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CAPSULE NETWORK SEVERAL YEARS LATER: A BIBLIOMETRIC ANALYSIS

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Abstract Bibliometric analysis aims to identify research trends, spot research centers, and find research gaps. We conducted a bibliometric analysis of the Capsule Network method from 2018 to 2023. The research flow began with data collection from Google Trends, Open Knowledge Maps and Scopus. Google Trends was used to get a rough idea of interest over time and the most popular countries. Open Knowledge Maps analysis helped identify intersections between papers related to Capsule Network. The primary data was obtained from Scopus, which was analyzed using ScienceDirect to determine the subject area and Publish or Perish to obtain metadata. The metadata was then analyzed using VOSviewer to identify keyword associations and understand annual trends, the number of articles, and most citations. We also searched for research gaps connected to the Connected Paper website to identify topics that could be developed in the future. The analysis showed a decline in interest in the Capsule Network method. We obtained 170 papers identified in Scopus with the highest publication in 2019 with 50 papers, then decreased by 86% in the following years. Most publications are in IEEE Access with the dominant subject area being Computer Science. The research gap that we can propose is related to quantum computation. We suggest further research on quantum computing which has excellent potential for the future development of the Capsule Network method.

Key words: Bibliometric, Capsule Network, Deep Learning, Review, Research Gaps.

AMS Mathematics Subject Classification: 00Bxx, 68T07, 68T10, 68T99.

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1 Introduction

In the scientific research world, bibliometric analysis has become an essential tool to evaluate and understand the dynamics of a research development. This analysis uses statistical and quantitative methods to measure the production and impact of scientific literature. Researchers can identify research trends, evaluate scientific collaborations, and determine the influence and relevance of specific scholarly works [1, 2]. This bibliometric analysis not only helps in measuring the productivity and quality of research but also enables the identification of research gaps that can form the basis for future research. One crucial aspect of bibliometric analysis is its ability to provide insights into the geographical distribution of research, patterns of collaboration between researchers and institutions, and identifying leading journals in a particular field. For example, citation analysis can reveal highly influential works, while co-authorship analysis can show relationships and networks between researchers [3]. Hence, bibliometric analysis

provides not only a retrospective overview of research development but also a potential projection of future research directions.

One of the latest bibliometric analyses is Windarto's research [4], which focuses on deep learning techniques for image segmentation by analyzing a dataset of research publications extracted from the Scopus database. The research focuses on the period from 2018 to 2022 when image segmentation becomes increasingly popular. Another example in [5], they conducted a comprehensive analysis of deep learning publications from 2007 to 2019. This analysis covers the complete publication structure, including the methods used, such as Capsule Network.

Capsule Network is an image classification method introduced by Geoffrey Hinton in 2017, which is one of the significant innovations in deep learning and computer vision [6]. This method offers a solution to some of the weaknesses of Convolutional Neural Networks (CNN), especially when handling the rotation and transformation of objects in the image. The statement that the Capsule Network method is better than CNN has been the main idea of [7–9]. However, according to [10], the CapsNet method has limitations, such as computational cost, sensitive to small variations, and limited real-world applications. In fact, [11] shows that the CapsNet method is not overpowered. There are a lot of possibilities to develop and become better. Hence, bibliometric analysis on the topic of Capsule Network is essential to understand the extent to which the method has been researched and developed and identify future research directions and potential.

In this paper, we perform a bibliometric analysis of the Capsule Network method. We use several publicly available sources and tools in a way that is easy for the reader to understand. Until now, no paper has specifically performed a bibliometric analysis of the method. Therefore, this paper can also be used as a major contribution to enriching the research on Capsule Network.

2 Methods

Our paper aims to conduct a bibliometric analysis of the Capsule Network method after it was first publicized in 2017. Our research spans from 2018 to 2023, six years since the Capsule Network method emerged. Some of the sources and tools we use are media that people can access for free (e.g., no Scopus login required), so they can be managed by readers more generally. The flow of our work follows the block diagram presented in Fig. 1. In the flow, there are several steps, which are explained in detail below.

The first step is data retrieval from several primary sources: Google Trends, Open Knowledge Maps, and Scopus. Google Trends was used to determine the popularity and interest in the topic of Capsule Network in various countries and specific periods. The popularity data obtained from Google Trends is data from the number of people who search for the keyword "Capsule Network" on the internet. Hence, the data can be used as an initial benchmark for the research interest being carried out. Open Knowledge Maps is a tool to visualize and map the literature to identify relationships and intersections between relevant papers. The results of Open Knowledge Maps can also be taken as an initial result of linking the Capsule Network method with other topics. The primary source of bibliometric analysis that we use comes from Scopus. The metadata from Scopus is very relevant in determining the interest of the Capsule

