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APPLICATION OF BIBLIOMETRIC ANALYSIS ON ROOT GROWTH ALGORITHM

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ABSTRACT

The root growth algorithm has often been used to solve challenging optimization issues. It is one of the metaheuristic algorithms inspired by root growth in plant behaviors. An article reviewed and analyzed bibliographic data on metaheuristics but is not specific on the topic of root growth algorithm. Therefore, this article presents a bibliometric analysis based on the topic of the root growth algorithm. It reviews the publication from the Scopus database. Based on the search process done on 14 February 2023 using the keywords of root growth algorithm, this article managed to gather 1836 articles from 1976-2023. However, this article only focuses on Engineering, Computer Science, and Mathematics to ensure it relates to the area the researcher wants to explore. Moreover, articles in the year 2023 will also be excluded due to incomplete data. After the researcher limited the data to those areas, it was reduced to 837 articles. This article uses three types of software: Microsoft Excel, VOSviewer software, and Harzing's Publish or Perish software to analyze the frequency, visualization mapping, and citation metrics analysis, respectively. The finding from the bibliometric analysis shows the researcher has noticed that the total publication keeps increasing rapidly from 2014 until 2022. The country that contributes the most to the root growth algorithm topic is China. Furthermore, the most productive author is Chen, H. and all the top 10 productive authors are from China except for Christofides, P. D., who comes from the United States. The top 10 sources of root growth algorithm research contributed over a quarter of the total articles (231 or 27.60%). The results of this study have significant implications for increasing the number of practices using the root growth algorithm in future research. Last but not least, bibliometric analysis on the topic of root growth algorithm is needed to identify influential publications, understand research trends, evaluate research impact, and identify potential research gaps in a concise manner, which helps researchers and readers stay informed, make informed decisions, and contribute to the advancement of knowledge in the field.

Keywords: Algorithm, Bibliometric Analysis, Citation Metrics, Metaheuristic, Root Growth, Visualization Map.

INTRODUCTION

Root growth algorithms can provide insight into the different methods used to simulate the growth and development of plant roots. Several approaches have been proposed and used to model root growth, including empirical, process-based, and data-driven methods (Zheng et al., 2021). Empirical methods make use of equations based on observations of real root growth to simulate root growth. These models are simple and can be used to predict the growth of roots under various conditions, but they may not be able to accurately capture the complex processes involved in root growth.

On the other hand, process-based models attempt to simulate root growth by modeling the various physiological and biochemical processes that drive root growth. These models can be more accurate in predicting root growth but can also be more complex and computationally intensive. Data-driven methods, such as machine learning algorithms, use data collected from real root growth to train algorithms that can then be used to predict root growth under different conditions. These methods can be highly accurate but may not always provide a good understanding of the underlying processes involved in root growth.

There have been several studies that have compared the performance of different root growth algorithms and found that process-based models tend to perform better than empirical models. In contrast, data-driven models can perform similarly to process-based models but with less computational intensity (Liu & Xie, 2020).

It should be noted that the accuracy of any root growth algorithm depends on the quality and quantity of the data used to train the algorithm and the complexity of the underlying processes being modeled. As such, the choice of a root growth algorithm will depend on the specific research needs and the resources available.

One example of a root growth algorithm is the RootBox model. RootBox is a process-based model that simulates the growth and development of plant roots by modeling the underlying physiological and biochemical processes (Dunbabin et al., 2013). The model uses a combination of mathematical equations and data from real root growth to simulate the behavior of roots in response to environmental factors such as water availability, soil structure, and nutrient availability.

In RootBox, root growth is modeled as a combination of apical growth and lateral branching. Apical growth is modeled using a differential equation that describes the rate of elongation as a function of root length, while lateral branching is modeled as a stochastic process that is dependent on the availability of resources in the soil.

The RootBox model has been used to simulate root growth in various plant species and has been found to accurately predict root growth under different conditions. Note that the model has also been used to study the impact of environmental factors on root growth and to evaluate the trade-offs between root growth and above-ground growth in plants.

