

IMAGE-BASED CRACK-DETECTION SYSTEM USING R-STUDIO AND VOS-VIEWER: A SCIENTOMETRICS LITERATURE REVIEW

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Abstract

This paper uses a bibliometric analysis of an image-based crack detection system using RStudio and VOS viewer software tools. In the experimental setup, we verified 210 documents found in the Scopus database with three sections: building walls, concrete surface, and concrete bridges from 141 sources like Journals, conferences, books, and Book chapters, etc., from 2014 to 2024. The R-studio will analyze the Scopus data as input, predict the plot, and cluster the table; then, the VOS-viewer will create a map. The Bibliometric coupling is used to generate a group of related themes with the help of a threshold value of 9, and seven cluster themes are generated. The three-field plot shows the usage of keywords by respective affiliations and countries, and China is the leading country in the domain. The annual scientific production performed right to move in publication output occurred in the 21st century, starting with remarkable growth in 2022 and continuing with a steady rise from 2021 to 2024. Most cited countries specify, especially regarding the total count of research publications resulting from their collaboration. Regarding the total number of research articles produced by a particular country, China has the highest number of research papers, contributing 115 publications. Of the number of research papers affiliated with each university, the topmost is Zhengzhou University, which contains 23 research articles. This paper's novelty is understanding modern literature instead of traditional surveys.

Keywords : Crack Detection; Image Processing ; Bridge Cracks,; Surface Cracks; Deep Learning;

1. Introduction

Image-based structural crack detection systems have emerged as pivotal components in Digital image processing, Artificial Intelligence, and Computer vision. Automated crack detection has become essential for effective structural monitoring in the present conditions of civil work construction. The laboring operation of detecting cracks takes much time, and inspectors suffer

from subjective judgments. Cracks have a major effect in ensuring structural classifications' safety, serviceability, maintainability, durability, and reliability [1].

In civil construction, a crack cannot be ignored, is connected to risk, and is a disastrous event; it may destroy the device's safety, robustness, and longevity. Therefore, an accurate crack is required to detect. Cracks happening due to incompatible causes are low-standard items, empirical response, unprocessed dead loss, etc., crack inspection by physical action has various defects, and it cannot detect undetectable cracks, and its reliability is low. A digital image processing method is developed to correctly find cracked images and undetectable cracks. So, there is a need for Digital Image processing techniques. Hence, it motivated us to research image-based crack detection and classification.

The research study's objectives are as follows:

To examine the publication trends.

Analyze the articles, authors, sources, affiliations, and countries.

Identify the latest themes and trends.

2. Methodology

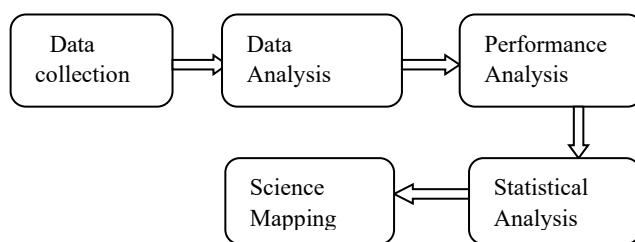


Figure 1. A Working flow of bibliometric analysis

The primary step is to gather the facts from several regions, use the bibliographic Scopus database, define search terms, do data extraction, and clean up the data. The next step needs to be analyzed regarding trends and patterns like co-citation, citation, bibliometric coupling, and keyword co-occurrences. The next step is to evaluate individual authors' publications, citations, and h-index, assess divergent organizations' exploration production and results, and estimate the investigation production of incompatible regions or countries. The next step is to create visual representations of the relationship between publications, authors, and affiliations of network graphs. The final step is to apply and identify the mapping techniques.

Table 1: Results of Data Scopus Data Analysis

MAIN INFORMATION ABOUT DATA (2014-2024)	Results
Timespan	2014:2024

Sources (Journals, Books, etc)	141
Documents	210
Annual Growth Rate %	22.48
Document Average Age	2.77
Average citations per doc	11.06
References	5331
Keywords Plus (ID)	1542
Author's Keywords (DE)	534
Authors	619
Authors of single-authored docs	11
Single-authored docs	14
Co-Authors per Doc	4
International co-authorships %	8.571
Article	109
book chapter	2
conference paper	97

3. Data Collection and its Analysis

The research papers on “crack detection,” “building walls,” “surface cracks,” or “bridge cracks” were collected from the Scopus database. From 2014 to 2024, 210 research papers related to keywords like crack detection, building walls, surface cracks, and bridge crack.