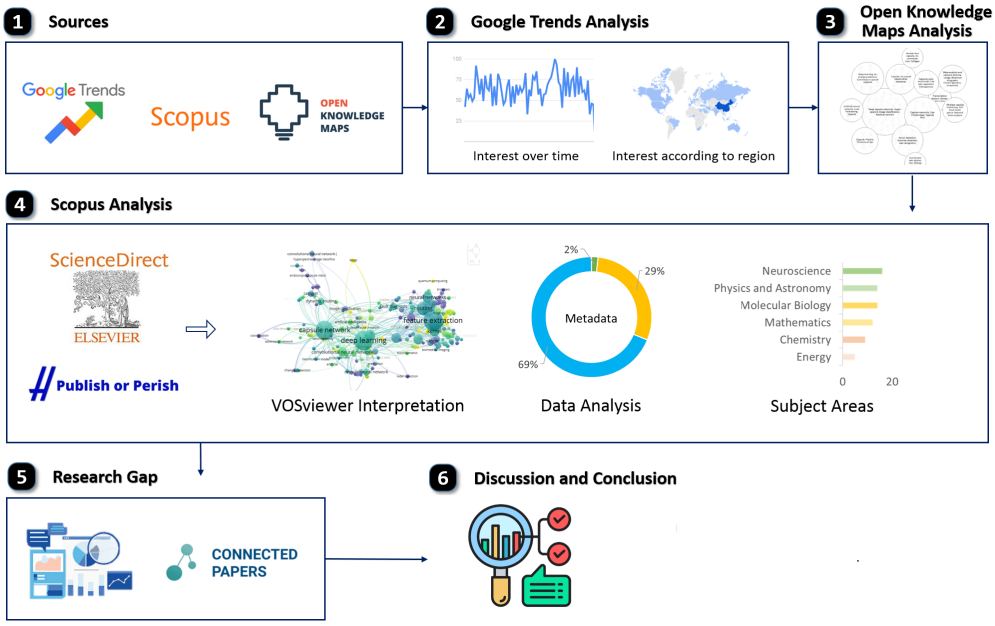


Figure 1: Bibliometrix analysis workflow block diagram.

Network method because it provides related scientific literature, including articles, conferences, and journals from each year.

The next step is data analysis, which starts with Google Trends data. At this step, the data was analyzed to understand the interest in the Capsule Network method over time. The data was taken from all countries, spanning the last five years, all categories, and focused on web searches. This analysis provides an initial overview of how the popularity of the Capsule Network method is growing globally. In addition, this data can also be used to identify the countries that are most searched for Capsule Network topics, thus providing insight into regions with high research activity. The next data will be analyzed from the Open Knowledge Maps website. The website offers visualizations that can help to determine the intersection between papers relevant to the Capsule Network. Mapping the relevant literature is helpful to find out the main themes that appear in the relevant literature. This visualization makes it easy to identify patterns and relationships between researchers and aids in understanding the overall context and development of the topic.

The significant development of the Capsule Network method can be recognized from the Scopus metadata. We only use one source of metadata, Scopus, to avoid duplication of information. Scopus metadata was extracted from the Publish or Perish application, with additional manual checking and data completion to make the results more accurate. The metadata is then processed and analyzed using the VOSviewer application to identify the relationship between keywords. This relationship can be determined from the relevance weight and placement in similar clusters. In addition, the metadata analysis included the number of articles published per year, the journal of publication, the most cited articles, etc., providing an in-depth understanding of the evolution and impact of Capsule Network research. In particular, we retrieved separate data through ScienceDirect to more easily identify the subject areas most frequently associated with the Capsule Network and provide an overview of the most relevant research domains.

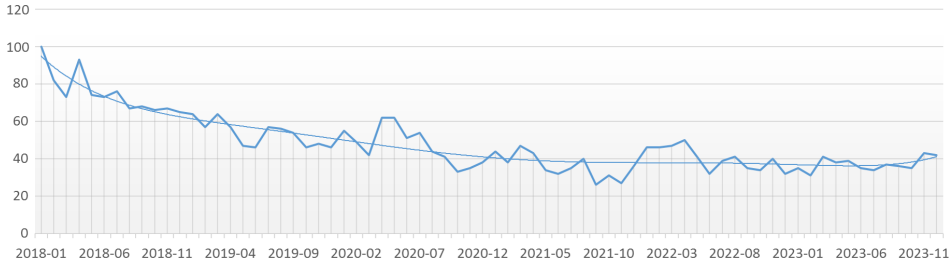


Figure 2: Trends in "Capsule Network" keyword searches over the past five years, sourced from Google Trends data.

Figure 3: A world map with a summary of countries that frequently search for the "Capsule Network" keyword, taken from Google Trends data.

The next step is further exploration of the analysis results to find research gaps. At this step, we identified topics that are still unexplored and have potential for additional development. We used Connected Paper to discover the relationships between the identified topics, allowing to find relationships and interconnections between the various papers. This analysis is essential for directing future research and identifying areas that require further exploration.

The last step is the discussion and conclusion. At this step, all the results from the previous analysis are integrated to get a more comprehensive final result. We also develop a discussion that includes interpretation of the results, implications of the findings, and relevance in the context of Capsule Network research. Our conclusions summarize the main findings, identify the research's limitations, and provide recommendations for future research. It is hoped that presenting a comprehensive and systematic bibliometric analysis of Capsule Network research will provide valuable insights for further development in the future.