Many others use different approaches to simulate root growth. The choice of a specific algorithm will depend on the specific needs of the research being conducted and the resources available. Hence, the bibliometric analysis on root growth algorithms was conducted to explore the literature on root growth algorithms in the Scopus database. It aimed to answer the following research questions:

Research Questions:
1. How far has the root growth algorithm research progressed in terms of publication?
2. Which author is the most productive in the field of root growth algorithm research?
3. What is the pattern of research on root growth algorithms that is scattered?

It is necessary to do the bibliometric analysis in order to demonstrate the development or increase of publications over time, the creation of new research paths, and the influence of particular research groups or institutions. Readers can use this information to stay current on industry trends and areas of emphasis. Moreover, this analysis also helps the readers to discover collaborations and networks among researchers studying the root growth algorithm topic. By visualizing the institutional collaborations and the co-authorship pattern, readers can understand knowledge exchange and collaborative dynamics within the research community.

In summary, bibliometric analysis gives readers insightful knowledge of the root growth algorithm topic, including significant publications, research gaps, research impact, networks of researchers, and research trends. This knowledge assists readers in staying updated, identifying what can have a big impact, and advancing scientific understanding. The rest of this paper is structured as follows. The next section discusses the flow of the bibliometric analysis that can be conducted. Consequently, the results have been presented in the third section. Lastly, the researcher provides the discussion and conclusion in the last section.

LITERATURE REVIEW

The root growth algorithm is one of the plant-inspired metaheuristic algorithms that outperform other algorithms on most benchmark functions in terms of accuracy on high-dimension functions (He et al., 2015). There is a bibliometric analysis of metaheuristics that studies the progressions of various types of metaheuristic algorithms (Ezugwu et al., 2021). Nevertheless, no researchers study the progress of publication, research impact, and the pattern of research using bibliometric analysis focusing only on one type of root growth algorithm topic.

According to Zhang et al. (2012), the root growth algorithm can obtain better performance than the other algorithms on the Griewank, Rastrigin, Rosenbrock, and Sphere functions. Based on the comparison, the root growth algorithm can optimize numerical function and perform better than the other competitors such as Genetic Algorithms (GA), Differential Evolution (DE), and Particle Swarm Optimization (PSO). The study by Ma et al. (2018) enhanced the root growth algorithm, a new Root System Growth Algorithm with Adaptive Population Variation (RSGA_APV). The finding indicates that RSGA-APV has a significant potential to be used in numerous complicated real-world situations because it has some promising ability against existing optimization algorithms on continuous stationary and dynamic optimization scenarios.

Furthermore, the comparison of metaheuristic algorithms inspired by nature has been made in the previous study, and the result shows that some metaheuristic algorithms from plant intelligence-based perform better compared to other nature-inspired and the algorithms helped solve complex problems (Akyol & Alatas, 2017). Based on the study by Chaparro (2022), the root growth algorithm has been applied in this study using the Reaction-Diffusion Root Branching (RDRB) and phenomenological models for the computational simulation and modeling techniques.

The root growth algorithm is a revolutionary method that draws inspiration from biology in this research on complex system modeling and computations (Zhang et al., 2012). Ideas for this broad optimization model came from observations of how soil-borne roots behave during growth.

In conclusion, the bibliometric analysis on the root growth algorithm topic showed that the publication progress increases consistently. This finding was consistent with previous studies that showed the superiority of the root growth algorithm in achieving the best model. Subsequently, the results of this study provide valuable insights for other researchers to identify the articles that have a high impact on journals, as they can use the root growth algorithm to make more accurate predictions in the neural network model.

