Emerging Trends and Key Themes in Deep Learning Sentiment Analysis: A Bibliometric Analysis from 2014 to 2025

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Abstract

This study presents a bibliometric analysis of sentiment analysis research using deep learning (DL) and Natural Language Processing (NLP), covering 454 publications from Scopus (2015–2024). The findings highlight key themes such as "sentiment analysis," "deep learning," and "data mining," reflecting their growing applications in social media, finance, and healthcare. The results indicate a 52.84% annual growth rate, demonstrating increasing academic interest. Global collaborations (23.35%) are expanding, with India, the United States, and Europe as leading contributors. Keyword analysis reveals a shift toward transformer-based models, adversarial machine learning, and contrastive learning, signaling advancements in sentiment classification. Emerging trends include multilingual sentiment analysis, hybrid fake news detection, and financial lexicons integrating explainable AI. Despite progress, challenges remain, including model interpretability, computational efficiency, and ethical concerns. Limited representation of low-resource languages and geographical disparities in research output highlight the need for broader interdisciplinary engagement. This study provides a comprehensive overview of sentiment analysis research, offering insights into technological advancements, collaborative trends, and future research opportunities. Addressing interpretability, cross-disciplinary integration, and real-world applications will be crucial for advancing the field.

Keywords: Sentiment Analysis, Deep Learning, Natural Language Processing (NLP), Bibliometric Analysis, Machine Learning.

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1. Introduction

Natural Language Processing (NLP) has emerged as a cornerstone of computational linguistics, with tasks like text classification and sentiment analysis playing pivotal roles in extracting insights from vast amounts of textual data. Text classification, a fundamental NLP task, has evolved significantly with the advent of deep learning (DL) techniques, enabling accurate categorization of text across diverse applications (Alzaidi et al., 2025). In Arabic NLP, challenges such as limited resources and linguistic complexity have driven the development of advanced models like the TCAODL-ANA, which combines bidirectional gated recurrent units (BiGRU) and Aquila optimization for improved performance (Alzaidi et al., 2025). Similarly, reinforcement learning (RL) and deep reinforcement learning (DRL) enhance sentiment analysis by reducing the reliance on labeled datasets while preserving contextual nuances (Eyu et al., 2025).

Social media platforms have further expanded the scope of sentiment analysis, particularly for analyzing real-time public opinions. Models integrating hybrid frameworks, such as CNN-BiLSTM combinations, have demonstrated remarkable accuracy in analyzing YouTube comments on sensitive topics like the Hamas-Israel conflict (Liyih et al., 2024). Meanwhile, advanced multimodal approaches incorporating image and text data have enhanced fake news detection, achieving high efficacy across multiple languages (Kumari & Singh, 2024).

Domain-specific challenges, such as analyzing sentiment in Arabic or Urdu, have led to innovations like the Arb-MCNN-Bi model and Enhanced UrduAspectNet, addressing linguistic intricacies with transformer-based architectures and graph convolutional networks (Almaqtari et al., 2024; Aziz et al., 2024). Financial lexicon models like XLex combine transformers with SHAP explainability to create efficient, interpretable sentiment analysis tools, significantly improving performance in financial text analysis (Rizinski et al., 2024).

Additionally, sentiment analysis in e-commerce and workplace feedback leverages NLP techniques to identify trends and improve organizational strategies. Frameworks utilizing deep learning, such as transformer-based models, have proven effective in categorizing user feedback and enhancing customer satisfaction (Alsaedi et al., 2024). Twitter sentiment analysis has also benefited from novel ensemble approaches, addressing challenges like slang usage and short-text analysis with superior accuracy (Sai Krishna et al., 2024; Mahalakshmi et al., 2024).

Finally, the interpretability of deep learning models remains a pressing concern, prompting the development of frameworks like NLPGuard and local interpretation methodologies, which address biases and improve transparency in sentiment classification tasks (Greco et al., 2024; Luo et al., 2024). These advancements collectively underscore the transformative impact of DL and hybrid methodologies on NLP applications across languages and domains.

2. Methodology

2.1 Research Design

1. This study employs a bibliometric research design to analyze advancements in sentiment analysis using deep learning (DL) and Natural Language Processing (NLP). Covering 454 publications from 2015 to 2024, the analysis identifies research trends, thematic advancements, and collaboration networks. Unlike experimental studies that focus on model development, this research systematically examines publication patterns, keyword evolution, and author collaborations to provide a comprehensive overview of the field’s progression.

