BIBLIOMETRIC ANALYSIS ON THE TOPIC OF EMBEDDED SYSTEMS: A PRACTICAL APPROACH

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ABSTRACT: The present work aims to carry out a bibliometric analysis on the field of embedded systems, with the aim of highlighting the major research trends, the geographical distribution of publications, collaboration networks and the main technological directions. The study is based on a data set extracted from international scientific databases (such as Web of Science and Scopus), applying quantitative methods of analysis of publications, citations and associated keywords. The results obtained indicate a significant increase in interest in embedded systems in the last two decades, correlated with the development of IoT, smart applications and artificial intelligence technologies. The countries and institutions with the highest impact in the field are also identified, as well as journals and conferences with increased visibility. By mapping the field, this paper contributes to understanding the structure and dynamics of research in embedded systems, providing a useful perspective for both researchers and practitioners in defining future development directions.
KEYWORDS: Bibliometric analysis, Embedded Systems, VOSviewer, Web of Science, Scopus

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1. INTRODUCTION

Bibliometric analyses describe and evaluate scientific activity by applying quantitative methods to bibliographic metadata (such as publications, citations, authorship, and keywords). A popular framing separates scientific mapping, which uses network and clustering techniques to show the conceptual, intellectual, and social structure of a research field, from performance analysis, which measures productivity and impact (e.g., citations, h-index, top sources). Citation-based and text-based methods like citation analysis, co-citation analysis, bibliographic coupling, co-authorship analysis, and co-word/keyword co-occurrence analysis are frequently used in science mapping. When combined, these methods enable researchers to identify knowledge bases, research fronts, collaboration communities, and thematic clusters. A significant trend since 2015 has been the growing application of bibliometrics as a field-level evidence synthesis technique, frequently in conjunction with systematic review logic (search methods, screening criteria, reproducibility) to lessen the selection bias common to solely narrative reviews. By bringing bibliometric research into line with the open reporting and selection processes frequently used in evidence synthesis, this hybridisation has increased their legitimacy [1].

The confluence of low-power microcontrollers, omnipresent sensing, and networked computation across industries like automotive, healthcare, industrial automation, and smart cities has fuelled the growth and diversification of embedded systems research over the last fifteen years. Bibliometric analysis, which uses publication metadata to track output growth, collaboration networks, conceptual clusters, and citation effect, has become a typical secondary-study technique to map and quantify this evolution. Reproducible science mapping across major indexes (Scopus, Web of Science) and even OpenAlex is now possible thanks to mature toolchains (e.g., Bibliometrix in R and VOSviewer) and PRISMA-aligned workflows that support performance analyses, co-authorship/co-citation networks, and keyword co-occurrence for trend detection [2].

Since 2010, the Internet of Things (IoT) and Cyber-Physical Systems (CPS), which combine sensors/actuators and real-time computation with networked services, have been a major theme stream connecting embedded research. Co-citation and co-occurrence analyses reveal clusters around Industry

4.0, analytics, cloud/edge integration, and security; bibliometric and scientometric studies consistently demonstrate sustained growth in CPS/IoT publications, with manufacturing/supply-chain CPS and industrial IoT emerging as high-impact application areas. CPS definitions, architectures, and testbeds are further formalised by foundational position papers and standards work, highlighting the embedded nature of CPS and its dependence on reliable computing and communication [3][4].

After 2014, edge computing in IoT-centric embedded systems increased dramatically, with bibliometric syntheses reporting "dizzying" increases in output and future lines of inquiry focused on big data, energy efficiency, and frameworks; network analyses highlight dominant venues (IEEE/ACM) and topic communities around AI at the edge, data management, and latency-sensitive control. Even as AI-enabled edge designs become more prevalent, this acceleration continues into the 2020s, with more detailed bibliometrics on edge preprints and theme modelling exposing gaps in security (under-represented) and real-world evaluation [5][6].

