Design of Mixed Reality Applications for Visualizing Integrated 3D Land Information Services

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Key words: Mixed Reality, 3D Land Information Services, 3D Cadastre, AR, VR

SUMMARY

Applications of mixed reality (MR), targeting users of augmented reality (AR) and virtual reality (VR), have become more popular because of their unique advantages. This paper presents both virtual reality and augmented reality applications that use 3D models from cadastral surveys and property-based data that follows the Land Administration Domain Model (LADM). Applications are designed to be able to present integrated 3D models and 2D land information for property professionals. This paper presents the procedures and challenges to process 3D point clouds data from various sensors i.e., drones, visual GNSS, handheld SLAM and to implement visualization and interaction designs of 3D and 2D land related data for AR & VR apps. The pipeline—which includes data collecting utilizing a variety of sensors and AI algorithms for model development—for converting 3D cadastral data into integrated land information is presented in this study. One of critical challenges that this paper worked on has been the integration of user location and 3D property representation on the mobile app, used by land professionals in the field. The land information systems on the AR systems superimpose digital data on the real world. Using the same 3D model, we also investigate how various placement strategies for MR might be used to give 3D city models for land administration services. For the VR users, both land professionals and landowners, utilize the glasses to explore the same 3D models and their related 2D land information for inspection and analysis purposes. Determining, documenting, and sharing data about land ownership, value, and planning is a complicated process that is part of land administration. Both developed AR and VR apps can help traditional systems overcome their inefficiencies and errors by offering real-time insights to land professionals.

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1. INTRODUCTION

Land administration deals with complex processes of determining, recording and disseminating information related to tenure, value and land use planning of property and land resources (United Nations & Economic Commissions for Europe, 2005). Traditional paper-based systems often suffer from inefficiencies, inaccuracies, and delays which cause a delayed response time, increased cost or low quality (Atazadeh, Olfat, et al., 2021). In order to address this, a technique based on the Fit for Purpose (FFP) principles is put forth for use in community-based land registration initiatives with the goal of enhancing surveyors' roles and assisting with the land administration procedure (Enemark et al., 2014). Land information systems play a crucial role in urban planning, real estate management, and environmental monitoring (Rajabifard et al., 2012). Hence, land professionals coming from municipality and land offices, private surveyors, bank institutions, professional valuers, notaries often require on-site assessments and visits. Traditional 2D maps and GIS interfaces often fall short in conveying and integrating the complexity and fragmented sources of land data. Mixed reality bridges this gap by overlaying digital information onto the physical environment through a mobile app, allowing users to interact with 3D models and geospatial data in a more intuitive manner.

Mixed reality (MR) applications that range from Virtual Reality (VR) to Augmented Reality (AR) have gained prominence in various domains due to their ability to blend virtual and physical world elements seamlessly. MR mixes real and virtual objects in a single display at the same time and location (Gyawali, 2023; Milgram, 1994). AR applications can bridge this gap by overlaying digital information onto the physical environment, allowing professionals to interact with land data seamlessly. AR technology has the potential to revolutionize land administration services by providing real-time, context-aware information to professionals in the field. An AR app offers a seamless integration into users' real world, while a VR app offers an immersive digital environment, distanced to users' real world.

In this paper, we propose the design of an AR application specifically tailored for disseminating integrated 3D land information services for property professionals. Our focus is on leveraging the 3D models from 3D cadastral survey and integrated property-based information, adhered to standardized Land Administration Domain Model (LADM) to enhance data visualization, decision-making, and collaboration when used by professionals such as land surveyors, valuers, bank officers, and urban planners in the field. We discussed key components, challenges, and considerations in developing such an application. Our goal is to enhance the user experience by providing an intuitive interface that combines 3D geospatial data with real-time visualizations. We discussed the key components of the application, including 3D data acquisition and processing, visualization techniques, and user interaction paradigms. Additionally, we explore the positioning challenges associated with AR development in the context of land information.