3 Results and Analysis

In this section, we explain the results that can be obtained from bibliometric analysis based on several sources. The sources we use are Google Trends, Open Knowledge Maps, and Scopus Database. We also analyze Research Gaps that can be taken and used as input for future research.

3.1 Google Trends Analysis

Google Trends[1] is one of the features provided by Google to know the popularity of search topics over a certain period. We used the keyword "Capsule Network" to find

[1]https://www.google.com/trends

the search trend for six years since its first publication (2018-2023). The results are shown in the graphs in Fig. 2 and Fig. 3. In Fig 2, it can be seen that the interest in the Capsule Network topic fluctuates significantly. The highest interest was in early 2018, reaching 100 searches a day and the lowest in the last quarter of 2021. The total searches in 2018-2023 were 904, 642, 566, 433, 483, and 446. There was a decrease in interest from the beginning of 2018 to the end of 2024 by 50.66%. The data obtained from Google Trends can change every time, so the accuracy of the data is not very good. However, the results of this decline in interest can be used as an initial speculation that interest in the Capsule Network method has begun to decline.

In Fig. 3, the interest of countries with searches for Capsule Network topics is shown, marked by color and frequency. The country with the highest interest is China, which has the highest search frequency of 100. This number indicates that Capsule Network topics are relatively more frequently searched in China. The level of popularity of the Capsule Network method in each country can be seen from the density of the color, the more intense the color, the higher the search frequency. Based on the data we obtained, not many countries have researched the Capsule Network method, so it can be concluded that the opportunity to develop research is still wide open in every country.

3.2 Open Knowledge Maps Analysis Analysis

Open Knowledge Maps[2] is one of the search engines that uses artificial intelligence to discover scientific knowledge and current research. We used this search engine to map the relevant literature in such a way that we could see the interconnections between papers and the main topics that emerged. In simple terms, we can see the intersection of research according to the keywords in each paper. We used the BASE option to search for research using the keyword “Capsule Network”. The results we obtained are shown in Fig. 4.

The data we obtained from Open Knowledge Maps shows that the Capsule Network method is interrelated with other topics. As shown in Fig. 4, there is the largest circle that includes Deep capsule networks, Hyperspectral image classification, and Residual networks, meaning that these topics are highly related to most research topics among the issues in the other circles. The contents of the overlapping circles can be the same or different. For example, for one of the circles shown in Fig. 4, there are many researches covering the Capsule Network method with their respective problems. Open Knowledge Maps can summarize related papers and direct them to relevant sources. Hence, the data obtained from the search engine can also be used as initial reference material that has intersections between them.

The data obtained from Open Knowledge Maps cannot be altered manually so that the resulting graph may include more general topics than the specific keywords given. For example, one of the circles in Fig. 4 has the main topics of Human lens capsule, Accommodation, and Collagen. These topics are research related to bioinformatics, but they can be detected because they contain the words “capsule". Therefore, we must be wiser in selecting data when using the help of Open Knowledge Maps, especially in finding research gaps.

[2]https://openknowledgemaps.org/

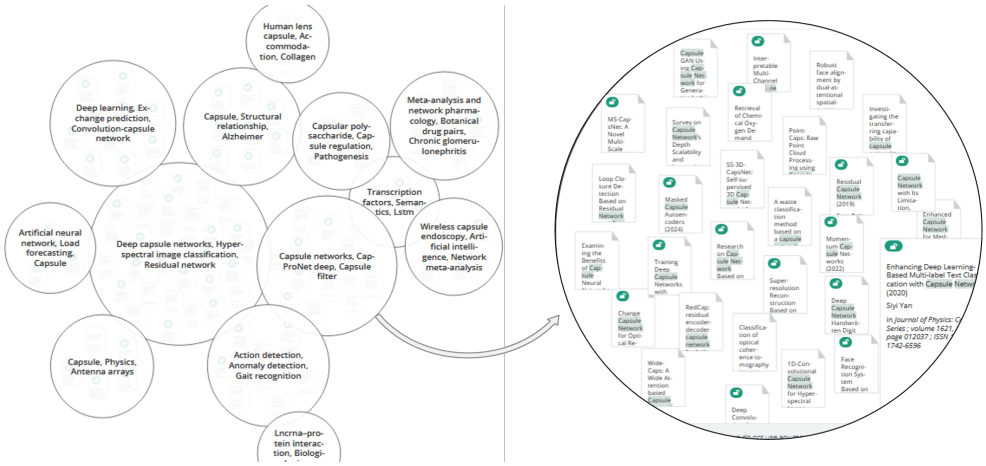


Figure 4: A graph of research overviews with the keyword “Capsule Network”, taken from Open Knowledge Maps data.

