Exploring Research Trends in Distributed Acoustic Sensing with Machine Learning and Deep Learning: A Bibliometric Analysis of Themes and Emerging Topics

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***Abstract*—This paper explores the emerging research trends in Distributed Acoustic Sensing (DAS) with the integration of Machine Learning and Deep Learning technologies. DAS has diverse applications, including subsurface seismic monitoring, pipeline surveillance, and natural disaster detection. Using the Scopus database, 323 documents published between 2011 and 2023 were analysed. Through a comprehensive bibliometric analysis using the "bibliometrix" R package, the study aims to document the advancement in DAS techniques over the last decade, highlighting the publication patterns, key contributors, and frequently explored themes. The analysis reveals a steady increase in research output, with significant contributions from China and the United States. Core research areas identified include seismic monitoring, pipeline security, and infrastructure health monitoring. Additionally, the paper examines the impact of key publications, influential authors, and prolific research institutions. The findings provide valuable insights for both academic and industrial stakeholders, underscoring the potential for future innovations in DAS applications and helping to identify potential research gaps.**

Keywords*—Machine learning; deep learning; distributed acoustic sensing; bibliometric

I. Introduction

Distributed Acoustic Sensing (DAS) is a novel tool in array seismology technique that detects the phase of backscattered laser pulses as they move across fiber-optic cables and correlates the measurement to the axial strain that a seismic wavefield's propagation causes to the cable [1]. DAS technology exploited the optical fiber to measure vibrations or sound that can be detected over the long range of cable [2]. DAS is also known as Coherent Optical Time-Domain Reflectometry, Distributed Vibration Sensing, phase-sensitive Optical Time-Domain Reflectometry or Coherent Optical Frequency-Domain Reflectometry. It has several interesting applications for example subsurface seismic monitoring [3], high-speed railway intrusion detection [2], pipeline monitoring [4], and linear infrastructures such as tunnels and pipelines [5]. Besides, DAS recordings also captured a wide range of seismic signatures, including those from anthropogenic and natural events like mining blasts, automobiles, concerts, and walking steps, as well as natural phenomena like earthquakes and thunderstorms [6].

DAS technology consists of several methods that utilise the effects of light-matter interaction to transform the fibre into a distributed sensor. The scattered light in the optical fiber has been utilised as the information carrier to sense and transfer the changes in external physical quantities. In an optical fibre, Raman, Brillouin, and Rayleigh scattering all contribute to the light that is scattered [7], [8]. The distributed acoustic sensing methods are based on the Rayleigh scattering which have been widely utilized in several applications [7], [9]. It is due to the uniqueness and advantages such as high spatial resolution, wide sensing bandwidth, and long-distance detection [7].

In the recent decade, DAS has been one of the most attractive and promising fiber-optic sensing technologies as it can identify and retrieve the various vibrations over a long distance and high sampling rate supplies abundant information of the surrounding [10]. Although several studies summarize distributed acoustic sensing techniques, most focus on recent advancements and scientific applications of DAS. Primarily, it covers most areas of human activities such as geophysics, culture, engineering, applied mechanics [11] as well as the natural events like earthquakes [1]. Limited studies exist that have concentrated on the published research on the development of DAS techniques. This study is contrasting to the other studies as it employs bibliometric methods for documenting the published research on the advancement of DAS techniques. As an addition to the domain of development for DAS technologies, this study adopts bibliometric analysis using "bibliometrix", an open-source tool for R package. It is used to analyse the existing literature on the development of DAS technologies.

Bibliometric analysis is an analysis on academic papers to explore for trend and pattern [12]. The use of mathematical and statistical techniques to evaluate the quantity and quality of published scientific literature, as well as to investigate research trends, authorship, citation analysis, the impact of publications, journal analysis, and patterns of collaboration within a particular field, is known as bibliometrics [13], [14], [15]. According to Tovalino [16], at the institutional level, bibliometric studies are significant because they enable the identification and assessment of scientific performance to give precise and impartial information by critically analysing published works. Bibliometrics demonstrates its usefulness in managing enormous volumes of scientific data and its noteworthy contribution to the impact of research. This popularity can be attributed to several factors, such as the advancement, availability, and accessibility of scientific databases like Google

Scholar, Scopus, and Web of Science as well as bibliometric tools like R and VOSviewer [15]. There are five stages of standard workflow for science mapping in to proceed with bibliometric analysis that are, study design, data collection, data analysis, data visualization, and interpretation [17]. Bibliometric analysis is widely applied in various field for analysing the trend of publication including in biological soil crusts [18], health [12], [14], [16], maritime industry [19], tourism [20], and so on.

This study is aiming to discover the emerging topics and research trends in DAS by detecting rising keywords and offering insights into potential future directions of research in DAS technologies. This paper used a bibliometric analysis of scientific literature review to answer the following research questions (RQ) based on the published research on DAS technologies:

RQ1: What is the annual pattern of the publication trends?

RQ2: What are the relevant sources of the publication?

RQ3: Which are the most cited papers?

RQ4: Which countries that are the most productive?

RQ5: What are the keywords that are frequently used?

RQ6: What are the dominant research themes or topics within the field?

The answer for these research questions will describe the direction of this study and add the value to the area of DAS technologies. The findings of this study have several impacts on academic and industry. For the academicians and scholars interested in DAS technologies, it provides an overview of research domain that introduce readers with the key studies, universities, authors, and concepts. In industry, the research trends and thematic analysis can provide insights into the most relevant and promising applications of DAS technologies. Industries can leverage this information to identify potential use cases and innovative solutions. Thus, the aim of this research was to examine the current trends and attributes of global publications on machine learning and deep learning in the context of distributed acoustic sensing (DAS).

