A Review: The Bibliometric Analysis of Emerging Node Localization in Wireless Sensor Network

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Abstract

As research in Node localization in WSN becomes ubiquitous, there is a dire need to interpret and map the increasing scientific knowledge and evolutionary trends so that a firm foundation can be laid for identifying knowledge gaps and advancing the domain. There is a critical need to interpret and map the expanding body of scientific knowledge and evolutionary trends as Node localization research in WSN spreads widely to establish a solid foundation for identifying knowledge gaps and developing the domain. Hence, this study aims to undertake a bibliometric analysis of node localization approaches. The Scopus central assemblage database was searched for titles that included "node localization", "wireless sensor network," and "WSN". A total of 1618 documents were published within the nineteen-study period (2003 - 2022). Microsoft Excel 365, R Bibliometric and Biblioshiny packages were implored for statistical analysis of approved published research articles. This study highlights the trends and current state of node localization research in WSN. It can aid researchers in gaining a thorough understanding of the most recent node localization techniques used in WSN.

Keywords: Bibliometric Analysis, Node Localization, Scopus database, Wireless Sensor Networks (WSNs).

1. Background

Wireless Sensor Networks (WSNs) are becoming increasingly popular. Wireless sensor networks are made up of a large number of dedicated battery-powered micro-sensors known as nodes that record and monitor the physical environment in which they are placed [1]. WSN collects and organizes data on environmental conditions in a central location. Because this is done wirelessly, the nodes can be dispersed in a spontaneous network formation [2]. Depending on the application, the positions of the sensors must be chosen in such a way that they maximize coverage of the area in which they are placed. This deployment strategy must be carefully considered. In the last half-century or so, a large number of optimization algorithms have been developed in an attempt to solve real-world problems. However, there are issues with optimizing some problems for the vast majority of them. When the problem dimension is large, they do not produce high-quality solutions, which prevents them from obtaining approximate global optimum solutions [3].

In wireless sensor networks, localization refers to determining the location of a device or sensor in the absence of additional infrastructure such as satellites. Existing algorithms for the localization of sensor nodes are divided into two categories: range-based and free range. Furthermore, algorithms for static anchors and static nodes, algorithms for mobile anchors and static nodes, algorithms for mobile anchors and mobile nodes, and algorithms for static anchors and mobile nodes are subdivided into these categories [4]. To determine the location of unknown nodes, the free range primarily considers geometric relationships between nodes, hop-count values, energy loss between nodes, network connection, and other factors, whereas range-based uses received signal (RSSI), time difference of arrival (TDOA), time of arrival (TOA), angle of arrival (AOA), and other factors (AOA) [5].

A few bio-inspired algorithms for localization have been introduced, which we will also investigate in this paper, such as evolutionary algorithms, swarm-based algorithms, bat optimization algorithms, and others inspired by animal social behaviour. It is an innovative approach to developing new computing techniques based on natural evolution [6]. Several simulations are used in the development of these algorithms, such as observing the behaviour and reactions of animals in the wild and building a model that depicts their behaviour. In other words, bio-inspired optimization algorithms are presented and analyzed to redefine parameter settings to improve the proposed algorithm's performance [7].

After deployment, wireless sensor network nodes must locate other nodes. This study examines various localization methods and their advantages and disadvantages. We examine the experiments and studies conducted by the authors that contributed to the conclusions reached in their studies. The singularity is a disadvantage of the Salam algorithm, which is an anchor-free algorithm. The study investigated possible solutions and concluded that Salam is effective in dense WSN [8]. According to Javed et al, (2022), after the ninth node localization cannot be determined due to Salam's challenges with its algorithm called singularity problem in 3D wireless sensor networks.

The distance vectors hop algorithm is an APS algorithm in which an anchor node uses a propagation method to flood its location to adjacent nodes. Messous et al [4] claim that the DV-Hop ranged-based algorithm is costly to compute due to the equipment used. Furthermore, DV hop algorithms included an error-checking system that assisted in the discovery of unknown nodes in the network. As a result, the accuracy per hop determined the localization accuracy. On the contrary, the per-hop distance may contain errors in the position of an unknown node. Furthermore, when calculating the distance between unknown nodes, the use of hop Size anchors is incorrect[4]. Furthermore, [10] proposed an online sequential algorithm based on the DV-Hop algorithm that includes and takes into account the localization of unknown nodes in a network as well as variations of their anchor nodes.

Another improved algorithm with regards to the DV-Hop algorithm suggests using the RSSI ranging technology, it corrects the minimum hop problem and the weighted average value (of estimated distance error and hop distance error) method corrects the average hop distance [11]. DV-Hop is anchor-based and would flood adjacent nodes with information via a propagation method. The original DV-hop algorithm was more expensive due to equipment. The localization accuracy had errors [10]. In the study, the DV-hop was improved on and saw increased localization accuracy conservative on costs. In light of this information, the DV-hop algorithm can be improved upon and yield greater results for its localization accuracy.

It is also believed in [13] that Steer Response Power (SRP)-based approaches that do not use information compression or disturbances can usually lead to more robust performances in noisy and reverberant acoustic environments. The goal of this work was to pinpoint the band-pass source. SRP-based techniques detect the source position or direction with only one decision step in the processing of sensor signals to determine location by utilizing a group of sensors' combined sum beamformer and spatially directed filter to the greatest extent possible. The authors in [13] used Monte Carlo simulations to evaluate the efficiency of the SRP-based localization method. A field experiment was also conducted, which revealed that the WR method achieved the best estimation for all grid distances, proving its effectiveness. Monte Carlo simulations and field experiments demonstrated that the proposed method outperforms some SRP-based methods in the outdoors. Localization methods are a new trend in the IT and IoT worlds. WSN is a component of IoT and requires greater mainstream acceptance because this technology will be critical in the fourth industrial revolution.

Wireless sensor nodes use energy primarily for three purposes: data sensing, data processing, and data transfer. To reduce the energy consumption of sensor nodes, a routing system based on clustering communication is used to transport data [14]. Because sensor nodes are battery-powered and cannot be constantly recharged in all environments, energy conservation and optimization of energy consumption are critical. Density-based clustering has been identified as one of the most effective methods studied [15]. Following that, many other algorithms and methods were investigated in conjunction with this concept, such as the Glow-worm Swarm Optimization algorithm, which increases the network lifetime and area covered by the WSN. It is much simpler than other algorithms because it only has a finite number of neighbor nodes with which to communicate [16].

However, more complex methods have been investigated, such as the Distributed Energy Efficiency Clustering (DEEC) Approach and the DEEC-Gaussian Gradient Distance Elimination Algorithm (DGGDEA), which aim to save the most energy in larger WSNs with a greater number of nodes [17]. We have learned from these papers that node localization must take into account limiting factors such as cost, computing power, and battery life. Algorithms have errors in their accuracy, but modifications will improve the algorithm's accuracy yield [18]. Bibliometrics is a quantitative analysis technique that uses mathematical and statistical techniques and tools to measure the connections and effects of published works in a specific field of study. This method can provide a broad overview of a large body of academic literature and can be used to identify influential research, writers, journals, groups, and countries over time [19]. It reveals new trends in article and journal performance, collaboration patterns, and research elements, in addition to examining the intellectual framework of an existing body of literature [20].