3.1 Data Analysis

The final dataset was exported from Scopus and saved in a dot CSV file; it will be executed on R-Studio and VOS viewer. The R-studio will analyze the data to predict a plot, table, clustering, etc. Further, the VOS-viewer will create a map based on the input data, i.e., Scopus data. The table below represents the information about Scopus data from 2014 to 2024.

4. Results and Discussion

4.1 Method

R studio and VOS-viewer are free tools for constructing and visualizing bibliometric networks. The networks include citation, co-citation, co-occurrence, bibliometric coupling, and co-author relationships. R programming is employed for performance analysis, and VOS-viewer is used for scientific analysis to map and analyze the dataset.

4.2 The Annual Production of Research Work

Table 2: Production of article and year

Year	Article
2014	5
2015	2
2016	4
2017	9
2018	12
2019	17
2020	16
2021	27
2022	37
2023	43
2024	38

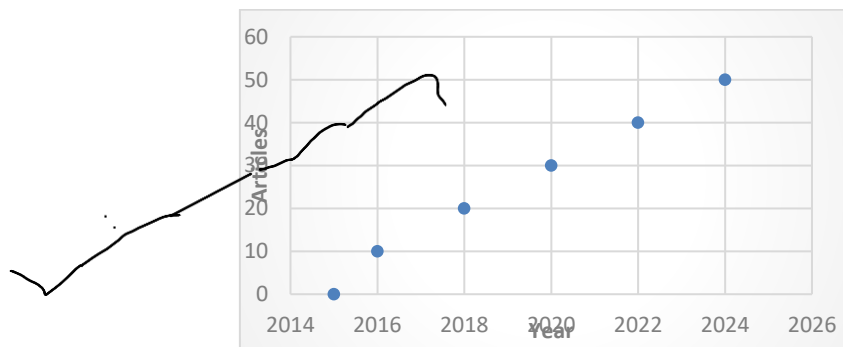


Figure 2: Graphical Representation of Annual Scientific Production

The above table shows that the R programming predicted the result of research based on the figures of published research articles in the given academic year. A minimum of 2 articles and a maximum of 43 articles in 2015 and 2023, respectively. Every year, article publication is increased till 2023.

4.3 Average Citations per Year

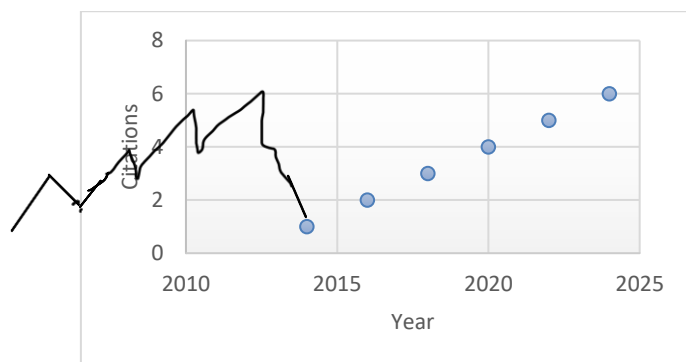


Figure 4: Graphical Representation of Average Citations Per Year

The concept of citable years, referring to the number of years with a substantial volume of publications, provides insights into the sustained impact of number theory research. The field has maintained a consistently high level of citable years.

4.4 Most Cited Countries

Table 3: The Collaborations of Cited Countries

Country	Article	SCP	MCP
CHINA	115	111	4
INDIA	14	12	2
KOREA	4	3	1
AUSTRIA	2	2	0
IRAN	2	2	0
JAPAN	2	1	1
THAILAND	2	2	0
CANADA	1	0	1
EGYPT	1	1	0
GERMANY	1	1	0

In the above table, the observation is that China is the topmost contributor, with 115 articles. It has the highest number of single-country publications (SCPs), with 111 and 4 multiple-country publications (MCPs). India follows with 14 articles; it has 12 SCPs and 2 MCPs. Australia, Iran, and Thailand each have 2 articles, all SCPs and no MCPs. Japan has two articles, one single-country publication and one multiple-country publication. Canada has one article, no SCPs, and one multiple-country publication. Egypt and Germany each have 1 article; it has only one SCP and no MCPs. India had a high proportion of international collaborations when compared to China. Korea and Japan also had good proportions of international collaborations relative to their whole output.

