Smart Home Interior Optimization using CNN and Deep Learning Models

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***Abstract*: Creating visually appealing and functional interiors is often challenging due to issues like poor space utilization, mismatched decor, and improper lighting. This paper addresses these problems with an AI Based website where users upload images of their living rooms for analysis using the YOLO algorithm. The system evaluates aspects such as lighting, saturation, and decor harmony, providing a style rating and personalized recommendations to enhance aesthetics and functionality. By offering rating and actionable insights, this solution simplifies interior design, making it accessible, efficient, and user-friendly.**

***Index Terms*: Machine Learning, Interior Decor, Computer Vision, Object Detection, Deep Learning.**

I. INTRODUCTION

Smart home interiors have become a cornerstone of modern living, blending aesthetics, functionality, and technology to create spaces that are not only visually appealing but also efficient and adaptable. These innovative designs make life easier by optimizing space, enhancing energy usage, and promoting convenience, which are essential for meeting the demands of contemporary lifestyles. The need for well-thought-out smart home interiors arises from the growing desire for personalized, stylish, and functional living environments that seamlessly integrate with technology. Approaches to achieving this include using cutting-edge AI tools, machine learning algorithms, and even manual techniques to analyse factors like lighting, spatial arrangement, and colour harmony.

In this paper, titled "*Smart Home Interior Optimization using CNN and Deep Learning Models*", we introduce a platform designed to simplify this process. The system leverages YOLO (You Only Look Once), a highly efficient real-time object detection algorithm, to identify and analyse elements in uploaded room images. Additionally, Convolutional Neural Networks (CNNs) are employed to evaluate patterns, colours, and textures while predicting style ratings. Together, YOLO and CNNs form the foundation for a powerful tool that provides detailed insights, actionable recommendations, and product suggestions tailored to enhance both the aesthetics and functionality of interior spaces. Using a robust stack of technologies like React, Python with Django or Flask, Tensor Flow, and OpenCV, the platform empowers users to transform their living spaces into harmonious, optimized environment.

II. LITERATURE SURVEY

To optimize smart home interiors, numerous machine learning algorithms have been explored, significantly enhancing the efficiency of addressing this challenge. Recent advancements in Deep Learning and Artificial Intelligence (AI) have further improved the precision and versatility of interior design optimization solutions. Below is an overview of notable contributions in this field, along with their key limitations.

A. Zhang, Tian, et al.: *"Machine Learning for Automated Placement and Colour Adjustment of Home Décor Items"*

This study presents a machine learning framework for automating the placement and colour adjustment of home décor items. The system analyses spatial arrangements and adjusts colours to create visually harmonious interiors, utilizing diverse datasets of interior designs to train its models. **Limitations**: While innovative, this approach lacks advanced object detection capabilities, restricting its ability to identify and classify room objects effectively. Additionally, it does not offer comprehensive style ratings or detailed enhancement suggestions, limiting its practical applicability.

B. Lu, Zhiwei, et al.: *"AI for Smart Furniture Design: Aesthetic Preferences and Spatial Constraints"*

This research introduces an AI-driven system to optimize furniture design based on aesthetic preferences and spatial constraints. The framework focuses on suggesting furniture arrangements that suit room dimensions and user tastes. **Limitations**: Although it addresses furniture design, the system does not extend its scope to broader interior elements like décor arrangement or colour coordination. It also lacks the ability to enhance user-uploaded images, which reduces its relevance for personalized interior design needs.

Volume: 09 Issue: 04 | April - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

C. Sharma, Ravi, et al.: *"Real-Time Style Recommendation for Interior Design Using Object Detection and AI"*

This paper proposes a real-time style recommendation system that employs object detection to analyse interior spaces and suggest improvements. It identifies furniture and décor elements, recommending adjustments to improve the room's aesthetic appeal.
Limitations: Despite its real-time capabilities, the system does not actively enhance existing décor arrangements or provide detailed product recommendations. This limits its usefulness in offering actionable insights for comprehensive interior improvements.

D. Redmon, J., & Farhadi, A.: *"An Incremental Improvement"*

This paper focuses on YOLOv3, a cutting-edge real-time object detection algorithm. YOLOv3's ability to detect objects with high speed and accuracy has been transformative in many fields.
Limitations: However, YOLOv3 has not been tailored for interior design applications. It lacks integration with style ratings or enhancement systems, making it unsuitable for addressing specific challenges in smart home interiors.
By addressing these gaps, the current paper integrates YOLO and CNNs to offer a complete solution for smart home interior optimization. This approach combines real-time object detection, style evaluation, and actionable recommendations, helping users create visually appealing and functional living spaces.

