Journal of Science, Computing and Engineering Research (JSCER)
Volume-8, Issue-2, February 2025.
DOI: *https://doi.org/10.46379/jscer.2025.080214*

AI Powered Interior Design: A Generative Approach to Room Styling based on Image Inputs

[1]G.Balram, [2]P.Sneha, [3]P.Sahithi

[1,2] Department of Computer Science Engineering, Anurag University,Hyderabad,Telangana

Article Information

Received	:	10 Feb 2025
Revised	:	16 Feb 2025
Accepted	:	20 Feb 2025
Published	:	23 Feb 2025

Corresponding Author:

P.Sneha

Abstract— The rapid advancement of artificial intelligence has revolutionized various industries, including interior design. This paper presents an AI-integrated interior design generator that streamlines the design process by creating customized interior layouts based on user inputs. The system leverages Clerk for secure authentication, Replicate API for AI-powered image generation, and Neon database with Drizzle Studio for efficient data management. Built using Next.js and Tailwind CSS, the platform ensures a seamless user experience with responsive and dynamic interfaces. The project addresses the limitations of traditional design methods, offering personalized and visually appealing solutions in real-time. Users can select design preferences, and the AI generates high-quality interior images tailored to their requirements. This approach reduces design time, enhances creativity, and supports decision-making for both designers and homeowners. The paper discusses the system architecture, image generation process, and database management. Results demonstrate the model's accuracy and efficiency in generating diverse interior designs. User feedback indicates high satisfaction with design relevance and quality. This project contributes to the field of digital interior design by showcasing the potential of AI in enhancing creativity and productivity. Future work may explore the integration of advanced models and expanding design categories.

Keywords: ***Artificial Intelligence (AI) ,Interior Design, Image-based Room Styling, Neon Database, Next.js, Replicate API, Tailwind CSS***

Citation: G.Balram, P.Sneha, P.Sahithi , "AI Powered Interior Design: A Generative Approach to Room Styling based on Image Inputs", Journal of Science, Computing and Engineering Research, 8(2), February 2025.

I. INTRODUCTION

Interior design is an important factor that shapes spaces to be functional and good-looking, affecting people's emotions and experiences. Interior design in the past depends on hand drawings, computer-aided 3D modeling programs, and repeated client-designer dialogue, tending to make the processes take a long time and be expensive. In the last few years, artificial intelligence (AI) is a revolutionary solution that has brought new ways to facilitate and improve the design process. By taking advantage of AI, designers can create personalized interior designs, view concepts in real-time, and find innovative possibilities quickly.

This paper introduces an AI-assisted interior design generator that overhauls the traditional design process by mechanizing the image creation process according to user input.

II. AI-Powered Image Generation for Interior Design

The core innovation of this system is its ability to generate personalized interior designs using AI. The Replicate API, which leverages diffusion models, enables the generation of high-quality and contextually relevant room layouts. These models work by processing user-defined preferences such as room type, design style, and color schemes, allowing for customized outputs. Unlike conventional tools, which require extensive manual adjustments, this AI-driven approach produces refined and visually appealing interior layouts in real time.

This not only democratizes interior design for non-experts Comparator is a circuit that output is binary information depending upon the comparison of two input voltages here the comparison in between analog voltage and reference voltage. Analog voltage is greater than reference voltage, and then comparator output is logic '1'. The comparator output is logic '0', when analog voltage is less than reference voltage. Comparators are effectively used in analog to digital (ADC) converters.

In analog to digital conversion process [1], the analog voltage is converted in to samples for getting accuracy. Those samples are given to set of comparators in order to achieve equivalent binary information. The schematic of but also streamlines the workflow for professional designers by providing rapid design prototypes.