The motivation behind this bibliometric study lies in its potential to bridge theoretical research with practical applications. By identifying key trends, influential works, and emerging themes, this study provides actionable insights for researchers and industry practitioners. For example, recognizing the growing interest in deep learning for seismic monitoring can guide the development of intelligent DAS systems for earthquake-prone regions. Similarly, the identification of underexplored areas such as DAS in smart agriculture opens new avenues for innovation.

The structured of this study begins with a description of the research methodology, including the methods and data extraction process. Then followed by the presentation of the bibliometric analysis with the interpretations of the results obtained, in addition to a discussion regarding the research questions. Limitations and a section on recommended future research are added to the conclusion section in the final step.

II. Literature Review

There are several articles that have reviewed and summarize the development of DAS technologies. Most of them focused on general review of the DAS technology including various aspects for instance, applications, history, and limitations. A comprehensive and systematic overview of the history of DAS has been done to observe the sensing principles, properties, system limitations and applications as well as the performance of DAS [8]. The study also specified that due to the development of numerous new technologies and the availability of affordable instrumentation techniques, it is projected that many more distributed sensing systems will be commercialised and widely implemented soon.

The recent advancement of the DAS techniques had been systematically reviewed which explaining the progress of and operation principles. It covered the uses of DAS in earthquakes monitoring, perimeter security, railway monitoring, underwater positioning, and energy exploration [7]. Another study reviewed the scientific applications of DAS technologies. It included the human activities for instance, humanitarian, engineering, materials, culture, applied mechanic, culture and geophysics. The study explained the characteristics that distinguish each specific set of applications and offers the theoretical basis for the most popular DAS methods as well as summarized the research achievements to develop the initial perspective for future work [11].

Another study reviewed the principles that involved in DAS system, covering the three types of the reflectometry to locate the Rayleigh backscattering (RBS) along the fiber and the techniques to recover the vibration waveform by the spectrum or phase of RBS and introduced the main DAS configurations and technologies [10]. The study concluded that DAS technology had still developed rapidly and should focus on improving performance of DAS system and two aspects of DAS signal processing for examples fully utilised the DAS data and pattern recognition in event detection.

The classification and evaluation of the specialty-fiber-based DAS systems are performed in accordance with the variations in scattering enhancement and preparation techniques. The reviewed paper explained that the DAS system has been widely used in many industries, including resource exploration, structural health monitoring, and for distributed hydrophones, because of the special benefits of the scattering-enhanced fibre [21]. There was a first study using bibliometric analysis to review the latest DAS technologies in signal processing and pattern recognition. It examined 861 research paper from the collection of Web of Science (WoS) that reporting on Distributed Optical Fiber Sensing (DOFS) signal processing and pattern recognition research and advancement. The study summarized that in addition to being able to solve the investigation of the ocean, glaciers, geocentric, and other active phenomena in geophysics, DOFS can play a significant role in industry, transportation, and energy [22].

III. Research Methodology

This section provides a step-by-step explanation of the methodology used to conduct a comprehensive bibliometric analysis of research trends in Distributed Acoustic Sensing, with

a specific focus on its integration with machine learning and deep learning technologies. This will enable the researchers to grasp the process undertaken to gather and analyse data.

A. Data Extraction and Search Strategy

The data was retrieved from one of the main databases that commonly used by the researchers that is Scopus. The databases have already been used in bibliometric analysis for the variety of understandings. Bibliometric analysis of this study was performed using Scopus database as of July 2023. The search term for "Distributed Acoustic Sensing" contained in the research title was used to search for relevant articles published in any language that related to research on DAS. The study focused on the research title of the articles as the title would be the main elements that the readers will observe [23], [24]. The research title represents the relevant topic that is significant with the research area and objective of the study.

The Scopus database was used in this study as most of the peer-reviewed articles published in this database come from well-known and leading academic publishers for instance, Elsevier, Emerald, Springer, Inderscience and Taylor and Francis Group [25]. By using this database in bibliometric analysis and mapping aims to provide a proficient understanding of the global trends in DAS technologies research.

The Fig. 1 illustrates the data extraction flow diagram employed in this study to retrieve relevant records pertaining to Distributed Acoustic Sensing (DAS) technology. The data was systematically extracted from the Scopus database, which served as the primary source of bibliographic information. This extracted dataset was subsequently utilized for a comprehensive bibliometric analysis, enabling the identification of publication trends, influential authors, key research themes, and collaborative networks within the field of DAS technology. This study refined the search to publishing year from 2011 to 2023 to identify the recent trend in DAS technologies research. For document types, the study excluded book chapter, review, letter, note, erratum, editorial, book and abstract report to avoid double or false counting of the documents. It just focused on conference paper and article. The data was extracted on 26th July 2023.

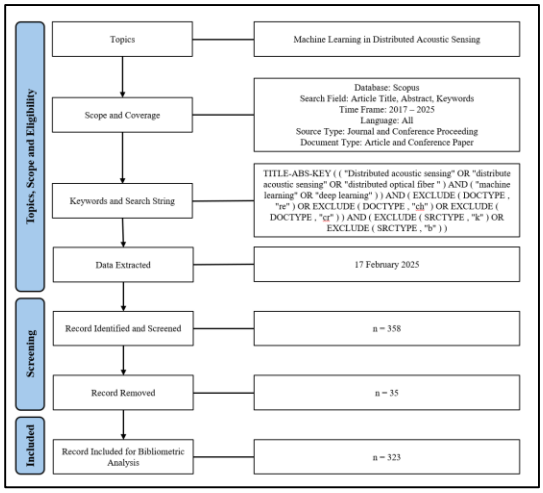

Fig. 1. Data extraction flow diagram source(s): [26].