Our proposed AR application aims to empower land surveyors, valuers, bank officers, and urban planners with real-time insights. By leveraging LADM and AR technology, it is expected that the service provider can streamline land administration processes, improve accuracy of decision-making, and enhance collaboration. Additionally, this innovative approach can significantly reduce the time, and resources required for land-related tasks, ultimately leading to more efficient and effective land management.

This paper will first present the pipeline processing in transforming 3D cadastral data into 3D integrated land information. Data acquisition is done to three urban wards of 215 ha in Yogyakarta City using three different sensors: Aerial Photos Drone, handheld SLAM, and Visual GPS. Later, the paper will discuss data processing and integration. The point clouds and imageries will be used to develop a set of 3D city models of the study area. The generated 3D models were prepared for two different types of users, i.e., the LOD 1 3D wireframe model for users working in the field with AR and the LOD2 and LOD 3 3D model for users working in the office with VR. The data integration will superimpose 2d land information with 3d models using pixelization approach.

2. LITERATURE REVIEW

2.1 3D Data Acquisition

The evolution of cadastral systems from 2D to 3D has significantly impacted various processes such as data acquisition, processing, management, storage, and visualization. Modern 3D cadastre requires advanced instruments. Teicu et al. (2022) employ a combination of Total Station (TS), GNSS instruments, UAVs with LiDAR sensors and RGB cameras, and Mobile Mapping Systems (MMS) for data acquisition. The work of Kocur-Bera & Grzelka (2022) compares the process of collecting cadastral data by using traditional methods and modern remote data acquisition methods with aerial photogrammetric image. Chio & Hou (2021) study the feasibility of a handheld LiDAR scanner to perform an urban cadastral survey.

Research shows several methods for capturing 3D cadastral data. Planimetric surveys, aerial photogrammetry, and laser scanning are the most common techniques used for cadastral measurement. Aerial photogrammetry covers wide areas quickly, while laser scanning offers the highest accuracy. Using both methods together can optimize data results. This research chose UAV and LiDAR for 3D data acquisition due to their superior accuracy, efficiency, and effectiveness.

2.2 3D Data Modeling

3D data modeling aims to create digital representations of real-world objects. Researchers have developed manual, semi-automatic, and automatic approaches for 3D modeling. Noardo et al. (2021) investigate several problems related to the implementation of the standard and the use of standardized data, especially IFC and CityGML. Rajabifard et al. (2022) use the

BIM-IFC format for modeling cadastral data, employing IfcSpace to define legal boundaries in 3D and storing Right, Restriction, and Responsibility (RRR) information as attributes. Olfat et al. (2021) and Stoter et al. (2024) also advocate for using the BIM format in IFC for 3D cadastres, focusing on effectively modeling, storing, and visualizing multi-story data. Atazadeh, Olfat, et al. (2021) propose extending IFC to LADM for 3D digital cadastres, linking LADM with BIM to integrate the legal and physical dimensions of buildings internationally.
Most research on 3D cadastral data modeling prefers the BIM-IFC format, which includes hundreds of entity classes. However, visualization typically relies on static web tools like Cesium JS. This research explores enhancing 3D cadastral data visualization by implementing MR through VR and AR, aiming to combine comprehensive data with immersive visualization for more effective evaluation and decision-making.

2.3 Data Integration

The integration of 2D and 3D cadastral data is becoming a prominent topic due to the increasing demand for converting 2D data to 3D. This shift is driven by the need to manage land limitations and overlapping vertical property rights (Rajabifard, 2014). Atazadeh, Halalkhor Mirkalaei, et al. (2021) explore the connectivity and integration possibilities between 2D and 3D cadastral data, supported by Gürsoy Sürmeneli et al. (2022) who examine the inadequacies of current models in effectively representing 3D data and integrating legal and physical objects.
As 2D and 3D integration advances, AI technologies like deep learning (DL) and machine learning (ML) are increasingly used in cadastral and property valuation. Lee et al. (2022) used ORB-SLAM, YOLO, and ICP algorithms for tracking and 3D estimation in AR. Zou et al. (2023) employed object detection models to create AR map symbols. Potsiou et al. (2023) proposed a low-cost property evaluation using BLE technology and ML for indoor positioning. Land (2022) highlighted GeoAI's role in change detection and feature extraction, while Shende (2021) explored ML and fuzzy logic in property valuation. These approaches illustrate AI's potential in enhancing LADM frameworks.

