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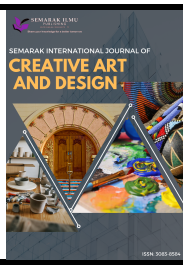

Exploring Current Methods and Trends in Heritage Preservation: A Systematic Mapping Study

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ABSTRACT

This research paper presents a systematic mapping study that aims to analyze the current methods and trends in heritage preservation. The field of heritage preservation is a multidisciplinary domain that focusses on the conservation and safeguarding of cultural, historical, and architectural assets. The study aims to provide a comprehensive overview of the techniques and approaches employed in the preservation of cultural heritage, with an emphasis on both traditional and modern methodologies. Through the utilization of a meticulous three-phased quality assessment procedure, this study examines and evaluates 25 peer-reviewed publications sourced from seven well-known digital libraries. The publications selected for analysis span the time frame from 2019 to 2024. The study aims to investigate two research questions: (1) What is the extent of research on heritage preservation, particularly concerning different cultural contexts and built environments? and (2) What are the current methods and approaches used in heritage preservation, particularly in addressing specific preservation challenges and technological advancements? The paper presents a synthesis and discussion of the findings from the literature review, offering insights and recommendations for future research directions in the field of heritage preservation. This paper aims to contribute to the advancement of knowledge and understanding of the state-of the-art techniques and challenges in heritage preservation. It offers valuable guidance for researchers, practitioners, and policymakers who are involved in the conservation of our shared cultural heritage.

1. Introduction

Preserving cultural heritage is an essential activity that goes beyond generations, providing as a way to protect historical artefacts and sites, as well as a channel for transmitting cultural values, knowledge, and identity. Heritage buildings and sites, being physical representations of cultural heritage, are especially vulnerable to many risks, such as environmental deterioration, urban development pressures, and the natural deterioration of materials over time. The area of historical

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preservation has expanded to include various approaches, technologies, and methods to address these risks and ensure the long-term survival of heritage assets.

Cultural heritage, whether tangible or intangible, refers to the cultural artifacts left behind by past generations. It is a crucial component in our modern society. Tangible cultural heritage as described by [1] includes a wide range of elements, such as buildings, structures, artifacts, and locations, which hold historical, aesthetic, and architectural significance. In contrast, intangible cultural heritage comprises various kinds of social practices, conceptual expressions, associated skills and tools, rituals, and crafts that individuals perceive as essential to the heritage [2]. Preservation means to prevent something of significance or value from deteriorating or being damaged, to maintain it and to keep it alive or undamaged. Preservation whether of natural or cultural heritage is extremely important to secure the historical past [3]. Preserving cultural and national heritage is of the utmost importance, as it is an irreplaceable source of life, inspiration from the past and historical landmarks for future generations. [4] stated that it is necessary to discover the microclimate conditions that are desired and appropriate for the studied heritage and historical buildings in order to slow their degradation and destruction. Microclimate, which includes elements like temperature, humidity, light exposure, and air quality, must be carefully managed in order to preserve historic buildings. Fluctuations in these conditions can lead to deterioration of materials, structural damage, the growth of mold and other harmful elements.

Maintenance is considered to be one of the key tasks within the field of preservation [5]. Maintenance is the continuous care and protection of a building's elements through minor repair works carried out to keep it in good order, thereby extending the life of such elements and the building as a whole for as long as possible. Nowadays, the use of digitalization in order to preserve cultural heritage presents a number of obstacles, some of which include a lack of available data, questions regarding the reliability of the data sources, and misalignments between contextual knowledge and digital content, which can be expensive and time-consuming [2].

1.1 Existing Reviews on Heritage Preservation

Recently, current approaches to machine learning have been getting more and more attention due to their capability of handling huge datasets, recognizing anomalies and, in some cases, filtering them out [4]. Machine learning and data science techniques could help people and businesses be more responsive to climate change by making it easier for them to get customized climate forecasts. Many heritage organizations' climate plans may gain benefit from technologies that process massive climate information, customize models, and summarize the results into informative visualizations [6]. Moreover, time-series forecasting and reconstruction is a job shared by several fields, including the Internet of Things (IoT), solar physics, the minimization of building energy use, and cultural heritage preservation [7]. IoT is not yet widely used in the preservation of cultural and national heritage, and only a small amount of research has been published on the topic [8].

Recent research published by [6] proposed that the IoT could be used to monitor air temperature and relative humidity in the Church of Santo Tomas and San Felipe Neri in Spain. IoT enables the computation and prediction of outdoor environmental conditions through the simulation of building behavior in the presence of external climate conditions. In addition, the proposed research paper presents by [7], a solution that utilizes Decision Tree, Support Vector Machine (SVM), and SVM Lite machine learning algorithms within an IoT-based framework. [4] further added that this capability has the potential to be revolutionary in the field of Heritage Science, which frequently relies on studies that require a large number of costly experimental observations and occasionally encounter issues with unreliable data.

