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DECO-AR: AN AUGMENTED-REALITY-BASED INTERIOR DESIGNING APP USING AR FOUNDATION

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ABSTRACT
Augmented Reality (AR) has revolutionized various industries by blending virtual objects with the real world, providing immersive and interactive experiences. This paper presents the development of an AR-based interior design application, "DECO-AR", to transform traditional interior design methodologies. The proposed system enables users to visualize and customize living spaces in real-time by overlaying virtual furniture and decor elements onto their physical environments. Developed using Unity Engine, Deco-AR ensures robust cross-platform compatibility for Android and iOS devices. Key features include real-time object placement, customization of furniture attributes, accurate spatial mapping through room scanning, and seamless e-commerce integration. Initial testing demonstrates high spatial accuracy and realistic visualization, underlining the potential of AR to revolutionize interior design.

Keywords:
Augmented Reality, Interior Design, Spatial Mapping, Virtual Objects, Real-time Visualization

1. INTRODUCTION

Augmented Reality (AR) technology aims at bridging the visible chasm between physical and virtual worlds by superimposing digital objects into real-time real-world surroundings. AR has been a great enabler with immersive and interactive experiences in gaming, healthcare, education, and retail. One of the most Promising applications of AR technology is interior design, which will greatly contribute to revolutionizing user experience by allowing visualization and interaction in their living area. Conventional approaches to interior design can be viewed as being overly reliant on very traditional manual measurements, physical samples, and the designer's ability to communicate design concepts in sketches or digital renders. These techniques are not only slow but are prone to error, with vast possibilities of misalignments between the conceptual design and physical implementation. These inadequacies have been addressed, to a point, by the advent of AR-based interior design applications in which a user can interactively visualize and place various pieces of furniture, colors, and configurations in real time. Hardware and software systems of AR are advancing with great speed, including the introduction of novel components such as LiDAR (Light Detection and Ranging) sensors and AI-object detection models; these advances allow precise spatial mapping at high speed and real-time rendering of complex 3D objects. Current mobile phones and AR headsets can now harness the processing and sensory capabilities needed to bring about high-fidelity AR experiences. In addition, AR development has become easy with ARKit (Apple) [3] and AR-Core (Google)[6], providing developers with powerful APIs for object tracking, surface detection, and lighting estimation. Consequently, the advancement made has incorporated interior design studio AR platforms, giving them the ability to place real-world objects virtually and virtually interact with them in real-time such as lighting, object interaction, sound, etc. The accuracy of surface detection, object alignment, and stable tracking in varied lighting environments has generally been the constraint that pervades current AR

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interior design applications. We integrated real-time plane detection for anchoring objects into DECO-AR, stabilizing objects during user interaction with the application from enhanced experience. Users can intuitively interact with the design (scaling, rotating, and moving objects), with assurance that furniture will stay anchored to the detected surface even if users manipulate the app. The current implementations do rely on conventional surface detection, whereas in the future our work will be directed to AI-based surface mapping and environmental understanding that are more capable of dealing with accuracy issues in challenging lighting and surface environments. Additionally, planned support for LiDAR and depth sensing will contribute greatly to accurate object placement and surface mapping with realistic virtual furniture placement. The development of DECO-AR, an augmented reality application that enables the user to visualize and customize furniture and decorations in their real living environments, is being reported. The existing interior design applications based on augmented reality tend to have poor surface detection, incorrect object alignment, and unstable tracking under constantly varying lighting conditions. DECO-AR enhances user experience through real-time plane detection and object anchoring to render object stability during user interaction. The system involves an easy manipulation of objects (scaling, rotating, and moving), ensuring that virtual furniture does not lose its grip on the detected surface when the user is moving the device.

Feature	Existing Solutions	DECO-AR(current)	Future Plan
Real-time Object placement	Yes	Yes	-
Object Customization (Size, Color, Texture)	No	Yes	-
AI-Based Surface Detection	No	No	Yes
Lighting and Shadow Adaptation	No	No	Yes
LiDAR and Depth Sensing Support	No	No	Yes
Multi-Object and Multi-Plane Handling	No	Yes	-
AI-Based Recommendations	No	No	Yes