This paper is divided into seven sections: section 1 provides the background of the bibliometric analysis, section 2 provides a discussion of related works, section 3 provides insight into the contribution of this paper, section 4 provides the research strategy and methodology used to obtain the information and findings, section 5 includes the results and further discussion of node localization in wireless sensor networks, and section 6 provides the conclusion for the study.

2. Related Work

A wireless sensor network, or WSN, typically has a few sensors in an area. WSNs are used to accomplish one or more goals, depending on the application. The positions of the sensors must be chosen in such a way that they maximize coverage of the area in which they are placed; thus, the deployment strategy chosen is critical [3]. In the last half-century or so, a large number of optimization algorithms have been developed in an attempt to solve real-world problems. However, there are issues with optimizing some problems for the vast majority of them. When the problem dimension is large, they do not produce high-quality solutions, which prevents them from obtaining approximate global optimum solutions [3]. Animal social behavior inspires these algorithms, which include evolutionary algorithms, swarm-based algorithms, and others. Several simulations are used in the development of these algorithms, such as observing the behavior and reactions of animals in the wild, building a model that depicts their behavior, and so on. In other words, bio-inspired optimization algorithms are presented and analyzed in order to redefine parameter settings in order to improve the proposed algorithm's performance.

Localization, according to [21], has become an important factor in the monitoring and control of applications such as military applications, smart buildings, health monitoring, and so on. Researchers are looking for efficient localization and tracking solutions. They want WSN-based solutions that can make a trade-off between real-time availability, precision, and robustness. Many different strategies have been proposed using various metrics such as received signal strength indicator, angle of arrival time of arrival, and impulse responses, but the proposed solution used received signal strength indicator (RSSI). The RSSI radio indicator is always present and easily measurable. Other existing methods frequently necessitate complex hardware and are costly. These methods also have many limitations, such as memory and energy. Similarly, the authors believe that the RSSI fluctuates a lot. This will have a negative impact on the precision of the localization results. As a result, researchers recommend neural networks and other machine learning-based methods for localization systems [22]. [22] conducted experiments to assess the performance of the localization algorithm. They used RSSI to incorporate the RT-based algorithm into their experiment. The authors then use the Kalman smoother to refine the position estimation. The RTS algorithm is one of the most commonly used Kalman smoother algorithms. The experiment's findings: The suggested method had the lowest percentage of error and variance. The combination of RT and KS yields a 5.8% error. It is 10.6% for RT alone and 12.5% when combined with KF. The proposed algorithm's variance is 0.12m, which is a low value. Finally, the authors demonstrated that their method has high accuracy for all estimated positions, even when the environment changes [21].

Furthermore, in [23], the two-dimensional (2D) and three-dimensional (3D) approaches in the localization model for WSNs were used to improve location identification within the close environment compared to outdoor dissemination on a small scale. The result was demonstrated by the accuracy performance of 2.83% to 2.96% when compared to other state-of-the-art algorithms. On the other hand, underwater localization was determined using optoacoustic signals for minimizing logistics and security risks by employing an underwater node (UWN), which aids in the transmission of optoacoustic signals for limited processes. When compared to traditional approaches for submerged transducers, the techniques show that accuracy for any surface, both dynamic and static signal nodes, is improved in the simulation analysis result [24]. Distance, transmitter and receiver for the indoor environment are expensive in wireless sensor networks for determining the positions of anchor node communications. The fingerprint mechanism was investigated in order to determine the number of nodes for the anchor node deployment algorithm (ANDA), with ANDA acting as an intermediary between the processes in order to reduce the redundancy complexity problem. The partitioning approach was grafted to carry out further experiments for sub-areas and dispatching the validity and superiority of all outcomes. ANDA significantly reduced the number of anchor nodes by 17% [25].

Similarly, another segmentation for fluid implementation across divided grid corners with an edge of 60 centimetres is the artificial neural network (ANN) with the use of a fingerprint mobile device for location determination approach. This method investigates both the online and offline modes of Xbee sensors to allow sensor communications to the anchor nodes, and the distances between the various grids of sensors were measured and aggregated in the database. Online processes were measured using receive signal strength indicator (RSSI) values, whereas offline processes were measured using ANN to determine co-ordinate and location error minimization [26]. Recently, the Distributed Energy Efficiency Clustering (DEEC) Approach, DEEC-Gaussian Gradient Distance Elimination Algorithm (DGGDEA) was investigated to determine node localization and energy optimization for sensor nodes ranging from 100 to 1500, 250 to 450 sensor nodes, and it was demonstrated that their approaches can minimize and optimize energy when compared to other classical approaches [17, 27, 28]. Singh and Sharma examined an energy-efficient clustering algorithm for WSNs (Wireless sensor networks) concerning the Particle swarm optimization (PSO) algorithm that increases the life span of the wireless sensor network. The most focused aim of the suggested algorithm was the selection of a corresponding cluster head, to minimize the intracluster distance and escalate the energy efficiency of the network [16].

The DEEC-Gaussian (Distributed energy efficient clustering) algorithm model assists the network to contain energy-efficient clustering with the distance between the sensor nodes and cluster head. All stationary sensor nodes are deployed, and the others are deployed and employed randomly. Aroba et al,(2021) suggest a new heterogeneous optimization approach alongside the DEEC-Gaussian (Distributed energy efficient clustering) algorithm which allows for efficient use of energy resources across all nodes in the network.

Furthermore, a distributed localization approach for sensor node identification and particle filtering optimization is used. the error of real-time localization and propagation within the period of operation of sensor node movement Their sensor node range and position were grafted for collation of information aggregated from both unknown and known locations with the use of a particle filtering approach to optimize node localization estimation results in WSNs were greatly improved in position accuracy and speedy time efficiency [29].

WSN (Wireless sensor networks) and node localization methods may be heavily used in IoT (Internet of things) applications. The background of true location-based services, on the other hand, is attracting enormous interest in

IoT applications. Several strategies, primarily based on computational intelligence algorithms, are proposed in the most recent literature to accomplish this. Baidar et al. (2022) discuss a node localization algorithm based on swarm intelligence techniques that is a hybrid Harris Hawks optimization (HHODE) based on differential evolution. In a wireless sensor network, the Harris Hawks optimization based on differential evolution (HHODE) algorithm uses Euclidian distance as the objective function to determine the best-fit coordinates of the sensor nodes. A few experiments are also conducted to demonstrate the efficacy of a Harris Hawks optimization based on a differential evolution algorithm in terms of network size, sensor communication range, geographic distribution, and beacon node density. HHODE outperforms Standard Differential Evolution (DE), Hierarchical optimistic optimization (HOO), Particle swarm optimization (PSO), and the Bat Algorithm in terms of node localization [30].

