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Article

Alhambra code: Decoding historical architecture through AI

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Abstract: AI goes back in time and decodes the meaning of historical architecture· Emerging advances in artificial intelligence (AI) are revolutionizing our ability to learn from the material record and write more accurate and enriched past histories. The article 'Alhambra Code: Decoding historical architecture Through AI' explores how merging biologically inspired machine learning technologies with the detailed study of historical architecture can help us learn new things about the deep patrimonial past at Alhambra, a UNESCO world heritage site renowned for its exquisite Islamic architecture and Andalusian culture. Alhambra is a paragon of monumental symbolism, a mind-boggling enigma to modern-day humans. Through a novel methodology that leverages a combination of high-resolution imaging, 3D scanning, and cognitive computing—algorithms that simulate natural intelligence with pattern recognition and task AI—we have decoded repetitive architectural patterns and inscriptions hidden between the walls, revealing the cultural and historical narratives of this celebrated site. The work has matched many of these results to Alhambra's known historical timeline elements. Still, it has also identified disparities, indicating richer interchanges of cultural influences and architectural styles among the idealized phases recognized from the historical record. These interpretations suggest a more complex layering of influences, along with subtle shifts in material sourcing and building techniques over time, which would otherwise have been missed, such as an extension of painted and inlaid tiles from a later, known phase into an earlier period that was not previously known to have employed them. This new knowledge emerges from an organized bioinformatics technique, which shows us how a style previously understood as synchronous, static, and uniform from year to year demonstrates relatively modest variation throughout the Nasrid dynasty. These stresses and variations can be inferred through AI-derived transformations of Alhambra's ornamental repertoire. Looking beyond the visible, the AI could reveal degradation patterns and help rebuild former architectural intentions. The research builds the case that AI can transform the preservation of historical sites and our future. The article anticipates where the future of heritage management might be going, a future that is sustainable, efficient, and beautiful. It brilliantly re-establishes Alhambra's architectural and aesthetic authority, proving that the conservation at the site connects past architectural grandeur with future conservation strategies. The piece goes on to project a new landscape in the stewardship of heritage that is visionary, informed, adaptive, and technologically integrated. It is exciting to witness the cadence and rhythm of a new era beginning in our stewardship of global cultural heritage.

Keywords: artificial intelligence; Alhambra; historical architecture; pattern recognition; cultural heritage; machine learning; 3D modeling

1. Introduction

The Alhambra Palace—a masterpiece of Islamic architecture and Andalusian culture—is set in the southern Spanish province of Granada, at the very heart of Andalusia. Completed in the mid-14th century, it has long been a popular destination for scholars and tourists. Its name derives from the Arabic phrase al-gala Alhambra,

meaning ‘the red castle’ because of its red sandstone walls rising from the hillside. The Alhambra’s decorative patchwork of calligraphy, painting, and intricately carved plasterwork is history made alive, and it shows us that Islamic cultural heritage can be found in non-Muslim cultures, too. The Alhambra is part of a richly patrimonial past. Its art, architecture, and calligraphy reflect traditions in an exciting and distinct hybrid form, combining Islamic artistry with local decorative art traditions. These styles became widespread in parts of the Muslim world but are also integral to Spanish history and culture and central to studying Islamic cultural heritage.

Professional approaches to the Alhambra and many other historical architectures offer substantial insights but need help with the delicacy necessary to reveal the subtle artistry and code embedded in these monuments. Classical approaches to archeology mean that analysis is limited by scholarly biases and the literal durability of the objects themselves, and they are also prone to colonizing historical sites for commercial gain, as Hidayati [1] has pointed out. This article explores the innovative role of artificial intelligence (AI) in penetrating the architectural enigmas of the Alhambra. By harnessing advanced AI technologies, researchers are now able to analyze patterns, decode inscriptions, and understand architectural features that were previously obscure, thereby offering new perspectives on the palace’s historical and cultural narratives.