A second important stream is safety-critical and real-time embedded systems, where hard real-time guarantees (WCET), reliability under fault models, and certification compliance (e.g., ISO 26262, DO 178C, IEC 61508) are highlighted in bibliometric and review-type research. Mixed-criticality scheduling, formal verification/model-based engineering, and RTOS advancements (FreeRTOS, QNX, VxWorks) are identified as key subjects in related surveys and research syntheses for the years 2010–2025, with ongoing focus on security flaws and system resilience. Industrial IoT cybersecurity bibliometrics, which identify clusters linking "embedded systems" with CPS, "network security," and blockchain-oriented approaches—while also noting a recent shift towards ML-driven intrusion detection—make the interaction between safety and connectivity especially evident [7][8].

The hardware/software co-design perspective covers embedded, edge, and CPS systems at the design-methodology level. Recent work revisits co-design in light of heterogeneous accelerators (GPUs/FPGAs), RISC-V, and AI-centric workloads, defining co-design as a path to performance, energy, and time-to-market optimisation in embedded deployments, despite the fact that foundational co-design literature predates 2010. A baseline panorama is provided by earlier systematic mappings specific to embedded software (e.g., mobile robotics and embedded software engineering circa 2010–2012), which highlight persistent gaps (e.g., architectural representations and lifecycle integration) and demonstrate growing interest in applying software engineering processes to embedded contexts [9][10].

A popular piece of software for creating, displaying, and investigating bibliometric networks obtained from scientific literature is called VOSviewer. Based on bibliographic data exported from large databases (e.g., Web of Science, Scopus) or accessed via APIs, the software allows researchers to map relationships among entities like publications, authors, journals, institutions, and keywords. It also facilitates network construction using links like co-authorship, co-citation, citation, and term co-occurrence. Network, overlay, and density views are among the visualizations generated by VOSviewer that make it easier to identify structural patterns, collaboration clusters, and thematic trends within a research domain. Its sophisticated graphical rendering and user-friendly interface are especially helpful for clearly and understandably representing large bibliometric maps. To preprocess bibliographic datasets and create maps of co-authorship, co-citation, and keyword co-occurrence, VOSviewer is frequently combined with complementary tools (like CiteSpace) in modern bibliometric protocols. This allows for thorough analyses of research landscapes and intellectual structures within scientific fields [11][12][13].

2. “EMBEDDED SYSTEMS” BIBLIOMETRIC ANALYZES KEYWORD

For the bibliographic research, the Web of Science (WoS) database was utilized. A bibliographic search was conducted using the compound keyword “Embedded systems” for the period 2010–2025. The retrieved datasets were exported from WoS and subsequently analysed using the bibliometric analysis software VOSviewer (VOSviewer, 2025), version 1.6.20. The number of records exported from WoS for bibliometric analysis is presented in Table 1.

Table 1. Number of papers subjected to bibliometric analysis

keyword	Number of papers	Period
”embedded system”	10196	2010-2025

Using the "Full Record and Cited References" option, the records were extracted as "Tab Delimited Files," guaranteeing a complete dataset that includes all relevant information and citation lists.

Since the term "embedded system" appears more than five times in the main Web of Science (WoS) database, it was included in the study. 1,430 of the 24,815 keywords that were found satisfied the requirement of five occurrences.

The co-occurrence network of keywords in articles about embedded systems is shown in Figure 1. Each node's size indicates how frequently the associated keyword appears. "Embedded system" (total link strength of 6,393), "embedded systems" (plural form of the same concept, total link strength of 1,916), "FPGA" (Field-Programmable Gate Array, total link strength of 1,222), "design" (total link strength of 1,251), and "deep learning" (total link strength of 832) were the most frequently occurring keywords.