The total documents extracted from Scopus database was 663 and all the documents were subjected to the bibliometric analysis. There were three applications used in this analysis to solve the research questions as well as visualize the data that had been extracted. Microsoft Excel was used to calculate the frequencies and percentage of the published materials then generate the relevant graphs and chart. To create and visualize the bibliometric network, an open-source tool "bibliometrix" package was installed in R and loaded the "biblioshiny" package which then provided a web interface for Bibliometrix.

B. Bibliometric Analysis Method

Bibliometrics is a research methodology that has been applied in information science field and library that used statistical tools for analysing the published academic studies [27]. There are numerous descriptive statistics of citation data are included in bibliometrics, as well as network analyses of authors, journals, universities, nations, and keywords based on citations and frequency analysis methods. Bibliometrics is a suitable approach for monitoring and summarising the statistical understanding of a specific phrase or concept that is published in the field of logistics and supply chain management. The researcher can examine and document a source of metadata data and knowledge transmission to the readers using the bibliometric analysis method [25].

This study used "biblioshiny" which is a web-specific R package (bibliometrix) for descriptive analysis of the research papers. The tools that include in "biblioshiny" are Bradford's Law, global citation, h, g, and m-index. "Biblioshiny" is a tool included in the package that is made for non-coders and offers a variety of options separated into categories for sources, documents, authors, conceptual structure, social structure, and intellectual structure. It offers means for comprehensive scientometrics and bibliometric analysis [28]. Besides, the information for scientific literature collected for bibliometric research also involved its conversion, extraction, duplicate checking, descriptive analysis, and network analysis. That research would be useful in calculating the authors' annual growth rate in terms of publications, citation analysis and many other metrics. Fig. 2 shows the methodology for bibliometric analysis.

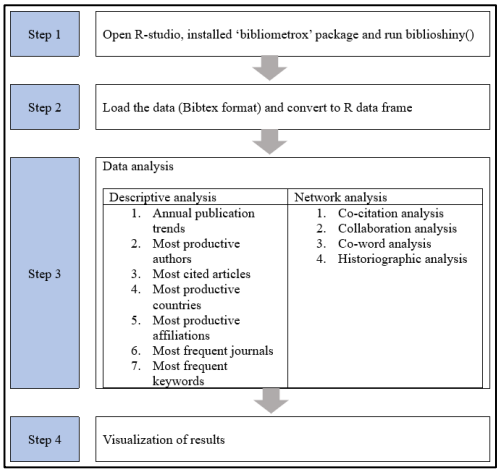

Fig. 2. Flow for bibliometric analysis source(s): [25], [29].

IV. Analysis and Results

This section discusses the output that relevant to the publication of DAS technologies that include in year 2011 until 2023. This involves all the information on the research trends, prolific authors, current state of publications, publication sources, highly cited paper, countries, affiliation, and the authors' keywords.

The dataset comprises 323 documents extracted from the Scopus database, covering the period from 2011 to 2023. The selection was refined to include only journal articles and conference papers, ensuring high-quality, peer-reviewed content. The dataset spans multiple disciplines, including geophysics, engineering, and computer science, reflecting the interdisciplinary nature of DAS research.

A. Descriptive Analysis

1) Citation analysis: Table I presents an overview of key citation metrics for a dataset of 323 documents published between 2017 and 2025. This dataset exhibits a strong annual growth rate of 14.72%, suggesting a rapidly expanding body of research within this area. The average citation count per document is 9.854, indicating a reasonable level of engagement with the published work. A substantial number of authors (922) have contributed to these publications, resulting in an average of 5.26 co-authors per document, highlighting a collaborative research environment. The dataset contains primarily journal articles (221) and a smaller amount of conference papers (102), reflecting a preference for disseminating research findings through traditional academic path. These metrics collectively demonstrate the productivity and significant impact of the research within year 2017 to 2025.

2) Annual Publication Trends: Table II and Fig. 3 illustrate the annual publication trends for DAS Technologies. Table II provides the raw numbers, showing a clear upward trend in publications over the years. Starting with only 5 publications in 2017, there's a steady increase, reaching 42 in 2022 and further accelerating to 93 in 2024. However, 2025 shows a sharp decline to just 15 publications, likely indicating incomplete data for that year.

The result of publication in DAS shows the increasing trend since DAS technology is a novel technology that quite demand in recent technology to monitor the vibration or acoustic sensing applications (pipeline, railway, bridge, tunnel, dam, building and landslide [5]) as it enables real-time and continuous measurement along the entire length of a fiber optic cable. In summary, both the table and figure highlight a significant increase in DAS Technologies publications over time, suggesting a growing research output. However, the substantial decrease in 2025 warrants further investigation and likely reflects incomplete data for that year, a crucial point to consider when interpreting these trends.

TABLE I. Citations Metrics

Metrics	Data
Number of Documents	323
Time Span	2017 – 2025
Annual Growth Rate %	14.72
Average citations per doc	9.854
Authors	922
Co-Authors per Doc	5.26
Article	221
Conference Paper	102

TABLE II. Annual Publications Trends of DAS Technologies

Year	Total Publication
2017	5
2018	7
2019	18
2020	23
2021	41
2022	42
2023	79
2024	93
2025	15

Fig. 3 visually represents this trend. The line graph depicts the annual scientific production, presumably in terms of the number of articles. The upward trajectory confirms the growing publication output, mirroring the data in Table II. The peak in 2024 is evident, followed by the dramatic drop in 2025. This visualization makes the growth trend and the potential data incompleteness for 2025 immediately apparent.

