

Tracking the research landscape of Infrared Thermography in Architectural Heritage: A Data-Driven View

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Abstract – The research landscape of international studies on the use of infrared thermography (IRT) as a non-destructive diagnosis tool for architectural heritage is analysed through a bibliometric study. The article examines various facets like the temporal trend of publications, the most prominent research fields engaged in the work, the scientific output by institution and country as well as the hot topics. Some preliminary deductions are subsequently drawn. The paper can be of interest for researchers and practitioners who work on non-destructive testing (NDT) for architectural heritage. It can also be helpful for planning future study or cooperation activities.

I. INTRODUCTION

Within the field of NDT, infrared thermography is as an essential tool for the investigation of buildings and has been widely utilized in cultural heritage research [1-3]. IRT is considered in the reconstruction of the historical growth of artefacts, study of construction methods, and relationship of their state of conservation with the materials involved. Significantly, thermographic examination makes possible the discovery of differential thermal responses due to conductivity and heat capacity differences among materials found in the first few centimetres of walls. These differences, i.e. the comparison of how different materials such as wood, brick, stone, and mortar react under thermal tension, can effectively be rendered visible with the thermal "imprints" they cast upon the overlying plaster surface, hence identifying concealed construction features as well as areas of potential interest.

This article makes use of a bibliometric study to examine and critically analyse the trends, evolution, and scientific panorama concerning the use of IRT for investigating architectonic heritage. In detail, the study aims to systematically chart the available literature, the research areas, the publication typologies, the most productive countries and institutions, and the hot issues. Bibliometric studies, have steadily gained traction across a wide array of disciplines, including medicine, economics, chemistry, biology, engineering, geography, and earth sciences. The

primary objective of these investigations is to delve into the evolution of research over time and to pick up on subtle patterns and emerging directions that may shape future scholarly inquiry [4-6]. The findings of this study may also encourage the scientific community to set up and strengthen interdisciplinary and transdisciplinary research networks, thereby helping to sustain and enhance the competitiveness of research initiatives within increasingly complex and dynamic international contexts.

II. DATA AND METHODOLOGY

With the aim of retrieving the relevant records pertinent to the research aims, the Scopus database was chosen. Scopus is amongst the world's largest and most comprehensive multidisciplinary databases of peer-reviewed scientific publications, covering more than 22,000 journals published by nearly 5,000 publishers worldwide, as well as books, conference papers and patents. The platform covers more than 330 disciplines and contains content in more than 40 languages offering powerful tools to analyse and visualize global research output (<https://www.elsevier.com/products/scopus>, accessed, 12 May 2025).

To capture the scope and the in-depth exploration of the research topic necessitated the systematic identification and selection of a range of precise search terms. These terms were used to search across a range of fields: titles, abstracts and keywords of the indexed documents to have a full coverage of the available literature and to reduce the risk of missing relevant research. The query used was (TITLE-ABS-KEY ("infrared thermography" OR "IR thermograph" OR "thermal imag*" OR "infrared imag*" OR "IR imag*") AND TITLE-ABS-KEY ("heritage building" OR "built heritage" OR "architect* heritage" OR "historic* building" OR "cathedral" OR "church" OR "monumental building" OR "historic* architecture" OR "Temple" OR "bell tower" OR "castle"). To eliminate possible false positives and guarantee a clean dataset, the title and the abstracts of all the documents returned by the search were manually checked and evaluated. This step was adopted to check the alignment of the content of each document to the precise scope of the bibliometric research

to increase the overall validity of the review. The selection of papers to be included in the bibliometric assessment was implemented without any document type restrictions on document type, document publication date, document publication language and subject area, to maintain an all-embracing and all-encompassing analysis of the literature. Once the records were pulled out from Scopus, they were downloaded in *.csv format on May 8, 2025. A conventional analysis of the dataset (e.g., publication trends, subject categories), was carried out using Microsoft Excel. The co-occurrence term networks were worked out with VOSviewer software (version 1.6.16; [7]), which generates distance-based maps to visualize potential relationships between terms [8]. Finally, author productivity was analysed using “Bibliometrix” package (version 4.1.2) in R (version 4.2.3) [9].