METHODS

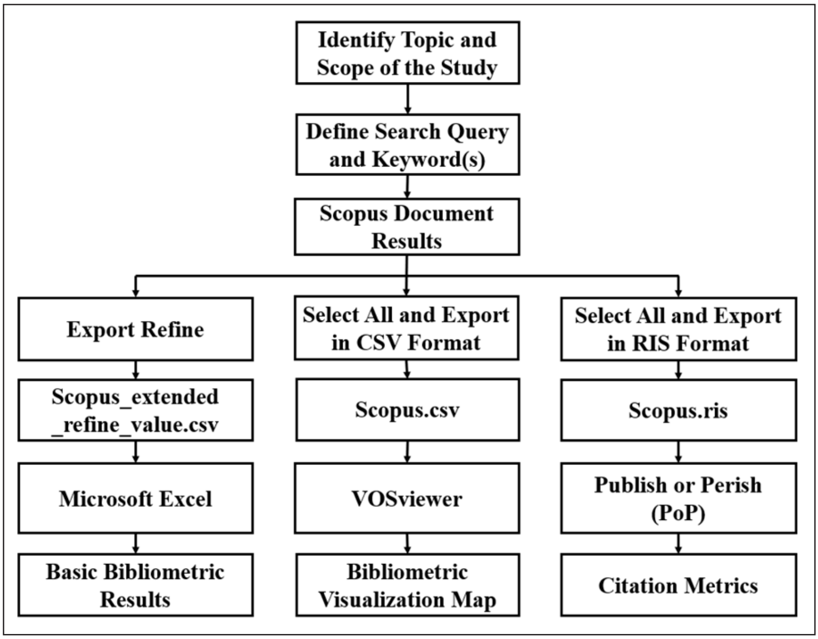
Data Collection

This study is a bibliometric analysis, which measures, visualizes, and analyses how scientific disciplines are built (Firdaus et al., 2019; Koskinen et al., 2008). It is engaged to describe the expansion of the desired field in a particular area of knowledge (Liu et al., 2018). It evaluates publications such as the impact factor, citations, publishers, and publication countries (Docampo & Cram, 2019; Iefremova et al., 2018; Lee, 2019).

Figure 1 illustrates the strategy to search the data from the Scopus database. Firstly, the researcher needs to identify the topic and scope of the study that the researcher wants to review. Then, define the search for the keyword by the search query. The researcher needs to set the aim to know what kind of data is needed and needs to be refined. Consequently, the data can be downloaded from three types of files, which are Scopus_extended_refine_value.csv, Scopus.csv, and Scopus.ris to do the basic bibliometric analysis using Microsoft Excel, Bibliometric Visualization Map using VOSviewer and Citation Metrics Analysis using Publish or Perish (PoP) software, respectively. VOSviewer is a popular tool with a simple graphic interface that can be used to create the author's keyword co-occurrence map (Visser et al., 2021). It allows for identifying significant research subjects and finding large research clusters related to the root growth algorithm. The bibliometric analysis flowchart is illustrated in Figure 1.