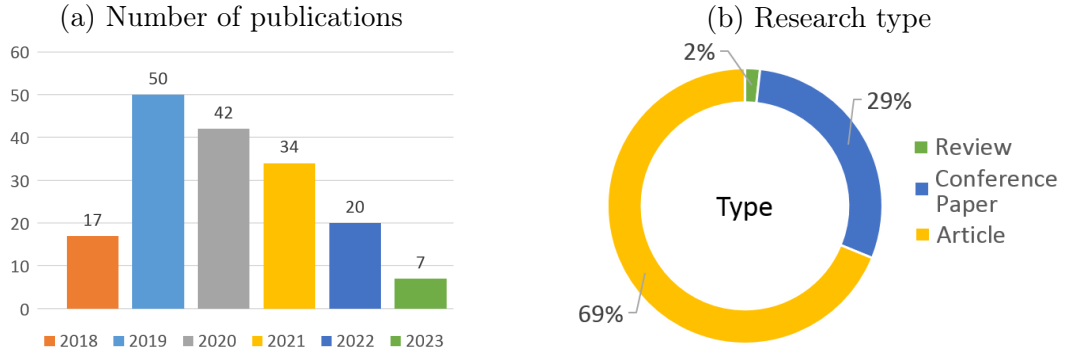


Figure 5: A summary of the extracted metadata, taken from the Scopus database.

3.3 Scopus Database Analysis

Metadata Analysis. Scopus[3] is one of the databases that has met the standards and reputation of international journals. As explained in the methods section, we used the Publish or Perish application and the ScienceDirect website to extract the Scopus database. Publish or Perish[4] is one of the most helpful software for retrieving and analyzing current research. We used the search for titles related to “Capsule Network" registered in the database in 2018-2023. We also manually sorted the retrieved metadata to get more accurate results. We collected a total of 170 papers and the details are shown in Fig. 5.

Fig. 5 shows a summary of the metadata obtained, which is the number of publications per year and the percentage of publication types. In the Google Trends results, the highest search was in 2018. However, in the Scopus database, Capsule Network method research was most published in 2019, as shown in Fig. 5a. This result is quite logical, considering that people were searching and researching in 2018, and the results were published in the following year. The graph also shows an increase in publications from 2018 by 194.12%, but a monotonous decline after 2019. As of 2023, the decline is

[3]https://www.scopus.com/
[4]https://harzing.com/resources/publish-or-perish

86%, meaning that interest in the Capsule Network method is starting to decline and is directly proportional to the Google Trends results.

Based on the 170 papers obtained, there are three publication types: Articles, Conferences, and Reviews. In Fig. 5b, it can be seen that the Article type has the most significant percentage of 69% and the lowest is the Review paper. In detail, Articles, Conferences, and Reviews have a total number of publications of 117, 50 and 3 papers, respectively. In terms of popularity, the Capsule Network method is still less competitive with other classification methods when compared to the Scopus database. We have observed several researches on the Capsule Network method and the reasons behind its decreasing interest. One of the main reasons is the high computational cost and the lack of availability of pre-trained models [10]. The complex construction of dynamic routing algorithms is certainly a challenge for the reason why this method is unpopular. Although the resulting accuracy is quite impressive in several cases [12–14], the computational speed is still less competitive with the pre-trained model [15] and in some cases the Capsule Network method is not better [16]. In addition, Capsule Network has a relative weakness in extracting local features. Hence, continuous development is made both from optimizing the network architecture [17–19] and improving the dynamic routing algorithm [20–22]. These facts are one of the reasons for the contribution of our bibliometric analysis paper to increase the frequency of research related to the topic of Capsule Network.

We further analyzed the metadata retrieved from the Scopus database. We first ranked the popularity of the research based on the number of citations, then examined the frequency of publication places of the published research. Finally, we wanted to know the author who made the most contributions. Tab. 1 shows the five most cited papers grouped by type. The most citations are in H.H. Nguyen's research [28], which uses the Capsule Network method to detect fake images and videos. The citation value per year (CPH) of the research is 80.60, meaning that each year, at least 80 papers cite the research. Furthermore, there are researches related to Hyperspectral Imagery by M.E. Paoletti [23] in the Articel type and MRI image-based COVID-19 identification by [33] in the Review type with a total citation of 291 and 335 respectively. Exciting results are shown in the research [33], which has a higher CPH value than [28], even though the year of publication is more recent, this result is supported because, in that year, there was a COVID-19 virus pandemic that raised the popularity of related papers. Overall, the average number of citations from 2018-2023 is 93.65, 83.12, 63.60, 40.32, 40.60, and 35.29, respectively. This average is already excellent because, at least in two months, there are two reference papers related to Capsule Network.

All papers were sourced from 30 conferences and 73 journals based on the data we collected. Tab. 2 summarizes the top ten sources of each type. The table shows that the journal with the most publications is IEEE Access. However, IEEE in other fields and conferences are also relatively numerous compared to other sources. This data shows that IEEE is a popular source that can be used as a publication destination. Another exciting piece of information is that various general journals, such as Neurocomputing, Scientific Reports, and Knowledge-Based Systems, accept the Capsule Network method. It opens up opportunities for new researchers who want to develop the Capsule Network method without paying particular attention to the intended jour-

Table 1: Top 5 most cited papers published, taken from the Scopus database.

