

Empty Shelf Detection and Product Recommendation

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Abstract—Empty shelf detection is a critical problem in retail environments, where maintaining fully stocked shelves ensures customer satisfaction and minimizes revenue loss. This paper presents an integrated system that combines Region-based Convolutional Neural Networks (RCNNs) and computer vision techniques to automate the detection of empty shelf areas and recommend suitable products for restocking based on nearby items. The proposed approach employs an RCNN model trained from scratch to detect empty regions in shelf images. A secondary object detection model identifies items adjacent to these empty spaces, providing contextual information for restocking recommendations. Cosine similarity is utilized to match the features of nearby objects with a pre-defined product database, enabling accurate and contextually relevant product suggestions. Experimental results demonstrate the system’s effectiveness in detecting empty spaces, identifying nearby objects, and generating actionable stocking recommendations, paving the way for more intelligent and efficient retail inventory management.

Index Terms—empty shelf, recommendation, cosine similarity, rcnn

I. INTRODUCTION

In the fast-paced retail industry, ensuring optimal shelf utilization is a fundamental aspect of enhancing customer experience and maximizing sales. Empty shelves can result in lost sales opportunities, reduced customer satisfaction, and diminished store reputation. Traditionally, shelf monitoring and restocking have relied on manual processes, which are labor-intensive, error-prone, and inefficient. With advancements in computer vision and deep learning, automated solutions have become increasingly viable for addressing such challenges.

This study introduces a novel system for detecting empty shelf areas and recommending products to restock based on their spatial and semantic relationship with nearby objects. The proposed system leverages the power of Region-based Convolutional Neural Networks (RCNNs) to detect and localize empty spaces on shelves accurately. A secondary RCNN model or a similar object detection framework is used to identify items adjacent to these spaces. By analyzing the feature similarity of detected objects and utilizing cosine

similarity metrics, the system suggests products that align with the category or theme of the nearby items.

The primary contributions of this research include:

- 1) A custom RCNN model designed to detect empty shelf regions with high accuracy.
- 2) An object detection module to identify nearby products, providing contextual information for recommendations.
- 3) A cosine similarity-based recommendation algorithm that ensures the suggested products align with the detected shelf context.

The remainder of the paper is structured as follows: Section 2 discusses related work, highlighting existing techniques in shelf monitoring and product recommendation. Section 3 describes the methodology, including dataset preparation, model architecture, and integration of the recommendation engine. Section 4 presents experimental results, showcasing the system’s accuracy and practical applicability. Finally, Section 5 concludes with insights into future research directions and potential enhancements.

By addressing the gap between automated shelf monitoring and intelligent restocking, this study aims to contribute a robust, scalable, and efficient solution to modern retail inventory management challenges.

II. LITERATURE REVIEW

A. Empty Shelf Detection

B. Recommendation

III. PREPARE YOUR PAPER BEFORE STYLING

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$$a + b = \gamma \quad (1)$$

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Please use “soft” (e.g., `\eqref{Eq}`) cross references instead of “hard” references (e.g., (1)). That will make it possible to combine sections, add equations, or change the order of figures or citations without having to go through the file line by line.

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- There is no period after the “et” in the Latin abbreviation “et al.”.
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TABLE I
TABLE TYPE STYLES

Table Head	Table Column Head		
copy	Table column subhead	Subhead	Subhead

^aSample of a Table footnote.



Fig. 1. Example of a figure caption.

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ACKNOWLEDGMENT

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REFERENCES

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REFERENCES

[1] G. Eason, B. Noble, and I. N. Sneddon, “On certain integrals of Lipschitz-Hankel type involving products of Bessel functions,” *Phil. Trans. Roy. Soc. London*, vol. A247, pp. 529–551, April 1955.

[2] J. Clerk Maxwell, *A Treatise on Electricity and Magnetism*, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[3] I. S. Jacobs and C. P. Bean, “Fine particles, thin films and exchange anisotropy,” in *Magnetism*, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.

[4] K. Elissa, “Title of paper if known,” unpublished.

[5] R. Nicole, “Title of paper with only first word capitalized,” *J. Name Stand. Abbrev.*, in press.

[6] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, “Electron spectroscopy studies on magneto-optical media and plastic substrate interface,” *IEEE Transl. J. Magn. Japan*, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetism Japan, p. 301, 1982].

[7] M. Young, *The Technical Writer’s Handbook*. Mill Valley, CA: University Science, 1989.

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