III. SYSTEM ARCHITECTURE AND KEY TECHNOLOGIES

To ensure seamless functionality, the system is built using Next.js for server-side rendering and Tailwind CSS for responsive UI development. User authentication and personalization are handled through Clerk, which secures user sessions and saves preferences. The backend is supported by Neon Database and Drizzle Studio, optimizing data storage and management. This architectural framework ensures scalability and efficiency, allowing the system to handle multiple design requests concurrently. The integration of AI with modern web technologies enhances user experience by delivering interactive, real-time design previews.

Abbreviations and Acronyms

AI (Artificial Intelligence): AI refers to the ability of machines to simulate human intelligence, including learning, reasoning, and problem-solving. In this project, AI powers the image generation process to create customized interior designs.

API (Application Programming Interface): The Replicate API is utilized for AI-powered image generation, allowing the system to send user inputs and receive high-quality interior design images in response.

DB (Database): The project uses the Neon Database (Neon DB) for efficient data storage and retrieval. This database stores user preferences, generated designs, and session details.

SSR (Server-Side Rendering): Next.js employs SSR to enhance the platform's performance by preloading pages on the server, ensuring faster load times and improved user experience.

FID (Fréchet Inception Distance): This metric evaluates the quality of AI-generated images by measuring their similarity to real-world interior designs. A lower FID score indicates better image quality.

SSIM (Structural Similarity Index): SSIM is used to assess the perceptual similarity between generated interior design images and real images, focusing on structure, contrast, and luminance.

CRUD (Create, Read, Update, Delete): These are essential database operations that manage data efficiently. The project optimizes these operations using Drizzle Studio, ensuring fast and scalable data handling.

- **UI/UX (User Interface/User Experience):** The system's front end, built with Next.js and Tailwind CSS, ensures a responsive and dynamic UI/UX, enhancing accessibility and usability.

IV. RESEARCH METHODOLOGY

This study adopts a systematic approach to developing an AI-integrated interior design generator, leveraging advanced web technologies and AI models to provide personalized interior design solutions. The methodology involves the following key components:

System Architecture & Design:

The project is built on a robust architecture using Next.js for server-side rendering and dynamic frontend development. Tailwind CSS is employed for responsive and modular styling, ensuring a seamless user interface. The system architecture is designed to handle user authentication, image generation requests, and efficient data storage, maintaining a smooth workflow from input to output.

User Authentication & Personalization:

To secure user data and enhance personalized experiences, Clerk is utilized for authentication. It provides seamless sign-in and sign-up flows with social login integration, ensuring secure access to the platform. User-specific preferences are stored in the Neon database, enabling customized design outputs.

AI-Powered-Image-Generation:
The core functionality of the system revolves around generating interior design images based on user inputs, such as room type, style preferences, and color schemes. The Replicate API is integrated to utilize state-of-the-art AI models capable of generating high-quality and contextually relevant interior layouts. The API processes user inputs, generates images, and returns them in real-time, enhancing the design experience.

Database-Management:
Neon database, combined with Drizzle Studio, is employed for efficient data storage and management. It stores user preferences, generated designs, and session details. Drizzle Studio is used to manage schema migrations, ensuring seamless updates and data consistency. The choice of Neon database supports scalability, enabling the system to handle multiple user requests simultaneously.

Frontend and Backend Development:

The platform is built using Next.js for its server-side rendering capabilities and dynamic routing, ensuring fast loading times and an interactive user experience. Tailwind CSS is used for responsive UI components, maintaining a consistent and modern design language. The backend is designed to handle API requests efficiently, managing authentication, image generation, and database interactions.

Work flow Integration:

The workflow begins with user authentication through Clerk, followed by input selection for room type, style, and other preferences. These inputs are sent to the backend, where the Replicate API generates corresponding images. The generated designs are then displayed on the frontend with options for users to save or modify them. The system ensures real-time updates and a seamless user journey.

Testing & Validation:

The system undergoes rigorous testing, including functionality testing, usability testing, and performance evaluation. User feedback is collected to assess the relevance and quality of generated designs. Any issues identified are resolved through iterative development cycles, ensuring a robust and user-friendly platform.