Figure 1

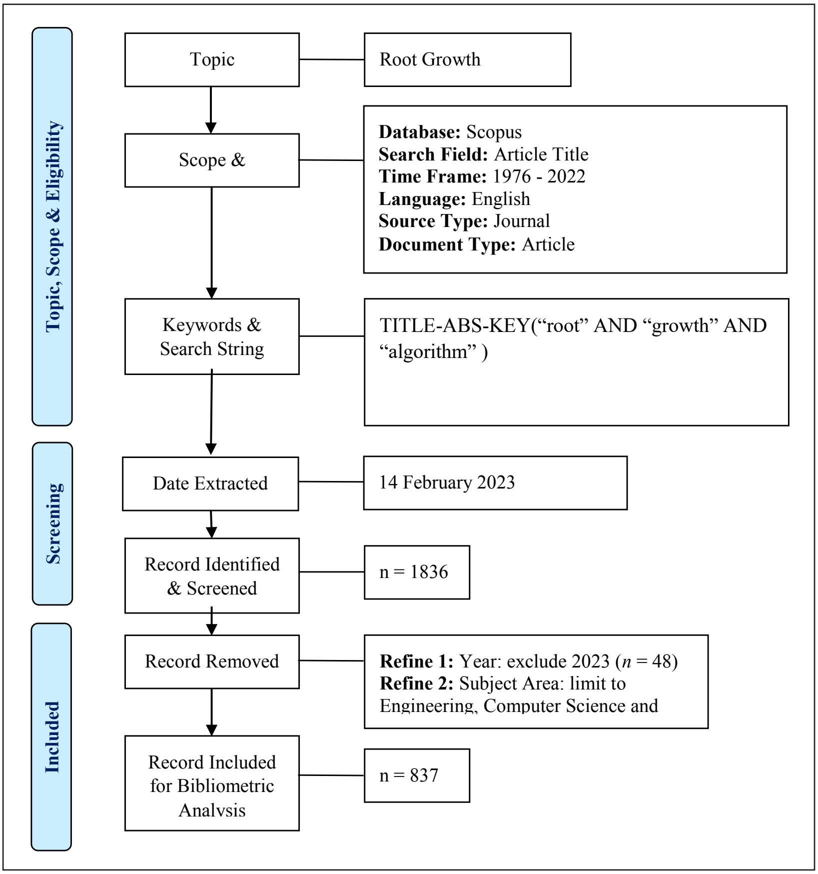
Bibliometric Analysis Flowchart



The data for this analysis were retrieved and downloaded from the Scopus database on 14 February 2023. From 1976 to 2022, the search term “root AND growth AND algorithm” was utilized in the title of the article. The researcher excluded the documents for the year 2023 (*n* = 48) due to incomplete data in 2023. The researcher included all the documents focusing on the subject area related to Engineering, Computer Science, and Mathematics from 1976 to 2022. Finally, 837 documents were identified and downloaded for further analysis, as depicted in Figure 2.

Figure 2

Search Strategy



Data Analysis

The researcher has combined network and performance analysis to achieve these research objectives. The performance analysis, including citation metrics and publication-related metrics using Harzing's Publish or Perish (Harzing, 2010), and data visualization were mapped using VOSviewer software (version 1.6.17).

RESULTS

This study analyzed the main bibliometric indicators to profile the research landscape on the root growth algorithm from 1976 to 2022.

Publication and Citation Trend

There were 837 publications on root growth algorithms retrieved from the Scopus database for this study. The first publication was published by Muller and Preparata, who also studied the 'root growth algorithm' (Muller & Preparata, 1976). It shows that the research progressed for 47 years on the root growth algorithm topic, and the publication has increased drastically since 2002.

Table 1

Year of Publication

Year	TP	NCP	TC	C/P	C/CP	*h*	*g*
1976	1	0.12%	1	20	20.00	20.00	1
1979	1	0.12%	1	4	4.00	4.00	1
1980	1	0.12%	0	0	0.00	-	0
1986	1	0.12%	1	3	3.00	3.00	1
1987	1	0.12%	1	1	1.00	1.00	1
1988	2	0.24%	1	184	92.00	184.00	1
1990	3	0.36%	2	10	3.33	5.00	2
1991	1	0.12%	0	0	0.00	-	0
1992	3	0.36%	3	139	46.33	46.33	2
1993	2	0.24%	1	5	2.50	5.00	1
1994	5	0.60%	4	61	12.20	15.25	3
1995	1	0.12%	0	0	0.00	-	0
1996	2	0.24%	2	15	7.50	7.50	2
1997	1	0.12%	0	0	0.00	-	0
1998	4	0.48%	3	536	134.00	178.67	3
1999	1	0.12%	0	0	0.00	-	0
2000	6	0.72%	4	209	34.83	52.25	4
2001	2	0.24%	2	14	7.00	7.00	2
2002	4	0.48%	4	45	11.25	11.25	2
2003	4	0.48%	2	46	11.50	23.00	2
2004	5	0.60%	4	101	20.20	25.25	2
2005	11	1.31%	11	406	36.91	36.91	6
2006	10	1.19%	8	146	14.60	18.25	5
2007	8	0.96%	6	880	110.00	146.67	5
2008	17	2.03%	11	179	10.53	16.27	8
2009	17	2.03%	13	221	13.00	17.00	8

(continued)