Numerous studies have been conducted by researchers in order to investigate the effectiveness of machine learning for the purpose heritage preservation. The study by [8] employed a range of machine learning models, such as Long Short-Term Memory (LSTM) and Gated Recurrent Units (GRU), [9] utilized a combination of a fuzzy inference system and multiple linear regression (MLR) and Multiple Linear Regression (MLR) machine learning technique was utilized to conduct the analysis [10]. However, despite the advancements in heritage preservation methodologies, there is no assured guarantee that current approaches can consistently achieve the desired outcomes, particularly in terms of accurately preserving the integrity of cultural assets and effectively addressing evolving preservation challenges.

Despite the growing body of literature on heritage preservation methods, there is a noticeable gap in studies that comprehensively address the impact of microclimate conditions on preservation priorities. Most existing research emphasizes general preservation techniques or focuses on individual factors without considering how environmental conditions such as temperature, humidity, and air quality that affect heritage sites differently over time. This study addresses this gap by systematically analyzing the integration of microclimate considerations within preservation strategies, specifically prioritizing maintenance needs based on environmental stressors. By identifying the intersection of preservation techniques with localized environmental factors, this research contributes a nuanced perspective to heritage preservation that is critical for the development of sustainable, context-sensitive conservation practices.

1.2 Scope of Study

To the best of our understanding, previous research has identified various methodologies aimed at enhancing the effectiveness of heritage preservation practices. However, a comprehensive review synthesizing and illuminating the current methods and trends in heritage preservation is lacking. This study employs a systematic mapping methodology to explore the existing trends and approaches addressing challenges related to the conservation of cultural heritage. The findings from this review can assist in the application of various preservation strategies for the following purposes.

Heritage preservation manifests in a wide array of techniques, ranging from traditional methods to modern, technology-driven approaches. Traditional methods often focus on the restoration and maintenance of physical structures, while modern approaches incorporate digital tools, material science innovations, and community engagement. This study seeks to determine the extent of research on heritage preservation, including the identification of trends and applications. Additionally, it investigates the current methods and approaches used in heritage preservation, with a focus on addressing specific problems and cultural contexts. Analyze the significance of domain-specific knowledge and data sources in the techniques utilized for heritage preservation. In order to enhance our comprehension of the implementation of current heritage preservation methodologies and to progress our research goals, we propose the following research questions (RQs):

RQ1: What is the extent of research on heritage preservation?

1. How many of the reviewed studies specifically focus on heritage preservation techniques and methodologies?
2. Among the studies that focus on heritage preservation, how have the methods and trends evolved over the years?
3. How many of these studies apply preservation methods within specific domains, such as environmental sustainability or community involvement?

4. Within these domains, how many studies are specifically applied to the preservation of cultural heritage in developing regions or underrepresented areas?

RQ2: What are the current methods and approaches employed in heritage preservation?

1. Which specific problems in heritage preservation are addressed by current methods and approaches?
2. What preservation techniques and strategies are frequently emphasized across different cultural and historical contexts?
3. How has the trend in heritage preservation evolved over the years?

1.3 Contribution

This systematic mapping study provides scholarly insights into the impact of current methodologies and trends on heritage preservation practices.

A comprehensive review of 25 peer-reviewed articles on heritage preservation is conducted. The study includes an analysis of how these methodologies and trends could inform future research in the field, along with a discussion of key considerations for selecting effective preservation strategies to enhance the conservation of cultural heritage.

Today, Brunei has emerged as a rapidly growing economy in Southeast Asia, ranking third in the production of oil and gas in the region [2]. Islam has become deeply ingrained into the nation's culture, serving as the nation's way of life and official religion. Despite the ongoing modernization, Brunei continues to uphold its traditional practices and cultural heritage, especially in its cuisine and traditional activities such as weaving of textile and handicraft products which carry social and national significance. The rural communities, who are living in remote Bruneian longhouses and villages, are the custodians of these traditions, ensuring the survival of this heritage industry.

Handicraft is a vital component of a nation's identity; it shapes our current understanding of the early stages of civilisation. An art that is ancient, yet informs us on how far we have come today as an emerging nation in the face of globalisation. Traditional handicraft products persist in modern times, and continue to play a significant role in income generation for longhouses population in Brunei Darussalam.

Brunei's weaving techniques, albeit present for as long as time could tell, have been subjected to innovation and modernization. Many industrialised and developing countries are still relying on handicraft industry as the cornerstone of their economy, making research on the development of handicraft industry as MSMEs remains relevant, necessary, and significant in today's digital and global world [3].

