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Generative AI-Based Form Exploration of Bugis Traditional Architecture: From Vernacular Morphology to Digital Reconstruction

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ABSTRACT
This study investigates how generative artificial intelligence (AI) interprets, reconstructs, and transforms the vernacular morphology of Bugis traditional architecture. Using a qualitative computational mixed-method design, the research combines field documentation of twenty Bugis houses with image-based generative modeling using diffusion frameworks. The results reveal that AI is capable of reproducing prominent morphological attributes including the saddle-shaped roof, elevated stilt structure, symmetrical façade, and longitudinal spatial axis demonstrating its ability to learn visually salient patterns from architectural datasets. However, significant transformations emerge in elevation, materiality, and spatial orientation, driven largely by algorithmic biases toward modernist forms. More critically, symbolic and cosmological elements central to Bugis architectural ontology such as vertical spatial hierarchy, ritual thresholds, and carved motifs are frequently diminished or omitted, indicating AI's limited capacity to interpret intangible cultural meaning. Despite these limitations, AI-generated hybrid forms provide valuable speculative insights into potential vernacular futures, suggesting that generative models can function as creative tools when guided by cultural expertise. The study concludes that generative AI offers meaningful opportunities for visualization and design innovation but must be integrated with culturally informed frameworks to ensure ethical and accurate representation of indigenous architectural heritage.

Keywords: Bugis architecture; generative AI; vernacular morphology; digital heritage; chitectural transformation; diffusion models.

INTRODUCTION

Traditional vernacular architecture represents a dynamic fusion of spatial intelligence, cultural identity, environmental adaptation, and socio-historical memory. In many regions of Indonesia, vernacular forms such as the iconic Bugis traditional houses (bola ugi) serve as repositories of ecological knowledge, symbolic cosmology, and social hierarchy. Scholars emphasize that vernacular architecture is not static; it evolves through continuous negotiation between tradition and adaptation (Rapoport, 2006; Oliver, 2017). Bugis architecture, in particular, is marked by elevated structures, modular wooden systems, and symbolic spatial divisions that reflect indigenous cosmology and social order (Abidin, 2020). As modernization accelerates, however, these traditional forms face threats of disappearance, fragmentation, and loss of cultural integrity.

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In recent decades, the growth of digital technology has shaped new approaches to heritage documentation and architectural preservation. Digital heritage studies increasingly rely on computational tools for 3D scanning, reconstruction, simulation, and immersive visualization (Ferri et al., 2020; Remondino, 2011). Yet while these technologies improve accuracy in capturing existing artifacts, they often struggle to interpret or generate hypothetical transformations of vernacular forms. Scholars argue that advanced computation should not merely archive, but also mediate cultural continuity through creative reinterpretation (Liu & Lim, 2022). This conceptual shift opens space for generative artificial intelligence (AI) to play a transformative role in the study of traditional architecture.

Generative AI has emerged as a powerful tool for architectural visualization, morphological transformation, and cultural documentation (Goodfellow et al., 2014; Ramesh et al., 2022). These models enable the transformation of text, image, and architectural data into new visual outputs, allowing designers and researchers to explore forms that blend tradition and innovation. Recent studies in computational design demonstrate that generative AI can model complex vernacular geometries, simulate environmental adaptations, and produce culturally grounded visual speculations (Hudson & Liu, 2023). Such tools unlock new opportunities to examine Bugis traditional architecture not only as a heritage object, but also as a living system with potential for future-oriented reinterpretation.

At the same time, scholars warn that digitization must be culturally sensitive, as the algorithmic reshaping of indigenous architectural forms risks collapsing symbolic meanings, ethnographic nuance, and cosmological logic (Jones & Silva, 2021). Bugis houses are not merely physical structures they encode spiritual values, kinship patterns, and life-cycle rituals (Pelras, 1996; Rahim, 2019). Therefore, applying generative AI to Bugis vernacular morphology requires a methodological framework that integrates computational experimentation with anthropological understanding. This underscores the importance of grounding AI-based visual transformations in the epistemology of Bugis cultural knowledge.

Despite emerging interest in AI-driven morphological exploration, limited scholarship specifically addresses the intersection of generative AI and indigenous Indonesian architecture. Studies on Javanese, Balinese, or Torajan architecture have explored digital documentation and parametric modeling, but rarely the generative reinterpretation of their traditional forms. In the context of Bugis architecture one of Southeast Asia’s most sophisticated maritime cultures, research gaps remain concerning how AI can synthetically explore morphology while preserving cultural meaning. This gap reveals an urgent need for interdisciplinary research bridging computational design, digital humanities, and vernacular architecture.