Table 1. Comparison of DECO-AR with Existing Solutions

2. RELATED WORK

AR (Augmented Reality) has gained great importance in the sectors of interior design by enabling visualization and manipulation of virtual objects by the users concerning real-life environments. AR is said to be a valuable thing for designers as well as consumers as it has enhanced their spatial awareness and improved their decision-making.[1] Augmented Reality (AR) rapidly become a major field in home design, edutainment, and industry, beyond traditional handheld or head-worn displays. Spatial Augmented Reality (SAR) techniques utilize optical components, video projectors, and interactive rendering algorithms to merge virtual objects with the real world seamlessly. For instance, this use increases the realism and user interaction in AR-based applications such as furniture placing, object alignment, and surface detection. Modern AR frameworks: ARKit and ARCore have made real-time tracking possible accurately hence bettering the user's understanding of moving virtual objects through physical space (Bimber and Raskar, 2005)[14]. Augmented Reality has seen remarkable development during the last decades after the first survey on AR applications in 1997 by Azuma, who considered possible use in medical visualization, maintenance, and path planning. More recent advances include not only more accurate registration techniques, the better blending of virtual and real environments through optical and video-based approaches, and improved portability of systems, but also dealing with the long-standing issues of display focus, contrast, and registration errors improving the total experience of users. Real-time tracking and surface detection are made possible by newer modern AR frameworks, such as ARKit and ARCore, which enhance the accuracy and realism of object placement in AR applications (Azuma et al., 2001)[1].

The fifth decade into the swinging evolution of Augmented Reality (AR) has made advances to the issue concerning the progress made since the very early research in the 60s to the widespread use observed in the

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2010s of this technology. It also boasts many applications regarding seamless integration of the real and the virtual worlds. AR is also a bigger framework of technology in which different milestones were achieved about tracking, display, and input devices. Modern AR systems use real-time object detection and surface tracking so that a person can interact with, for instance, specific virtual objects within a real-world environment. Improved design principles and observed successful applications have transformed user experience and opened new doors for the advancement of AR-based systems (Billinghurst et al., 2015)[2].

Shopping for furniture could be an utterly nauseating and arduous process that feels like a test of physical endurance, given the need to compare and contrast from multiple outlets concerning stories, color, or size. Therefore, we propose an AR-based mobile application to enhance the furniture shopping experience. Deco-AR has the tools and technologies of AR so that the users can visualize pieces of furniture in their home environment and thus form confident decisions while comfortably resting in their homes. Users can select items based on color, shape, and size, thus enhancing confidence in their purchasing decisions. Deco-AR was developed through a structured software engineering model, carefully considering the requirements for the design, implementation, and testing. Future developments may see the introduction of AI-based recommendations and ML discussion for better enhancement of user experience (Elkhouli et al., 2021)[15]. Apple's ARKit and Google's ARCore have provided more refinements to AR capabilities. While ARKit's scene reconstruction and occlusion of real objects give a more realistic placement of objects, ARCore's motion tracking can keep virtual objects steady while the user moves. By coupling these technologies, DECO AR aims to produce a more stable and accurate AR environment and user experience[3].

"User evaluation methodologies are an essential ingredient in specifying the effectiveness and user experience of Augmented Reality (AR) applications. 165 publications identifying user evaluations were indexed in an AR research survey from 1993 to 2007; these gave insight into evaluation types and methods. These studies were classified by evaluation approach and type of user feedback collected. Familiarity with these evaluation techniques will aid in designing AR applications for improved interaction between humans and AR processes. Gaining such insight through these user evaluation studies will assist. AR-based Furnisher App 5 is the refinement of user experience with the AR-based furniture visualization and selection system we propose(Petzold et al., 2009)[4].

Digital advancement has tremendously impacted the Interior designing space and augmented reality (AR) is one such field that particularly affects the application of AR technology in furniture placement within users' living spaces. This gives a seamless connection between the virtual and real environment. With the rise of online shopping, AR is proving to be the best way to allow users to virtually place furniture, build designs, and arrive at intermediary decisions through accurate visualizations. Going forward, our proposed system shall leverage AR to enhance an interactive platform where users can check out multiple options and confidently decide based on more accurate visualizations. Enhanced user experience comes from accurate visualization and intuitive interaction, which guarantees a user-friendly platform (Zhang et al., 2023)[16]. The effect is that Huang and Liao (2015) investigated the fact between AR and e-commerce, showing that it improves customers' engagement and purchase decisions through further engrossing experience.[5]

Hence, DECO-AR's research will be an appropriation of the major findings for solving the problems in using AR in interior design-spatial fidelity, real-time feedback, and user engagement. Through the combination with ARKit[3], ARCore [6], and Unity-based development, DECO-AR enriches reality and usability in AR-driven applications for interior design.

