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Augmented Reality Based Home Designer

Prof. W. P. Rahane, Siddhi Gathe, Komal Shinde, Kamesh Joshi
Department of Information Technology Engineering
NBN Sinhgad Technical Institutes Campus, Pune, India

Abstract: *This paper introduces "Augmented Reality Home Designer," an advanced application that leverages Augmented Reality (AR) and Virtual Reality (VR) technologies to revolutionize home design visualization and interaction. Traditional methods such as 2D blueprints, static images, and showroom visits often fail to provide an immersive and accurate representation of furniture placement and interior aesthetics. Our approach overcomes these limitations by allowing users to virtually position and visualize furniture in real-time within their own living spaces using an interactive AR interface. Unlike existing AR-based interior design applications that are often complex or require high-end devices, our solution focuses on accessibility and user-friendliness, making AR tools available to a broader audience regardless of technical expertise or device constraints.*

In addition, our platform facilitates seamless integration for furniture retailers, enabling them to showcase digital furniture models interactively. This feature enhances customer engagement by providing a realistic, lifelike experience using VR visualization with a standard camera interface. By combining AR's real-time spatial mapping with VR's immersive capabilities, the Augmented Reality Home Designer aims to redefine the way homeowners, interior designers, and furniture retailers approach space planning and décor selection. The proposed system employs Python, OpenCV, and AR SDKs to deliver an intuitive real-time visualization tool, ensuring high performance across various devices.Through extensive research, we address critical challenges in AR-based interior design, including visualization difficulties, the steep learning curve of professional design software, and limited accessibility of advanced design tools.

Keywords: Augmented Reality (AR), Home Design, Virtual Reality (VR), Furniture Visualization, Accessibility, Interactive Design, User Experience, Real-Time Rendering, Smart Interiors, Spatial Computing

I. INTRODUCTION

Recently, augmented reality (AR) technologies have made significant strides, particularly in the realm of furniture arrangement systems. These systems allow users to overlay virtual objects like sofas, paintings, flowerpots, chairs, and tables onto the real world, providing a powerful tool for visualizing how new furniture will fit into a space without the need to purchase or physically move items. This capability helps users make more informed decisions about their interior design by offering a realistic preview of potential changes. Augmented Reality (AR) is a form of Computer Vision Technology that seamlessly integrates virtual information into the real environment, effectively merging the virtual and the real into a cohesive experience. While current AR solutions offer substantial benefits, they often cater to a limited audience or require advanced technical skills. Our project, "Augmented Reality Home Designer," addresses this gap by developing a platform that not only makes AR technology more accessible to the general public but also enables furniture stores to contribute their designs directly to the platform. This allows clients to visualize these designs in their own homes using VR through a camera interface, thereby enhancing their decision-making process with a lifelike, immersive experience.

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II. CHALLENGES IN HOME DESIGN VISUALIZATION

A. Difficulty in Visualization

Home designers often struggle to effectively communicate their design ideas to clients, leading to challenges in helping clients visualize how the final design will appear in their actual living space. This gap in visualization can result in misunderstandings and dissatisfaction with the final product.

B. Lack of Professional Software Skills

Many designers lack the technical expertise required to use advanced home design software, which limits their ability to create accurate and detailed visualizations. This technical barrier can impede the design process, making it difficult to convey ideas clearly to clients.

C. Imagination Gap

Clients frequently face difficulties in imagining how furniture or other materials they see online or in stores will fit and look in their own homes. This imagination gap can lead to uncertainty and hesitation in decision-making, as clients may struggle to visualize the final outcome.

D. Inaccessible Advanced Design Systems

Advanced home design software can be costly and complex, making it inaccessible to many designers, especially those working independently or in smaller firms. This lack of access further exacerbates the challenges in creating effective visualizations and communicating design concepts to clients.

E. Proposed Solution

To address these challenges, we propose the development of an augmented reality home design application using Python and OpenCV. This application will empower designers to create real-time, interactive visualizations of their design ideas, enabling clients to see how various elements would fit into their actual space. By bridging the gap between designers' concepts and clients' expectations, this project aims to provide a more accessible and user-friendly solution for home design visualization.