III. DEEP LEARNING MODELS

A. Definition:

Deep learning is a subset of machine learning that employs artificial neural networks with multiple layers to model intricate patterns in large datasets. It excels in image recognition, natural language processing, and time-series forecasting by learning automatically from data without manual feature engineering. Techniques like CNNs, RNNs, and GNNs are widely applied across diverse domains for solving complex challenges.

B. Classification of Models:

Deep Learning models (refer fig.1) are classified based on their architecture and the type of data they process. The primary categories include:

- Convolutional Neural Networks (CNNs): Specialize in image and video processing tasks such as object detection and classification.
- Recurrent Neural Networks (RNNs): Designed for sequential data like text or time-series, excelling in tasks such as speech recognition and language modeling.
- Graph Neural Networks (GNNs): Effective for graph-structured data, commonly used in social network analysis and spatial relationship modeling.

This paper leverages advanced deep learning techniques to analyze and enhance home interior designs. The primary model used is YOLO (You Only Look Once) for object detection, combined with CNNs for additional analysis.

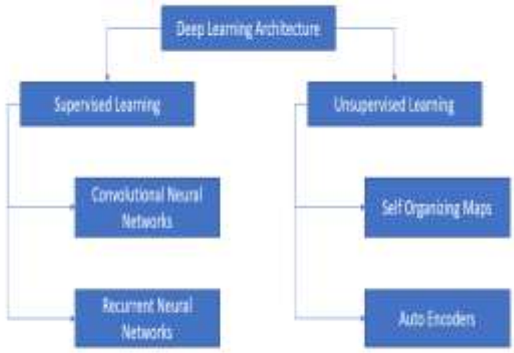

Fig .1. Deep Learning Model Architecture

These models enable the system to process visual data effectively, identifying furniture, décor elements, and spatial arrangements from user-uploaded images. By analyzing these factors, the system provides actionable insights to improve room aesthetics and functionality.

C. YOLO Object Detection:

YOLO, a state-of-the-art real-time object detection model, plays a pivotal role in this paper. The model (refer fig.2) processes images by dividing them into grids, simultaneously predicting bounding boxes and class probabilities for objects within the image. This facilitates accurate detection and classification of furniture and décor items, allowing the system to evaluate their placement, size, and compatibility within the design.

Advantages of YOLO in this Study:

- High-speed detection ensures quick feedback for users.
- High precision enables accurate recommendations for rearranging or enhancing décor items.
- Real-time performance makes it suitable for interactive applications.

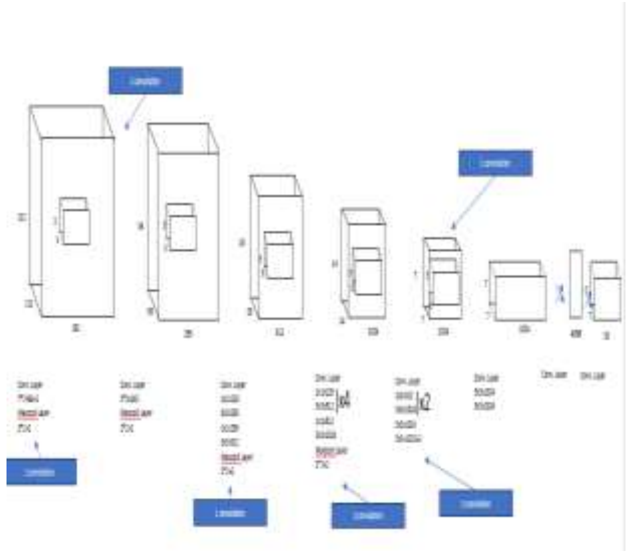

Fig. 2. YOLO Model Architecture

By employing YOLO, the system achieves high-speed detection while maintaining precision, making it suitable for real-time applications. This ensures that users receive quick and accurate feedback on their room designs, including recommendations for rearranging items or adding new décor to enhance the space's aesthetic appeal.

D. Complementary Deep Learning Models:

In addition to YOLO, CNNs are utilized to identify patterns in user-uploaded images and predict style ratings. By analysing visual features such as textures and other visually impactful features, CNNs enable the system to:

- **Predict a style rating** based on the design features of user-uploaded images.

