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Augmented Reality in Architecture using Unity and Vuforia

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***Abstract*— This research explores the application of Unity 3D and Vuforia in creating an augmented reality (AR) system for visualizing houses. Current methods of visualizing houses for potential buyers or renters often rely on static images, floor plans, or 2D renderings which can lead to decreased interest and a less satisfying experience. AR offers a transformative solution for real estate, assisting buyers and professionals in decision-making. We developed an AR application that lets users interact with 3D house models in real-world settings, testing its usability and potential benefits. Our findings highlight the promise of AR in redefining house visualization and its role in the real estate industry's future.**

Keywords—Augmented Reality, Unity 3D, Vuforia, House Visualization, Real Estate, User Experience, Design Collaboration

I. Introduction

In the realm of real estate, the power of visualization is paramount. The ability to see, explore, and experience a property before making a significant investment is a crucial factor in the decision-making process for buyers, architects, and real estate professionals. In this digital age, where immersive technologies are redefining various industries, augmented reality (AR) stands out as a groundbreaking tool with the capacity to completely transform how we deal with and understand real estate properties. Augmented Reality (AR) is a form of virtual reality technology that combines the real-world environment a user perceives with digital content produced by computer software. These computer-generated images typically enhance the appearance of the user's actual surroundings. AR systems superimpose virtual data onto a live camera feed, which can be viewed through devices like headsets, smart glasses, or mobile devices, enabling users to see three-dimensional images [16]. Modern mobile devices come with a camera, microphone, and other sensors like a gyroscope, accelerometer, GPS, and compass. Designing augmented reality learning apps for tablets or smartphones is convenient since these devices are small, reasonably priced, and can be used to integrate a variety of features like sensors, location-based functionality, picture and speech recognition, and more. In simpler terms, AR provides an interactive engagement within the real world, where real-world objects are "enhanced" by computer-generated sensory information, which can include sensations that are smell, touch, somatosensory, hearing, and vision. These AR objects may vary in interactivity and dynamism, some being interactive and dynamic while others remain static. Historically, real estate visualization has primarily relied on two-dimensional representations, such as photographs, floor plans, and brochures. While these traditional mediums provide a basic understanding of a property, they often fall short of conveying the true essence and spatial dynamics of a space. Augmented reality, as an emerging technology, offers a promising solution to this limitation. By seamlessly blending the physical and digital worlds, AR enables users to overlay virtual elements, such as 3D models, onto the real environment they inhabit. This unique capability allows individuals to walk through properties, explore their interiors, and interact with design modifications, all within the comfort of their real-world surroundings. The use of Unity 3D in conjunction with AR further amplifies the possibilities in the field of real estate visualization. Unity 3D is a powerful, cross-platform game development engine known for its versatility and flexibility. When harnessed for AR applications, Unity 3D empowers developers to create dynamic, visually appealing, and interactive encounters that help close the gap between reality and imagination. This research seeks to elucidate how the integration of Unity 3D into AR can reshape the way we perceive and interact with properties, offering novel solutions that benefit various stakeholders in the real estate industry. The potential impact of this research transcends the confines of the real estate sector. It touches upon areas of architecture, interior design, marketing, and customer engagement. The convergence of AR and Unity 3D has the capacity to enhance decision-making, streamline design processes, and foster more transparent and immersive interactions between buyers, sellers, and professionals. With the growing demand for innovative, technology-driven solutions in the real estate industry, this research endeavours to shed light on the transformative potential of augmented reality for house visualization using Unity 3D. Through a comprehensive exploration of the technical capabilities, user experience, and real-world applications of this integration, we aim to contribute to the ongoing evolution of the real estate landscape and the broader sphere of immersive technology.

This research paper delves into the realm of AR and its application in house visualization, leveraging the capabilities of Unity 3D to create innovative, interactive, and intuitive experiences for users.

II. STATEMENT OF PROBLEM

In the last few years, there has been a sudden increase in the world population, leading to more demand of space and real estate. Buyers of houses undergo a plethora of decision-making problems regarding the design and architecture of their house. The process of deciding whether to purchase or rent a house is a significant life decision and hence requires time and patience. The people who are interested in the purchase of a house are only able to see a 2D map of the house and hence struggle to accurately perceive the overall dimensions and layout of their house. As a result, architects and real estate agents are actively searching for technologies that can be integrated into the house planning process, aiming to assist potential buyers and renters in making more informed decisions.

