10.48047/jocaaa.2024.33.06.49

Graph-Based Optimization: A Bibliometric Analysis of Research Directions and Applications

Preetha Mathew
Department of Mathematics, Baselius College, Kottayam, Kerala, India

Abstract

Graph-based optimization is a computational approach that leverages graph structures to efficiently solve complex problems involving relationships, paths, and networks across diverse fields. This study presents a comprehensive bibliometric analysis of graph-based optimization literature using data extracted from the Scopus database. The analysis was conducted with the support of bibliometric software tools—Biblioshiny and VOSviewer—which enabled visualization and interpretation of research trends and scholarly networks. The annual scientific production indicates a steady growth in publications, especially after 2010, reflecting increasing academic and practical interest in the domain. The most relevant authors were identified based on publication frequency, with Krzysztof Michalak emerging as a leading contributor. Key publication venues included Lecture Notes in Computer Science and various IEEE conference proceedings, underscoring the technical and interdisciplinary nature of the field. Trend topic analysis highlighted a shift from foundational graph concepts to application-driven research, such as SLAM, sensor fusion, and knowledge graphs. The thematic map revealed a balance between well-developed motor themes and emerging niche areas. Co-citation network analysis of cited authors demonstrated the intellectual structure of the field, while keyword co-occurrence revealed strong interdisciplinary linkages. Finally, a network visualization of country collaborations showcased the global and collaborative nature of research in graph-based optimization.

Keywords: Graph-based optimization, Bibliometric analysis, Biblioshiny, VOSviewer

1. Introduction

Graph-based optimization leverages the mathematical structure of graphs to solve complex optimization problems [1], [2]. Graphs, consisting of vertices and edges, provide a versatile framework for modeling relationships and dependencies in real-world scenarios, such as transportation networks, communication systems, and supply chain management [3]. By applying graph-theoretic concepts, optimization techniques can address problems involving shortest paths, network flow, and resource allocation [4]. The approach's adaptability makes it a cornerstone in fields like operations research, artificial intelligence, and computational biology [5].

The importance of graph-based optimization lies in its ability to model and solve problems with intricate interconnections efficiently [6]. For instance, routing algorithms in logistics employ graph models to identify the shortest or most cost-effective paths, reducing time and fuel costs [7]. Similarly, social network analysis uses graphs to optimize connections and recommend users, enhancing user engagement [8]. In biological networks, graph-based methods facilitate understanding protein interactions, advancing drug discovery [9]. These applications highlight the practical relevance and transformative potential of graph-based optimization in diverse domains [10].

Graph-based optimization encompasses a variety of techniques, including classical algorithms like Dijkstra's and Bellman-Ford for shortest path problems and more advanced methods like maximum flow and minimum spanning tree algorithms [11]. Recent advancements incorporate machine learning and metaheuristic approaches, such as genetic algorithms and ant colony optimization, to address more complex and non-linear problems [12]. These techniques enable solutions to dynamic, large-scale, and multi-objective optimization challenges, pushing the boundaries of what can be achieved through graph-based methodologies [13].

10.48047/jocaaa.2024.33.06.49

Despite its advantages, graph-based optimization faces challenges, such as scalability in handling massive graphs and adapting to dynamic changes in real-time systems [14]. Computational efficiency and data sparsity remain areas requiring innovation [15]. Advances in quantum computing and parallel processing hold promise for addressing these limitations, potentially revolutionizing the field [16]. Moreover, the integration of graph-based optimization with other technologies, such as blockchain and artificial intelligence, opens new avenues for research and application, ensuring its relevance in solving future optimization problems.

Bibliometric analysis has become an essential tool for understanding the research trends, impact, and collaborations in scientific domains [17], [18]. In the context of graph-based optimization, this method provides valuable insights into the evolution of the field, identifying influential publications, prominent authors, and leading research clusters. By analyzing metadata from scientific databases, bibliometric studies offer a systematic overview of the field's growth, enabling researchers to identify knowledge gaps and emerging trends [17], [19]. Tools like Biblioshiny and VOSviewer have simplified the process, allowing for comprehensive and visually appealing analyses [20], [21].

Biblioshiny, an interactive web interface for the R-based Bibliometrix package, facilitates the extraction and analysis of bibliometric data [20], [21], [22]. It provides features such as trend analysis, citation networks, and thematic mapping, making it ideal for exploring the dynamics of graph-based optimization research [23], [24]. Similarly, VOSviewer is renowned for its ability to create and visualize bibliometric networks, such as co-citation, co-authorship, and keyword co-occurrence networks [25], [26]. Its graphical outputs, including heatmaps and cluster diagrams, enable users to identify relationships and patterns within the literature, contributing to a deeper understanding of the field's intellectual structure [27], [28].

The objective of conducting a bibliometric analysis on graph-based optimization using Biblioshiny and VOSviewer is to uncover the key themes, influential contributors, and collaborative networks shaping the field. By mapping the research landscape, this study aims to highlight the interdisciplinary applications of graph-based optimization and its growth trajectory. The findings can guide future research efforts, inform funding decisions, and facilitate knowledge dissemination among scholars and practitioners. Such analyses are pivotal for fostering innovation and addressing the complex challenges in this rapidly evolving domain.

2. Materials and Methods

This study employs a bibliometric analysis approach to explore the academic literature on Graph-Based Optimisation. Bibliographic data were collected from the Scopus database, known for its extensive coverage of scholarly publications [29], [30]. The query used for data retrieval was: TITLE-ABS-KEY ("Graph-Based Optimization"). The search was conducted without restrictions on language, and the dataset included peer-reviewed journal articles, book chapters, and conference papers to ensure comprehensive coverage of the topic. A total of 304 records were retrieved, spanning from 1983 to 2024, representing contributions from 238 different sources. The retrieved data underwent a meticulous screening process to remove duplicates and ensure accuracy. The refined dataset was saved in "CSV" file format, which was then imported into bibliometric analysis software for further processing using VOSviewer and Bibloghiny software.