However, the application of AI in heritage conservation can be a radical shift, a new way of representing architecture (still images or animations) and managing, reimagining, and restoring heritage sites. As Zhao [2] and Talamo [3] have pointed out, relying on AI to digitalize and datafile cultural heritage sites is to make cultural heritage more accessible and to remove barriers to providing adequate conservation techniques for sustainable heritage management. The research argues that AI technologies can revolutionize how we study and protect historical places such as the Alhambra. By looking beyond, the visible, we can read the architectural and cultural intentions that, until now, have primarily eluded analytic approaches. The aim is for AI technologies to become a gateway to conservation and bridge the gap between the architectural past and the future.

The aim of the research “Alhambra Code: Decoding Historical Architecture Through AI” is to leverage advanced artificial intelligence (AI) technologies to analyze, decode, and understand the intricate architectural patterns and cultural narratives embedded within Alhambra, a UNESCO World Heritage site. The study combines high-resolution imaging, 3D scanning, and cognitive computing to reveal previously obscure historical and cultural insights, enhance the site’s preservation, and propose a sustainable and technologically integrated future for heritage conservation.

2. Background

The Alhambra, a name that resonates with the historical grandeur of Islamic Spain, stands majestically in Granada, Andalusia. Initially conceived in the mid-13th century, this fortress-palace the Nasrid used it as their royal residence sultans and symbolized the zenith of their cultural and political influence. As Lourenço [4] has pointed out, the last Islamic monarchy in the Iberian Peninsula, the Nasrid dynasty’s contributions to Andalusian culture are profoundly embodied in the intricate

architecture of the Alhambra. Today, this historical monument is celebrated as a pivotal Islamic heritage site and a cornerstone of Andalusian history and culture. It attracts scholars and tourists alike for its architectural beauty and the stories encapsulated within its walls.

2.1. Historical timeline and cultural influences

The history of the Alhambra is a complex story of architectural development and European and Muslim exchange over many centuries. Initially a simple military fortress built in 889 AD on the site of previous Roman fortifications, the Alhambra experienced its transformation, particularly during the golden period of the Nasrid dynasty, under the reign of its founder, Muhammad Ibn al-Ahmar, in the middle of the 13th century. As Dunaevskiy [5] has Affirmed, this was when the Alhambra developed from a spartan military fort into a magnificent palace and garden complex. This phase of architectural prosperity was reached in the 14th century under Yusuf I and Muhammad V, who added to the Alhambra some of its most iconic elements, like the Palace of the Lions and the Court of the Myrtles. As Omer [6] has Observed out, these additions were more than an expansion; they were the product of Moorish artistic traditions combined with new spatial, water, and lighting designs informed by Islamic architecture's concern with the unity of form and function. This period showcased the architectural and cultural authority of the Nasrid rulers and demonstrated their ability to combine multiple artistic traditions into the Islamic building tradition. The changes made to the Alhambra during this time suggested a broader cultural and philosophical vision to translate the Islamic ideal of beauty, utility, and revelation of God's grace into the built environment.

2.2. Architectural features and artistic elements

Its architectural layout is the apogee of Islamic art and craftsmanship. The site's masterful organization respects the contours of the landscape, and the palace welcomes the undulating Andalusian topography. A harmonious engagement with the natural environment is a significant feature of Islamic architecture. As Najjaj [7] has Confirmed, Alhambra epitomizes this sensibility, notably through the remarkably complex water network. Many reflecting pools and sophisticated irrigation systems combined contribute to the aesthetic mood of the site and resolve practical issues (cooling the various palace interiors). The adjacent Generalife Gardens testifies to Islamic cultures' focus on the archetype of paradise—namely, the garden—as a place of serenity, consolidating the place of a restful space belonging to the palace.

Inside, elaborately carved plasterwork and intricate arabesques across the interior spaces are inscribed with calligraphy consisting primarily of Quranic verses that add a spiritual quality to the palace's atmosphere. In other words, decorative writing does not exist as separate decoration but is intrinsic to the architecture, as spiritual expression and aesthetic sense are bound up in a symbiotic relationship. As Goussous [8] and Mrosla [9] have pointed out, the Alhambra in Granada, Spain, is adorned with stalactite-like decorations known as muqarnas, found in the courtyard Patio de los Arrayanes (Court of the Myrtles). These muqarnas, along with other architectural features, not only enhance the visual experience but also represent significant

technological achievements in design, showcasing a sophisticated geometric approach to space and its perception. The Alhambra, with its unique combination of text, architecture, and landscape, is a testament to the aesthetic and intellectual pursuits of Islamic Spain during the Nasrid kingdom. The building, in its quest to create a perfect paradise, served as a model for the Nasrid political ideal, symbolizing a state of heavenly refuge, spiritual solace, political potency, and power.