III. RESULTS AND DISCUSSION

Publication trend

The total number of documents is 206. Temporal trend of scientific production (Fig.1) highlights an unprecedented rise in the number of articles throughout the period from 1991 to 2025.

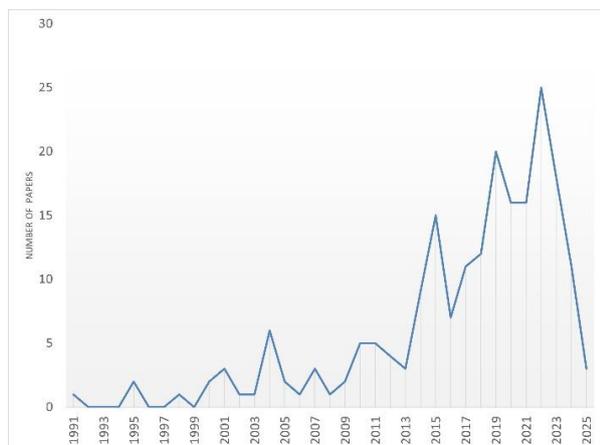


Fig. 1- Publication trend

During the period from 1991 to 2008, editorial activity maintained very low values with few articles, in the order of fewer than five documents annually, which indicates still minimal interest in the theme. Starting from year 2009, there is gradual recovery of activity, which became more intense since year 2015. This trend culminated in year 2022, the year with the greatest number of documents published (more than 25 documents), indicating growing scientific interest and potential enlargement of disciplinary applications. Conversely, values for year 2023 and 2024 show a drop which may be due to circumstantial factors, such as changes of priorities in research.

Subject categories

The thematic analysis (Fig. 2) highlights a clear prevalence of publications in the Engineering sector (23%), followed by Materials Science (14%) and Computer Science (12%), confirming the strong technical-scientific imprint of the studied domain. The remaining disciplines, including Physics, Mathematics, Earth Sciences, Environmental Sciences and Social Sciences, show a more limited but balanced presence, suggesting an interdisciplinary approach.

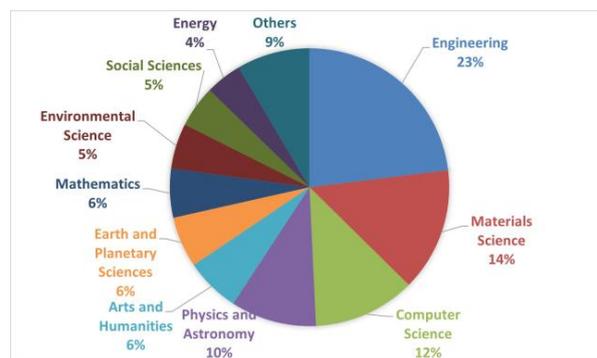


Fig. 2-Subject categories

Document typologies

The analysis of the distribution of publication types (Fig. 3) shows a clear prevalence of articles (62%), followed by conference papers (31.1%). The remaining categories — book chapters (4.4%), reviews (1.9%), data papers (0.5%), and short surveys (0.5%) — represent a marginal fraction of the total.

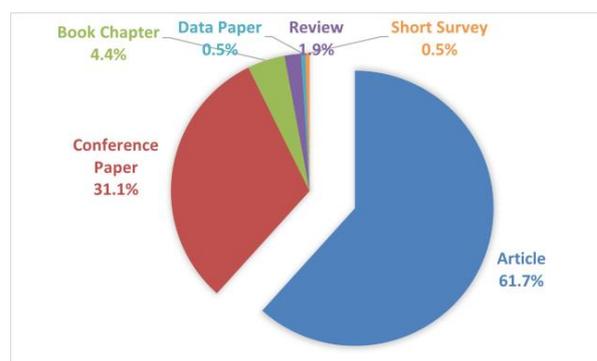


Fig. 3-Document typologies

Country contribution

The geographical distribution of scientific production (Fig. 4) highlights a clear predominance of Europe, which contributes the majority of publications, led by Italy (83 documents, 33.0%). Asia shows a growing presence, albeit with lower volumes, while the Americas are less