3. Results and Findings

3.1. Main Information of the investigation

Table 1 provides a comprehensive overview of the bibliometric profile of research on graph-based optimization from 1983 to 2024. A total of 304 documents were published across 238 sources, reflecting a steady annual growth rate of 9.06% and indicating increasing scholarly interest in the field. The average document age is 7.38 years, and the average citation per document stands at 18.44, suggesting moderate academic impact. The dataset includes 2,766 Keywords Plus and 800 author keywords, pointing to diverse and evolving research themes. Authorship analysis reveals a high level of collaboration, with 969 contributing authors and only 23 single-authored documents; the average

10.48047/jocaaa.2024.33.06.49

number of co-authors per paper is 3.69, and 18.09% of the publications involve international collaboration. Most contributions are in the form of conference papers (170), followed by journal articles (127) and a few book chapters (7), consistent with the norms of computer science and optimization research communities.

Table 1. Main Information of the Investigation

Description	**Results**
MAIN INFORMATION ABOUT DATA	
Timespan	1983:2024
Sources (Journals, Books, etc)	238
Documents	304
Annual Growth Rate %	9.06
Document Average Age	7.38
Average citations per doc	18.44
References	8563
DOCUMENT CONTENTS	
Keywords Plus (ID)	2766
Author's Keywords (DE)	800
AUTHORS	
Authors	969
Authors of single-authored docs	11
AUTHORS COLLABORATION	
Single-authored docs	23
Co-Authors per Doc	3.69
International co-authorships %	18.09
DOCUMENT TYPES	
article	127
book chapter	7
conference paper	170

3.2. Annual Scientific Production

Figure 1 illustrates the annual scientific production in the field from 1983 to 2024. The publication trend reveals a slow and sporadic beginning, with minimal output between 1983 and 2000, where only a handful of papers were published. A noticeable upward trend begins in the early 2000s, with gradual increases from 2004 onward. From 2010, the field shows a steady rise in publications, suggesting growing academic interest and broader research application. A significant surge is observed after 2013, peaking notably in recent years. The years 2019 to 2024 mark the most productive phase, with a record high of 35 publications in 2024, indicating heightened global attention and research activity in graph-based optimization. This consistent growth, especially in the last decade, reflects the increasing relevance of graph-based methods in solving complex optimization problems across various domains.

10.48047/jocaaa.2024.33.06.49

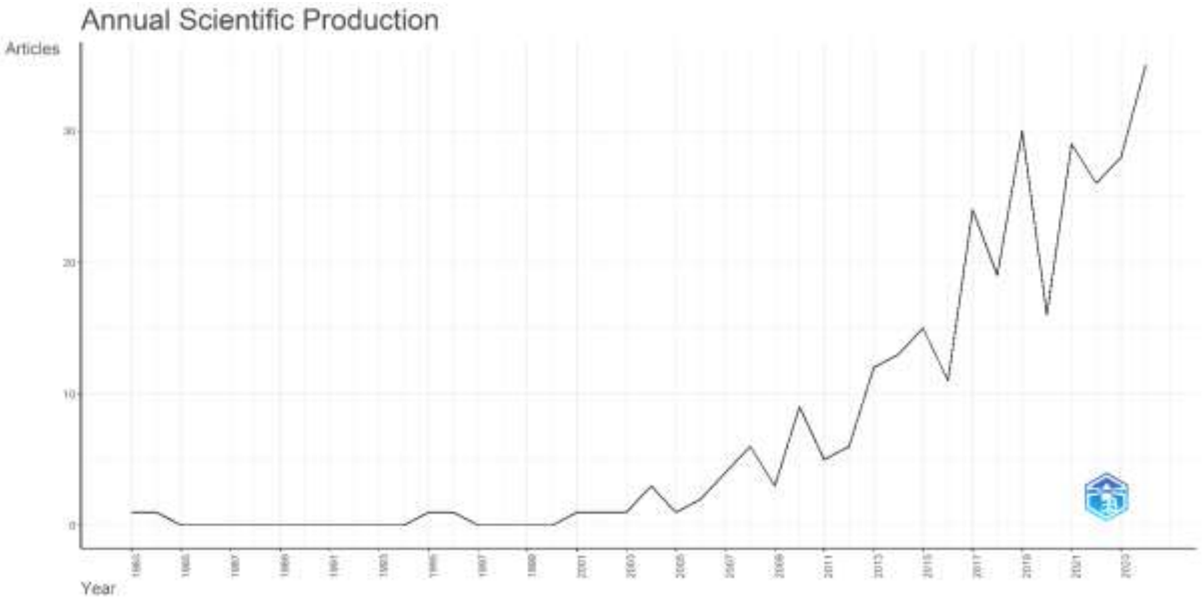

Figure 1. Annual Scientific Production

3.3. Most Relevant Authors

Table 2 highlights the most prolific contributors based on the number of documents published. The most dominant author is Krzysztof Michalak, who stands out significantly with 12 publications, indicating his central role in advancing research in this domain. He is followed by U. Stilla, with 6 publications, and Sreyasee Das Bhattacharjee and Yusheng Xu, both with 4 publications. A cluster of authors—Leomar S. Da Rosa, Kevin Eckenhoff, Damien Ernst, Patrick Geneva, M. Akif Gülsün, and Ludwig Hoegner—each contributed 3 papers, showing consistent engagement with the topic. The visual representation reinforces the leadership role of Michalak, with a large marker at the far right, while the steady contributions of others suggest a healthy collaborative environment among mid-level contributors. This distribution of productivity implies both established and emerging researchers are actively shaping the scholarly landscape of graph-based optimization.