Type	Cites	Authors	Title	Year	CPY
Article	291	M.E. Paoletti	Capsule Networks for Hyperspectral Image Classification [23]	2019	58.20
	284	Z. Zhu	A convolutional neural network based on a capsule network with strong generalization for bearing fault diagnosis [24]	2019	56.80
	262	S. Toraman	Convolutional capsnet: A novel artificial neural network approach to detect COVID-19 disease from X-ray images using capsule networks [25]	2020	65.50
	188	C. Xiang	MS-CapsNet: A Novel Multi-Scale Capsule Network [26]	2018	31.33
	135	Y. Liu	Multi-channel EEG-based emotion recognition via a multi-level features guided capsule network [27]	2020	33.75
Conference	403	H.H. Nguyen	Capsule-forensics: Using Capsule Networks to Detect Forged Images and Videos [28]	2019	80.60
	352	P. Afshar	Brain Tumor Type Classification via Capsule Networks [29]	2018	58.67
	264	Y. Zhao	3D point capsule networks [30]	2019	52.80
	225	P. Afshar	Capsule Networks for Brain Tumor Classification Based on MRI Images and Coarse Tumor Boundaries [31]	2019	45.00
	204	W. Zhao	Investigating capsule networks with dynamic routing for text classification [32]	2018	34.00
Review	335	P. Afshar	COVID-CAPS: A capsule network-based framework for identification of COVID-19 cases from X-ray images [33]	2020	83.75
	131	M. Kwabena	Capsule Networks вЂ“ A survey [34]	2022	65.50
	40	A.A. Akinyelu	Brain Tumor Diagnosis Using Machine Learning, Convolutional Neural Networks, Capsule Neural Networks and Vision Transformers, Applied to MRI: A Survey [35]	2022	20.00

nal because the main focus is the method, so the journals covered can be pretty broad following their respective domain knowledge. In addition to the source of publication, an exciting thing that can be studied is the authors who often contribute.

Our database has 149 different authors contributing to Capsule Network research. We sorted the author data based on the frequency of the name appearing frequently and the total number of citations obtained, resulting in the top five researchers. The data is shown in Tab. 3. The author with the most contributions is P.Afshar, who has six papers with a total citation of 1043. Of the six papers, there is one with the most

Table 2: Top 10 sources with the highest number of publications from Scopus database.

Total	**Article**	**Total**	**Conference Paper**	**Total**	**Review**
13	IEEE Access	5	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	1	Pattern Recognition Letters
5	IEEE Transactions on Geoscience and Remote Sensing	4	ICASSP, IEEE International Conference on Acoustics, Speech and Signal Processing - Proceedings	1	Journal of King Saud University - Computer and Information Sciences
4	Neurocomputing	4	Proceedings of the 2018 Conference on Empirical Methods in Natural Language Processing, EMNLP 2018	1	Journal of Imaging
4	Computers in Biology and Medicine	3	Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition		
4	IEEE Geoscience and Remote Sensing Letters	3	ACL 2019 - 57th Annual Meeting of the Association for Computational Linguistics, Proceedings of the Conference		
3	IEEE Signal Processing Letters	3	Advances in Neural Information Processing Systems		
3	IEEE Transactions on Instrumentation and Measurement	3	Conference on Empirical Methods in Natural Language Processing and 9th International Joint Conference on Natural Language Processing, Proceedings of the Conference		
3	Scientific Reports	2	Proceedings of the IEEE International Conference on Computer Vision		
3	Measurement: Journal of the International Measurement Confederation	2	International Conference on Computer Graphics, Visualization, Computer Vision and Image Processing 2021		
3	Knowledge-Based Systems	1	Proceedings - International Conference on Image Processing, ICIP		

Table 3: Top 5 Authors with the most contributions, taken from Scopus database.

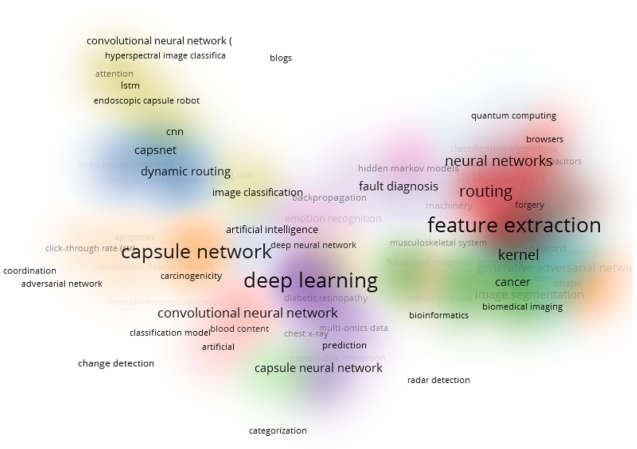
Authors	Contribution		Most Popular Paper	
	Total	Cites	Most Cited	Title
P. Afshar	6	1043	352	Brain Tumor Type Classification via Capsule Networks [29]
R. Huang	3	279	118	Deep Adversarial Capsule Network for Compound Fault Diagnosis of Machinery Toward Multidomain Generalization Task [36]
M.E. Paoletti	2	319	291	Capsule Networks for Hyperspectral Image Classification [23]
Y. Liu	2	171	135	Multi-channel EEG-based emotion recognition via a multi-level features guided capsule network [27]
B. Zhang	2	109	56	Knowledge Guided Capsule Attention Network for Aspect-Based Sentiment Analysis [37]

