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A BIBLIOMETRIC STUDY ON BLOCKCHAIN CONCEPT: A THEME ANALYSIS AND FUTURE DIRECTIONS FOR COMPUTER SCIENCE TRAINING

Abstract: This paper aims to study the blockchain concept domain in the computer science field due to bibliometric study. Authors employed bibliometric and network analysis techniques to analyze existing literature. In total, 719 articles in the period of 2019 to August 2023 from the Web of Science (WOS) database were analyzed after applying search string, and criteria for inclusion and exclusion. Initial data screening involved the extraction of fundamental information, followed by data analysis based on co-occurrence, bibliographic coupling, and citation using special program software VOSviewer and R program. research areas "compute science" and "engineering". In addition to that, VOSviewer and R-based tools illustrate the application of text mining involves utilizing computational techniques to extract, analyze, and represent the key concepts and relationships within the field of blockchain technology. Data analysis primarily involved co-occurrence analysis, bibliographic coupling, co-authorship examination, citation analysis, and co-citation analysis. In the context of a blockchain concept thematic analysis, was applied clustering by coupling. Furthermore, it was conducted the thematic analysis to scrutinize the content of prior studies in the computer science field using clustering by coupling. Ranking of the authors, organizations, and countries was applied according to total link strength metric which was used to quantify the overall strength of connections between nodes within a network. Besides, citation analysis has also been conducted to assess the articles' ranking, considering both worldwide and localized citations. Bibliometric results indicate blockchain concepts within such thematic frameworks as access control scheme, identity management system, supply chain management, artificial intelligence integration, blockchain technology applications, and blockchain smart contract.

Keywords: blockchain; blockchain concept; computer science; bibliometric study

Introduction

Blockchain is a revolutionary concept in the computer science and engineering field that has garnered significant attention and is transforming various industries. Blockchain is 'a secure platform, ledger, or database where buyers and sellers could store and exchange value without the need for traditional intermediaries' initially described by Tapscott D. and Tapscott A. [1]. At its core, a blockchain is a decentralized, distributed, and immutable digital ledger that records transactions or data securely and transparently.

Nowadays the speed of the development of technology is so fast that the laws of certain countries do not keep pace with their rapid development and growing popularity. Blockchain technology can change everything related to money markets, payments, financial services, the economy, and all other industries of human activity. Blockchain is a fundamentally new paradigm that allows you to organize activities with optimal effort efficiency at a much larger scale than other existing paradigms. Blockchain technology is rich in new concepts that can become an integral part of the intellectual baggage and professional knowledge set of a modern person. Blockchain technology helps to realize that everything we see and experience, every system in our life is to some extent an economic system, a resource distribution system.

Blockchain technology, initially introduced as the underlying technology for cryptocurrencies, has expanded its applications beyond finance to areas such as supply chain management, healthcare, and more. Concurrently, text mining techniques have gained prominence for their ability to extract valuable insights from textual data.

Combining these two fields offers a unique perspective on understanding the key concepts and relationships within the blockchain domain. Bolívar and Muñoz [2] employed text mining analysis to represent emerging technologies implementation in public services. VOS techniques mirror the MDS approach in terms of aim – i.e., "a dimensionality reduction technique used to represent high-dimensional data in a lower-dimensional space while preserving the pairwise distances between data points as much as possible" [3, 4].

Blockchain technology has emerged as a disruptive innovation with far-reaching implications across various industries. As the field continues to evolve, researchers and practitioners seek to gain a comprehensive understanding of its conceptual landscape. This literature review aims to explore the integration of text mining techniques in the analysis of the conceptual apparatus within the blockchain domain, focusing on its applications within the realm of computer science.

Blockchain technology holds great promise in the education sector, offering several important advantages that can significantly impact the way education is delivered, managed, and accessed. Despite the availability of studies in education related to authentication in the course system [5], the Ethereum system for issuing and managing academic certificates [6], and a private blockchain-based platform for managing and exchanging data [7], there is surprisingly little research on the concept of blockchain in the context of the general conceptual apparatus of computer science. Blockchain technology facilitates a broad spectrum of possibilities within the realm of education [8], including the creation of digital learning pathways [9] and the establishment of higher education systems based on smart contracts [10]. However, these studies consider blockchain as a tool of application, but not as an object of study for learning and acquiring the necessary skills and competence to use it. This research fills this gap by conducting a bibliometric analysis of the blockchain concept in computer science using text mining software tools such as VOSviewer and R program. To conduct this analysis and report the results, we consulted manuals of foreign scholars [11, 12]. In this way, the objective of this study is to address the following inquiries:

Q1. Which countries, articles, authors, and journals hold the greatest influence in the realm of blockchain concept in the computer science field?