Table 2. Most Relevant Authors

Authors	Articles
MICHALAK, KRZYSZTOF	12
STILLA, U.	6
DAS BHATTACHARJEE, SREYASEE	4
XU, YUSHENG	4
DA ROSA, LEOMAR S.	3
ECKENHOFF, KEVIN	3
ERNST, DAMIEN	3
GENEVA, PATRICK	3
GÜLSÜN, M. AKIF	3
HOEGNER, LUDWIG	3

3.4. Most Relevant Sources

Table 3 presents the most influential publication venues, reflecting where researchers most frequently disseminate their work. The Lecture Notes in Computer Science (LNCS) series, including subseries in Artificial Intelligence and Bioinformatics, leads significantly with 17 publications, highlighting its central role as a key outlet for cutting-edge developments in algorithmic and applied optimization. The

10.48047/jocaaa.2024.33.06.49

IEEE International Conference on Robotics and Automation (7 articles) and the IEEE International Conference on Intelligent Robots and Systems (6 articles) follow, underscoring the close linkage between graph-based optimization techniques and robotics applications. Other notable sources include Sensors (Switzerland) with 5 articles and IEEE Access and ISPRS Archives, each contributing 4 articles, showing the application of graph-based optimization in sensor networks, open-access dissemination, and spatial sciences. Conferences such as ICASSP, IEEE ITSC, and the IEEE Intelligent Vehicles Symposium—each with 3 contributions—further confirm the multidisciplinary interest in this field, particularly within signal processing, intelligent transportation, and autonomous systems. The presence of IEEE Transactions on Medical Imaging (3 articles) also suggests a growing impact of graph optimization in biomedical and healthcare domains. Overall, the diversity of sources reflects the broad applicability and interdisciplinary nature of graph-based optimization research.

Table 3. Most Relevant Sources

Sources	**Articles**
LECTURE NOTES IN COMPUTER SCIENCE (INCLUDING SUBSERIES LECTURE NOTES IN ARTIFICIAL INTELLIGENCE AND LECTURE NOTES IN BIOINFORMATICS)	17
PROCEEDINGS - IEEE INTERNATIONAL CONFERENCE ON ROBOTICS AND AUTOMATION	7
IEEE INTERNATIONAL CONFERENCE ON INTELLIGENT ROBOTS AND SYSTEMS	6
SENSORS (SWITZERLAND)	5
IEEE ACCESS	4
INTERNATIONAL ARCHIVES OF THE PHOTOGRAMMETRY, REMOTE SENSING AND SPATIAL INFORMATION SCIENCES - ISPRS ARCHIVES	4
ICASSP, IEEE INTERNATIONAL CONFERENCE ON ACOUSTICS, SPEECH AND SIGNAL PROCESSING - PROCEEDINGS	3
IEEE CONFERENCE ON INTELLIGENT TRANSPORTATION SYSTEMS, PROCEEDINGS, ITSC	3
IEEE INTELLIGENT VEHICLES SYMPOSIUM, PROCEEDINGS	3
IEEE TRANSACTIONS ON MEDICAL IMAGING	3

3.5. Trend Topics

Figure 2 presents a timeline of trending topics, highlighting the temporal evolution and frequency of key research terms from around 2014 to 2024. The term "graph" has the longest and most consistent presence, indicating its foundational role throughout the decade. More specific terms such as "graph-based optimization", "graph optimization", and "slam" (Simultaneous Localization and Mapping) began to gain visibility around 2018–2019, with "graph-based optimization" showing the highest frequency, indicating its emergence as a core focus area in recent research.The terms "optimization" and "sensor fusion" became prominent around 2020, reflecting growing interest in integrating multiple data sources and solving complex optimization problems. Other emerging areas such as "indoor positioning", "mobile robot", and "localization" appear in the 2021–2023 window, suggesting the application of graph-based techniques in robotics and navigation. Notably, "knowledge graph" appears most recently (around 2023–2024), pointing to a cutting-edge shift toward semantic technologies and AI-driven applications.Overall, the figure demonstrates a clear thematic evolution from foundational graph concepts to advanced, application-driven topics, underscoring the field's dynamic growth and its expanding intersection with robotics, AI, and sensor systems.