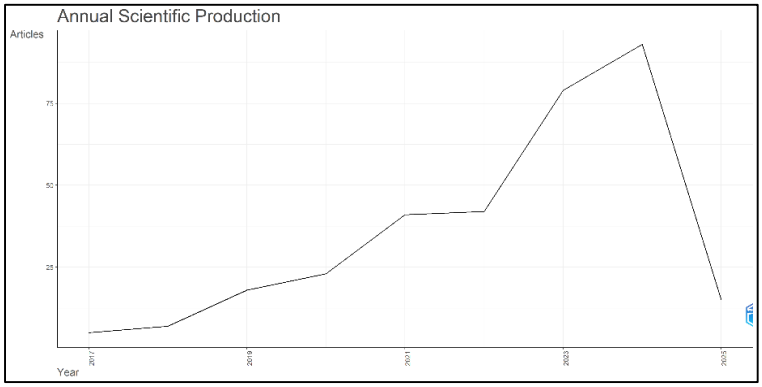

Fig. 3. Number of total publications and total citation per year.

TABLE III. TOP 5 HIGHLY CITED PAPERS

No.	Title	Year	Cites	Cites Per Year
1.	First Field Trial of Distributed Fiber Optical Sensing and High-Speed Communication Over an Operational Telecom Network	2020	139	23.17
2.	An Event Recognition Method for Φ-OTDR Sensing System Based on Deep Learning	2019	122	17.43
3.	Machine Learning Methods for Pipeline Surveillance Systems Based on Distributed Acoustic Sensing: A Review	2017	115	12.78
4.	A Dynamic Time Sequence Recognition and Knowledge Mining Method Based on the Hidden Markov Models (HMMs) for Pipeline Safety Monitoring With Φ-OTDR	2019	110	15.71
5.	An interactive mouthguard based on mechanoluminescence-powered optical fibre sensors for bite-controlled device operation	2022	100	25

3) Most cited papers: Table III presents the top five most highly cited papers in the dataset, ranked by total citations. The most cited paper, "First Field Trial of Distributed Fiber Optical Sensing and High-Speed Communication Over an Operational Telecom Network" (2020), has received 139 citations, averaging 23.17 citations per year. Following closely is "An Event Recognition Method for Φ-OTDR Sensing System Based on Deep Learning" (2019) with 122 total citations and a yearly average of 17.43. "Machine Learning Methods for Pipeline Surveillance Systems Based on Distributed Acoustic Sensing: A Review" (2017) ranks third with 115 citations and a yearly average of 12.78. The fourth position is held by "A Dynamic Time Sequence Recognition and Knowledge Mining Method Based on the Hidden Markov Models (HMMs) for Pipeline Safety Monitoring With Φ-OTDR" (2019) with 110 citations and an average of 15.71 per year. Finally, "An interactive mouthguard based on mechanoluminescence-powered optical fibre sensors for bite-controlled device operation" (2022) has garnered 100 citations, achieving a yearly average of 25. This table highlights the most influential works in the field, showcasing a range of applications and methodologies, with a notable emphasis on pipeline monitoring and the use of machine learning techniques.

4) Most relevant source of DAS: The Fig. 4 illustrates the distribution of publications on Machine Learning in Distributed Acoustic Sensing (DAS) across the top ten most relevant sources. GEOPHYSICS emerges as the leading source with 17 publications, suggesting its significance in this interdisciplinary field. A cluster of powerful sources, including IEEE Transactions on Geoscience and Remote Sensing, IEEE Sensors Journal, Journal of Lightwave Technology, and SENSORS, each contribute between 13 and 14 publications.

Proceedings of SPIE and IEEE Transactions on Instrumentation and Measurement each account for nine publications. Further contributions come from the Journal of Applied Geophysics and SEG Technical Program Expanded Abstracts, with 8 publications each, indicating the connection to geophysics and exploration. Finally, Frontiers in Earth Science contributes six publications, representing a smaller but still notable presence in the publication landscape. This distribution underscores the multidisciplinary nature of Machine Learning in DAS, geophysics, and sensor technology field.

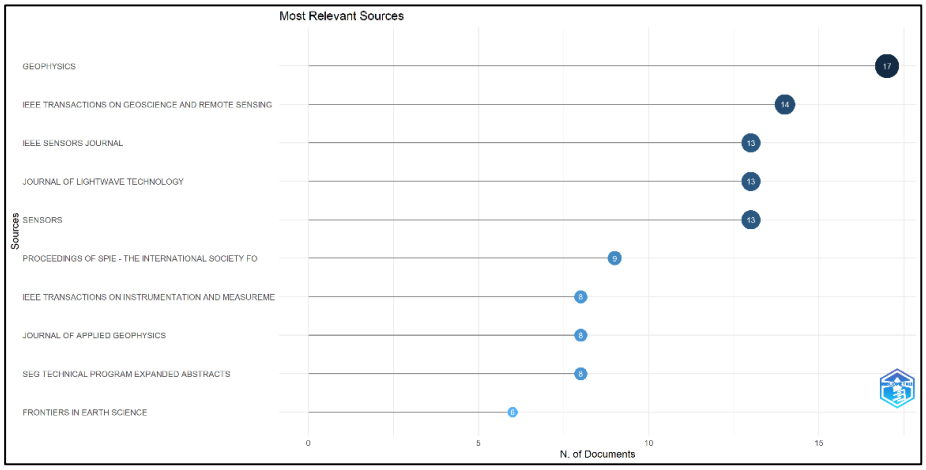

Fig. 4. Top 10 Sources for DAS technology.

