Preliminary Analysis and Feasibility Study of using Mixed Reality (MR) with AI-Powered Object Recognition for Residential Renovation

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**Abstract.** Malaysia's residential construction sector still uses old-fashioned visualization and communication tools, like paper-based floor plans, which frequently result in misunderstandings and misaligned designs between clients and contractors. Even though professional programs like SolidWorks and SketchUp provide sophisticated visualization, smaller businesses and non-technical users cannot afford or use them due to their complexity. By creating an Artificial Intelligence (AI) and Mixed Reality (MR) application, this study fills the gap and facilitates more collaborative, immersive, and intuitive renovation planning. A user-centered design (UCD) methodology was used in this initial stage, under the direction of community-based participatory research (CBPR). Four experienced contractors participated in semi-structured interviews to determine workflow issues and provide input on system specifications. The resulting conceptual framework improves decision-making and reduces errors by utilizing AI-powered object recognition and scene understanding to match virtual designs with real-world spaces. In order to modernize renovation procedures and enhance communication in residential construction, the study sets the groundwork for a scalable, user-centric MR solution.

## INTRODUCTION

Excellent communication and cooperation between contractors and homeowners is essential for the intricate process of home renovation. Planning and visualization are problematic even for many renovation projects in modern construction. The finished results often elude the imagination of the average homeowner. For this reason, the reliance on verbals and 2-D plans is taken to a new level, a level that could lead to unfulfilled expectations and disappointment if the plans are not converted into workable, quality solutions by the contractors [1]. Plans must be convertible, comprehensible, and realizable for the renovation.

One possible remedy for these problems is the pairing of Artificial Intelligence (AI) and Mixed Reality (MR) technology. Whereas MR creates and develops dynamic, immersive environments that take user comprehension and decision-making to the next level, enabling them to visualize suggested renovations in real time, AI endows this experience with the power of object recognition (and thus, the precision of role recognition) [2][3]. By knowing what to do with what it sees, AI isn't just making MR better, but also powering the spatial computing that allows everything to function as a smart remodeling plan [4][5].

This study investigates the means by which a renovation planning system based in virtual reality (VR) can include the use of artificial intelligence (AI) and the mixed reality (MR) technologies of tomorrow. The ambition is to fashion a kind of user-centered framework that cuts down on design inconsistencies, amplifies spatial comprehension, and allows stakeholders to work together in real-time. The system aims to enable non-technical users, like homeowners and renovation contractors, to actively engage in the co-design and validation of renovation concepts by utilizing immersive visualization and innovative design assistance.

## Literature Review

Similar to many other industries around the world, Malaysia's construction sector has historically executed and carried out projects using conventional techniques. Paper is frequently used to keep track of important documents like floor plans, blueprints, and attendance records. Despite being simple and economical, these approaches are prone to mistakes, misunderstandings, and inefficiencies[5]. Floor plans, for example, are scaled diagrams that show the dimensions and arrangement of a structure in order to convey a general idea of a project, however, they are not clear enough for accurate visualization[2]. This may cause miscommunications between clients and contractors, which might impact the project's overall quality and result. Software programs such as SolidWorks, Autodesk, and SketchUp have been developed to improve visualization and design accuracy in order to overcome some of the drawbacks of conventional techniques. These applications enhance planning and communication by enabling engineers and designers to produce intricate 2D and 3D models [6]. Unfortunately, the general workforce or clients cannot easily access these tools because they are primarily designed for professionals with specific training and certification. Non-technical stakeholders might find it difficult to understand technical drawings and models, which could result in misaligned expectations. Even with their sophisticated features, visualization software today is unable to give a realistic or immersive view of designs[7]. Even though programs like SketchUp and Autodesk can replicate intricate models, they are limited to computer screens, which makes it difficult for stakeholders to envision how the design will look in real life. Additionally, these programs frequently need powerful computers to manage intricate renderings, which presents a challenge for smaller businesses or individuals with less funding [8]. Widespread adoption is hampered by this, particularly in areas like Malaysia where many contractors have limited funding. The need for an approachable and immersive solution is underscored by the construction industry's partial adoption of visualization software and dependence on conventional methods. By allowing users to place digital models on actual environments, Mixed Reality (MR) technology presents a singular chance to close this gap [8][9]. In contrast to existing software, MR tools offer an interactive, user-friendly interface that supports improved decision-making and collaboration at every stage of the building process, even for non-technical stakeholders.

