AI-Powered BIM Based AR Application for Construction

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Abstract: Augmented Reality (AR) in Construction overlays digital information onto real-world environment with precision. Building Information Modeling (BIM) integrates comprehensive 3D models and data into the construction process. While construction firms are updated using BIM and CAD software to create detailed 3D model Not only that errors prohibited during the building plan design phase because the construction of something is intended to last for generations, but it could also be difficult to identify those errors without close inspection.Misalignment between the design and actual on-site implementation is one of the primary drivers of delays.The proposed project aims to develop an AR and BIM-based Android application that overlays 3D models onto 2D construction plans. Therefore, the proposed scheme is divided into four phases. In the first phase we use Autodesk forma is a cloud-based design tool tailored for architects for early-stage building and site analysis. It uses AI to optimize designs for environmental factors, offering real-time feedback. Second step is to create 3D model for floor plan using BIM software Revit. In the third phase, we use AR software development kit Vuforia to overlay digital content on real-world environment. Last step is using Android SDK Tools for testing on an Android Device.

1 INTRODUCTION

The construction industry is increasingly using advanced digital technologies like Building Information Modelling (BIM) and Augmented Reality (AR) to enhance project in different terms. BIM facilitates the use of 3D models and detailed data to improve collaboration, accuracy, and decision-making across various stages of construction projects. Even though, there remain challenges in translating digital designs into physical construction Often, misinterpretation of traditional 2D drawings or even traditional 3D BIM models results in inconsistency during construction, leading to delays, cost overruns, and the need for rework (Kwon, Arau, et al. 2014). This tells the importance of improving the precision and efficiency of construction inspection and planning. The integration of AR and BIM presents a powerful solution to these challenges. AR overlays digital models onto physical environments, offering a real-time, interactive interface that allows users to explore and analyze construction elements directly on-site or through 2D plans, which improves the detection of inconsistencies and enhances construction management (El Ammari and Hammad, 2019). By combining BIM's detailed design models with AR's immersive visualization, it becomes easier to catch design errors before they lead to costly rework (Chen, Abbas, et al. 2020).Recently, researchers have explored the integration of artificial intelligence (AI) into AR-BIM applications to further enhance the construction process. AI- driven tools optimize design performance by analyzing environmental factors such as sunlight and wind patterns, helping architects and engineers make informed design decisions early in the project (Nguyen and Tran, 2021).This research introduces an AI-powered BIM and AR-based Android application designed to improve construction planning and inspection by overlaying 3D models onto 2D construction plans. The proposed application leverages AI for optimizing early-stage designs and utilizes AR for real-time visualization and error detection. This solution aims to minimize errors, reduce rework, and enhance overall project efficiency, contributing to more accurate project execution and cost management (Riaz and Kaleem, 2021).

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1.1 Motivation

It is difficult to ensure that designs are accurately implemented on-site is critical to avoid costly mistakes and delays. Even with modern tools like BIM, there are still challenges when it comes to translating these designs into real-world construction. Errors often occur because workers have to interpret complex 2D plans or even traditional 3D models, which can be difficult and time-consuming.This research aims Integrating Augmented Reality (AR) with BIM allows for real-time visualization of digital models in the physical environment, making it easier to identify potential issues early. By developing an Augmented Reality (AR) application that overlays 3D BIM models onto 2D construction plans, this project aims to reduce errors, save time, and improve collaboration, ultimately leading to better project outcomes.

1.2 Problem Statement

The construction industry frequently encounters difficulties in accurately transforming digital designs into physical structures, resulting in misunderstandings of Building Information Modeling (BIM) and traditional 2D drawings. These misunderstandings often lead to significant errors, costly rework, and project delays. Existing approaches do not sufficiently incorporate Augmented Reality (AR) and artificial intelligence (AI), limiting the effectiveness of design visualization and the early detection of discrepancies during construction. Thus, there is a need for a solution that integrates AR, BIM, and AI to improve efficiency in construction planning and inspection.

1.3 Objective

The integration of Building Information Modeling (BIM)with Augmented Reality (AR) enables users to see three-dimensional building designs overlaid on real-world environments, making the project more immersive and engaging AR technology allows field workers to better understand and communicate design information, makes possible for discussions about potential conflicts and enabling the team to collaboratively make informed decisions Our approach streamlines the construction process by minimizing errors and providing real-time information, ultimately enhancing overall project effectiveness.