Q2. What prevailing themes and trends can be observed within the domain of blockchain technology in the computer science field?

Q3. What are the research gaps and future trends in light of the blockchain concept?

Following this, the study aims to provide the subsequent enhancements to the current body of research:

In this research, an extensive bibliometric literature examination was carried out using an R-powered tool and VOSviewer. A descriptive evaluation was undertaken to identify the predominant topic areas and the yearly publication count. Additionally, we conducted analyses encompassing co-occurrence, bibliographic linkage, citation, co-authorship, and co-citation to uncover the impactful articles, authors, nations, and institutions. Within the framework of thematic cluster analysis, works of Cao et. al [13], Elghaish et. al [14], Wamba et. al [15], Xie et. al [16]. Ma et. al [17], Mollah et al [18] were identified as works with the greatest contribution.

After employing software-driven thematic analysis, this study developed a thematic framework to categorize the existing literature, facilitating a more convenient exploration of the primary research directions. The thematic analysis of the concept of blockchain in the field of computer science and engineering will allow us to create an educational program that provides a methodology for concepts related to blockchain technology for effective teaching of blockchain technologies at universities.

Methods and Materials

The primary emphasis of this research lies in conducting a bibliometric analysis of the concept of blockchain within the computer science and engineering domain. The research we propose involves the evaluation of published articles within the computer science field, specifically focusing on blockchain technology. We employ different statistical tools, such as VOSviewer and an R-based tool, to quantitatively analyze visual data. Initially, we gather data from various search engines and then conduct an assessment to determine the number of articles published each year and their corresponding research areas. Additionally, we provide insights into influential authors, countries, organizations, and relevant journals within the blockchain-based supply chain domain. Moreover, we highlight the most impactful subject areas and articles based on the data we select. Consequently, our proposed bibliometric study encompasses articles related to blockchain technology in the realm of computer science.

In the first step, we applied a screening procedure to select publications. We employed search queries to gather data from the chosen databases (WOS) for mining. The data extraction was performed on August 1, 2023. We started by querying the WoS database with the search such terms as "blockchain", "blockchain technologies" and "blockchain concept" in the field "title" for the period from 2019 to August 2023. Afterward, we filtered by research areas "compute science" and "engineering", thus gathering 719 articles. Extracted publications included 609 articles and 110 reviews total from 240 sources.

The main information of descriptive analysis included the total number of authors (2572) and showed average years since the publication equal to 1.74. The mean citations per paper was 18.55 and the average citations per year per doc was 6,156. The international co-authorships percentage was 41.17. According to Fig. 1, it is noticed the growing tendency of publications with this topic at the peak of 220 articles in 2022, whereas the publication of articles in 2023 is still in progress. In 2020 the number of articles has doubled due to the COVID-19 epidemic.
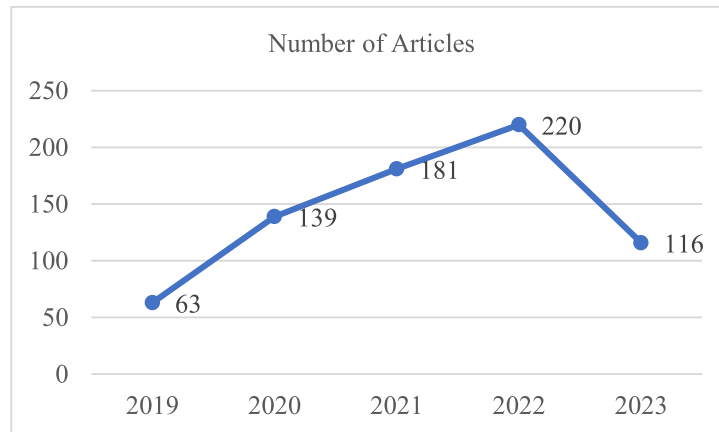
Figure 1. Annually published number of articles related to the blockchain concept