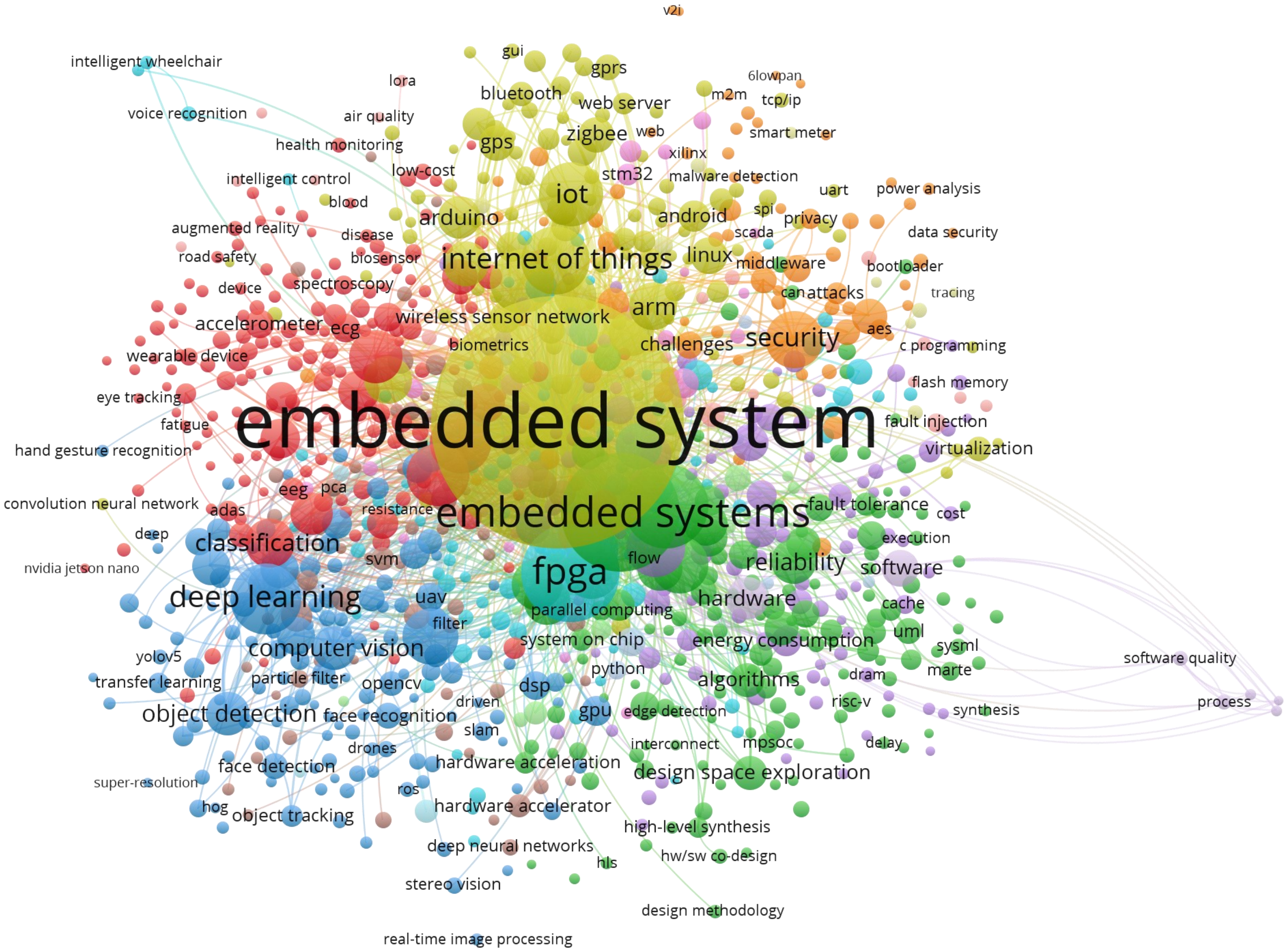

Figure 1. Bibliometric analysis of keywords in publications on "embedded systems". Co-occurrence of keywords (Generated by VOSviewer [13])

