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From Blueprint to Reality: Augmented Reality Applications in 3D Architectural Model Representation

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ABSTRACT: The use of augmented reality (AR) in architectural modeling has introduced new possibilities for enhancing design visualization and communication. This study presents the development and implementation of a mobile AR application that allows users to view and interact with three-dimensional architectural models in real-time using marker-based technology. Built with Unity and Vuforia, the system enables clients to explore virtual building designs from multiple perspectives through their smartphones or tablets. This interactive approach not only improves spatial understanding but also bridges the gap between technical design and user comprehension. The solution is lightweight, portable, and cost-effective, making it accessible for both designers and clients. Field testing demonstrated that the system supports more efficient project evaluation, fosters better collaboration, and provides a more immersive design experience. The results suggest that AR can play a significant role in reshaping how architectural concepts are communicated, with promising implications for the future of design and construction workflows

KEYWORDS: Augmented Reality (AR), Architectural Visualization, 3D Modeling, Marker-Based AR, Unity Engine, Vuforia SDK

I. INTRODUCTION

Architectural visualization has traditionally relied on blueprints, 2D drawings, and scaled physical models to communicate design concepts. While effective to a degree, these methods often fail to convey spatial depth and functional flow in a way that clients can intuitively understand. As a result, design misinterpretations and late-stage alterations remain common challenges in the field (Knoll & Hechinger, 2008).

Augmented Reality (AR) presents a promising solution to bridge this communication gap. By superimposing digital 3D models onto real-world environments, AR allows stakeholders to experience a structure's form, scale, and spatial relationships interactively. With the growing availability of mobile devices and AR development platforms, such as Unity and Vuforia, it has become feasible to create cost-effective and portable AR systems for architectural applications.

In this study, we explore the development of a marker-based AR application designed to visualize residential architectural models. The system enables users to scan printed markers using their smartphones, triggering the display of a 3D house model that can be rotated, scaled, and examined from multiple perspectives. This method not only enhances the clarity of design elements but also fosters client engagement and informed feedback during early design stages.

II. LITERATURE SURVEY

The last few years have witnessed accelerated integration of Augmented Reality (AR) into architectural and construction workflows, driven by advancements in mobile computing, cloud rendering, and real-time 3D engines. Unlike earlier implementations, recent systems emphasize portability, user-centered design, and seamless integration with Building Information Modeling (BIM) platforms.

A study by Zhou et al. (2021) emphasized how AR applications now play a vital role in early-stage design by allowing users to overlay architectural elements on physical sites in real time. Their research showed that such interaction leads to more informed client feedback, reduces miscommunication, and shortens the design revision cycle.

Similarly, Alizadehsalehi et al. (2022) explored the fusion of AR with construction site data, demonstrating how digital overlays can assist in real-time decision-making and progress tracking. The authors reported that AR-guided inspections significantly reduced coordination errors and improved task execution speed in multi-disciplinary teams.

In the educational context, Kensek and Noble (2020) noted that architecture students using AR platforms gained a deeper understanding of spatial relationships and structural composition compared to traditional CAD-based instruction. They highlighted that mobile AR tools made remote learning in architectural studios more effective, especially during pandemic-induced restrictions.

With the increasing maturity of AR toolkits such as Unity AR Foundation and ARCore/ARKit, researchers have begun focusing on usability and system robustness. A usability study by Lin et al. (2023) found that gesture-based controls and intuitive interfaces improved non-expert user engagement with architectural models. They also reported that AR applications with markerless tracking are becoming more prevalent, reducing the dependence on fixed image targets.

Sustainability and virtual prototyping have emerged as key areas of interest. A review by Petrovic et al. (2024) indicated that AR, when paired with digital twins and IoT sensors, enables predictive simulations and energy efficiency analysis during design planning stages—thereby contributing to smarter and greener building practices.

III. METHODOLOGY

The development of an Augmented Reality-based architectural visualization system followed a structured approach involving system design, tool selection, model creation, and implementation testing. This section outlines the step-by-step process used to create and deploy the mobile AR application.

The objective was to build a marker-based AR application capable of displaying a 3D architectural model on a mobile device. The design included the following key components:

- Image Marker: A custom-designed printed marker used to trigger AR visualization.
- 3D Model: A virtual representation of a home, created using Blender.
- AR Engine: Vuforia SDK was used to recognize the marker and render the model.
- Development Platform: Unity Engine served as the primary development environment.
- Target Platform: Android mobile devices were used for deployment and testing.

Table 1: Tools and Technologies

Component	Technology Used
3D Modeling	Blender
AR Development	Unity 3D + Vuforia SDK
Programming Language	C#
Deployment Platform	Android (via Unity Android Build)
Operating System	Windows 10

3.1 Development Phases

Phase 1: Marker Preparation: A unique image marker was created and uploaded to the Vuforia developer portal. After generating a license key, the marker was downloaded and integrated into the Unity project.

Phase 2: 3D Model Design: Using Blender, a simplified 3D architectural model was constructed to represent the layout and design of a small home. The model was exported in a Unity-compatible format (FBX or OBJ).

