Enhancing Interior Design Visualization and Interaction Through Unity-Based Augmented Reality

Aishwarya Lohakare[*1], Nachiket Ashok Shinde[*2], Arun Haridas Attikkachalil[*3], Dr. Umesh Pawar[*4]

[*1,2,3,4]Sandip University, Nashik, India.

Abstract:

The concept of augmented reality (AR) in interior design has its origins in science fiction, where futuristic environments were imagined with digital overlays that seamlessly blended with real-world spaces. These early fictional depictions inspired the development of AR technology, which has since become a practical tool with real-world applications.Designers can use AR to visualize and experiment with different design elements, such as furniture, layouts, and color schemes, all within the context of an actual physical space. AR enables clients to see how various design ideas will appear in their homes or offices, providing a clearer understanding of the final result before any physical changes are made. Through real-time visualizations and immersive experiences, clients can explore multiple design options, make adjustments, and refine their choices on the spot. This capacity for experimentation not only enhances decision-making but also fosters creativity, as clients can visualize different styles and configurations without the need to physically move furniture or make costly changes. As AR becomes more integrated into interior design, it has revolutionized the design process, making it more efficient and interactive. This paper explores how AR technology is being applied specifically to customized and interactive furniture solutions. The research focuses on developing a user-friendly and interactive AR application that leverages on-screen visualizations to simplify the furniture selection and arrangement process. The proposed app aims to allow users to place virtual furniture in their real-world spaces, customize it in real time, and interact with the virtual objects in a way that makes the design process more intuitive and enjoyable. Through this app, the design experience becomes more personalized and accessible, benefiting both designers and clients.

Keywords: Augmented reality (AR), Interior designing, 3D Modeling, Real-world Application

I.Introduction

This research paper explores the use of Augmented Reality (AR) technology to enhance the interior designing process. Readers are recommended to have basic knowledge of AR principles, mobile development tools like Unity 3D, and AR platforms such as AR Foundation and Google ARCore for better comprehension of the implementation.The developed AR application is designed for Android devices compatible with ARCore. Users should ensure their device has a functioning camera, motion sensors (accelerometer and gyroscope), and sufficient processing power to support smooth AR experiences. Adequate lighting conditions are crucial, as AR plane detection performs best in well-lit, non-reflective environments.Users can place, scale, rotate, and reposition virtual furniture models within their physical environment using real-time interactions. Multi-touch gestures are supported for object manipulation, and steady movements are recommended for optimal results. An "Undo" feature allows the removal of recently placed objects, while a local database saves layouts for retrieval after restarting the app.