III. OBJECTIVES

The objectives of this project are as follows:

- To explore the role of augmented reality in enhancing user experience in interior design applications.
- To design and implement an interactive AR-based prototype for home design using mobile or wearable devices.
- To enable real-time placement and visualization of furniture and decor elements in a physical space using AR.
- To evaluate the usability, accuracy, and effectiveness of the AR-based system through user testing.
- To compare traditional home design methods with the proposed AR-based approach in terms of user satisfaction and design efficiency.

IV. LITERATURE REVIEW

In our comprehensive review of existing research, we found two studies particularly relevant to our project:

- The study titled "Augmented Reality in Interior Design" published in the International Research Journal of Engineering and Technology (IRJET), Volume: 06, Issue: 03, March 2019, explored the limitations of traditional interior design, which often relies on imagination or static images, making it difficult for users to accurately visualize how furniture will look and fit in their actual space. The proposed solution was to develop an Augmented Reality (AR) system that overlays virtual furniture onto the user's real environment, allowing them to see and interact with 3D models in real-time. This approach makes the design process more intuitive and accurate, directly aligning with the objectives of our project.

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• Another relevant study is "Interior Design in Augmented Reality Environment" published in the International Journal of Computer Applications (0975– 8887), Volume 5– No.5, August 2010. This research addressed the challenges faced by architects and interior designers in visualizing and modifying furniture within real-world spaces, which can lead to design inaccuracies and inefficiencies in collaborative discussions. The authors proposed the development of an AR system that enables real-time visualization, modification, and interaction with virtual furniture in a physical space. This system aimed to offer a dynamic and flexible user interface, allowing for precise adjustments and enhancing collaborative efforts, thus improving the overall accuracy and efficiency of interior design projects.

• The research titled "Interior Design using Augmented Reality Environment" published in the International Journal of Innovative Research in Science, Engineering and Technology (ISO 3297: 2007 Certified Organization), Vol. 5, Issue 4, April 2016 addressed the difficulties users face in visualizing how furniture will fit and look in their actual space using traditional methods. The proposed solution was an AR system that utilizes Android smartphones to overlay and interact with virtual furniture in real environments. This system allows users to select, modify, and see how furniture fits in their space in real- time, leading to improved design accuracy and user satisfaction.

• In the study "An Augmented Reality Design Tool to Guide Furniture Arrangements at Home" by Chuhan Qu, School of Industrial Design, Georgia Institute of Technology, the challenges users face in arranging furniture to optimize their home environment and psychological well-being were explored. The research proposed an AR tool that integrates Feng Shui principles with iterative prototyping, guiding users in making informed furniture placement decisions. The tool was designed to enhance users' home environments through interactive AR visualizations and was evaluated for usability with real users. This approach emphasizes the role of guided design recommendations in improving the overall harmony and functionality of interior spaces.

• The study "Interior Design using Augmented Reality" published in the International Research Journal of Engineering and Technology (IRJET), Volume: 08 Issue: 04, April 2021, addresses limitations in existing AR furniture arrangement systems, such as manual viewpoint adjustments and limited interface usability. The research proposes an AR system that utilizes FAST corner detection for real-time tracking without the need for identification markers. This system automatically calculates the optimal viewpoint for arranging virtual furniture, simplifying scene manipulation and improving users' understanding of room layouts.

• The conference paper "Enhancing the System Model for Home Interior Design Using Augmented Reality," published in December 2021, focuses on improving AR systems for home interior design by addressing challenges related to latency, occlusion, and user experience. The proposed solution is a mobile AR app that uses marker-less AR and Simultaneous Localization and Mapping (SLAM) to provide real- time, accurate visualizations of furniture in a user's home. The system enhances the user experience by offering improved response times and intuitive touch gesture controls, adhering to ITU-T standards.

• The journal paper "Interior Design Using Augmented Reality," published in Volume: 05, Issue: 05, May 2023, explores the role of AR technology in interior design by enabling real-time visualization and remote collaboration between designers and clients. The study highlights AR's benefits in reducing design costs, minimizing the need for physical prototypes, and enhancing interactive experiences through virtual object placement in real-world spaces. The findings align with our project's goal of improving design accessibility, decision-making, and user engagement through AR-based visualization tools.