4.5 Total Citations Average*Table 4: A Global Analysis of Citations*

Country	TC	Average Article Citations
CHINA	1351	11.7
KOREA	166	41.5
AUSTRIA	72	36
INDIA	70	5
SWITZERLAND	36	36
TURKEY	34	34
US	31	31
HUNGARY	20	20
THAILAND	17	8.5
IRAN	13	6.5
INDONESIA	10	10

In the above table, observation comprises information from multiple countries showing the total citations (TC) to their research articles and the averages of how often each article is cited. China has been taking highest citations of 1351 with an average of 11.7 citations per article, while Indonesia has fewest total citations at 10 but achieves an average of 10 citations per article.

4.6 Most Relevant Affiliations

The above table shows the top 10 university affiliations and the number of research articles each university has produced. The topmost University is Zhengzhou University, which contains 23 research articles; Central South University, which contains 10 research papers, is the least compared to others.

Table 5 : Most Relevant Affiliations

Affiliations	Article
ZHENGZHOU UNIVERSITY	23
TIANJIN UNIVERSITY	19
CHONGQING UNIVERSITY OF POSTS AND TELECOMMUNICATIONS	18
FUZHOU UNIVERSITY	17
CHANG'AN UNIVERSITY	13
CHINA THREE GORGES UNIVERSITY	12
HEBEI UNIVERSITY OF TECHNOLOGY	12
NORTH CHINA UNIVERSITY OF WATER RESOURCES AND ELECTRIC POWER	12
CHANG'AN UNIVERSITY	11
CENTRAL SOUTH UNIVERSITY	10

4.7 Science Mapping

Science mapping is a symmetrical representation of documents, authors, and fields related to bibliometric mapping. Science mapping is a comprehensive analysis that helps to understand current trends.

4.7.1 Recent Trends

The experimental setup uses keyword analysis to establish the arising research trends. The Author's green keywords signify the most recent trends in the area. The author keyword is 2 of a minimum number of occurrences, Source-Author's estimation produced 1824 keywords, and 382 is the threshold.

4.7.3 Bibliometric Coupling

Bibliometric coupling is used to recognize groups of studies related to themes. Bibliometric coupling is stronger when more references share two publications. When two publications are coupled bibliographically, both cite a third publication.

Table 6: First Pertinent Theme Semi-Automated

Cluster	Authors name	Name of documents	Citation	Pertinent theme
1	Cai et al [2].	Bridge surface crack detection algorithm based on yolov3 and attention mechanism	19	Automated semi-supervised crack detection and segmentation using computer vision based on a yolov3 model.
	Dogaon et al [3].	A new mobile convolution neural network-based approach for pixel-wise road surface crack detection	34	
	Hu et al [4].	Road surface crack detection method based on improved yolov5 vehicle-mounted images	15	
	Wang(a) et al [5].	Semi-supervised semantic segmentation network for surface crack detection	72	
	Wang(b) et al [6].	A real-time bridge crack detection method based on improved inception – resent-v2 structure	43	
	Zhang (2020) et al [7].	On-bridge surface crack detection based on an improved yolov3 algorithm	58	
	Zhang (2022) et al [8].	Automated bridge surface crack detection and segmentation using computer vision-based deep learning model	75	
	Zhang(2023a) et al [9].	Automated bridge crack detection method based on lightweight vision models.	25	
	Zheng et al [10].	Lightweight bridge crack detection method based on signet and bottleneck depth-separable convolution with residuals	16	

