective of the study was to develop a robust online system for managing stock and inventory. The system aims to address common challenges faced by businesses, such as overstocking, stock outs, and inefficient inventory tracking. By providing a centralized platform, the system ensures that inventory data is accurate and up-to-date, which is crucial for making informed business decisions. The architecture of the system is designed to be scalable and secure. It typically includes the following components:

a. **Frontend**: A user-friendly interface developed using modern web technologies like HTML, CSS, and JavaScript. This interface allows users to interact with the system easily, perform inventory checks, and generate reports.
b. **Backend**: The backend is built using robust server-side technologies such as Node.js or Python, which handle the business logic and data processing.
c. **Database**: A relational database like MySQL or PostgreSQL is used to store inventory data. The database schema is designed to efficiently manage large volumes of data and ensure quick retrieval.
d. **APIs**: RESTful APIs facilitate communication between the frontend and backend, ensuring seamless data flow and real-time updates.

The system provides real-time updates on inventory levels, helping businesses maintain optimal stock levels and avoid overstocking or stock outs. Automated notifications are sent to users when stock levels fall below a predefined threshold, ensuring timely replenishment. Also, the system generates detailed reports and analytics on inventory usage, sales trends, and stock levels. These insights help businesses make data-driven decisions. The paper suggests several areas for future research and enhancement by integrating AI and machine learning algorithms to predict inventory needs and optimize stock levels based on historical data and trends and Developing mobile applications to provide users with on-the-go access to inventory data and management features.

Hemalatha (2024) developed an Intelligent Inventory Management System. The research work addresses the critical need for efficient inventory management systems in modern businesses. Traditional methods often fall short in providing real-time data and accuracy, leading to inefficiencies and increased operational costs. The authors propose an intelligent system that leverages advanced technologies to overcome these challenges. The objectives of the research were to develop an intelligent inventory management system that provides real-time data on inventory levels, integrate weight sensors and advanced controllers to monitor and analyze inventory data continuously and enhance operational efficiency by reducing manual intervention and errors in inventory tracking. The system employs several key components such as Weight Sensors which continuously monitor the weights of products, providing real-time data., Selec PID500-U Controller which also receives data from the weight sensors via RS485 communication and uses special variables to analyze the weight data. Human-Machine Interface (HMI) that displays the results, offering instant visibility of inventory levels The system successfully provides precise, real-time insights into inventory levels. This allows businesses to streamline operations, reduce costs and enhance productivity. The Intelligent Inventory Management System represents a significant advancement in inventory management by integrating state-of-the-art technology. It offers a revolutionary approach to inventory tracking, providing precise, real-time insights that enable businesses to thrive in competitive markets however, the work only manages one items and potential difficulties in integrating with legacy systems The authors suggest several areas for future research in developing more sophisticated algorithms for data analysis, exploring the system's application in other areas, such as chain of supply.

Jangale et al. (2024). developed an IOT based smart shelve inventory management system. The research focuses on developing a smart shelf inventory management system using IoT technologies to manage and track inventories more efficiently and automatically.

The system's objectives are to give real-time inventory level data, minimize errors, and cut down on manual work. The principal aims of the research were to develop and execute a smart shelf system utilizing Internet of Things (IoT) technology for real-time inventory management, minimize the labor-intensive manual process associated with inventory tracking, and furnish precise and prompt notifications for inventory replenishment. The system makes use of several IoT components, such as:

a. ESP32 Module: Acts as the central processing unit for the system.
b. Ultrasonic Sensors: Measure the inventory levels on the shelves.
c. LCD Display: Shows real-time data on inventory levels.
d. Buzzer and Indication Light: Provide alerts when inventory levels drop below a certain threshold.
e. Power Supply and Voltage Regulator: Ensure stable operation of the system.

The methodology involves setting up these components to work together seamlessly. The ESP32 module collects data from the ultrasonic sensors and processes it to determine the current inventory levels. This data is then displayed on the LCD screen and used to trigger alerts via the buzzer and indication light when necessary.

The implementation of the IoT-based smart shelf system demonstrated several benefits:

a. Real-Time Monitoring: Decisions could be made promptly because the technology offered real-time data on inventory levels.
b. Error Reduction: Automated tracking reduced the likelihood of human errors in inventory management.
c. Efficiency: The system streamlined the inventory management process, saving time and labor.
d. Alerts and Notifications: The system effectively alerted users when inventory levels were low, ensuring timely replenishment.