Particle swarm optimization (PSO), Butterfly optimization algorithm (BOA), firefly algorithm (FA), and grey wolf optimizer (GWO) have all been shown to be useful in node localization. Particle swarm optimization employs a swarm population of particles that travels around the search space in search of the best solution. The butterfly optimization algorithm is inspired by the butterfly's food foraging methods. Butterflies use receptors to detect food. The algorithm emits the 'fragrance' of each 'butterfly (node), which can be detected by other 'butterflies'. The 'fragrance' changes depending on where it is. The Firefly algorithm mimics the lighting and flashing behaviors of fireflies. Finally, the grey wolf optimizer was inspired by the grey wolf, which travels in groups of 5-12 wolves. They are known to follow an alpha, beta, and omega social hierarchy. The fittest solution would be considered the alpha in this algorithm [31]. However, as another suitable method for node localization, [31] proposed the salp swarm algorithm. This paper also demonstrated that the Salp Swarm algorithm outperforms the other algorithms in terms of computation time, number of localized nodes, and localization accuracy. The salp algorithm was inspired by the salp's swarming behavior. They form a chain that aids in locomotion when foraging.

Furthermore, Punithavathi's [32] Multi-objective manta ray foraging optimization-based node localization with intrusion detection (MOMRFO-NLID) approach is divided into two parts: optimal Siamese neural network (OSNN)-based intrusion detection and manta ray foraging optimization (MRFO)-based node location. In the Optimal Siamese neural network (OSNN) technique, the manta ray foraging optimization (MRFO) method is used to hyperparameter tune the conventional Siamese neural network (SNN), increasing detection rate. The improved results of the Multi-objective manta ray foraging optimization-based node localization with intrusion detection (MOMRFO-NLID) technique are investigated thoroughly. The results are examined in terms of various measurements, and a maximum accuracy of 0.921 is obtained. In terms of many evaluation factors, the experimental results showed that the Multi-objective manta ray foraging optimization-based node localization with intrusion detection (MOMRFO-NLID) technique outperformed other strategies. Load balancing and timing strategies may be used in the future to improve the performance of the Multi-objective manta ray foraging optimization-based node localization with intrusion detection (MOMRFO-NLID) technique [32].

Furthermore, the DV (Distance vector)-Hop algorithm is a popular localization algorithm because it is simple to implement and requires little hardware. However, when nodes are distributed unevenly, the accuracy of the algorithm results suffers. As a result, a better method for dealing with this problem was developed [33]. This neural dynamic approach improves the DV-Hop algorithm's reliability and consistency by using algebraic equations to account for changes in distance and coordinates over time. By transforming the conventional localization model, a time-varying algebraic expression is produced. Distances in the equation gradually approach their true values as the number of iterations increases, and coordinates are simultaneously corrected within a predetermined correction range. These accelerate the convergence of the neural dynamic (ND)-DV-hop algorithm. The ND-DV-Hop algorithm has demonstrated significant progress in addressing the issue of localization in wireless sensor networks with limited hardware resources [33].

Nonetheless, node localization has proven to be a critical component in wireless sensor networks for maximizing the benefits that these networks have to offer. While there are numerous techniques, methods, and algorithms for localizing nodes in a WSN (Wireless sensor network), there are some challenges. Energy efficiency is not only the first challenge that wireless sensor networks must overcome, but it is also a critical one. The goal is to be able to build larger networks that use less energy, but it is clear that as the number of sensor nodes increases, so does the amount of energy required to power those nodes. In their study titled "Energy efficiency of IoT networks for environmental parameters of Bulgarian cities," the authors [34] take a novel approach. The appropriate modules and devices had been chosen for the construction of WSN for Bulgarian cities. The goal is to be able to build larger networks that use less energy, but as the number of sensor nodes increases, so does the amount of energy required to power those nodes.

The appropriate modules and devices had been chosen for the construction of WSN for Bulgarian cities. The average power consumed by the network increases as the number of nodes increases, but the energy consumption may decrease depending on where the nodes are located. It is possible to improve the performance of the wireless sensor network by using the proper routing protocols. Distance-based dynamic duty cycle allocation (DBDDCA) is one such protocol [35]. Nodes located far from the base station save energy by transmitting for shorter periods of time using this protocol. The authors concluded in [34] that it is critical to consider the overall size and complexity, as well as the number and location of nodes, when designing WSNs for future use.

3. Search Strategy and Research Approach

For this research article, information was obtained from a database that provides access to journal articles as well as the references found in those articles. The database chosen includes a wide range of meticulously selected text with revised material relating to scholarly literature from a wide range of fields. Scopus contains nearly 36,377 titles from 11,678 publishers, 34,346 of which are peer-reviewed journals in top-level subject fields. To find topic-related articles for this research study based on node localization, exclusion terms were required. With exclusions, a total of 1618 documents were extracted for analysis. The search results yielded seven document types, 825 of which were articles. For articles published between 2003 and 2022, the search strategy included a 19-year domain inclusion. Figure 1 depicts the search strategy employed in this research article.