Therefore, this paper aims to balance these contrasting views on the past versus present by exploring on the innovative practices of Brunei's traditional handicraft products, its cultural preservation practices, the challenges, and opportunities faced by the handicraft entrepreneurs and the support they require.

2. Methodology

In selecting articles for this systematic mapping study, we employed a rigorous set of inclusion and exclusion criteria to ensure the relevance, quality, and consistency of the reviewed literature. The inclusion criteria required studies to focus on heritage preservation methodologies, be peer-reviewed, and published within the 2019-2024 period, as detailed in Table 2 of the methodology. Additionally, each study was assessed for methodological robustness, emphasizing clear research

objectives, sound data collection and analysis techniques, and the applicability of findings to the heritage preservation domain. To refine the selection process, we implemented a three-phase quality assessment procedure, starting with title and abstract screening to filter out unrelated studies, followed by duplicate and retraction checks, and concluding with full-text review based on relevance to our research questions. This systematic approach ensured that only studies meeting high-quality standards were included, providing a robust basis for analyzing current trends and gaps in heritage preservation research.

Table 1
Online repositories of literature

No.	Digital Library	URL
1	Scopus	https://www.scopus.com/
2	ACM Digital Library	https://dl.acm.org/
3	IEEE Xplore	https://ieeexplore.ieee.org/
4	ProQuest	https://www.proquest.com/
5	ScienceDirect	https://www.sciencedirect.com/
6	SpringerLink	https://link.springer.com/

Table 2
Online repositories of literature

No.	Inclusion Criteria	Exclusion Criteria
1	Published later than 2018	Published prior 2019
2	Relevant to heritage preservation	Not relevant to heritage preservation
3	Peer-reviewed and published literature	Non-peer-reviewed literature
4	Proposed or used methodology	Retracted and duplicated literature

Table 3
Online repositories of literature

No.	Exclusion Criteria
1	(“heritage preservation” OR “heritage conservation”) AND
2	(“machine learning” OR “Artificial Intelligence” OR “Internet of Things”) AND
3	(“method” OR “approach” OR “technique”)

Table 4
Online repositories of literature

Database	Filter Details
Scopus	Year: 2019-2024 Subject Area: Computer Science, Environmental Sciences, Document Type: Conference Paper, Article, Conference Review, Book Chapter, Review, Book Language: English
ACM	Year: 2019-2024 Document Type: Proceedings, Research Article Media Type: PDF
IEEE	Year: 2019-2023 Document Type: Conferences, Journals, Early Access Articles, Books
ProQuest	Year: 2019-2024 Source Type: Books, Conference Papers & Proceedings, Dissertations & Theses, Scholarly

Science Direct	Journal Language: English Year: 2019-2024 Article Type: Review Articles, Research Articles, Book Chapters Subject Areas: Computer Science, Environmental Sciences
Springer Link	Language: English Year: 2019-2024 Content Type: Conference Paper, Book, Article, Conference Proceedings
Web of Science	Language: English Year: 2019-2024 Document Types: Proceeding Paper, Article Access, Review Article, Book Chapters Language: English

Table 5
Online repositories of literature

Database	S1	S2	S3	Inclusion	Exclusion
Scopus	4628	59	16	2	14
ACM	336	162	26	1	25
IEEE	1010	150	99	13	86
ProQuest	666	104	47	1	46
Science Direct	4133	346	43	1	42
Springer Link	483	224	95	2	93
Web of Science	903	83	28	5	23
Total	12159	1128	354	25	329

2.1 Planning

The present study conducted a comprehensive literature search that included publications from seven well-known databases, as specified in Table 1. The choice of these digital libraries was made based on their strong scientific credentials and their acknowledged significance and applicability to the research.

The incorporation of inclusion and exclusion criteria is crucial for researchers as it helps to minimize bias, define the scope of the search, identify relevant publications, and exclude studies that are not aligned with the objectives of the study. The manual screening of peer-reviewed articles against these criteria allows researchers to evaluate whether the implemented or proposed heritage preservation algorithm strategies are in line with research standards. The inclusion and exclusion criteria employed in this research are outlined in Table 2. Commencing from the specified starting year 2019, and extending to 2024, or 2024 for certain libraries, ensures the inclusion of only the latest literature, minimizing bias, sharpening the search focus, and capturing relevant publications while excluding studies misaligned with the research objectives.

The search string was formulated using expressions related to the research questions (RQs), with the aim of identifying relevant phrases or synonyms used in articles discussing the sentiment analysis of popular perceptions of heritage preservation algorithms. Iterative pilot conducted searches, refining the search keywords as necessary. The research focusses on the search string that includes terms related to heritage preservation and different approaches, as described in Table 3. The

literature search involves conducting a series of searches, beginning with the first search (S1) and applying specific filters. The details of these filters for each database can be found in Table 4. The filters used in this study include criteria such as year, subject area, document type, language, and inclusion/exclusion criteria. These filters are applied during the literature retrieval process as an initial step.