In the construction industry, high technology has grown in relevance, specifically in niche markets like offshore oil and gas. Because of the massive financial gains from their investments, this industry has continually embraced cutting-edge solutions. Advanced technologies like Virtual Reality (VR), which is employed in project design, training, and simulation, are widely used during offshore construction for oil and gas platforms [10]. The large margins and demand within the oil and gas industry render such investments profitable as they adopt and lead new technologies from the beginning. As early as the mid-1990s, when simulation and virtual prototyping began to be used in project planning and training, the oil and gas industry began using VR. Through virtual reality (VR), engineers can conduct virtual walkthroughs and visualize complicated offshore platforms, spotting possible design flaws prior to construction. This reduces mistakes and improves safety in real operations. VR training further enables personnel to practice emergency situations in safe virtual conditions, preparing them without exposing them to real dangers. These features have established VR as a critical tool in this competitive market.

Virtual reality (VR) has changed offshore oil and gas construction, yet its uptake in smaller markets, such as home building, is minimal. The main reasons include the exorbitant upfront expenses and insufficient strong financial incentives in these markets in comparison to those for oil and gas. For example, homeowner remodels have smaller budgets and frequently can't afford to purchase high-end equipment. But increasing availability has motivated efforts to refine VR technology for more affordable and larger-scale applications such as home and business remodeling [10]. The effort to extend virtual reality (VR) to smaller construction markets demonstrates the technology's widespread potential. Even on smaller projects such as home remodels, virtual reality (VR) can improve planning and visualization by lowering costs and streamlining interfaces. This shift closes the gap between large-scale industrial applications and day-to-day construction needs and also smooths the way for access to advanced equipment. The construction industry is on the cusp of a revolution in terms of technology that can benefit every sector regardless of size and affordability as a result of ongoing advancements in virtual reality and its implementation in devices ranging from smartphones to MR headsets [11].

## VR Development Tools for Construction and Renovation: A Technological Landscape

Virtual reality (VR) is revolutionizing the construction industry by providing immersive experiences that enhance planning, training, and collaboration. Virtual reality (VR) has been used by architects and engineers to create real 3D models of building projects like the client's home real environment. Asset owners and investors can walk through their properties such as buildings and houses before they are constructed or renovated with the use of virtual reality (VR). This exercise would identify any design problems or early issues. For example, VR can provide an almost real-life view of what a completed building will eventually look like, thereby informing decisions and lowering the need for costly revisions. Other than visualization, VR also plays a critical role in terms of staff preparedness and safety training. Since construction environments are dangerous in nature, virtual reality (VR) allows employees to practice how to walk and respond to potential hazards in a controlled environment. This reduces hazards and accidents without exposing workers to harm. In addition, virtual reality (VR) would be able to improve communication and reduce delays by allowing geographically dispersed teams to collaborate on the same virtual models in real time. These capabilities illustrate how virtual reality (VR) has the potential to completely transform construction project planning and execution, leading to better industry productivity and safety in the end. Home renovations are typically plagued by issues like homeowners' inability to visualize designs and lack of communication between clients and contractors. By blending virtual and physical designs, MR provides an interactive visualisation solution. Paired with AI-powered object detection, this combination enhances spatial awareness and reduces errors through the detection of real-world objects such as furniture and walls [12]. A review of the top ten virtual reality software tools [10] provides context for the innovations behind immersive experience. They cover different facets of VR development, such as modelling, animation, and real-time interactivity, and can prove to be immensely helpful for beginner and veteran developers. Some of the software comprises Unity, Unreal Engine, Blender, and others, and they refer to their manifold applications and benefits within the VR landscape [10].