2 LITERATURE REVIEW

Cheng, Riaz, and Kaleem (2021)(Cheng, Riaz, et al. 2021) explored the benefits of AR, BIM, and AI integration in improving overall construction workflows, highlighting significant gains in efficiency and accuracy on-site, with a focus on enhanced decision-making through real-time data visualization and automation tools. Grau and Hartmann (2019)(Grau and Hartmann, 2019)further emphasized the role of AR and BIM integration in refining construction planning and facilitating collaboration among project stakeholders. Their study indicated that using AR for visualizing BIM models improved stakeholder communication and reduced planning errors. The application of AR combined with BIM for on-site management was investigated by Kirschen and Sonnentag (2018)(Kirschen and Sonnentag, 2018), who illustrated how AR-assisted BIM models could support site managers in monitoring and managing construction activities, ultimately reducing project delays and enhancing safety compliance. Hammad and Zhang (2019)(Hammad and Zhang, 2019)also examined AR and BIM synergy, noting that the integration promotes better collaboration between remote teams and on- site personnel by offering real-time model updates and interactive project reviews. Cheng, Yuan, and Wang (2021)(Cheng, Yuan, et al. 2021) introduced AI and AR for real-time BIM-based construction planning, proposing that this integration enables adaptive planning and improves project scheduling accuracy. The use of AI in AR applications for construction was further analyzed by Chen, Lai, and Lin (2020)(Chen, Lai, et al. 2020), who discussed how AI-driven AR can optimize BIM processes by enabling predictive modeling and on-site risk identification, thereby enhancing overall project performance. Abbas and Marino (2020)(Abbas and Marino, 2020) presented a case for AI-powered AR in facilitating BIM-based construction site inspections.

3 ARCHITECTURE

3.1 Site Analysis and Initial Planning

Data Collection: Gather detailed information about the construction site, including topography, existing structures, and environmental conditions like sunlight,temperature and wind efficiency etc.

Preliminary Design: Utilize the collected data to create initial building designs, ensuring they align with site constraints and regulatory requirements.

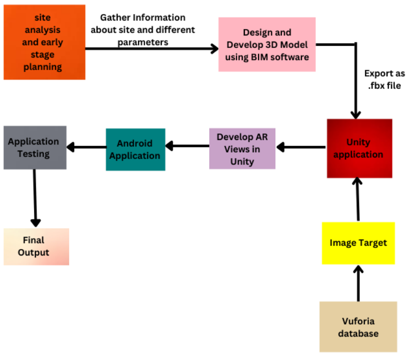

Figure 1: workflow of integration of augmented reality with Building Information Modeling.

3.2 Design and Develop BIM Model

Following the site analysis, a Building Information Model (BIM) is created. The BIM model includes detailed structural, architectural, mechanical, electrical and plumbing information, serving as a 3D representation of the building. This is typically developed using software like Autodesk Revit. The model then goes through a review and correction phase. If there are any errors, they are corrected at this stage before moving on to the next step, ensuring the model is accurate and ready for use.

3.3 Export BIM Model as .fbx File

After finalizing the BIM model, it is exported as an .fbx file, which is a common format used for 3D models and compatible with visualization platforms. This export is necessary to integrate the BIM model with the augmented reality software.

3.4 Vuforia Database

In this architecture, Vuforia is an augmented reality (AR) software development kit that enables the recognition of image targets, such as 2D construction plans, and overlays 3D BIM models onto them, allowing for visualization in real- world environments. It acts as the core AR engine for aligning digital content with physical environment.

3.5 Unity Application

The next step is to use Unity, a game development engine, to build the Augmented Reality (AR) view. The 3D BIM model exported earlier is integrated into Unity, where the Vuforia SDK helps with recognizing image targets and rendering the augmented reality overlay.Once the AR functionality is built in Unity, it is ready for deployment.

3.6 Android Application

The AR application is then packaged as an Android app using the Android development tools.The app is prepared for use on Android devices, where the 3D BIM model can be viewed in augmented reality. Once the testing is completed and all issues are resolved, the application is finalized. This ensures that the 3D BIM models are accurately displayed on top of 2D plans, providing enhanced visualization and collaboration for construction teams.

4 METHODOLOGY

4.1 Site Analysis and Early-Stage Building Planning

The first phase involves conducting a thorough site analysis to optimize early-stage building plans. For this, we used Autodesk Forma, which leverages AI to assess environmental factors such as sunlight, energy efficiency, and wind patterns. These factors play a crucial role in the optimization of the architectural design, ensuring the early-stage plans are accurate and sustainable (Chen, Abbas, et al. 2020)(Zhang and Liu, 2021).

4.2 Design and Development of the BIM Model

In the second phase, a Building Information Model (BIM) is created using Autodesk Revit which makes things easier This model incorporates architectural, structural, and MEP (mechanical, electrical, plumbing) data. After design checks and corrections the BIM model is exported in .fbx format for compatibility with AR platforms .Exporting the model as an .fbx format for compatibility with AR platforms. Exporting the model as an .fbx file enables real-time visualization and interaction within AR applications (Pan and Ismaeil, 2020). This format is widely used for integration into AR platforms, ensuring seamless visualization during later stages(Kwon, Arau, et al. 2014).

