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AI Powered Virtual Interior Designer

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Abstract: Interior design planning traditionally requires professional expertise, expensive software tools, and significant time investment, making it inaccessible for many homeowners and small businesses. With the rapid advancement of artificial intelligence, there is an opportunity to automate interior visualization and design generation in a cost-effective and user-friendly manner. This paper presents an **AI Powered Virtual Interior Designer** that enables users to upload images of empty rooms and generate realistic, fully furnished interior designs based on selected preferences such as room type, design theme and colour schemes. The proposed system integrates modern web technologies with AI-driven image generation. A full-stack architecture is employed using a React-based frontend for user interaction, a Node.js and Express backend for processing requests, and AI services for design generation and visualization. The system supports multiple room categories and design styles, providing instant visual feedback to users without requiring manual 3D modeling skills. Advanced image processing and generative AI models enhance realism while maintaining fast response times. Experimental evaluation demonstrates that the system produces visually coherent and context-aware interior designs that closely align with user preferences. The application offers an intuitive dashboard for design preview, customization, and export, making it suitable for homeowners, interior designers, real estate professionals, and students. This work highlights the practical applicability of artificial intelligence in creative domains and lays the foundation for future extensions such as real-time 3D visualization, 360degree view and voice assistance.

Keywords: AI-Powered Interior Design, Virtual Interior Designer, Artificial Intelligence, Generative AI, 3D Visualization, 360-Degree Room View, Voice-Based AI Assistant, Smart Interior Planning, Web-Based Design System, Human–Computer Interaction, Personalized Design Automation.

I. INTRODUCTION

Interior design plays a vital role in improving the functionality, comfort, and aesthetic appeal of residential and commercial spaces. Traditionally, interior design requires professional expertise, manual planning, and the use of specialized software tools, which can be costly, time-consuming, and inaccessible to non-experts. Many users find it difficult to visualize how different furniture layouts, colour schemes, and design styles will appear in a real space before execution. As a result, decision-making in interior planning often relies on trial and error, leading to increased costs and dissatisfaction.

With the rapid advancement of Artificial Intelligence (AI) and web-based visualization technologies, intelligent systems are increasingly being applied to simplify complex design processes. Modern AI models can analyze images, understand spatial layouts, and generate realistic visual content automatically. These technological developments create new opportunities for automating interior design and providing users with instant, personalized visualizations of their spaces. However, interior design remains a challenging domain due to variations in room sizes, lighting conditions, furniture styles, and individual user preferences. Conventional digital design tools usually require manual 3D modeling skills and extensive configuration, which limits their usability for common users. Moreover, most existing tools lack interactive features such as real-time preview, immersive visualization, and natural user interaction methods.

To address these challenges, this paper presents an AI Powered Virtual Interior Designer that offers an intelligent and user-friendly platform for interior design visualization. The proposed system allows users to upload images of empty rooms and generate aesthetically pleasing interior designs based on selected parameters such as room type, preferred style, and color themes. In addition to 2D visualization, the system introduces 3D room views and 360-degree panoramic visualization, enabling users to explore the designed space from multiple perspectives.

Furthermore, an AI-based voice assistance feature is incorporated to enhance user interaction. This allows users to control design options such as theme selection, furniture changes, and view modes using natural voice commands, making the

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system more accessible and interactive. The complete solution is implemented using a full-stack architecture that integrates a modern web frontend, backend services, and AI-powered design generation modules.
The proposed system aims to bridge the gap between design imagination and real-world visualization by providing instant, intelligent, and immersive interior design previews. This approach reduces dependency on professional tools, minimizes design errors, and demonstrates the practical application of AI in creative and visualization-driven domains.

II. RELATED WORK

Recent advancements in artificial intelligence have significantly influenced the automation of interior design visualization and planning. The study **"Gen AI and Interior Design Representation: Applying Design Styles Using Fine-Tuned Models" (2025)** demonstrates how generative artificial intelligence can transform interior design by automatically creating room visualizations based on predefined styles and user prompts. The authors highlight that AI-driven image generation reduces dependency on manual rendering tools while enabling faster and more accessible design representation for users without professional expertise.