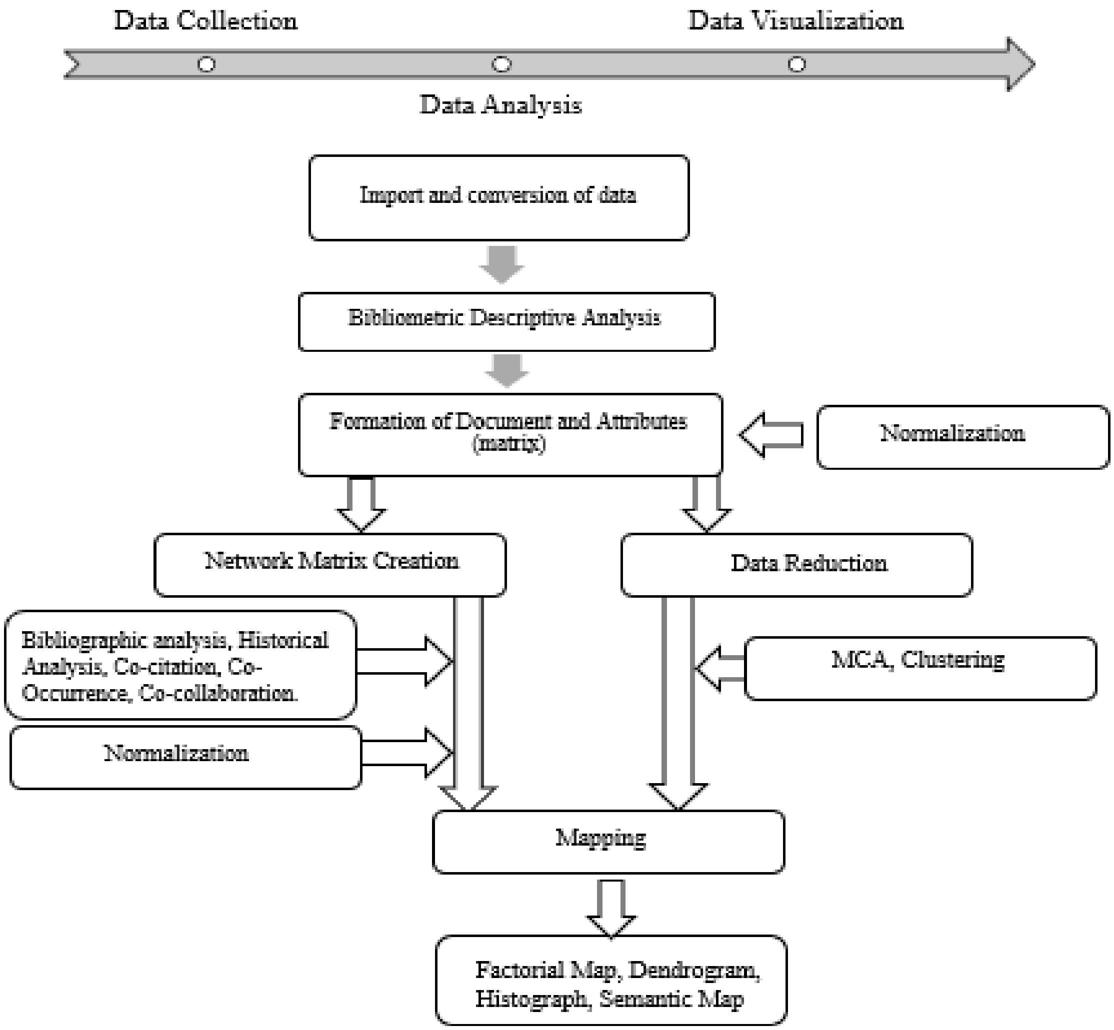

Figure 1: Bibliometric Analysis Processes for Node Localization

Bibliometric software allows for extensive data analysis and tracking of author or researcher productivity and impact. Furthermore, it allows scholars to keep up with the most recent literature relevant to their academic fields without becoming overwhelmed by the current abundance of material available. Bibliometrics is the statistical analysis and evaluation of bibliometric published information and scientific and technical literature. It is also known as statistical and mathematical techniques applied to literature and other forms of communication [36]. Citation analysis and textual analysis are two techniques commonly used in bibliometric analysis. This application is useful because it includes instructions for importing Scopus bibliographic data. Furthermore. Following the acquisition of the documents, a bibliometric examination of the writers' origins, publishers, associations, and sources was conducted.

Graphs were created to help understand the data after word analysis, network construction for co-citations, academic collaboration, and co-word analyses. The collaboration of networks in high-producing countries and writers in the research on node localization was portrayed and visualized using the R language's VOSviewer package. With the command vos, the VOSviewer application has been called to generate collaborative mappings for both nations and authors. path = '', type = "VOSviewer", size = T, delete; multiple = T The visualization maps were created with VOSviewer 1.6.17 and then used to analyze and show the relationships between the countries, authors, and terminology in the research.

4. Results and Discussions

The restrictions applied during the extraction of documents for this research article were based on the contents required, which are node localization machine learning of wireless sensor networks, as well as the publication period. The Scopus literature search yielded 1618 documents, which were divided into seven document types. Table 1 contains a list of the document types that were used, including articles, books, papers, and reviews. The number of authors and authors who wrote papers independently are also included, as are the number of no-authored and single-authored documents discovered. The data's information period and average age are 7,7 years in 19 years.

Table 1: table consisting of descriptions of the main information used in this research study.

DESCRIPTION	RESULTS
MAIN INFORMATION ABOUT DATA	
TIMESPAN	2003:2022
SOURCES (JOURNALS, BOOKS, ETC)	783
DOCUMENTS	1618
ANNUAL GROWTH RATE %	23,71
DOCUMENT AVERAGE AGE	7,7
AVERAGE CITATIONS PER DOC	9,708
REFERENCES	28385
DOCUMENT CONTENTS	
KEYWORDS PLUS (ID)	5262
AUTHOR'S KEYWORDS (DE)	2558
AUTHORS	
AUTHORS	2731
AUTHORS OF SINGLE-AUTHORED DOCS	57
AUTHORS COLLABORATION	
SINGLE-AUTHORED DOCS	90
CO-AUTHORS PER DOC	3,25
INTERNATIONAL CO-AUTHORSHIPS %	12,5
DOCUMENT TYPES	
ARTICLE	825
BOOK	2
BOOK CHAPTER	13
CONFERENCE PAPER	741
CONFERENCE REVIEW	28
REVIEW	9

Figure 2 depicts the data extraction flow process. The total number of documents to be analyzed is calculated by first limiting the publication period by year and then removing all documents that are not of the article type.