The system showed promising results however, it also had some limitations:

a. The system's scalability to larger and more complex inventory environments was not extensively tested.
b. The system's performance is heavily reliant on the proper functioning of IoT components, which may require regular maintenance and updates. The study comes to the conclusion that by offering real-time monitoring, lowering errors, and increasing efficiency, IoT-based

smart shelf solutions may greatly improve inventory management.

c. The findings suggest that such systems are valuable tools for modern inventory management, particularly in environments where timely and accurate inventory tracking is crucial.

Chowdhury et al (2023), developed a Smart Inventory Management System with Forecasting Technique Applied to Efficiently Handle Industrial Asset. The research addresses the complexities of modern inventory management. The authors propose an innovative system that integrates demand forecasting to optimize inventory levels, thereby preventing overstocking and understocking issues. The study's main goal is to create an intelligent inventory management system that uses forecasting methods to improve industrial asset management's effectiveness. The system's objective is to provide companies with real-time information on stock levels, fluctuations, and stock outs so they can decide on production, sales tactics, and inventory replenishment with knowledge. The research employed a multi-faceted approach to develop the inventory management system. The methodology includes:

a. System Design: The system is designed to integrate six individual inventory management systems into a unified platform managed by a single administrator. This consolidation allows for streamlined operations and better control over inventory levels

b. Forecasting Techniques: Various forecasting techniques were implemented to predict future product demands. These techniques help in planning inventory replenishment and production schedules, thereby reducing the risk of stock outs and overstocking

c. Performance Analysis: The system's performance was evaluated using a set of metrics to determine its effectiveness in managing inventory levels and meeting customer demands.

The implementation of the smart inventory management system yielded several positive outcomes:

a. Improved Inventory Control: The system provided better control over inventory levels, reducing the instances of stock outs and overstocking.

b. Increased Efficiency: By integrating forecasting techniques, the system enhanced decision-making processes related to inventory management, leading to more efficient operations

c. Enhanced Accuracy: The real-time data provided by the system improved the accuracy of inventory records, reducing discrepancies and errors.

d. Better Decision Making: The system's forecasting capabilities enabled businesses to make more informed decisions regarding inventory replenishment and production planning.

The proposed system offers significant improvements in inventory control, efficiency, and decision-making. However, the complexity of implementation and dependence on accurate data are notable challenges that need to be addressed for broader adoption

Chukomin (2023). worked on the development of an IoT-based inventory management solution and training module using smart bins. addresses the increasing need for flexibility, transparency, and changeability in warehouse environments. This need arises from the demand for cost-efficient production of small batch sizes, which requires adaptable and transparent material and information flows. The primary objective of this research was to develop and validate an IoT-based inventory management solution and a corresponding training module. The solution aims to enhance the transparency and flexibility of material flows within warehouses by using smart bins equipped with weight mats and additional sensors. Through the use of weight mats to measure the content of the bins, independent of the specific component geometry, the smart bins at Werk150, the Factory on the ESB Business School campus allow logistics decision-makers to transparently base their decisions on the weights of the various components they track. The data collected is analyzed using AI-based algorithms to optimize processes and give logistics decision-makers a transparent basis for decision-making. These components are connected to an IoT hub to collect and analyze data on material consumption and manual handling operations. The study highlights the importance of integrating IoT technologies into inventory management systems to address the challenges posed by manual processes in warehouses. The smart bins' ability to provide real-time data on material consumption and handling operations is crucial for creating a transparent and efficient inventory management system. The training module developed alongside the IoT solution ensures that students and industry professionals can effectively implement and utilize these technologies in practice. While the study provides valuable insights into the benefits of IoT-based inventory management solutions, it is limited to the specific context of the ESB Business School's Werk150 factory. Further research is needed to validate the findings in different industrial settings and to explore the scalability of the solution.

Noguerra (2023). Worked on the Design and Evaluation of an Innovative Mobile Solution: QR Code-based Inventory Monitoring System. The research aims to explore how RFID (Radio Frequency Identification) and inventory management systems can function more efficiently thanks to barcode technology. It focuses on the capabilities of these technologies to provide efficient tracking and monitoring, thereby optimizing inventory levels and improving overall operational efficiency. The objective of the work was to develop a user-friendly mobile application for inventory management, integrate QR code technology to streamline inventory processes and evaluate the system's performance concerning precision, efficacy, usability, security, and maintainability. The research uses a comprehensive methodology to achieve its objectives. The development process involves several key steps:

a. System Design: Item tracking, inventory reporting, managing supplies both in and out, management, and other features are all included in the design of the mobile application.
Each item in the inventory has a unique QR code that contains relevant data.

b. Implementation: The system was implemented using mobile devices equipped with cameras for QR code scanning. Instant insight into stock movements and levels was made possible by the application's real-time changes to the inventory database.

c. Evaluation: The system was assessed based on several criteria, such as correctness, effectiveness, efficiency, usability, security, and maintainability. User feedback is obtained in order to assess the system's efficacy and identify areas that require further development.