2. To ensure transparency and methodological rigor, this study follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework for systematic data selection. Articles were identified from the Scopus database using structured queries with "Sentiment Analysis," "Deep Learning," and "Natural Language Processing" as primary keywords. After removing duplicates and excluding non-relevant sources, only peer-reviewed journal articles in English were retained. The final dataset of 454 publications was analyzed to uncover keyword distributions, citation trends, and global research collaborations.

3. Applying PRISMA principles enhances the credibility and reproducibility of this bibliometric study by ensuring systematic article selection and eliminating potential biases. This structured approach provides a reliable foundation for assessing emerging research themes and collaborative networks in sentiment analysis using DL and NLP.

2.2 Data Collection

A structured approach was used to retrieve and refine bibliometric data from the Scopus database, ensuring a high-quality dataset for analysis. The following selection criteria were applied.

1. Document Type: Only journal articles were included, resulting in 454 records, while conference papers and other document types were excluded to maintain consistency and reliability.

2. Keywords: A targeted search strategy used three primary keywords—"Sentiment Analysis," "Deep Learning," and "Natural Language Processing"—to focus the dataset on relevant studies.

3. Language: The dataset was limited to English-language publications to ensure accessibility and standardization.

4. Open Access: To facilitate wider availability, the dataset included both Gold Open Access and Hybrid Gold Open Access publications.

5. Timeframe: The study spans 2015 to 2024, covering nearly a decade of evolution in sentiment analysis research.

These criteria resulted in a comprehensive dataset capturing research from diverse journals and institutions, with metadata including publication year, source title, author affiliations, and citation data for further analysis.

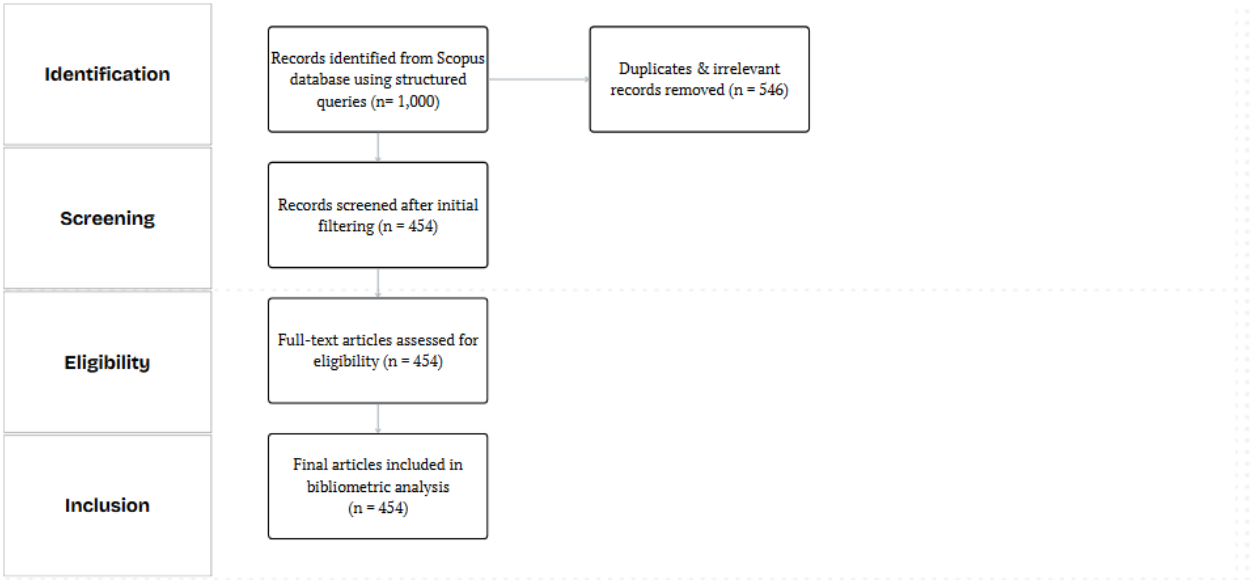

Figure 1 A PRISMA flow diagram

2.3 Data Analysis

The study utilizes bibliometric techniques to assess publication trends, keyword distribution, and research collaborations. The methodology includes:

1. Performance Analysis:
    - Evaluates annual scientific production, keyword frequency, and research output growth.
    - Identifies leading authors, institutions, and journals contributing to sentiment analysis research.
2. Science Mapping:
    - Keyword Co-occurrence Analysis: Maps trending topics and thematic evolution in the field.
    - Collaboration Network Analysis: Examines institutional and international research partnerships, visualizing global research connections.
3. Tools for Analysis:
    - Bibliometrix in R: Processes and visualizes bibliometric data, generating citation trends, thematic maps, and keyword networks.
    - Network Visualization: Illustrates co-authorship links and country-level collaborations, offering insights into global research dynamics.