This study introduces a generative AI-based framework for the visual and morphological exploration of Bugis traditional houses, emphasizing how digital reconstruction and form transformation can support both preservation and innovation. By integrating image-based datasets, architectural typologies, and generative models, this research aims to produce speculative transformations that maintain cultural logic while expanding design possibilities. The methodological contribution lies in using AI not simply as a representational tool, but as an analytical medium capable of revealing underlying morphological patterns embedded in Bugis vernacular architecture.

Ultimately, this research contributes to broader debates on the future of indigenous architecture in the digital age. As AI increasingly shapes architectural imagination, questions arise regarding agency, authenticity, and cultural continuity. By centering Bugis architecture as a case study, the present work demonstrates how generative AI can foster a more nuanced dialogue between heritage preservation and computational innovation. In doing so, the study

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aligns with global efforts to articulate ethical, culturally grounded, and technologically empowered models for sustaining vernacular knowledge systems (Khalaf et al., 2023). This article thus positions AI-driven design not as a threat to tradition, but as a catalyst for reimagining the role of local wisdom in contemporary architectural futures.

METHOD

This study employed a qualitative computational mixed-method design that integrates vernacular architectural analysis with generative artificial intelligence techniques. Mixed-method frameworks are increasingly used in architectural heritage studies to combine cultural interpretation with digital modeling (Tsilimigras & Remondino, 2022). The overall methodological orientation is exploratory, aiming to understand how Bugis traditional house morphology can be reinterpreted and digitally transformed through AI-generated visual outputs. Similar exploratory computational approaches have been applied in studies of vernacular design and digital reconstruction (Ferri et al., 2020; Liu & Lim, 2022). This sequential design begins with documenting traditional Bugis architectural characteristics, continues with dataset preparation, and ends with the generation and analysis of visual outputs from diffusion-based AI models.

The subjects of this research consist of two interconnected units of analysis: architectural artefacts and digital outputs. The architectural subject refers to Bugis traditional houses (bola ugi) located in South Sulawesi, selected for their authenticity and representativeness of vernacular typologies. Previous ethnographic studies highlight that Bugis houses embody symbolic cosmology, modular craftsmanship, and hierarchical spatiality (Pelras, 1996; Rahim, 2019). A total of twenty houses were documented through photography, sketches, and secondary sources. The digital subject consists of visual artefacts produced by generative AI systems, aligning with contemporary digital heritage studies that treat AI-generated images as computational interpretations rather than literal reconstructions (Hudson & Liu, 2023).

Data collection involved three interconnected procedures: field-based architectural documentation, dataset curation, and computational experimentation. Field documentation followed standard heritage recording methods, including photographic surveys and architectural sketching (Letellier, 2017). Secondary sources such as ethnographic archives and government records were included to strengthen architectural completeness. Dataset curation followed established image preprocessing standards in AI research, including resizing, noise reduction, and metadata labeling (Karras et al., 2020). Computational experimentation was conducted using diffusion-based models (Stable Diffusion and Midjourney), following generative model protocols described by Ramesh et al. (2022). Variations in prompts, parameters, and seeds were systematically recorded to enable interpretive comparison across outputs.

Instrument development was centered not on questionnaires, but on analytical coding instruments for reading architectural morphology. A morphological coding sheet was developed based on vernacular architecture theories (Rapoport, 2006) and categories commonly used in Southeast Asian traditional house studies (Waterson, 2017). The instrument included descriptors related to roof geometry, elevation systems, spatial divisions, façade articulation, and cultural symbols. Two experts—one in Bugis cultural studies and one in vernacular architecture—validated the instrument, following expert-validation procedures recommended in qualitative instrument development (Creswell & Poth, 2018).

Data analysis followed a three-layered interpretive technique. The first layer involved morphological analysis of traditional Bugis houses, identifying essential typological

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characteristics. Such typological reading is consistent with architectural morphology studies (Kronenburg, 2014). The second analytical layer consisted of visual comparison between original images and AI-generated outputs, using an approach similar to computational visual analysis frameworks proposed in cultural-heritage computing (Müller et al., 2021). This comparison evaluated the extent to which generative AI retained, modified, or transformed vernacular elements. The third layer incorporated cultural interpretation by aligning emergent patterns with ethnographic literature on Bugis cosmology, symbolism, and spatial logic (Abidin, 2020; Pelras, 1996). Triangulating architectural, computational, and cultural analyses strengthens the reliability of findings in digital heritage research (Stylianidis & Remondino, 2016).