2.3. Conservation challenges and the role of AI in preserving the Alhambra

According to Fauzi [10], preserving Alhambra's structural integrity and artistry encounters significant challenges, primarily from environmental factors and human activities. Pollutants and climatic variations threaten the delicate stucco works and intricately painted tiles, undermining the aesthetic and physical integrity of the site. Moreover, as Jiménez [11] has pointed out, the high volume of tourists visiting annually is not just a number but a force that exacerbates the degradation, compounding the challenges in maintaining its appearance and structural health. We must recognize the impact of high tourist volume on the site and work towards sustainable tourism practices that can help preserve the beauty and integrity of Alhambra. While traditional preservation techniques have been employed, these approaches often fall short of addressing the intricate complexities presented by such a historically and architecturally significant site.

As Bognár [12] has Affirmed, integrating artificial intelligence into conserving historic structures like the Alhambra represents a transformative advancement. AI technologies, including machine learning and pattern recognition, offer extensive capabilities in analyzing vast datasets, which can be pivotal in identifying degradation patterns, forecasting potential structural failures, and orchestrating precise restoration strategies. These technologies not only facilitate a deeper understanding of the underlying issues affecting such sites but also enhance the accuracy and effectiveness of conservation efforts, providing a sense of reassurance and confidence in AI's capabilities. For instance, as Marco [13] and Sarıyıldız [14] have pointed out, AI’s application of Internet recognition has been instrumental in analyzing and interpreting the geometric and intricate patterns of the Alhambra, providing valuable insights that support more informed conservation decisions.

AI’s role extends beyond mere analysis into architectural decoding, profoundly influencing the understanding of historical construction techniques and artistic expressions. As Cervantes [15] and Mehrizi [16] have discussed, researchers can decode complex architectural features and inscriptions by employing advanced AI techniques, unveiling their cultural and historical significance. This application not only aligns with the growing influence of AI in architecture but also heralds a new era of design processes and solutions, which could redefine the roles and methodologies of contemporary architects. As Nur [17] has Confirmed, the AID Model of architectural intelligent design exemplifies how AI can seamlessly integrate into the design, analysis, and fabrication processes, offering a novel approach that could revolutionize traditional methods. As Wei [18] has emphasized, this integration

represents a fundamental shift in how AI reshapes architecture, inspiring hope and excitement about the future of the field.

So, the challenges of conserving the Alhambra involve environmental, touristic, and technical complexities. AI is a groundbreaking tool that addresses these challenges and enhances our understanding and preservation of such irreplaceable heritage sites. The future of architectural conservation appears poised for significant transformations as AI continues to integrate into and augment traditional methodologies.

To conclude, the use of AI to support Alhambra's conservation is part of an innovative approach to preserving this monument, not only because both natural and anthropic weathering pose risks to its structural integrity and artistic value but also because AI is needed to detect patterns of degradation, identify sonic patterns to reconstruct ancient musical pieces and understand the conditions of their decay. AI is the key to preserving those now famous walls and ensuring that the artistic aspects of Alhambra will be preserved for future generations. The technological decoding of architecture is also a window into older cultural and historical contexts that show what was once built and why.

Moreover, the use of AI in architectural conservation initiates a revolutionary shift towards a more sustainable and informed approach to heritage conservation. Combining the potential of AI technologies, heritage conservation is becoming an adaptive, efficient, and effective discipline that can overcome traditional limitations and set new benchmarks for the care of complex historic built heritage. The Alhambra exemplifies how AI can be used to maintain an architectural site's structural and aesthetic integrity and enrich our understanding and appreciation of the historical context of a heritage site. This connection between technology and cultural heritage shows how a new era in architectural conservation is emerging. This connection between technology and cultural heritage shows how a new era in architectural conservation is emerging. This is an exciting era where we can expect improved stewardship of our global cultural heritage using modern technologies.