## AI and Mixed Reality to Improve Stakeholder Engagement and Renovation Planning

# Artificial Intelligence (AI) plays an important role in enhancing Mixed Reality (MR) systems to be more responsive and intelligent. AI and MR when combined would create a more natural and smooth experiences in most sectors that are already familiar with the use of VR. The most advanced feature would be the object recognition. Using computer vision, AI can identify real-world objects such as doors, tables, and chairs. This allows individuals to visualize to plan on new additions such as cabinets or change the wall paint colors with the capability of ensuring suitability to their own space. Features such as this is particularly useful for domestic minor or major renovations. AI analyses and converts data from sensors and cameras to represent a particular layout of a room. Applying these features in MR systems would allow AI to position virtual objects such as ornaments or furniture in the right manner to represent the real environment. These characteristics render MR tools to be more convenient and interactive, especially for the use in renovation design. AI also enhances MR through Natural Language Processing (NLP), that would allow users to communicate with systems using voice. The incorporation of NLP would make it easier to navigate applications, search for a specific item, or edit virtual models without having to lay hands on a screen. This hands-free feature is especially beneficial in settings like construction sites or collaborative planning sessions.

Also, AI could learn user activity and interests to provide appropriate suggestions. Using predictive analytics, AI can suggest design components like color schemes, furniture arrangement, or materials based on experience or trends. The information assists the users in saving time and making smarter decisions to lead to improved project outcomes [8]. AI will come in handy to make Mixed Reality (MR) simulations more responsive and real. Through real-time responsive dynamic scenario generation, AI will be able to create the simulation of actual world problems such as equipment failure or hazards to safety where this is especially useful in construction training. The simulations become intelligent through learning from user behavior and provide learning experiences that are customized to improve decision-making and enable the users to develop pertinent skills. Because of this, MR has become a useful tool for industries requiring practical practice in a secure and controlled environment. In MR applications, AI fills the gap between digital and real-world experiences and enables more natural and intuitive interactions. This convergence of MR and AI is transforming healthcare, construction, and retail industries with context-aware and immersive solutions. Applied to enrich training sessions or provide realistic visualizations for renovating the home, MR technology driven by AI is enabling unparalleled creativity and productivity in real-world applications [12].

# Methodology

In order to ensure that the home renovation planning system is rooted in the actual habits and needs of its primary users, in this study a User-Centered Design (UCD) approach was utilized in the context of Community-Based Participatory Research (CBPR). In-situ observations and semi-structured interviews during home renovations were among the methods used for data collection. Four contractors, as the key user group that would be primarily responsible for carrying out renovation designs and interfacing directly with customers, were the only ones interviewed during this preliminary phase. As contractors both have deep domain knowledge and direct experience with the inefficiencies and problems in the current renovation processes, it was intentional and strategic to interview them first. Prior to sitting down with end users, their input is essential in defining technical limitations, communicative shortcomings, and areas of system enhancement. The interview group included two midcareer contractors with 10 to 20 years of business and two veteran contractors with over three decades' experience in residential building. Blending these professional history backgrounds provided both individuals with a perception of long-standing tradition and contemporary trends in the field. To set the participants at ease and facilitate unambiguous expression of themselves, all interviews were conducted in Malay, as it is the language of preference by most Malaysian contractors. The utilization of Malay also facilitated cultural sensitivity and improved response reliability. Besides interviews, site visits to live renovation sites were made to observe workflow issues, space constraints, and communication. These site observations supplemented interview findings by capturing an up-close view of the contractors' daily working life. Future studies will incorporate homeowner responses to further actualize their needs and expectations. This step is needed to assist in refining the system from the user perspective and to ensure that the design process remains inclusive and balanced.