III. LITERATURE SURVEY

The literature survey encompasses a diverse range of topics within the field of Augmented Reality (AR), spanning from emerging technologies and educational applications to industrial uses, healthcare, gaming, and ethical considerations. In the realm of AR displays, Xiong's[1] work anticipates improved performance through advancements in metasurfaces and micro-LEDs, addressing challenges in AR technology. Similarly, Qiao et al.[2] explores the potential of Web AR, using 5G networks for real-time interaction. Chen et al.[3] article discusses integration of smart wearable technology with AR for more natural human-computer interaction. The foundational work of Azuma[4], lays the groundwork for understanding AR concepts, technologies, and display variations. In education, the survey reveals AR's beneficial effects on students' understanding and enthusiasm, with applications in the "flipped classroom" model[5]. Cardoso et al.[6] assessed the applicability and utility of augmented reality (AR) in actual industrial processes.. Scavarelli et al.[7] examined how VR and AR might be used in social learning environments for teaching, while also pointing to fresh directions for future study. Tzima, Styliaras and Bassounas[8] studied the level of distribution of AR technology and teachers' perspectives on the necessity of continual learning and the process of creating 3D models. Czok et al.[9] provided a matrix of assessments to assess the current augmented reality methods for teaching engineering and life sciences like Chemistry and Biology, while also offering guidelines for the creation of new augmented reality applications.. Chen and Liu[10] examined how augmented reality learning activities in conjunction with various methods, such as teacher-driven demonstration and a student-focused hands-on, affected students' curiosity in the sciences and their theoretical knowledge of chemistry. Khan, Johnston and Ophoff[11] compared the learning inspiration of students employing the AR smartphone app prior to and soon after. Tezer et al.[12] analyzed research using narrative review techniques to identify global trends in the field of AR apps and research. Wang et al.[13] discussed about comfortable wearable device interfaces based on small wires for potential use in AR and VR apps. Fan, Antle and Warren[14] presented a expansive study of the research on the use of augmented reality (AR) as a tool for early language acquisition. Roopa et al.[15] suggested revolutionizing the dynamic AR schooling system for high-quality learning, promising improved student engagement and personalized learning experiences. The study of Chen et al.[16] focuses on finding solutions for the low-latency object detection, processing efficiency, and classification issues in applications that use AR. Bursali and Yilmaz[17] analyzed the impact of augmented reality (AR) applications on learning persistence and understanding of texts, as well as to investigate the opinions of fifth-grade students regarding AR apps. Rienow et al.[18] presented five AR apps, teaching using remote sensing data from various sensors on board the International Space Station (ISS) about tropical cyclones, human-induced desertification, usage of energy, gravitation, and blooms of algae. Paliokas et al.[19] proposed the incorporation of extra instructional and gaming components into the main AR application to improve the overall experience of on-site museum visitors. Cruz et al.[20] proposed a system that uses augmented reality and deep learning methods in tandem to give the user relevant information. Venkatesan et al.[21] proposed the use of AR for biomedical applications. Mourtzis et al.[22] presented the creation of an augmented reality application that would allow users to customise robotic cells and participate in the design process. AR for the tourism industry was also explored by Cranmer et al.[23]. Hassan and Ramkissoon[24] analysed the experience of visitors within the framework of tourism based on nature, with a focus on applications of augmented reality (AR). The survey also addresses crucial considerations such as ethics in AR by Slater et al.[25] and the potential of AR in mental health and well-being[26]. The exploration of AR advancements, including holographic AR[27], and the integration of 3D modeling for remote collaboration[28] highlight the ongoing evolution of AR technology. The survey also acknowledges challenges and potential future directions for AR technology. For instance, refining taxonomies to accommodate emerging AR devices (Milgram and Kishino, 1994)[29], and exploring the integration of real-time sports and AR in sports applications[30] are identified as areas for further investigation. Wang et al.[31] presented the creation of virtual reality environments for train stations using Unity3D and investigates the key techniques involved in designing such vivid scenes. Ablyaev et al.[32] designed a mobile augmented reality system for early literacy using Unity3D and Vuforia which motivated children to learn alphabets. A model of a learning system was developed by Kravtsov and Pulinets[33] putting textbook illustrations to use with AR technology. Ali and Neşe[34] identified relevant research in AR, architecture, and cultural heritage and evaluated AR technology's development process from the past to the present. Carmigniani et al.[35] studied the latest developments in terms of technology, systems, and applications for augmented reality. It also detailed the work done by numerous research groups, the rationale behind each new system, and the challenges and issues that arise when developing certain AR apps. Liu, Sohn and Park [36] demonstrated how to use AR technology in a Unity 3D environment and create a game.. Li and Tang [37] analysed the fundamentals of AR and created a comprehensive system for displaying human body organs and tissues with engaging features using Unity3D and Vuforia. Martins et al.[38] provided an overview of the key ideas and addressed the advantages, difficulties, and prospects of using augmented reality (AR) to facilitate better decision-making by utilising situated visualisation for displaying data in context. Syahputra et al. [39] created a programme that uses AR technology to display a virtual house structure on a real estate brochure.. Raja and Lakshmi Priya [40] suggested utilising ICT tools and virtual and augmented reality to improve quality in the evolving online school system throughout the COVID-19 pandemic. Tan, Chandukala and Reddy[41] outlined four broad uses of AR technology in retail settings. Challenor and Ma[42] conducted an overview of Augmented Reality Uses in Heritage Visualisation and History Education