Table 7: Second Pertinent Theme Automated

Cluster	Authors name	Name of documents	Citation	Pertinent theme
2	Chen (2023) et al [11].	Building surface crack detection using deep learning technology	9	Automated pixel-level crack detection for deep learning approach
	Han (2018) et al [12].	Structural surface crack detection method based on computer vision technology	31	
	Ji (2018) et al [13].	Automated Pixel-level surface crack detection using U-net	34	
	Kim (2021) et al [14].	Surface crack detection using deep learning with shallow CNN architecture for enhanced computation	136	
	Li (2020b) et al [15].	Bridge crack detection based on ssenets	23	
	Vivekananthan (2023) et al [16].	Concrete bridge crack detection image processing technology by using the improved Otsu method	21	
	Xu (2019) et al [17].	Automatic bridge crack detection using a convolutional neural network	173	
	Zhang(2023b) et al [18].	Mobilenetv3-bis: a broad learning approach for automatic concrete surface crack detection	11	
	Zhu (2019) et al [19].	Method for bridge crack detection based on the U-net convolutional networks	44	

Cluster 2, “Automated crack detection for deep learning approach,” focuses on an innovative approach to evaluating image-based civil structural crack detection and classification.

The table demonstrates the evolution of techniques ranging from artificial intelligence, deep learning, and computer vision for crack detection of surfaces, emphasizing computational efficiency and accuracy. From the above table, nine publications are coupled bibliographically, all citing relevant themes as Automate

Cluster 3, “Automatic pixel level bridge crack detection algorithms based on convolutional neural networks,” focuses on leveraging deep learning techniques to efficiently and accurately detect surface cracks across different materials and infrastructures. This collection of studies demonstrates diverse approaches to surface crack detection, leveraging deep learning, advanced algorithms, and innovative imaging techniques for efficiency and precision. From the above table, a total of nine publications, all of which cite the theme as CNN.

Cluster	Authors name	Name of documents	Citation	Pertinent theme
4	Kou (2022) et al [29].	Optical surface crack detection method based on semantic segmentation replacement for magnetic particle inspection	20	Automated structure surface crack detection using the improved Otsu methods
	Li(2019a) et al [30].	Dam surface crack detection based on deep learning	18	
	Li (2021) et al [31].	Pixel-level crack detection using deep fusion about recurrent residual convolutional and context encoder network	50	
	Li (2022) et al [32].	Automatic bridge crack detection using boundary refinement based on real-time segmentation network	14	
	Li (2023) et al [33].	Automatic bridge crack detection using unmanned aerial vehicles and faster r-CNN	77	
	Liang fit (2019) et al [34].	Bridge crack detection algorithm raised on image processing under complex background	19	
	Siriborvornratanakul (2022) et al [35].	Downstream semantic segmentation model for low-level surface crack detection	9	
	Wang (2020) et al [36].	A vision-based active learning convolutional neural network model for concrete surface crack detection	28	
	Wu (2021) et al [37].	Surface crack detection is based on image stitching and transfer learning with a pre-trained convolutional neural network.	29	

Table 8: Third Pertinent Theme CNN

Table 9: Fourth Pertinent Theme Otsu

Cluster	Authors name	Name of documents	Citation	Pertinent theme
3	Deng (2020) et al [20].	Research on an iron surface crack detection algorithm based on an improved YOLOv4 network	19	Automatic pixel-level bridge crack detection algorithms based on convolutional neural networks
	Joshi (2022) et al [21].	Automatic surface crack detection using a segmentation-based deep learning approach	35	
	Jung (2017) et al [22].	Fast and non-invasive surface crack detection of press panels using image processing	14	
	Jung (2019) et al [23].	Rapid and non-invasive surface crack detection of pressed panel products based on online image processing	13	
	Kyslytsyna (2021) et al [24].	Road surface crack detection method based on conditional generative adversarial networks	14	
	Mirbod (2022) et al [25].	Intelligent concrete surface crack detection using computer vision, pattern recognition, and artificial neural networks	13	
	Qu (2019) et al [26].	Lining seam elimination algorithm and surface crack detection in concrete tunnel lining	36	
	Yu (2017) et al [27].	Efficient crack detection for tunnel lining surface cracks based on infrared images	54	
	Zhu (2020) et al [28].	Robust image-based surface crack detection using range data	29	

Cluster 4, “Automated structure surface crack detection using the improved Otsu method, “delves into advanced techniques for surface crack detection across various structures, aiming to improve precision, reliability, and adaptability. The above table has nine authors from publications, all of which cite a theme as the Otsu method. We could explore integrating