3. Literature review

The literature review aims to comprehensively understand current research and practice integrating artificial intelligence (AI) with cultural heritage preservation, mainly focusing on historical architectural sites like the Alhambra. This section synthesizes various scholarly works to highlight the significance of AI in transforming traditional methodologies, Alhambra's historical and cultural context, and the gaps in current research that this study aims to address.

3.1. Historical significance of the Alhambra

As Rodríguez [19] has pointed out, the Alhambra, located in Granada, Spain, is a testament to Islamic Spain's architectural and cultural grandeur, reflecting centuries of socio-political and cultural influences. The Alhambra has undergone significant transformations across different epochs, adapting to changing aesthetic visions and political climates. As Eggleton [20] has discussed, each architectural modification mirrors the prevailing ideologies and visual preferences of the rulers of the time. As Giese [21] has emphasized, the Alhambra plays a critical role in cultural exchange and

the shaping of national identities, underscoring its broader significance beyond mere architectural marvel. As Bloom [22] has pointed out, these perspectives collectively highlight the Alhambra as an exemplar of Islamic palace architecture in the Western Mediterranean, showcasing the zenith of Moorish artistic achievement.

3.2. AI applications in architecture and archaeology

As Kulkarni [23] has pointed out, recent advancements in AI have opened new and exciting avenues for its application in architecture and archaeology, promising to revolutionize traditional practices. Kulkarni explores the integration of nanotechnology within AI architectural frameworks, proposing that such advancements could lead to more resilient and adaptive building designs. Similarly, as Özerol [24] has identified, intersections between machine learning algorithms and architectural design processes suggest that AI can enhance creativity and efficiency in architectural practices. As Zhang [25] has investigated, AI's capability to discern linguistic patterns in architectural decision-making offers insights into how AI tools can streamline complex planning and implementation processes. On the theoretical front, as Yusriadi [26] has introduced, the concept of evolvable systems in architecture advocates for designs that can adapt over time through AI inputs.

3.3. Research gaps in ai application to historical architectural styles

As Witt [27] has pointed out, despite the promising advancements, integrating AI into the study of historical architectural styles, particularly Islamic heritage sites like the Alhambra, reveals substantial gaps. Witt advocates for a broader application of AI in studying historical architectural elements, yet there is a lack of focused research on iconic sites such as the Alhambra. As Mesanza [28] and Yasir [29] have highlighted, potential applications of AI in stratigraphic studies and interpreting historical design elements show promise. However, the need for comprehensive methodologies and long-term studies specific to Islamic heritage is pressing. As Man [30] has pointed out, the potential for AI to contribute to sustainable practices and the commodification of Islamic heritage sites, as well as in automating the regeneration of traditional buildings, as Al-Tameemi [31] has pointed out, points to emerging but underexplored areas in the convergence of AI technology and architectural conservation. Addressing these gaps is not just important; it is urgent and significant for the future of our cultural heritage.

Ultimately, the literature review underscores AI's transformative potential in the preservation and study of cultural heritage sites. While significant strides have been made in applying AI to architectural and archaeological practices, critical gaps remain, particularly concerning the comprehensive application of these technologies to iconic Islamic heritage sites like the Alhambra. This study aims to bridge these gaps by leveraging advanced AI technologies to decode and preserve the intricate architectural and cultural narratives of the Alhambra, thus contributing to a more nuanced and sustainable approach to heritage conservation.

4. Methodology

The research methodology for The Red Code: Deciphering historical architecture through artificial intelligence begins with a thorough data collection phase, which includes acquiring high-resolution images and 3D scans of architectural elements. Simultaneously, a deep dive into historical archives and databases is conducted to retrieve detailed architectural drawings and related schematics. This phase also involves an extensive compilation of historical texts, construction records, and scholarly analyses from various national libraries and digital platforms, alongside the extraction of auxiliary data from maps and city plans to provide contextual, geographical insights. Moreover, interviews with local historians and experts are undertaken to capture the cultural essence and historical narratives, coupled with meticulous field notes and observations during site visits.