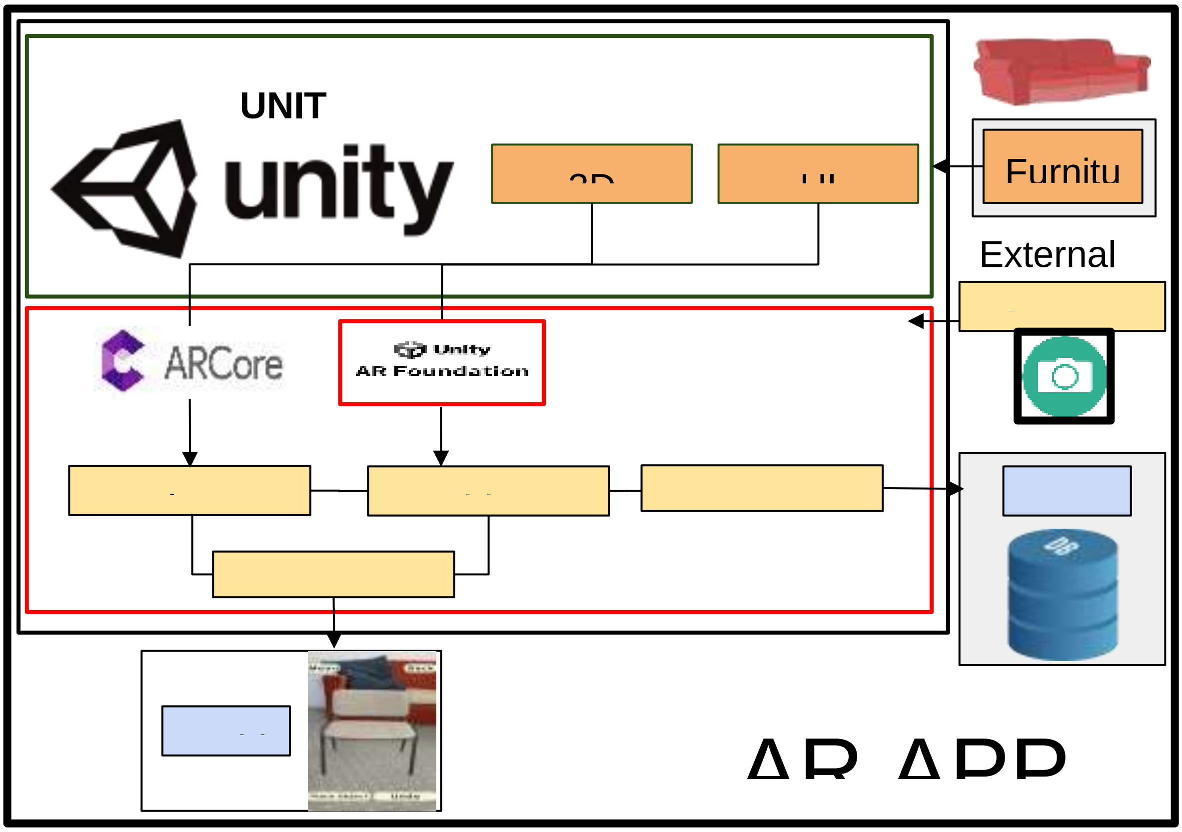
During evaluation, users should observe frame rate stability, surface detection accuracy, and interaction responsiveness. Environmental factors such as lighting and surface texture significantly impact the precision and realism of object placement. Testing across multiple devices is encouraged to assess compatibility and performance consistency. Future developers are encouraged to expand features by integrating AI-based furniture arrangement suggestions, collaborative design through AR Cloud Anchors, and larger furniture libraries. Although the current application is optimized for Android, its design structure can be adapted for iOS platforms using Unity’s cross-platform capabilities.

II.Literature Review

Consumers and designers are increasingly drawn to the immersive potential of augmented reality (AR) in interior design. Jan Janusz's work highlights the use of AR to create point clouds and meshes from room data using device option information to form point clouds or meshes, facilitating area learning, depth perception, and motion tracking. However, the reliance on high-performance mobile devices for this computer-aided design presents a barrier to widespread adoption. Ayman Kandil, Bader Al-Jumaah, and Iyad Abu Doush further demonstrate the value of AR in enhancing user experience through their AR3D model, which enables designers to practice with user-provided designs and receive real-time feedback. 25 participants evaluated their proposed solution, leading to improvements in the second version with the help of user recommendations. While their AR3D model improves with user input, the process remains time-consuming and resource-intensive, indicating the need for more efficient solutions.

Yuh-Shihng Chang, Kuo-Jui Hu, Cheng-Wei Chiang, and Artur Lugmayr explore the educational application of AR using AR tags for layout plan instruction, showcasing its versatility across Android and iOS platforms. They focus on creating blueprints before designing the model of the scene and overlaying the virtual object's 3D image. However, this process is labor-intensive and shifts attention away from technical aspects, and the furniture cannot be placed in the real world or time. Similarly, Peter Kán, Andrija Kurtic, Mohamed Radwan Jorge, and M. Loáiciga Rodríguez's automatic interior design system in AR, based on hierarchical procedural rules, offers personalized furniture selection using a recommender service, with 3D models downloaded on demand from the server. However, this automatic layout leads to no personal or professional input, and there are limited user interactions. Yoga Sharia, Budi Santoso, and Tri Kuat utilize maker detection for three-dimensional object generation in interior design education, providing a creative and captivating teaching aid that has been tested on different devices. Nonetheless, the essential role of markers for 3D object generation and their potential to disorient users due to excessive numbers underscores the ongoing challenges in perfecting AR applications for interior design.

III.Architecture Diagram



(Fig 1 Architecture)

Unity 3D: At the heart of this AR application lies Unity 3D, a powerful game engine that serves as the primary development platform. It provides the necessary tools for creating and managing the 3D environment, integrating virtual objects like furniture models, and designing the user interface. Unity acts as the central hub, orchestrating the interaction between various components and ultimately rendering the final augmented reality scene, seamlessly blending the virtual and real worlds.

AR Foundation: Bridging the gap between Unity and the underlying AR platform is AR Foundation, a Unity package that simplifies cross-platform AR development. It acts as an abstraction layer, allowing developers to access common AR features like camera access, plane detection, and device tracking without writing platform-specific code. In this architecture, AR Foundation facilitates communication with Google ARCore, enabling the application to leverage its advanced AR capabilities.