This comprehensive bibliometric study provides critical insights into the evolution, impact, and collaboration patterns of sentiment analysis research. By identifying key research clusters and emerging trends, this study establishes a solid foundation for future advancements in sentiment analysis using DL and NLP.

3. Results

The bibliometric analysis covered publications from 2015 to 2024, capturing data from 454 documents authored by 1,409 contributors across 304 sources. Single-authored documents accounted for 27 publications, indicating that most research in this field is conducted through collaborative efforts. The

level of international collaboration is evident, with 23.35% of all publications involving co-authors from different countries. The average number of co-authors per document is 3.39, further reinforcing the collaborative nature of research in sentiment analysis and deep learning.

The analysis reveals a 52.84% annual growth rate, demonstrating the rapidly increasing interest in sentiment analysis and deep learning research. The dataset includes 968 unique author keywords, reflecting the thematic diversity and evolving research trends in this domain.

In terms of impact, the average number of citations per document is 22.68, indicating substantial academic influence and engagement within the field. The average document age is 3.73 years, suggesting that the dataset predominantly consists of relatively recent publications. However, the absence of reference data in the extracted dataset limits citation network analysis. Figure 2 summarizes these key bibliometric characteristics, illustrating the significant growth, collaboration trends, and research impact in sentiment analysis and deep learning.

Figure 2. Main information.

3.1 Annual Scientific Production

The analysis of annual scientific production for the period 2015 to 2024 demonstrates a steady increase in research activity in sentiment analysis and deep learning. The dataset includes 454 documents, showing a consistent upward trend in the number of publications over the years.

From 2015 to 2019, the field experienced a gradual rise, with a notable surge in publications around 2018–2019. Following this period, the growth rate slightly stabilized but remained steady until 2021, after which a sharp increase in the number of articles was observed between 2021 and 2024. This indicates a renewed and growing interest in the field, possibly driven by advancements in deep learning models and increased applications in real-world sentiment analysis tasks.

The sustained upward trend suggests that sentiment analysis and deep learning continue to attract academic attention, with a high potential for further expansion. The increased publication volume in recent years reflects the evolving landscape of research in this domain, highlighting emerging methodologies, interdisciplinary applications, and collaborative efforts.

Figure 2 illustrates the annual distribution of publications, emphasizing the growth trajectory of deep learning applications in sentiment analysis. Figure 3 illustrates the annual distribution of publications, emphasizing the dynamic and rapidly evolving nature of the field.

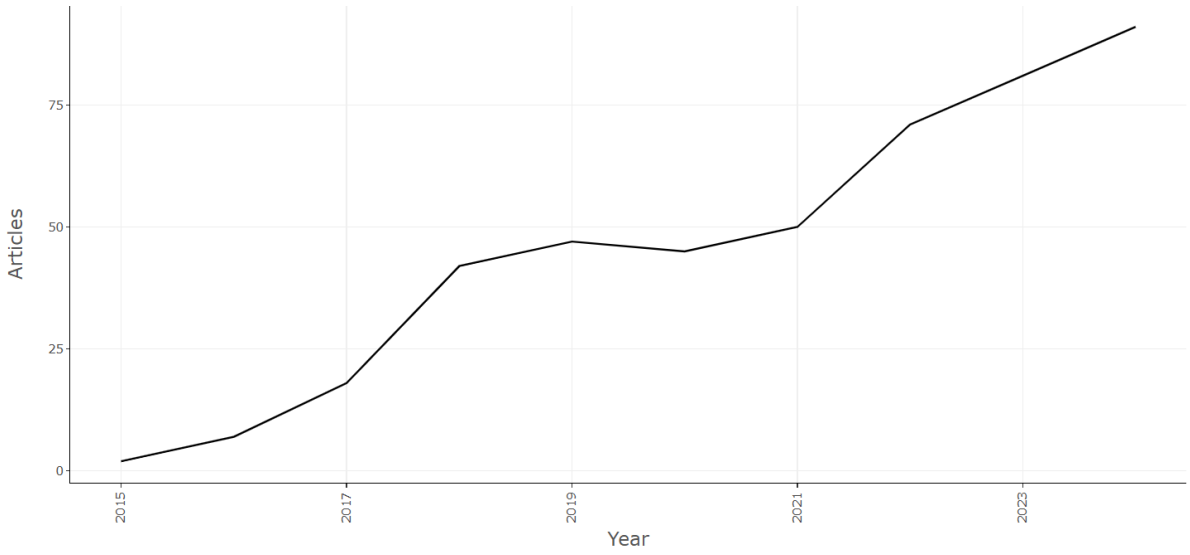

Figure 3. Annual scientific production in deep learning for Sentimet Analysis (2015–2025).