CNNs are trained on a diverse dataset of interior designs, allowing the system to make reliable predictions about the overall aesthetic rating of a room. These ratings form the basis for providing users with actionable suggestions to optimize their interiors.

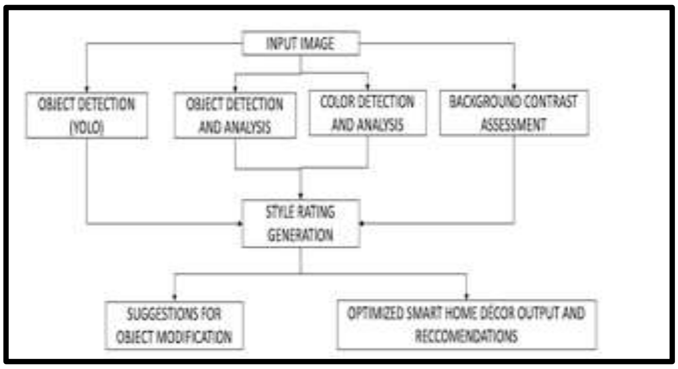

Fig. 3. Research Flow

By integrating YOLO and CNNs, the paper provides a comprehensive solution for interior design optimization. YOLO focuses on feature extraction and object detection, while CNNs specialize in analysing patterns and predicting style ratings.

The combination of these technologies enables the system to:

- Generate side-by-side visual comparisons of the original and enhanced designs.
- Provide accurate style ratings along with suggestions for rearranging items or adding new décor elements to enhance the space's visual appeal.

This integration ensures an efficient and user-friendly platform for creating aesthetically pleasing and functional interiors.

IV. METHODOLOGY

Dataset Preparation:
A curated dataset of high-quality interior design images is collected and preprocessed to ensure uniformity by resizing, normalizing, and removing noise for consistent input.

Feature Extraction:
The YOLO model is used for object detection, identifying furniture and décor items in the uploaded images. CNNs analyse textures, colours, and patterns, while GNNs evaluate spatial relationships to ensure aesthetic harmony and functional layouts.

Style Scoring:
The system evaluates images based on factors such as colour coordination, object placement, and overall aesthetic balance, assigning a comprehensive style score.

Design Enhancement:
For images receiving lower style scores, the system suggests improvements, including rearranging furniture, adding decorative elements, and modifying colour schemes to improve the room's aesthetics and functionality.

Feature Recommendations:
The system analyzes décor and furniture, providing recommendations on enhancements and suitable replacements to improve overall room aesthetics and harmony.

Product Recommendations:
The system provides a list of recommended décor items, including details such as product names, colours, prices, and purchase links from platforms like Amazon and Flipkart, enabling users to implement changes seamlessly.

System Deployment:
A web-based platform is developed, allowing users to upload room images, receive detailed style scores, view optimized designs, and explore actionable recommendations.

The dataset for this paper comprises 1812 living room images collected from Kaggle and other online sources, along with 362 test images, divided into 80% training and 20% testing sets. Images are preprocessed by resizing, normalizing pixel values, and removing noise for consistency.

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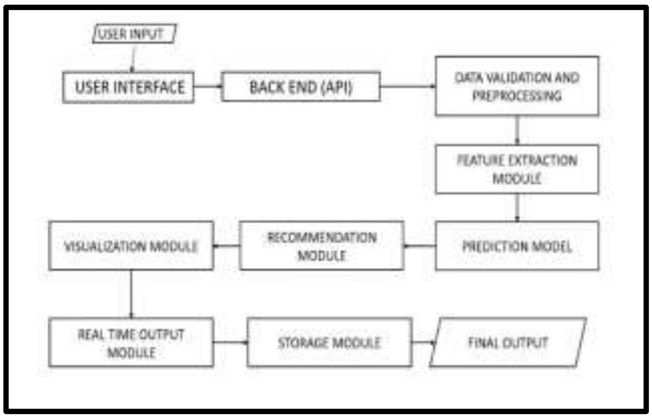

Fig. 4. Proposed System Architecture

Using YOLO for object detection, furniture and décor elements are identified, while CNNs and GNNs analyse textures, colours, and spatial arrangements. The model is trained on the processed data, validated with the test set, and optimized for accuracy. Once validated, the system predicts and enhances new user-uploaded images, improving room aesthetics and functionality with precision.