citations, which is 352. The paper is a research on the classification of brain tumors that was conferred in 2018. At the same time, other researchers contribute an average of 1.11, which means that almost all researchers only publish one paper except for the top few researchers, as in Tab. 3. There is interesting information based on the data that the author obtained. There is no mention of Sabour or Hinton as the inventors of the Capsule Network method. This can happen because the research they conducted didn't use the editorial "Capsule Network" in the title, so it was not detected using the Publish or Perish application. Furthermore, we analyzed Scopus data by reviewing keyword relevance.

Keywords Analysis. Keywords are an essential part of a paper. However, not all papers include keywords in their documents, so it is necessary to have a manual filter to find the papers that contain keywords. All the papers we collected have been filtered with keywords. We use the VOSviewer[5] application, which is one application that can be used to find out the keyword connections between papers. Hence, the latest topic trends and research gaps can be analyzed. The total number of keywords we obtained from 170 papers was 335, divided into 36 clusters. The relationship between clusters in terms of density visualization and keywords in the top five clusters is shown in Fig. 6. The figure shows that the three most frequently used keywords are capsule network, deep learning, and feature extraction. These three keywords are commonly used because they cover the method's name, the type of artificial intelligence, and the novelty of the Capsule Network method, which lies in the feature extraction process. In addition, there are several clusters marked with the same color. For example, for the green color, cluster two, the keywords used are related to its application in the health field. Hence, the keywords incorporated are cancer, biomedical imaging, blood vessels, and others.

Keyword relationship analysis can also be obtained from its network visualization. The keywords used in each paper can be connected so that the network of keywords can be known to each other. The network visualization of each keyword is shown in Fig. 7.

[5]https://www.vosviewer.com/



Top 5 Clusters	
Cluster	**Keywords**
1	browsers, computer hacking, computer science, convolutional codes, cryptocurrency, decoding, encoding, feature extraction, fuses, internet of things, knowledge engineering, machine learning algorithms, malware, mathematical model, motion pictures, routing, semantics, sentiment analysis, smart cities, speech processing, syntactics, task analysis
2	bayes methods, biomedical imaging, blood vessels, brain, brain cancer, brain modeling, cancer, capsule neural networks, clustering algorithms, convolutional neural networks, image segmentation, lung, machine learning, magnetic resonance imaging, measurement uncertainty, offline signature verification, pathology, predictive models, retinal vessels, tumors, uncertainty, vision transformers.
3	activations, attention model, capsnet, cross-domain sentiment classification, deep neural networks, domain adaptation, driver distraction, dynamic routing, lesion classification, mu, multi-label text classification, nash equilibrium, pattern recognition, posture classification, recommendation system, renewable energy, routing-by-agreemen, sign language, skin disease, spatio-temporal features, wind speed prediction,
4	analysis, applications of capsnet, architectures of capsnet, attention, blood cells, capsule, cnn, deep learnin, endoscopic capsule robot, gru, hyperspectral, image classification, localization, lstm, neural network, nlp, possibility density, rcnn, sequential deep learning, text classification, visual odometry,
5	bert, breast cancer, capsule neural network, chest x-ray, classification, deep learning, diabetic retinopathy, fake news detection, mammogram, medical image analysis, medical imaging, metaheuristic algorithms, multi-omics data, non-static word embedding, of cancer-related genes, prediction, protein-dna interaction, pssm, residue, routing-by-agreement, white blood cells (wbc),

Figure 6: Cluster density visualization of the keyword relationships, taken from Scopus database.