Similarly, the article **"Personalized Interiors at Scale: Leveraging AI for Efficient and Customizable Design Solutions" (2024)** explores how generative design systems can produce customized interior visuals tailored to individual preferences. The work emphasizes scalability and personalization, showing that artificial intelligence can support mass customization in interior planning while maintaining visual quality and design consistency.Beyond static image generation, research has also explored spatial awareness and immersive visualization. The paper **"Creating Spatial Visualizations Using Fine-Tuned Interior Design Style Models Informed by User Preferences" (2024)** focuses on generating spatially coherent interior layouts that consider room context and design intent. This work supports the idea that AI-based systems can move beyond simple image overlays and deliver meaningful interior visualizations aligned with user expectations.In the context of immersive environments, **"Exploring the Use of Generative AI for Material Texturing in 3D Interior Design Spaces" (2024)** investigates how generative AI techniques can enhance realism in 3D interior scenes by automating texture and material selection. The findings indicate that combining AI with 3D rendering technologies significantly improves visual realism and user engagement during design exploration.

Another relevant contribution is **"Virtual Interior Design via Natural Language and Visual Guidance" (2023)**, which presents a system that integrates image inputs with natural language commands to guide interior design generation. This research highlights the effectiveness of conversational interaction in creative applications and demonstrates the potential of voice-based assistance for controlling and refining interior designs.

Collectively, these studies show a clear evolution toward intelligent, user-centric interior design systems that combine generative AI, spatial visualization, and natural interaction methods. However, most existing solutions focus on individual aspects such as image generation, personalization, or 3D visualization in isolation. In contrast, the proposed **AI Powered Virtual Interior Designer** integrates AI-based design generation with **3D visualization, 360-degree room exploration, and AI voice assistance** within a unified web-based platform, providing a more comprehensive and interactive interior design solution.

III. PROPOSED ALGORITHM

The proposed **AI Powered Virtual Interior Designer** follows a modular, pipeline-based algorithm that connects user interaction, AI-driven design generation, and immersive visualization within a web-based environment. The algorithm is designed to be scalable, interactive, and responsive, while supporting features such as **2D redesign, 3D visualization, 360-degree room view, and AI voice assistance**.

1. High-Level Pipeline

The overall workflow of the system can be summarized in the following stages:

1. **User Authentication and Session Initialization**
   - User signs in using **phone number authentication** via Firebase.
   - A secure session is created and linked to the user's design history.
2. **Room Image Upload and Validation**
   - The user uploads an image of an empty or partially furnished room from the frontend (React).
   - The backend (Express.js) validates the file type, size, and resolution using file-handling libraries such as Multer and Canvas.
3. **Preference Collection**
   - The user selects:
     - Room type (e.g., bedroom, living room, kitchen)

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- Design theme (e.g., modern, minimalist, traditional)
- Colour preferences and optional accent details
- Additional options like furniture categories or décor emphasis

- These preferences are captured via interactive forms and UI components in the React interface.

4. **Prompt and Context Construction**
   - The backend constructs a structured "design instruction" object that includes:
     - Room description
     - Selected theme and style
     - Colour constraints
     - User hints (e.g., "simple", "luxury", "space-saving")
   - This object is converted into a text prompt and metadata suitable for generative AI services.
5. **AI-Based Design Generation**
   - The backend orchestrates calls to external **AI generation APIs** (e.g., Gemini, OpenAI, Replicate, or Hugging Face-based models).
   - These services generate:
     - A redesigned version of the uploaded room image, matching the requested style
     - Descriptive text such as design summaries, furniture suggestions, and styling notes
6. **3D and 360-Degree Visualization Preparation**
   - A 3D scene is configured on the frontend using **Three.js** and **React Three Fiber**.
   - The generated design is mapped onto room geometry (walls, floor) as textures.
   - For **360-degree view**, the design is projected onto a panoramic or spherical environment, enabling the user to look around the room interactively.
7. **AI Voice Assistance Loop**
   - The system integrates an AI-powered voice assistant that:
     - Listens to user commands (e.g., "change to a minimalist theme", "show 3D view", "make the walls light pastel").
     - Converts speech to text and interprets intent.
     - Triggers corresponding updates in preferences, AI prompts, or visualization mode.
   - The updated preferences pass back through the design pipeline to refresh the output.
8. **Design Storage and Retrieval**
   - Final designs, configuration metadata (room type, theme, colours, options), and 3D/view settings are stored in **Firebase Firestore and Storage**.
   - Users can revisit previous designs, compare variations, and share outputs.