IV. AUGMENTED REALITY DEVELOPMENT TOOLS

The development environment commonly used for visualizing and interacting with three-dimensional graphics is Unity . Unity is a versatile tool for creating both two- and three-dimensional applications and games. It offers compatibility with various operating systems, including Windows, OS X, Windows Phone, Android, Apple iOS, and Linux. Additionally, Unity applications can be launched and used in web browsers through the Unity Web Player plugin. These applications are compatible with DirectX and OpenGL, making them adaptable for various platforms. A significant advantage of Unity is its cross-platform capability, allowing developers to use the same code with minimal modifications to create appls for many platforms simultaneously. The functionality of Unity can also be expanded using the Asset Store, which offers a wide array of plugins and extensions.

One more famous game engine is the Unreal Engine, which differs from Unity in its documentation. Unreal Engine utilizes C++, while Unity employs C# and Java. Unreal Engine incorporates a modular system of components that are interdependent, simplifying the transfer of projects between systems. Supported systems for Unreal Engine include Microsoft Windows, Linux, Mac OS, Mac OS X, Xbox, Xbox 360, PlayStation 2, PlayStation 3, PSP, PS Vita, Wii, Dreamcast, GameCube, and various portable devices such as Apple (iPad, iPhone) running iOS .

For creating AR experiences, developers commonly turn to systems like Vuforia and Kudan. Vuforia enables applications on mobile devices with cameras to recognize and interact with objects, images, text, and markers. This recognition can "revitalize" these objects as 3D models on the device's screen. For instance, Vuforia can bring mechanisms to life by scanning them with the Vuforia Object Scanner utility, creating markers for object recognition. This technology is supported on Android 4.0.3 and iOS 7 and above, and it is also compatible with AR spectacles like the Epson Moverio .

Kudan is a similar AR development system known for its enhanced marker tracking capabilities, including wider viewing angles, faster marker acquisition, extended tracking distances, and adaptability to challenging lighting conditions. Kudan offers marker and marker-less augmented reality methods. The marker technology allows for reliable tracking of objects and the creation of custom markers, while marker-less technology enables object tracking without the need for special markers. Kudan, like Vuforia, employs the OpenCV computer vision library, which is versatile, supporting multiple operating systems and offering interfaces in C++, C, Java, and Python, along with a rich collection of optimized algorithms for computer vision and machine learning.

EasyAR is a user-friendly and free alternative to Vuforia, available on Android, iOS, UWP, Windows, OS X, and Unity platforms. The choice of AR development tools depends on the specific challenges and . Tools like Daqri, MixAR, and ZooBrust are relatively straightforward and do not require advanced programming skills, while SDKs such as ARToolKit, Unifeye Mobile SDK, and Wikitude are designed for more experienced developers .