Phase 3: Unity Project Setup: The Unity Engine was used to import the 3D model and configure the AR camera and image target. Vuforia's AR camera prefab replaced the default camera. The 3D model was made a child object of the marker target to ensure alignment when tracked.

Phase 4: Integration and Interaction: Basic interactions such as model rotation were implemented using C#. A toggle-based script allowed users to rotate the model using an on-screen button.

Phase 5: Building and Deployment: After finalizing the scene setup, the project was built using Unity's Android Build Settings. The output APK file was installed on Android devices for testing.

3.2 Testing Strategy

System testing was carried out to ensure stable marker detection, accurate model rendering, and interactive responsiveness. Key aspects tested included:

- Marker recognition range and angle
- Model visibility and scale consistency
- Rotation functionality and performance on different devices
- User feedback on clarity and usability

IV. IMPLEMENTATION

The algorithm for AR_Model_Visualizer is as follows:

Input:

- Image marker (physical or printed)
- Pre-built 3D model of architecture
- Mobile device with camera and AR support

Output:

- Real-time rendering of the model on marker detection
- Optional rotation control via button input

Steps:

1. **Start Application**
 - Launch the AR mobile application.
 - Initialize the AR engine and camera preview.

2. Marker Registration

- Load the marker reference image from the Vuforia database.
- Associate the 3D model with the marker as a target.

3. Model Loading

- Import the 3D architectural model into the Unity scene.
- Attach it as a child to the image target GameObject.

4. Camera Feed Monitoring

- Continuously scan the camera view for the marker image.
- IF marker is detected:
 - Activate AR model rendering.
 - Position and scale the model to align with the marker.

5. User Interaction Loop

- Monitor UI button click.
- IF rotation button is clicked:
 - Toggle rotation status flag.
- IF rotation flag is true:
 - Apply incremental Y-axis rotation to the model.

6. Maintain Tracking

- Continuously update model orientation and position based on camera movement.
- IF marker is lost:
 - Pause rendering or hide the model.

7. Exit Condition

- On user exit or system stop:
 - Release camera and memory resources.
 - Close the application.

V. RESULT AND FUTURE SCOPE

The developed AR application was successfully tested on multiple Android devices, demonstrating stable performance across different screen resolutions and processing capabilities. Users were able to scan the printed marker, instantly visualize the 3D architectural model, and interact with it using touch-based controls. Feedback from initial users—including architecture students and clients—indicated a substantial improvement in understanding design proportions, spatial layouts, and overall aesthetics compared to traditional 2D drawings or static models.

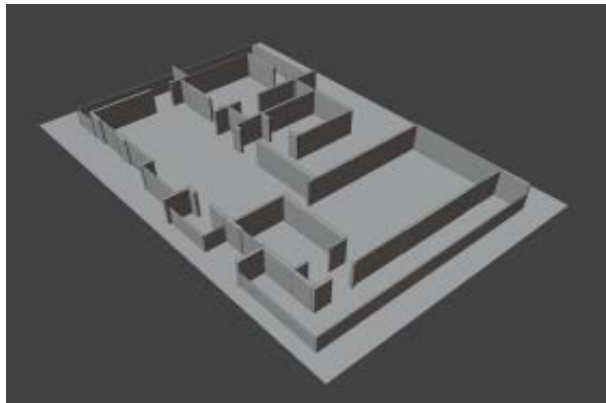
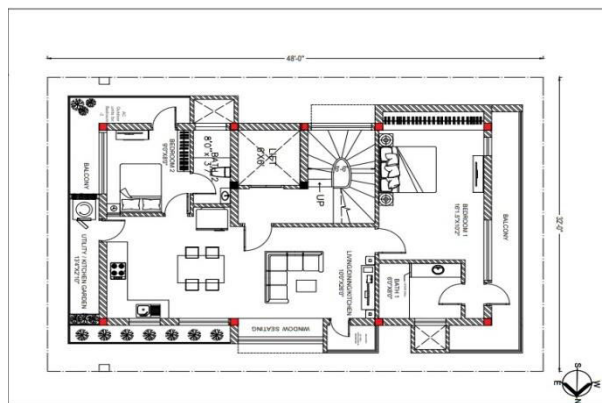


Fig1: Blue Print and 3D model

The application enabled users to rotate the model, inspect interiors through perspective zooming, and interact with structural elements—all without needing extensive technical knowledge. This hands-on interaction contributed to more effective client-designer communication and faster design iterations during the feedback cycle.