2.4 Data Visualization

3D spatial data represents objects in three dimensions, including height (z-values) and geometric details (Apeh & Rahman, 2023). Its demand is rising, with uses in computer graphics, VR, and MR. 3D objects can be modeled using wireframe, surface, or solid modeling. Wireframe lacks surface detail, while solid modeling includes topological and geometric data, with examples like Constructive Solid Geometry (CSG) and Boundary Representation (B-Rep). B-Rep defines objects by boundaries, whereas CSG uses a tree structure with Boolean operators (Hoffmann, 1989).
Besides the data model, tiling is crucial for efficiently visualizing large 3D objects. Tiling allows vast and intricate 3D data to be broken down into smaller 'tiles,' enabling smooth and detailed visualization by streaming the data efficiently. A common use of 3D tiles is seen in 3D Tiles Cesium, a cross-platform virtual globe designed for dynamic spatial data visualization. 3D Tiles facilitate the streaming and rendering of massive 3D geospatial content such as Photogrammetry, 3D Buildings, BIM/CAD, Instanced Features, and Point Clouds.

They define a spatial data structure and a set of tile formats optimized for 3D streaming and rendering (Open Geospatial Consortium, 2022).

2.5 Application Design & Usability

The development of technology has extended beyond 3D visualization to include virtual environments like VR and AR. VR allows users to enter and interact with virtual scenes, providing immersive experiences that can substitute for real-world visits, particularly in cases of limited mobility or external factors like a pandemic (Meirinhos et al., 2022). VR experiences are often built on game engines such as Unity, which supports high-quality 2D and 3D game design and cross-platform capabilities (Tsai et al., 2021).

Research utilizing game engines for 3D modeling includes Pavelka & Landa (2024), who used Unreal Engine for 3D GIS data visualization, and Helbig et al. (2022), who used Unity3D for 3D visualization from environment mobile sensor data. Laksono et al. (2019) presented a 3D city using the Structure from Motion (SfM) method from aerial photos to obtain LoD 1, integrating parcel data. Studies by Nesaif & Shagufta (2023) found that VR technology can enhance clients' purchase intentions by improving presentation efficiency and providing product information interactively.

AR integrates virtual objects into the real world, blurring the boundaries between them. It combines views of physical objects with virtual environments. Research in AR includes Boboc et al. (2022) survey of AR systems in cultural heritage in last decade and studies by Loaiza Carvajal et al. (2020), Rizvić et al. (2021) and Zimmer et al. (2021) exploring VR-AR in cultural heritage to relive the past and complement museum information. In engineering, VR-AR is used for visualization, such as Bauer & Lienhart (2023) implementation of automatic remote Total Station monitoring for dynamic urban scenes in Unity, and Bauer et al. (2024) use of MR in monitoring applications. Boos et al. (2023) utilized AR to visualize planned buildings in construction, and Fridhi & Frihida (2019) integrated 3D GIS and AR to visualize architectural objects from laser scanning, modeled in Sketchup.

A review of the literature reveals a gap in the use of MR within the LADM. While current MR studies focus on immersive visualization for tourism and cultural purposes, LADM, 3D cadastre, and land parcel visualization remain primarily in 3D or web-based formats. Given MR's ability to provide immersive experiences and supplement digital information in real-time, this research aims to bridge the gap in land administration visualization. This study proposes using MR, specifically VR and AR, to enhance land administration. It introduces pixelization for efficiently gathering, storing, and analyzing 2D attributes and legal information related to land parcels. By combining land scoring parameters, AI, and advanced statistical analyses within the pixelization framework, and integrating detailed attribute information with immersive VR and AR visualization of land and building geometries, this research aims to offer a novel approach to land administration visualization.