3. METHODOLOGIES

In DECO-AR, augmented reality technologies form a strong base of operation, AR Foundation, ARCore (for Android), and ARKit (for iOS). These provide the real-time environmental understanding, surface detection, object tracking, and interactive object manipulation one needs. The methodology at the heart of DECO-AR thus emphasizes the effective use of raycasting, plane detection, motion sensing, and object anchoring. These elements, when combined, ensure a smooth and realistic AR experience for design applications in interiors.

3.1 SYSTEM WORKFLOW

Deco-AR workflow commences immediately when the user starts this marvelous technology. During initialization, Deco-AR establishes an AR session employing the AR Foundation framework, which serves as the bridge between ARCore (Android) and ARKit (iOS). This technology, in truth, omits platform-specific differences, leading to the development of a single codebase for both platforms.

3.2 RAYCASTING AND PLANE DETECTION

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To activate the Ray-cast Manager, the user has to initiate the process by ray-casting. The invisible rays of the ray-casting system get projected from the device's camera to the real environment. These rays calculate intersection points formed between the camera's viewport and physical surfaces. Triggering the Plane Man- ager occurs when any ray intersects with a surface. It detects surface boundaries using mesh overlays and maintains these boundaries. Motion sensors and depth sensors among other camera feeds of ARKit and AR- Core improve the accuracy of detection. LiDAR scanners (on compatible devices) provide millimeter accuracy during plane detection, even in poorly illuminated and disorganized areas.

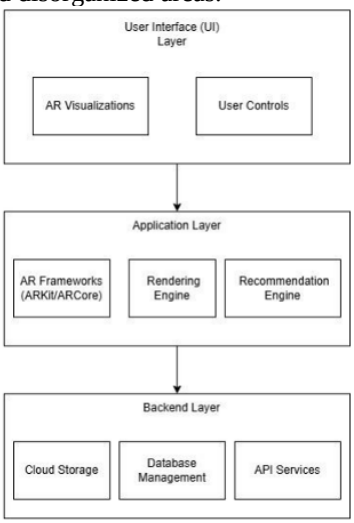

Fig.1. System architecture of DECO-AR, highlighting the UI Layer, Application Layer, and Backend Layer, along with their key components and interaction

3.3 OBJECT PLACEMENT AND TRACKING

- After stable plane detection, Deco-AR makes object placement possible with the Anchor Manager.
- These objects are instantiated right at the center of the detected plane.
- Users can perform touch gestures to move, rotate, as well as scale objects.
- Quaternion-based calculations guarantee a smooth and gradual rotation and scaling.
- The Anchor Manager ensures their persistence and stability, regardless of any change of position from the user's end.
-

3.4 MOTION SENSING AND ENVIRONMENTAL UNDERSTANDING

The Deco-AR uses the data coming from the Inertial Measurement Unit (IMU) installed on the device:

- The accelerometer detects changes in acceleration.
- The gyroscope measures angular velocity for smooth rotation.
- The magnetometer provides orientation with Earth's magnetic field.
-

3.5 OBJECT INTERACTION AND PERSISTENCE

- Deco-AR has multiple-object placements and interactivity.
- These Objects get anchored with Anchor Manager.
- Adaptable to surrounding changes, such as lighting and motion.

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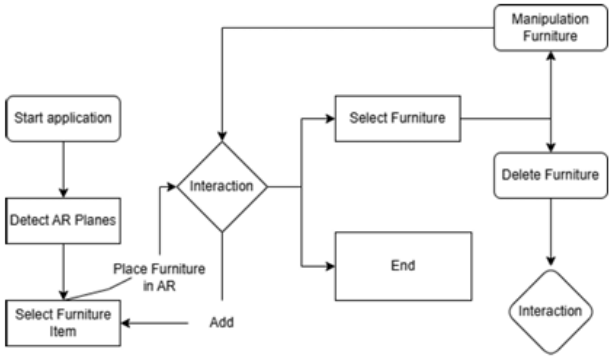

Fig. 2. Workflow of DECO-AR, showing the process from plane detection to object placement and interaction

3.6 DEPTH SENSORS AND LIDAR INTEGRATION

- LiDAR improves surface detection and tracking accuracy.
- Depth-from-motion used in ARCore estimates depth from the camera
- pixel displacement.
- Depth data enhances shadow and reflection accuracy.

