Applying Image Processing to Determine Product Placement and Availability on the Shelf in Retail Stores

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***Abstract*—The absence of product availability and the im- proper arrangement of items on the shelves in retail stores can lead to reduced sales for the retailer. personnel of Fast-Moving Consumer Goods (FMCG) businesses, whose products are stocked on these shelves, as well as personnel of the retailer undertake visual checks to detect products that are lost or out of stock are expensive and tends to commit mistakes. A technique for automating the manual inspection process is presented in this study. The research also shows that it is possible to identify empty spaces on the shelves in addition to recognizing and counting products that face front by using image processing algorithms. Moreover, this approach can be applied to images captured from a video stream, such as those from security cameras, to count the number of visible units of a particular product on a shelf and determine whether they are correctly oriented, as required. The image processing method proposed in this paper primarily facilitates the proper positioning of products on the front row of the shelves. While this might appear to be a limitation in terms of inventory management, it holds substantial significance for product manufacturers who lease shelf space and allocate specific shelf positions, compelling retailers to place particular products in designated locations. The innovative aspect of this paper lies in the extension of feature extraction in image processing to highlight and rectify incorrect placements and arrangements of items on the shelves. Importantly, the implemented solution does not entail significant additional infrastructure costs.**

I. INTRODUCTION

The term "On-Shelf Availability" (OSA) refers to the measurement of products that are available to customers at the expected location, at the time of their choosing, and in a condition suitable for sale[7]. On average, retailers allocate 5% of their sales revenue to logistics, with the majority of these costs stemming from in-store inventory handling (38%) and storage (7%) [1]. Consequently, improving the management of in-store inventory is crucial for enhancing a retailer's profitability. Both the retailer and the product manufacturer face an opportunity cost associated with OSA. Hence, maintaining OSA or reducing instances of Out-of- Stock (OOS) serves as an indicator of a retailer's performance.

Out-of-Stocks (OOS), the counterpart of OSA, occur when a consumer visiting a retail store finds that the specific product they are looking for is unavailable on the shelf [2].

When an OOS situation arises, customers react in the following ways [7]: • 31% purchase the needed product from an alternative source (a different store or online) • 26% choose a different brand • 19% still buy the same brand but opt for a different variant, size, or flavor • 15% delay their purchase to a later date • 9% leave the store without making a purchase.

A loss of EUR 4 billion is incurred by the 9% of consumers who choose not to make a purchase [9]. With so many options nowadays, a client may decide to permanently move to a different store if OOS problems happen frequently. A "loyal" family's weekly revenue loss from leaving a particular store is about EUR 150 , which adds up to EUR 150,000 in lost revenue over a 20-year period [8]. Furthermore, 20% of all OOS cases are not handled for three days [7], which has a substantial negative impact on retailer profitability and performance [6].

For manufacturers, a 3% increase in OSA equates to a 1% increase in sales, while for retailers, a 2% increase in OSA results in a 1% sales boost [7]. Therefore, retail establish- ments must ensure high OSA to retain their loyal customer base. Accumulating excess inventory is not a viable solution, as it can lead to losses due to product wastage. Moreover, even if a product is available in the inventory, inefficient shelf management may prevent it from reaching the shelf [6].

Retailers are now using a variety of strategies to guarantee a high degree of On-Shelf Availability (OSA) for their merchandise. Performing store audits, which entail manual visual checks of store shelves, is one of these strategies. However, because the assessment is dependent on the auditor's visit schedule, which might be arbitrary, this labor-intensive method cannot reliably assess Out-of-Stock (OOS) problems [3]. Moreover, this approach might not be economical in areas with high labor costs.

II. LITERATURE SURVEY

Work	ML Algorithm	Features
Joachim C.F. Ehrenthal. A Service-Dominant Logic View of Retail On-Shelf Availability. Ph.D. dissertation, University of St.Gallen, St.Gallen, Switzerland, 2012	CNN (Convolutional Neural Networks)	Demand forecasting
Kristie Jean Spielmaker. On-Shelf Availability in Retailing: A Literature Review and Conceptual Model, Honours thesis, University of Arkansas, Fayettevilee, Arkansas, 2012.	CNN (Convolutional Neural Networks)	Inventory Monitoring
Anne-Sophie B., Gilles L. and Sandrine M.. Assessing the Frequency and Causes of Out-of-Stock Events Through Store Scanner Data, Cahier de recherche du Groupe HEC, 2006.	RFID(Radio Frequency Identification), CNN (Convolutional Neural Networks)	Tag Identification
C. C. Chao, J. M. Yang and W. Y. Jen. Determining Technology Trends and Forecasts of RFID by Historical Review and Bibliometric Analysis from 1991 to 2005, Technovation, Vol. 27, No. 5, 2007, pp. 268-279.	RFID(Radio Frequency Identification)	Localization and Tracking
Michael K, & McCathie, L. The pros and cons of RFID in supply chain management, Proceedings of the International Conference on Mobile	RFID(Radio Frequency Identification)	Data Filtering and Processing
Rahul Moorthy, Swikriti Behera and Saurav Verma. On-Shelf Availability in Retailing. International Journal of Computer Applications (0975 – 8887) Volume 116 – No. 23, April 2015, PP. 47-51.	CNN (Convolutional Neural Networks)	Real-Time Monitoring and Alerts
Technical Research and Applications, Volume 2, Issue 4 (July-Aug 2014), PP. 197-199.		
Somaraju Boda. Feature-Based Image Registration, M.Tech thesis, National Institute of Technology, Rourkela, 2009.	YOLO(You Only Look Once)	Rotation-Invariant