Based on the analysis of relevant sources, a deeper understanding of research impact is crucial to complement the assessment of publication volume.

Table IV shows a comprehensive evaluation that takes into consideration the influence and reach of these publications. Therefore, examining metrics such as citation counts, h-index, or journal impact factor (JIF) provides a more nuanced perspective on the relative importance and influence of these sources within the academic community. By integrating both publication quantity and impact, a more robust and insightful analysis of the research landscape can be achieved.

TABLE IV. THE TOP 10 SOURCE IMPACT ON MACHINE LEARNING IN DAS

Sources	Total Publication	H - Index	G - Index	M - Index	Total Citations	Start of Publication Year
JOURNAL OF LIGHTWAVE TECHNOLOGY	13	9	13	1.286	518	2019
GEOPHYSICS	17	7	13	1.167	176	2020
SENSORS	13	7	11	1.4	139	2021
IEEE GEOSCIENCE AND REMOTE SENSING LETTERS	6	4	6	1.0	108	2022
IEEE SENSORS JOURNAL	13	4	11	0.8	130	2021
IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING	14	4	9	1.0	94	2022
IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT	8	4	8	0.8	77	2021
OPTICS EXPRESS	4	4	4	0.667	100	2020
SEG TECHNICAL PROGRAM EXPANDED ABSTRACTS	8	4	7	0.444	57	2017
FRONTIERS IN EARTH SCIENCE	6	3	5	0.75	32	2022

The productivity of the journals over the years is shown in Fig. 5. It illustrates the temporal evolution of publication output across five key sources relevant to the research domain. The cumulative publication count from 2017 to 2025 reveals distinct growth trajectories for each source. GEOPHYSICS demonstrates the most substantial and consistent increase in publications, signifying its prominent role in disseminating research within this field. IEEE Sensors Journal also exhibits steady growth, albeit at a lower rate. Particularly, IEEE Transactions on Geoscience and Remote Sensing shows a marked surge in publications starting around 2022, suggesting an expanding interest in the area within the remote sensing community. Journal of Lightwave Technology and SENSORS show more moderate and consistent growth patterns. The cumulative nature of the data, along with potential data incompleteness for 2025, should be considered when interpreting these trends.

5) The Country that contributes most to publications: The Result indicates the top 10 countries from where the most DAS technology research publications originated. China leads by a significant margin, with 945 publications, followed by the USA with 288. A substantial drop occurs to the third-highest, Saudi Arabia, with 68 publications. The UK follows with 49, while South Korea and Spain tie with 29 each. India has 25 publications, and Singapore and Turkey share 24. Malaysia rounds out the top 10 with 23 publications. Table V highlights a strong concentration of research output in China, followed by the USA, with a considerable gap before other contributing countries.

TABLE V. TOP 10 COUNTRIES THAT HAVE THE MOST PUBLICATIONS

Country	Total Publications
CHINA	945
USA	288
SAUDI ARABIA	68
UK	49
SOUTH KOREA	29
SPAIN	29
INDIA	25
SINGAPORE	24
TURKEY	24
MALAYSIA	23

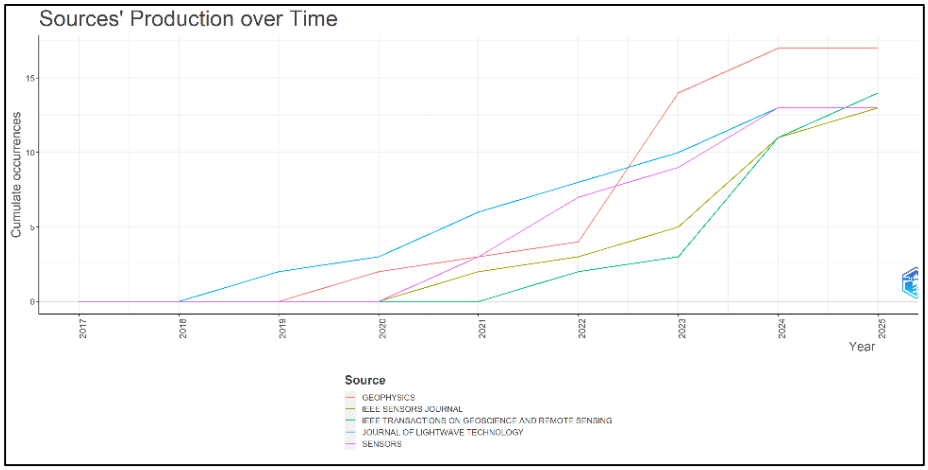

Fig. 5. Productivity of journals over the years.

B. Network Analysis

1) Analysis of keyword co-occurrence patterns: The Fig. 6 depicts a keyword co-occurrence network related to Distributed Acoustic Sensing (DAS) research. It visually represents the relationships between frequently used keywords in publications, highlighting leading research themes and their interconnections. The nodes in the network represent individual keywords, with larger node sizes representing higher frequency of occurrence. The lines connecting the nodes represent the co-occurrence of these keywords within the same publications. For instance, the blue cluster emphasizes "acoustic sensing", "machine learning", and "deep learning", suggesting a strong focus on data analysis and intelligent systems in DAS applications. The green cluster centres around "seismic data", "seismic waves", and "seismology", indicating a significant portion of research dedicated to seismic applications of DAS. Lastly, the red cluster highlights "optical fibers", "fiber optic", and related terms, indicating the fundamental role of fiber optics in DAS technology. The network provides a valuable overview of the intellectual landscape of DAS research, showcasing the key concepts and their associations. It reveals the interdisciplinary nature of the field, bridging signal processing, machine learning, and geophysics, among other disciplines. The co-occurrence network serves as a powerful tool for understanding the evolution and current trends in DAS research.