2.2 Execution

The following section provides an overview of the steps involved in processing and filtering the publications obtained from searches conducted in digital libraries. Initially, a pool of 12,159 records was collected from the first search and filters. Among the different sources, Scopus had the highest number of publications with 4,628 records, while the lowest number was from ACM Digital Library with 336 records, as shown in Table 5. The search is then further conducted by extending the search strings S2 and S3, resulting in a reduction of the total literature outputs to 1128 and 354 respectively. From the 354 results, metadata such as title, author, abstract, and published date are extracted and organized into a list for further filtering.

In order to exclude publications that did not meet the inclusion criteria, a three-phased quality assessment procedure was implemented. The research process consists of three main stages which are title and abstract filtering, removal of duplicate and retracted publications, and full-text filtering. Table 5 provides an explanation of the number of articles that were filtered at the conclusion of step three.

In the initial phase, the 354 publications were screened based on their title and abstract. As a result, 281 publications were excluded as they did not involve the discussion of heritage preservation and did not address the research questions (RQs). The titles, abstracts, and keywords were carefully examined in order to assess the relevance of the articles for inclusion or exclusion, according to the criteria specified in Table 2. The articles were then cross-checked for redundancy and retracted publications in the second stage, resulting in the removal of 23 additional articles. After applying full-text filtering, the current number of excluded publications is 329, which corresponds to stage 3 of the process. Following the application of the exclusion and inclusion criteria, a total of 25 articles were selected and included in this study as shown in Figure 1.

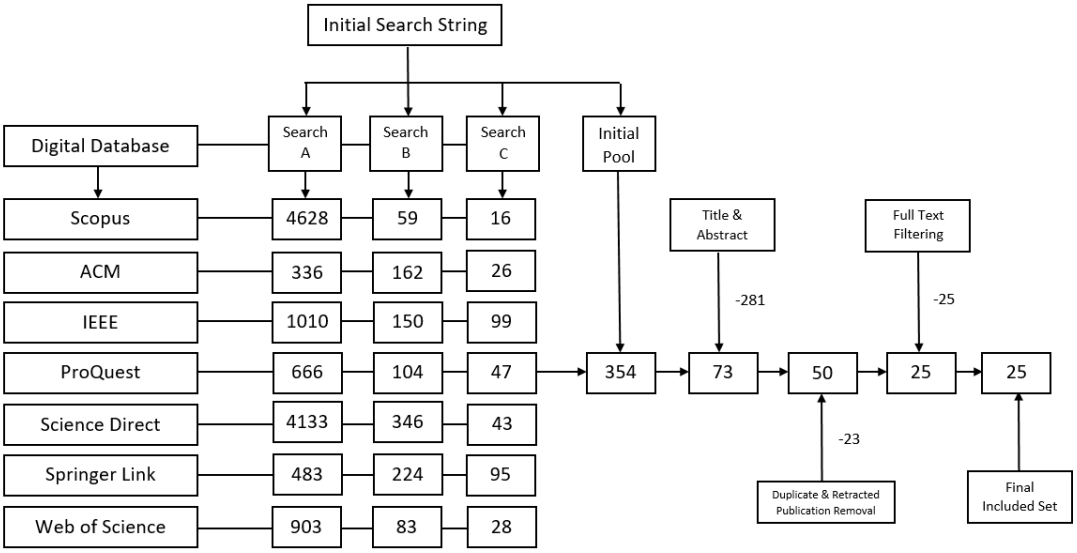

Fig. 1. Publication dataset filtering summary

2.3 Synthesis

This section will analyze the information that has been extracted in order to answer the research questions that have been provided. The initial data collection was arranged based on the development of heritage preservation to address Research Question 1 (RQ1). The metadata, which includes the year of publication of the paper, is catalogued to provide an overview of the dataset.

The dataset is further analyzed based on the approaches taken within the papers to address Research Question 2 (RQ2). This includes the dataset used, evaluation methods, and language of application, among others.

Finally, the outcome of the study was submitted for peer review. Discussions are conducted during the reviewing process, and the final outcome is documented in an Excel spreadsheet. This process is currently done manually. Table 6 shown the list of papers.