Product OSA has been significantly improved by technology as well. Retailers all over the world are using QR codes more and more to learn about products and shelf status. Specialized 2D barcodes designed for data transmission are called QR codes. These QR codes can send text messages, open websites, and let store management know what's on the shelves right now. Over 14 million mobile users scanned QR codes in 2011, according to a survey [8]. Approximately 40% of these users did so inside retail establishments. To notify the store management when a requested product is missing, customers must scan the QR code on the shelf. This approach, however, mostly depends on client participation.

Many well-established retailers are adopting Radio- Frequency Identification (RFID) technology to enhance OSA. RFID technology is considered one of the most important tech-nologies of the 21st century as it enables real-time tracking of products within the supply chain [4].

RFID comprises unique ID tags, readers, and software necessary to integrate RFID components into a broader information processing system [5]. These tags, affixed to individual products, store various information points about the products, which are then readby the reader, converted into digital data, and transmitted to the information processing system [5]. The use of RFID tags contributes to improved inventory accuracy, enhanced OSA, and the elimination of OOS.

By placing a fixed RFID reader between the back room and the sales floor, retailers can track product movement, and employees can utilize handheld read- ers to conduct daily inventory checks of items on store shelvesand racks [6]. However, it's worth noting that RFID technologycan be costly, and the price of RFID tags has historically been a significant barrier to its widespread adoption in Supply ChainManagement (SCM) [7].

Another technology in use is weighted sensor shelves, which incorporate a weight-sensing mat, an RFID reader, and a ZigBee transceiver (a device for both transmitting and receiving radio waves). These mats are placed on store shelvesand are designed to detect changes in product weight, allowing the back-end software to calculate product quantities. Never- theless, the installation cost of this technology is relatively high, which limits its widespread adoption.

III. METHODOLOGY

Object detection is the process of identifying specific objects within an image. Typically, feature extraction and matching techniques are combined to achieve object detection.

Feature detection involves pinpointing significant areas within an image, while feature extraction assists in represent- ing these identified areas as feature vectors. The matching process then compares the feature vectors of a reference imagewith those of a target image to detect the reference object in thetarget image. The object displayed in the reference image withthe highest number of matches concerning the target image is selected as the detected object [10].

In this study, we propose a methodology for real-time void space detection and product positioning analysis in retail management using machine learning techniques. The methodology involves the application of YOLO v9, a state-of-the-art object detection algorithm, to analyze images captured by security cameras within retail environments. By leveraging machine learning capabilities, this approach aims to enhance on-shelf availability (OSA) and optimize product placement strategies. Using feature extraction techniques like "extractFeatures," features are extracted once they have been detected. Image registration and geometric transformation are included in feature extraction. In order to align the target image with the reference image, image registration is essential. Aligning two or more images that were obtained at various times, with different sensors, or from different angles is known as registration, and it is a key task in image processing. The target and reference images may be judged to be different even when they are not due to misalignment between the images, such as the inversion of one of the images (the target image, for example). For this reason, image registration is necessary for object detection.

Geometric transformation, which alters the locations of pixels in two photographs and creates correspondences between points in one image and their equivalents in the other, is the method used to achieve image registration. After feature extraction, the desired object is identified by comparing its features in the target image to those in the reference image, which is the image of the object that has to be recognized.

IV. FLOWCHART

A. *Obtain Real-Time Security Camera Images:*

In this step, security cameras are positioned strategically throughout the retail space to continuously take pictures of the shelves. Real-time information about the availability and placement of products is provided by these photos.
The photos that are taken are used as the raw data for later phases of processing and analysis. Clear, high-resolution photos are necessary for precise product and void space identification and detection.

B. *Use YOLOv9 to Find Void Spaces:*

YOLOv9, or "You Only Look Once version 9," is an object detection technique that relies on deep learning. It is used to identify empty spots on the shelves—areas where products are missing—in the photos that have been taken.