represented compared to their traditional role. Africa and Oceania are almost absent. This heterogeneity suggests inequalities in terms of resources, infrastructures and access to international research networks, raising questions about the equity and inclusiveness of the global scientific system.

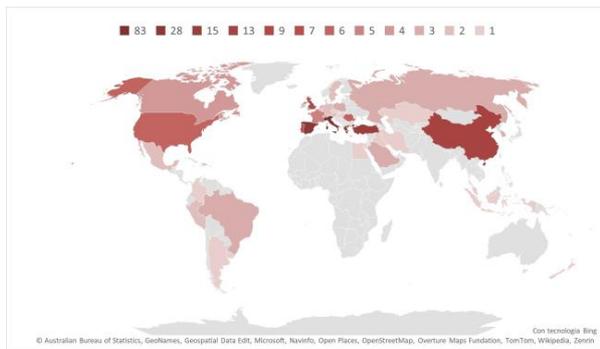


Fig. 4-Country contribution

Institution productivity

The analysis of data relating to the scientific production of 160 institutions shows a clear concentration of productivity in a small group of institutions. Only 13 institutions have published at least 5 articles (Fig. 5). At the top of the list are the Italian National Research Council (20 articles), the Polytechnic of Milan (16) and the National Technical University of Athens (14), followed by other European technical and university centers. This small group of institutions, although numerically limited, represents the hub of the research.



Fig. 5-Productivity of the most prolific institutions

Their high productivity suggests a strong involvement in structured projects, international collaborative networks and the ability to attract funding. On the contrary, the majority of institutions show a reduced production (with 93 institutions having only one article to their credit), outlining a fragmented panorama in which a few entities

drive the overall production.

Authors

679 are the authors involved in total. As per Lotka's Law explaining the inverse square distribution of productivity in science, most authors are 'occasional,' having written a single paper only, and a few 'core' authors produce numerous publications (Fig. 6). The author's production over time of the most productive authors is reported in Fig. 7. An increase in productivity is noted between 2014 and 2021.

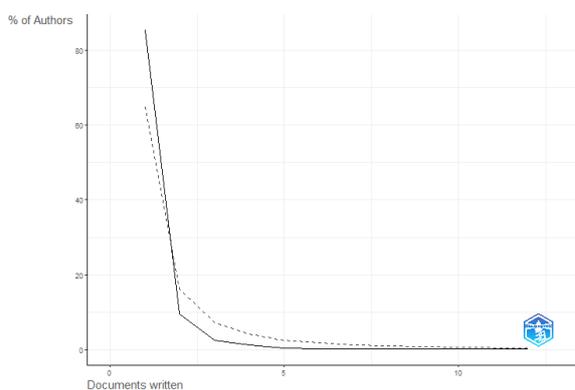


Fig. 6- Author productivity through Lotka's Law. The dotted line refers to the theoretical distribution.

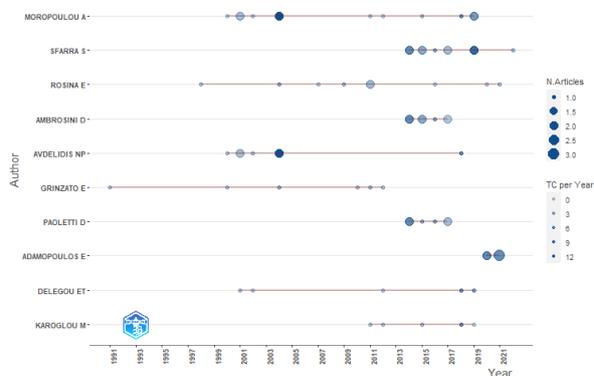


Fig. 7- Publication trends of the 10 most prolific authors (TC=Total Citations)