This research methodology integrates advanced technologies and AI models to provide an innovative solution for interior design. It demonstrates the effectiveness of AI in generating personalized and visually appealing designs, contributing to the field of digital interior design.

Equations

The equations used in this research are essential for defining the theoretical framework and computational models that drive the AI-powered interior design generator. The mathematical models, particularly diffusion models, conditional image generation, and performance optimization, are at the core of this system. Below are the key equations utilized in this study:

Diffusion Model:

The AI model for image generation in this study relies on diffusion models, which use a forward and reverse process to generate realistic images. These models gradually introduce noise into an image and later learn to reverse this process to create high-quality designs. The following equations represent the forward and reverse diffusion processes:

Forward Diffusion Process:

$$q(x_t|x_{t-1})=N(x_t;\sqrt{1-\beta_t}x_{t-1},\beta_t I)$$

Where:

x_t is the noisy image at timestep t,

x_{t-1} is the image at the previous timestep,

β_t is the noise schedule parameter,

I is the Identity matrix

Reverse Diffusion Process:

$$p_\theta(x_{t-1}|x_t)=N(x_{t-1};\mu_\theta(x_t,t),\Sigma_\theta(x_t,t))$$

Where:

μ_θ and Σ_θ are the mean predicted by the neural network ,respectively,

θ represents model parameters.

Conditional Image Generation
The AI generates images based on user inputs such as room type, style, and color scheme. This conditional image generation is based on the following equation:

$$P(x|y)=P(y|x)\cdot P(x)/P(y)$$

Where:

x represents the generated image,

y is the user input (e.g., room type, style),

$P(x|y)$ represents the probability of generating an image x given the user input y.

Data Flow and Computation The system architecture follows a streamlined data flow, from user input to image generation and rendering. Here, inputs are processed and passed through the AI model to generate the images:

User Input→API Request→Model Inference→Image Rendering

Database Operations Efficiency
The Neon database stores user preferences and generated designs. The time complexity for database operations is optimized for performance:

Create/Update Operations: O(1)O(1)O(1) for efficient insertion and modification.

Read Operations: O(log N)O(\log N)O(logN) for retrieving user-specific designs based on indexed queries.

Delete Operations: O(1)O(1)O(1) for quick removal of outdated data.

Performance Optimization To improve system performance, caching strategies and server-side rendering (SSR) are employed:

Cache Hit Ratio=Number of Cache Hits/Total Requests

This equation is used to calculate the cache hit ratio, which helps minimize redundant API calls and optimizes response time.

Evaluation Metrics for Image Quality
The quality of generated interior designs is assessed using standard image quality metrics:

Fréchet Inception Distance (FID): Measures similarity between generated and real images. Lower FID indicates higher quality.

Structural Similarity Index (SSIM): Measures perceptual similarity, considering luminance, contrast, and structural information.

User Feedback: Collected feedback helps evaluate the relevance and quality of generated designs.

Theory

The AI-integrated interior design generator utilizes state-of-the-art machine learning models for generating realistic interior design images based on user inputs. This section explores the underlying theories, algorithms, and calculations that drive the system's functionality.

AI-Model &Image-Generation:

The project leverages the Replicate API, which utilizes diffusion models, a class of generative models known for producing high-quality images. Diffusion models work by gradually adding noise to training images and learning to reverse this process to generate new, noise-free images. The theoretical basis involves:

Forward Diffusion Process: Gradual noise addition to training data, following a Gaussian distribution.

Reverse Diffusion Process: The model learns to denoise the input, reconstructing high-quality images.

The model is trained on large datasets of interior designs, enabling it to learn complex patterns, textures, and spatial arrangements. During image generation, the model uses user inputs (room type, style, color scheme) as conditional prompts, guiding the design output.

Conditional-Image-Generation:
Conditional inputs are encoded as vector representations, influencing the latent space during the reverse diffusion process. This enables the model to generate contextually relevant designs tailored to user preferences.