Several important conclusions are drawn from the assessment of the inventory monitoring system based on QR codes:

a. Accuracy: The system demonstrates high accuracy in tracking inventory items, significantly reducing errors associated with manual processes.
b. Efficiency: The use of QR codes streamlines inventory processes, reducing the time required for stock-in and stock-out operations.
c. Usability: The mobile application is user-friendly, with intuitive interfaces that facilitate easy navigation and operation.
d. Effectiveness: The system effectively optimizes inventory processes, minimizing stock outs and enhancing decision-making.
e. Security: Secure access is ensured through user registration and authentication, protecting sensitive inventory data.
f. Maintainability: The system has features for upgrades and improvements and is made to be readily maintained.

Despite its promising results, the study acknowledges several limitations:

a. Scalability: The system may face challenges in scaling up to accommodate larger inventories or more complex operations.
b. Integration: Integrating the QR code-based system with existing enterprise systems may require additional effort and resources.
c. User Adoption: Ensuring widespread adoption of the system among users may necessitate training and support.

Mobile technology can completely transform inventory management, as demonstrated by the design and assessment of a study on a QR code-based inventory monitoring system. The system's exceptional performance in terms of accuracy, efficiency, usability, effectiveness, security, and maintainability shows that it is highly appropriate for a range of businesses. Notwithstanding the study's many flaws, it provides a solid foundation for future research and development in this area. By addressing the challenges that have been discovered and looking into new technological advancements, future study can increase the effectiveness and utility of QR code-based inventory management systems.

Mohamed & El Saber, (2023). development of an Intelligent decision support system for optimizing inventory management. The goal of the research is to optimize inventory management through the creation of a machine learning-based decision support system (DSS). This study's main goal is to create an intelligent DSS that uses machine learning methods to improve inventory control procedures. By automating inventory optimization, the system seeks to lower expenses while raising customer satisfaction. The study suggests a framework for combining different machine learning techniques, including Random Forests (RF), Support Vector Machines (SVM), and Artificial Neural Networks (ANNs). These techniques are used to create strong models for sales prediction. A case study of Walmart and extensive experimentation are used in the study to verify the effectiveness of the recommended system.The experimental findings show that by offering precise demand estimates and optimizing inventory levels, the suggested DSS can greatly enhance inventory management. The system demonstrated potential in transforming inventory management practices and enhancing supply chain performance. However, the study acknowledges several limitations, including challenges related to data availability and quality. The study indicates that additional investigation is necessary to tackle these concerns and investigate the feasibility of implementing the suggested approach in various organizational settings.

Prabakaran et al (2023). Advanced smart inventory management system using IoT. The research presents a modern approach to inventory management leveraging the Internet of Things (IoT) technology. The primary objective of the study is to develop an automated system for efficient inventory management using IoT aiming to provide real-time data on inventory levels, reduce management costs, improve operational efficiency and optimize inventory levels to reduce waste and ensure product availability. The system comprises various sensors and microcontrollers, including:

- **a. Sensors:** IR sensors, ultrasonic sensors, and load cell sensors are strategically placed to monitor various parameters such as quantity, presence, and weight of inventory items.
- **b. Microcontrollers**: Arduino Uno and NodeMCU are used to process sensor data and transmit it to the cloud.
- **c. Cloud Platform:** The cloud platform stores and processes the data, providing real-time insights into inventory levels.
- **d. User Interface:** A web or mobile interface allows users to monitor and control the system remotely.

The data flow in the system begins with the sensors collecting information about the inventory. This data is then processed by the microcontrollers and transmitted to the cloud. The cloud platform analyzes the data and provides real-time insights to the user through the interface. The system also includes status LEDs to indicate the current state of the inventory. The implementation of the IoT-based inventory management system has shown significant improvements in inventory management. While the system shows promise, the paper also discusses potential challenges and limitations, including:

- a. **Calibration**: Ensuring the accuracy of sensors requires regular calibration.
- b. **Data Security:** Protecting the data transmitted to and from the cloud is crucial.
- c. **Integration:** Integrating the system with existing enterprise systems can be complex.