The statistics from Fig. 2 also show that China (354) and India (188) stand out as the fore-most nations in terms of the number of published articles. These two countries collectively contribute approximately 45% of the total articles, with the USA (144) and Australia (94) following closely. The representation of published articles for each country can be observed in Fig. 2.
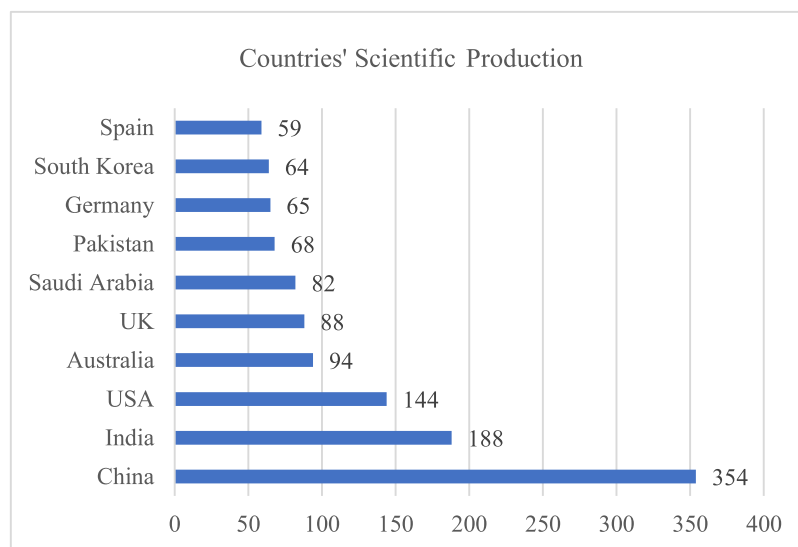

Figure 2. Number of articles published by each country

Network analysis

Researchers have utilized techniques like keyword extraction, named entity recognition, and co-occurrence analysis to identify and categorize essential terms related to blockchain, such as "consensus mechanism", "smart contracts", and "decentralization". These extracted concepts are often visualized using network graphs, providing insights into the relationships and connections among different blockchain concepts. We applied bibliometrix, an R-based tool for mapping literature, and VOSviewer for visualizing scientific data networks. Our data analysis primarily involved co-occurrence analysis, bibliographic coupling, co-authorship analysis, citation analysis, and co-citation analysis.

In VOSviewer, "association strength" refers to the measure of connection or relationship between two items, such as authors, keywords, or documents. This measure helps determine

how closely related or connected these items are within the context of the analyzed dataset. Association strength can be calculated based on various metrics, depending on the type of data being analyzed as follows:

$$AS_{ij} = \frac{C_{ij}}{w_i \, w'_j} \qquad (1)$$

which is "this pertains to the ratio between the real instances of i and j appearing together and the expected instances of i and j appearing together, assuming that their co-occurrences are statistically independent".

Total Link Strength (TLS) is a network metric used in network analysis to quantify the overall strength of connections between nodes within a network. It provides a summary measure of the interactions or relationships between nodes in a network graph. The concept of "Total Link Strength" is often used in various types of network mapping, including social networks, citation networks, and co-authorship networks.

The Total Link Strength value provides an aggregated measure of a node's importance or influence within the network. Nodes with higher Total Link Strength values have more significant connections with other nodes, indicating a higher degree of collaboration, interaction, or influence. This metric can help identify key nodes within the network, which may correspond to central figures, influential authors, highly cited papers, or important entities in a specific domain.

The bibliometrix tool, based on R, offers a diverse range of literature mapping capabilities. In comparison to alternative tools, it efficiently filters the data. On the other hand, VOSviewer offers extensive visualization options across various categories. Specifically, VOSviewer primarily offers three types of visualizations: "network visualization," "overlay visualization," and "density visualization."

Co-occurrence analysis (co-word analysis)
The result of the Co-occurrence analysis showed approximately 2108 keywords, but with a minimum number of keyword occurrences of 5, only 125 meet the threshold. Using the VOSviewer software, the connection of these keywords was mapped and visualized. Based on Fig. 3, these keywords were divided into six clusters.

Figure 3. Network visualization of all keywords

Table 1 illustrates the TLS score for the top 10 authors' keywords. Among these keywords, "Blockchain" and "Internet of Things" emerged as the most significant ones in this category. Author keywords are ranked based on fractional TLS values.

Table 1. Co-occurrence analysis results for the author

Keyword	Occurrences	TLS
Blockchain	467	1194
Internet of things	132	468
Smart contract	137	446
Security	81	349
Privacy	47	211
Distributed ledger	36	158
Peer-to-peer computing	24	143
Cloud computing	27	128
Artificial intelligence	28	107
Ethereum	32	107

Bibliographic coupling

Authors, institutions, and nations are ranked through bibliographic coupling, using TLS values to gauge the strength of the connections between two nodes (authors, institutions, and countries). Following the application of threshold criteria, Table 2 presents the top 10 authors, institutions, and countries. Quoc-Viet Pham attained the highest impact score, with Niyato Dusit and Liyanage Madhusanka following closely behind. This suggests that their contributions to the blockchain concept hold greater significance compared to other authors, and their articles are particularly noteworthy. Regarding the top ten organizations. University College Dublin is recognized as the most influential organization operating in this field. The table also presents TLS values for countries, with China, India, the USA, and England ranking as the most impactful nations in sequence. It's worth noting that China has published a greater number of articles compared to India and the USA, and the quality of China's articles surpasses that of other countries. Additionally, it's interesting to observe that certain developing countries like India and Pakistan also make substantial contributions to this domain.