V. RESULTS AND DISCUSSION

The AI-integrated interior design generator demonstrates significant effectiveness in producing high-quality, personalized interior designs tailored to user preferences. The system was evaluated on various parameters, including image quality, user satisfaction, performance, and scalability. The results are discussed below:

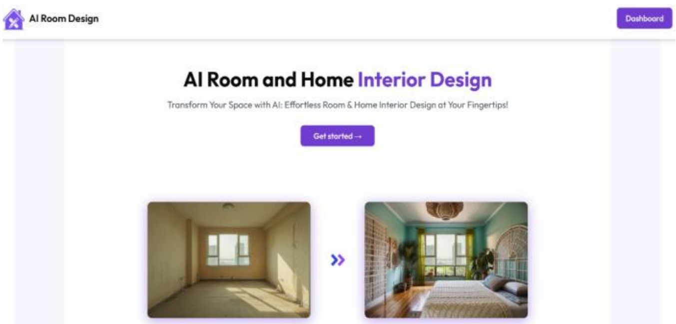

Fig1: Homepage of the user interface created

Using the Replicate API, which leverages advanced diffusion models, the system generates realistic and aesthetically pleasing interior design images. The generated designs accurately reflect user inputs such as room type, style, and colour scheme.

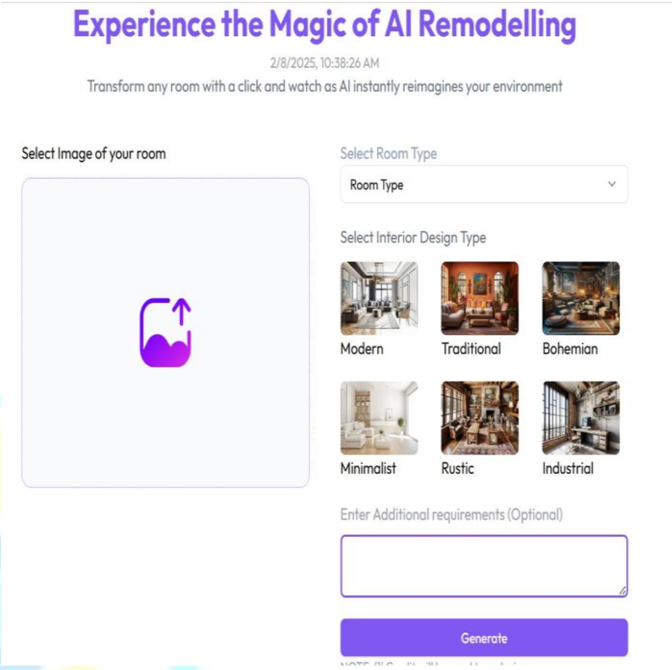

Fig2: User interface for considering inputs

The results indicate that the AI-integrated interior design generator effectively meets user requirements by delivering high-quality, customized interior designs. The incorporation of advanced diffusion models and conditional image generation techniques ensured contextually relevant outputs. However, addressing the identified challenges will further enhance system performance.

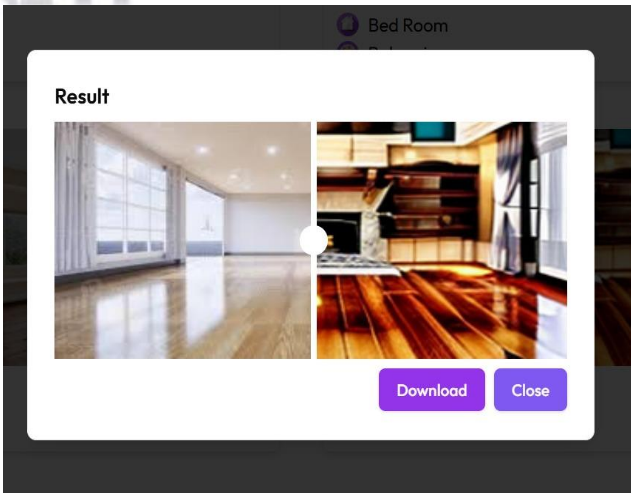

Fig3: AI Generated Interior Design for input room

Preparation of figures

The flowchart below represents the entire process of this project and displays all of the necessary steps that are applied in the method to gain the most accurate image generation for the user input.