3. METHODS

In regard to the 3D model development, the created 3D models in the study area were done partly with help of Artificial Intelligence (AI) such as Machine Learning (ML) and Deep Learning (DL). For generating Digital Terrain Model (DTM) out of Digital Surface Model

(DSM), this work extracted ground point clouds (by implementing DGCNN algorithm (Wang et al., 2019)) and developed building footprints (by using YOLO algorithm (Redmon et al., 2016)). Further this work developed LOD 1 (by extruding OHM i.e., DSM – DTM (Fissore & Pirotti, 2019)). Semi-automatic data conversion and editing was done to convert 2D parcel boundaries into 3D primitives and 3D building models into LOD2 3D models. Work is still done to generate automatically from 3D property wireframe visualization out of 3D city models representing property boundaries (3D building models and 2D parcel extrusion). For the time being, this work also uses manual editing to improve building facades of LOD3 models. The overarching concept of the proposed research is depicted in the Figure 1.

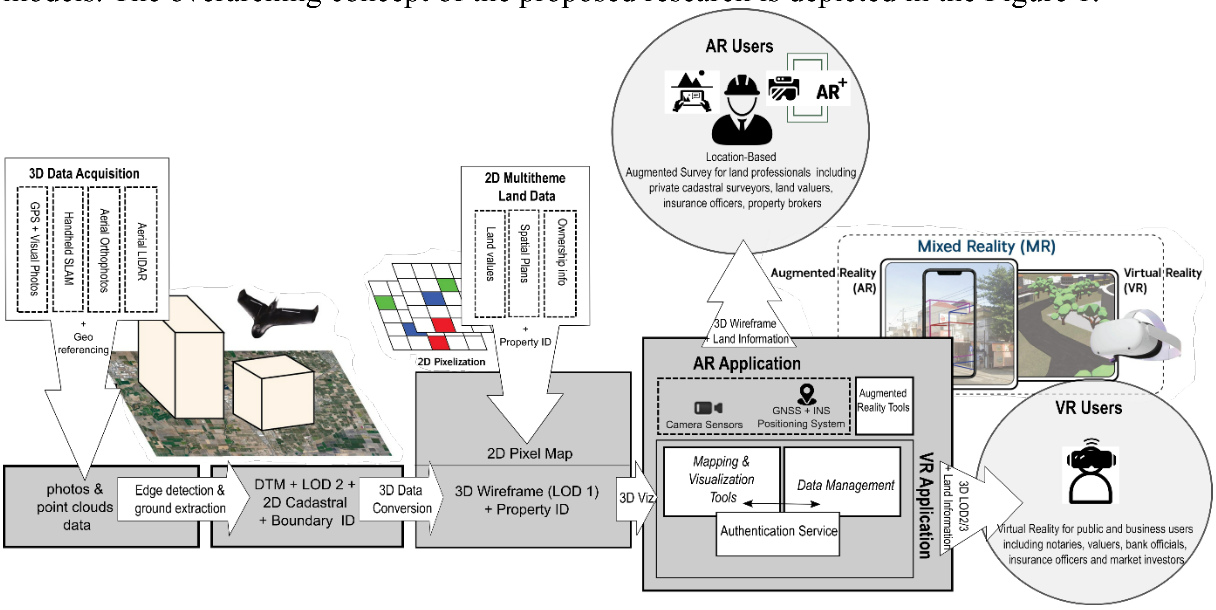


Figure 1. Propesed framework

3.1 Data Acquisition

The dataset collected from field measurements included LiDAR, SLAM, and visual GNSS, using three distinct sensors: a UAV drone, a handheld SLAM device, and Visual GPS. The UAV drone and Visual GPS generate high-resolution photographs, which, when taken with sufficient overlap, can be aligned to derive point cloud data. This process is further enhanced by the handheld SLAM, which also produces point clouds. Point cloud data forms the foundational element for constructing 3D models. Additionally, orthophotos from the UAV drone are used to delineate building outlines and land parcels. Each dataset undergoes pre-processing and is combined into one comprehensive dataset for generating 3D models.

