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ILLUMINATING HERITAGE THROUGH DIGITAL DOCUMENTATION OF RUMAH GADANG KAJANG PADATI

Shahrul Yani Said[1)*] **, Desy Aryanti**[2)] **,Mohammad Cahyo Novianto**[3)]**, Afdal Nazmi**[4)]**, I Nengah Tela**[5)] **& Putranesia**[6)]

[1)]Institut Seni Kreatif Nusantara (INSAN), Universiti Teknologi MARA, 41450 Shah Alam, Selangor, MALAYSIA

[2)4)5)6)]Faculty of Engineering and Planning, Universitas Bung Hatta, Ulak Karang, Sumatera Barat, INDONESIA

[3)]Jaringan Arsip Arsitektur Indonesia (JAAI), Omah Library, Karang Mulya, Kec. Kembangan, Kota Tangerang, INDONESIA

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Email correspondence: shahrulyani@uitm.edu.my

ABSTRACT

Heritage preservation in the digital era offers innovative opportunities to safeguard and showcase cultural assets. This study presents the use of Matterport Pro2 for 3D digital documentation of Rumah Gadang Kajang Padati, a traditional Minangkabau house, conducted over two days in Pauh and Kuranji, Sumatera. Rumah Gadang, as an iconic symbol of Minangkabau culture, faces threats from environmental changes and urban development; thus, creating an accurate digital record is vital for future research, conservation, and heritage management. The primary objectives of this research are to establish detailed insights into the architectural style, materials, and construction methods used in Rumah Gadang Kajang Padati. The process involved capturing detailed spatial and structural data using Matterport PRo2, a versatile 3D imaging technology capable of producing high-resolution virtual models. These digital models enable a thorough analysis of architectural features, interior layouts, and construction details that are essential for cultural and scholarly understanding. The digital documentation also plays a critical role in promoting remote accessibility, educational initiatives, and community engagement, ensuring wider awareness and appreciation of Rumah Gadang's cultural significance. Furthermore, the non-intrusive nature of the digital process minimises impact on fragile heritage structures while producing comprehensive, interactive virtual representations suitable for conservation planning and academic research. This study demonstrates that properly executed digital documentation is an essential tool for safeguarding intangible cultural heritage, especially at remote or threatened sites. Ultimately, the project underscores the importance of integrating advanced digital technologies in heritage preservation efforts, helping to preserve and disseminate cultural identity for future generations.

Keywords: Digital Heritage Preservation, 3D Documentation, Rumah Gadang Kajang Padati, Matterport Pro2, Architectural Analysis

1. INTRODUCTION

Preserving traditional architectural forms, such as the Rumah Gadang Kajang Padati, is paramount for maintaining cultural identity and historical continuity. These vernacular structures, deeply embedded in the local culture, represent a tangible link to ancestral ways of life and indigenous building practices (Trisyanti et al., 2023). However, many of these

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significant heritage buildings face threats from modernization, environmental degradation, and a lack of comprehensive documentation, underscoring the urgent need for advanced preservation methodologies (Li et al., 2025). Digital documentation, particularly through techniques like close-range photogrammetry and Building Information Modelling, offers a robust solution for capturing and archiving the intricate details of such heritage sites, thereby facilitating their long-term conservation and public engagement. This approach leverages advanced technological capabilities to create precise digital surrogates, which are crucial for detailed analysis, virtual reconstruction, and educational dissemination (Li et al., 2025). This digital transformation allows for the meticulous recording of architectural elements that might otherwise be lost, providing an invaluable resource for future generations of scholars and conservationists (Tolle et al., 2022).

2. LITERATURE REVIEW

The role of information technology in architectural preservation, especially within the context of Malay architectural heritage, has been increasingly recognized for its efficacy in modeling, rendering, and database creation (Faisal et al., 2021). Despite this recognition, preliminary studies indicate a disproportionate focus on colonial architectural documentation, leaving indigenous Malay architectural heritage, such as the Rumah Gadang, underrepresented in digital archives (Harun & Mahadzir, 2021). This gap highlights the necessity for dedicated efforts to digitally document traditional Malay dwellings, which are increasingly vulnerable to disappearance due to rapid development and societal changes (Faisal et al., (2021), Noor et al., (2020). The intricate designs and construction techniques of these historical Malay buildings are difficult to reproduce accurately, often resulting in incomplete or imprecise data when manual measurement methods are used (Mustafa et al., 2020). Consequently, the absence of comprehensive digital models impedes effective conservation planning and educational initiatives for these unique structures (Ali et al., 2018). This deficiency is further compounded by traditional conservation approaches, which often rely on physical restoration and prove insufficient for managing the multifaceted challenges associated with deteriorating heritage structures (Shin & Kang, 2025). This highlights a critical need for integrating advanced digital technologies, such as laser scanning and photogrammetry, to overcome the limitations of conventional 2D CAD-based records that inadequately capture the complex structural details of wooden architecture (Kim et al., 2025). Furthermore, the rigorous documentation of these structures serves as a cornerstone for preventive maintenance and ongoing monitoring, providing critical information for decision-makers involved in their preservation(Quintero, 2017).