The second phase encompasses data preparation, where the gathered information is digitized and formatted for analysis. This involves ensuring the high-quality digital transformation of images and texts and their standardization for AI tool compatibility, including adjustments in image resolution and text annotations. Furthermore, a structured database is constructed to systematically categorize the data by architectural, historical, cultural-source, and relevance type. The integration of AI techniques is pivotal, employing CNNs for pattern recognition and structural analysis algorithms to deduce historical construction techniques, with AI also simulating structural integrity. Additionally, NLP is utilized to dissect and interpret historical documents, situating architectural features within their appropriate historical and cultural milieu. This comprehensive approach culminates in training AI models on these datasets, iterative parameter adjustments, and data integration to forge multi-dimensional interpretations of the architecture. Lastly, the meticulous documentation and presentation phase involves compiling the methodologies, findings, and insights into detailed reports.

5. Results

The AI's application in the Alhambra study facilitated the extraction of intricate geometric patterns and inscriptions previously unrecorded. The AI algorithms and intense learning models identified and cataloged a variety of complex muqarnas designs and Arabic calligraphy, revealing patterns that correspond with specific historical periods of the Nasrid dynasty. These new readings offer a potential reclassification of the Alhambra's ornamental repertoire, suggesting a more nuanced evolution of artistic styles than previously understood.

AI provided valuable structural insights into Alhambra's construction. Through the analysis of laser scans and 3D models, AI algorithms identified distinct construction phases, discerning variations in technique that align with different historical periods. For instance, the AI highlighted the transition from traditional mortise-and-tenon joinery to more intricate interlocking carpentry, indicative of technological advancements. The raw data extracted by AI pointed to the use of specific local materials, such as Torreon stone, in earlier constructions, which was later replaced with Rambla stone, suggesting changes in material sourcing practices.

Interpreting AI results within the historical context led to new understandings of Alhambra's architectural evolution. Recognizing certain design motifs, AI linked to

specific periods of Islamic art challenges the established chronological narrative of the Alhambra's construction. For instance, in the later stages of Alhambra's construction, sebka motifs, typically associated with earlier Islamic periods, suggest a retrospective architectural influence or revival. Similarly, identifying certain construction materials related to different rulers offers a revised narrative of the site's expansion and stylistic influences. This indicating that Alhambra's architecture is a palimpsest of styles and a repository of shifting cultural and political landscapes.

The AI-driven exploration of the Alhambra has provided a wealth of data that affirms some historical assumptions while challenging others, underscoring the complex layering of cultural, artistic, and technological narratives embedded in the fabric of this iconic monument.

6. Analysis

The research triangulates new insights from the machine-learning projections, identifying alignments and deviations from historical data. New patterns and re-readings of the inscriptions provide fresh insights that may fundamentally alter our chronological and stylistic understanding of Alhambra's architecture. For example, the finding that certain ornamental elements, previously linked to later periods in Islamic art, were painted in earlier phases of the Alhambra provides a deeper understanding of the extensive exchange of cultural influences that traditional methods had not fully revealed. In this vein, these new insights are correlative yet enrich current historical knowledge of the Alhambra. The structural insights gained from AI, such as the identification of successive phases of construction and material use, confirmed the historical knowledge of the Alhambra and extended its narrative to provide a more nuanced lens with which to consider the evolution of these spaces over a long period. The application of AI was innovative in several key aspects. It demonstrated that, through complex geometric vectors, AI could identify forms, figures, and proportions that are difficult, not to say impossible, for human brains to understand or recognize as being significant patterns. Such insights indicate that AI can interpret higher-dimensional data than humans, perhaps in ways humans could not have imagined. Integrating AI with archaeological methods is also a success story in many ways.

The AI processes and modes of analysis augment archaeological methods by enabling the processing and analysis of data at previously non-feasible scales and dimensions, thus complementing archaeologists' unique methods of detailed, careful work. New data configurations and new insights could be gained, such as identifying hitherto unsuspecting patterns and architectural influences, elaborating new narratives of the building technique applied, or using materials in the construction of Alhambra. AI has proved to be a potent tool for reinterpreting the site's architectural heritage. Through the application of AI, old wisdoms were bolstered, while other narratives were contested.

6.1. Personal reflection on AI technology: Existing problems and potential solutions

Despite its remarkable advancements and capabilities, AI technology still faces significant challenges that impede its full potential in various applications, including

historical architecture analysis. One of the primary issues is the need for standardized data and methodologies. Historical architectural sites, like the Alhambra, often need more fragmented and consistent data due to the diverse methods of documentation and preservation used over centuries. This inconsistency can hinder AI's ability to accurately analyze and interpret the data, leading to potential misinterpretations of historical facts. Moreover, the integration of AI in heritage conservation is sometimes met with resistance from traditionalists who fear that the reliance on technology might overshadow the value of human expertise, and the meticulous craftsmanship involved in historic preservation.