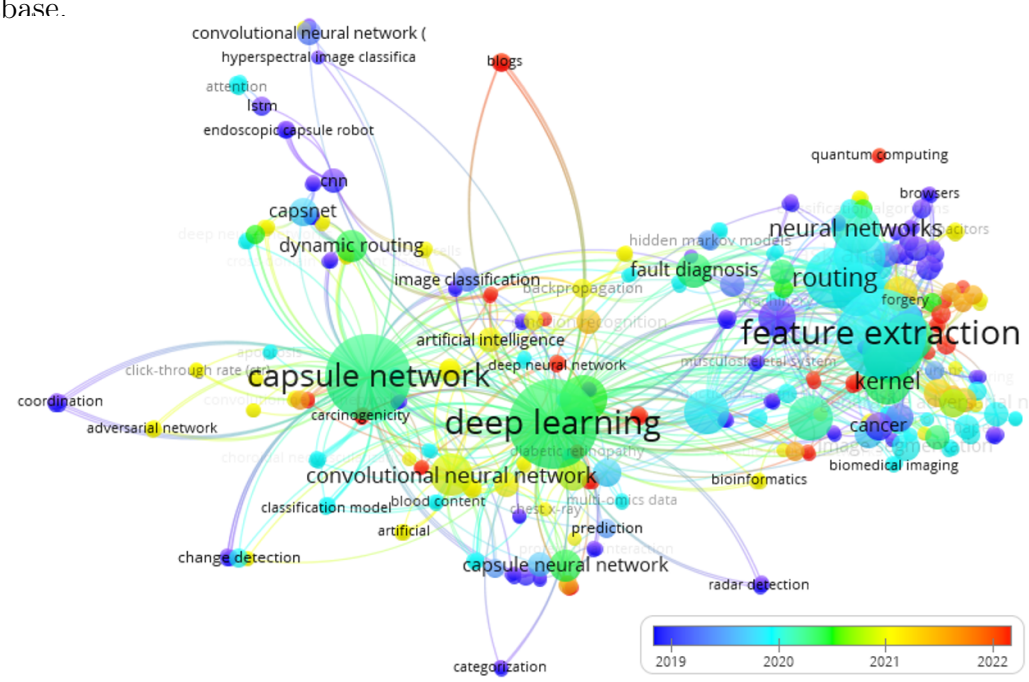


Figure 7: Network visualization of the keyword relationships, taken from Scopus database.

It can be seen that the three frequently used keywords have a network of almost every keyword and are by the cluster visualization. In addition, we can conclude that the keywords in recent research (colored red) are relatively close to the feature extraction keywords. This means that recent researchers often focus on developing the Capsule Network method in feature extraction and its modification based on related areas. Some keywords have no network with others, i.e. quantum computing and quantum machine learning. Hence, we can conclude that few researches have developed the Capsule Network method in the quantum area.. Further analysis will focus on areas often used to create Capsule Network.

Subject Area Analysis. Subject area analysis is an approach to thoroughly evaluate and understand a particular discipline based on related research areas. The aim is to

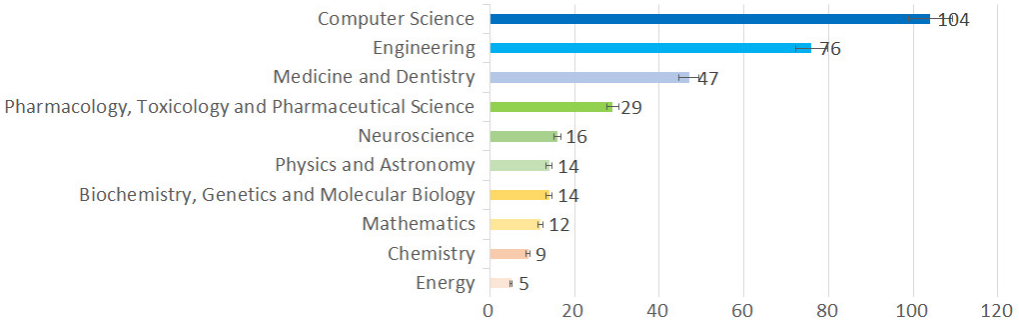


Figure 8: Distribution of research by subject area, taken from ScienceDirect database.

A paper that cites research in graphics.

Title	Last author	Year	Citations	Graph references
A Review of Barren Plateaus in Variational Quantum Computing	M. Cerezo	2024	3	17
Universal adversarial perturbations for multiple classification tasks with quantum classifiers	Yun-Zhong Qiu	2023	0	11
Training robust and generalizable quantum models	Christian Holm	2023	2	8
Predominant Aspects on Security for Quantum Machine Learning: Literature Review	Jeanette Miriam Lorenz	2024	1	7
Quantum Transfer Learning with Adversarial Robustness for Classification of High-Resolution Image Datasets	Muhammad Usman	2024	0	6
Drastic Circuit Depth Reductions with Preserved Adversarial Robustness by Approximate Encoding for Quantum Machine Learning	Muhammad Usman	2023	4	6
Quantum Machine Learning on Near-Term Quantum Devices: Current State of Supervised and Unsupervised Techniques for Real-World Applications	Raymond H. Putra	2023	4	6
A Comparative Analysis of Adversarial Robustness for Quantum and Classical Machine Learning Models	Pascal Debus	2024	0	5
Generating Universal Adversarial Perturbations for Quantum Classifiers	Apurva Narayan	2024	0	5
Does provable absence of barren plateaus imply classical simulability? Or, why we need to rethink variational quantum computing	Zoe Holmes	2023	29	5

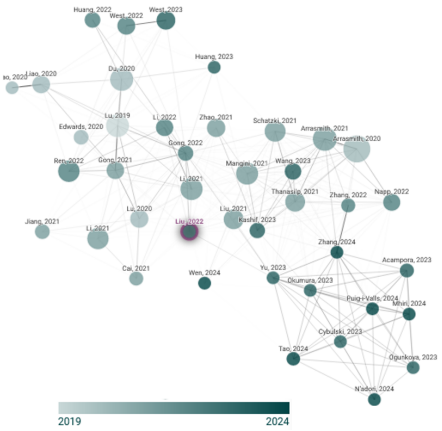


Figure 9: Graph network related to research [38], taken from Connected Papers data.

identify trends and developments in the field. As explained in the metadata analysis section, the database obtained from Publish or Perish does not contain related fields of research. Therefore, we used specific sources from ScienceDirect to make it easier to analyze the data and be accessible to the public. We obtained 326 papers that contained the keyword “Capsule Network" in the title editor; after further analysis, it turned out that there were 53 unrelated papers. Hence, the accuracy of the subject area of research obtained from the ScienceDirect database is about 75.23%. Fig 8 shows the obtained subject area from ScienceDirect database.