Table 2. Analysis of bibliographic coupling: the top 10 contributing authors, countries, and organizations

Authors (TLS)	Organizations (TLS)	Countries (TLS)
Quoc-Viet Pham (458)	University College Dublin (1360)	Peoples R China (31 659)
Niyato Dusit (437)	University of Oulu (1327)	India (24 797)
Liyanage Madhusanka (359)	University of New South Wales (930)	USA (22 650)
Chen Yu (315)	Nanyang Technological University (732)	England (17 913)
Xu Ronghua (315)	King Abdulaziz University (564)	Australia (17 421)
Kumar Neeraj (313)	King Saud University (352)	South Korea (17 134)
Salah Khaled (274)	Khalifa University (254)	Saudi Arabia (16 953)
Jayaraman Raja (259)	Southeast University (207)	Canada (16 541)
Alazab Mamoun (228)	Chinese Academy of Sciences (139)	Pakistan (12 033)
Shah Syed Attique (130)	Taif University (113)	Germany (10 092)

A bibliometrix, which is an R-based tool, was employed to generate the triple field plot depicted in Fig. 4. This plot illustrates the interconnectedness among authors (on the left), affiliations (in the middle), and authors' keywords (on the right). The plot is constructed based on count values, such as the number of publications per author, institution, and the frequency of keywords appearing in the database. However, the arrangement of the sequence may vary. The graph unveils that three authors, in affiliation with Nanyang Technological University, have been responsible for the majority of publications related to blockchain technology. These articles predominantly focus on blockchain technology itself and its core applications, including smart contracts and traceability. Additionally, sustainability emerged as a prominent keyword across many of the articles.
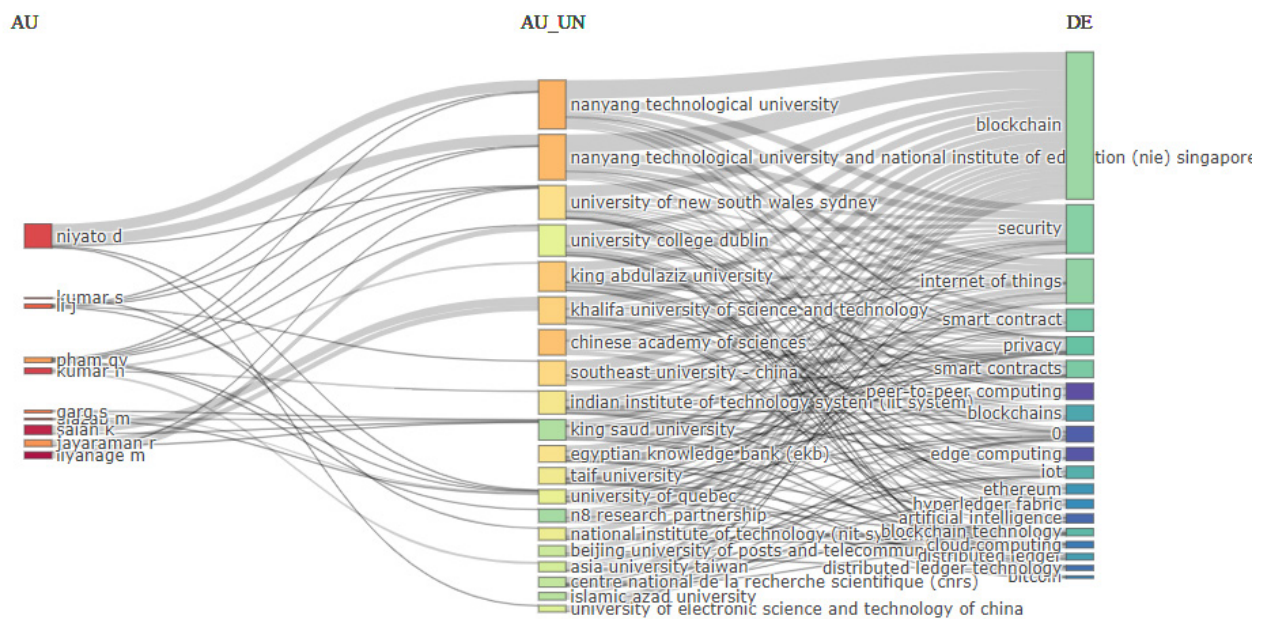
Figure 4. Triple field plot of authors, affiliation, and keywords

Moreover, the authors from the University of New South Wales University and University College Dublin do a lot of research in this field. According to the given graph, the King Abdulaziz University and Khalifa University from Saudi Arabia have made a huge contribution to blockchain research as compared to others.