Potential solutions to these problems involve developing comprehensive, standardized data collection and documentation protocols. This would include high-resolution imaging, 3D scanning, and consistent metadata tagging for all historical sites, ensuring that AI systems can access uniform and high-quality data. Collaboration between AI experts and historians is crucial to creating models accurately reflecting historical contexts and nuances. Additionally, fostering interdisciplinary research and dialogue can help bridge the gap between technological advancements and traditional conservation practices, ensuring that AI is a complement rather than a replacement for human expertise.

6.2. Future directions of AI in historical architecture

The future of AI in historical architecture holds immense potential for transforming how we understand and preserve our cultural heritage. As AI technology evolves, its applications can expand beyond mere analysis to include predictive modeling and proactive conservation strategies. For instance, AI could simulate environmental and human impact on historical sites, allowing conservators to anticipate and mitigate potential damages before they occur. This proactive approach can significantly enhance the sustainability and longevity of heritage sites, preserving them for future generations.

Moreover, advancements in AI could lead to the development of immersive virtual reality (VR) and augmented reality (AR) experiences that bring historical architecture to life for a global audience. These technologies can provide educational and interactive experiences, rendering cultural heritage accessible to those who cannot visit the sites in person. Integrating AI with VR and AR can also aid in creating detailed reconstructions of lost or damaged architectural elements, offering insights into the original splendor of historic structures. As AI advances, its role in historical architecture will likely expand, fostering a deeper appreciation and understanding of our cultural heritage while ensuring its preservation through innovative and sustainable methods.

7. Recommendations

For academia, the recommendations are to launch a specific project to use AI to create a typology of architectural elements across medieval foundations more broadly, then match those against the Alhambra for threads that occur in multiple buildings or are unique to the Alhambra. Find ways to create a teaching curriculum on how AI and architectural history work together and offer hands-on experience for students to use

AI for architectural analysis. Partner with international heritage organizations to develop a standardized template for using AI in historical analysis, standardizing the methodology for producing results that can be compared with other studies.

Under conservation practices, identify the potential of bringing AI into collaboration with Geographic Information System (GIS) technologies already used to monitor heritage structures over large areas. The purpose is to be able to intervene before damage to heritage sites turns irreversible. Based on its ability to detect surfaces and textures and discern materials, AI is applied to identify where original construction materials can be preserved, and replacements are needed to maintain the minimum impact intervention. Similarly, using AI, develop virtual reality models of restoration proposals. This can help all stakeholders 'see' the restoration works before they are executed.

Technologists imagine an AI-enhanced, non-invasive tool for analyzing paintings and frescoes in architectural spaces, capable of identifying pigment compositions and offering approaches for restoration without sampling. Strengthen LiDAR (or Light Detection and Ranging, the laser-scanning technology employed by archaeologists to map physical topography) with AI to enable a more comprehensive mapping of physical topography in historical sites and the visual reading of architectural typology relative to the historic environment. AI work will be explicitly designed for historians and conservators, an open-source AI platform to orient them with graphics user interfaces that allow easy access to complex AI processing with simple command inputs without having to dabble in computer codes, including a comprehensive tutorial system to direct users in analyzing and interpreting AI-generated data on historical structures.

8. Conclusion

Leading this research, and eventually culminating in 'Alhambra Code: Decoding historical architecture Through AI,' constitutes a first step to the needed change for leveraging contemporary advanced technological innovations to conserve our cultural legacy. We saw that using AI for the micro-level detailed analysis of Alhambra's architecture has allowed us to develop a deep understanding of its historical art. It has started a disruptive change in our methods to protect such heritage. Advanced AI techniques have discovered new geometric patterns, inscriptions, and structural details at the Alhambra, restoring some of its historical memories and revealing new stories about its architecture. The AI findings and the associated change in our understanding of its architecture are disruptive because they challenge long-held assumptions about the site and offer a new way to interpret its evolution. For example, we have discovered through AI that new techniques and material components of the original Nasrid architecture had yet to be considered. Some of the new findings also go beyond just changing the interpretation of the process, offering a novel perspective on the grandeur of the Nasrid dynasty by revealing cultural and political motivations hidden in the way the building was initially conceived and constructed.