Because YOLOv9 can detect objects in real time, it is a good tool for swiftly evaluating vast amounts of photos. The algorithm assists retailers in identifying regions that need to be restocked or attended to in order to ensure optimal product availability by precisely identifying vacant spots.

C. *Give the input reference and the target picture.*

In this stage, the system receives reference photographs of properly packed shelves as input. These reference photos act as standards by which to measure how the shelves are currently doing.

The target image, which shows the shelves as they are right now as obtained by the security camera, is given to the system. The system detects differences in product availability and positioning by comparing the target image with the reference images.

D. *Preprocess the images:*

In order to improve quality and streamline processing, incoming images are preprocessed before feature extraction and analysis. By doing this, the grayscale photos are converted, which lowers the computational cost of the actions that follow.

Furthermore, photos can be edited as necessary to highlight particular focal points, like individual shelves or product displays. By removing redundant data, cropping increases the effectiveness of feature extraction and comparison algorithms.

E. *Feature extraction and matching of descriptors:*

Finding important locations or features, such corners, edges, or blobs, in the reference and target photos is the process of feature extraction. The visual and geometric qualities of these features are then described by computing descriptors, which are numerical representations of these aspects.

F. The descriptors of the reference and target images are compared using descriptor matching techniques, including the closest neighbor approach. Through the establishment of feature correspondences, the system is able to discern similarities and differences between the images.

G. *Syncing :*

In order to evaluate the similarity between the reference and target images, the system synchronizes their collected attributes in this step. To find the level of connection between the images, this entails comparing the retrieved features and descriptors.

There are two approaches explained for synchronization: directly comparing descriptors or creating a connection between characteristic locations in the reference image and descriptors in the target image. Accurate comparison and alignment of the images for further analysis are made easier by both techniques.

H. *Finding the Positions of Products:*

The system determines the product placements in the target image by utilizing the synchronized features between the reference and target images. To locate products, this entails comparing features and descriptors from the reference image with those in the target image.

The system can evaluate the spatial distribution of products on the shelves and discover any deviations from the ideal arrangement shown in the reference photographs by precisely detecting the positions of the products.

I. Putting Found Products on Display:

When products are found in the target image, the system surrounds them with polygons or bounding boxes to graphically represent their locations. This gives the specified products and their places on the shelves a clear visual depiction.

Retailers can take use of the exhibited products' actionable insights, which emphasize product regions and point out empty places that need to be filled or rearranged.

J. *Iterative Procedure:*

Because the entire procedure is iterative, the retail environment can be continuously observed and analyzed throughout time. The system repeats the identification, comparison, and visualization processes whenever new images are taken by the security cameras in order to deliver current information about the availability and location of products.

V. RESULTS

A. *Finding Void Spaces:*

Finding empty areas in the retail setting was successful when using YOLOv9 for real-time object detection. In order to ensure product availability and restock shelves in a timely manner, the algorithm was able to precisely identify places on the shelves where products were missing.

B. *Analysis of Product Positioning:*

The methodology's use of synchronization and feature matching techniques made it easier to identify product placements within the taken photos with accuracy.

Through an analysis of the features of the reference and target photos, the system was able to identify products and display their placements on the shelves.

C. *Perspectives on Shelf Management:*

Real-time image capture, analysis, and visualization in an iterative manner yielded insightful information on shelf management techniques. Retailers were able to optimize shelf design and product distribution by gaining actionable knowledge.

VI. CONCLUSION

In conclusion, our research effectively illustrated the viability of employing image processing methods, particularly those implemented in MATLAB R2013a, to automate the labor-intensive activity of scanning shop shelves. We were able to count the number of front-facing products on shelves and efficiently locate empty spaces by implementing our suggested method. Our solution demonstrated remarkable flexibility by allowing for modifications, such as products with various colored packaging, and guaranteeing precise identification even in intricate situations where products are arranged in close proximity to one another. Although analyzing larger real-time shelf shots took longer than with smaller, prepared images, our low-cost implementation allows shop managers to monitor in real-time. Although more tuning is required to fully utilize the system's potential for practical applications, our research provides a strong basis for further developments in this field.

VII. FUTURE SCOPE

There are a number of ways we might further our research in the future. Assessing the system's effectiveness in various lighting scenarios is one interesting avenue to pursue, as ambient light and image quality can have a big influence on outcomes.

Through extensive research and algorithmic refinement, we can increase the robustness of the system and guarantee consistent performance in a variety of conditions. Further studies could also compare intended planograms with actual product placements in order to identify and correct cases of incorrect or inadequate placing, especially at shelf fronts.

Our method has the ability to be tested in real-store settings with additional automation and optimization, which would yield insightful information for improving shelf management tactics. Improving the system's overall efficacy and usefulness will require addressing issues like the detection of tiny vacuum spaces.

VIII. References

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