The UAV drone generates two primary datasets: orthophotos and point clouds. Ensuring the accuracy of LiDAR data, which serves as the main dataset for 3D models, is crucial as it covers a significantly larger area than other instruments. The Visual GPS complements the SLAM and UAV LiDAR by creating accurate positions with panoramic photos or videos, which can also be processed into point cloud data. The collected data from Visual GPS are important to develop LOD 3 models. All the datasets are integrated into a comprehensive dataset representing the 3D conditions of the research location, with each dataset complementing the others to result in detailed point cloud data (Figure 2).

Figure 2 Sample result of dataset

3.2 3D Data Modeling

The objective of 3D data modeling is to create detailed 3D models from field data measurements. The pre-processed and integrated data from SLAM, UAV drones, and Visual GNSS results in a comprehensive dataset that accurately represents the terrain and objects within the research location. However, not all objects in the dataset are modeled into 3D models; the selection of target objects depends on the research focus and desired outcomes. This work specifically processes the following 3D objects:

- VR: Buildings, Trees, and Terrain. Buildings are modeled in LOD2, providing detailed information about each building's geometry, height, number of floors, and other relevant attributes essential for valuation.
- AR: Land Parcels, modeled into LOD1 and represented as a wireframe box only, representing the boundaries of each parcel.

These targeted 3D models enable land surveyors, valuers, bank officers, and urban planners to accurately assess buildings and their boundaries, facilitating informed decision-making.

3.2.1 Generation of 3D Terrain Model

In this study, the DTM provides the 3D terrain base for visualizing buildings and land parcels. Both DSM and DTM data are used to compute the Object Height Model (OHM), representing building heights. The process involves classifying ground point clouds into ground, vegetation, and buildings, with ground points forming the DTM and building points creating 3D models. Deep Learning techniques, particularly the DGCNN algorithm, enhance classification efficiency and accuracy. The OHM is calculated by subtracting the DTM from the DSM, serving as a height reference for 3D models. Ensuring consistent pixel resolution between DSM and DTM is vital for accurate OHM representation. The DTM is used as the ground base in VR/AR, while the OHM provides height references for 3D building models and land parcels.

3.2.2 3D Buildings Model (LOD2 and LOD3)

The 3D building models are generated at LOD2 and LOD3 per CityGML standards, including detailed walls and roofs. The semi-automatic creation process uses AI for building detection and manual modeling for roofs and facades to ensure accuracy. Building footprints are detected from orthophotos using the YOLO algorithm and serve as the base for real-world positioning. Roofs are manually modeled in Sketchup Pro, and classified point cloud data ensures accurate heights and geometry. This results in detailed LOD2 3D models accurately representing the buildings in the research area (Figure 3).

3.2.3 <u>3D Land Parcel Model (LOD1)</u>

A land parcel defines legal ownership and use, traditionally recorded in 2D by the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency. This research aims to convert Indonesia's 2D cadastre to 3D, visualizing it via VR and AR to delineate boundaries and improve access for stakeholders. Unlike LOD2 3D building models, 3D land parcels are visualized at LOD1 with simple extrusions from the ground to a specific elevation, using the OHM value. This wireframe representation reduces load times in AR applications due to its lightweight nature.

(a) (b)

Figure 3. AI result for building detection (a) and sample result of 3D building modeling (b)

3.3 Pixelization and Data Integration

This research integrates both 2D and 3D visualizations. The application uses pixelization for 2D data, enabling analysis and planning with land scoring parameters, while AR technologies provide seamless integration between objects in camera and 3D visualization. In order to enhance 3D AR geometry, a 2D attribute layer was added. The pixelization approach divides maps into 5x5 grids, each with selectable 2D information layers like land value, ownership, and transactions, offering simple and clear spatial data visualizations.

