Intelligent Eyes on Buildings: A Scientometric Mapping and Systematic Review of AI-Based Crack Detection and Predictive Diagnostics of Building Structures

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Contributor: Mehdi Mohagheghi , Ali Bahadori-Jahromi , Shah Room

Artificial Intelligence (AI)-based crack detection in buildings uses computer vision and deep learning to automatically identify structural cracks from inspection images. In recent years, many studies have explored this topic, but the overall development of the field, its methodological practices, and the remaining challenges are still not fully clear. Unlike most previous reviews that focus mainly on technical methods, this study combines a large-scale scientometric mapping of the research field with a focused technical analysis of recent AI-based crack detection methods specifically applied to building structures. This study therefore provides a dual-layer review covering research published between 2015 and 2025. A total of 146 Scopus-indexed publications were analysed using Visualization of Similarities viewer (VOSviewer) to examine publication growth, thematic evolution, collaboration patterns, and citation structures. In addition, a focused technical review of 36 highly relevant studies was carried out to analyse task formulations, model families, datasets, evaluation protocols, and methodological practices. The results show a rapid increase in research activity after 2020, largely driven by advances in deep-learning and Unmanned Aerial Vehicle (UAV)-based inspections. At the same time, collaboration networks remain uneven, and citation influence is concentrated in a limited number of research communities. The technical review further shows that most studies focus on detection-level tasks, particularly You Only Look Once (YOLO)-based models, while predictive diagnostics, automated inspection reporting, and decision-oriented Structural Health Monitoring (SHM) are still rarely addressed. Current datasets and evaluation protocols also remain mostly perception-oriented, which makes it difficult to assess robustness, generalisability and long-term predictive capability.

AI computer vision scientometric analysis crack detection building inspection predictive diagnostics deep learning

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Ensuring the long-term safety and performance of buildings has become increasingly essential as urban regions continue to expand and building components deteriorate due to ageing, environmental exposure, and material fatigue. Among various types of surface deterioration, cracks are widely recognised as the earliest and most informative indicators of structural distress in buildings. Continuous monitoring of crack formation and growth is therefore essential to help prevent progressive damage and to maintain structural reliability over time [1]. Previous studies on building condition assessments report that traditional inspection practices continue to rely primarily on manual visual assessments and handheld measurement tools. Such approaches have been associated with high labour demands and observer-dependent variability, which can limit their suitability for large-scale or frequent inspection tasks [2]. Recent work in AI, computer vision (CV), and deep learning (DL) has increasingly focused on automated methods for identifying and analysing building cracks. Within this body of research, convolutional neural networks (CNNs) are frequently reported to provide reliable recognition results across challenging surface textures, variable lighting conditions, and noisy image data [3]. Also, several recent studies have applied object detection frameworks from the YOLO family to real-time crack localisation, particularly in inspection scenarios using drone imagery or handheld cameras **Figure 1**. These studies report improved practicality compared with manual inspection workflows [4].