10.48047/jocaaa.2024.33.06.49

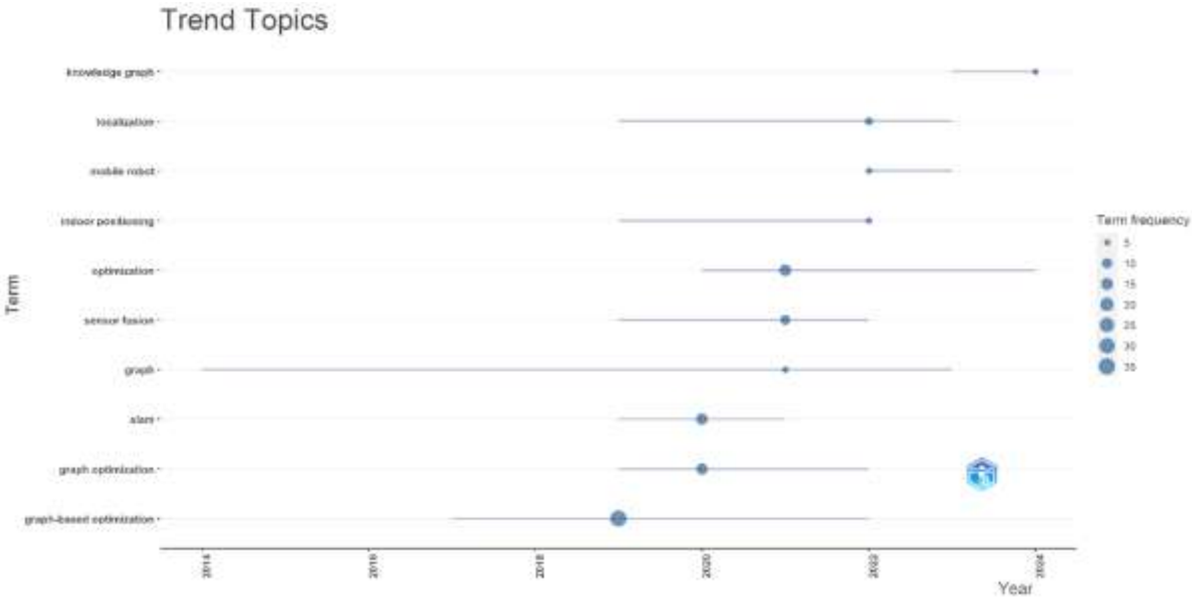

Figure 2. Trending topics in graph-based optimization

3.6. Thematic Map

Figure 3 presents a thematic map of research themes based on their centrality (relevance) and density (development level). The upper-right quadrant, representing motor themes, includes topics that are both highly relevant and well-developed. Notably, graph-based optimization, graph theory, deep learning, semantic segmentation, and indoor positioning fall into this quadrant. These themes are currently driving the research frontier, showing strong internal cohesion and external influence across related fields such as computer vision, robotics, and artificial intelligence. Their strategic positioning indicates they are focal points of innovation and application within the domain.

The basic themes found in the lower-right quadrant include optimization, graph optimization, sensor fusion, SLAM (Simultaneous Localization and Mapping), and machine learning. These topics are foundational and widely connected but are still under development or refinement. Their presence here suggests that they serve as pillars for more advanced research while continuing to evolve with new methodologies and integrations. These themes are essential for newcomers to understand the structure and evolution of the field and represent broad, interdisciplinary areas that support ongoing innovation.

On the other hand, the niche themes in the upper-left quadrant—such as graph signal processing, loop closing, point cloud processing, and design optimization—are well-developed but less central, often representing specialized or isolated lines of inquiry. The emerging or declining themes in the lower-left quadrant, including ant colony optimization, pose graph optimization, and indoor localization, may be early-stage developments gaining traction or older topics losing prominence. Overall, this thematic map reveals a mature yet dynamic research landscape, with a healthy balance between core foundational topics, specialized investigations, and emerging frontiers.