Wikitude empowers developers to create their own augmented reality applications from scratch or integrate AR functionality into existing applications. A comparison of popular augmented reality development tools is provided in Table 1.

Table 1. *Comparison of AR tools*

	Type	Cross-platform	Programming Languages	Documentation
Unity	Boost Software License	Windows, OS X, Windows Phone, Android, Apple iOS, Linux	C#, JavaScript	+
Unreal Engine	Boost Software License	Microsoft Windows, Linux, Mac OS, Mac OS X, Xbox 360, PlayStation 2, PlayStation 3, PSP, PS Vita, Wii, Dreamcast, Gamecube	C++	+
Vuforia	Free + Commercial SDK option	iOS, Android, Unity	C++, Java, Objective C, .NET	+
Kudan	Free + Commercial SDK option	Microsoft Windows, Linux, Mac OS X, Xbox 360, PlayStation 2, Playtation 3, PSP, PS Vita, Wii, Dreamcast, Gamecube	C++, C, Java, Python	+
OpenCV	Boost Software	iOS, PC, Android, Linux	C/C++, Python, Java, Ruby, Matlab, Lua	+
Wikitude	Free + Commercial SDK option	Android, iOS, Smart Glasses	C#, Java	–

After studying table 1[42] The Unity and Vuforia SDK were chosen for the building of "House Visualization" app due to their accessibility, the availability of essential features, the option to integrate additional tools, and the accessibility of supplementary services.

V. VUFORIA FEATURES USED

1) Image Recognition: Vuforia offers robust image recognition capabilities, allowing developers to recognize and track images in the real world to trigger AR content.

2) Object Recognition: In addition to image recognition, Vuforia supports object recognition, enabling the recognition and tracking of 3D objects as triggers for AR experiences.

3) Marker-Based Tracking: Markers are pictures or objects that are registered with an application and serve as information triggers within it in MR or AR. The virtual content overlays the marker's real-world position in the camera view when the device's camera detects these markers in the real world (during the operation of an AR or MR application). Numerous marker types, such as QR codes, real reflective markers, Image Targets, and 2D tags, can be used for marker-based tracking. An Image Target is the most basic and widely used kind of marker in video game applications.

4) Extended Tracking: Extended tracking allows AR experiences to persist even when the tracked image or object is temporarily out of the camera's view, providing a more seamless user experience.

5) Smart Terrain: The Smart Terrain feature allows developers to create dynamic environments by recognizing and interacting with real-world objects and surfaces.

6) Unity Integration: Vuforia seamlessly integrates with popular game development engines like Unity, providing a familiar environment for developers to create AR content.

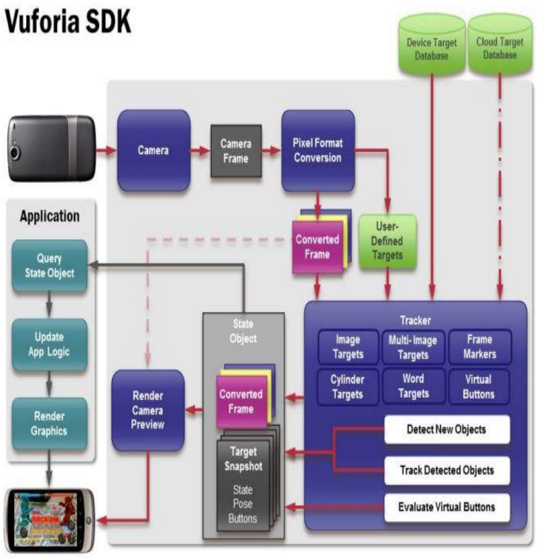

***Figure 1**. Workflow of Vuforia SDK*

VI. PROCESS OF DEVELOPING AND PRODUCING AUGMENTED REALITY APP

6.1 Establishment of the Environment

(1) Download Unity 3D 5.5.0 and after that install

(2) Download the extensions of Vuforia QCAR

(3) Using Vuforia Net, create the identifying object.