3.2 Word Cloud Plot

The word cloud visualization highlights the most frequently occurring keywords in the analyzed dataset, offering a comprehensive overview of the central themes and research focus in sentiment analysis using deep learning (DL) and Natural Language Processing (NLP). The prominence of certain keywords suggests key areas of academic interest, emerging methodologies, and interdisciplinary connections within the field.

1. Dominant Themes
   - The keywords "sentiment analysis," "deep learning," and "data mining" appear most prominently, emphasizing the study's core focus on leveraging DL and NLP for sentiment classification.
   - The significant presence of "learning systems" and "machine learning" indicates the role of computational models in enhancing sentiment analysis performance.
   - These dominant terms confirm the ongoing evolution of DL techniques in processing and interpreting text-based sentiment data.
2. Emerging Topics
   - Several secondary keywords, such as "social networking (online)," "learning algorithms," and "text mining," suggest a growing emphasis on sentiment analysis applications in social media platforms and real-time data streams.
   - Keywords like "transformer," "long short-term memory (LSTM)," and "deep neural networks" highlight the increasing adoption of advanced architectures for sentiment classification and contextual understanding.
   - The presence of "opinion mining" and "classification of information" reinforces the interdisciplinary nature of sentiment analysis, extending beyond text classification to broader analytical frameworks.
3. Interdisciplinary Connections
   - Terms such as "natural languages," "support vector machines," and "semantics" reflect the integration of computational linguistics and statistical methods in sentiment analysis.
   - The inclusion of "adversarial machine learning" and "contrastive learning" indicates a rising interest in robust AI techniques to counter challenges like adversarial attacks, bias mitigation, and interpretability in sentiment classification models.
   - "Decision trees" and "convolutional neural networks (CNNs)" suggest the diverse range of machine learning approaches being applied alongside deep learning in this domain.

Overall, the word cloud illustrates the rapid advancement and diversification of sentiment analysis research, with a strong emphasis on deep learning techniques, social media applications, and interdisciplinary machine learning methodologies.
Figure 4 provides a visual summary of these key research trends, emphasizing the major thematic areas shaping the evolution of sentiment analysis in recent years.

Figure 4. Word Cloud Plot.

3.3 Co-author Network
The co-author network presented in Figure 5 The network visualization highlights the collaborative relationships among researchers in the field of sentiment analysis and deep learning (DL). Each node represents an author, and the size of the node corresponds to their contribution and frequency of collaboration. The edges (connections) between nodes indicate co-authorship links, forming clusters that reflect different research communities.

The network is divided into distinct clusters, each representing a group of researchers working on specific themes within the domain:

- The red cluster represents a well-connected group of authors, including Xu J, Sun X, Li C, and Zhang S, who are actively collaborating on deep learning methodologies for sentiment analysis. Their strong interconnections suggest a productive research network focused on advancements in NLP techniques.
- The orange cluster consists of Balshaban KB, Hajj W, and Habash N, indicating another concentrated research group working closely together, likely contributing to specialized topics such as Arabic NLP and deep learning applications in sentiment analysis.
- The purple cluster features researchers such as Ashraf, Rustam F, and Ullah S, highlighting a collaboration focused on sentiment classification, data mining, and machine learning-based approaches.
- The blue cluster is centered around Mishra S, Diesner J, and Kotecha K, representing researchers engaged in interdisciplinary studies, possibly integrating computational linguistics and explainable AI techniques.
- The green cluster shows a smaller but distinct collaboration between Hasan KMA and Hasan M, which may indicate research efforts focusing on low-resource language sentiment analysis or domain-specific sentiment classification.

The network structure underscores the interdisciplinary and collaborative nature of sentiment analysis research, with some highly connected clusters indicating strong research partnerships, while smaller, more isolated groups highlight niche or emerging research areas. The presence of multiple clusters

suggests a diverse range of topics within the field, from transformer-based models to multilingual sentiment analysis and real-world applications.
Figure 5 illustrates these co-authorship connections, emphasizing the evolving research landscape and the potential for greater collaboration across different research domains.