10.48047/jocaaa.2024.33.06.49

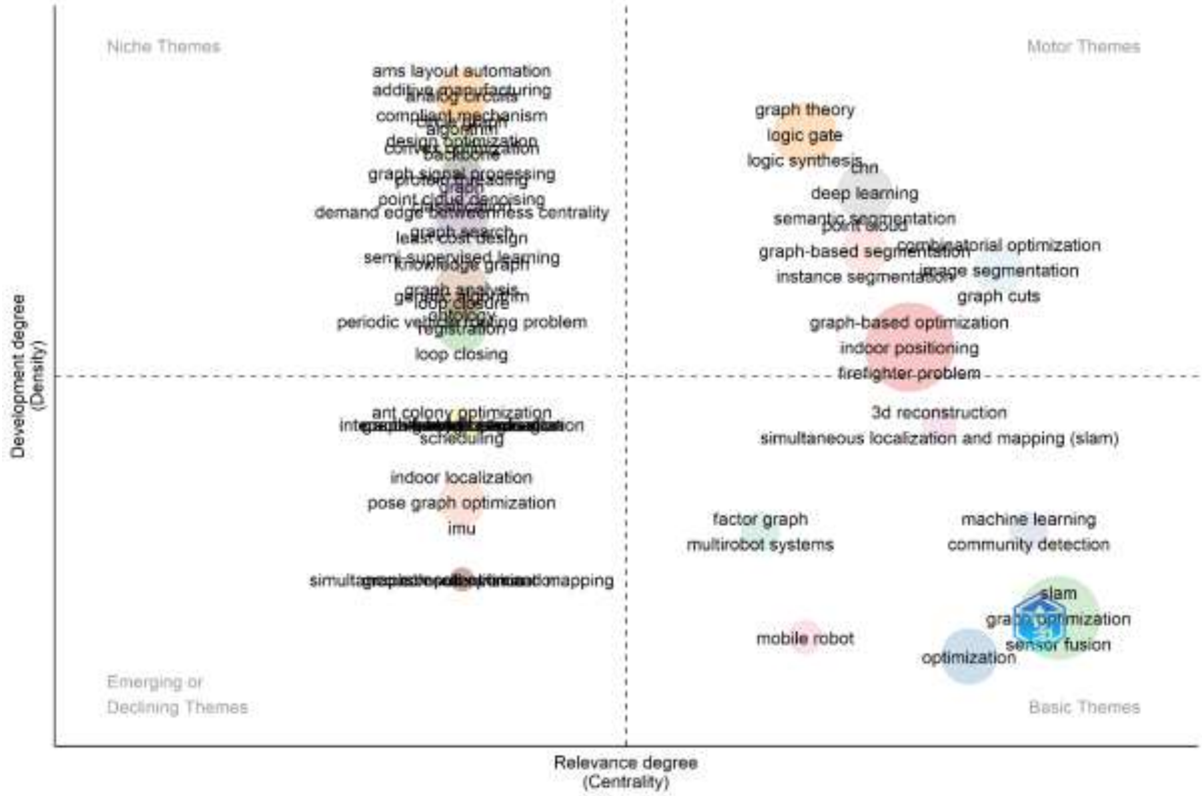

Figure 3. Thematic visualisation of keywords

3.7. Co-citation of Cited Author

Figure 4 presents a co-citation network of authors using VOSviewer, where the size of the nodes indicates the frequency of an author's citation, and the proximity and connections between nodes reflect how often they are cited together. The clusters are color-coded to represent different thematic or research communities within the broader field of graph-based optimization. In the green cluster, Burgard W. stands out as a central and frequently co-cited author, closely connected with Dellaert F., McKay N.D., Henry P., and Rusu R.B. This group is likely focused on robotics, SLAM (Simultaneous Localization and Mapping), and related areas. The red cluster, which includes Zhang L., Xu Y., Liu J., and Stilla U., shows another core group of co-cited researchers, indicating strong collaboration and thematic coherence in areas such as image segmentation, computer vision, and optimization algorithms.

The blue cluster, comprising Zhang J., Tang C., IEEE, Najman L., and USA, may indicate institutional or regional networks (possibly focused on signal processing or computer vision). Michalak K., placed in the yellow cluster, is a notable author with strong links to Laporte G. and Dorigo M., suggesting a distinct research direction, possibly related to ant colony optimization or logistics. Meanwhile, isolated or smaller clusters like those with Bertozzi A.L. or Gallego G. point to niche but influential contributions.Overall, the figure reveals the intellectual structure of the field by highlighting prominent authors, thematic communities, and the strength of scholarly influence based on co-citation patterns. This map aids in identifying leading voices and collaborations in the graph-based optimization research domain.

10.48047/jocaaa.2024.33.06.49

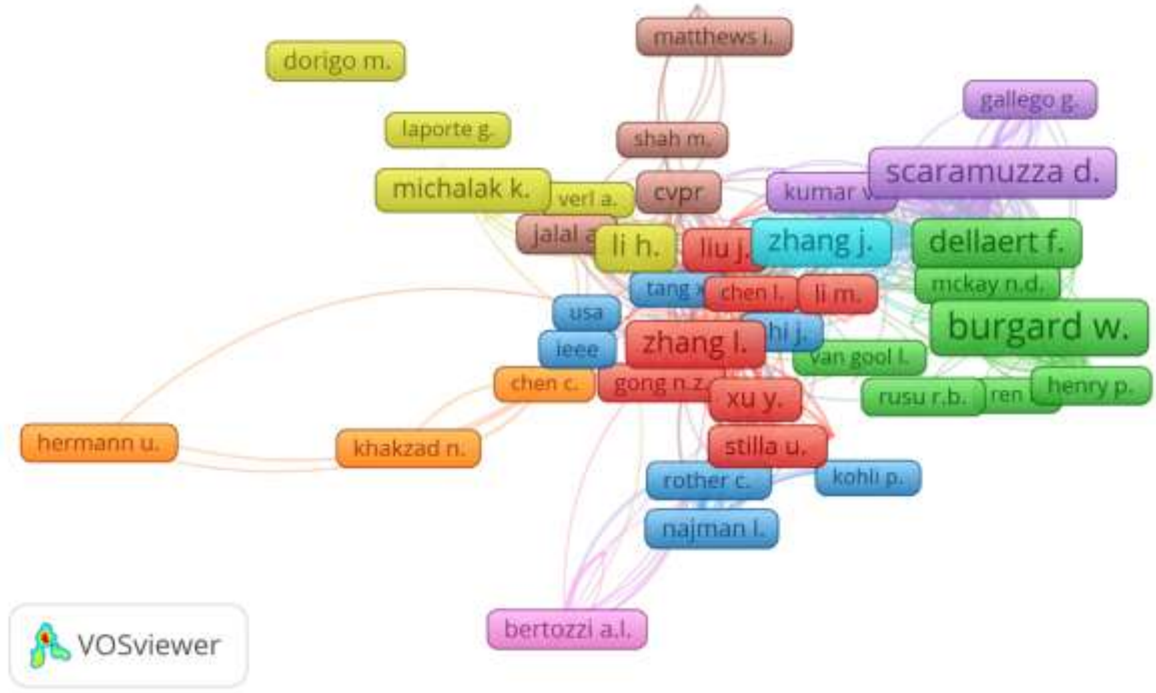

Figure 4. Co-citation of cited authors

3.8. Co-occurrence of Keywords

Figure 5 visualizes the co-occurrence network of author keywords. The size of each node reflects the frequency with which a keyword appears, while the links between them represent how often pairs of keywords co-occur in the same documents. Clusters are color-coded to highlight distinct thematic areas or research subfields. At the center of the network, "graph-based optimization" appears as the most dominant and frequently used keyword, forming the core of the research field. It is closely connected to terms like "combinatorial optimization," "machine learning," "SLAM," and "sensor fusion," indicating strong interdisciplinary interactions. These connections suggest that graph-based optimization is heavily utilized in solving complex machine learning tasks and robotic localization problems.

Other prominent clusters include "graph theory" and "logic gate" (blue cluster), showing a theoretical foundation, and "optimization" and "graph" (turquoise cluster), which highlight methodological strength. The green cluster around "sensor fusion" and "SLAM" reflects application-oriented research in robotics and spatial awareness. The presence of keywords like "CNN," "active learning," and "graph-based segmentation" in other clusters suggests growing interest in integrating deep learning techniques and computer vision with graph-based optimization approaches. Overall, this co-occurrence map reveals a rich and interconnected research ecosystem, with "graph-based optimization" at its hub, bridging theory and application across multiple domains.