Ethical considerations were embedded throughout the research process. Digital heritage scholars emphasize the importance of cultural sensitivity when employing AI tools to reinterpret indigenous forms (Jones & Silva, 2021). All photographic documentation was conducted with permission from local homeowners, and AI-generated outputs were reviewed to ensure that no sacred or culturally restricted symbolism was misrepresented. Following ethical guidelines in digital anthropology and heritage visualization, the study treats generative outputs as speculative artefacts rather than authoritative representations (Khalaf et al., 2023).

This method integrates ethnographic grounding, architectural morphology, and generative AI computation to examine the transformation of Bugis traditional architectural forms. This hybrid methodological approach reflects best practices in emerging digital-heritage research, where cultural meaning and computational creativity must be balanced with sensitivity and analytical rigor (Bentkowska-Kafel et al., 2020). Through this combination, the study provides a robust foundation for understanding how AI can support both preservation and creative reinterpretation of vernacular architecture.

RESULT AND DISCUSSION

This section presents the empirical findings of the study, organized into four major sub-findings that reflect the interaction between documented Bugis vernacular morphology and generative AI reinterpretations. Each finding is supported by descriptive statistics, comparative matrices, and qualitative observations. The discussion following each table synthesizes the implications of these patterns for understanding generative AI's interpretive capacity and its cultural limitations.

Result

Consistency of Vernacular Morphology in Bugis Traditional Houses

Field documentation across twenty Bugis houses reveals a high degree of morphological consistency. This reinforces the understanding that Bugis vernacular architecture is governed by stable typological codes that reflect cosmological beliefs, social structure, and environmental strategies.

Table 1. Core Morphological Features Identified in Field Documentation

Morphological Feature	Description	Frequency (n=20)
Elevated stilt structure	2.5–3 m wooden stilts to avoid floods & house spirits	18
Saddle-shaped roof (*boluloang*)	Double-sloped roof with symbolic significance	17
Symmetrical façade	Central staircase, paired windows, balanced massing	19
Longitudinal spatial axis	Oriented front–back according to kinship function	16
Modular joinery	Wooden interlocking joints, no metal fasteners	20

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The consistency in these features demonstrates the robustness of Bugis vernacular logic and aligns with ethnographic studies describing Bugis houses as cosmological and socio-spatial texts (Pelras, 1996; Waterson, 2017).

Generative AI Output Categories and Transformation Tendencies

A total of 260 AI-generated images were analyzed. Outputs were grouped into three dominant categories that reflect different extents of morphological preservation and reinterpretation.

Table 2. Categories of AI-Generated Architectural Transformations

Output Category	**Defining Characteristics**	**Proportion of Outputs**
Vernacular Preservation	High fidelity to original roof, elevation, and façade	38%
Hybrid Transformations	Mix of Bugis traits with modern minimalism, glass, steel	42%
Symbolic Abstractions	Stylized silhouettes, exaggerated motifs, speculative forms	20%

The predominance of hybrid outputs suggests that generative AI tends to merge traditional cues with contemporary global aesthetics rather than strictly reproduce vernacular forms.

Comparative Morphological Shifts Between Real and AI-Generated Forms

A detailed comparison was conducted using a morphology matrix to evaluate which architectural elements were preserved and which were altered by AI.

Table 3. Morphology Matrix: Field Data vs. AI Interpretations

Architectural Element	**Human Documented Morphology**	**AI-Generated Interpretation**	**Degree of Transformation**
Roof form	85% saddle	72% saddle; 28% experimental forms	Medium
Elevation	90% elevated	65% elevated; 35% ground/floating	High
Façade symmetry	95% symmetric	81% symmetric	Low
Materiality	100% wood	64% wood; 36% glass/steel	High
Spatial orientation	80% longitudinal	59% longitudinal; 41% lateral	Medium

The most significant transformations occurred in elevation and materiality. AI frequently replaced wooden materials with glass or steel, suggesting an algorithmic bias toward modern architectural tropes.

Retention and Distortion of Cultural Symbolism

While structural aspects were often preserved, symbolic and cosmological features of Bugis architecture were inconsistently captured. Key losses included hierarchical vertical cosmology (*rakkeang*, *kale bola*, *awa bola*), ritualized placement of stairs and thresholds, carved motifs expressing ancestry and maritime identity, encoded spatial gender and kinship roles.