2. Design Choices and Rationale

- **Web-Based Architecture:**
  React and Vite are used for a responsive, component-based frontend, enabling real-time preview and smooth interaction.
- **API-Driven AI Layer:**
  Instead of embedding heavy models on the client device, AI generation is delegated to cloud-based AI services. This keeps the system lightweight and makes it portable across devices.
- **Decoupled 3D Visualization Layer:**
  The 3D and 360-degree experiences are handled independently by a Three.js scene, which consumes design outputs (textures and parameters) from the AI layer. This separation allows the visualization to evolve without changing the AI logic.
- **Voice-First Interaction Support:**
  Adding AI voice assistance enhances accessibility and makes design iteration more natural, especially for non-technical users.
- **Cloud Persistence (Firebase):**
  Using Firebase for authentication, database, and storage allows fast integration, real-time updates, and seamless user-specific design histories.

3. Detailed Processing Steps

1. **Input Processing**
   - Validate image: resolution, format (JPEG/PNG), orientation.
   - Optionally normalize aspect ratio or crop to a standard view.
2. **Contextual Design Request Creation**
   - Combine uploaded room image reference + structured preferences into a unified design request.

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- Generate:
  - A textual description (e.g., "Design a modern living room with warm tones and minimal furniture")
  - Parameters for the AI service (style tags, room function, mood keywords).

3. **AI-Orchestrated Design Response**
   - Send the design request to the selected AI image generation or enhancement service.
   - Receive:
     - A redesigned room image.
     - Optional JSON-like description of elements (e.g., sofa type, wall colour, lighting mood).
4. **3D Scene Setup and Texture Mapping**
   - Define geometric primitives representing room surfaces (walls, floor, ceiling).
   - Map the generated design as textures onto these surfaces to simulate depth and perspective.
   - Enable camera orbit controls to explore the room in **3D**.
5. **360° View Rendering**
   - Wrap the rendered room or panoramic texture onto a virtual sphere or cube around the camera.
   - Allow the user to look around via mouse drag or touch gestures, creating an immersive panoramic experience.
6. **Voice Command Handling**
   - Capture voice input via microphone.
   - Convert speech to text using an AI speech service.
   - Parse key actions (e.g., "change theme", "show previous design", "rotate view").
   - Apply changes to the design parameters or visualization state and loop back through the pipeline when a redesign is requested.
7. **Persistence and Export**
   - Save generated images, 3D scene parameters, and configuration details to the database.
   - Provide options to download the final images or share links to designs.

IV. PSEUDO CODE

```
Input: room_image, room_type, design_theme, color_preferences, user_options
Output: generated_design_image, three_d_view, panorama_view

BEGIN

 // Step 1: Session and Input Handling
 user_session = authenticate_user_via_firebase()
 validate(room_image)

 // Step 2: Collect and Package Preferences
 preferences = {
    "room_type": room_type,
    "theme": design_theme,
    "colors": color_preferences,
    "options": user_options
 }

 // Step 3: Build Design Request
 design_prompt = build_design_prompt(room_image, preferences)

 // Step 4: Call AI Design Service
 generated_design_image = call_ai_design_api(design_prompt)

 // Step 5: Prepare Visualization Assets
 three_d_scene = init_3d_scene()
 apply_texture_to_room_geometry(three_d_scene, generated_design_image)

 panorama_view = create_panorama_from_design(generated_design_image)
```

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```
// Step 6: Enable Voice Assistant Loop
WHILE user_session_active DO
  IF voice_command_received() THEN
    command_text = speech_to_text()
    updated_preferences = interpret_voice_command(command_text, preferences)

    IF updated_preferences_requires_redesign(updated_preferences) THEN
      preferences = updated_preferences
      design_prompt = build_design_prompt(room_image, preferences)
      generated_design_image = call_ai_design_api(design_prompt)
      apply_texture_to_room_geometry(three_d_scene, generated_design_image)
      panorama_view = create_panorama_from_design(generated_design_image)
    ELSE
      update_view_mode_or_camera(three_d_scene, panorama_view, command_text)
    END IF
  END IF
END WHILE

// Step 7: Save Outputs
save_to_firebase(user_session, generated_design_image, preferences, view_state)