Co-authorship analysis
To comprehend the collaborative contributions of multiple authors, a co-authorship analysis was conducted. In the realm of research, co-authorship analysis quantifies the extent of joint publications among scholars, contributing to the expansion of knowledge. Fig. 5 shows the leading four author clusters, established with a minimum of five citations as a threshold and a resolution of 1.0. A glance at Table 3 reveals that within cluster 1 (highlighted in red), Kundu Dipanjali and Rahman Anichur are the predominant authors, each possessing 39 TLS. Quoc-Viet Pham and Ruby Rukhsana. In Cluster 2 (green), Quoc-Viet Pham and Ruby Rukhsana demonstrate greater author productivity. Meanwhile, Cluster 3 (blue) is characterized by Niyato Dusit and Koh Leong Hai as productive authors, and in Cluster 4 (yellow), Gadekallu Thippa Reddy and Maddikunta Praveen emerge as prominent collaborative authors.
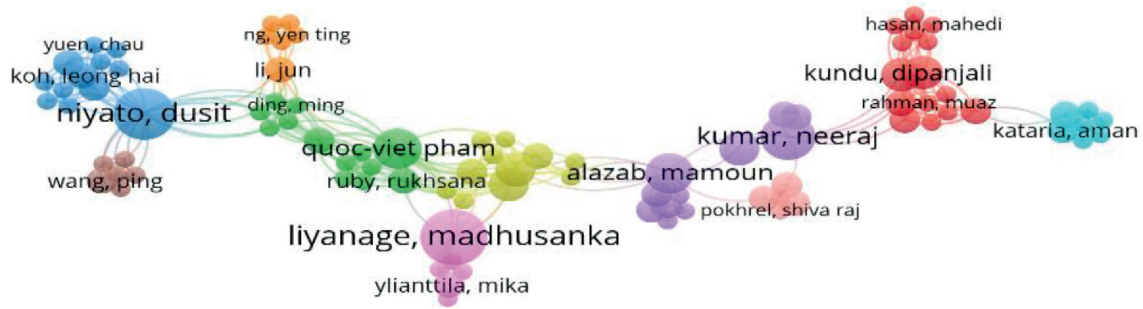
Figure 5. Top author clusters obtained from the co-authorship analysis

The leading authors within certain clusters coincide with the top 10 authors identified in the bibliographic coupling analysis. This observation also suggests that a significant number of authors are based in the same region (China) and tend to collaborate with fellow authors located in close geographic proximity.

Table 3. Links and TLS for co-authorship analysis for an author

Cluster 1(red)	Citations	TLS	Cluster 2 (green)	Citations	TLS
Kundu Dipanjali	35	39	Quoc-Viet Pham	382	77
Rahman Anichur	35	39	Ruby Rukhsana	252	32
Band Shahab S.	19	23	Nguyen Dinh C.	121	24
Debnath Tanoy	19	23	Ding Ming	115	17
Hasan Mahedi	16	20	Le Long Bao	115	17
Islam Md Jahidul	16	20	Seneviratne Aruna	115	17
Nasir Mostofa Kamal	16	20	Pathirana Pubudu N.	115	17
Rahman Ziaur	16	20	Poor H. Vincent	115	17
Sara Umme	16	20	Ding Zhiguo	6	9
Tiwari Prayag	15	33	Le Mai	6	9
Hossain Md Sazzad	15	11	Yang Zhaohui	6	9
Khan Md Saikat Islam	15	11	Fang Fang	6	9
Rahman Muaz	15	11	Hwang Won-Joo	6	9
Muhammad Ghulam	15	11			
Cluster 3 (blue)			**Cluster 4 (yellow)**		
Niyato Dusit	469	108	Gadekallu Thippa Reddy	266	84
Koh Leong Hai	284	74	Maddikunta Praveen	266	84
Lam Kwok-Yan	284	74	Dev Kapal	261	53
Zhao Jun	284	74	Deepa N.	246	23
Ghias Amer M. Y. M.	163	22	Prabadevi	246	23
Yang Lei	163	22	Pandya Sharnil	20	65
Zhang Xin	163	22	Boobalan Parimala	15	32
Guan Yong Liang	121	54	Ramu Swarna Priya	15	32
Sun Sumei	121	54	Thien Huynh-The	15	32
Mollah Muhammad Bauer	121	54	Ahmed Waqas	5	35
Mollah Muhammad Baqer	163	22	Javed Abdul Rehman	5	35
Yuen Chau	121	54			