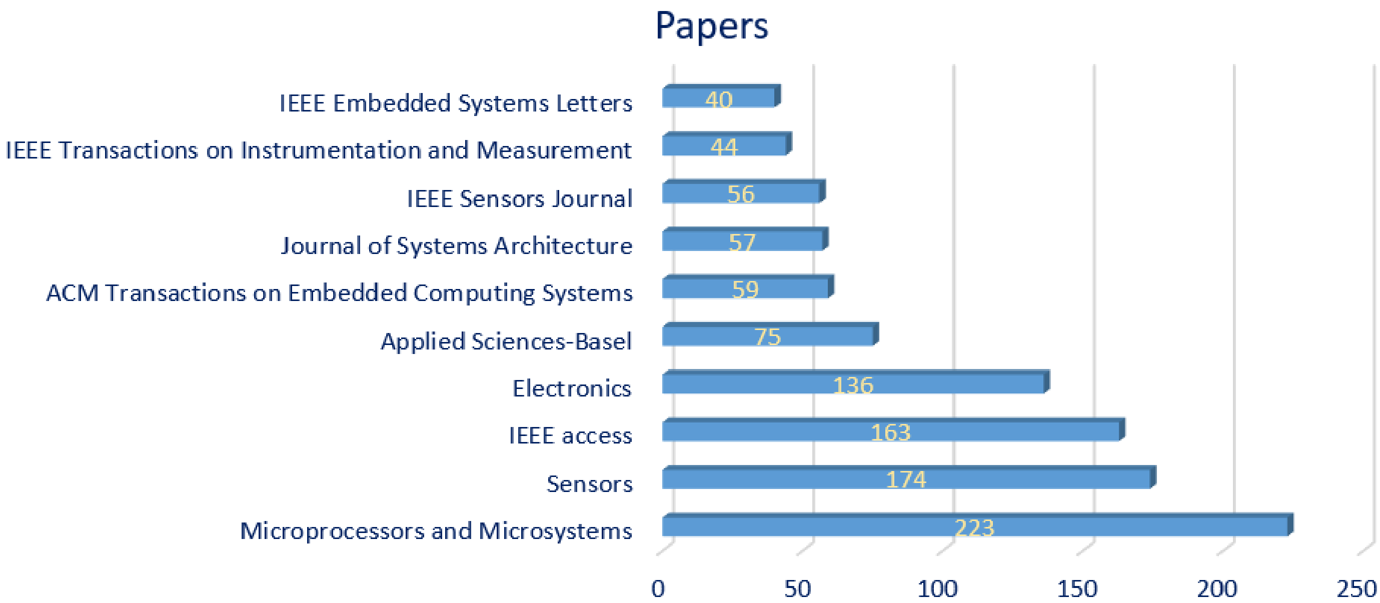

Figure 2. The most active Top 10 journals. Journals with the most published papers in the field of "embedded systems" (data extracted by VOSviewer [13])

Research on “embedded systems” has been published in 5,359 journals, 242 of which have published more than five papers. According to publications indexed in the main WoS database, a total of 1,027 papers were published in the ten most active journals.

The 10 most active journals in embedded systems are shown in Figure 2. With 223 articles published, Microprocessors and Microsystems was the top-ranked publication. On the other hand, with 2,273 citations, IEEE Access was the journal with the highest number of citations (Fig. 3).