Co-occurrence term maps and hot issues

To build the co-occurrence term map, noun phrases were extracted from the titles and abstracts of the selected documents. VOSviewer then sorted out these noun phrases by assigning a relevance score. For this study, we decided to single out the top 60% most relevant terms from among those noun phrases that appeared at least 5 times. In addition, to single out the most significant terms, we opted to make use of the thesaurus text file feature, which allows

users to merge different spellings of the same term as well as synonymous terms referring to a common concept (e.g., ‘IRT’ and ‘infrared thermography’) Finally, overly general or irrelevant words that might have slipped through the automated process were manually filtered out to refine the dataset further (e.g., ‘present work,’ ‘region’). The co-occurrence term map highlights three main clusters (Fig. 8).

Green cluster

The green cluster (Fig. 8) —the largest, comprising 61 words—focuses on the application of IRT in building diagnostics aimed at targeted conservation. This cluster highlights the use of IRT to pinpoint issues such as water infiltration, structural defects, damage, and the detachment of decorative elements or plaster. It also covers assessments related to air condensation risks, emphasizing IRT’s versatility in preventive conservation strategies.

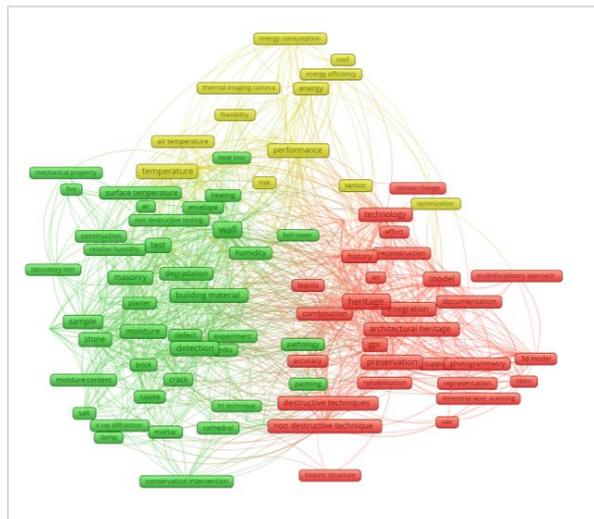


Fig. 8- Co-occurrence term map (network visualization)

The rising damp generally correlates with the occurrence of water infiltration and migration phenomena, which spread throughout large sections of heritage buildings, leading to noticeable damage such as surface material loss, micro-cracks, and white salt efflorescence [10-11]. To tackle these issues more efficiently, researchers have come up with automated techniques for detecting moisture in historical structures, paving the way for streamlining inspection processes and optimizing decision-making in conservation strategies [12]. An innovative active thermographic procedure has also been put forward and tested under laboratory conditions, aiming to assess moisture levels through a non-destructive approach [13]. Some authors have laid out a novel method to estimate key environmental parameters, such as air temperature, relative humidity, and velocity, by drawing on thermographic readings [14]. Furthermore, to mitigate

moisture-related deterioration, the risk of condensation on heritage surfaces has also been investigated. Researchers have determined thermal properties such as emissivity and albedo, as well as Blinn–Phong BRDF values, through the combined use of thermal imaging and 3D scanning techniques [15]. Concerning damage detection, researchers have turned to some solutions, putting forward CNN-based algorithms capable of automatically detect cracks and damage in thermal infrared imagery [16]. To dig deeper into wall subsurface, a hybrid thermographic (HIRT) method has also been introduced, which brings together temporal analysis and solar excitation to draw out quantitative data, including defect depth [17]. Other field in which IRT has been used refers the early identification of microbial biofilms on limestone, enabling timely and non-invasive interventions [18].