Citation analysis

Citation analysis aids in gaining insights into the research landscape concerning authors, countries, and organizations. Table 4 illustrates that Niyato Dusit and Liyanage Madhusanka received the most citations, with Gadekallu following closely behind. The United States, China, and the United Kingdom lead in terms of the most referenced articles. This suggests that researchers in these countries may be concentrating on trending research areas within this field.

Table 4. TLS and citation analysis for the top 10 authors, countries, and organizations

Authors	(TLS) Citation	Countries	(TLS) Citation	Organizations	(TLS) Citation
Niyato Dusit	(108) 469	Peoples R China	(352) 2842	Beijing University of Posts and Telecommunications	(99) 460
Liyanage Madhusanka	(89) 383	India	(319) 1663	Nanyang Technological University	(86) 534
Gadekallu Thippa Reddy	(84) 266	USA	(261) 2412	University of Oulu	(78) 567
Huang Tao	(84) 289	England	(259) 2274	Vellore Institute of Technology	(75) 296
Liu Jiang	(84) 287	Australia	(197) 1369	Khalifa University	(74) 434
Liu Yunjie	(84) 287	South Korea	(192) 1444	University College Dublin	(72) 443
Maddikunta Praveen Kumar Reddy	(84) 266	United Arab Emirates	(128) 910	Pusan National University	(69) 382
Tang Helen	(84) 287	Ireland	(106) 593	University of New South Wales	(66) 428
Xie Junfeng	(84) 287	Italy	(91) 645	King Saud University	(62) 223
Xie Renchao	(84) 287	Germany	(86) 549	Deakin University	(59) 376

In comparison, bibliographic coupling proves to be the most effective method for clustering and sharing the intellectual context among interconnected articles, while citation analysis offers insights into the quantity of accepted published articles. Consequently, the combined findings from both bibliographic coupling and citation analysis demonstrate that the Beijing University of Posts and Telecommunications has produced influential and widely accepted articles in the current era. The institution plays a substantial role in shaping the intellectual framework and delineating research boundaries. This study also conducted citation analysis to assess the articles' rankings using both global and local citation counts. Table 5 shows the article rankings based on global citations.

Table 5. Top 10 most cited articles based on the global citation

Author	Title	Journal Name	LC	GC	GCPY
Liyanage M (2022)	Industry 5.0: A Survey on Enabling Technologies and Potential Applications	Journal of Industrial Information Integration	11	246	123
Salah K (2020)	Industrial Internet of Things: Recent Advances, Enabling Technologies, And Open Challenges	Computers & Electrical Engineering	23	182	45,5
Niyato D (2021)	Blockchain For Future Smart Grid: A Comprehensive Survey	IEEE Internet of Things Journal	24	163	54,33
Niyato D (2021)	Blockchain For the Internet of Vehicles Towards Intelligent Transportation Systems: A Survey	IEEE Internet of Things Journal	24	121	40,33
Kumar N (2019)	Blockchain-Based Distributed Framework for the Automotive Industry in A Smart City	IEEE Transactions on Industrial Informatics	13	116	23,2
Niyato D (2021)	Federated Learning Meets Blockchain In Edge Computing: Opportunities and Challenges	IEEE Internet of Things Journal	24	115	38,33
Liyanage M (2021)	Survey on Network Slicing for Internet of Things Realization In 5g Networks	IEEE Communications Surveys and Tutorials	11	108	36
Niyato D (2019)	A Survey on Blockchain: A Game Theoretical Perspective	IEEE Access	24	70	14
Salah K (2020)	Blockchain For Digital Twins: Recent Advances and Future Research Challenges	IEEE Network	23	67	16,75
Salah K (2019)	Trust Management in Social Internet Of Vehicles: Factors, Challenges, Blockchain, And Fog Solutions	International Journal of Distributed Sensor Networks	23	67	13,4

A local citation (LC) quantifies the number of times a paper is cited within the network. Conversely, a global citation (GC) denotes the count of citations an article garners within the entire database, serving as a measure of the article's overall popularity within its field. Liyanage M. et al. (2022) achieved the highest global citation score at 246, with Salah K. (2020) and Niyato D et al. (2021) closely trailing with global citation scores of 182 and 163, respectively. One significant factor behind this could be that Liyanage M et al. (2022) provided an extensive examination of Industry 5.0: Enabling Technologies and Potential Applications. It's worth noting that global citation count is not the sole criterion for ranking. Intriguingly, Niyato D (2021) received a higher local citation score of 24, compared to Salah K (2020) with a local citation score of 23. This highlights the authors' cross-disciplinary engagement within the blockchain domain.