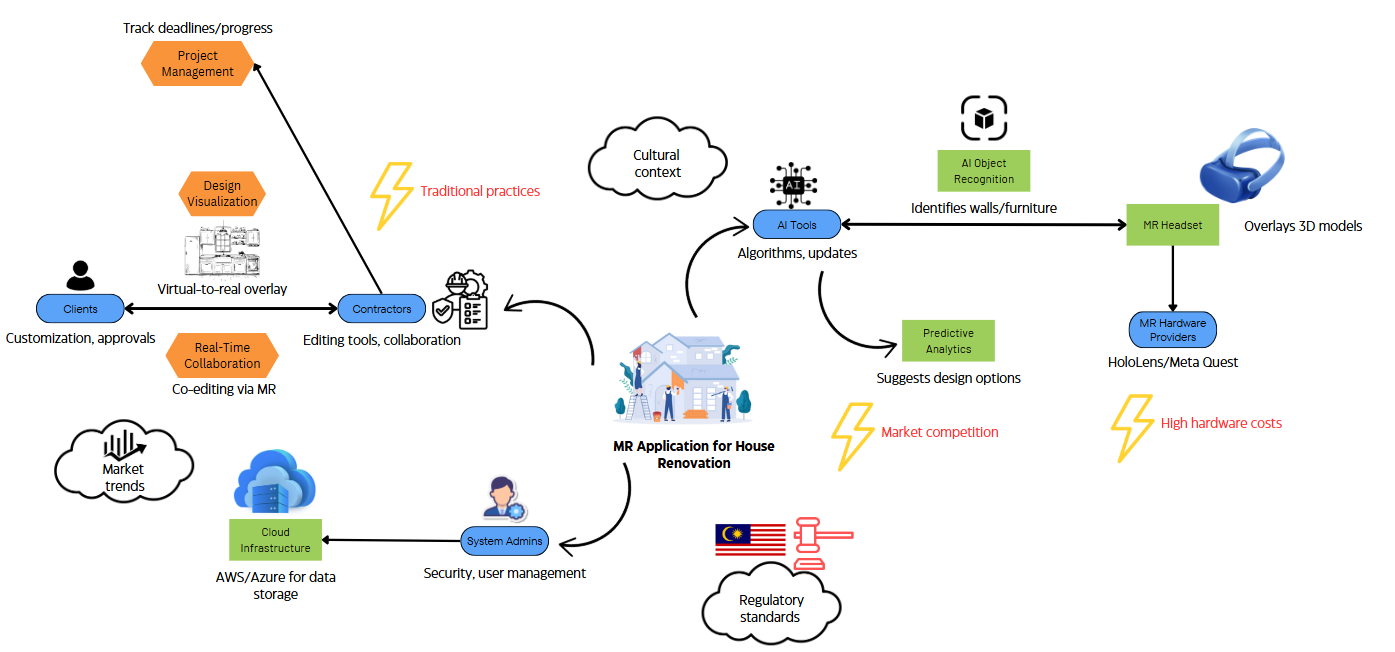
# FINDINGS

Results gathered through interviews and physical observations indicated several overarching challenges and opportunities of using a Mixed Reality (MR)-enabled renovation support system, specifically from the contractors' perspective. One of the most frequently mentioned concerns was the costly nature of implementation. Most participants expressed hesitation about the expense of investing in MR devices and maintaining the necessary cloud infrastructure. For contractors, this kind of up-front cost can be daunting. Resistance to change in using new technology was another common issue. Contractors highlighted that it was not an easy task to instruct their crews to leave traditional work processes behind. This resistance often stemmed from the need to retrain employees, something that can take time and disrupt ongoing projects. Furthermore, limited internet connectivity, particularly at rural or remote renovation sites was commonly mentioned as a practical limitation. Without a stable internet connection, the full functional ability of the MR application could be compromised with limited efficiency in certain settings. Nevertheless, although there can be limitations, contractors also pointed out a number of benefits and opportunities in the use of the MR-based renovation tool. Among the most appreciated features was improving communication with clients. With the real-time visual previews of proposed changes, the application gets everyone on the same page, where better visualizations can reduce misunderstandings along the renovation process. Contractors also enjoyed the manner in which the software automates tedious processes, such as estimating material needs and developing design representations. These functionalities could potentially save time and increase overall effectiveness. A few participants even mentioned the potential for the tool to facilitate more sustainable practices. With clearer visualizations, it is simpler to avoid over-ordering materials or ordering unnecessary changes, which minimizes waste. These results indicate a few important avenues for further development. To foster broader acceptance, the application must be not only accurate but also simple to use, particularly for those users who might be resistant to making the change to digital solutions. The issue of cost indicates the necessity for pricing flexibility to be able to fit companies of varying sizes. Since internet connectivity may be inconsistent in some areas, especially on remote job sites, offline capability or reducing the need for constant connectivity will be necessary. Lastly, offering prominent training resources and ongoing support will be critical to allowing contractors to feel confident and competent in using the technology.