• The journal paper "Augmented Reality (AR) Based Interior Designing," published in Volume: 06, Issue: 04, April 2024, examines the integration of AR in interior design and its impact on visualization, client engagement, and decision-making. Using qualitative and quantitative methods, the study highlights AR's advantages over traditional design methods by enabling real-time furniture and décor visualization through digital overlays. The findings support our project by reinforcing AR's role in improving user experience, enhancing interactive design visualization, and streamlining the decision-making process.

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V. METHODS AND TECHNOLOGIES

In order to realize the objectives of the Augmented Reality Home Designer, a strategic selection of methods and technologies has been made, reflecting a thorough understanding of the technical requirements and challenges involved in creating a robust AR-based application.

A. Python

Recognized for its versatility and extensive libraries, Python has been chosen as the primary programming language. Its strong support for computer vision and augmented reality development provides a solid foundation for building the core functionalities of the application.

B. OpenCV

The Open-Source Computer Vision Library (OpenCV) will play a pivotal role in image processing. By leveraging OpenCV, the application will be able to efficiently detect and track surfaces, recognize patterns, and seamlessly overlay virtual objects within the real-world environment, ensuring an immersive AR experience.

C. Augmented Reality SDKs

To enhance the application's AR capabilities, integration with platform-specific AR SDKs such as AR Core (for Android) and AR Kit (for iOS) will be undertaken. These SDKs are critical for enabling precise object placement and interaction within the 3D space, tailored to the user's specific device and operating system.

D. Machine Learning

The incorporation of basic machine learning algorithms will enable the application to recognize and categorize objects within the user's environment. This will enhance the accuracy and reliability of virtual object placement, making the AR experience more intuitive and responsive to the user's needs.

E. 3D Rendering

Advanced 3D rendering techniques will be utilized to create realistic visualizations of furniture and design elements. These visualizations will be overlaid onto the live camera feed, providing users with an accurate and real-time preview of how their design choices would appear in their actual space.

F. Real-Time Tracking Algorithm

The development of an efficient real-time tracking algorithm is essential for maintaining the stability and accuracy of the virtual objects within the AR environment. This algorithm will ensure that objects remain correctly anchored in place as the user moves around the room, preserving the integrity of the design visualization.

G. User Interface (UI) Design

A user-centric approach will be adopted in designing the interface, focusing on simplicity and intuitiveness. The UI will facilitate easy navigation, allowing users to seamlessly select and position furniture within the augmented environment, thereby enhancing the overall user experience.

This comprehensive selection of methods and technologies is designed to deliver a practical and innovative solution for home designers and clients, transforming the design process into an interactive, accessible, and highly effective experience.

VI. SOFTWARE AND HARDWARE REQUIREMENTS

A. Software Requirements

1) Operating System:

• Development: Windows 10/11, macOS, or Linux.

• Deployment: APK for Android 8.0 (Oreo) or higher; System App for Windows 10/11 or macOS.

2) Programming Languages:

• Python 3.10.

3) Development Tools:

• Anaconda Navigator for Python environment and package management.

• Visual Studio Code (VS Code) as the primary code editor.

• Android Studio for APK development, if necessary.

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• Git for version control.
4) Libraries and Frameworks:
• OpenCV, AR Core/AR Kit, Numpy, PyOpenGL.
5) Database:
• SQLite (if required).
6) Testing and Deployment:
• PyTest, Android Emulator, Buildozer, PyInstaller.
B. Hardware Requirements
1) Development:
• Minimum: Intel Core i5, 8 GB RAM, 256 GB SSD, Integrated/Dedicated GPU.
• A high-resolution web camera for real-time AR
functionality and accurate room scanning.
2) Testing:
• Mid to high-end Android/iOS devices with camera support.
3) Deployment:
• Devices running Android 8.0+, iOS 12+, Windows 10/11, or macOS with a connected web camera for AR operations.

VII. APPLICATION SPECIFICATIONS

1) Application Type:
• AR Home Design Visualization Tool.
2) Key Functionalities:
• Real-time room scanning, virtual furniture placement, and a user-friendly interface.
3) Performance:
• Real-time tracking and smooth rendering.
4) Usability:
• Intuitive controls with minimal setup.
5) Security:
• Ensuring data privacy throughout usage.

VIII. PROJECT MOTIVATION

The primary motivation for this project is to develop a home design system that addresses existing challenges in interior design visualization. By leveraging and enhancing digital rendering and modeling capabilities, this project aims to create an Augmented Reality (AR) based home design application that brings design ideas into reality, offering a comprehensive and convenient platform for interior design.