Google ARCore: Providing the core augmented reality functionalities is Google ARCore, which empowers the device to understand and interact with the real world. ARCore delivers crucial features like motion tracking, environmental understanding, and light estimation, allowing the application to accurately place and anchor virtual objects within the user's physical space. By processing data from the device's camera and sensors, ARCore enables a realistic and immersive AR experience, making it a critical component of this architecture.

The AR application employs Unity 3D as its central engine, leveraging its capabilities to integrate 3D models and user interface elements. These 3D models, which may include furniture or other virtual objects, are placed within the real-world environment captured by the device's camera. AR Foundation acts as an intermediary, enabling Unity to seamlessly interact with Google ARCore. ARCore processes the camera feed and sensor data to understand the environment, allowing for accurate placement and interaction with virtual objects. Users can place these objects using the "Place object" module. The application may also utilize a "Database Collection" and a "Local Database" to manage and store AR-related data. Real-time processing ensures that the augmented scene dynamically adjusts to changes in the environment and user interactions. Finally, the "Mobile Output" displays the augmented reality view, seamlessly blending the virtual and real worlds.

IV.Test Cases

3.1 Functional Test Cases :

Test Case ID	Test Case Description	Expected Result	Actual Result	Status
TC_F01	Launch the AR Application	Application should launch successfully and shows camera feed	Application launched successfully and shows camera feed	Pass
TC_F02	Place a furniture object	Object should be placed on the surface realistically	Object is placed on the surface realistically	Pass
TC_F03	Scale a placed object	Object should scale proportionally according to gesture	Object scales proportionally according to gesture	Pass

TC_F04	Rotate a placed object	Object should rotate smoothly without distortion	Object rotates smoothly without distortion	Pass
TC_F05	Undo a placed object	Last placed object should disappear from the scene	Last placed object disappears from the scene	Pass
TC_F06	Delete a placed object	Selected object should be removed from the scene	Selected object is removed from the scene	Pass
TC_F07	Multiple Object Placement	Multiple objects should be placed without performance lag	Multiple objects are placed without performance lag	Pass
TC_F08	Surface detection with visual feedback	Application should automatically detect horizontal surfaces and display visual dots as indicators	Application detects surface and displays tracking dots accurately	Pass
TC_F09	Object persistence during session	Placed objects should remain visible and interactable until manually deleted or session exited lag	Objects persist in scene unless removed or back button is pressed	Pass
TC_F10	Reposition a placed object	User should be able to select and drag a previously placed object to a new position on the same surface	Object is repositioned successfully to the new desired location	Pass

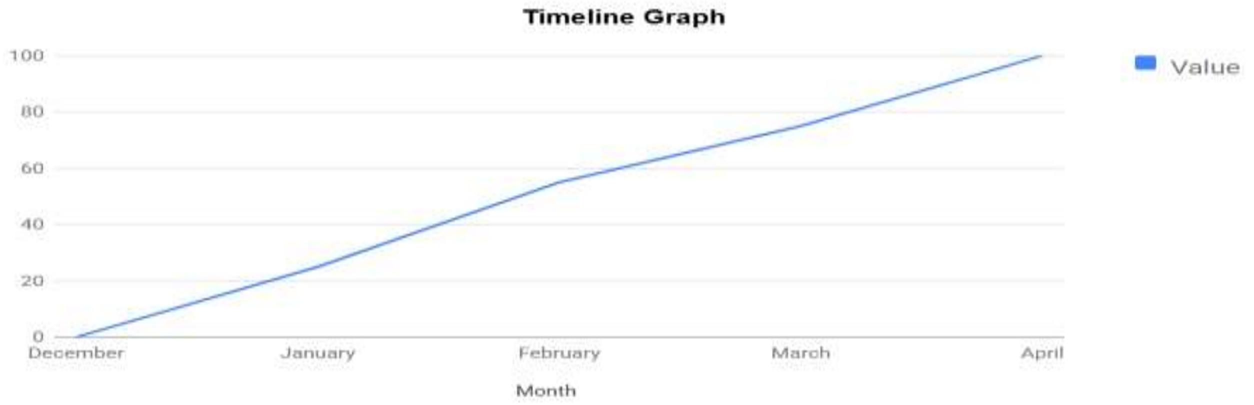
3.2 Non-Functional Test Cases:

Test Case ID	**Test Case Description**	**Expected Result**	**Actual Result**	**Status**
TC_NF01	App performance in different lighting	Should perform better in bright/moderate light; minimal tracking loss	Performs better in bright/moderate light; minimal tracking loss	Pass

TC_NF02	Frame Rate Stability	FPS should remain between 30–60 for smooth experience	FPS remains between 30–60 for smooth experience	Pass
TC_NF03	Battery Consumption Test	Battery usage should be acceptable for an AR app (~10-20%)	Battery usage is acceptable for an AR app (~10-20%)	Pass
TC_NF04	App crash resistance	App should remain stable without crashes or memory errors	App remains stable without crashes or memory errors	Pass
TC_NF05	Cross-device compatibility	App should function consistently across devices	App functions consistently across devices	Pass

V.Statistical Graph

4.1 Timeline Graph



(Fig 2 Timeline Graph)

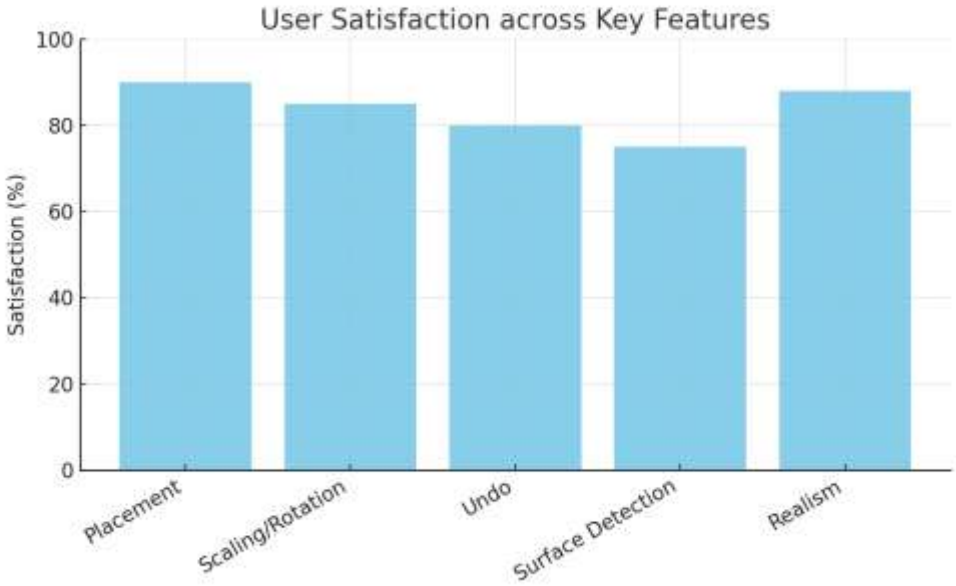
- **Timeline Graph (Value Over Months)**

1. **Steady Growth:** The value consistently increases from December to April.
2. **Zero Start:** It begins from 0 in December, suggesting either a new launch or starting point.
3. **January Boost:** Noticeable rise in January (~25 value).
4. **Major Jump in February:** Sharp growth continues, crossing 50.
5. **Continued Increase in March:** Smoother growth compared to earlier months (~75 value).
6. **Peak in April:** Value reaches 100, indicating the highest growth in this timeline.

4.2 User Satisfaction

- **User Satisfaction across Key Features**

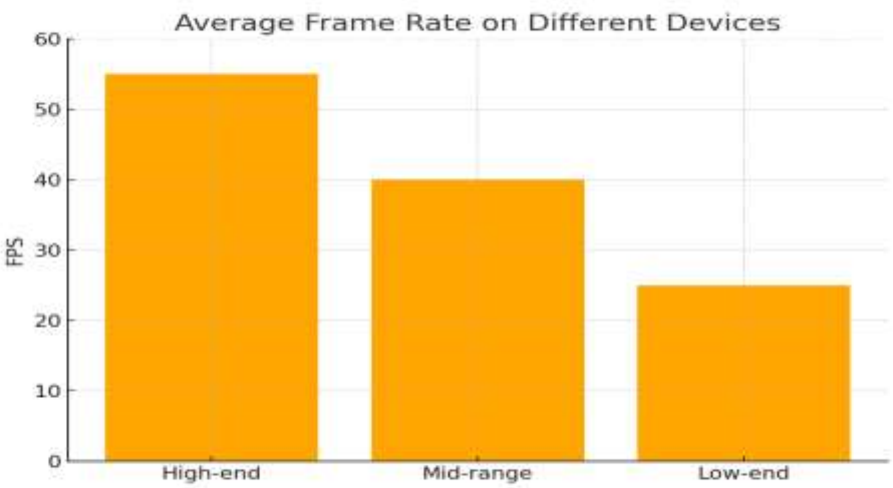
1. **Placement Satisfaction Highest:** Placement feature scored around 90%, the best among all.
2. **Scaling/Rotation is Strong:** Slightly lower than Placement, at about 85%.
3. **Undo Feature Mid-Range:** Satisfaction for Undo is around 80%.