# System Design

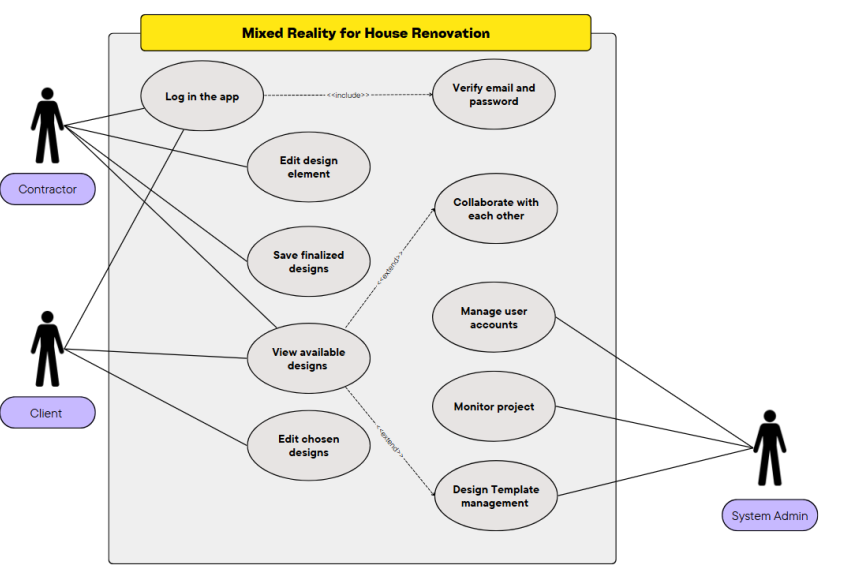
In order to assist with home renovations, the system design entails creating a Mixed Reality (MR) application that is integrated with AI-powered object recognition. It has modules for interactive 3D environments with MR devices, real-time visualization, and AI-driven detection of room elements like walls and furniture. A user-friendly interface and data storage for managing designs and user inputs support the design's guarantee of the smooth integration of virtual objects into real-world settings.

The key players, elements, and interactions needed for the MR application for renovations in homes to work well are depicted in the Figure 1 diagram. In a Mixed Reality setting, the system's primary users such as clients and contractors visualize, alter, and work together on home remodelling designs. AI tools that recognize objects, such as walls and furniture, are among the system's primary features. These tools improve the renovation process by offering predictive analytics to recommend design options. Real-time visualization and co-editing are made possible by the MR Headset, which overlays 3D models into actual environments. Cloud infrastructure is a type of supporting infrastructure that is used to track market trends and store project data. While the Project Management and Real-Time Collaboration modules aid in tracking progress and facilitate smooth co-editing among stakeholders, system administrators oversee security, user management, and compliance with regulatory standards. The system's effectiveness and adoption are influenced by external factors like market competition, cultural context, and traditional practices. Limitations in the application of MR technology are also emphasized, including difficulties such as expensive hardware. Considering both user requirements and external limitations, this integrated ecosystem guarantees that the MR application expedites the renovation process.