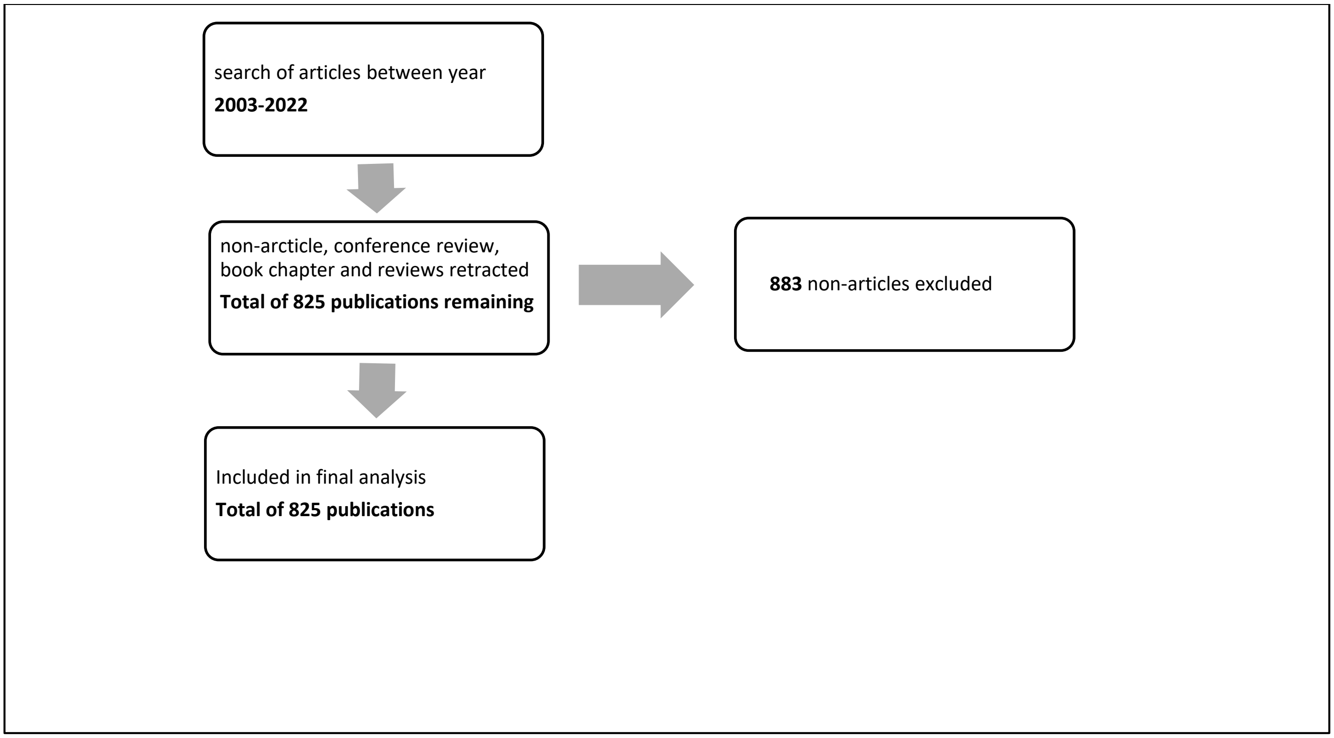

Figure 2: Extraction Flow Diagram

Figure 3 shows a 3D pie chart of the document types discovered during the Scopus document search mentioned in point 4 of this research paper. The pie graph shows that conference papers and articles account for the vast majority, accounting for 97% of the total, while other documents account for the remaining 3%.

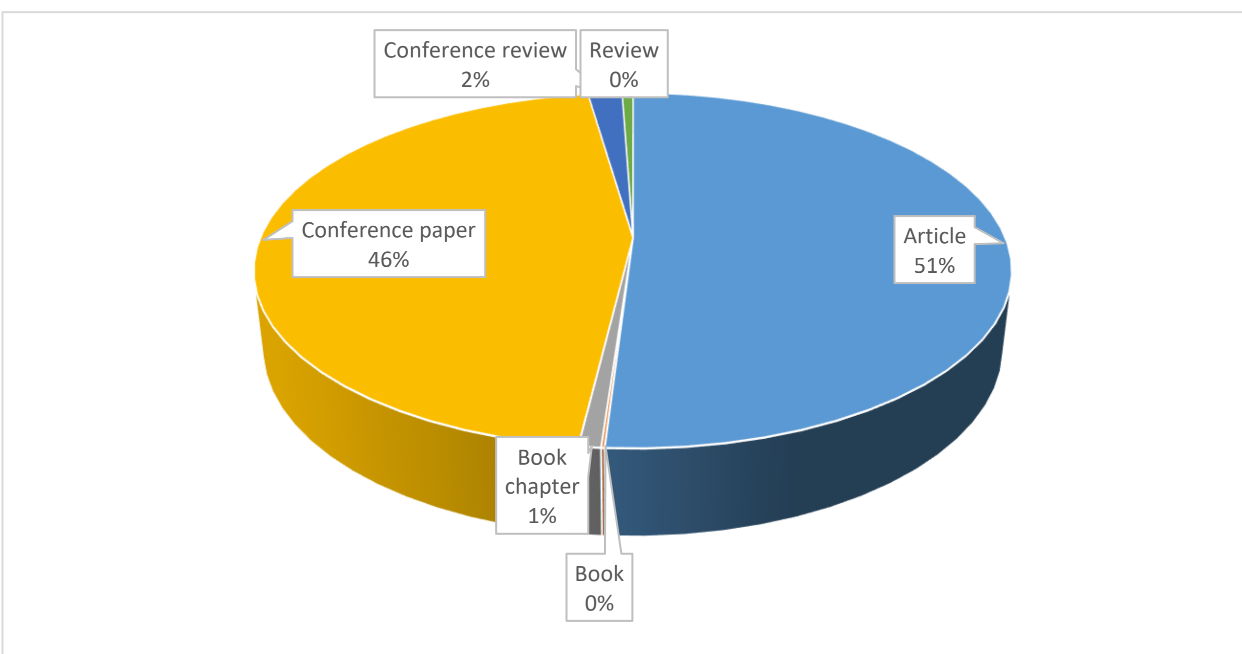

Figure 3: Extracted document types pie chart

The results of the historiographic analysis are depicted in the figure below as a network map of successive direct author citations. Figure 5 depicts the outcome, which aids in determining when the articles were examined. Figure 5 depicts the nodes of historical direct citations in each year beginning in 2015. Every node corresponds to a work of writing that was cited in the year in question. The nodes are the linear lines that connect the publications and citations. Figure 5 shows that there are no nodes for the years 2018, 2016, and 2014, indicating that no linked papers were mentioned during those years. However, in the year 2019, the article [31] about the salp swarm for a node is the most cited publication with a significant 6 citations, 2 in the year 2021, and 4 in the year 2022.

The authors of the paper [31] claimed to have approached the node localization problem as an optimization problem. In that article, the salp swarm algorithm (SAA) is used to locate nodes in wireless sensor networks. The proposed SAA-based localization algorithm's effectiveness was examined and compared to the particle swarm optimization (PSO), butterfly optimization algorithm (BOA), and firefly algorithms (FA). In terms of computing time, number of localized nodes, and localization accuracy, using a SAA-based localization algorithm to solve an optimization problem via trial-and-error yields a better result.

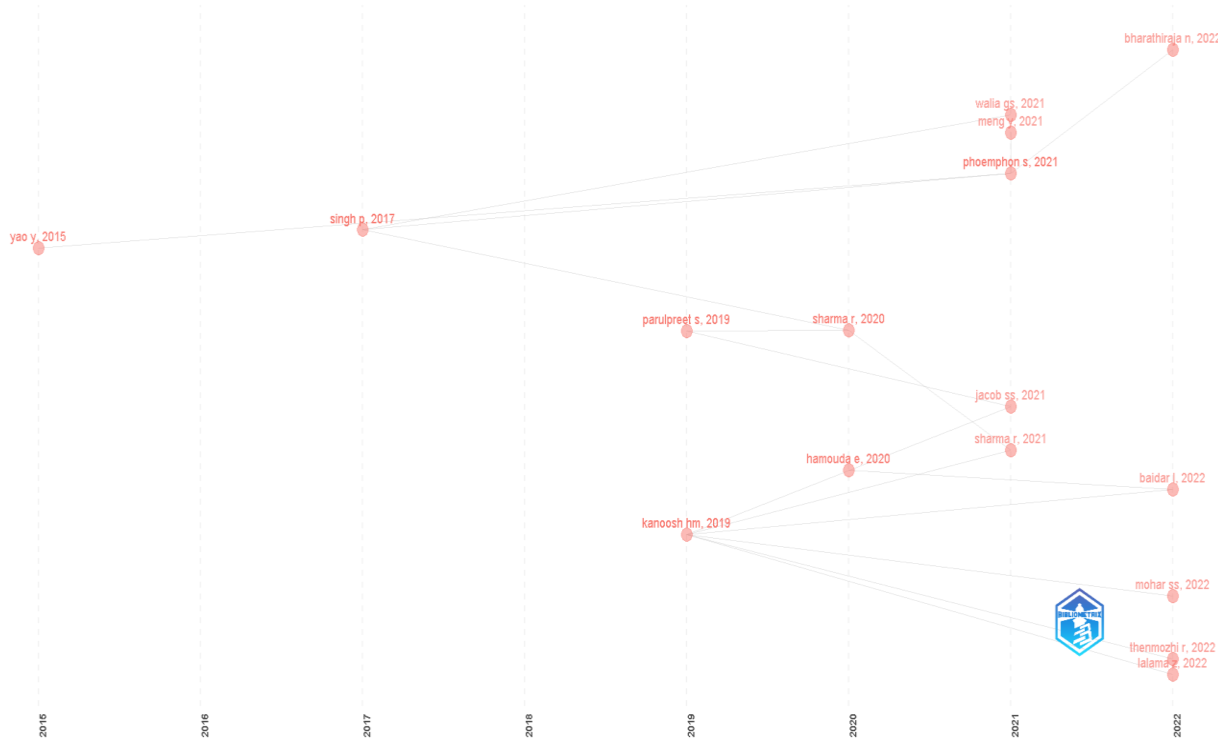

Figure 4: Historical direct citation network depicting direct citations for articles from 2015-2022.