Kanyip and Srivaramangai (2023), developed a Livestock Inventory Management System (LIMS). The system was designed to streamline the management of livestock inventories, enhancing efficiency and accuracy in tracking and managing livestock data. The research is motivated by the challenges faced by livestock farmers in managing their inventories. Conventional techniques are frequently labor-intensive, error-prone, and manual. The study highlights the requirement for a more efficient system that leverages modern technology to address these issues. The objectives of the research were to design a user-friendly LIMS that can be easily adopted by farmers and help enhance the efficiency and precision of managing livestock inventories. The research employed a systematic approach to develop the LIMS. The system was designed using Android Studio, XML, Java, and MySQLite. The choice of these technologies was driven by their robustness and compatibility with mobile devices, enabling a broad spectrum of users to access the system. The system was tested in a real-world environment to evaluate its performance. The authors conducted a series of tests to ensure the system's reliability, accuracy, and user-friendliness. Feedback from users was collected and used to make necessary improvements. The implementation of the LIMS showed significant improvements in the management of livestock inventories. The technology minimized errors and cut down on the time and effort needed for inventory management. Users reported high satisfaction with the system's ease of use and the accuracy of the data provided. The system developed was not an intelligent system and its built as a standalone system. The authors suggest that future research could explore the integration of additional features, such as predictive analytics and IoT devices, to further improve the system.

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III. METHODOLOGY

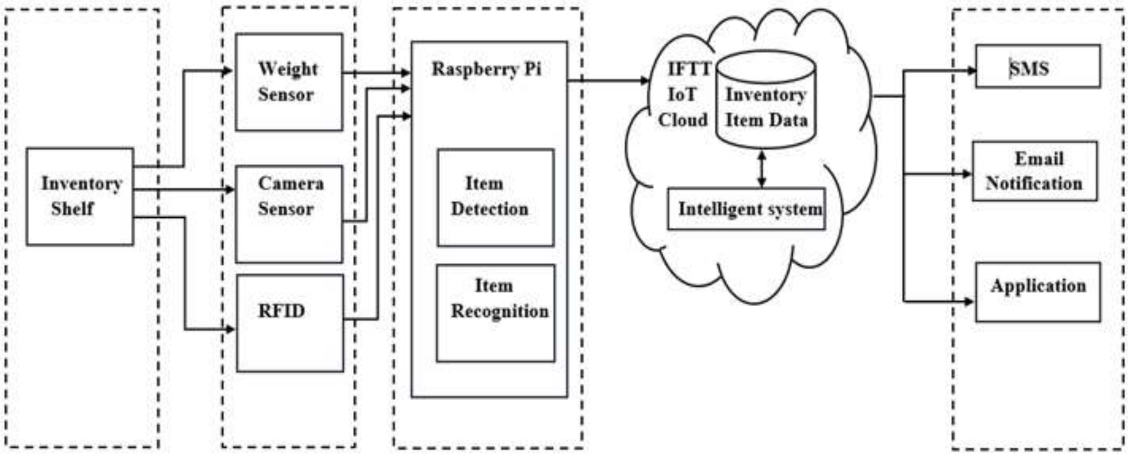

Fig 1 IoT-enabled Intelligent Inventory Management System Architecture

The proposed research will be carried out in five phases namely, Shelf Monitoring, intelligent reorder level, inventory items image data preprocessing, inventory item detection and recognition.

a. **Shelf monitoring** will involve managing of inventory shelf with the introduction of weight sensors and RFID, the sensors detect addition and removal of inventory items from the shelf and the database is updated in real time. The RFID carries information about inventory items for identification when placed or removed from the shelf for effective management of the inventory.

To get the net weight calculation of each integrated inventory shelves we subtract the tare weight (i.e. the weight of the empty shelf) to get the net weight:

$$w_{net}\ (t) = w(t) - w_{tare} \quad (1)$$

Where $\mathbf{w_{net}(t)}$ is the total weight of the items currently on the shelf, excluding the tare weight (the weight of the empty shelf or any packaging), **w(t)** is the total measured weight (including the shelf or packaging), and $\mathbf{w_{tare}}$ is the tare **weight.**

For item count estimation, assuming each item on the shelf has a known average weight w_{item}. The number of items can be calculated as:

$$n(t) = \frac{w_{net}\ (t)}{w_{item}} \quad (2)$$

Where:

n(t) is the number of items at time t.