Table 6
List of papers

No.	Title	Year	Database
1	Machine Learning-Based Crack Detection Methods in Ancient Buildings	2024	ACM
2	Revealing the structural behaviour of Brunelleschi's Dome with machine learning techniques	2024	Scopus
3	Revolutionizing cultural heritage preservation: an innovative IoT-based framework for protecting historical buildings	2024	Web of Science
4	Using machine learning and satellite data from multiple sources to analyze mining, water management, and preservation of cultural heritage	2024	Web of Science
5	Bridging past and present: cutting-edge technologies for predictive conservation of built cultural heritage	2024	ProQuest
6	Using machine learning to predict artistic styles: an analysis of trends and the research agenda	2024	Springer Link
7	Examining Potential for Sustainable Development through Adaptive Reuse and IoT: A Case Study of Kapurthala, India	2023	IEEE
8	A Deep Learning Framework for Cultural Heritage Damage Detection for Preservation; Based on the Case of Heunginjimun and Yeongnamnu in South Korea	2023	IEEE
9	AI and Swedish Heritage Organisations: challenges and opportunities	2023	Springer Link
10	Artificial Intelligence And Cultural Heritage: Design And Assessment Of An Ethical Framework	2023	Web of Science
11	New Perspectives on Heritage: A Deep Learning Approach to Heritage Object Classification	2023	IEEE
12	Detecting the Past: Advancements in Comic Panel Detection for Cultural Heritage Preservation	2023	IEEE
13	Current State and Future of Building Information Modeling for Sustainable Heritage Buildings	2023	IEEE
14	Revolutionizing Heritage Site Information Retrieval: A Deep Learning Approach Utilizing CNN and SVM for Effective Classification of Cultural Heritage Sites	2023	IEEE
15	Unleashing the Potential of Transfer Learning Technique for Cultural Heritage Classification and Preservation at Qal'at al-Bahrain Site Museum	2023	IEEE
16	The Applications of Internet of Things in Architectural Heritage Preservation	2023	IEEE
17	A Deep Learning Approach to Protecting Cultural Heritage Buildings Through IoT-Based Systems	2022	IEEE
18	Integration of The Indonesian Cultural Heritage and Natural History Based on Digital Technology 4.0: A Conceptual Framework	2022	IEEE
20	Built Cultural Heritage and Digital Transition: The New Role of Data and Artificial Intelligence Applications in Administrative Procedures	2021	Scopus

21	Internet of Things (IoT) for masonry structural health monitoring (SHM): Overview and examples of innovative systems	2021	Web of Science
22	Using Machine Learning to Identify Factors Contributing to Mould in the Celje Ceiling Painting	2021	IEEE
23	Using Machine Vision Based of Preventive Maintenance and Management of Historic Buildings	2021	IEEE
24	Self-adaptive Sensing IoT Platform for Conserving Historic Buildings and Collections in Museums	2020	Web of Science
25	Deep Learning and Cultural Heritage: The CEPROQHA Project Case Study	2019	IEEE

3. Results

From the research conducted in section II, the results obtained from the data and information will be used to address the research questions and will be explained in this section.

3.1 Research on Heritage Preservation

The trend of heritage preservation studies has shown a significant increase in publications discussing the issue starting from 2019 and onwards as shown in Figure 2. Over the years, researchers have studied and implemented methodologies, results, and improvements to solve and innovate solutions for heritage preservation in different domains. In this mapping study, we conducted additional filtration to analyze the specific topic of research on heritage preservation methodology. The results of the filtration, as discussed in the previous section, indicate that there is a limited amount of research on the topic. Specifically, there are less than 25 papers that specifically address the area of interest.

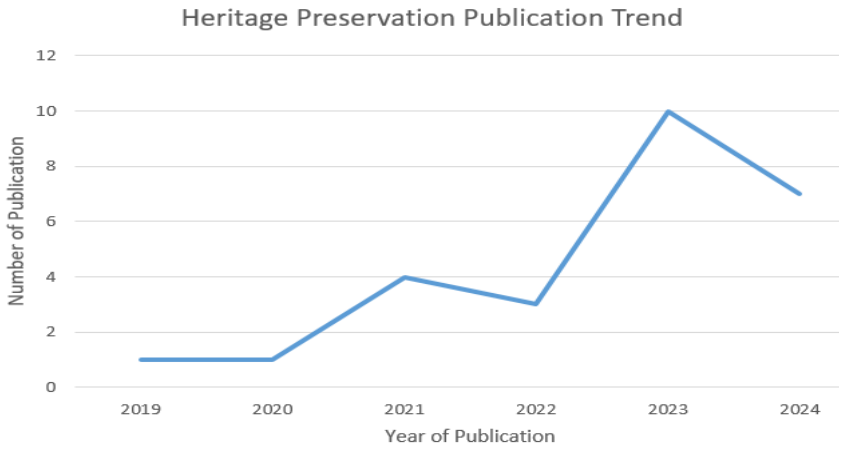

Fig. 2. Publication trend

On the other hand, the trend of research on machine learning and internet of things of heritage preservation has been quite popular in recent years, although there are still relatively few researchers studying the topic as shown in Table 7.