10.48047/jocaaa.2024.33.06.49

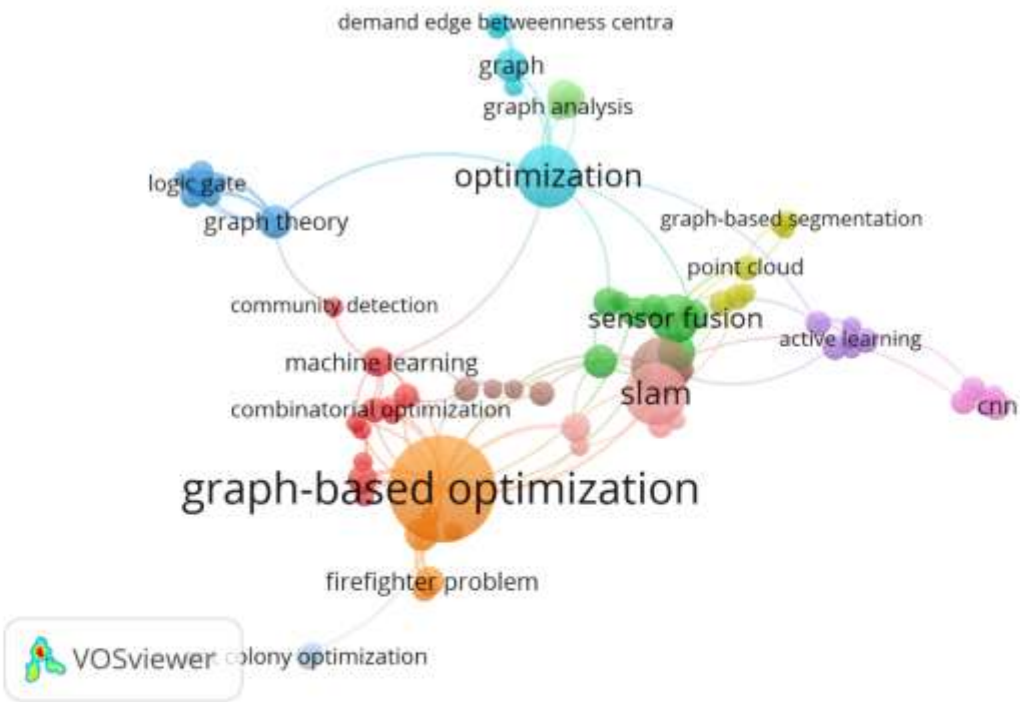

Figure 5. Co-occurrence of author keywords

3.9. Co-authorship of Countries Collaborations

Figure 6 visualizes the international co-authorship network, as mapped by VOSviewer. Each node represents a country, with its size indicating the volume of publications, while the connecting lines denote collaborative ties between countries. The clusters are color-coded to reflect distinct groups of closely collaborating nations. The United States appears as the most prominent node in the network, highlighting its leading role in global research output and international collaboration in this domain. It is closely connected with countries such as Germany, Switzerland, Austria, Singapore, and Japan, indicating strong transcontinental research partnerships. Germany also emerges as a central hub within the red cluster, maintaining strong links with Poland, Belgium, and Hong Kong, suggesting active regional and global engagement. The China-centered cluster shows connections with Singapore, Australia, Brazil, and South Korea, reflecting growing participation from Asia-Pacific nations. Meanwhile, countries like Japan, Canada, and Ireland form smaller but significant nodes, often linking across clusters. This co-authorship map reveals a globally interconnected research community in graph-based optimization, with notable hubs in North America, Europe, and Asia, and increasing cross-regional collaboration essential for addressing complex optimization challenges in various technological and applied fields.