These digital replicas serve as precise records, safeguarding cultural treasures for future generations and providing a basis for research, education, and conservation (Xing et al., 2025). Moreover, digital documentation strategies are crucial not only for preserving the physical attributes but also for capturing the intangible heritage associated with these structures, thereby enriching the cultural discourse around them. Despite these advancements, a significant challenge remains in implementing and adopting 3D digital documentation techniques as a standard method, partly due to the lack of expertise that bridges digital documentation and heritage conservation(Foo et al., 2023). This necessitates a multidisciplinary approach, integrating specialists from both fields to overcome methodological hurdles and ensure accurate, comprehensive digital representations of cultural heritage (Foo et al., 2023). Indeed, the precise capture of complex geometries, often challenging with manual methods, is now reliably achieved through laser scanning, providing a robust foundation for architectural conservation and restoration (Abdelalim, 2025). These advanced techniques, encompassing laser scanning and photogrammetry, are particularly valuable for large-scale heritage sites and complex architectural details, where traditional documentation methods fall short in capturing intricate deformations and structural nuances (Omuzlu & Turan, 2024).

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2.1 Digital Photogrammetry

The application of digital photogrammetry, in particular, offers significant advantages for preparing revision and design documentation for historical structures, ensuring their unique character and values are preserved for future generations (Hulimka & Tunkel, 2024). However, while terrestrial laser scanning is highly effective for generating geometrically robust 3D models, it is often limited by its earth-bound nature, making the documentation of elevated or inaccessible architectural elements challenging (Mateus et al., 2019). This limitation is effectively addressed by UAV-based photogrammetry, which provides a flexible and efficient means to capture comprehensive datasets from various perspectives, thereby overcoming the access restrictions inherent in terrestrial methods (Xu & Chen, 2025). This integration of diverse scanning methodologies allows for a more holistic and accurate digital representation of complex heritage structures, merging the high-resolution detail of terrestrial scans with the broad, inaccessible vantage points offered by aerial photogrammetry (Tunalıoğlu et al., 2025).

The combination of aerial photography and terrestrial laser scanning creates a comprehensive and precise 3D model, essential for detailed analysis, preservation, and virtual dissemination of cultural heritage sites (YURTSEVER, 2023). This integrated approach ensures both geometric precision and visual realism, providing a robust foundation for conservation efforts and detailed scholarly analysis (Pritchard et al., 2023). For instance, projects such as the documentation of the Aachen Cathedral and the Baptistery of San Giovanni in Florence have successfully implemented such integrated methodologies, demonstrating their effectiveness in creating comprehensive digital archives for complex heritage sites (Pritchard et al., 2023). Such an integrated approach, leveraging both terrestrial laser scanning and digital photogrammetry, substantially enhances spatial coverage and precision, thereby bolstering confidence in design decisions for conservation projects (Mateus et al., 2019). Integrating these techniques, such as combining terrestrial laser scanning with photogrammetry, allows for the creation of highly accurate and dense point clouds, overcoming the limitations of single data acquisition methods (Liu & Li, 2024) (Ulvi & Hamal, 2024). This multi-sensor approach is crucial for capturing the intricate geometries and complex surface textures characteristic of heritage structures like the Rumah Gadang, ensuring a holistic and detailed digital representation ; Pierdicca et al., 2023). Furthermore, the nuanced interplay between the accurate geometric data from terrestrial laser scanning and the rich textural information from photogrammetry provides an unparalleled level of detail for historical reconstruction and virtual accessibility (Corns et al., 2024) (Małyszek et al., 2023).