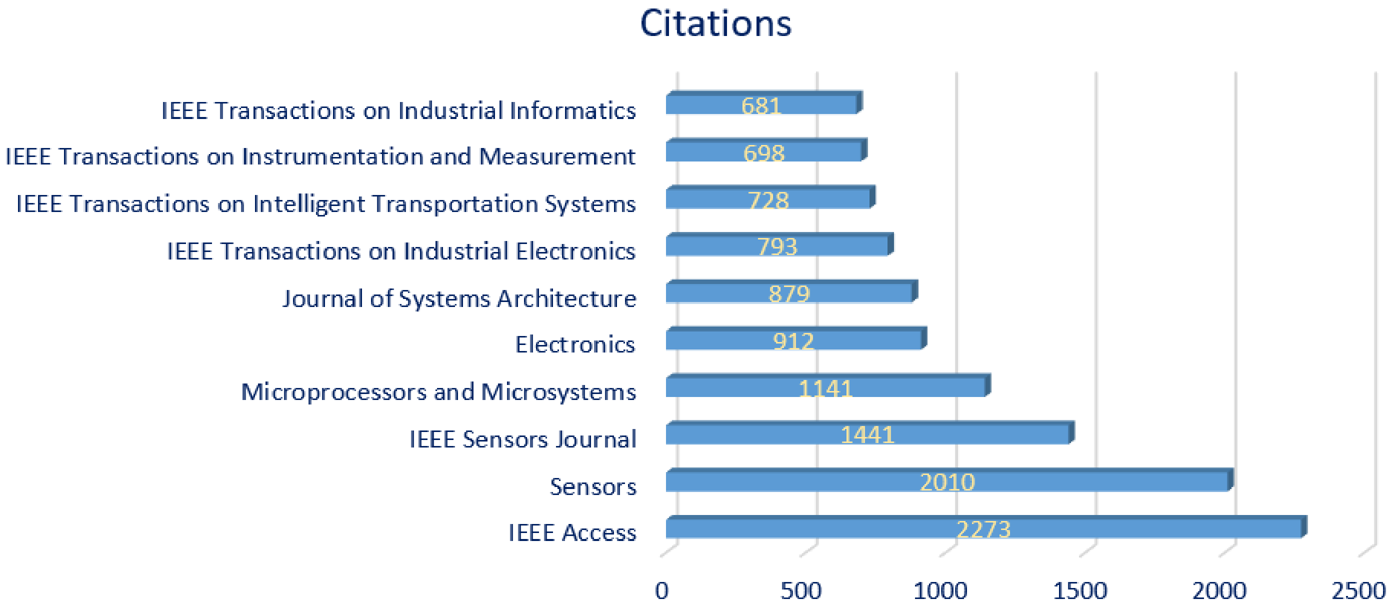

Figure 3. The most active Top 10 journals. Journals with the most cited papers in the field of "embedded systems" (data extracted by VOSviewer [13])

Tables 2, 3, and 4 list the top ten nations, organisations, and authors with the most research activity on the subject of "embedded systems." Kyungpook National University's Daejin Park is one of the individual contributors, having written 26 works that have received 81 citations. The Chinese Academy of Sciences generated 123 articles that were mentioned 603 times at the institutional level. China is the top country, with 2,428 papers with 11,306 citations.

Table 2. The top ten most active countries in the field of "embedded systems"

Country	Number of papers	Number of citation
Peoples R China	2428	11306
USA	1081	13491
India	950	4842
South Korea	541	4247
Taiwan	509	2995
Germany	458	3396
France	447	3255
Italy	427	4407
Brazil	354	1820
Spain	267	2356

Table 2 summarizes the top ten countries contributing to research on “embedded systems” within the broader context of embedded systems. China leads the ranking with 2,428 publications and 11,306 citations, reflecting its dominant role in this research domain. The United States follows with 1,081 papers but surpasses China in citation impact, accumulating 13,491 citations, indicating higher average influence per publication. India ranks third with 950 papers and 4,842 citations, highlighting its growing presence in embedded systems research. South Korea and Taiwan occupy the fourth and fifth positions, with 541 and 509 publications respectively, both demonstrating strong regional engagement. European countries such as Germany, France, Italy, and Spain also feature prominently, collectively contributing significant scholarly output and citation impact. Brazil completes the top ten with 354 papers and 1,820 citations, underscoring the global distribution of research efforts in this field.
The graphical distribution of Citation-Countries in the "embedded systems" field is shown in Figure 4.