10.48047/jocaaa.2024.33.06.49

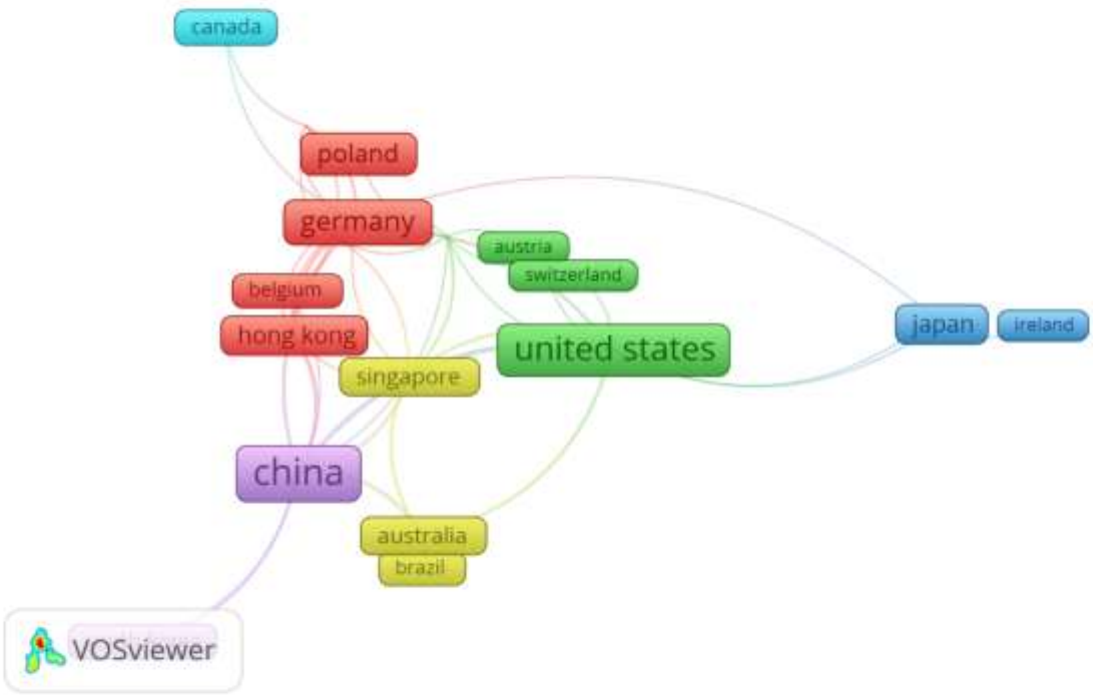

Figure 6. Co-authorship of countries

Discussions

The bibliometric analysis reveals that graph-based optimization has witnessed a substantial and consistent growth trajectory, particularly over the past decade. From a sparse beginning in the 1980s and 1990s, the annual scientific production significantly increased post-2010, reaching a peak of 35 publications in 2024. This indicates the rising academic and practical interest in graph-based methods for solving complex optimization problems. The field is marked by a high degree of collaboration, with a large number of contributing authors and relatively few single-authored papers. The average of 18.44 citations per document suggests moderate but growing impact. Notably, conference proceedings dominate the publication types, emphasizing the fast-paced, applied nature of research in this area, especially in computer science, robotics, and AI contexts.

From a thematic perspective, the keyword co-occurrence and thematic maps show a transition from theoretical foundations to applied innovations. Core themes such as "graph theory," "optimization," and "sensor fusion" form the basis for more specialized and well-developed motor themes like "graph-based optimization," "semantic segmentation," and "indoor positioning." The emergence of new terms like "knowledge graph" and "active learning" reflects a shift toward data-driven, AI-integrated approaches. Thematic clustering shows how graph-based optimization is now embedded in interdisciplinary problem-solving, including robotics (SLAM), computer vision, and combinatorial optimization. This intellectual evolution is also reflected in co-citation networks, where prominent authors such as Michalak, Burgard, and Stilla form distinct but interconnected research communities contributing to the advancement of the field.

The analysis of international collaborations highlights the global reach and interconnectedness of graph-based optimization research. The United States emerges as the most central contributor, actively collaborating with countries such as Germany, Switzerland, Singapore, and Japan. Germany and China also function as regional research hubs, with strong ties to both neighboring and distant nations. This widespread co-authorship pattern reflects the multidisciplinary nature and broad applicability of graph-based optimization, which requires diverse expertise and perspectives. Together, the findings underscore a mature, collaborative, and rapidly evolving research ecosystem with expanding boundaries and significant potential for future innovation.

10.48047/jocaaa.2024.33.06.49

Conclusion

This bibliometric analysis provides a comprehensive overview of the research landscape in graph-based optimization, highlighting its steady growth, key contributors, thematic evolution, and global collaboration patterns. The field has matured significantly, with increasing interdisciplinary applications in areas such as robotics, artificial intelligence, and sensor systems. Thematic and trend analyses reveal a shift from foundational theories to advanced, application-oriented research. Prominent authors, sources, and international partnerships underscore the collaborative and diverse nature of this domain. Based on the findings, it is recommended that future researchers explore underdeveloped yet emerging themes such as pose graph optimization and knowledge graphs. Additionally, fostering more cross-country and cross-disciplinary collaborations can further enrich the field. Finally, integrating graph-based optimization with evolving technologies like quantum computing and deep learning may open new avenues for innovation and impact.

References

[1] A. L. Bertozzi and E. Merkurjev, "Graph-based optimization approaches for machine learning, uncertainty quantification and networks," in *Handbook of Numerical Analysis*, vol. 20, Elsevier, 2019, pp. 503–531.

[2] J. Zhang, K. A. Ehinger, H. Wei, K. Zhang, and J. Yang, "A novel graph-based optimization framework for salient object detection," *Pattern Recognit.*, vol. 64, pp. 39–50, 2017.

[3] Y. Chen, Y. Li, J. D. Kalbfleisch, Y. Zhou, A. Leichtman, and P. X.-K. Song, "Graph-based optimization algorithm and software on kidney exchanges," *IEEE Trans. Biomed. Eng.*, vol. 59, no. 7, pp. 1985–1991, 2012.

[4] P. Kovács, "Efficient Algorithms for Graph Optimization Problems," 2019, doi: 10.15476/elte.2019.029.

[5] H.-J. Hung, W.-C. Lee, C.-Y. Shen, F. He, and Z. Lei, "Leveraging Transfer Learning for Enhancing Graph Optimization Problem Solving," pp. 339–351, 2024, doi: 10.1007/978-981-97-2253-2_27.

[6] M. Alaeiyan and H. Kharazi, "Application of n-distance balanced graphs in distributing management and finding optimal logistical hubs," *Iran. J. Manag. Stud.*, vol. 9, pp. 783–793, Oct. 2016, doi: 10.22059/IJMS.2017.60093.

[7] Donglin, "Research on Route Optimization System of Logistics Distribution Center Based on Computer Big Data Technology," *2023 IEEE 6th Int. Conf. Inf. Syst. Comput. Aided Educ. ICISCAE*, pp. 1067–1071, Sep. 2023, doi: 10.1109/ICISCAE59047.2023.10393328.

[8] Y. Hou and M. Jia, "A Data-Driven Collaborative Forecasting Method for Logistics Network Throughput Based on Graph Learning," *IEEE Access*, vol. 11, pp. 61059–61069, 2023, doi: 10.1109/ACCESS.2023.3287102.

[9] A. Rodionov, H. Choo, and K. Nechunaeva, "Framework for biologically inspired graph optimization," *Proc. 5th Int. Conf. Ubiquitous Inf. Manag. Commun.*, Feb. 2011, doi: 10.1145/1968613.1968626.

[10] Z. Cai, Y. Yang, X. Zhang, and Y. Zhou, "Design a Robust Logistics Network with an Artificial Physarum Swarm Algorithm," *Sustainability*, Nov. 2022, doi: 10.3390/su142214930.