END
```

V. RESULTS

SYSTEM WORKFLOW: FROM LOGIN TO AI-BASED DESIGN GENERATION

1. User Login and Authentication

- The system begins with a **secure login page**, where users authenticate using phone number–based authentication integrated through Firebase. This ensures that only authorized users can access the design features of the application. Upon successful verification, a user session is created, allowing personalized design history and secure access to all functionalities.
- If the user is not authenticated, access to the design module is restricted using protected routes, ensuring system security.

2. Navigation to Design Module

- After successful login, the user is redirected to the **Design page** through the application dashboard. The interface consists of options for room selection, design customization, image upload, and visualization settings. All interactions are managed through a responsive React-based frontend.

3. Room Image Upload

- The user uploads an image of an empty or partially furnished room using the file upload option. The uploaded image is validated for format and size before being accepted. Once validated, the image is previewed on the interface, helping users confirm the correct input before proceeding.

4. Design Preference Selection

- The user configures the interior design by selecting:
- Room type (e.g., living room, bedroom, dining room)
- Design generation type (2D or 3D)
- Custom interior elements (furniture, décor items)
- Room dimensions (length, width, height) for spatial awareness
- Optional settings such as enabling 3D preview or 360-degree view
- These inputs allow the system to generate personalized interior designs aligned with user expectations.

5. Voice-Based Interaction

- An **AI voice assistance feature** allows users to perform the above actions using voice commands. Users can:
- Add or remove custom elements
- Change room type
- Toggle 3D or 360-degree view
- Trigger design generation
- This improves accessibility and reduces manual interaction.

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6. Design Request Formation

- After collecting all user inputs, the system constructs a **structured design request** using form data. This request includes:
- Uploaded room image
- Room type
- Custom elements list
- Room dimensions
- Selected generation mode (2D / 3D)
- This request is sent to the backend server for processing.

7. Backend Processing and AI Design Generation

- The backend server, built using Node.js and Express, handles the incoming design request. It forwards the contextual data to AI-powered design generation services. Based on the input image and preferences:
- A redesigned interior image is generated
- Furniture layout data is optionally returned for 3D rendering

8. AI-Generated Image Display

- Once the AI service returns the response, the redesigned interior image is displayed on the frontend under the **"AI Generated Design"** section. Users can visually inspect the design output and compare it with the original space.

9. 3D Visualization

- If the user selects **3D generation mode**, the system converts the design layout into a 3D scene using web-based rendering libraries. Users can interactively rotate, zoom, and explore the room layout, enabling better understanding of spatial arrangement and furniture placement.