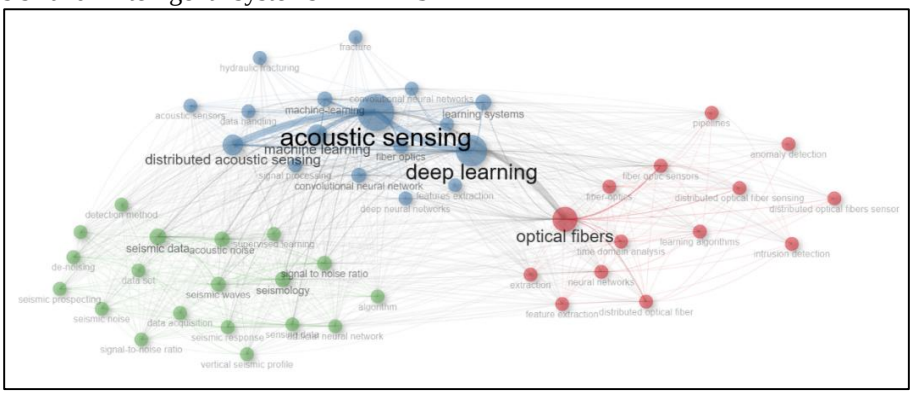

Fig. 6. Keyword co-occurrence network of machine learning in DAS.

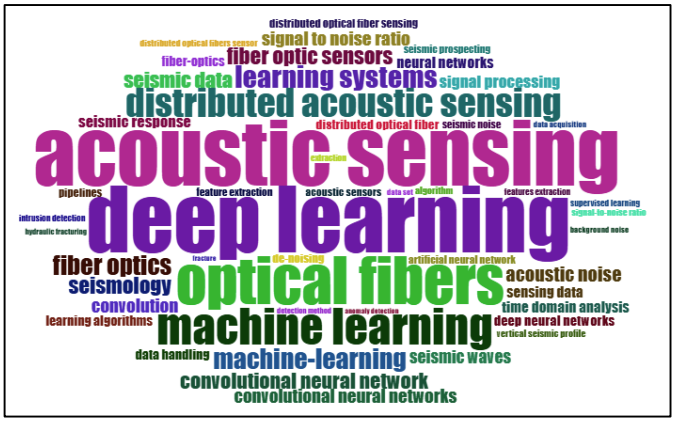

Fig. 7. Word cloud for machine learning in DAS.

Continuing the analysis of keyword co-occurrence patterns, Fig. 7 presents a word cloud visualization of the most frequently occurring terms. This visualization offers a complementary perspective to the network graph, emphasizing the relative prominence of individual keywords. The size of each word reflects its frequency within the corpus, providing a quick overview of relevant themes. Significantly featured are terms like "acoustic sensing", "deep learning", and "optical fibers", reinforcing the key areas identified in the network analysis. The co-occurrence of these terms, implied by their proximity in the cloud, further underscores the interdisciplinary nature of the research, bridging signal processing, machine learning, and optical fiber technologies. Other frequently occurring terms, such as "seismic data", "machine learning", and "distributed acoustic sensing", highlight the specific applications and methodologies prevalent in the field. While the word cloud provides a less granular view of the relationships between keywords compared to the network graph, it effectively highlights the most salient concepts and reinforces the overall trends observed in the co-occurrence analysis.

2) Thematic mapping of research landscape: The thematic map in Fig. 8 visually organizes key research themes related to a particular field, likely Distributed Acoustic Sensing based on prior context, along two axes: relevance (centrality) and development (density). The arrangement of each theme cluster reveals its relative importance and maturity within the research landscape. For instance, acoustic sensing, machine learning, and distributed acoustic sensing are positioned in the Basic Themes quadrant, indicating high relevance and development. Deep learning and related terms, also in Basic Themes, suggest a similarly strong presence but perhaps with slightly lower density. Seismology, seismic data, and acoustic noise fall into the Motor Themes quadrant, signifying high relevance but potentially lower development compared to the basic themes. Optical fibers, fiber optic sensors, and time domain analysis are in the Niche Themes quadrant, implying lower relevance and development, possibly representing specialized or emerging areas. Themes in the Emerging or Declining Themes quadrant are not explicitly shown but represent areas of potentially changing research interest. This strategic visualization facilitates the understanding of the intellectual structure of the

field, highlighting core themes, specialized areas, and potential future research directions.

While the current dataset provides a comprehensive overview, future studies could incorporate additional databases such as Web of Science and IEEE Xplore to enhance coverage. Moreover, evaluating the bibliometric trends across different datasets would help assess the scalability and generalizability of the findings, especially in rapidly evolving subfields like AI-driven DAS.

The findings of this study align with previous bibliometric analyses in related domains. For example, Zhu et al. [22] conducted a bibliometric review of signal processing in distributed optical fiber sensing and highlighted similar trends in the adoption of deep learning techniques. Compared to their broader scope, this study provides a more focused analysis on DAS with AI, revealing specific gaps such as limited research in real-time deployment and cross-domain applications. These comparisons validate the robustness of the current analysis while highlighting unique contributions.

Recent advancements in AI have significantly influenced DAS applications. Mienye and Swart (2024) [30] conclude their study that deep learning is advancing rapidly, propelled by continuous improvements in neural network architecture, training techniques, and computational power. These innovations have enabled the successful application of deep learning models across diverse fields such as medical imaging, autonomous navigation, financial analytics, and language processing, showcasing their adaptability and significant real-world impact.