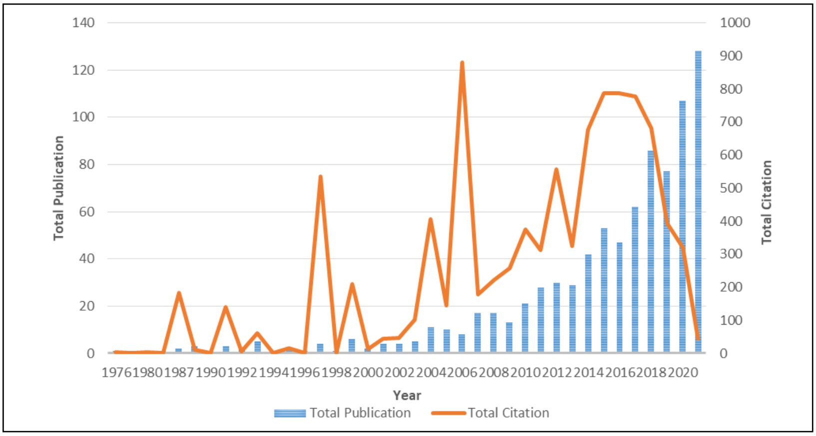
Year	TP	NCP	TC	C/P	C/CP	*h*	*g*
2010	13	1.55%	10	258	19.85	25.80	8
2011	21	2.51%	19	376	17.90	19.79	10
2012	28	3.35%	24	313	11.18	13.04	9
2013	30	3.58%	25	557	18.57	22.28	12
2014	29	3.46%	24	324	11.17	13.50	11
2015	42	5.02%	38	677	16.12	17.82	14
2016	53	6.33%	46	788	14.87	17.13	15
2017	47	5.62%	41	788	16.77	19.22	15
2018	62	7.41%	55	778	12.55	14.15	15
2019	86	10.27%	70	682	7.93	9.74	14
2020	77	9.20%	62	395	5.13	6.37	11
2021	107	12.78%	77	319	2.98	4.14	8
2022	128	15.29%	21	45	0.35	2.14	3
Total	**837**	**100.00%**					

Notes: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; and g=g-index.

Table 1 presents that the total number of publications from 1974 until 2004 is less than 10 because the researcher was unfamiliar with the root growth algorithm. After 2004, the total publications by year will keep increasing rapidly until 2022. However, in terms of total citations, the number of citations after 2016 dropped drastically until the present year.

Figure 3

Total Publications and Citations by Year



Geographical Distribution of the Publication

Table 2 shows the most productive countries based on the number of publications. China contributed almost half of the total publications. This was followed by the United States (*n* = 159 or 19.95%), India (*n* = 70 or 8.78%), the United Kingdom (*n* = 41 or 5.14%), and Canada (*n* = 28 or 3.51%). In terms of citations, China had the lead, followed by the United States, India, the United Kingdom, and Canada.

Table 2

Top 10 Countries Contributed to the Publications.

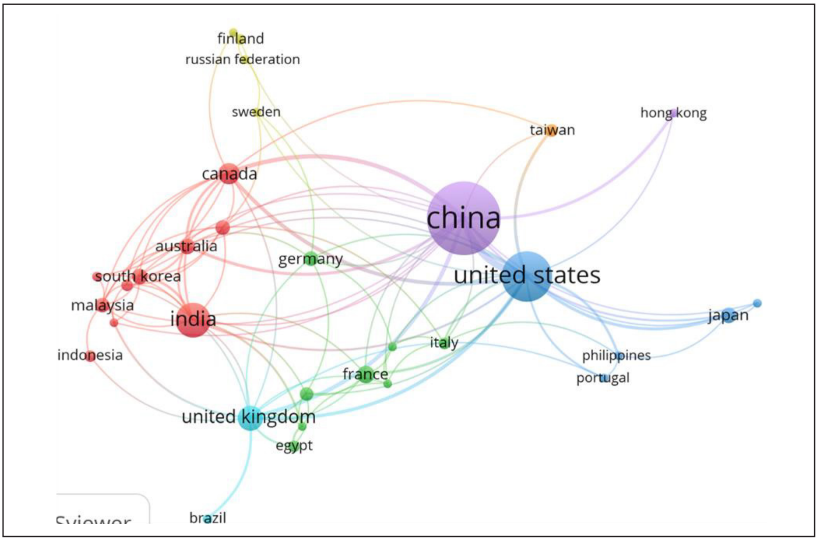
Country	TP	NCP	TC	C/P	C/CP	*h*	*g*
China	353	274	2967	8.41	10.83	26	38
United States	163	125	3337	20.47	26.70	32	54
India	78	51	598	7.67	11.73	11	23
United Kingdom	43	38	746	17.35	19.63	14	26
Canada	30	26	376	12.53	14.46	9	19
France	20	17	858	42.90	50.47	9	17
Australia	16	14	254	15.88	18.14	8	14
Japan	16	12	166	10.38	13.83	6	12
South Korea	16	12	249	15.56	20.75	6	12
Germany	14	14	316	22.57	22.57	9	14