$w_{net}(t)$ is the net weight of the items on the shelf at time t.

w_{item} is the average weight of a single item.

For inventory tracking to maintain a running total of inventory based on weight sensor readings we have:

$$n_{total}\ (t) = n_{initial} + \sum_{i=0}^{t} \Delta n(i) \quad (3)$$

Where $n_{total}\ (t)$ is the total number of items on the shelf at time t, $n_{initial}$ is the initial number of items on the shelf at the start of the observation period (at t=0),

$\sum_{i=0}^{t} \Delta n(i)$ is the summation represents the cumulative change in the number of items from the start of the observation period up to time t and $\Delta n(i)$ represents the change in the number of items at each time step i

b. **The intelligent reorder** level of the system will be implemented using Neuro Fuzzy model, the input to the model are demand, D and inventory level, I the output of the model, order quantity, Q and reorder point, R. For Fuzzification, the fuzzy set dεD where D represent the universe of discuss for demand and the fuzzy set iεI where I represent the universe of discuss for inventory level consist of an element denoted by x.

For the Fuzzy inference engine, the fuzzy employs the trapezoidal membership functions given by:

$$f(x{:}\,a,b,c,d) = \left\{max\ (min\frac{x-a}{b-a}, 1, \frac{d-x}{d-c}), 0\right\} (4)$$

where a is the minimum and d is the maximum of the linguistic parameters, b and c are the core values of the linguistic variable x that bounds its shape such that a ≤ X ≤ b. Each of these parameters is described with one of the following linguistic terms: Very Low, Low, Average, High and Very High. In this work Mamdani type fuzzy inference is adopted for the fuzzification of the demand and the supply values.

For Defuzzification, to decide the optimal order level, a crisp value is needed and to achieve an exact value, the centre-of-gravity method.

c. **Inventory items image data preprocessing**

Will involve obtaining images of an inventory item using camera. As weight Sensor detects addition and removal of inventory items from the shelf, the camera is triggered to take a picture of the items on the shelf.

Each captured images $\boldsymbol{I_{raw}}$ is made to go through some series of pre – processing operations to enhance clarity under varying lighting conditions. The image goes through three stages of data pre-processing namely; Gamma Correction, Difference of Gaussian Filtering and Contrast equalization to improve the quality of detection.

The gamma correction algorithms improve the local dynamic range of an image in darker or shadowed area by expanding it, while it compresses the dynamic range in brighter regions. This adjustment is governed by the pixel value γ. Essentially, it replaces gray-level with the gray-level X, that is:

$$X = X^{1/\gamma} \quad (5)$$

where γ < 1 produces darker images, γ > 1 produces lighter images and γ=1 produces no effect.

The Difference of Gaussian (DOG) filtering Algorithm is a grey scale image enhancement techniques designed to eliminate shadows within an image. Its purpose is to enhance the visibility of edges and other intricate details present in a digital image. The DOG impulse response is formally defined as follows:

$$DOG(x,y) = \frac{1}{2\pi\sigma_1^2} e^{-\frac{x^2+y^2}{2\sigma_1^2}} - \frac{1}{2\pi\sigma_2^2} e^{-\frac{x^2+y^2}{2\sigma_2^2}} \quad (6)$$

where the default values for σ_1 and σ_2 are chosen as 1.0 and 2.0 respectively.

The Contrast Equalization Algorithmadjust the image intensities to normalize a reliable measure of the overall intensity variation in intensity.

$$I(x,y) = \frac{I(x,y)}{(mean\ (min\ (\tau|I(x',y')|)^{\alpha}))^{1/\alpha}} \quad (7)$$

$$I(x,y) = \frac{I(x,y)}{(mean\ (\tau|I(x',y')|^{\alpha}))^{1/\alpha}} \quad (8)$$

where the mean is mean over the unmasked part of the image α which is a strongly compressive exponent that reduces the influence of large values and τ is a threshold used to truncate large values after the first phase of normalization.