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Table 4. Symbolic Retention Across AI Outputs

Symbolic Element	Presence in Field Data	Presence in AI Outputs	Interpretation
Vertical cosmology	Strong	Weak	AI overlooks metaphysical hierarchy
Carved wooden motifs	Frequent	Rare	AI prioritizes surface geometry
Ritual spatial coding	Strong	Minimal	Symbolic functions unrecognized
Maritime symbols	Moderate	Rare	Cultural identity underrepresented

These distortions point to the challenge AI faces when interpreting intangible cultural knowledge that is not visually explicit in the training data.

Discussion

The results collectively demonstrate a dynamic but uneven relationship between Bugis vernacular morphology and AI-generated reinterpretations. The high consistency of field-documented features affirms that Bugis architecture operates within a rigorous cultural and structural framework, supporting longstanding theories of Southeast Asian vernacular stability (Rapoport, 2006; Waterson, 2017). However, the generative AI outputs reveal that while the models can learn and reproduce visually salient features such as roof shapes and façade symmetry—they struggle to capture the deeper layers of meaning embedded in spatial organization and symbolic ornamentation.

The tendency toward hybridization in AI outputs highlights the model's inclination to merge traditional traits with contemporary globalized architectural aesthetics. This phenomenon has also been observed in AI-mediated reconstructions of Balinese and Khmer heritage, where the algorithm selectively emphasizes modern materials and clean geometries (Müller et al., 2021; Widodo, 2021). Such patterns suggest that the visual biases present in the AI training corpus particularly the prevalence of modernist imagery on the internet—shape the model's generative tendencies, overshadowing the culturally grounded vernacular logic of the Bugis architectural tradition.

The distortion of symbolic and cosmological elements is more troubling from a cultural heritage perspective. As noted by Jones and Silva (2021), generative AI often "flattens" indigenous symbolic systems because it interprets cultural objects primarily through surface features rather than embedded meaning. In the case of Bugis architecture, this resulted in the loss of spatial metaphysics and ritual hierarchy—elements that define the cultural ontology of the built form (Rahim, 2019; Pelras, 1996). This underscores the epistemological limitation of AI: it can reproduce visual morphology but cannot infer symbolic structure unless explicitly trained with culturally annotated data.

Despite these limitations, the hybrid forms produced by AI offer intriguing potential for design innovation. The speculative reimagining of Bugis forms—such as elevated structures combined with steel frames or parametric reinterpretations of saddle roofs—demonstrates the generative model's capacity to function as a creative catalyst. This aligns with emerging literature arguing that AI can serve as a partner in architectural exploration, enabling designers to test new vernacular futures without erasing historical identity (Hudson & Liu, 2023; Liu & Lim, 2022).

Ethical implications must also be considered. As Khalaf et al. (2023) caution, AI-driven heritage reconstruction should involve human cultural experts to contextualize and critique algorithmic outputs. Without such guidance, AI-generated reinterpretations risk

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producing culturally inaccurate or misleading representations that could shape public perception in problematic ways. Thus, while AI can enrich architectural imagination, it must be deployed within frameworks that respect cultural integrity and prioritize indigenous epistemologies.

Overall, the integrated results and discussion reveal that generative AI possesses substantial capability in recognizing and reproducing key morphological patterns of Bugis vernacular architecture. However, it remains limited in encoding culturally embedded symbolism and is prone to introducing modernist biases. The study highlights both the opportunities and risks of using AI as a tool for heritage interpretation, reinforcing the need for interdisciplinary collaboration between technologists, architects, and cultural scholars.

CONCLUSION

This study shows that generative AI can effectively reproduce and reinterpret the morphological features of Bugis traditional architecture, yet it remains limited in recognizing the cultural logic and symbolic meanings embedded in vernacular forms. While AI consistently captured visually prominent elements—such as the saddle-shaped roof, elevated structure, and symmetrical facade, it frequently introduced modern materials and global design aesthetics, resulting in hybridized outputs shaped by algorithmic biases. More critically, AI struggled to retain symbolic components central to Bugis cosmology and cultural identity, including ritual spatial hierarchies and carved motifs. This reveals a fundamental limitation: AI can model surface morphology but cannot fully encode intangible cultural knowledge. Despite these gaps, AI-generated hybrids demonstrate potential for design innovation, offering new ways to explore future vernacular forms when guided by cultural expertise. The findings highlight the importance of human–AI collaboration and culturally informed datasets to ensure ethical and accurate heritage interpretation. In sum, generative AI is a powerful tool for visualizing and speculating upon Bugis architectural futures, but cultural meaning-making must remain anchored in human expertise.

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