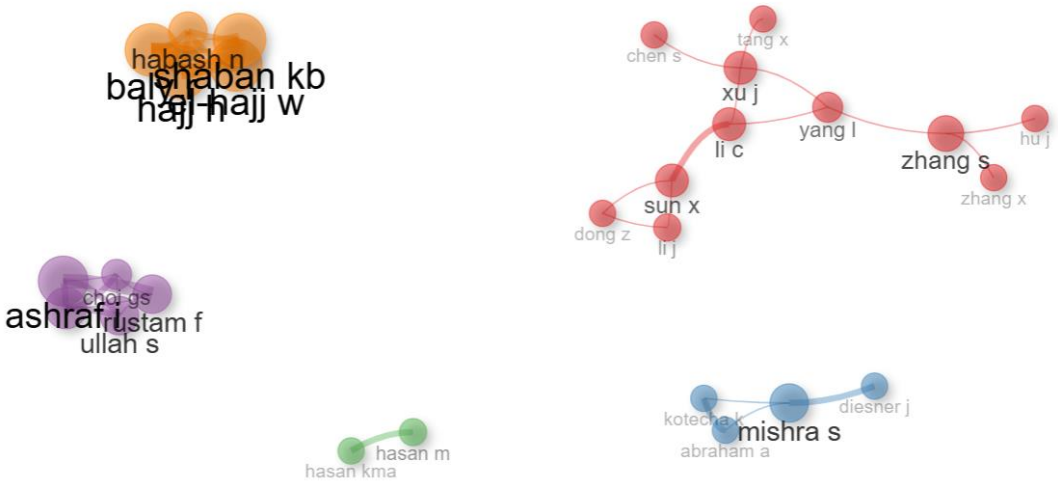

Figure 5. Co-author network.

3.4 Trend topics
The timeline visualization in Figure 6 illustrates the evolution of key research topics in sentiment analysis, deep learning, and NLP from 2017 to 2024. The size of the circles indicates the frequency of each term, highlighting emerging trends and shifts in focus.

- Core topics like "deep learning," "sentiment analysis," and "data mining" have consistently grown, with a surge in 2023–2024, reaffirming their central role in NLP research.
- Advanced methodologies, such as "contrastive learning," "adversarial machine learning," and "federated learning," have gained traction in recent years, reflecting a shift toward more sophisticated and robust AI technique.
- Deep learning architectures, including "deep neural networks" and "convolutional neural networks," show increasing adoption, supporting sentiment classification and contextual understanding.
- Classification techniques peaked in 2021, with 94 occurrences of "classification (of information)", indicating a strong focus on refining sentiment analysis models.

Overall, the trends reveal a progressive shift from traditional machine learning to deep learning-driven sentiment analysis, with increasing emphasis on explainable AI, multilingual NLP, and adversarial robustness in future research.