Notes: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; and g=g-index.

Figure 4 portrays the visualization map of the co-authorship based on countries that have a minimum of 5 citations. The result shows that China, the United States, and India are the countries that published a lot on the topic of the ‘Root Growth Algorithm’.

Figure 4

Co-authorship Based on Countries Network Visualization Map (Full Counting)



Most Productive Authors

The top 10 most productive authors are listed in Table 3. Based on the number of publications each had published, Chen, H., and Wang, P. were the major contributing authors. However, Huang, J. obtained the highest citations in terms of total citations, followed by Chen, H., Zhu, Y., and Wang, P. All the top 10 productive authors are from China except for Christofides, P. D., who comes from the United States. Note that h-index (Hirsch, 2005) measures the broad impact of researchers' scientific achievement, especially in sciences and medicine. Three authors, Chen, H., Feng, H., and He, Y. obtained the highest value of h-index, which is 5.

Table 3

Most Productive Authors

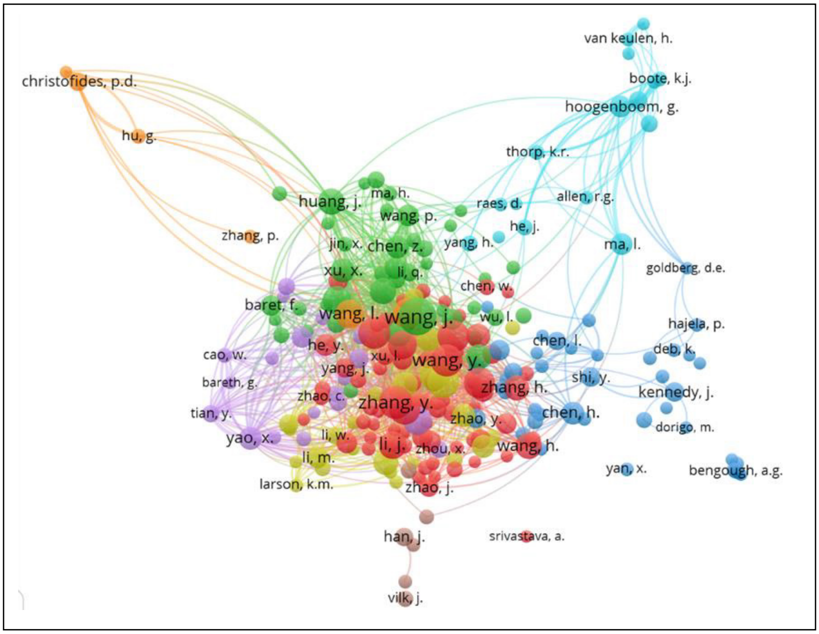
Author's Name	Affiliation	Country	TP	NCP	TC	C/P	C/CP	*h*	*g*
Chen, H.	Tiangong University	China	10	9	102	10.20	11.33	5	9
Wang, P.	China Agricultural University	China	10	9	72	7.20	8.00	4	8
Li, L.	China Agricultural University	China	7	7	37	5.29	5.29	4	5
Zhu, Y.	Fudan University	China	7	7	79	11.29	11.29	4	7
Ma, L	Software College of Northeastern University	China	6	5	65	10.83	13.00	4	5
Zhang, H.	Guizhou University	China	6	6	47	7.83	7.83	3	6
Christofides, P.D.	University of California	United States	5	3	42	8.40	14.00	3	3
Feng, H.	Beijing Academy of Agriculture and Forestry Sciences, Information Technology Research Center	China	5	5	46	9.20	9.20	5	5
He, Y.	College of Biosystems Engineering and Food Science	China	5	5	63	12.60	12.60	5	5
Huang, J.	Ministry of Agriculture of the People's Republic of China	China	5	5	146	29.20	29.20	3	5

Notes: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; and g=g-index.