4.3 AR Integration Using Vuforia and Unity

The third phase focuses on integrating the BIM model into Augmented Reality. Here, Vuforia SDK is employed to recognize 2D construction plans (referred to as image targets) and overlay the 3D BIM model onto them. Vuforia's robust image recognition technology allows users to visualize detailed 3D structures superimposed on real-world 2D drawings. This 3D model is rendered using Unity, a powerful game engine that supports AR development, creating an immersive experience for users to explore building models in a real-world context (Nguyen and Tran, 2021).

4.4 Android Application Development and Testing

Once the AR model is fully developed, it is compiled into an Android application. The application allows on-site construction teams to visualize the 3D BIM model overlaid on 2D floor plans in real time. The testing phase ensures the accuracy of the AR overlay, verifying alignment and performance on various Android devices. Any errors identified during this phase are corrected, and the application is retested to ensure it functions correctly without any misalignment issues(El Ammari and Hammad, 2019). The final product is an easy-to-use Android app that facilitates real-time construction inspections and design verifications(Riaz and Kaleem, 2021).This methodology leverages BIM and AR technologies to improve the visualization, collaboration, and efficiency of construction processes. Through detailed site analysis, model development, AR integration, and testing, this approach ensures accurate visualization of construction plans, thereby reducing errors and rework during the building phase(Zhang and Liu, 2021).

5 RESULTS AND ANALYSIS

5.1 Site Utilization Analysis

The first phase of this project focused on assessing how effectively the site could be utilized for two potential building designs. By analyzing the layout and spatial organization, the following observations were made.

Structure 1: The initial design utilized less of the available site area, resulting in a significant portion of unused space, particularly along the north and south- facing sides This design approach provided more open areas,but it didn't fully capitalize on the potential for maximizing the constructed environment.

Structure 2: Whereas the second design was more optimized for site coverage. It strategically used the entire plot area to incorporate a more efficient distribution of spaces like rooms, hallways, and outdoor areas. This design ensured that the building blueprint aligned with the site boundaries, leaving minimal wasted space while providing a balanced indoor- outdoor experience.

Conclusion: The second structure was better at utilizing the site fully, creating a more functional layout without compromising natural ventilation and accessibility. By integrating rooms in strategic areas of the plot, the structure maximized the building's efficiency.

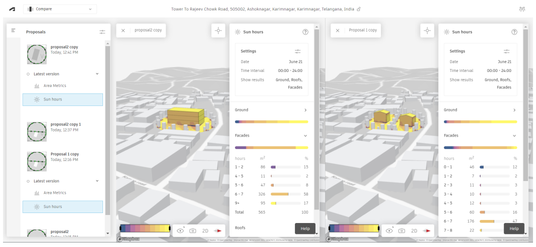

Figure 2: Comparison of two structures.

5.2 Environmental Considerations

In the context of this project, Autodesk Forma was used to perform in-depth environmental analysis, particularly focusing on sunlight exposure . The tool's ability allowed for accurate simulations and insights that were crucial to improve the design for sustainability and energy efficiency.

Sustainability: The combination of sunlight exposure and ventilation analysis performed in Autodesk Forma demonstrated the sustainable potential of the design. By carefully optimizing the window placements and room layouts in Structure 2, it became clear that the building would harness more natural light throughout the day, thereby minimizing the need for artificial lighting. Additionally, improved natural ventilation reduced the building's cooling demands, making it significantly more energy-efficient and environmentally friendly.

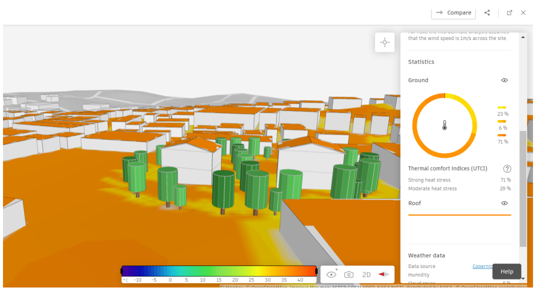

Figure 3: Thermal Comfort Indices.

5.3 BIM Model Integration

The BIM model (shown in the images) played a critical role in the analysis, offering a comprehensive 3D visualization of both structures. This allowed for several detailed comparisons and analyses.
The BIM model gave an accurate visualization of the spaces and their relationships. For example, it was easier to see how room layouts were positioned relative to site boundaries and how they interacted with open spaces or courtyards.The 3D model provided insights into roof design, elevation heights, and slopes, which helped evaluate how well the structures would withstand environmental elements like wind and rainfall.The model helps in identifying potential clashes between structural elements (e.g., walls intersecting with windows), which was not easily detectable in 2D plans. This allowed for real-time adjustments and design improvements.