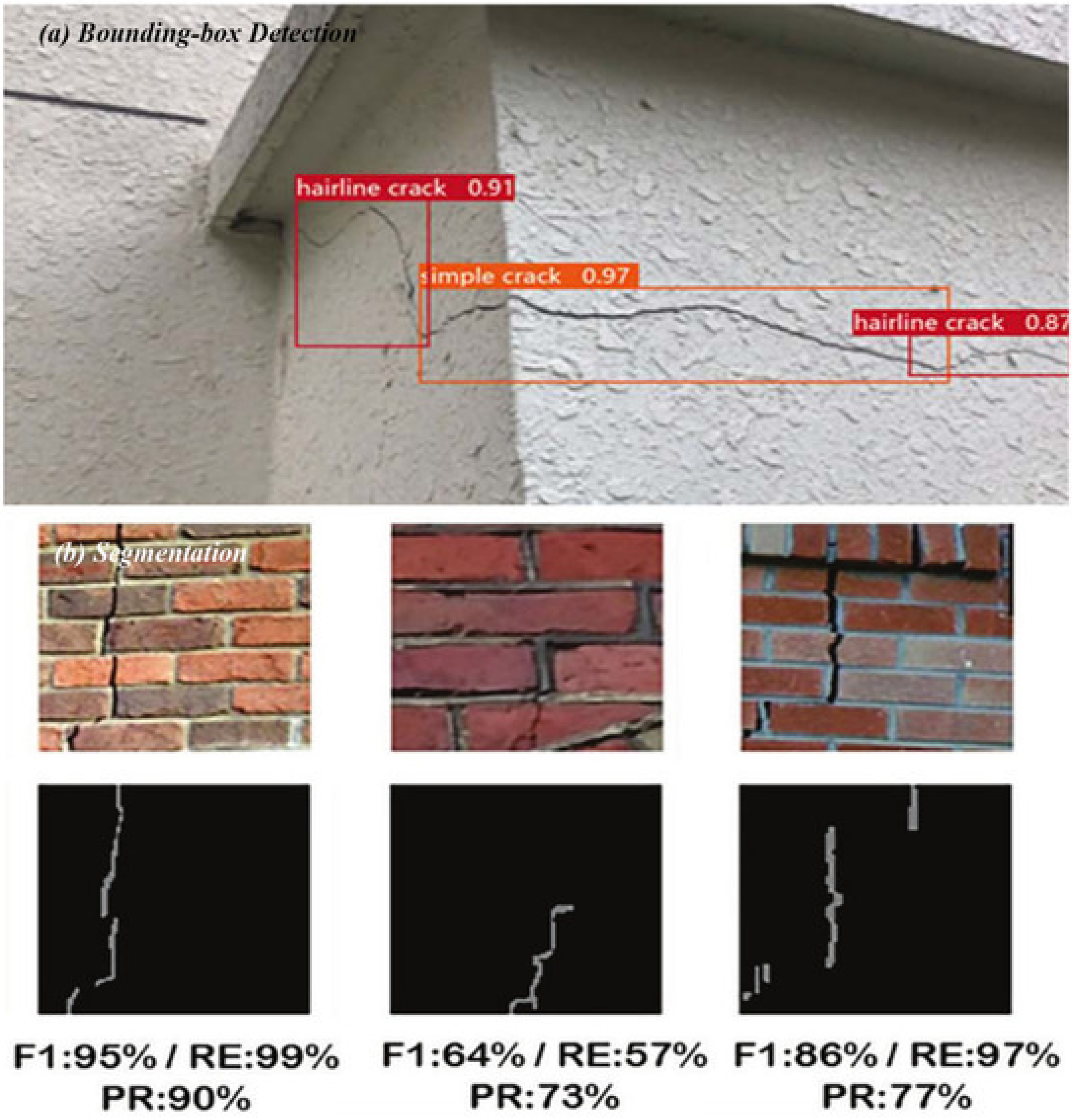

Figure 1. Examples of AI-based building crack detection: (**a**) bounding-box detection (adapted from ref. [5]); (**b**) segmentation (adapted from ref. [6]).

In addition to object detection-based approaches, several recent studies have investigated the use of transfer learning to enhance detection accuracy in building defect inspection tasks, particularly when available datasets are small or highly specialised. This strategy has been reported as a practical option in contexts where access to large, fully annotated datasets remains limited [7]. Some recent studies have also explored Generative Adversarial Networks (GANs) as a way to mitigate data imbalance and limited training samples in damage and defect detection tasks, including in related engineering and industrial inspection contexts. However, these approaches are still relatively limited in building-specific crack detection studies [8][9][10].

Alongside these methodological approaches, recent work has also considered how inspection data are collected in practice. Drones, smartphones, and high-resolution cameras are widely discussed as practical options in building inspection studies. In some cases, UAV-mounted cameras are able to capture façade images with enough clarity, which can then be used for automated crack detection tasks [11]. Recent studies have also examined the use of lighter deep-learning models and edge-AI devices for real-time crack recognition on mobile platforms. These approaches are reported to support on-site building inspection workflows, especially where real-time processing is required [12]. Semantic segmentation models, including the U-Net architecture and DeepLab families, have also helped improve pixel-level outlining of fine cracks. This has made more detailed defect quantification and modelling possible [13].

As these methods and technologies developed, more researchers started to focus on AI-based crack detection in buildings, with many related studies published between 2020 and 2024 [3]. Multiple studies have focused on topics such as CNN architectures, segmentation accuracy, drone-assisted inspection, and mobile-based detection systems, and they are reflecting increasing interest in automated approaches to building assessments [14]. Despite the growing number of studies, the existing literature remains fragmented. While many studies focused on algorithmic performance, image processing techniques, or specific façade conditions, broader research patterns, thematic clusters, and collaboration structures are still unclear [15]. Moreover, existing review studies have mainly examined isolated technical or application-specific aspects of crack detection, and as a result, they do not provide a unified, building-oriented view of AI-based crack analysis [1][3][16][17][18][19][20][21][22][23][24][25].

Whitin this broader context, automated crack detection has become a core element of modern SHM. As buildings age and urban environments grow denser, the need for scalable, objective, and automated inspection technologies becomes increasingly clear. Based on prior research, computer-vision and machine-learning methods are widely used for infrastructure monitoring and SHM, offering efficient strategies for defect detection and structural assessments of bridges, pavements, and other civil systems [26][27][28][29]. In the case of buildings, unique characteristics, such as diverse materials, localised damage patterns, and operational environments, introduce challenges that are not fully addressed by broader infrastructure-oriented reviews. Because of this gap, several aspects of AI-based building crack detection are still discussed separately in the literature, which makes a focused and systematic review necessary. Such a review can help connect scientometric trends with technical methods and provide a clearer direction for future research and practical applications.