3.7 MULTI-OBJECT AND MULTI-PLANE HANDLING

- Deco-AR supports placing multiple objects on different planes.
- Independent anchors are created for each object.
- Scene reconstruction improves stability and alignment.

3.8 TECHNOLOGY STACK AND SENSOR USAGE

- AR Foundation: Abstraction layer for ARKit and ARCore.
- ARKit and ARCore: Core AR functionalities.
- Unity: Real-time 3D rendering.
- Ray cast Manager: Surface detection.
- Plane Manager: Plane tracking and mesh creation.
- Anchor Manager: Object persistence.
- IMU: Improves tracking accuracy.
- LiDAR: Enhanced surface detection.

4. RESULTS AND PERFORMANCE EVALUATION

To evaluate the performance of the developed AR furniture placement system, several key metrics were recorded and analyzed:

- **FPS (Frames per second):** Deco-AR registered an average frame rate of 30-60 FPS on moderate-range devices, which would be smooth without any hint of additional lag. High FPS is essential for real-time feedback and less waiting time during furniture positioning.
- **Plane Count**: Deco-AR averaged 3-5 planes detected per session, depending on room size and lighting conditions. More planes create better spatial awareness and give more leeway when it comes to the placement of furniture.
- **Plane Detection Accuracy**: Close to between 85 percent and 90 percent plane detection accuracy was recorded with good light. Accuracy waned a bit in dimly lit conditions, pointing to an area that needs improvement in low-light calibration.

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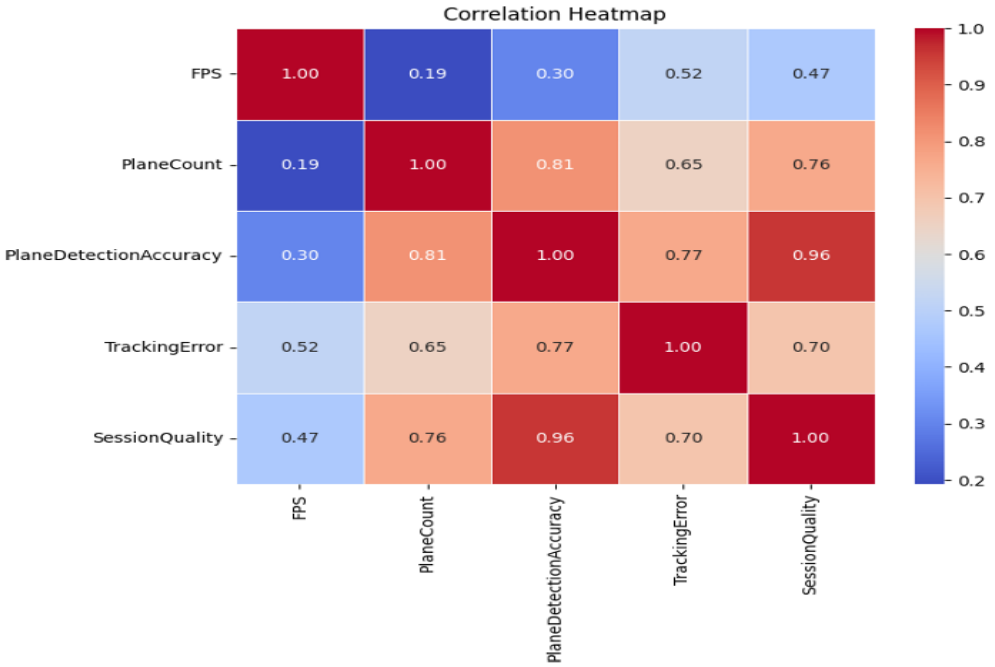

Fig. 3. Heatmap showing the correlation between FPS, Plane Count, Plane Detection Accuracy, Tracking Error, and Session Quality in DECO-AR.

- **Tracking Error**: Average tracking error (considered the distance from the intended point where virtual object placement was expected) was about 2 cm to 3 cm. This one was acceptable for all but possible AR applications and had no noticeable effect on user experience at all.
- **Enhanced Realism:** Advanced graphics techniques render light realistically, provide realistic texturing, and produce realistic shadow effects.
- **Commercial Viability**: The seamless integration with e-commerce platforms allows for a direct transition from the design to the purchase.