(Fig 3 User Satisfaction across key features)

4. **Surface Detection Lowest:** Only about 75% satisfied, making it the feature needing most improvement.
5. **Realism Close to Top:** Realism gets around 88%, showing users appreciate realistic effects.
6. **Overall Positive:** All features have satisfaction above 75%, meaning users are generally happy.

4.3 Average Frame Rate On Different Devices

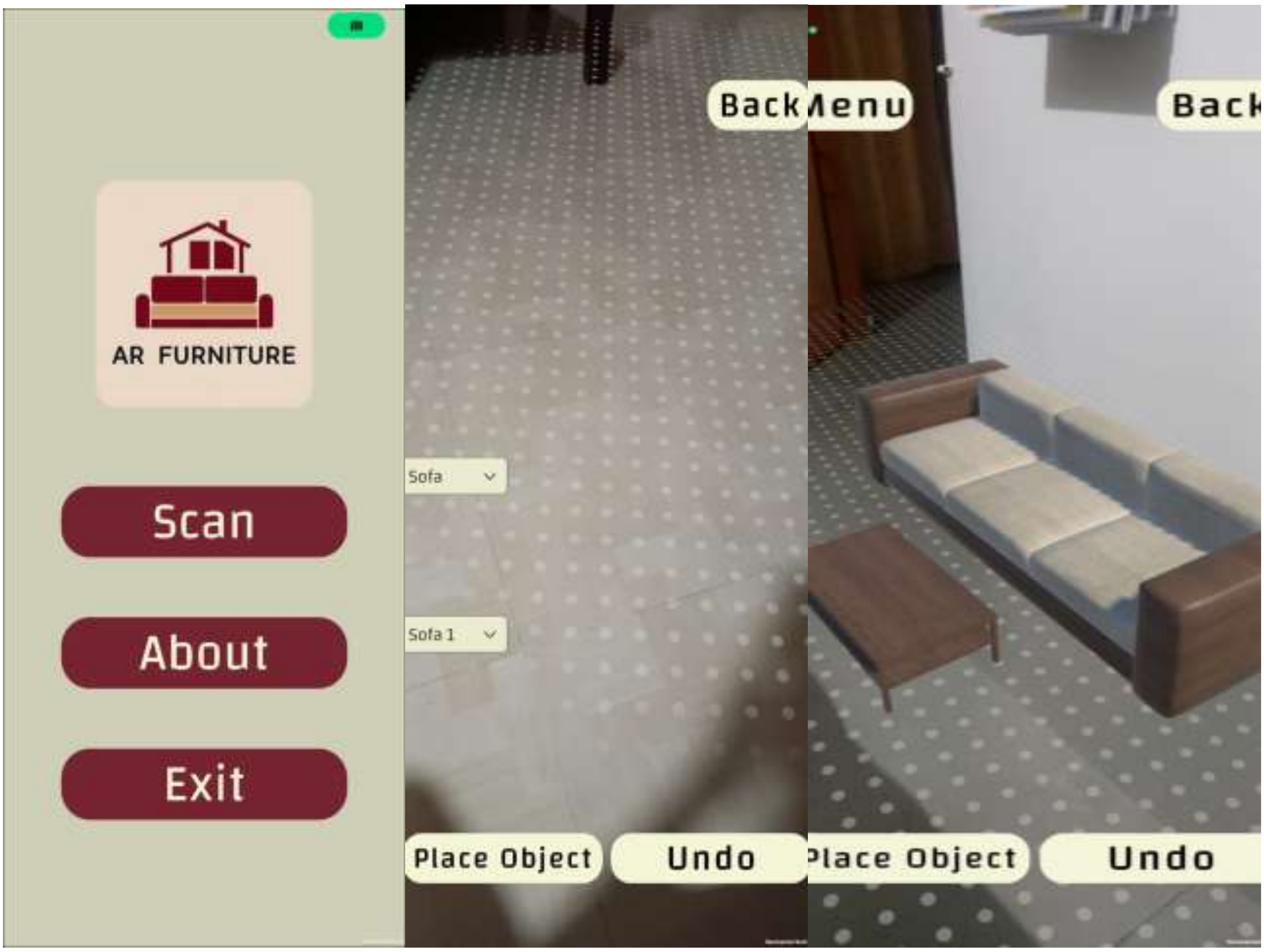


(Fig 4 Average Frame Rate On Different Devices)