The synergy of these technologies allows for the creation of intricate three-dimensional models, crucial for documenting architectural patterns and managing various levels of detail (Prasidya et al., 2025). This integrated data acquisition and processing strategy, incorporating middle- and raw-level fusion, proves particularly beneficial for complex architectures, yielding comprehensive and reliable 3D documentation (Medici et al., 2024). The resulting models, comprised of dense point clouds and high-resolution textures, form a robust base for future conservation activities and historical analysis, effectively capturing both the geometry and the aesthetic attributes of the structure (Małyszek et al., 2023) (Pilato et al., 2023).
However, while laser scanning offers rapid and generally accurate point clouds, its textural quality can be limited, even with attached cameras, and the sheer volume of data generated for complex objects like heritage buildings can be overwhelming (Murtiyos et al., 2019). Conversely, photogrammetry excels at capturing high-quality texture information but may struggle with precise geometric accuracy in certain conditions, highlighting the complementary nature of these techniques (Małyszek et al., 2023). Therefore, integrating Terrestrial Laser Scanning and digital photogrammetry provides a robust solution, allowing for the generation of comprehensive 3D models with both precise geometric measurements and rich textural detail, effectively addressing the limitations of each individual technique (Mateus et al., 2019; Murtiyos et al., 2019). This multi-sensor approach, encompassing laser scanning and photogrammetry, creates a more complete and accurate digital representation of cultural

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heritage objects, providing comprehensive data that single documentation methods cannot achieve (Salach et al., 2016). The resultant hybrid datasets enable the creation of Heritage Building Information Models, which offer a sophisticated framework for integrating various types of historical, architectural, and conservation data within a geometrically accurate 3D environment (Liu & Li, 2024). This integration, for example, allows for colourized laser scanning aided by photogrammetry, where the scan data provides the dimensional skeleton and the photographic data contributes to the visual realism (Pritchard et al., 2023). The strategic integration of multiple sensors and data sources is pivotal for overcoming the individual weaknesses of each method, thereby generating highly accurate and complete geometric surveys necessary for modeling, interpretation, representation, and digital conservation (Remondino & Rizzi, 2010) (Curto et al., 2023).

2.2 Terrestrial Laser Scanning and Photogrammetry

The integration of Terrestrial Laser Scanning and photogrammetry has been widely adopted in cultural heritage documentation due to its superior accuracy, high resolution, and efficient data acquisition, enabling thorough, non-invasive object capture without requiring repeated field surveys (Liu et al., 2023). This combined approach, leveraging both the spatial accuracy of laser scanning and the detailed visual information from photogrammetry, creates comprehensive 3D point clouds and holistic grids that accurately document the geometry of heritage structures (Zhang & Zou, 2022). This sophisticated integration further facilitates the creation of Heritage Building Information Models, which are indispensable for managing the extensive and heterogeneous data associated with cultural heritage, enhancing spatial coverage and precision (Barhoumi & Hajji, (2024), Alshawabkeh et al. (2021). These advanced geomatic techniques, which encompass both range-based and image-based methods, have significantly evolved, specializing and enhancing every phase from data acquisition to the generation of detailed 3D metric products and their subsequent dissemination (Bastonero et al., 2014).

The evolution of these methodologies underscores their crucial role in accurately capturing the intricate details of historical structures, which is paramount for both preservation and accessibility (Alshawabkeh et al., 2021). The digital 3D models resulting from such integrated approaches become crucial reference frames for understanding and monitoring heritage documentation, creating data sources suitable for assisting in conservation, restoration, and reconstruction projects (Malinverni et al., 2019). This digital preservation strategy not only aids in safeguarding cultural heritage from deterioration but also enables broader public engagement and scientific analysis through virtual access and interactive visualizations (Perfetti et al., 2018). Furthermore, these digital twins, developed from the fusion of diverse geomatic techniques, facilitate advanced applications like predictive maintenance and structural analysis, offering a holistic understanding of the heritage asset's current state and future vulnerabilities (Kuroczyński & Argasiński, 2025). This comprehensive approach thus moves beyond static record-keeping, establishing an interactive and semantically structured digital representation that supports long-term conservation and facilitates immersive public engagement (Abdelalim, 2025).