Existing review papers usually provide narrative or technical summaries of the literature and can be helpful for understanding specific methods or applications. Also, many of these reviews are based on a limited number of studies, which means they do not always capture how the research field is structured at a wider level. Aspects such as patterns of influence, collaboration among researchers, and the gradual development of knowledge are often only briefly addressed. Scientometric analysis looks at the literature from a different angle by relying on quantitative, data-driven methods to study scientific activity, making it possible to identify relationships and structures that may not be obvious in narrative reviews [30]. This approach uses quantitative data taken from publications, citation records, and research networks to examine how the field has changed and developed over time [31].

In this study, we examine research on AI-based crack detection in buildings using two main perspectives. First, we use scientometric analysis to look at overall research activity, including how studies are distributed over time, how researchers collaborate, and which topics receive the most attention. We then review the technical aspects of existing work more closely, focusing on methodological choices, evaluation settings, and modelling strategies. By combining these two views, the study provides both a general overview of the field and a more detailed understanding of how technical approaches have evolved [32][33]. We organise this study around two complementary objectives. Using this dual approach, we aim to link broader scientific patterns with detailed technical evidence in building structural health monitoring.

As described by Ellegaard and Wallin (2015), scientometric analysis can be used to study research output, identify influential researchers, and examine how knowledge develops and spreads within a field. They also note that this type of analysis can reveal patterns that are often not clear in traditional narrative reviews [34]. While scientometric techniques have been applied to broader research areas, including artificial intelligence in civil engineering, crack analysis in concrete structures and pavements, and automated building inspections, fewer studies have focused specifically on AI-based building crack detection [35].

Structural health monitoring systems can rely on different types of data, including vibration signals, acoustic measurements, strain sensing, and visual inspection data [36]. However, in recent years, vision-based SHM approaches have become increasingly prominent due to advances in computer vision and deep learning. These approaches use image data collected through cameras, drones, or inspection platforms to automatically detect structural defects such as cracks. The present review primarily focuses on this vision-based branch of SHM, where AI and deep-learning models are applied to image data for crack detection in building structures.

So far, AI-based crack detection in buildings has not been the subject of a dedicated scientometric analysis. Despite the increasing number of related studies, the literature is still dispersed across multiple research areas. A targeted scientometric review may help organise this work, provide a clearer view of global research patterns, and identify directions that merit further investigation. Such an analysis can reveal how topics such as real-time detection, drone-based imaging, segmentation modelling, and lightweight architectures have evolved, while also identifying underexplored areas that warrant future research. Given this dispersed research landscape and the absence of a comprehensive and building-focused scientometric understanding of the domain, it becomes important to examine how studies on AI-based crack detection in building structures have collectively developed over time. The present study attempts to address the following central question: how has research on AI-based crack detection in building structures evolved over the past decade in terms of its scientific growth, thematic organisation, and patterns of collaboration? Therefore, the first part of this study aims to conduct a comprehensive scientometric analysis of AI-based crack detection research in building structures from 2015 to 2025. The objectives of this part are to:

(1) Analyse publication growth and citation dynamics.

(2) Identify leading authors, institutions, and countries in the field.

(3) Map collaboration networks at the author, institutional, and national levels.

(4) Examine keyword co-occurrence patterns and thematic clusters.

(5) Identify emerging trends, methodological developments, and research hotspots.

(6) highlight research gaps and propose future research directions.

While these objectives address the large-scale scientometric structure of the field based on the full corpus of 146 Scopus-indexed publications, they do not provide sufficient insight into the detailed technical choices adopted in state-of-the-art AI-based crack detection and predictive diagnostics studies. And, in a second layer of analysis, this study conducts a focused systematic technical review of a core subset of the most recent and thematically relevant publications. This technical review is guided by the following research questions (TRQs).

TRQ1—Application domains and problem formulations.

What types of crack detection, defect characterisation, and predictive diagnostic tasks have been formulated in recent AI-based studies for buildings?

TRQ2—AI and machine-learning model families.

Which families of machine-learning and deep-learning models have been employed, and how do their reported performances compare?

TRQ3—Datasets and data acquisition settings.

What are the main characteristics of the datasets used in these studies in terms of data modality, size, annotation strategy, and public availability?

TRQ4—Evaluation protocols and performance metrics.

How are training and evaluation protocols designed, and which performance metrics are used to assess model effectiveness?

TRQ5—Hyperparameter optimisation and methodological rigour.

To what extent are systematic hyperparameter optimisation and robust methodological practices reported in the core studies?

Structure of the Paper

The rest of this paper is organised as follows: Section 2 outlines the data collection process and scientometric methodology. Section 3 presents the bibliometric and network analysis results. Section 4 reports the systematic technical review results. Section 5 provides an in-depth discussion of the thematic clusters, methodological insights, and emerging trends. Finally, Section 6 concludes the paper by summarising the main contributions and offering directions for future research.

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