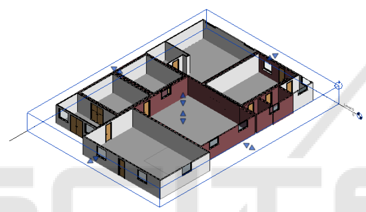

Figure 4: Internal view of 3D Building Information Modeling (BIM) model of 2D drawing.

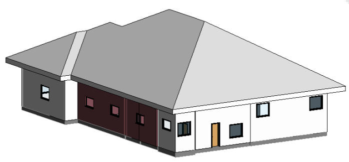

Figure 5: External view of 3D Building Information Modeling (BIM) model of 2D drawing.

5.4 Augmented Reality (AR) Integration for Design Verification

A key feature of this analysis was the use of AR technology to overlay the BIM model onto the 2D site drawings (as demonstrated in the provided AR photos). This provided real- time insight into the structure's spatial behavior within its environment.

3D Model Overlay on 2D Plans: AR allows users to project the 3D BIM model over the printed 2D plans, providing an interactive view of how the building would appear in reality. This highlighted any inconsistency between the designed model and the flat 2D representation.

Enhanced Visualization: The AR projection helped visualize both the exterior and interior spaces, making it easier to assess room sizes, window placement, and circulation paths. This gave stakeholders a realistic sense of scale and layout that's hard to capture in traditional 2D drawings alone.

User Interaction: The AR model could be viewed from multiple angles, allowing users to understand the building from various perspectives. This added depth to the design process, enabling more informed decisions on aesthetics and functionality.

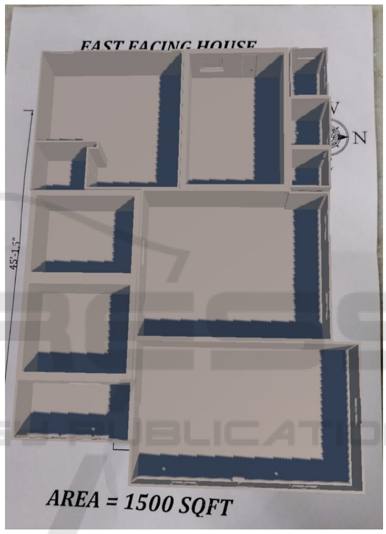

Figure 6: Internal view of 3d model after Augmented Reality(AR) integration with Building Information Model(BIM).

6 CONCLUSION

This research highlights the transformative potential of integrating Augmented Reality (AR) with Building Information Modeling (BIM) in the construction industry By developing an AR-based Android application that overlays 3D BIM models onto 2D construction plans, we aim to improve visualization, improve error detection, and streamline the construction inspection process. The proposed methodology allows construction teams to interact with digital models in real time, facilitating better communication and collaboration among stakeholders. Early results suggest that this approach can significantly reduce misinterpretations of design documents, minimize costly re-

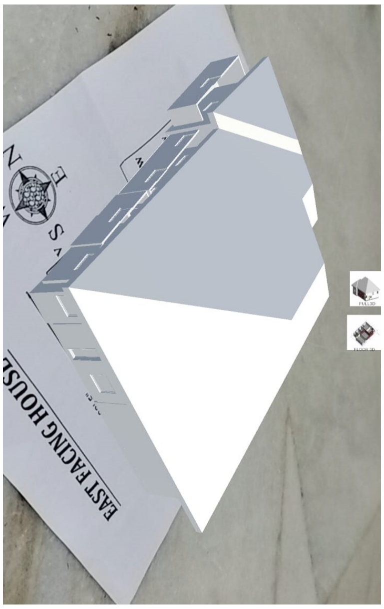

Figure 7: External view of complete 3D model after Augmented Reality(AR) integration of Building Information Modeling (BIM).

work, and improve overall project efficiency.The integration of AI in the early design stages further optimizes the planning process by considering environmental factors, ensuring that projects are not only accurate but also sustainable. By empowering field workers with tools that enhance their understanding of complex designs, this research paves the way for more informed decision-making and increased accountability throughout the construction process.

7 FUTURE WORK

In the future, several improvements can be made to further enhance the integration of Augmented Reality (AR) and Building Information Modeling (BIM) in construction. One potential way is to incorporate more advanced AI features that can predict design problems and optimize building plans in real time based on environmental factors. Additionally, conducting more extensive field tests with construction teams will provide valuable feedback to improve the usability and functionality of the application. Another promising area is to integrate other emerging technologies, such as the Internet of Things (IoT), which would allow real-time data sharing and better collaboration among project teams. These efforts will help make construction processes more efficient and accurate while reducing errors and delays.

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