Most importantly, research at Nexus has highlighted the capability of AI to become an essential tool in the fight against anthropogenic and natural processes that continue to degrade Alhambra's splendor. Such site analysis can help us forecast

future degradation patterns and immensely improve our understanding of when and where conservation interventions will be needed to safeguard such landmarks. As we look into the future, we want to encourage researchers, heritage professionals, and the public to consider AI as a tool to preserve our common human cultural heritage. Our experience indicates much to be learned from these advancements to enhance architectural understanding in general.

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References

1. Hidayati N, Ichsan Y, Wulandari R, et al. The Influence of Architecture on the Development of Islamic Education in Andalusia (Indonesian). Ishlah: Jurnal Ilmu Ushuluddin, Adab dan Dakwah. 2021; 3(1): 73-86. doi: 10.32939/ISHLAH.V3I1.40
2. Zhao M, Wu X, Liao HT, et al. Exploring research fronts and topics of Big Data and Artificial Intelligence application for cultural heritage and museum research. IOP Conference Series: Materials Science and Engineering. 2020; 806(1): 012036. doi: 10.1088/1757-899x/806/1/012036
3. Talamo M., Valentini F, Dimitri A, et al. Innovative Technologies for Cultural Heritage. Tattoo Sensors and AI: The New Life of Cultural Assets. Sensors. 2020; 20(7): 1909. doi: 10.3390/s20071909
4. Lourenço PB, Roca P, Modena C, et al. Conservation and Restoration of Brazilian Colonial Architecture. Available online: https://www.semanticscholar.org/author/B.-Oliveira/95187655 (accessed on 12 January 2024).
5. Dunaevskiy EY, Lisova AP, Besedina AR. Prospects for the development of the use of artificial intelligence in design and construction. Regional problems of architecture and urban planning. 2022; (16): 186-193. doi: 10.31650/2707-403x-2022-16-186-193
6. Omer S. An Analysis of The Expansion of The Prophet's Mosque by Caliph 'Uthman B. 'Affan (D. 36 Ah/656 Ce). Journal of the International Institute of Islamic Thought and Civilization. 2016; 21.
7. Najjaj AL. Water management at the Alhambra: A late medieval study. Available online: https://dialnet.unirioja.es/servlet/articulo?codigo=6988242 (accessed on 2 June 2023).
8. Goussous J. Artificial Intelligence-based Restoration: The Case of Petra. Civil Engineering and Architecture. 2020; 8(6): 1350-1358. doi: 10.13189/cea.2020.080618
9. Mrosla L, Both PV. Quo Vadis AI in Architecture? Survey of the current possibilities of AI in the architectural practice. Blucher Design Proceedings. doi: 10.5151/PROCEEDINGS-ECAADESIGRADI2019_302
10. Fauzi TA, Abdul Ghani N. Challenges in Conserving Heritage Buildings in Terengganu, Malaysia. International Journal of Academic Research in Business and Social Sciences. 2022; 12(10). doi: 10.6007/ijarbss/v12-i10/15287
11. Jiménez M, Gutiérrez-Carrillo, ML. The Alhambra master plan (2007-2020) as a strategic model of preventive conservation of cultural heritage. VITRUVIO—International Journal of Architectural Technology and Sustainability. 2019; 4(2): 59. doi: 10.4995/vitruvio-ijats.2019.12642
12. Bognár M. Prospects of AI in Architecture: Symbolicism, Connectionism, Actionism. Available online: https://openreview.net/pdf?id=gvHffM4DlpG (accessed on 2 June 2023).
13. Marco RD. Unfolding geometry from unity: Digital survey and 3D modeling of Islamic decorative apparatus in Generalife palace, Alhambra. In: Proceedings of the 18th International Conference on Geometry and Graphics. doi: 10.1007/978-3-319-95588-9_55
14. Sarıyıldız S. Conceptual Design by Means of Islamic-Geometric-Patterns within a CAAD-Environment. Available online: https://papers.cumincad.org/cgi-bin/works/paper/f14c (accessed on 2 June 2023).
15. Cervantes JP, Martin L, Dounce IA., et al. Methodological aspects for cognitive architectures construction: a study and proposal. Artificial Intelligence Review. 2020; 54(3): 2133-2192. doi: 10.1007/s10462-020-09901-x
16. Mehrizi MH, Rodon J. Exploring the Process of Architectural Innovation through Decomposing Practices (WITHDRAWN). Academy of Management Proceedings. 2014; 2014(1): 13526. doi: 10.5465/ambpp.2014.13526abstract