This research combines field measurements and agency data into a comprehensive dataset for 3D modeling. The design is to offer comprehensive and complete grids regarding land values, land title status and property taxes in the area. The data were collected from the local land offices and local municipalities. The public data related population density and disaster risk are pixelized for the study area. Pixelization of these datasets provide fast and comprehensive 2D analysis of the area which can be useful for land professionals in the field. 2D views use pixelated datasets for a top-down perspective, whereas 3D visualizations provide immersive VR-AR experiences with detailed LOD2 buildings and LOD1 land parcels, integrating 2D attributes for enhanced and intuitive data access. The ultimate outcome of this research is to optimalize data and information delivered through the apps for monetization in forms of either users' subscriptions or information accesses. However, the monetization model is out of scope to be presented in this paper.

3.4 Data Visualization with VR-AR

Data visualization is crucial in this research, serving as the main interface for user interaction. We chose VR-AR environments to create mixed reality (MR) experiences, allowing users to view 3D models from multiple perspectives. We use Unity as the game engine for developing the VR environment. Each model is meticulously scaled to ensure accurate dimensions. A two-dimensional attribute information layer is appended to each building, detailing legal and pertinent data for taxation or valuation purposes. The Meta Quest headset is used to visualize the VR game, providing an immersive experience for exploring 3D property and land data.

The application employed for creating AR utilizes Unity AR development to generate and simulate the LOD1 wireframe of land parcels. This modeled wireframe is enriched with comprehensive land information, including legal status, tax records, transaction history, and spatial patterns. The AR application is developed for Android devices as standalone applications, incorporating both 3D AR visualization and 2D pixelization. The integration of 2D and 3D visualization provides a robust tool for field surveyors and valuators in cadastral surveying.

Both VR and AR applications were developed using Unity, a robust game engine renowned for its versatility in game development. The choice of a game engine and game-based output for these visualizations aims to foster interactivity between users and digital objects, whether they are buildings or wireframes of land parcels. While Android ARCore was considered, it lacked the capability for interactive object manipulation and information retrieval. Therefore, Unity was selected to enhance interactivity and user engagement in both VR and AR applications. 3D Models for the VR app are represented as LOD2 and LOD3 models, while models for the AR app use LOD1 of land parcels.

4. RESULT

4.1 3D Model Result

This research leverages 3D models enriched with property-based information, adhering to LADM standards, to enhance visualization, decision-making, and collaboration for professionals such as land surveyors, valuers, bank officers, and urban planners using MR experiences with VR and AR. The transformation of 2D data into 3D models improves its visualization and application as real-world data. The models, created semi-automatically from field measurements and point cloud data, ensure high quality through advanced instruments and AI extraction methods.

The research tailored 3D models for VR and AR visualization: buildings, trees, roads, and terrain for VR, and land parcel wireframes for AR. VR buildings were modeled at LOD2, with notable landmarks at LOD3, while AR wireframes were at LOD1. The semi-automatic modeling process involved extruding land parcels based on the OHM and manually creating LOD2-3 models. These 3D models serve as digital twins, enabling remote assessment by professionals, resolving land parcel boundary issues without physical presence, and facilitating efficient land management through immersive VR experiences. Figure 4 below illustrates the 3D models for three urban wards in the research location.

(a)

(b)

Figure 4. 3D Building Model (a) and 3D Wireframe Model (b) in research location

4.2 Pixelization Result

This research uses MR, incorporating VR and AR, to visualize 3D land information services, alongside 2D techniques for accurate position determination. The CityDB Web Map Client is employed for high-performance 3D web visualizations of CityGML models. 3D building models are created in CityGML LOD2 format and visualized with web client services. The database system uses PostGIS with PostgreSQL, enriching 3D models with 2D attributes like legal status and IDs. This combination of a comprehensive database and interactive visualizations results in a complete web-based information system.

Pixelization approach was proposed in this research to complement the 3D visualization with 2D attribute regarding land information. The use of 'pixel' is based on various factors, but mostly inspired by tiling concept. However, for each tile or each pixel (defined in 5 x 5) pixels contain various insight and information delivered to the user. The user of pixel facilitates the user even without geospatial background to understand and get to know information of a location. Inside each pixel then assisted with AI for real-time analysis and simulation for the user. Users can pick a location and draw to create an area to determine which area to explore. From user input, backend server will create a query and real time analysis and delivered for user. Various land information has been imported in the database including legal status or ownership, property taxes, and land value (Figure 5).