Table 7
List of papers discussing machine learning heritage preservation

No.	Title	Author
1	Machine Learning-Based Crack Detection Methods in Ancient Buildings [11]	Fang T., Hui Z., Rey W. P., Yang A., Liu B, He Y

2	Revealing the structural behaviour of Brunelleschi's Dome with machine learning techniques [12]	Masini, S., Bacci, S., Cipollini, F., Bertaccini B
3	Revolutionizing cultural heritage preservation: an innovative IoT-based framework for protecting historical buildings [13]	Casillo M, Colace F, Gaeta R, Lorusso A, Santaniello D, Valentino C
4	Using machine learning and satellite data from multiple sources to analyze mining, water management, and preservation of cultural heritage [14]	Sousa JJ, Lin JH, Wang Q, Liu G, Fan JH, Bai SB, Zhao HL Pan HY, Wei WJ, Rittlinger V
5	Using machine learning to predict artistic styles: an analysis of trends and the research agenda [15]	Valencia J., Pineda G. G, Pineda V. G, Valencia-Arias, A, Arcila-Diaz, J, de la Puente
6	Examining Potential for Sustainable Development through Adaptive Reuse and IoT: A Case Study of Kapurthala, India [16]	Kaur H., Sood V., Sood M
7	The Applications of Internet of Things in Architectural Heritage Preservation [17]	Li S., Du K., Xu W., Cao Y
8	A Deep Learning Approach to Protecting Cultural Heritage Buildings Through IoT-Based Systems [18]	Casillo, M., Colace, F., Gupta, B. B., Lorusso, A., Marongiu, F., Santaniello, D.
9	Cultivating historical heritage area vitality using urban morphology approach based on big data and machine learning [19]	Wu, J., Lu, Y., Gao, H., Wang, M
10	Internet of Things (IoT) for masonry structural health monitoring (SHM): Overview and examples of innovative systems	Scuro C, Lamonaca F, Porzio S, Milani G, Olivito RS
11	Using Machine Learning to Identify Factors Contributing to Mould in the Celje Ceiling Painting [20]	Popov S., Kavkler K., Dzeroski S
12	Using Machine Vision Based of Preventive Maintenance and Management of Historic Buildings [21]	Chen W. Y., Cheng C. W
13	Self-adaptive Sensing IoT Platform for Conserving Historic Buildings and Collections in Museums [22]	Tse R, Im M, Tang SK, Menezes LF, Dias AMPG, Pau G

3.2 Methods and Approaches

A variety of methods have been proposed and established within the studies analyzed within this mapping study. The researcher explores various methodologies, such as supervised, unsupervised, knowledge-based, and hybrid approaches, to address the heritage preservation problem. In addition to the approaches used in developing heritage preservation with machine learning, this study also includes methods from the internet of things and AI within its scope.

Table 8
Methods used in papers

No.	Title	Methodology
1	Machine Learning-Based Crack Detection Methods in Ancient Buildings	The authors conducted a survey of articles published over the past five years in both ML and CH domains. This review aimed to identify where research activities have been performed from an ML perspective. The authors highlight the use of traditional statistical methods, such as in analyzing archaeological artefacts.
2	Revealing the Structural Behaviour of Brunelleschi's Dome with Machine Learning Techniques	The paper aims to analyze the structural behavior of Brunelleschi's Dome using machine learning techniques. The study focuses on various machine learning methodologies to analyze the collected data which is Dimensionality Reduction Techniques include Kernel Principal Component Analysis (KPCA), Isometric Mapping (Isomap) and t-distributed Stochastic Neighbor Embedding (t-SNE).