According to the number of publications relevant to node localization, the top ten authors are Liu Y, Zhang Y, Nia Na, Wang J, Wang X, Wang Y, Zhang J, Wang Z, Li J, and Liu W, with 51 articles, 32 articles, 31 articles, 26 articles, 26 articles, 25 articles, 24 articles, 23 articles, 21 articles, and 21 articles, respectively. Yunhao Liu, a Chinese scholar, contributes the most of the authors within the selected data set. Liu Y co-authored an article on localization with Zheng Yang and Zimu Zhou in 2013. This article, titled "From RSSI to CSI: Indoor localization via channel response"[37], was cited 996 times according to Google Scholar. Another notable paper by Liu Y is "Locating in fingerprint space: Wireless indoor localization with little human intervention," which was published in 2012 and received 852 citations.

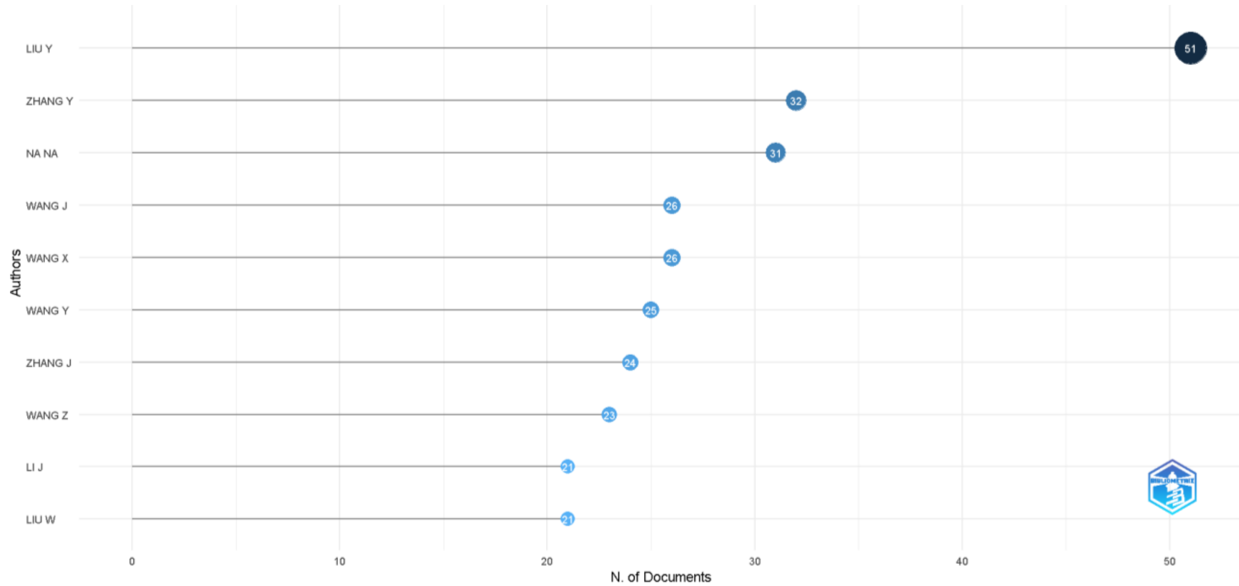

Figure 5: Most relevant authors with publications related to node localization.

In figure 6, the authors' output from 2003 to 2022 is shown in conjunction with figure 5 above. The graph key on the right aids in the interpretation of the figure and the information displayed.

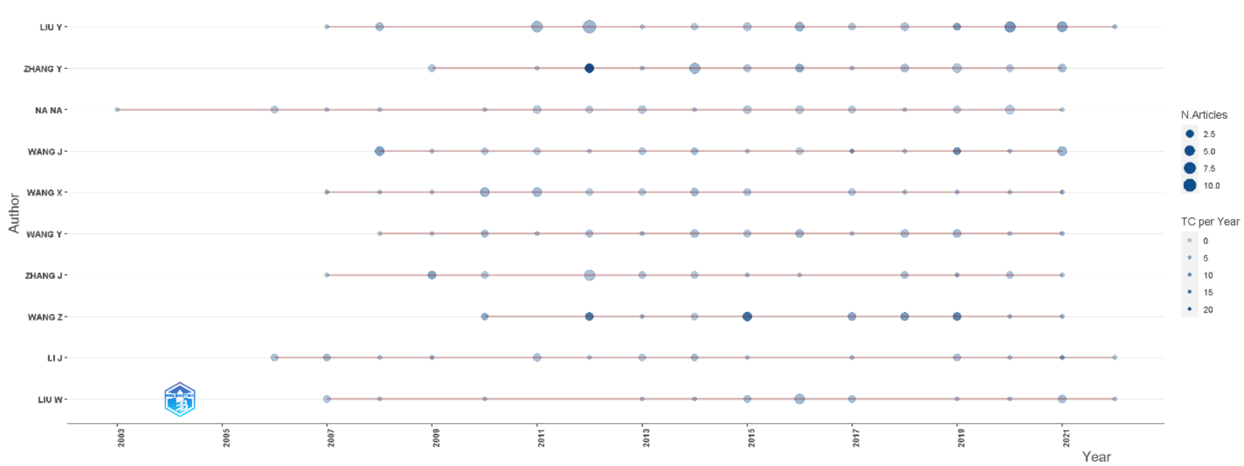

Figure 6: Graph presenting authors' production over time.

The cluster analysis map below highlights the theme of collaboration in relation to this research article. The size of the nodes represents the topic's significance and input, whereas the vertical lines represent the topics that are used collaboratively. The figure below clearly shows that the topics 'Wireless sensor networks,' 'Sensor nodes,' 'Node localization,' and 'Algorithms' are frequently mentioned.