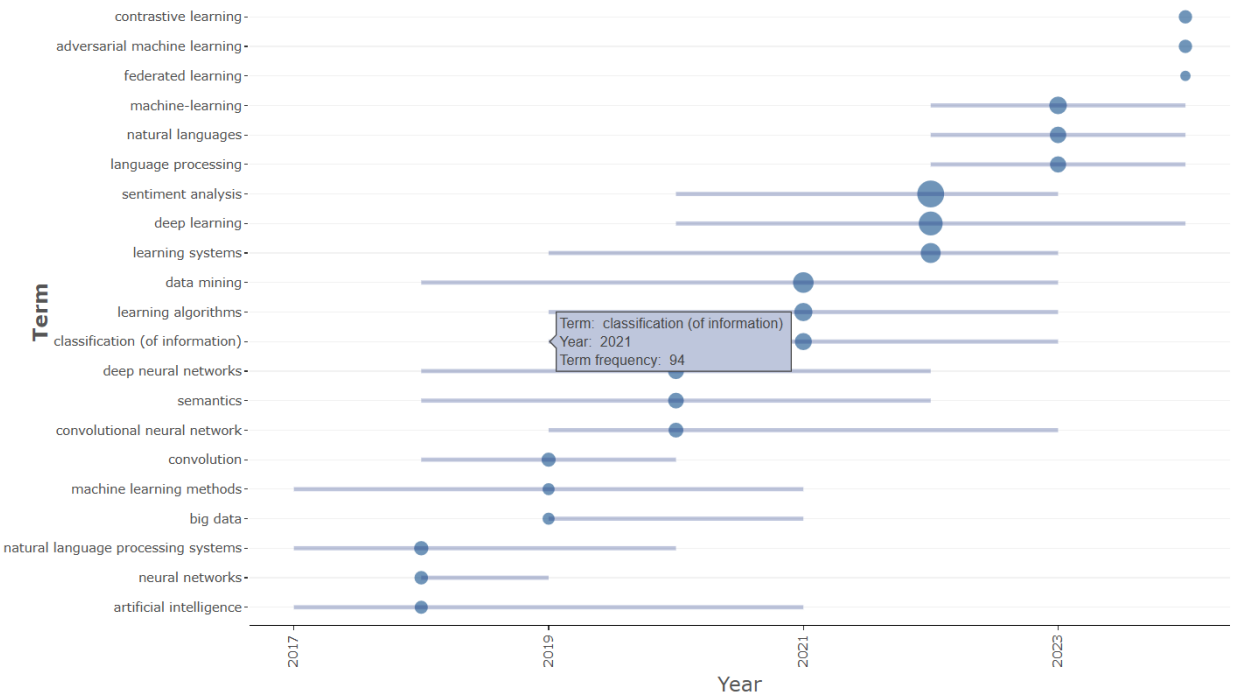

Figure 6. Trend topics.

3.5 Countries' Collaboration World Map

The collaborative network presented in Figure 7 The world map illustrates global research collaborations in sentiment analysis and deep learning, with connections between countries representing co-authored publications. The intensity of blue shading indicates the level of research activity, where darker shades represent higher contributions.

Key Observations:

- India appears as a major research hub, engaging in extensive collaborations with Europe, North America, and other Asian countries.
- Strong connections are evident between the United States, the United Kingdom, Germany, and China, highlighting key global research partnerships.
- Several European and Asian countries actively contribute to international collaborations, suggesting a growing interdisciplinary and cross-border research trend.
- Emerging research participation is visible from regions in Africa, the Middle East, and South America, though with fewer collaborative links compared to dominant research hubs.

This map highlights the international nature of sentiment analysis and deep learning research, emphasizing the importance of global cooperation in advancing these fields. Future studies could explore the impact of regional expertise and interdisciplinary collaborations to further enrich research contributions.

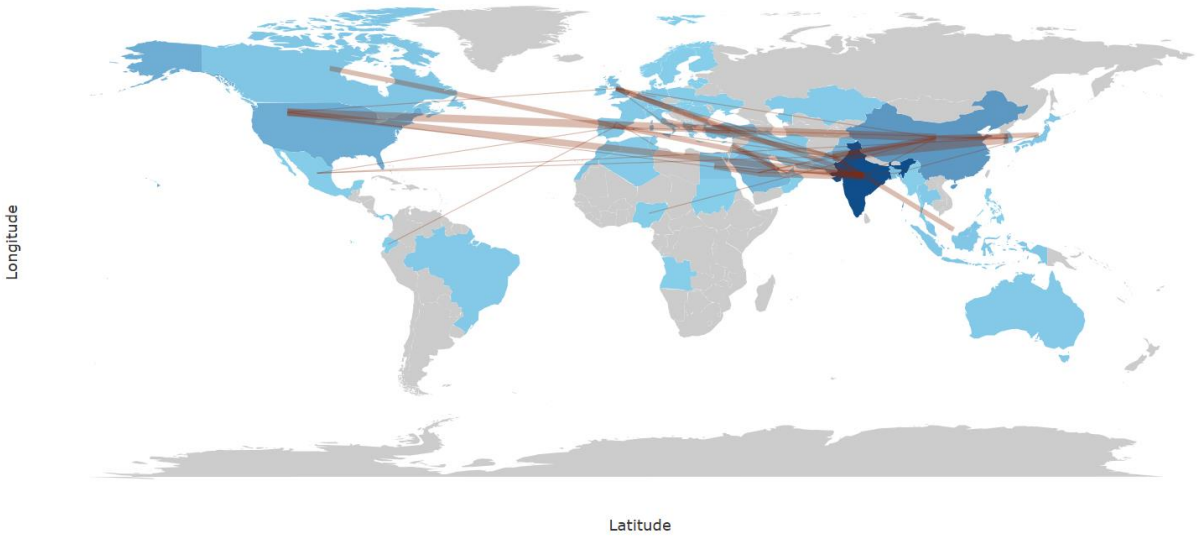

Figure 7. Countries' Collaboration World Map

3.6 Factorial Analysis

The thematic map visualization in Figure 7 the image provides a strategic overview of key research topics in sentiment analysis using deep learning (DL) and Natural Language Processing (NLP). The X-axis (Dim 1: 34.7%) represents the degree of centrality, indicating the importance of a topic within the broader research domain, while the Y-axis (Dim 2: 18.47%) represents density, signifying the level of topic development and specialization.