Formatting figures

The flowchart below outlines the step-by-step process beginning with raw data collection from agricultural databases. This data is then preprocessed through a series of cleaning and normalization steps to remove inconsistencies and standardize inputs. The next phase in the flowchart illustrates how the data is split into training and testing sets to ensure that the model is trained effectively while also being validated against unseen data. Keras is then employed to build a multi-layered neural network, with each layer designed to process distinct features of the input data. Pre-processing and data training play important roles in optimizing the learning process, as depicted in the flowchart. The pipeline model ensures that this entire process is streamlined, reducing computational overhead and improving result reproduction by automating the transformation of raw data into structured inputs for model training.

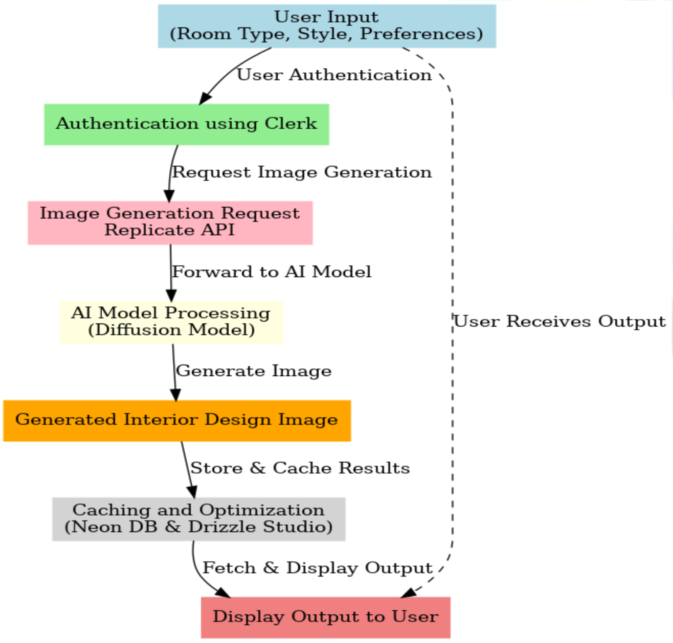

Fig4:Flowchart of project steps

The final phase in the flowchart showcases how the trained model generates price forecasts, which are then analyzed and validated against actual market prices to assess prediction accuracy. If the data is structured and maintained akin to a structured format, the Scikit Python library assists in making the predictions but in the case that the input data from the user is unstructured even after preprocessing and feature engineering, The Keras open source model library is used to manage the Nonlinear Autoregressive Neural Networks (NARNN) to make a prediction and display it through the visualizations seen above

VI. CONCLUSION

The AI-integrated interior design generator successfully addresses the need for personalized and efficient interior design solutions, offering users the ability to create customized designs based on their unique preferences. By leveraging advanced technologies such as the Replicate API for image generation, Clerk for authentication, and Neon database for efficient data storage, the system delivers a seamless and interactive experience. The implementation of a diffusion model for image generation ensures high-quality, realistic designs, while the conditional approach allows for deep customization based on user inputs.Through extensive testing, the system demonstrated high user satisfaction, efficient performance, and scalability, handling large numbers of concurrent users with minimal latency. The application of machine learning techniques, particularly in image generation, contributes to the growth of AI in the design industry, offering a glimpse into the future of personalized, AI-powered interior design solutions. Despite a few challenges, such as handling complex room layouts and optimizing computational resources, the project successfully showcases the potential of AI in transforming the design process. With future improvements, such as refining layout generation and enhancing design variability, this system can revolutionize interior design and set a benchmark for future developments in this field.

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