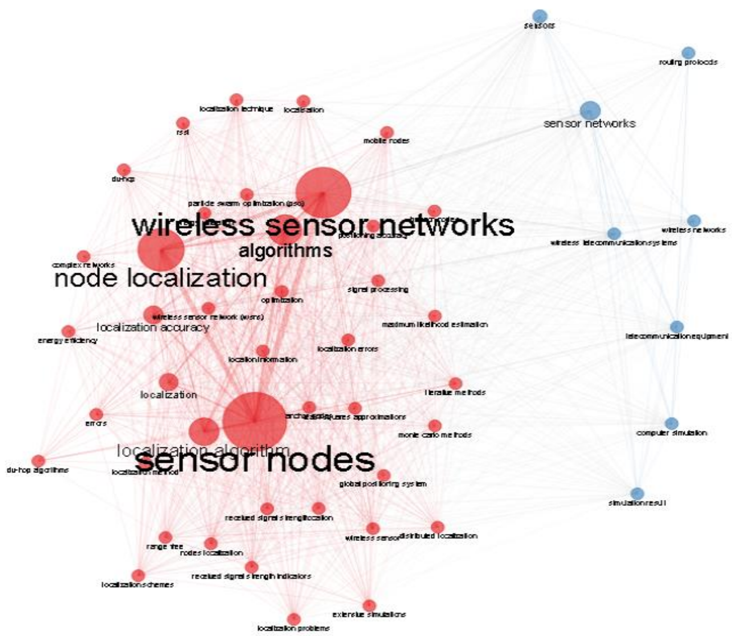

Figure 7: Node localization collaboration maps

'Localization of sensor nodes in wireless sensor networks using bat optimization algorithm with enhanced exploration and exploitation characteristics,' according to [40] in a paper titled 'Localization of sensor nodes in wireless sensor networks using bat optimization algorithm with enhanced exploration and exploitation characteristics.' According to [40], localization for sensor nodes within WSNs is critical in many applications. One of the main problems that WSNs face is localization, because data acquired by sensor nodes is useless unless the source of the data is found. Over the last few years, numerous researchers have investigated a variety of optimization strategies for locating sensor nodes in WSNs. Every optimization algorithm has benefits and drawbacks. These optimization techniques are based on how various natural systems behave and seek food sources. Optimization techniques can be used to solve the problem of sensor node localization. The paper [40] proposed the bat optimization technique to localize these sensor nodes within WSNs. The above-mentioned author and co-writers chose bat algorithms because of their distinct characteristics such as frequency tuning, automatic zooming, and parameter control.

In this study, multiple correspondence analysis (MCA) is used because it allows you to examine the interaction pattern between a large number of categorical dependent variables. As a result, it can be viewed as a generalization of principal component analysis in which the attributes to be investigated are categorized rather than quantifiable [41]. The diagram below depicts a conceptual structure map of four trend topics related to node localization in wireless sensor networks.

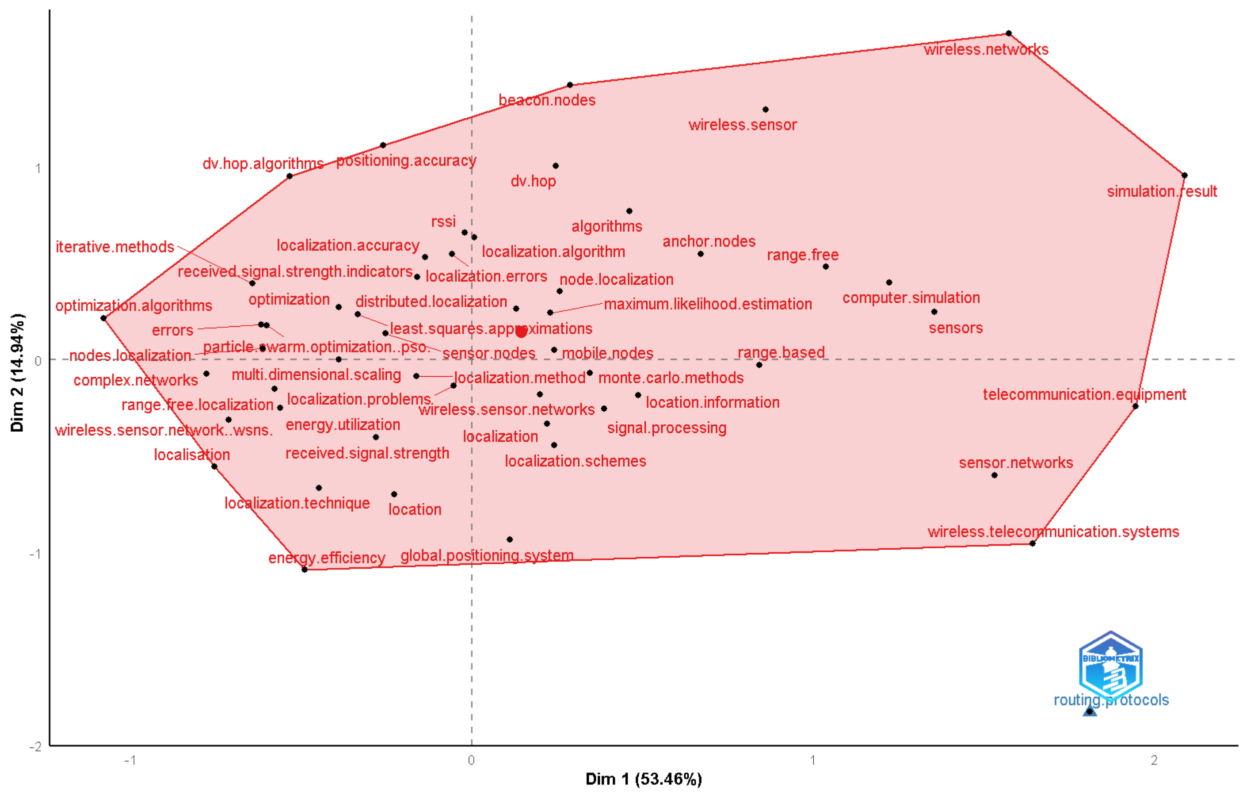

Figure 8: Conceptual Structure map of trend topics relating to node localization in wireless sensor networks

Thematic networks are built around the frequency and frequency with which a keyword appears [43]. A thematic evolution analysis examines relevant themes over time. A thematic area is defined as a collection of these that evolve over time [44]. The main goal is to thematically identify significant issues concerning the development of node localization between 2003 and 2022. This analysis result is presented in the form of a Sankey diagram, which efficiently organizes the field applicable themes. In the Sankey diagram, each subject or topic is represented by a node. The number of keywords detected in that subject determines the size of the node. Furthermore, the connecting line between them represents the study's shift in focus over time. The width of the line between two subjects indicates how frequently shared keywords occur. As shown in figure 9, the 19 years were divided into two time periods: 2003-2014 and 2015-2022.

Thematic evolution is observed between 2003 and 2014 in two topic areas: wireless sensor networks and sensor networks. However, the number of topic areas increases to seven during the second period, 2015-2022, and includes sensor nodes, computational complexity, wireless sensor networks, power management, non-line of sight, anisotropy, and node localization. One of the two original subject areas, wireless sensor networks, has been carried over to the main research subject. This could be because node localization revolves around wireless sensor network innovations, so it can be considered the primary theme. However, emerging topic areas such as power management, anisotropy, and computational complexity demonstrate that there is an ongoing thematic evolution in this research field, which has grown dramatically with more ongoing articles being produced on this topic each year.