3	Revolutionizing Cultural Heritage Preservation: An Innovative Iot-Based Framework for Protecting Historical Buildings	This work introduces an IoT-based system combining monitoring, predictive maintenance, and decision-making regarding the implementable interventions for protecting cultural heritage buildings. For this purpose, deep and machine learning techniques allow for the detection and classification of damages on specific materials.
4	Using Machine Learning and Satellite Data from Multiple Sources to Analyze Mining, Water Management, and Preservation of Cultural Heritage	This paper presents a range of techniques and methods that were applied for in-depth analysis and utilization of Earth observation data.
5	Bridging Past and Present: Cutting-Edge Technologies for Predictive Conservation of Built Cultural Heritage	The paper introduces The Mu.S.A platform, which stands for Multi-Sensor Assessment, is central to the methodology. It utilizes an Internet of Things (IoT) architecture to facilitate real-time data acquisition and processing. This platform allows for remote access to data, enabling users to monitor conditions continuously.
6	Using Machine Learning to Predict Artistic Styles: An Analysis of Trends and the Research Agenda	The paper explores machine learning models that predict artistic styles in paintings, highlighting their ability to analyze extensive datasets of historical and contemporary art. The study identifies research gaps and proposes a future agenda, emphasizing the need for advanced algorithms and better visualization of machine learning processes in artistic style prediction.
7	Examining Potential for Sustainable Development through Adaptive Reuse and IoT: A Case Study of Kapurthala, India	The paper explores the potential of adaptive reuse of historical buildings in Kapurthala, India, emphasizing their role in sustainable urban development and cultural preservation. The study aims to synthesize existing knowledge on IoT applications in heritage preservation and assess the cultural significance of historical buildings.
8	A Deep Learning Framework for Cultural Heritage Damage Detection for Preservation; Based on the Case of Heunginjimun and Yeongnamnu in South Korea	The paper addresses the urgent need for effective preservation methods for cultural heritage in South Korea, highlighting recent incidents of damage to significant structures. It proposes a deep learning framework that utilizes CCTV footage to detect abnormalities in wooden cultural heritage sites, specifically Heunginjimun and Yeongnamnu. The study aims to enhance existing inspection methods by integrating artificial intelligence, thereby improving the speed and accuracy of damage detection.
9	AI and Swedish Heritage Organisations: challenges and opportunities	This article examines the challenges and opportunities that arise with artificial intelligence (AI) and machine learning (ML) methods and tools when implemented within cultural heritage institutions (CHIs), focusing on three selected Swedish case studies.
10	Artificial Intelligence and Cultural Heritage: Design and Assessment of an Ethical Framework	The study aims to design an ethical framework of principles to assess the application of this ground-breaking technology at CH. It explores and analyses in depth the ethical challenges and opportunities presented by the use of AI to improve CH preservation.
11	New Perspectives on Heritage: A Deep Learning Approach to Heritage Object Classification	The paper explores the use of deep learning (DL) algorithms, specifically a hybrid model combining Convolutional Neural Networks (CNN) and Recurrent Neural Networks (RNN), for classifying cultural heritage objects based on attributes like style and material.
12	Detecting the Past: Advancements in Comic Panel Detection for Cultural Heritage Preservation	The paper focuses on comic panel detection, historical murals, and the application of the Faster R-CNN algorithm for restoration techniques in cultural heritage preservation. It

		highlights the potential of digital preservation technologies to enhance accessibility and documentation of cultural artifacts.
13	Current State and Future of Building Information Modeling for Sustainable Heritage Buildings	The paper discusses the significance of digital heritage and the challenges in preserving heritage buildings, emphasizing the need for sustainable management practices.
14	Revolutionizing Heritage Site Information Retrieval: A Deep Learning Approach Utilizing CNN and SVM for Effective Classification of Cultural Heritage Sites	The study addresses the challenges of gathering accurate information on cultural heritage sites, which is crucial for their protection and conservation. It proposes a system that leverages CNN and SVM to extract and classify data related to the historical significance, architectural features, and preservation status of these sites.
15	Unleashing the Potential of Transfer Learning Technique for Cultural Heritage Classification and Preservation at Qal'at al-Bahrain Site Museum	The Qal'at al-Bahrain Site Museum is a UNESCO World Heritage site that preserves artifacts from the ancient Dilmun civilization, making its preservation crucial for cultural and tourism industries. This research explores the application of transfer learning (TL) techniques to enhance artifact classification and preservation, aiming to improve accuracy and reduce human error in the process.
16	The Applications of Internet of Things in Architectural Heritage Preservation	The paper emphasizes the use of deep learning algorithms for predictive modeling. These techniques are particularly effective in recognizing patterns and making predictions based on large datasets. The authors explore how these methods can be applied to assess risks in existing buildings and infrastructure.
17	A Deep Learning Approach to Protecting Cultural Heritage Buildings through IoT-Based Systems	The study focuses on Preventive Conservation (PC) for cultural heritage, emphasizing the need for non-invasive monitoring of environmental factors like temperature and humidity to prevent damage to historic buildings. It proposes a system utilizing IoT and advanced data analysis techniques, including Machine Learning and Neural Networks, to enable real-time monitoring and predictive maintenance of cultural assets.
18	Integration of the Indonesian Cultural Heritage and Natural History Based on Digital Technology 4.0: A Conceptual Framework	The paper focuses on the preservation of cultural wealth and natural history through digital technology 4.0, emphasizing the roles of big data and artificial intelligence. The study argues that integrating cultural heritage preservation with digital technology can enhance tourism, national identity, and global recognition of Indonesia's cultural wealth.
19	Cultivating Historical Heritage Area Vitality using Urban Morphology Approach based on Big Data and Machine Learning	The paper discusses the evolution of historical heritage conservation from individual buildings to entire areas, emphasizing the need for diversified utilization to enhance vitality. The study employs machine learning algorithms, particularly ridge regression and LightGBM.
20	Built Cultural Heritage and Digital Transition: The New Role of Data and Artificial Intelligence Applications in Administrative Procedures	The paper outlines how a systemic use and a statistical view of design project data, according to the definition of automatically verifiable standard elements, could help guarantee a higher level of knowledge functional to the improvement of cultural assets protection.
21	Internet of Things (IoT) for Masonry Structural Health Monitoring (SHM): Overview and Examples of Innovative Systems	The main aim of using the IoT paradigm is related to the possibility of a connectivity extension of several common SHM devices by means of Internet. It is exposed a general overview of the SHM systems used by the authors for masonry structures belonging to historical and cultural heritage, arguing their use for the protection from earthquakes with related advantages.