d. **Item detection:** For every pre-processed image, the task of item detection is performed using the R-CNN Model and it building the base CNN using MobileNet architecture. MobileNet divides the convolution of the pre-processed item image at pixel point into a 3 × 3 depth wise convolution and a 1 × 1 pointwise convolution. This approach effectively reducing both computational cost and number of parameters involved. The depthwise convolution with one filter per input channel of an inventory image can be expressed as follows:

$$G_{k,l,m} = \sum_{i,j} K_{i,j,m} \ . \ F_{k+i-1,l+j-1,m} \quad (9)$$

Where K is the depthwise convolutional kernel of the size D_k x $D_k x\ M$ the m_{th} filter in K is applied to the m_{th}channel in F to produce the m_{th} channel of the filtered output feature map G. Depthwise convolution has a computational cost of:

$$C_{G,} = D_K.D_K.M.D_K.D_K \quad (10)$$

The fusion of depthwise convolution and 1 x 1 (pointwise) convolution is referred to as depthwise separable convolution and it incurs a computational cost of:

$$C_{G,P} = D_K.D_K.M.D_K.D_K + M.N.D_F.D_F \quad (11)$$

By expressing convolution as a two-step process of filtering and combining, are reduction in computation is achieved as follows:

$$\frac{D_K.D_K.M.D_K.D_K + M.N.D_F.D_F}{D_K.D_K.M.N.D_K.D_K} = \frac{1}{N} + \frac{1}{D_K^2} \quad (12)$$

Subsequently, the region proposal Network (RPN) is utilized to generate a collection of anchor boxes from the convolution feature map generated by the MobileNet-v3 architecture. The RPN yields two output stemming from these anchor boxes. The first output represents the objectiveness score, indicating the likelihood that an anchor corresponds to an inventory items, such as Coke, Fanta or Milo. The second output involves bounding box regression, which fine-tunes the anchor to a better align with the items. By utilizing the final proposal coordinates along with their objectness scores, a robust set of proposals for incorrect items is established. Given that these anchor often overlap; the proposals can also exhibit overlapping regions on the same items. to address this issue of duplicate proposal, this work adopts the Soft Non-Maximum Suppression (NMS) algorithms

Consider an initial proposal set denoted as $P_{in} = \{P_1, P_2, P_3, \ldots\ldots P_n\}$ which is the output from

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the object proposal layers, with the proposals arranged in order of their objectiveness score. For any given proposal p_i, any other proposal that shares more than a predefined threshold T in terms of overlap with p_i, is referred to as a neighbor proposal to p_i. In the context of this work, the threshold for neighboring proposals, T, is established at 0.5 through cross-validation. Let S_i represents the objectiveness score of p_i which corresponds to the highest value within the classification score vector of p_i. Within a proposal set, the proposal with the highest objectiveness score is termed the winning proposal. Suppose p_i is a winning proposal and p_j is identified as a neighbor proposal p_i. The updated objectiveness score of p_j denoted by S_j^u is determined by :

$$S_j^u = S_i\left(1 - O_{p_i, p_i}\right) \quad (13)$$

Where O_{p_i, p_j} denotes the Intercession over Union (IoU) between proposal p_i and proposal p_j and is computed as follow:

$$O_{p_i, p_j} = \frac{\text{area}\,(p_i \cap p_j)}{\text{area}\,(p_i \cup p_j)} \quad (14)$$

The final stage in the proposed framework is the classifier. Following the extraction of features for each proposal through RoI pooling, these features are utilized or two primary objectives within the classifier. First, it aims to categorize the proposals into one of the inventory items. Second, it adjusts the bounding box for each detected item based on the predicted class.

e. **Item recognition:** The inclusion of the item recognition stage is vital for distinguishing between correct an incorrect placement of items on the inventory shelves. In this research, one shot algorithms is adopted for the item recognition process. This stage is important in distinguishing between items correctly placed and incorrectly placed in an inventory stores. One short algorithms is a machine learning based approach for image classification that evaluates the similarity and dissimilarity between two images. It relies on a specialized form of convolutional neural networks known a s Siamese Neural Network (SNNs). Siamese networks process two distinct input, passing through two identical subnetworks with matching architecture, parameters and weights. These networks are trained to assess the distance between features into the two input images.

This model's implementation was conducted using the Python programming language and associated libraries. Performance evaluation was carried out utilizing standard metrics such as confusion matrix, accuracy, precision, recall, f1 score and mean average precision (mAP)

IV. IMPLEMENTATION

The R-CNN model will be implemented on Google Colab using Python programming language, PyTorch Library and Open CV. The IoT system environment will be implemented using Raspberry Pi 4, Pi Camera, weight Sensor and If-This-Then-That (IFTTT) IoT cloud platform. Theproposed research will be evaluated using accuracy, precision, recall and f1 score

V. CONCLUSION

The proposed research is expected to establish an intelligent IoT system to effectively monitor inventory items and provide an intelligent system for inventory item identification and correct placement for proper manage of inventories

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