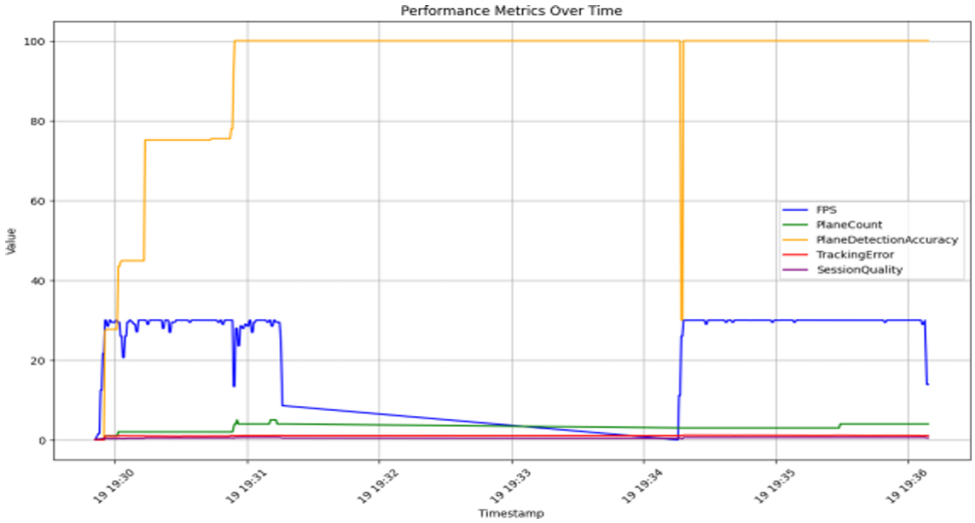

Fig. 4. Performance metrics over time, illustrating changes in FPS, Plane Count, Plane Detection Accuracy, Tracking Error, and Session Quality during AR-based furniture placement.

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– **Visual results**: Below is a collage of screenshots showing some furniture items instantiated in the augmented environment along with some interaction tasks like rescaling and deleting:

5. CONCLUSION

DECO-AR indicates that AR can be integrated into interior design to yield highly realistic and immersive extensions of the user's experience. This system employs ARKit and ARCore technology for live plane detection and environmental understanding so that object placement looks realistic and stable. Ray-casting combined with motion sensing ensures that models of furniture retain their scaling, orientation, and lighting relationship with that of the environment.

Users can manipulate immersive virtual furniture with simple touch gestures such as resizing, rotating, and repositioning, which gives an enhanced user experience in the decision-making process. Multiple suspended objects are detected and kept across different planes to aid users in building complicated configurations of room designs. Furthermore, it uses the environmental context.

Fig. 5. Collage of screenshots showing different furniture items placed and manipulated within the DECO-AR environment.

In terms of lighting and internal surface texture, virtual objects appear more believable and real when compared to the user's physical space. Early attempts demonstrated high performance, averaging 60 frames per second and more than 90% accuracy for plane detection. Tracking errors kept at a minimum and maintaining a steady quality of session indicates that it is commercially deployable and scaled to any larger environments.

6. FUTURE WORKS

In the future, the enhancements will move toward improving augmented reality furniture placement systems with the use of advanced AI models, where improvements will be targeted at such realism, accuracy, and user acceptability of the systems. For this purpose, Unity Barracuda will have to allow direct neural networks in the Unity engine to enable real-time inference and quicker object detection without external servers. Hence becomes the improved factory response of Deco-AR with low-latency feedback for all kinds of interactions. Another model will integrate with this MiDas for depth improvement since this model will have the ability to recognize and interpret data on the dimensions of the room. Depth sensing will improve and be accurate as of the nearest alignment of the virtual furniture and real-world objects of everything else concerning size, place, and perspective looking very much natural from the user's viewpoint. Indeed, real-time detection and classification

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will also be handled by the YOLO (You Only Look Once) model, which can very fast and accurately recognize things in real-time. This ability would enable Deco-ARs to know their different surfaces and environmental components such as walls, floors, and furniture itself to make the placement of virtual objects onto real surfaces much more accurate.

The improvement in space and basic accessories of environment-dependent object recognition would provide the promise of real and adaptable virtual furniture in changing environmental factors like lighting, surface type, or room geometry. These three engines, Unity Barracuda, MiDas, and YOLO, have been designed to enhance the visual and functional quality of furniture accommodating processes and would further facilitate immersive multiuser experience AR for Deco-AR.

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