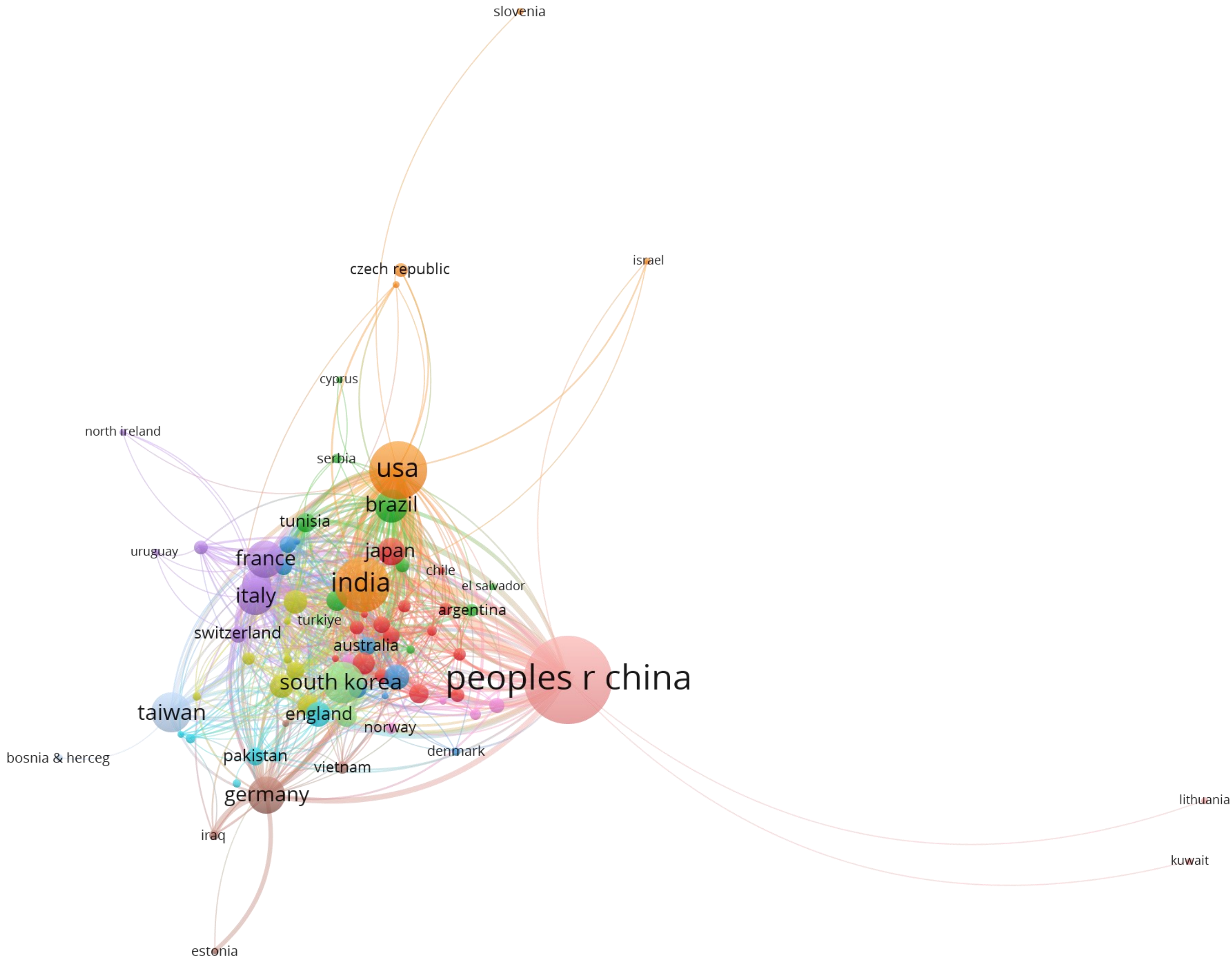

Figure 4. Citation-Countries in the field of "embedded systems" (Generated by VOSviewer [13])

Table 3. The top ten most active organizations in the field of "embedded systems"

Organization	Number of papers	Number of citation
Chinese Acad Sci	123	603
Beihang Univ	81	355
Tsinghua Univ	72	902
Zhejiang Univ	57	450
Harbin Inst Technol	50	347
Kyungpook Natl Univ	47	179
Malardalen Univ	46	183
Natl Cheng Kung Univ	46	421
Politecn Torino	43	277
Seoul Natl Univ	43	426

The top ten organisations involved in "embedded systems" research are listed in Table 3. With 123 publications and 603 citations, the Chinese Academy of Sciences is ranked #1, demonstrating its dominant position in this field. Tsinghua University is notable for its impact on citations, with 902 citations from 72 articles, while Beihang University comes in second with 81 papers and 355 citations. Strong participation from Chinese institutions may be seen in the contributions of Zhejiang University (57 papers, 450 citations) and Harbin Institute of Technology (50 papers, 347 citations). With 47 and 46 articles, respectively, Kyungpook National University (South Korea) and Mälardalen University (Sweden) rank among the top contributors worldwide. The list is completed by Seoul National University (South Korea), Politecnico di Torino (Italy), and National Cheng Kung University (Taiwan), all of which have substantial scholarly production and citation effect. These findings demonstrate the global dispersion of embedded systems competence as well as the dominance of Chinese research institutions.

The graphical distribution of Citation-Organizations in the "embedded systems" field is shown in Figure 5.