The map highlights four quadrants representing different categories of research themes. The top-right quadrant contains high-centrality, high-density topics, such as logistic regression techniques, deep learning, and convolutional neural networks, which are well-established and mature themes in sentiment analysis. The bottom-right quadrant consists of high-centrality, low-density topics, including machine learning techniques, text processing, and feature extraction, indicating that these are core themes but still evolving with emerging methodologies.

In contrast, the top-left quadrant represents low-centrality, high-density topics, such as contrastive learning and text mining, which are highly specialized but not yet widely integrated into mainstream research. The bottom-left quadrant contains low-centrality, low-density themes, including natural language processing, computational linguistics, and decision-making, suggesting that these areas are either declining in relevance or in the early stages of development within the sentiment analysis domain. Overall, this thematic map illustrates the evolving landscape of sentiment analysis research, with deep learning and advanced machine learning techniques playing a dominant role. The presence of emerging methodologies such as contrastive learning and adversarial machine learning indicates a shift toward more sophisticated and context-aware sentiment classification techniques, reflecting the ongoing transformation of the field.

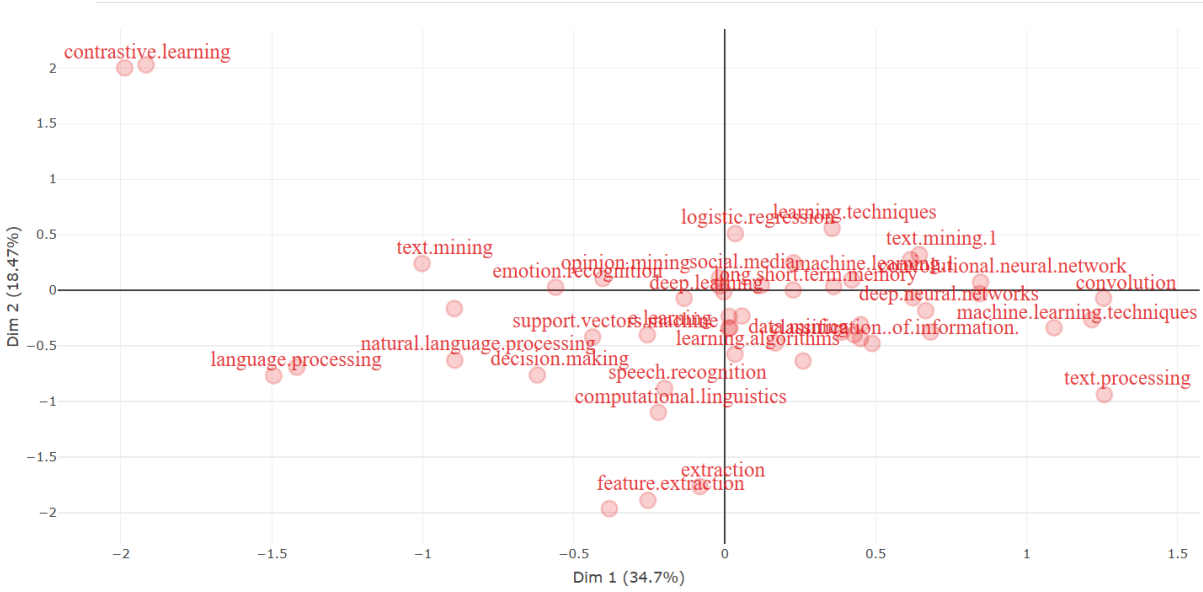

Figure 8. Factorial Analysis

4. Discussion

This bibliometric analysis provides a comprehensive overview of sentiment analysis research using deep learning (DL) and Natural Language Processing (NLP) from 2015 to 2024. The findings highlight a consistent growth rate of 52.84% per year, demonstrating the increasing academic interest in this domain. Core research themes such as "sentiment analysis," "deep learning," and "data mining" dominate the field, with a clear shift towards transformer-based architectures, adversarial machine learning, and contrastive learning. The evolution of keyword trends suggests an increasing focus on multilingual sentiment analysis, fake news detection, and financial lexicons integrating explainable AI, reflecting the expanding scope and real-world applicability of sentiment analysis techniques.