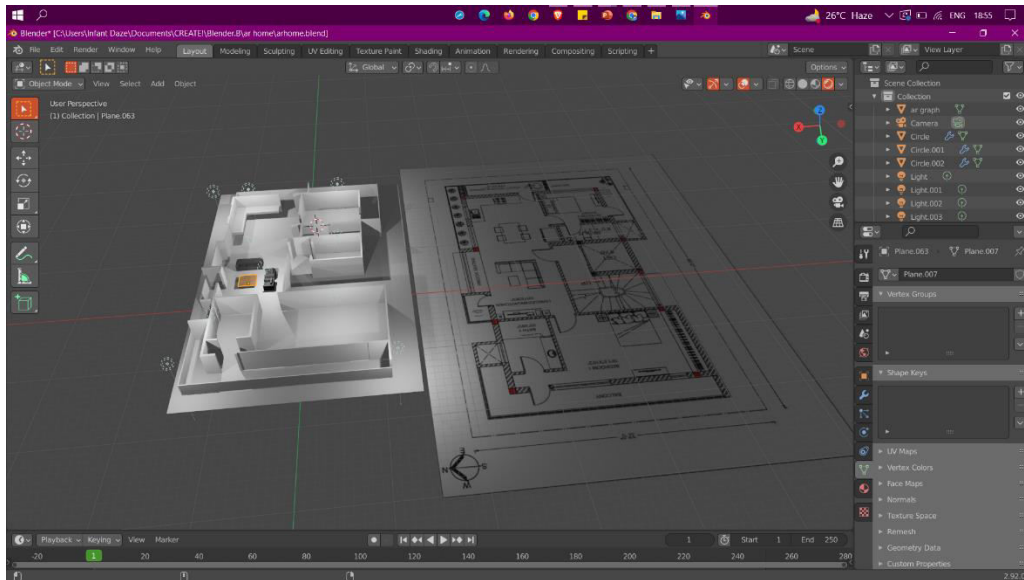


Fig 2: System Implementation

Despite its benefits, the current system has a few limitations. It is marker-dependent, which restricts use to pre-defined physical images, and the interactions are basic, limited to rotation only. Additionally, lighting conditions and camera quality influenced the accuracy of marker recognition.

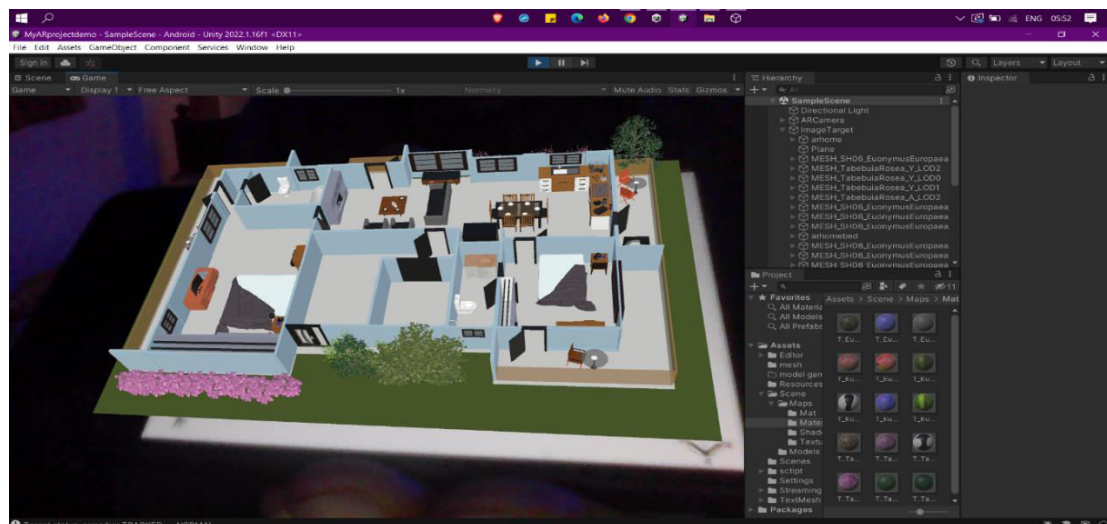


Fig 3: Mobile Implementation

Looking ahead, future enhancements can focus on:

- Markerless Tracking: Integrating ARCore/ARKit to eliminate the need for physical markers and enable model anchoring in real-world environments.
- Gesture-Based Controls: Expanding interaction capabilities using pinch, swipe, and tap gestures for scaling, translation, and model selection.
- Interior Navigation: Allowing users to virtually "walk through" architectural spaces by integrating first-person navigation.
- Real-Time Collaboration: Enabling multiple users to view and modify the model simultaneously using cloud-based synchronization.
- IoT and Sensor Integration: Combining AR with environmental sensors or BIM data to display dynamic elements like lighting, HVAC behavior, and energy consumption predictions.

By embracing these advancements, the system can evolve from a visualization tool into a comprehensive design and planning assistant. This aligns with the larger industry trend of merging digital technologies with sustainable, user-centered architecture. With increasing accessibility to mobile AR and 3D content creation tools, the potential for broader adoption across educational, commercial, and construction domains is significant.

VI. CONCLUSION

This study demonstrates the effectiveness of Augmented Reality as a transformative tool in architectural visualization. By allowing users to interact with 3D models in real time through mobile devices, the developed AR application bridges the gap between technical design and user comprehension. The system's marker-based approach, built using Unity and Vuforia, offers a lightweight, affordable, and user-friendly solution that enhances spatial understanding and design communication. While current features focus on model display and basic interaction, the results confirm AR's potential to improve client engagement, streamline feedback loops, and support more informed design decisions. As AR technology continues to evolve, its integration into architectural workflows will likely expand, enabling richer, more immersive, and collaborative design experiences. This positions AR not only as a visualization tool but as a vital component in the future of architecture and construction.

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