Cluster	Authors name	Name of documents	Citation	Pertinent theme
5	Inoue et al [38].	Deployment-conscious automatic surface crack detection	17	“An unsupervised methodology for structural crack recognition utilizing genetic programming and percolation methods.
	Mubashshira et al [39].	An unsupervised approach for road surface crack detection	17	
	Oliveira et al [40].	Road surface crack detection: improved segmentation with pixel-based refinement	136	
	Qu (2018) et al [41].	Concrete surface crack detection with the improved pre-extraction and the second percolation processing methods	22	
	Qu (2019) et al [42].	The algorithm of concrete surface crack detection based on genetic programming and percolation	32	
	Quan et al [43].	The method of road surface crack detection by the improved Otsu threshold	40	
	Rau (2017) et al [44].	Bridge crack detection using multi-rotary UAV and object-based image analysis	28	
	Zhang (2021) et al [45].	Implementation of surface crack detection method for nuclear fuel pellets guided by the convolutional neural network.	9	

multiple technologies, real-time deployment, and enhancing adaptability to diverse conditions for innovative research work.

Table 10: Fifth Pertinent Theme Genetic

Cluster 5, “An unsupervised methodology for structural crack recognition utilizing genetic programming and percolation methods, “highlights advanced methodologies like genetic programming, percolation, segmentation, and innovative technologies for effective crack detection across diverse surfaces and structures. The table investigates automatic surface crack detection with applications across various domains, such as concrete, road surfaces, bridges, and nuclear fuel pellets. Primary themes emphasize improved accuracy, deployment-conscious designs, and

innovations in unsupervised methods for crack detection. The table has eight authors' publications, all citing a theme as a genetic method.

Table 11: Sixth Pertinent Theme Laser Scanning Thermography

Cluster	Authors name	Name of documents	Citation	Pertinent theme
6	Geng (2022) et al [46].	Non-destructive surface crack detection of laser-repaired components by laser scanning thermography	9	A technique approach for surface crack detection in carbon fiber reinforced plastics using pulsed eddy current testing and laser spot thermography.
	Shi et al [47].	A technique combining laser spot thermography and network for surface crack detection laser engineering net shaping	30	
	Wu (2014a) et al [48].	Surface crack detection for carbon fiber reinforced plastic using pulsed eddy current based on rectangular different probe	17	
	Wu (2014b) et al [49].	Surface crack detection for carbon fiber-reinforced plastic (CFRP) materials using pulsed eddy current testing	18	

Cluster 6, “A technique approach for surface crack detection in carbon fiber reinforced plastics using pulsed eddy current testing and laser spot thermography, “focuses on an innovative approach to analyzing image-based methods for detecting and classifying cracks on the civil structure. This category groups together research efforts focusing on detecting surface cracks using advanced techniques, particularly for materials like carbon fiber-reinforced plastics (CFRP) and laser-repaired components. These studies explore innovative and non-destructive testing methods to identify cracks efficiently and accurately. The table is divided into four entries, each representing a document, its author(s), citation count, and the specific theme it addresses.

Table 12: Seventh Pertinent Theme Advanced methods in crack detection

Cluster	Authors name	Name of documents	Citation	Pertinent theme
	Chanda et al [50].	Automatic bridge crack detection –a texture	34	Automatic crack detection based on

7		analysis– based approach		infrared thermography and texture analysis
	Li(2020a) et al [51].	Surface crack detection in pre-casted slab track in high-speed rail via infrared thermography	26	

Cluster 7, “Automatic crack detection based on infrared thermography and texture analysis, “Focuses on an innovative approach to evaluating

image-driven crack detection and classification for civil applications. bridge crack detection and complement it with texture analysis to automate the process. rail track inspection, showing how thermal imaging can be tailored to the unique requirements of rail systems. This paper develops an automated system for detecting bridge cracks by integrating infrared thermography with texture analysis. The approach analyses surface patterns and thermal responses to identify cracks effectively.

Conclusion

This work conducted a bibliometric analysis on image-driven methods for civil structural monitoring, crack detection, and classification using R-Studio and VOS-viewer. In this research work, input is Scopus database information for the last 10 years to understand analysis, visualization, and constructing bibliometric networks in the fields’ advancement and present state of the research work. We identified certain research gaps. The research gap needs to be filled to advance image-based crack detection systems.

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