Red cluster

The red cluster (Fig. 8), consisting of 38 terms, concerns the integration of IRT with other technical tools like photogrammetry, laser scanning, UAVs, and ground-penetrating radar (GPR) for three-dimensional (3D) recording and modelling of architectural heritage. Thus, this cluster highlights a multidisciplinary expression of cultural heritage knowledge. The datasets resulting from the use of these technologies frequently incorporated into digital reconstructions or Historical Building Information Models (H-BIM), enabling detailed analysis and long-term monitoring of structural health [19-21].

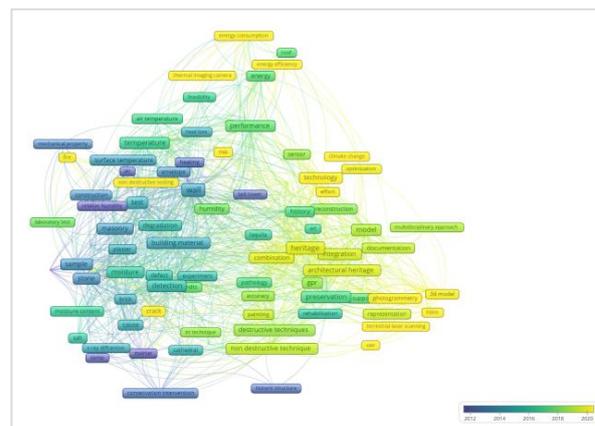


Fig. 9- Co-occurrence term map (overlay visualization). The terms in yellow are the most recent.

As shown in the overlay visualization (Fig. 9, terms in light green and yellow), this integrated use of thermography within a broader, multidisciplinary framework marks a recent and methodologically advanced evolution in the field of heritage conservation.

Yellow cluster

The yellow cluster (Fig. 8), comprising 18 terms, encapsulates a key research theme centred on the use of

IRT as a non-invasive diagnostic technique for assessing the thermal performance and energy consumption of historical buildings. As we can see, at its core this strand focuses on the integration of thermographic analysis with energy conservation strategies, aiming to enhance the efficiency of heritage structures while preserving their architectural authenticity. This approach is especially pertinent in the context of global climate change, which demands a critical and forward-looking assessment of how historic buildings can adapt and remain resilient in a changing environment. For instance, a combination of software tools and onsite equipment, such as thermal imaging cameras and data loggers, has been employed to monitor the physical conditions of buildings, particularly their thermal performance [22]. Other studies have investigated the effectiveness of energy efficiency measure (EEMs) packages by integrating infrared thermography with building simulation models [23]. Further research has put forward tailored sets of interventions to improve energy efficiency and reduce consumption, based on a detailed analysis of thermal transmittance rates, temperature and humidity data, and infrared thermal images [24]. Litti et al. (2015) introduced a method designed to assess, in situ, the thermal performance of traditional masonry buildings and quantify the extent of its deterioration due to variations in moisture distribution [25]. Additional research has delved into the behavior of traditional solid walls, particularly examining the impact of internal insulation on their hygrothermal performance using a combination of heat flux sensors (for U-value measurements), thermal imaging surveys, and interior wall temperature monitoring [26].

IV. CONCLUSIONS

This study highlights the accelerating scientific interest in IRT as a key non-destructive diagnostic technique in architectural heritage research. The marked increase in publications from around 2015 onwards is indicative of increased interest and research innovation in the subject. Geographically, the studies are centred in Europe with a prominent role by Italy, but global involvement is uneven. The thematic groups identified from conservation diagnostics to energy performance evaluations demonstrate IRT's utility and changing function in the conservation of built heritage. Refinement of methods and increased international collaborative work are necessary to promote inclusivity and enhance the sustainable management of historic buildings.

Like all bibliometric studies, this work has some limitations. It may have missed relevant articles due to incomplete search queries and the results depend heavily on the database used, possibly excluding important works like grey literature or non-English publications. Finally, focusing on metrics like publication and citation counts can overlook the actual depth or societal value of the research, leading to potentially misleading deductions.

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