3. METHODOLOGY

This section delineates the methodological framework employed for the digital documentation of Rumah Gadang Kajang Padati, including data collection, processing, and the development of a full digital model. The aim was to harmonise precision, completeness, and correctness across all stages, from early planning to final distribution, thereby ensuring high-quality data and reproducible processing (Hamp et al., 2025). The choice of particular techniques was guided by the complicated architectural features of Rumah Gadang Kajang Padati, emphasizing methods that could effectively capture both detailed nuances and the overall structural integrity (Eker et al., 2022). This study utilized a hybrid methodology

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combining terrestrial LiDAR scanning and photogrammetry to overcome current deficiencies in historic documentation, intending to generate a foundational dataset for HBIM-based heritage preservation (Abdelalim, 2025).

4.0 THE RESULT

The outcome of this methodological approach is a highly detailed and semantically rich digital representation of Rumah Gadang Kajang Padati, which not only captures its complex geometry but also embeds historical and material information crucial for conservation (Hoàng et al., 2025). This integrated digital twin serves as a robust platform for ongoing structural monitoring, restoration planning, and academic analysis, providing unprecedented insight into the architectural nuances and heritage value of the structure (Shimoda et al. (2025), Hoàng et al. (2025). The extensive dataset generated through this process includes high-resolution point clouds and detailed meshes, which are subsequently utilized for the development of comprehensive Building Information Models that can integrate both geometric accuracy and semantic information (Liu & Willkens, 2021). This approach effectively creates a multilayered digital archive that meticulously captures both geometric precision and cultural context, proving particularly effective for complex timber structures like Rumah Gadang Kajang Padati (Hoàng et al., 2025). Beyond static geometric representation, this methodology lays the groundwork for dynamic applications such as damage simulation, structural analysis, and the production of educational VR/AR content, thereby enhancing both preservation and public engagement (Hoàng et al., 2025).

The 3D documentation process using the Matterport Pro2 3D camera successfully created a detailed digital record of the selected houses in Pauh (P16, 25, and 26). The scanning included the entire interior of the building, capturing architectural features, materials, and spatial relationships with high accuracy. The resulting dataset offers a multi-dimensional representation that supports both technical architectural analysis and cultural interpretation of the traditional dwelling.

4.1 Digital Deliverables from the scanning

Table 1: List of deliverables from 3D Documentation using Matterport

OUTPUT TYPE	FORMAT	DESCRIPTION	APPLICATION
Interactive 3D Virtual Model	Online (Matterport link / QR code)	Complete navigable 3D scan of the house, including exterior and interior spaces.	Spatial analysis, virtual exhibition, public access.
3D Mesh Model	.OBJ / .FBX	High-resolution textured mesh model derived from the scan.	Visualization, 3D rendering, educational use.
Point Cloud Data	.E57 / .XYZ	Geometric spatial data of the entire house.	Measurement, CAD integration, conservation planning.
2D Floor Plans & Elevations	PDF / DWG	Automatically extracted orthographic projections.	Documentation, spatial typology study.
360° Panoramic Images	JPG	Panoramic stills from each scan point.	Material and surface analysis.
Measurement Data	CSV / Matterport Cloud	Dimensional data including room height, width, and area.	Quantitative analysis of spatial organization.
Annotation (MatterTags)	Cloud-based / Screenshot	Descriptive tags identifying spaces, materials, and motifs.	Cultural and architectural interpretation.

4.2 Spatial and Dimensional Output

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The Matterport system automatically generated accurate 2D floor plans and dimensional measurements, allowing quantitative assessment of spatial organisation. Table 2 summarises the primary spatial dimensions extracted from the 3D model.

Table 2: Summary of the dimensions of the spaces based on digital documentation data

SPACE	LENGTH (FT)	WIDTH (FT)	FLOOR AREA (FT^2)	FUNCTION
P16				
Serambi (Veranda)	34'10"	8	81	Reception and resting area
Rumah Ibu (Main Hall)	32'19"	10	742	Main living and family area
Rumah Dapur (Kitchen)	17'11"	22	384	Food preparation and dining
P25				
Serambi (Veranda)	6'10"	28'	196	Reception and resting area
Rumah Ibu (Main Hall)	17'	33'6"	439	Main living and family area
Rumah Dapur (Kitchen)	11'1"	22'11"	307	Food preparation and dining
P26				
Serambi (Veranda)	7'2"	28'	196	Reception and resting area
Rumah Ibu (Main Hall)	30'5"	16'4"	500	Main living and family area
Rumah Dapur (Kitchen)	14'8"	15'7"	203	Food preparation and dining