1) To obtain a license for Qualcomm Vuforia's development, begin by navigating to the development home page. Then, proceed to the License Manager section and click on the "Add License Key" option. Opt for the "Development" license type and assign a name to your application, such as "First App." This action will result in the creation of the necessary license key.

2) To establish a database, initiate the process by selecting "Add Database" within the Target Manager. Name the database anything like "MyDB" and this action will signify the successful completion of the database creation procedure.

3) To generate a target, first, choose the recently created "MyDB". Then, proceed to set up the target identification. Opt for "Single Image" and specify the image path. Define the picture width as required and finalize the target creation process.

6.2 Process of AR House Visualization App Creation

(1) Open Unity and create a new project

(2) Download the Unity package extensions inside Vuforia.

(3) Open Unity and import the downloaded Unity package file along with the Vuforia extensions.

(4) Once you have imported the assets, you will notice that the Plugins folder and Vuforia will be present within the Asset directory. Remove the Main Camera from the Hierarchy, and then proceed to place the AR Camera and Image Target from the Vuforia / Prefabs directory into the scene.

(5) Select AR Camera in Hierarchy then the Inspector window will display. Inside the Inspector window, click on "Open Vuforia Configuration" and proceed to input the App License Key. Go to Vuforia website, locate your existing License Key, and then place it into Unity while adjusting settings as necessary.

(6) To inspect the Image Target in the Hierarchy, click on it to open the Inspector window. Inside the Image Target Behavior, select "database" and pick the Unity package file that was recently imported. Then, once more, choose the Image Target and designate the target image found within the imported file.

(7) Include necessary 3D model into the Hierarchy. Place the model onto the Image Target, as shown in figure 2, making it an associated object of the Image Target. Adjust the settings associated with the model accordingly.

(8) Finally, we click on build and run

Figure 2. *3D model is placed on the target image*

Launching the application

The 3D model could be displayed on the target image as shown in figure 3, without any complications. As the camera's position changes from its previous state, the corresponding positions and angles between the camera and the real scene adjust accordingly. Thanks to the tracking of matching images, the application can precisely detect these changes and respond appropriately. Consequently, the virtual objects overlaid onto the real scene adapt in real-time to variations in the camera's position and angle. If the camera loses sight of the matching image, the virtual object will disappear.

Figure 3. *3D model of building forms on top of target image*

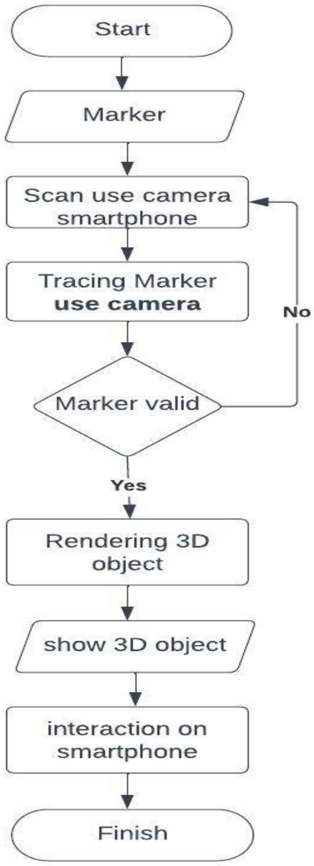

Figure 4. Overview of Methodology

CONCLUSION AND FUTURE SCOPE

This paper highlights the utilization of Unity 3D technology and Qualcomm QCAR development tool, Vuforia. It proceeds to introduce fundamental concepts and framework. Building upon this foundation, it simulates a three-dimensional scene using Unity 3D. The Vuforia engine detects and tracks identification features, generating corresponding 3D models based on the relative position and orientation information of various markers on the visual plane. This innovative application not only enhances the user experience in visualizing and interacting with architectural designs but also provides a valuable tool for architects, designers, and homeowners to make more informed decisions in the planning and design of their living spaces. Additionally, the experience gained from developing the house visualization app has given us new ideas for improving mobile visualization apps. In the future, we plan to expand our database with a greater variety of three-dimensional structures, improve the texture and graphics of the buildings, audio explanations to better explain each aspect of house planning.

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