Blockchain concept themes

Thematic analysis refers to a qualitative research approach employed to recognize, examine, and communicate recurring patterns (referred to as themes) in a dataset, typically comprised of textual or qualitative information. It provides insights into the underlying meanings, ideas, and concepts present in the data. In the context of a blockchain concept thematic analysis, was applied clustering by coupling.

Bibliometrix offers various clustering algorithms for grouping similar articles based on their bibliographic coupling similarities. The most commonly used algorithm is hierarchical

clustering, but other methods like k-means can also be used.

By utilizing clustering through coupling, we identified six thematic categories. These clusters are visually differentiated by various colors, as depicted in Fig. 6. They were defined by impact and centrality measures. By considering impact metrics, you can identify articles that have made significant contributions to the field and have been widely recognized by other researchers. An analysis of the clustering by coupling showed that the centrality and impact for red colored cluster were equal to 0,42 and 1,99, blue colored cluster performed 0,43 and 2,08, green colored cluster performed 0,37 and 2,67, violet colored cluster performed 0,42 and 1,37, orange colored cluster performed 0,41 and 2,9 and brown colored cluster performed 0,41 and 4,45.
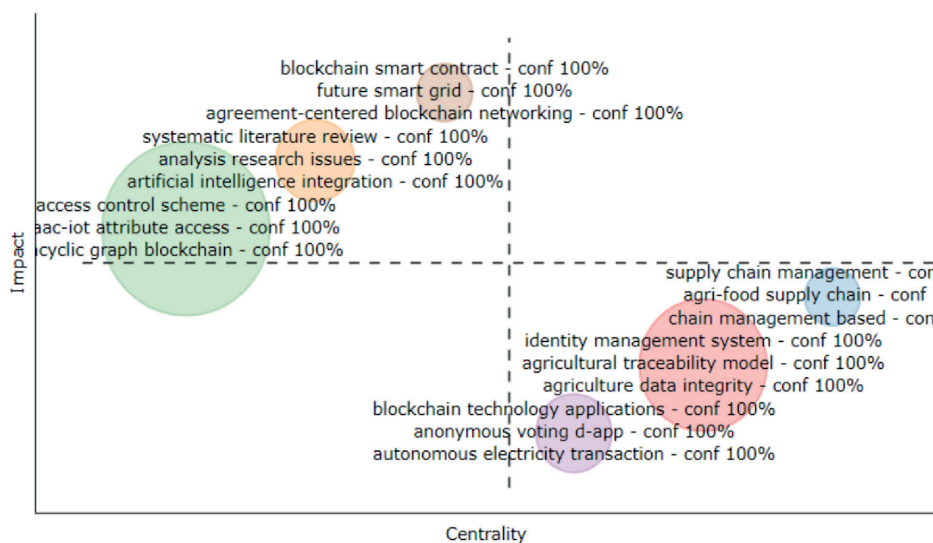
Figure 6. Cluster Map by coupling

The "Access Control Scheme" cluster is one of the dominant clusters, containing 12% of articles. The article with the highest Local Citation Score in the cluster reveals the description of the consensus mechanism in the IoT system and discusses such mechanisms as Proof of Work (PoW), Proof of Stake (PoS), and Direct Acyclic Graph (DAG) based consensus mechanisms and show DAG consensus benefits and future challenges.

The main contributor of the "Identity Management System" cluster identified research gaps in existing IoT and blockchain applications due to implementing IoT and Blockchain integration solutions for the construction industry in the transformation to smart cities.

The cluster labeled "Supply Chain Management" comprises 4% of all articles. These articles explore the possibilities of implementing blockchain technology in managing agri-food supply chains. It was provided applications, the benefits/value, and the challenges/issues of bitcoin, blockchain, and fintech in several industries and recommend leveraging research on these technologies to better understand them, optimize their business strategies and develop critical insights for decision-making.