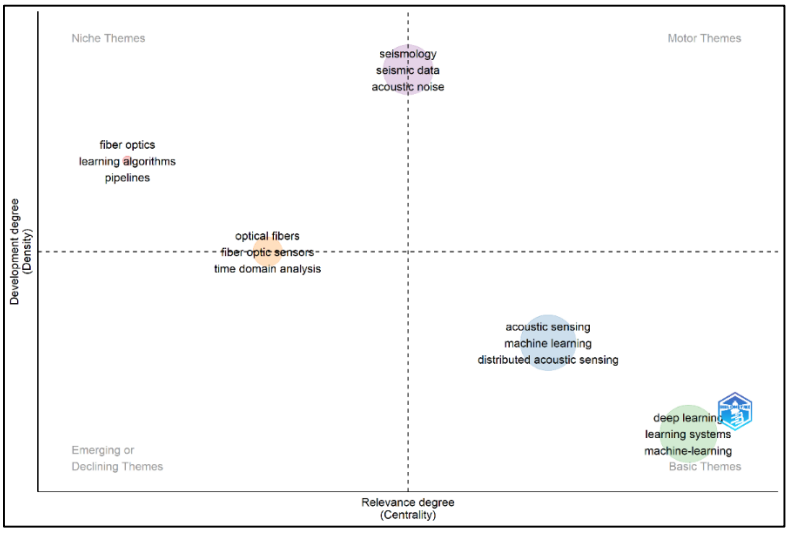

Fig. 8. Thematic mapping of machine learning in DAS.

V. Conclusion

The bibliometric analysis of DAS (Distributed Acoustic Sensing) research from 2011 to 2023 reveals significant growth and increasing global interest in the technology. The number of publications has steadily increased, with a sharp rise in research activity from 2020 to 2022. The highest number of publications was in 2022, indicating that DAS technology continues to gain traction, particularly due to its wide-ranging applications in seismic monitoring, pipeline security, and infrastructure health monitoring.

Descriptive analysis revealed key publication trends, influential sources, and major contributing countries, demonstrating a rapidly expanding field with a strong presence in China. Network analysis, employing keyword co-occurrence networks and thematic mapping, illuminated the intellectual structure of the field, identifying core research themes such as deep learning, acoustic sensing, optical fibers and so on. The word cloud visualization reinforced the prominence of key terms and concepts, providing a complementary perspective on the dominant research directions. The thematic map further contextualized these themes, showcasing their relative relevance and development within the research landscape.

In conclusion, these findings offer valuable insights into the evolution, current state, and potential future trajectories of research in machine learning and deep learning in DAS, serving as a resource for researchers, practitioners, and industrial. DAS technology has established itself as a critical tool for real-time acoustic and seismic monitoring, with increasing academic and industrial interest. The continued research and development efforts are likely to drive further innovation in applications across various fields, ensuring the relevance and growth of DAS technologies in the coming years.

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References

[1] N. J. Lindsey, H. Rademacher, and J. B. Ajo-Franklin, “On the Broadband Instrument Response of Fiber-Optic DAS Arrays,” J Geophys Res Solid Earth, vol. 125, no. 2, Feb. 2020, doi: 10.1029/2019JB018145.

[2] Z. Li, J. Zhang, M. Wang, Y. Zhong, and F. Peng, “Fiber distributed acoustic sensing using convolutional long short-term memory network: a field test on high-speed railway intrusion detection,” Opt Express, vol. 28, no. 3, p. 2925, Feb. 2020, doi: 10.1364/oe.28.002925.

[3] T. M. Daley et al., "Field testing of fiber-optic distributed acoustic sensing (DAS) for subsurface seismic monitoring," Leading Edge, vol. 32, no. 6, pp. 699–706, 2013, doi: 10.1190/tle32060699.1.

[4] H. Wu et al., "One-Dimensional CNN-Based Intelligent Recognition of Vibrations in Pipeline Monitoring With DAS," Journal of Lightwave Technology, vol. 37, no. 17, pp. 4359–4366, Jun. 2019, doi: 10.1109/jlt.2019.2923839.

[5] H. H. Zhu, W. Liu, T. Wang, J. W. Su, and B. Shi, "Distributed Acoustic Sensing for Monitoring Linear Infrastructures: Current Status and Trends," Oct. 01, 2022, MDPI. doi: 10.3390/s22197550.

[6] T. Zhu, J. Shen, and E. R. Martin, "Sensing Earth and environment dynamics by telecommunication fiber-optic sensors: An urban experiment in Pennsylvania, USA," Solid Earth, vol. 12, no. 1, pp. 219–235, Jan. 2021, doi: 10.5194/se-12-219-2021.

[7] Y. Shang et al., "Research Progress in Distributed Acoustic Sensing Techniques," Aug. 01, 2022, MDPI. doi: 10.3390/s22166060.

[8] X. Bao and L. Chen, "Recent Progress in Distributed Fiber Optic Sensors," Jul. 2012. doi: 10.3390/s120708601.

[9] Y. Xie, M. Wang, Y. Zhong, L. Deng, and J. Zhang, "Label-Free Anomaly Detection Using Distributed Optical Fiber Acoustic Sensing," Sensors, vol. 23, no. 8, Apr. 2023, doi: 10.3390/s23084094.

[10] Z. He and Q. Liu, "Optical Fiber Distributed Acoustic Sensors: A Review," Jun. 15, 2021, Institute of Electrical and Electronics Engineers Inc. doi: 10.1109/JLT.2021.3059771.