IX. FLOW DIAGRAM: UML ACTIVITY DIAGRAM

For the Augmented Reality Home Designer, a UML Activity Diagram is ideal for illustrating the sequential flow of activities within the AR system. This diagram clearly visualizes the process, decision points, and parallel activities, making it suitable for research papers by providing a clear overview of the system's operation.

A. UML Activity Diagram Summary

• Start: Process begins.
• Real World: Physical environment.
• AR Camera: Captures real-world view
• Live Stream: Continuous video feed.
• Select Component: User selects design elements.
• Detecting: System identifies surfaces and objects.

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• Process/Track Ground Plan: Processes and tracks the environment.
• Showing Measurement: Displays surface measurements.
• Rendering Components: Renders virtual design elements.
• Combine Virtual & Real Objects (AR): Merges virtual objects with the real-world environment.
• AR Model Display: Displays the augmented reality model.
• Insert in Rendering Components: Adds additional virtual elements.
• Virtual Things to Be Augmented: Prepares virtual objects for integration.
• VR Objects: Final AR model with integrated VR objects.

Fig. 1. Unified Modeling Language (UML)

X. USE CASE DIAGRAM SUMMARY

The Use Case Diagram illustrates the key interactions between users and the Augmented Reality Home Designer application. It highlights the essential steps involved in placing and visualizing furniture within an augmented environment.

A. Process Overview:
1. Start: Initiates the process.
2. Select Component from List: User chooses a design element from the available options.
3. Select Position of Ground Plan: User specifies where the component will be placed in the room layout.
4. Choose Measurement of Component: User defines the dimensions of the selected component.
5. Set Component: Positions the component in the virtual environment.
6. Display Furniture 3D Model in Real World: Shows the 3D model of the furniture overlaid in the real-world environment.
7. End: Concludes the process.

This Use Case Diagram provides a clear view of the user's journey from selecting a component to visualizing it in their space, supporting a comprehensive understanding of the application's functionality.

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Fig. 2. Use Case Diagram

XI. DESIGN AND DEVELOPMENT

The Augmented Reality Home Designer system operates through four key modules, each contributing to the overall functionality:

1) Live Stream:
Captures and continuously streams the real-world environment, providing a real-time feed for AR interactions.

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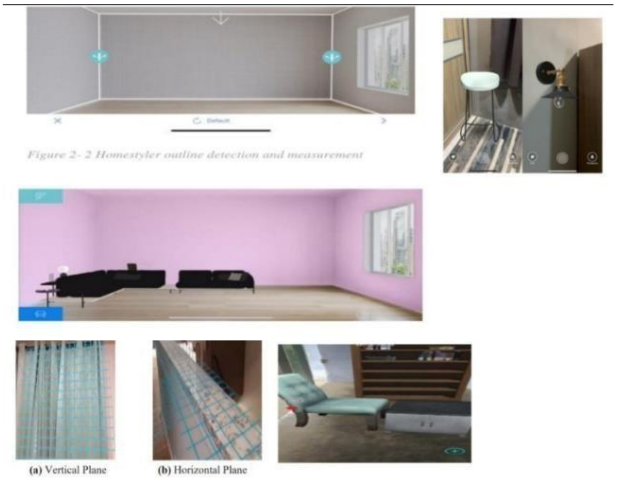

Fig. 3. Plain Detection

2) Detection:
Identifies and tracks surfaces and objects within the environment, enabling accurate placement of virtual components.
3) Measurement:
Measures the dimensions and spatial relationships of the detected surfaces to ensure precise scaling of virtual objects.
4) Combine Virtual and Real-World Object:
Integrates virtual furniture and design elements with the real-world environment, creating an augmented reality experience.
These modules work together to deliver a seamless and interactive AR experience for home design, allowing users to visualize furniture and décor in their actual space.