The co-authorship network analysis reveals strong international collaboration, with India, the United States, and European countries emerging as major contributors. While well-connected research clusters indicate active collaboration and knowledge exchange, the presence of smaller, isolated research groups suggests opportunities for greater interdisciplinary engagement, particularly in underrepresented languages and emerging economies. Despite the advancements, several challenges persist. The average citation impact per document (22.68) indicates strong academic engagement, but newer studies may require more time to gain recognition. Furthermore, interdisciplinary integration with fields such as psychology, ethics, and computational linguistics remains limited, restricting a more holistic understanding of sentiment analysis applications. Additionally, practical deployment challenges such as model interpretability, computational efficiency, and ethical concerns continue to hinder large-scale implementation.

Overall, sentiment analysis research using DL and NLP has experienced significant growth, with increasing adoption of advanced AI techniques and expanding international collaborations. However, addressing interdisciplinary gaps, enhancing model transparency, and fostering greater global research participation will be essential for maximizing real-world impact. Future research should focus on broadening linguistic representation, refining explainable AI methods, and integrating sentiment analysis across diverse applications such as finance, healthcare, and social media analytics to ensure the continued evolution and effectiveness of sentiment analysis technologies.

Limitations of the Study

While this study offers valuable insights into sentiment analysis research using deep learning (DL) and Natural Language Processing (NLP), several limitations may impact the comprehensiveness and generalizability of the findings. Addressing these constraints in future research will help refine and expand the scope of sentiment analysis studies.

1. Time Frame Restriction: This study analyzes publications from 2015 to 2024, providing a focused view of recent advancements. However, earlier foundational works are not extensively covered, which may limit a historical perspective on the evolution of sentiment analysis techniques.

2. Data Source Limitation: The study relies solely on the Scopus database, which, while comprehensive, excludes studies from other major repositories such as Web of Science, IEEE Xplore, and arXiv. These sources may contain significant contributions, particularly in interdisciplinary and emerging technical domains.

3. Impact Assessment Constraints: The citation-based impact analysis is limited, as recent publications may not yet have accumulated significant citations. This affects the assessment of long-term influence, as newly published works require time to gain recognition and impact.

4. Collaboration Gaps: The co-authorship analysis reveals both well-connected research clusters and isolated groups. While independent research efforts contribute to specialized knowledge, limited cross-disciplinary collaboration may restrict knowledge exchange and innovation across different research domains.

5. Keyword Coverage Limitations: The keyword analysis captures key themes like "deep learning" and "natural language processing", but emerging interdisciplinary topics such as ethical AI, cultural biases in sentiment analysis, and applications in underrepresented languages—are less prominently represented.

6. Practical Applicability: While the study discusses theoretical advancements, it does not extensively explore real-world deployment of sentiment analysis models. Practical considerations such as computational efficiency, ethical concerns, and scalability in real-world applications remain underexplored.

7. Geographical Representation Bias: The international collaboration rate (23.35%) highlights significant global research engagement. However, contributions from developing regions may be underrepresented, limiting insights into low-resource languages and regional sentiment analysis challenges.

8. Focus on Quantitative Analysis: This study primarily employs bibliometric techniques to analyze research trends and collaboration patterns. However, qualitative insights, such as challenges faced by researchers, ethical concerns, and practitioner feedback on sentiment analysis models, are not included.

5. Conclusion

This study highlights the steady growth and dynamic evolution of sentiment analysis research using deep learning (DL) and Natural Language Processing (NLP), emphasizing its interdisciplinary and global nature. By identifying key themes such as "transformer models," "multilingual sentiment analysis," and "adversarial machine learning," the findings address Research Question 1, demonstrating how DL techniques have been integrated with NLP to enhance sentiment analysis across diverse domains.

Despite these advancements, challenges related to practical deployment, ethical concerns, and model interpretability remain significant, directly addressing Research Question 2. The findings emphasize the need for explainable AI models, bias mitigation in multilingual sentiment analysis, and improved scalability for real-world applications. Tackling these challenges is crucial to maximizing both the societal and industrial impact of sentiment analysis technologies.

The study also underscores the importance of international collaboration, with a 23.35% global co-authorship rate, reflecting an increasingly interconnected research landscape. However, the presence of smaller, isolated research clusters and limited representation from underrepresented regions aligns with Research Question 3, suggesting the need for broader and more inclusive research collaborations.

Future efforts should prioritize interdisciplinary partnerships, bridging geographic disparities, and supporting resource-constrained researchers to create a more equitable research ecosystem.

By linking academic innovations to practical applications, this study provides a foundation for advancing sentiment analysis research. Researchers and practitioners can leverage these insights to overcome existing limitations and drive the development of AI-powered sentiment analysis tools in areas such as social media monitoring, healthcare, and financial analysis. Ultimately, this study underscores the transformative potential of DL and NLP in shaping the future of sentiment analysis research and its broader impact on society.

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