(a) (b)

Figure 5. Pixelized data and 3D model in AR app (a) 2D map of area (b) 3D building close to users' location

4.3 VR-AR Result

The 3D property objects, including the 3D building model and 3D land parcel wireframes. VR creates a virtual world for users to explore building models without visiting the actual location, while AR overlays real-life objects with virtual ones, merging reality with the virtual world. This dual approach enhances land administration processes by providing immersive and interactive experiences for various stakeholders. This approach is motivated by the lessons learnt from the current national land administration project which still finds that the same time-same place interaction involving owners and related parties is difficult to implement. Meanwhile AR app can accelerate accurate and comprehensive field inspection connecting contextual information from the office with property objects.

Figure 6. Sample of VR result of 3D building model visualization

In the 3D VR model (Figure 6), the geometry, scale, and size of each building are meticulously maintained. The scale corresponds accurately to real-world structures, with the modeling process starting from a point cloud base to ensure precision. Although the current VR version lacks a feature for measuring building geometries, this will be added in a future update. Users can freely explore the virtual world by controlling the VR controller using VR glasses (Figure 7), walking or teleporting to navigate across the map.

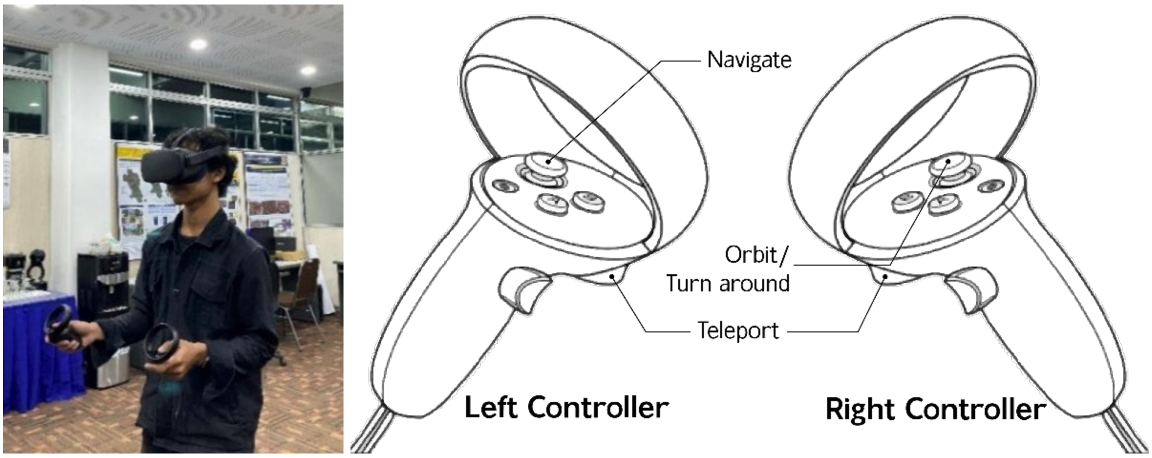
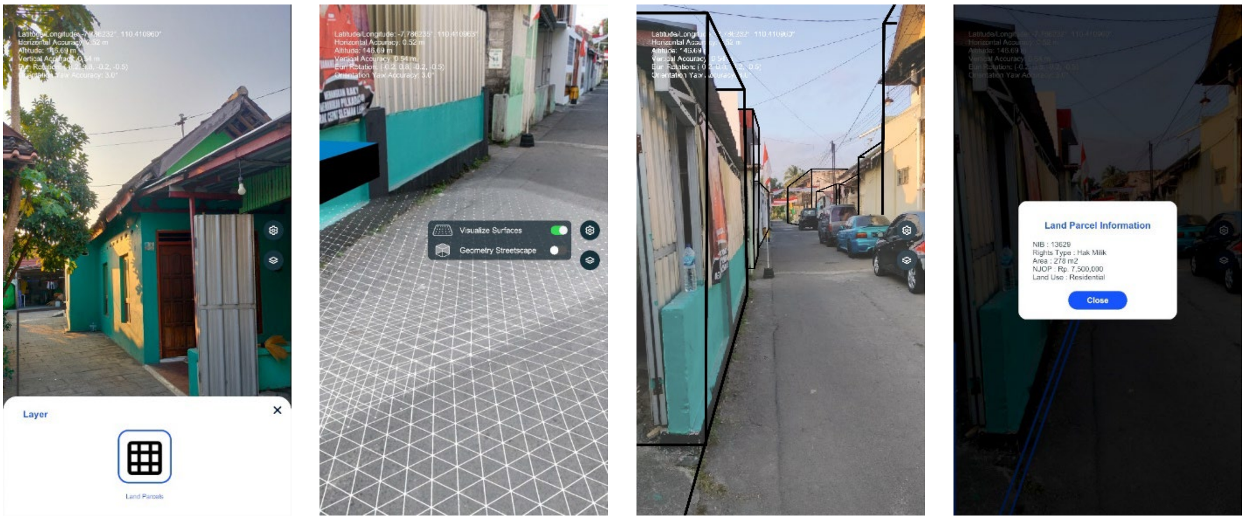