The network visualization map of the co-citation based on cited authors has been shown in Figure 5. It indicates that Wang, J. is the author that has the highest number of citations which are 181 citations and has a link with 218 authors.

Figure 5

Co-citation Based on Cited Author (Full Counting)



Research Work Pattern Across the Sources

Table 4 shows the top 10 sources of root growth algorithm research, contributing more than a quarter of the total articles (231 or 27.60%). In terms of total citations, ‘Nongye Gongcheng Xuebao Transactions of The Chinese Society of Agricultural Engineering’ obtained the highest total citations (739), followed by ‘Computers And Electronics in Agriculture’ (732) and ‘Lecture Notes in Computer Science Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics’ (710). Even though ‘Nongye Jixie Xuebao Transactions of The Chinese Society for Agricultural Machinery’ has the second highest in total publications, the total number of citations (213) is lower than ‘Sensors Switzerland’ (267).

Table 4

Top 10 Source Titles

Source Title	TP	NCP	TC	C/P	C/CP	h	g
Nongye Gongcheng Xuebao Transactions of The Chinese Society of Agricultural Engineering	74	65	739	9.99	11.37	16	21
Nongye Jixie Xuebao Transactions of The Chinese Society for Agricultural Machinery	41	33	213	5.20	6.45	9	12
Computers And Electronics in Agriculture	34	33	732	21.53	22.18	14	26
Lecture Notes in Computer Science Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics	24	13	710	29.58	54.62	7	13
Sensors Switzerland	18	17	267	14.83	15.71	10	16
International Journal of Molecular Sciences	10	9	129	12.90	14.33	5	9
IEEE Access	8	7	165	20.63	23.57	4	7
IEEE Transactions on Geoscience and Remote Sensing	8	7	39	4.88	5.57	4	6
Proceedings Of SPIE The International Society for Optical Engineering	8	3	15	1.88	5.00	3	3
Applied Soft Computing Journal	6	6	147	24.50	24.50	6	6

DISCUSSION AND CONCLUSION

The aim of this study is to explore the literature on root growth algorithms in the Scopus database. This study reviews all kinds of scholarly works based on the title "Root Growth Algorithm ʻʼ for searching patterns. Overall, bibliometric details of 837 documents reported in 47 years (1976-2022) were extracted from the Scopus database.

This study has analyzed a few parts to answer the research question regarding the research progress in terms of publication, the most productive author, and the pattern of the research. Based on the bibliometric analysis that has been conducted, the researcher has noticed that the total publication keeps increasing rapidly from 2014 until 2022. However, in terms of total citations, the number of citations after 2016 dropped drastically. The countries that contribute the most to the root growth algorithm topic are China, the United States, India, the United Kingdom, and Canada, with a total publication of 353, 159, 70, 41, and 28 publications, respectively. Furthermore, the most productive author is Chen, H. and all the top 10 productive authors are from China except for Christofides, P. D., who comes from the United States. The top 10 sources of root growth algorithm research contributed more than a quarter of the total articles (231 or 27.60%).

This article holds significance as it addresses a previously unexplored aspect. In the previous study, the researcher reviewed and analyzed bibliographic data on metaheuristics but was not specific on the root growth algorithm topic. Therefore, this article aims to bridge that gap and provide valuable insights. Moreover, the bibliometric analysis of the root growth algorithm is needed to identify influential publications, understand research trends, evaluate research impact, and identify potential research gaps concisely. The research gap in this article is that the researcher only focuses on the root growth algorithm topic and extracts the data from the Scopus database. For future research, the researcher can analyze other kinds of metaheuristic algorithms to focus more on the algorithm that the researchers are interested in. The researcher can also extract the data from other databases like Web of Science, Google Scholar, and MDPI.

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