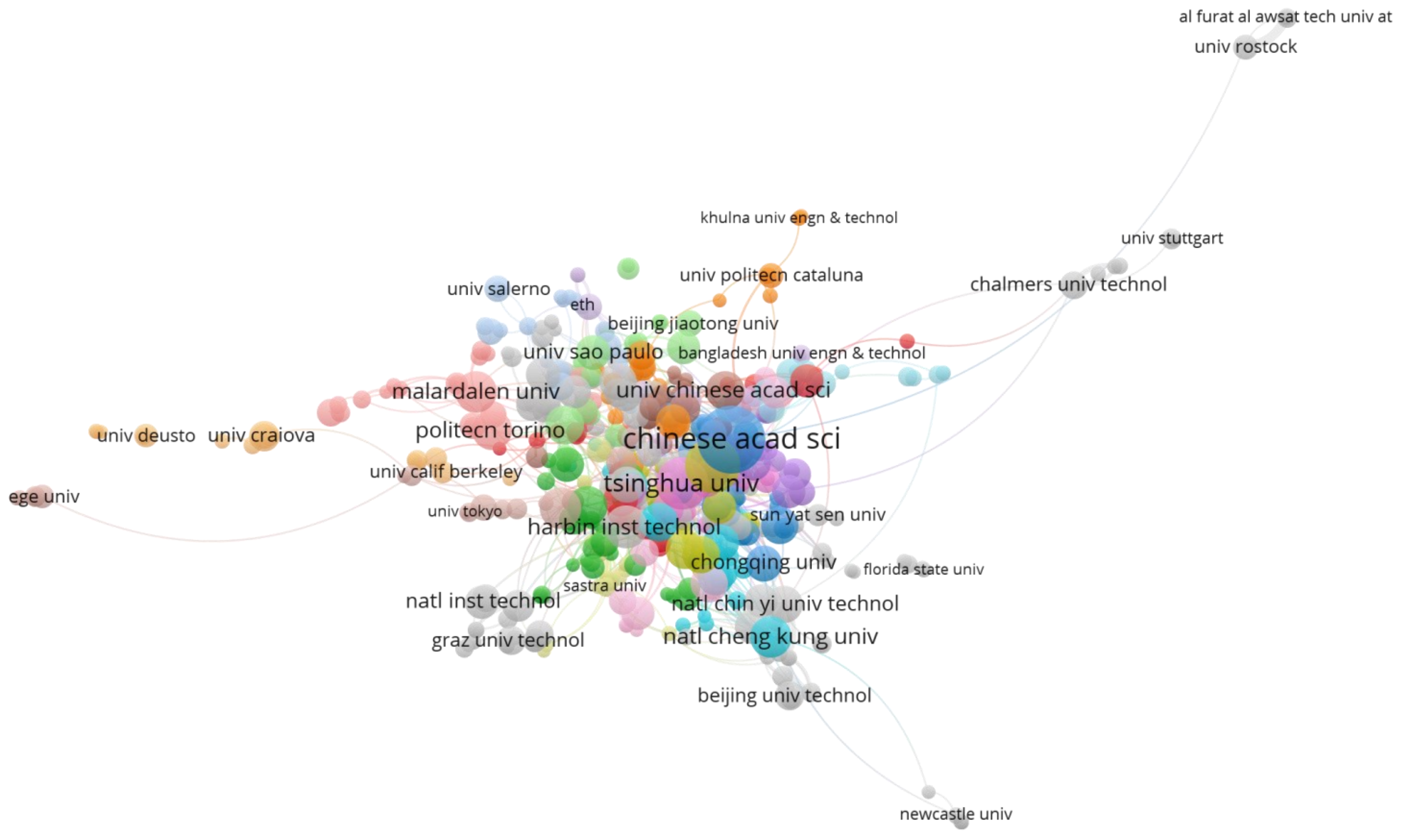

Figure 5. Citation-Organizations in the field of "embedded systems" (Generated by VOSviewer [13])

Table 4. The top ten most active authors in the field of "embedded systems"

Author	Number of papers	Number of citation
Parkz Daejin	26	81
Khalgui, Mohamed	23	174
Benini, Luca	22	247
Din, Sadia	19	1
Lee, Seung Eun	19	76
Wang, Xiang	18	58
Guo, Jiun-In	15	53
Lysecky, Roman	15	90
Jeon, Jae Wook	14	57
Mosbahi, Olfa	14	109

The top ten authors in the topic of "embedded systems" are shown in Table 4. Daejin Park is the most productive, with 26 articles and 81 citations. Luca Benini stands off for citation impact with 247 citations from 22 publications, indicating strong influence in the field, while Mohamed Khalgui comes in second with 23 papers and 174 citations. Seung Eun Lee (19 papers, 76 citations), Xiang Wang (18 papers, 58 citations), and Sadia Din (19 papers) are more noteworthy contributors. Both Roman Lysecky and Jiun-In Guo wrote 15 papers, with Lysecky receiving 90 citations. Jae Wook Jeon (14 papers, 57 citations) and Olfa Mosbahi (14 papers, 109 citations) round out the list. These findings show a combination of high production and varying citation impact, with some authors exhibiting significant effect in relation to the number of publications.