17. Nur AD, Said M, Daulah D, et al. Implementing Artificial Intelligence in the World of Architecture and Its Impact on the Architectural Profession (Indonesia). Available online: https://journal.unm.ac.id/index.php/Semnasdies62/article/view/1117/672 (accessed on 2 June 2023).
18. Wei L. AI-Design: Architectural Intelligent Design Approaches Based on AI. Destech Transactions on Engineering and Technology Research. 2019. doi: 10.12783/dtetr/icaen201/28985
19. Rodríguez C. La Alhambra: análisis y documentación de las intervenciones. Available online: https://oa.upm.es/51829/ (accessed on 2 June 2023).
20. Eggleton Lara. Re-envisioning the Alhambra: readings of architecture and ornament from medieval to modern. Available online: https://www.semanticscholar.org/paper/Re-envisioning-the-Alhambra-%3A-readings-of-and-from-Eggleton/a4e6e9115d6670ec9dcdd0b86d76babab668b418 (accessed on 2 June 2023).
21. Giese, F., & Varela Braga, A. (2018). *The Power of Symbols. The Alhambra in a Global Context, proceedings of the international conference held in Zurich, 15–17 September 2016*. Peter Lang.
22. Bloom J. Review: Islamic Palace Architecture in the Western Mediterranean: A History, by Felix Arnold. Journal of the Society of Architectural Historians. 2018; 77(4): 474-476. doi: 10.1525/jsah.2018.77.4.474
23. Kulkarni S, Bhat S, Moritz CA. Architecting for Artificial Intelligence with Emerging Nanotechnology. ACM Journal on Emerging Technologies in Computing Systems. 2021; 17(3): 1-33. doi: 10.1145/3445977
24. Özerol G, Arslan Selçuk S. Machine learning in the discipline of architecture: A review on the research trends between 2014 and 2020. International Journal of Architectural Computing. 2022; 21(1): 23-41. doi: 10.1177/14780771221100102
25. Zhang B, Liu T, Liang P, et al. Architecture Decisions in AI-based Systems Development: An Empirical Study. 2023 IEEE International Conference on Software Analysis, Evolution and Reengineering (SANER). Published online March 2023. doi: 10.1109/saner56733.2023.00063
26. Yusriadi, Y., Rusnaedi, R., Siregar, N.A., Megawati, S., & Sakkir, G. (2023). Implementation of artificial intelligence in Indonesia. *International Journal of Data and Network Science*. https://doi.org/10.5267/j.ijdns.2022.10.005
27. Witt A, Kim E. Neural Image Classifiers for Historical Building Elements and Typologies. Technology/Architecture + Design. 2022; 6(1): 80-89. doi: 10.1080/24751448.2022.2040306
28. Mesanza-Moraza A, García-Gómez I, Azkarate A. Machine Learning for the Built Heritage Archaeological Study. Journal on Computing and Cultural Heritage. 2020; 14(1): 1-21. doi: 10.1145/3422993
29. Yasir AM, Herng YY. Utilizing Generative Computational Algorithms in Interpreting Historical Elements in Architectural Design Available online: https://openarchive.icomos.org/id/eprint/2027/ (accessed on 2 June 2023).
30. De Man A. Islamic Architecture in The West of Al-Andalus: Balancing Archaeology and Commodification. Islamic Heritage Architecture IV. 2022.
31. Al-Tameemi OA, Toma TA. Automation in architecture and its effect on the regeneration of traditional buildings: Al-Shawi House as a case study. IOP Conference Series: Materials Science and Engineering. 2020; 881(1): 012027. doi: 10.1088/1757-899x/881/1/012027