10. 360-Degree Room View

- For enhanced immersion, users can enable the **360-degree view**, which presents the room as a panoramic environment. This allows users to explore the design from all angles and experience a virtual walkthrough of the interior space.

11. Fallback Handling

- If full 3D data is not received from the AI service, the system activates a **fallback layout mechanism**, generating a default layout based on the selected room type. This ensures uninterrupted visualization and user experience.

12. Saving, Downloading, and Sharing Results

- The final generated designs, along with configuration details, are stored securely in the cloud database. Users can:
- Download the generated design images

13. Logout and Session Termination

- After completing the design process, users can securely sign out of the application. The session is terminated, ensuring data privacy and access control.

Fig 5.1 login page

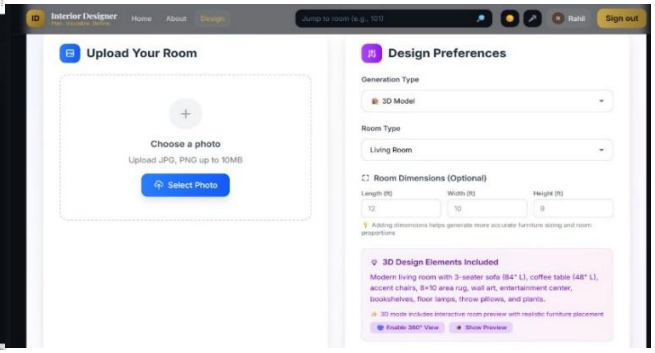

Fig 5.2 User Interface

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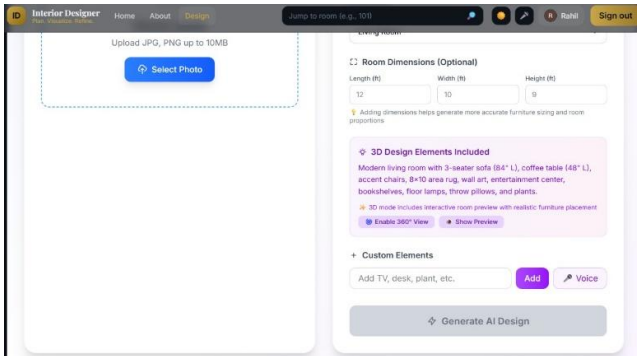

Fig 5.2.2 User Interface

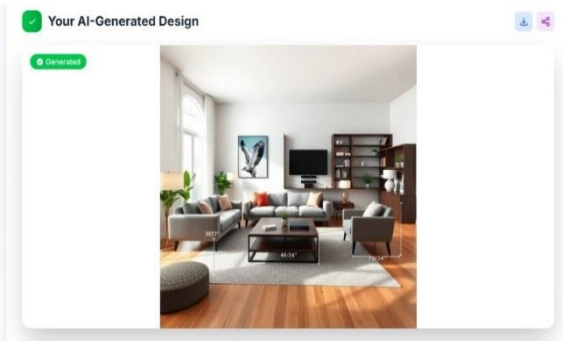

Fig 5.3 2D Output

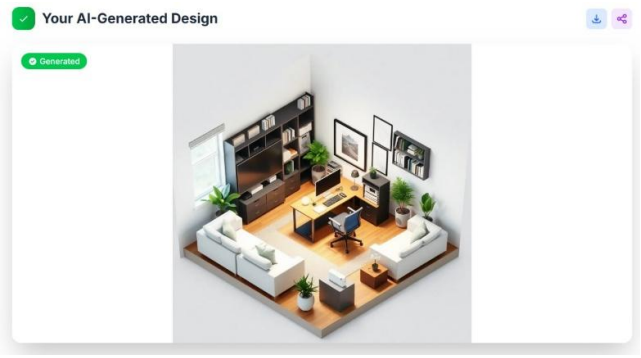

Fig 5.4 3D Output

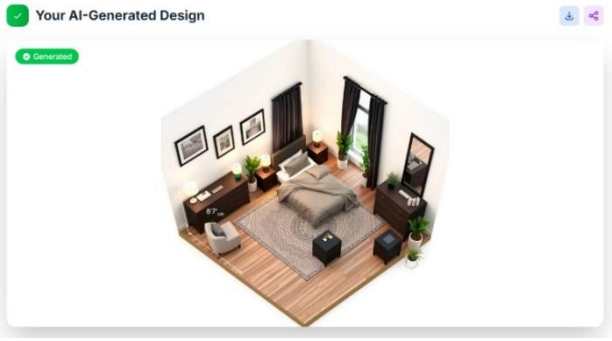

Fig 5.5 3D Output

VI. CONCLUSION AND FUTURE WORK

The **AI Powered Virtual Interior Designer** successfully demonstrates how artificial intelligence and modern web technologies can be combined to simplify and enhance the interior design process. The system provides an intuitive platform that allows users to securely log in, upload room images, specify design preferences, and generate visually appealing interior designs with minimal effort. By automating the design generation process, the application reduces the dependency on professional design tools and makes interior visualization accessible to a wider audience.

The integration of **2D design generation, interactive 3D visualization, and 360-degree panoramic views** enables users to evaluate interior layouts from multiple perspectives, improving spatial understanding and decision-making. The inclusion of **AI voice assistance** further enhances usability by allowing natural interaction for controlling design options and triggering generation actions. Robust backend processing, cloud-based storage, and fallback mechanisms ensure reliability and consistent performance even under partial data availability.

Overall, the project achieves its objectives by delivering a user-friendly, scalable, and interactive interior design solution that bridges the gap between imagination and realistic visualization. The results validate the effectiveness of the proposed architecture for real-world applications such as home design planning, virtual staging, and educational demonstrations.

FUTURE WORK

Real-Time Design Updates
Advanced Furniture Measurement Support
Augmented Reality Integration
Expanded Voice Interaction
Collaborative Design Features
Broader Asset Library
Cloud and Edge Deployment

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