[11] B. G. Gorshkov et al., "Scientific Applications of Distributed Acoustic Sensing: State-of-the-Art Review and Perspective," Feb. 01, 2022, MDPI. doi: 10.3390/s22031033.

[12] Z. H. Zamzuri, "A bibliometric analysis of COVID-19 research in Malaysia using latent dirichlet allocation," Sains Malays, vol. 50, no. 6, pp. 1815–1825, Jun. 2021, doi: 10.17576/jsm-2021-5006-26.

[13] A. Quincho-Lopez and J. Pacheco-Mendoza, "Research Trends and Collaboration Patterns on Polymyxin Resistance: A Bibliometric Analysis (2010–2019)," Front Pharmacol, vol. 12, Oct. 2021, doi: 10.3389/fphar.2021.702937.

[14] M. Cabanillas-Lazo et al., "A 10-Year Bibliometric Analysis of Global Research on Gut Microbiota and Parkinson's Disease: Characteristics, Impact, and Trends," Biomed Res Int, vol. 2022, 2022, doi: 10.1155/2022/4144781.

[15] I. Passas, "Bibliometric Analysis: The Main Steps," Encyclopedia, vol. 4, no. 2, pp. 1014–1025, Jun. 2024, doi: 10.3390/encyclopedia4020065.

[16] F. Mayta-Tovalino, J. Pacheco-Mendoza, A. Diaz-Soriano, F. Perez-Vargas, A. Munive-Degregori, and S. Luza, "Bibliometric Study of the National Scientific Production of All Peruvian Schools of Dentistry in Scopus," Int J Dent, vol. 2021, 2021, doi: 10.1155/2021/5510209.

[17] M. Aria and C. Cuccurullo, "bibliometrix: An R-tool for comprehensive science mapping analysis," J Informetr, vol. 11, no. 4, pp. 959–975, Nov. 2017, doi: 10.1016/j.joi.2017.08.007.

[18] X. J. Yang et al., "Bibliometric analysis of the status and trend of biological soil crusts research from 1912 to 2023," Apr. 01, 2024, KeAi Communications Co. doi: 10.1016/j.rcar.2024.05.001.

[19] Z. H. Munim, M. Dushenko, V. J. Jimenez, M. H. Shakil, and M. Imset, "Big data and artificial intelligence in the maritime industry: a bibliometric review and future research directions," Maritime Policy and Management, pp. 577–597, 2020, doi: 10.1080/03088839.2020.1788731.

[20] V. Della Corte, G. Del Gaudio, F. Sepe, and F. Sciarelli, "Sustainable tourism in the open innovation realm: A bibliometric analysis," Sustainability (Switzerland), vol. 11, no. 21, Nov. 2019, doi: 10.3390/su11216114.

[21] Y. Sun et al., "Review of a Specialty Fiber for Distributed Acoustic Sensing Technology," Photonics, vol. 9, no. 5, May 2022, doi: 10.3390/photonics9050277.

[22] C. Zhu, K. Yang, Q. Yang, Y. Pu, and C. L. P. Chen, "A comprehensive bibliometric analysis of signal processing and pattern recognition based on distributed optical fiber," Jan. 01, 2023, Elsevier B.V. doi: 10.1016/j.measurement.2022.112340.

[23] H. R. Jamali and M. Nikzad, "Article title type and its relation with the number of downloads and citations," Scientometrics, vol. 88, no. 2, pp. 653–661, 2011, doi: 10.1007/s11192-011-0412-z.

[24] R. Zakaria, A. Ahmi, A. H. Ahmad, and Z. Othman, "Worldwide melatonin research: a bibliometric analysis of the published literature between 2015 and 2019," 2021, Taylor and Francis Ltd. doi: 10.1080/07420528.2020.1838534.

[25] N. A. Abdul Rahman, A. Ahmi, L. Jraisat, and A. Upadhyay, "Examining the trend of humanitarian supply chain studies: pre, during and post COVID-19 pandemic," Journal of Humanitarian Logistics and Supply Chain Management, vol. 12, no. 4, pp. 594–617, Nov. 2022, doi: 10.1108/JHLSCM-01-2022-0012.

[26] N. Kushairi and A. Ahmi, "Flipped classroom in the second decade of the Millenia: a Bibliometrics analysis with Lotka's law," Educ Inf Technol (Dordr), vol. 26, no. 4, pp. 4401–4431, Jul. 2021, doi: 10.1007/s10639-021-10457-8.

[27] T. P. Liang and Y. H. Liu, "Research Landscape of Business Intelligence and Big Data analytics: A bibliometrics study," Expert Syst Appl, vol. 111, pp. 2–10, Nov. 2018, doi: 10.1016/j.eswa.2018.05.018.

[28] A. Nasir, K. Shaukat, I. A. Hameed, S. Luo, T. M. Alam, and F. Iqbal, "A Bibliometric Analysis of Corona Pandemic in Social Sciences: A Review of Influential Aspects and Conceptual Structure," 2020, Institute of Electrical and Electronics Engineers Inc. doi: 10.1109/ACCESS.2020.3008733.

[29] N. Lazar and K. Chithra, "Comprehensive bibliometric mapping of publication trends in the development of Building Sustainability Assessment Systems," Environ Dev Sustain, vol. 23, no. 4, pp. 4899–4923, Apr. 2021, doi: 10.1007/s10668-020-00796-w.

[30] I. D. Mienye and T. G. Swart, "A Comprehensive Review of Deep Learning: Architectures, Recent Advances, and Applications," Information (Switzerland), vol. 15, no. 12, Dec. 2024, doi: 10.3390/info15120755.