[11] A. Serban and G. Sandou, "Mixed Ant Colony Optimization for the Unit Commitment Problem," pp. 332–340, Apr. 2007, doi: 10.1007/978-3-540-71618-1_37.

[12] G. Xin, "Function Optimization Based on Programming Mixed Ant Colony Algorithm with Genetic Algorithm," *Comput. Knowl. Technol.*, 2009, [Online]. Available: https://consensus.app/papers/function-optimization-based-on-programming-mixed-ant-xin/b89a67181f405a4ca68fbf3ba652e02a/

[13] T. Fei, X. Wu, L. Zhang, Y. Zhang, and L. Chen, "Research on improved ant colony optimization for traveling salesman problem.," *Math. Biosci. Eng. MBE*, vol. 19 8, pp. 8152–8186, Jun. 2022, doi: 10.3934/mbe.2022381.

[14] S. D. Pasham, "Network Topology Optimization in Cloud Systems Using Advanced Graph Coloring Algorithms," *Res. Anal. J.*, Nov. 2023, doi: 10.18535/raj.v6i11.426.

10.48047/jocaaa.2024.33.06.49

[15] V. C. Manduva, “Advancing AI in Edge Computing with Graph Neural Networks for Predictive Analytics,” *Res. Anal. J.*, May 2024, doi: 10.18535/raj.v7i05.400.

[16] Y. Huang, F. P. Nugraha, S. Jin, Y. Zhang, B. Zeng, and Q. Shao, “Quantum Graph Optimization Algorithm,” Apr. 2024, [Online]. Available: https://consensus.app/papers/quantum-graph-optimization-algorithm-huang-nugraha/c7de5ae374fd5a8898b8112ea22f05d0/

[17] N. Abas, H. Hussin, N. M. Hardi, and N. Hashim, “Exploring the interconnection of social media, mental health and youth: A bibliometric analysis,” *Soc. Manag. Res. J.*, Oct. 2023, doi: 10.24191/smrj.v20i2.24401.

[18] A. F. Abbas, A. Jusoh, A. Masod, and J. Ali, “A Bibliometric Analysis of Publications on Social Media Influencers Using Vosviewer,” *J. Theor. Appl. Inf. Technol.*, vol. 99, no. 23, pp. 5662–5676, 2021.

[19] M. Alavi, A. Valiollahi, and M. Pakravan, “Bibliometric Analysis of research trends on Graph Neural Networks,” *2024 20th CSI Int. Symp. Artif. Intell. Signal Process. AISP*, pp. 1–8, Feb. 2024, doi: 10.1109/AISP61396.2024.10475285.

[20] R. Komperda, “Likert-type survey data analysis with R and RStudio,” *ACS Symposium Series*, vol. 1260. pp. 91–116, 2017. doi: 10.1021/bk-2017-1260.ch007.

[21] J. S. Racine, “RSTUDIO: A platform-independent IDE for R and sweave,” *Journal of Applied Econometrics*, vol. 27, no. 1. pp. 167–172, 2012. doi: 10.1002/jae.1278.

[22] P. Thangavel and B. Chandra, “Two Decades of M-Commerce Consumer Research: A Bibliometric Analysis Using R Biblioshiny,” *Sustainability*, vol. 15, no. 15, p. 11835, Aug. 2023, doi: 10.3390/su151511835.

[23] J.-H. Huang, X.-Y. Duan, F.-F. He, G.-J. Wang, and X.-Y. Hu, “A historical review and Bibliometric analysis of research on Weak measurement research over the past decades based on Biblioshiny,” *ArXiv Prepr. ArXiv210811375*, 2021.

[24] M. H. Fahamsyah, I. Mawardi, N. Laila, and M. S. Shabbir, “Global Islamic Banking Development: A Review and Bibliometric Analysis Using R-Biblioshiny Application,” *Muqtasid J. Ekon. Dan Perbank. Syariah*, vol. 14, no. 1, pp. 69–92, 2023.

[25] N. J. Van Eck and L. Waltman, “Software survey: VOSviewer, a computer program for bibliometric mapping,” *Scientometrics*, vol. 84, no. 2, pp. 523–538, Aug. 2010, doi: 10.1007/s11192-009-0146-3.

[26] Y. Yu *et al.*, “A bibliometric analysis using VOSviewer of publications on COVID-19,” *Ann. Transl. Med.*, vol. 8, no. 13, pp. 816–816, Jul. 2020, doi: 10.21037/atm-20-4235.

[27] F. Husain and M. S. Mustafa, “A Decade of Islamic Banking Research: Bibliometric Review with Biblioshiny and Vosviewer,” *Jambura Sci. Manag.*, vol. 5, no. 2, pp. 67–85, 2023.

[28] N. J. Van Eck and L. Waltman, “VOSviewer: A computer program for bibliometric mapping,” *12th International Conference on Scientometrics and Informetrics, ISSI 2009*. pp. 886–897, 2009. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84901992309&partnerID=40&md5=2b19eafa3759e96b197c3ec7535a731f

[29] P. Mongeon and A. Paul-Hus, “The journal coverage of Web of Science and Scopus: a comparative analysis,” *Scientometrics*, vol. 106, no. 1, pp. 213–228, Jan. 2016, doi: 10.1007/s11192-015-1765-5.

[30] J. Baas, M. Schotten, A. Plume, G. Côté, and R. Karimi, “Scopus as a curated, high-quality bibliometric data source for academic research in quantitative science studies,” *Quant. Sci. Stud.*, vol. 1, no. 1, pp. 377–386, Feb. 2020, doi: 10.1162/qss_a_00019.