22	Using Machine Learning to Identify Factors Contributing to Mould in the Celje Ceiling Painting	The research aims to analyze factors contributing to the deterioration of historical ceiling paintings in Slovenia, specifically focusing on mould damage. The research utilized various classification methods to build predictive models. Nine different classification techniques were applied, including Decision Tree (DT), Classification Rules (CR), Bagging (with DT and CR), Random Forest (RF), Naïve Bayes (NB), Logistic Regression (LR), Support Vector Machines (SVM) and K-Nearest Neighbors (KNN).
23	Using Machine Vision Based of Preventive Maintenance and Management of Historic Buildings	The paper discusses the advancements in machine vision technology, which utilizes computer software and hardware to interpret the three-dimensional world. The research employs Deep Neural Network (DNN) technology to identify damage in wooden structures, particularly from termite infestations. By collecting and analyzing photos of affected areas, the system can detect abnormalities and provide management solutions
24	Self-adaptive Sensing IoT Platform for Conserving Historic Buildings and Collections in Museums	This paper propose the design of the sensor device in the IoT platform for conserving historic buildings and collections in museums. The sensor device is self-adaptive, running continuously without any interruption causing by the instability of power and network connection.
25	Deep Learning and Cultural Heritage: The CEPROQHA Project Case Study	The project employs various deep learning methods, including Convolutional Neural Networks (CNNs) for visual data classification and Generative Adversarial Networks (GANs) for data completion. These techniques are designed to enhance the classification and annotation of cultural data, as well as to fill in missing information.

Based on the results obtained, as shown in Table 8, it is evident that the progress of heritage preservation machine learning is in progress in order to reach optimal accuracy throughout time by addressing relevant concerns.

4. Results and Discussion

The findings of this study indicate that there exists an extensive amount of research that encompasses the subject of heritage preservation. Nevertheless, within the realm of heritage preservation in the machine learning, numerous studies have been conducted to address the very challenging issue of development. In contrast, the strategies employed in the investigations conducted in this mapping study exhibit variation, with a predominant utilization of supervised, knowledge-based, and hybrid approaches. The authors have predominantly chosen to employ the methodology of utilizing annotated information and constructing corpora in their respective investigations.

Many studies converge on the use of digital tools, such as IoT and machine learning, to monitor environmental conditions and predict degradation in heritage sites. However, approaches differ in their handling of data and application focus on some prioritize real-time monitoring for immediate responses to environmental fluctuations, while others employ predictive modeling to inform long-term conservation strategies. For instance, IoT-based systems often focus on continuous environmental data collection, enabling proactive maintenance, whereas machine learning models frequently emphasize anomaly detection in structural health monitoring, which is critical for early damage identification. This diversity in methodology not only reflects the multi-faceted nature of heritage preservation but also underscores the field's progression towards integrating technology

with traditional practices. By synthesizing these approaches, the field can leverage a combination of immediate and predictive insights, addressing both present-day and future preservation needs, thereby enriching the scope and applicability of heritage conservation efforts. The continuation of research and development in the field of heritage preservation is essential to ensure the progress of this machine learning application in augmenting knowledge. Numerous studies currently rely on news stories as their primary source of data for their investigations.

Furthermore, it is important to conduct a comprehensive examination of the advancement of legacy preservation in the field of machine learning, given its distinctiveness in comparison to other machine learning approaches. This uniqueness necessitates the utilization of a customized algorithm in order to attain the highest level of precision in the obtained results.

5. Conclusion

This paper presents comprehensive mapping research on the various approaches and trends that are now being utilized in the field of heritage preservation, with a particular emphasis on the machine learning and internet of things domain categories. This study examines 25 papers that have been subjected to peer review and are sourced from seven notable digital databases. The publications are analyzed based on a variety of criteria, including methodology and domain-focused applicability to the entire system. The purpose of this article is to identify the primary issues, applications, and gaps in the field of heritage preservation. Additionally, the paper offers insights and recommendations for the future paths of research. The paper concludes that heritage preservation is an area of research that is both promising and evolving, and that it has the potential to be beneficial.

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