- **Average Frame Rate on Different Devices**

1. **Best on High-End Devices:** Average FPS is about 55, ensuring smooth performance.
2. **Mid-Range Devices Decent:** Average FPS drops to 40, still playable but not the best.
3. **Low-End Devices Struggle:** FPS drops to around 25, affecting smooth gameplay or experience.
4. **Noticeable Performance Gap:** Clear difference between device categories.
5. **Optimization Needed for Low-End:** Indicates a need for optimization for better low-end device support.
6. **High-End Offers Premium Experience:** Best performance and user experience are available on high-end devices.

VI.Result



(Fig 5.1 Main Menu) (Fig 5.2 Scan) (Fig 5.3 Placed Furniture)

Figure 5.1 shows the app's main menu. You can see options like "Scan" to initiate the AR experience, "About" for information about the app, and "Exit" to close it.

Figure 5.2 shows the app actively scanning the environment. The camera view shows a floor, and the app is detecting planes (flat surfaces) to anchor the virtual furniture. You can see dropdown menus labeled "Sofa" and "Sofa1," where the user can select different furniture models. Buttons for "Place Object," "Undo," and a "Back Menu" to return to the "Main menu".

Figure 5.3 showcases the result of placing a virtual sofa and a coffee table in the real-world environment. The AR technology overlays these 3D models onto the camera feed, making it appear as if they are actually in the room. The users can interact with these virtual objects using touch gestures: pinch to resize, two-finger twist to rotate, double-tap to delete, and tap and drag to reposition.

VII.Conclusion and Future Scope

The integration of Augmented Reality (AR) technology into interior designing marks a major advancement in how designers and clients visualize and interact with spaces. Traditional methods, dependent on 2D sketches, physical models, and static images, often left gaps in understanding. This project demonstrates how AR bridges those gaps by offering real-time, life-size visualizations of virtual furniture within real environments. Users can place, scale, rotate, and customize furniture models interactively, leading to a more immersive and informed design experience. The AR application, developed using Unity 3D, AR Foundation, and ARCore, features an intuitive interface that enhances spatial awareness and decision-making. Real-time adjustments allow users to experiment with layouts and configurations, reducing the time, cost, and effort typically required for design changes. Performance testing indicates that the application operates smoothly under optimal lighting, maintaining stable frame rates and responsive object manipulation. User feedback highlights the application's usability and effectiveness, though improvements such as better surface detection in low-light conditions could enhance the experience further. This project underlines the transformative potential of AR in making interior design more interactive, personalized, and accessible. By enabling users to visualize and modify elements within their actual spaces before making physical changes, AR enhances creativity and confidence in decision-making. Future developments, such as AI-driven layout suggestions and cloud-based collaboration features, could further expand the capabilities of AR, shaping the future of the interior design industry.

The integration of Augmented Reality (AR) into interior designing opens several exciting possibilities for future development and innovation. As technology continues to evolve, the capabilities of AR applications can be significantly expanded to offer even more immersive, intelligent, and collaborative design experiences. One of the major future enhancements involves incorporating Artificial Intelligence (AI) into the AR system. AI can analyze room dimensions, lighting, and user preferences to recommend optimal furniture layouts, color schemes, and decor choices, further personalizing the design experience. AI-based design assistance would reduce decision fatigue for users and enhance creativity. Another promising direction is the implementation of AR Cloud Anchors or persistent AR experiences. This would allow users to save their designs in the cloud and access or edit them across multiple sessions and different devices. It would also enable multi-user collaboration, where multiple clients or designers can view, edit, and discuss the same interior space in real-time, regardless of their physical locations.
Finally, expanding the app for cross-platform support (iOS, Windows Mixed Reality, etc.) and compatibility with wearable AR devices like smart glasses could make the experience more immersive, hands-free, and user-friendly.

VIII.Acknowledgement

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