**FIGURE 1.** Rich diagram for MR application

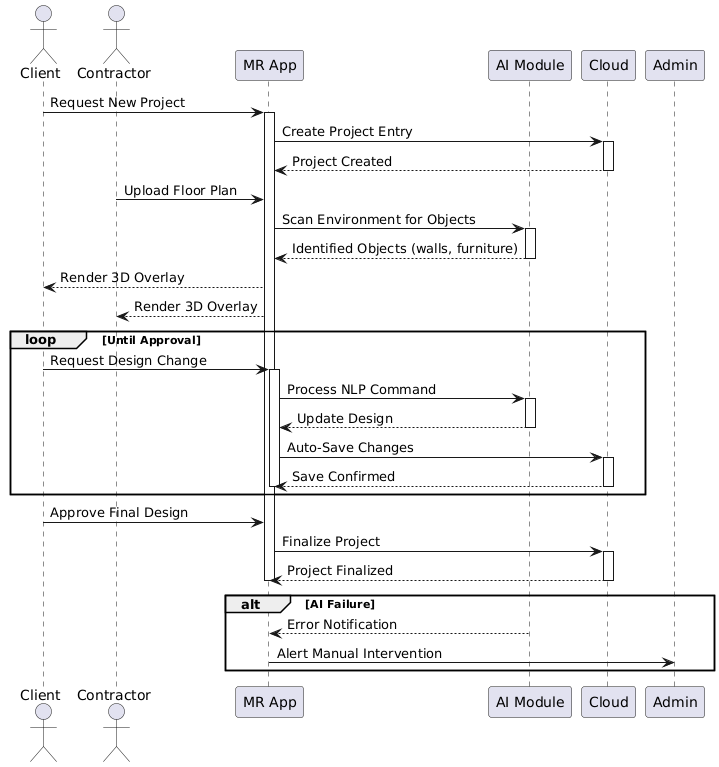
The use case diagram below combines artificial intelligence (AI) and mixed reality (MR) to facilitate improved user interaction, design accuracy, and teamwork, as illustrated in Figure 2. The information obtained from semi-structured interviews with four highly experienced contractors who were considered to be the system's main users during the first stage of this user-centred design (UCD) study was used to create this diagram. The primary user group interviewed in this phase are contractors, who are in charge of viewing available templates, working with clients and other stakeholders, and editing and finalizing renovation designs. Although they are yet to be interviewed, the client, who are the end users, can view and alter a few designs to let the contractor's experience shape the system initially. The system administrator is in charge of maintaining design templates, monitoring projects, managing user accounts, and confirming credentials.



**FIGURE 2.** Use-case diagram

Contractors provided critical input on workflow pain points, communication challenges, and design validation needs that directly informed the system’s functional requirements and use cases.

The sequence diagram in Figure 3 shows how the three main entities which include the client, the MR application, and the system database. All entities interact with one another during a normal session in the Mixed Reality for House Renovation system. The system's objectives of real-time visualization, smooth design iteration, data persistence, and personalization are all illustrated in this sequence diagram, which depicts the dynamic interaction between the user, system, and backend. It provides a visual representation of the paper's user-centered, AI-MR-enhanced workflow, illustrating how intuitive interactions take the place of conventional, static design communication techniques.



**FIGURE 3.** Sequence diagram

The interface design was developed using Figma and follows a user-centered design (UCD) approach to ensure accessibility, clarity, and functionality for non-technical users such as homeowners and contractors, as shown in Figure 4. The layout is optimized for interaction within a Mixed Reality (MR) environment using the Meta Quest Pro headset, with additional support for mobile app interaction in early-stage prototyping. The interface is proposed as per the feedback from the participants of the interview where they require simplicity on a "clean, non-technical layout" to avoid intimidation, visualization on seeing the room updates “before reading the specs,” influencing the MR-first design, and real-time feedback.

A drawing of a kitchen

AI-generated content may be incorrect.

**FIGURE 4.** Proposed user interface diagram

# CONCLUSION

This study investigated ways to improve the usability and accessibility of Mixed Reality (MR) technology for home remodeling, particularly through the use of AI-powered object recognition to enhance user interaction with real-world environments. High prices, technical difficulty, and a dearth of user-friendly tools for homeowners and contractors were among the main issues identified. In response, the suggested solution emphasizes a more user-friendly and reasonably priced interface while maintaining strong features like precise object detection and real-time interaction. y bridging the gap between virtual design and actual construction, the renovation process will be made simpler and more effective. Future developments will involve extending the system's application to other domains, such as smart homes and interior design, and testing it in real-world settings.

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