Figure 7. Controller system in exploring VR of 3D building model

VR app targets notaries, managers, the public, banks, insurance companies, and property audiences, offering integrated digital and real-world visualizations of 3D models, including buildings and environmental elements like trees and roads. Thus, using VR in their corresponding places or in a coordination meeting at a typical mediation room (i.e., commonly found in the local land offices), VR users interact with 3D models and land information. AR is intended for field surveyors, valuers, insurance officials, and brokers, requiring real-location visits to interact with overlaid virtual objects, focusing on land parcels in a wireframe form.

The developed AR application is a standalone Android application enhanced with 2D pixelization. It includes several key components designed to assist users in acquiring land information. The process begins with selecting land parcel layers, followed by detecting and visualizing ground surfaces. The application then displays a wireframe in AR, and when the user interacts with this wireframe, detailed land parcel information is presented on the screen. The application requires Android devices with specifications that support depth information and GPS sensors for accurate positioning. This AR tool aims to aid surveyors and valuators in the field by providing an efficient means of determining land parcel information (Figure 8).



(a) (b) (c) (d)

Figure 8. Sample of AR result of 3D wireframe land parcel visualization: (a) menu, (b) detecting ground, (c) wireframe, (d) popup information

5. CONCLUSION

The research proposes a workflow for implementing AR & VR apps for land administration services and their potential for monetization of land information to wider users. VR and AR offer benefits to provide more efficient and effective cadastral data visualization and interaction, beyond the merely same time-same place interactions in delivering land administration services. This research framework integrates 3D cadastral data and land information with mixed and extended reality tools. It also uses pixelization to store 2D attribute information, enabling real-time analysis with AI algorithms. This approach provides a comprehensive experience for professionals like land surveyors, valuers, bank officers, and urban planners, combining 2D and 3D data to create detailed land parcel stories. The research uses CityGML for 3D data modeling, with VR app is visualizing LOD2 and LOD3 of building models and AR app is visualizing the wireframes of LOD1 of land parcels. The framework ensures accurate legal land information. Future improvements could integrate environmental and mitigation data. Pixelization could enhance data analysis and delivery. Overall, the framework showcases that AR and VR uses for 3D land information services offer potential to be improved further.

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Bagus Imam Darmawan is the CEO of MAPID, a leading technology company in Indonesia specializing in Location Analytics. With a background in geoinformatics, Bagus has driven the development of innovative geospatial solutions, including SINI AI, which address complex challenges across various sectors. Under his leadership, MAPID has transformed data into actionable insights, impacting industries such as flood management and market expansion. Bagus is also dedicated to cultivating future talent through MAPID Academy, an initiative that nurtures the next generation of leaders in geospatial technology.

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