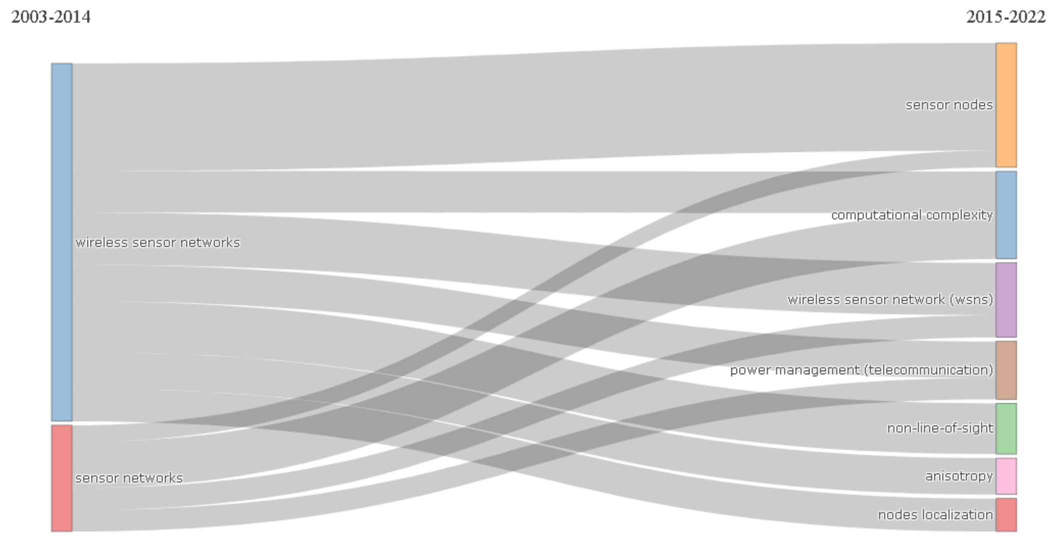

Figure 9: thematic evolution of keywords in this topic field from 2003-2022

Countries that produce a greater number of research papers on a specific topic are held in higher regard in that field for any subsequent publications. Figure 10 depicts the top ten countries most frequently cited in the field of node localization. China has the most citations (5278) and thus takes the lead. They are followed by the United States of America, which has 3216 citations. India, Japan, Canada, Saudi Arabia, Hong Kong, Korea, Egypt, and Serbia round out the top eight. Figure 10 depicts five Asian countries (China, India, Korea, Hong Kong, and Japan), two North American countries (the United States and Canada), one Middle Eastern country (Saudi Arabia), one European country (Serbia), and one African country (Egypt). Asian countries are more visible in the research field of node localization, accounting for half of the top ten citation-producing countries.

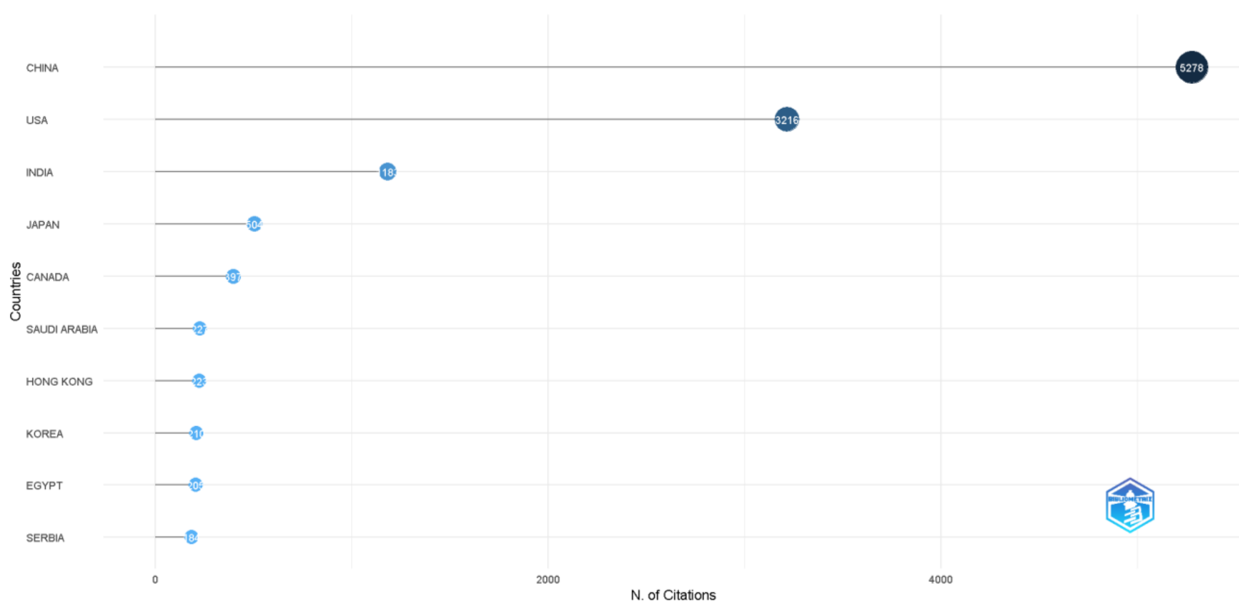

Figure 10: Most countries cited in the node localization field of research.

5. Future Research Directions of Node Localization

The Internet of Things (IoT) can connect a massive number of sensors, actuators, and intelligent devices to provide continuous connectivity. Localization is a critical procedure when using sensor nodes to detect and monitor targets in an IoT context. Localization in IoT networks has recently been studied by researchers for a variety of purposes [45]. Device-based and device-free solutions are used for IoT node localization. While device-free technologies are well suited for a wide range of application contexts, device-based technologies have made significant strides toward the best location approximation. The Internet of Things networks can solve location estimation problems using a variety of localization approaches; however, integrating these techniques and using the bare minimum of anchor nodes in such configurations has practical limitations. It is therefore critical to design appropriate and cost-effective localization systems. As a result, utilizing the Internet of Things can provide a possibility for future research development of node localization in wireless sensor networks.

6. Conclusion

The purpose of this research paper was to examine and evaluate global scientific output on the topic of node localization in wireless sensor networks. Records from Scopus and Web of Science were analyzed alongside analyses of top researchers and publishers. Authors were geographically mapped, and their journals were evaluated. This study is thought to be the first to conduct a bibliometric analysis of node localization in wireless sensor networks. Multiple algorithms, hybrid algorithms, and alternative algorithms are being introduced and studied as research in this field expands rapidly. With the current innovation of bio-inspired algorithms, a new area of research has attracted and piqued the interest of researchers. We believe that this bibliometric analysis will be useful to both experienced academics and emerging researchers who plan to play an active role in this field. The analysis also provides scientific research intuitions that can be used to create fact-based descriptions and visualize study results.

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