4.2 Visual Output

The Matterport 3D scan produced high-resolution imagery suitable for architectural illustration and heritage visualisation. Representative outputs are shown below:

Figure 1: Visual images generated from Matterport scanning for P16 and P25
Source: matterport.com

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Figure 2: Visual images generated from Matterport scanning for P26
Source: matterport.com

4.4 Analytical Outputs

Table 3: The analytical outputs can be obtained from 3D Documentation using Matterport

ANALYTICAL OUTPUT	DESCRIPTION	RESEARCH RELEVANCE
Spatial Zoning Diagram	Visualization of functional zones (public–private–service) based on floor plan.	Understanding spatial hierarchy and gendered use of space.
Orientation Diagram	Mapping of building alignment relative to cardinal directions.	Reveals cultural and environmental adaptation principles.
Material Mapping	Annotated model indicating different timber species and construction joints.	Conservation planning and material study.
Structural Condition Map	Highlighted areas showing deterioration or missing components.	Heritage conservation and restoration assessment.

Table 3 presents the analytical output derived from digital data collected through Matterport technology, which plays a crucial role in enhancing research outcomes. Matterport captures 3D spatial data, allowing for immersive virtual representations of physical spaces. Through its advanced imaging and data processing capabilities, researchers can obtain detailed models that illustrate not only the physical attributes of an environment but also its functional aspects.This data can be analysed in various ways to address specific research questions. For instance, by utilising 3D models, researchers can conduct spatial analyses to understand how design elements within a space influence user behaviour or experiences. The output can reveal patterns of movement, interaction, and occupancy within the environment, providing insights into spatial dynamics that traditional methods may overlook.

Additionally, the ability to annotate and layer data over these 3D models facilitates a multifaceted analysis that integrates qualitative and quantitative insights. Metrics such as dimensions, spatial relationships, and user-generated data can all be visualized within the context of the 3D environment, leading to a deeper understanding of how various elements

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interact within a given space. Furthermore, the immersive nature of Matterport technology enables stakeholders to engage with the data more meaningfully, making the findings accessible and comprehensible to a broader audience. This relevance extends across multiple fields, including architecture, urban planning, and the social sciences, where understanding spatial relationships is integral to developing effective solutions and recommendations. Overall, Matterport's analytical output enhances the research process by providing robust, data-driven insights that facilitate a comprehensive understanding of spatial environments, ultimately contributing to more informed decision-making and design practices.

4. CONCLUSION

The current research underscores the pivotal role of digital documentation, particularly through HBIM, in safeguarding architectural heritage like Rumah Gadang Kajang Padati. This approach not only enhances the accuracy and detail of documentation but also provides a dynamic framework for long-term preservation, allowing for the anticipation of material aging problems and prioritization of sustainable conservation actions (Angulo, 2024). This systematic application of HBIM procedures further demonstrates its practical utility in recording, restoring, and managing even severely damaged or lost wooden architectural heritage sites (Kim et al., 2025). Even with minimal physical remains, sites can be digitally restored by leveraging HBIM and historical reasoning, showcasing its strengths in version tracking and systematic documentation throughout the restoration process (Kim et al., 2025). The detailed digital reconstruction possible with HBIM ensures that every architectural component's dimensions, material attributes, and design basis are systematically cataloged, offering a robust foundation for scholarly analysis and practical conservation (Kim et al., 2025).

Moreover, this comprehensive digital record can incorporate additional information such as metadata, original survey data including laser scan point clouds, orthographic imagery, and surface models, thereby forming a rich, multi-faceted database (Dore & Murphy, 2012). Such integrated digital documentation serves as an invaluable decision support system for cultural heritage management, aiding in effective, systematic preservation efforts (Mustafa et al., 2019). The outcomes of this rigorous process are finalized and presented on robust 3D platforms, allowing for a comparative evaluation across different rendering and interaction environments. This comprehensive digital framework not only facilitates in-depth analysis but also fosters an urban management culture characterised by active participation, transparency, and collective intelligence, thereby enriching the interpretative potential of heritage assets (Clini et al., 2025). These interoperable parametric objects, rich with historical information and external databases, can also serve as gateways to be continually enriched with semantic vocabularies, acting as innovative hubs for accessing digital, tangible heritage artefacts (Brumana et al., 2017). This continuous enrichment is vital for maintaining an up-to-date and comprehensive record of cultural heritage, ensuring its authenticity and integrity are preserved for future generations (Esponda et al., 2017).

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