Cluster "Artificial Intelligence Integration" revolves around the systematic literature review and analysis of research issues in this area. This cluster contains 3% of the total articles. It was examined blockchain features, such as trust-free, transparency, pseudonymity, democracy, automation, decentralization, and security through the improvement of smart city services from the perspectives of smart citizen, smart healthcare, smart grid, smart transportation, supply chain management, and others.

The "Blockchain Technology Applications" cluster is also one of the hot research domains. In particular, the study focused on the core technologies of security, privacy and trust in crowd-sourcing services and application scenarios.

The final thematic cluster, labeled "Blockchain Smart Contract," encompasses 3% of the articles, which primarily delve into topics related to the future smart grid and blockchain networking centered around agreements. It was presented a contemporary survey due to the Integration of Blockchain and IoV for future Intelligent Transportation Systems.

Results and Discussion

As in the previous case, we tried to find answers to the research questions to identify the research gaps addressed domain blockchain concept. Descriptive statistics reveal a noticeable rise in the number of articles concerning the blockchain concept within the computer science domain over the past five years.

With regards to the nation, China released the largest quantity of papers in contrast to other countries. Conversely, India and the USA took the forefront from China in authorship and co-citation examination when comparing TLS and citation metrics. The majority of authors and institutions originate from Chinese establishments, with a predominant research focus on blockchain concepts.

Furthermore, blockchain challenges, i.e., the Internet of things, smart contracts, security, distributed ledger, peer-to-peer computing, cloud computing, artificial intelligence, and Ethereum, still require further examination. Substantial empirical research has been carried out in developed countries, exploring various enterprises. We propose a similar investigation be undertaken for developing countries.

Additionally, this study offers a theoretical framework for conducting thematic analysis, aiding researchers in surveying the current literature and drawing attention to areas where limited attention has been directed. Fig. 7 illustrates the distribution of articles across these categories. In summary, there is a substantial need for further research in the realms of consensus mechanisms and the fusion of artificial intelligence with blockchain technology.
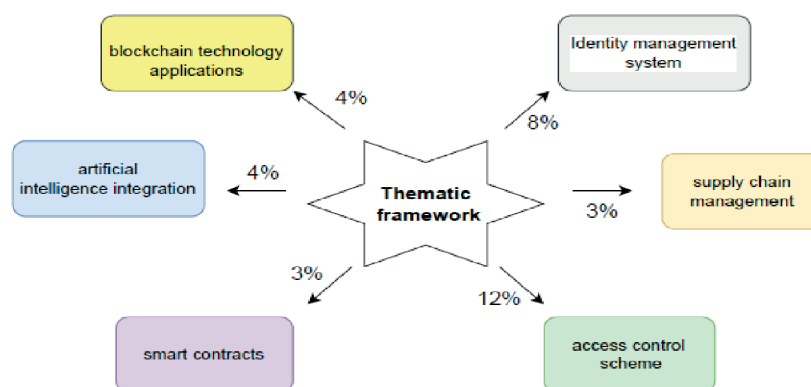

Figure 7. Thematic framework of blockchain concept in computer science

Furthermore, articles were categorized into clusters, concerning centrality and impact metrics. In the framework of themes, it was conducted such subthemes as the agricultural traceability model, agri-food supply chain, anonymous voting, agreement-centered blockchain networking, acyclic graph blockchain, and autonomous electricity transaction. Moreover, the last subtheme connected with autonomous electricity transaction is widely researched by local

scholars in the case of modeling the peer-to-peer negawatt trading in a demand-side flexibility-driven transactive energy system [19] and a distribution locational marginal price transactive energy (TE) framework for distribution systems [20].

Conclusion

This study offers an overview of research articles within the field of computer science focusing on blockchain concepts. It encompasses fundamental details from prior literature, such as articles, annual publications, and subject categories, utilizing an R-based tool. Additionally, it examines influential authors, articles, journals, and countries. The analysis employs VOSviewer for bibliometric network analysis and visualization. Furthermore, the study presents a thematic framework summarizing the content of earlier literature.

The data analysis software (VOSviewer, an R-based tool) primarily prioritizes recently published articles over older ones. As a result, there's a possibility of overlooking important information during the data analysis process.

During the process of conducting bibliographic coupling analysis, the outcome derived from VOSviewer analysis relies on the choice of several nodes (threshold value) as a representative sample. This approach could potentially lead to the omission of certain publications that have received less attention. Therefore, forthcoming research could explore alternative bibliometric software options to address the constraints of this study effectively.

The objective of this research is to pinpoint the present state of research and emphasize the areas that need further exploration in future studies concerning blockchain technology. Based on the results obtained, identified thematic topics can be included in the structure of the educational program plan.

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