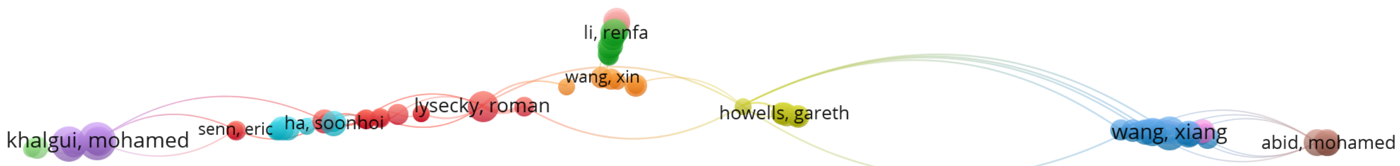

Figure 6. Citation-Authors in the field of "embedded systems" (Generated by VOSviewer [13])

The graphical distribution of Citation-Authors in the "embedded systems" field is shown in Figure 6.

3. CONCLUSIONS

Using information taken from the Web of Science database and examined using VOSviewer, this study has provided a thorough bibliometric analysis of embedded systems research conducted between 2010 and 2025. The findings unequivocally show that scientific output in this area has been steadily and rapidly increasing, confirming the important part that embedded systems play in the wider development of digital technologies like edge computing, cyber-physical systems (CPS), artificial intelligence, and the Internet of Things (IoT). Both technological maturity and growing application domains—from industrial automation and automotive systems to healthcare and smart infrastructure—are reflected in the rising number of publications and citations.

A significant conceptual convergence between embedded systems and new technologies—specifically, FPGA-based design, deep learning, real-time processing, and system-level design methodologies—is highlighted by the keyword co-occurrence analysis. These results show that diverse, intelligent, and networked systems are replacing conventional standalone embedded platforms. According to Wolf's groundbreaking work on embedded system design problems and opportunities, these trends align with earlier foundational research that emphasised the transformation of embedded systems into networked and adaptive computing entities [14]. This evolution is further supported by more recent research, which positions embedded systems as essential facilitators of CPS designs and real-time intelligent control [15].

The analysis shows a highly globalised research ecosystem from an institutional and geographic standpoint. The United States continues to have the highest citation impact, indicating significant scientific influence and visibility, but China emerges as the most prolific contributor in terms of publication volume. Strategic national investments in embedded and intelligent systems research are reflected in the dominance of leading universities and research institutions, especially from China, Europe, and East Asia. The preponderance of publications in Elsevier and IEEE-indexed journals at the journal level highlights the field's technical and engineering focus. The author-level study reveals a combination of high productivity and high impact contributors, indicating that both larger collaborative networks and ongoing individual research programs are beneficial for embedded systems research. This finding is consistent with other bibliometric and survey-based research that highlights the collaborative and interdisciplinary nature of embedded systems engineering, particularly when it comes to real-time constraints, energy efficiency, and safety-critical applications [16]. The bibliometric patterns found in this study point to a number of interesting avenues for further investigation. These include hardware-software co-design for heterogeneous architectures like RISC-V and FPGA-accelerated systems, security and resilience in networked embedded devices, energy-conscious and sustainable system design, and AI-enabled embedded platforms. Supporting next-generation embedded applications at the edge and in safety-critical domains would require tackling these issues, according to recent survey and roadmap publications [17].

In conclusion, the bibliometric analysis offers researchers, practitioners, and policymakers a useful reference framework by charting the intellectual framework, significant contributors, and thematic development of embedded systems research. The results promote well-informed decision-making and future innovation in the embedded systems field by documenting historical and contemporary trends as well as identifying new research needs and strategic opportunities.

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