XII. SCOPE AND ANALYSIS

The Augmented Reality Home Designer project is designed to address the evolving needs of the home design and real estate markets by integrating advanced AR features and expanding its capabilities. Below is a concise overview of its scope and analysis, aligned with IEEE research paper guidelines:

A. Scope Enhancements:

1) Enhanced AR Features: The application will improve object recognition, enable real-time interaction with virtual furniture, and provide more accurate room scanning for a seamless AR experience.
2) Smart Home Integration: Integration with smart home devices and smart furniture will create a more connected and interactive environment, enhancing the user's control over their space.
3) Expanded Furniture Library: Partnerships with furniture retailers will allow a broader selection of furnishings, including the option for custom designs, providing users with more choices.
4) Real Estate Applications: The app will support virtual staging and augmented reality walkthroughs, offering real estate professionals a powerful tool for showcasing properties.
5) AI Design Assistance: AI algorithms will be implemented to offer personalized design suggestions and recommendations, making the design process more intuitive.
6) Social and Collaborative Features: Users will be able to share their designs on social media and collaborate with others in real-time, fostering a community-oriented design approach.

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7) Sustainability Focus: The app will highlight eco- friendly furniture options and provide material impact analysis, supporting sustainable home design choices.

B. Market and Feasibility Analysis:

1) Market Demand: There is a high demand for AR- based home design tools, particularly in the post-pandemic era, where remote visualization has become increasingly important.

2) Technical Feasibility: While the necessary technologies are available, precise room scanning and real- time performance across various devices require sophisticated algorithms and optimization.

3) User Adoption: The app is designed to appeal to interior designers, homeowners, and real estate professionals. A user-friendly interface will be critical for widespread adoption.

4) Competition: The application will compete with existing solutions like IKEA Place, but can differentiate itself with advanced AR features and smart home integration.

5) Revenue Potential: Potential revenue streams include partnerships with furniture retailers, in-app purchases, and a B2B model targeting real estate agencies.

6) Challenges: Achieving accurate room scanning and maintaining balanced performance across different devices will be key challenges to address.

7) Scalability: The project has significant scalability potential, with opportunities to expand into other markets and continuously update its features to stay ahead of competitors.

This analysis provides a comprehensive overview of the project's scope, market potential, and challenges, demonstrating its feasibility and potential impact on the home design industry.

XIII. IMPLEMENTATION SCENARIOS

The Augmented Reality Home Design System is a versatile tool used in various scenarios:

• Homeowners: Visualize home designs before making purchases.
• Interior Designers: Enhance client presentations with immersive AR visuals.
• Real Estate Agents: Virtually stage properties for better buyer engagement.
• Retailers: Allow customers to preview furniture in their homes.
• Educators: Provide hands-on AR experience in design courses.
• DIY Enthusiasts: Experiment with design ideas before execution.

These scenarios highlight the system's wide-ranging applications, enhancing communication and decision- making across multiple industries.

XIV. CONCLUSION AND FUTURE WORK

The Augmented Reality Home Designer project offers a novel approach to enhancing the home design and real estate industries through the integration of augmented reality technology. By providing real-time visualization capabilities, this application empowers both homeowners and designers to make well-informed decisions, thereby minimizing the risk of costly design changes during the construction phase. The project's ability to facilitate intuitive management of complex design data and to offer an interactive platform for client engagement underscores its potential as a valuable tool in modernizing the design process.

Looking ahead, several opportunities for further development have been identified. Future work may focus on enhancing the application's AR capabilities with improved object recognition, real-time interactions, and more precise room scanning. Additionally, integrating smart home devices and expanding the furniture library through partnerships with retailers could significantly increase the application's utility. The implementation of AI-driven design suggestions, coupled with social and collaborative features, would also add considerable value, enabling users to share and refine designs collectively. Moreover, the application could be expanded for use in real estate, particularly in virtual staging and AR walkthroughs. A focus on sustainability, offering eco-friendly furniture options and material impact analysis, could further align the project with contemporary design trends. These enhancements will ensure that the Augmented

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Reality Home Designer remains at the forefront of innovation, continuing to meet the evolving needs of the home design and real estate sectors.

XV. ACKNOWLEDGMENT

We would like to express our sincere gratitude to everyone who contributed to the development of the Augmented Reality Home Designer project. Special thanks to our research advisors and industry experts for their invaluable insights and guidance. We also appreciate the dedication and expertise of our development team and collaborators. Their collective efforts were crucial in bringing this project to completion. Additionally, we are grateful to the organizations and participants who provided feedback and helped validate the application's effectiveness. This project would not have been possible without the support and contributions of all involved.

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