V. RESULTS AND DISCUSSION

Our study introduces an AI-powered system for enhancing home interiors by analyzing room images, detecting furniture, and evaluating color coordination. It generates a style score, offers visual comparisons, and suggests improvements like furniture rearrangement or added décor, with updated images and purchase links. While effective, the system relies on high-quality images, as low-resolution inputs may reduce accuracy. Future enhancements will integrate advanced AI models and expanded design options to enhance precision and usabilitycould include advanced AI models and more design options to improve accuracy and usability.

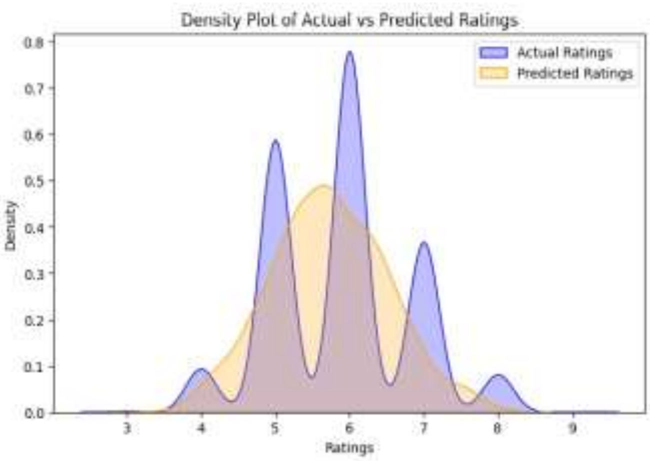

Fig. 5. Density Plot Representing Actual and Predicted Ratings

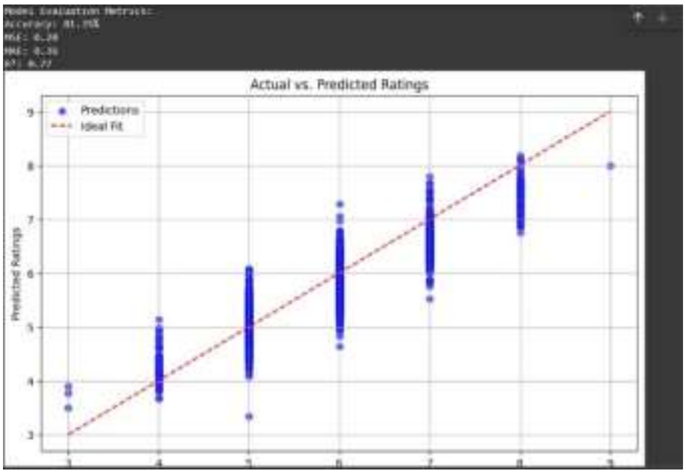

Fig. 6. Graph Representing Actual and Final Predictions along with scalar measures

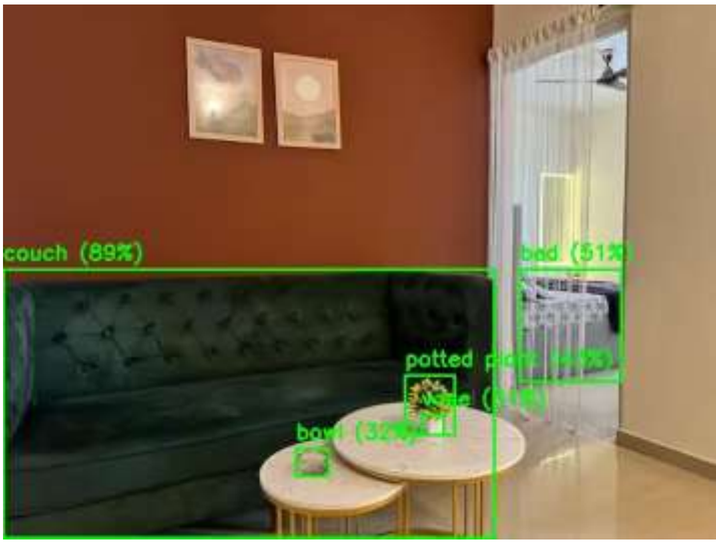

Fig. 7. Image Representing Object Detection along with accuracies

VI. CONCLUSION

This study presents a novel approach to YOLO-based object detection in interior design, providing an intelligent platform for optimizing living spaces. By identifying furniture, décor, and spatial arrangements, the system offers data-driven recommendations to enhance aesthetics and functionality. Advanced image processing evaluates color harmony and spatial balance, guiding users in rearranging furniture, adding décor, or optimizing lighting. Integrating AI precision with design creativity, this research demonstrates how computer vision and deep learning can transform interior design using AI-driven insights and make advanced tools widely accessible.

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