Fig. 8 shows that Computer Science and Engineering fields dominate, which could be due to the greater focus or popularity of research or applications in these areas. Medicine and Dentistry are also popular fields, which is in line with the results of keyword analysis, which states that applications in the bioinformatics area are pretty frequent. The fields of Mathematics, Chemistry, and Energy have fewer researchers. Hence, there are still many opportunities that can be developed and applied to these areas of research.

4 Research Gaps and Discussion

This section explains the exciting information we gathered from the analysis, which can be used as suggestions for future research. Based on the Scopus database, in 2023, only two researches that developed the Capsule Network method, i.e. modification with transformers and quantum-based computing. Transformers are one of the new

mechanisms that are quite popular and have even become a new image classification method, which is Vision Transformer [39]. The powerful Vision Transformer integrated in the Capsule Network method can improve the accuracy up to 2.29% [14]. This type of merging modification has frequently been performed in deep learning methods and has relatively good results. At the same time, quantum computing is one of the rising topics, with its concept incorporated into deep learning methods. There has only been one quantum-based Capsule Network research so far, which is the research in the paper [38]. This follows the results of VOSviewer, which shows that the keyword quantum computing is not related to other keywords because it is still new. Therefore, the development of the Capsule Network method is very wide open in the quantum domain. We try to analyze further [38] research with its reference relationship using Connected Papers[6], which is a visual tool to find out the relationship of a paper with other papers. The network visualization of the [38] research is shown in Fig. 9. Based on the figure, it can be seen that the related research is still related to the latest papers. The top ten papers also reference the research on the graph. All of these papers are research related to quantum computing. Hence, it can be concluded that the research gap in the quantum area, especially the Capsule Network method, is still wide open.

5 Conclusion

In conclusion, we have conducted a bibliometric analysis of the data we collected based on reliable sources and tools. We used Google Trends data to find indications of research trends, identifying a decline in interest in the Capsule Network method. We also used Open Knowledge Maps to identify intersections with other topics. The primary data we used came from Scopus. We get 170 related papers with each percentage of Article, Conference, and Review types, respectively 69%, 29%, and 2%. The most publications were in 2019, with as many as 50 papers and a decrease afterward by 86%. The total citations are 10849, and most publications are in IEEE Access. The most contributing author is P. Afshar, with a total of 6 related paper contributions. The most dominant subject area on the ScienceDirect website is computer science, with 104 papers.

At the end of the discussion, we propose a topic that can be developed in the future according to the research gaps obtained. That topic is the use of quantum computing in the Capsule Network method. Up to now, there has been no hybrid computing on the Capsule Network method. Hence, the development in the realm of quantum computing is still wide open and can be useful in future research.

References

[1] Hu W., Xu Y, *The published trend of studies on covid-19 and dietary supplements: Bibliometric analysis*, Frontiers in immunology, 13 (2022), 1065724.

[2] Ramadhan S., Raharjo S. B., Taufik O. A., Kozin W., Habibullah A., Dudin A., Lisyawati E., *Global research trend in digital learning: Analysis using bibliometrix on the scopus database*, Educational Administration: Theory and Practice, 30.4 (2024), 1537-1547.

[6]https://www.connectedpapers.com/

[3] Derviş H., *Bibliometric analysis using bibliometrix an r package*, Journal of scientometric research, 8.3 (2019), 156-160.

[4] Windarto A. P., Yuhandri Y., Bukhori S., *Bibliometric analysis of image segmentation with deep learning: An analytical study*, in International Conference on Mechatronics and Intelligent Robotics, 2023, 61-79.

[5] Li Y., Xu Z., Wang X., Wang X., *A bibliometric analysis on deep learning during 2007-2019*, International Journal of Machine Learning and Cybernetics, 11 (2020), 2807-2826.

[6] Sabour S., Frosst N.,Hinton G. E., *Dynamic routing between capsules*, Advances in neural information processing systems, 30 (2017).

[7] Yang S., Lee F., Miao R., Cai J., Chen L., Yao W., Kotani K., Chen Q., *Rs-capsnet: an advanced capsule network*, IEEE Access, 8 (2020), 85007-85018.

[8] Fan C., Xie H., Tao J., Li Y., Pei G., Li T, Lv Z., *Icaps-reslstm: Improved capsule network and residual lstm for eeg emotion recognition*, Biomedical Signal Processing and Control, 87 (2024), 105422.

[9] Wijaya R. N. R., Setiyono B., Yunus M., Sulistyaningrum D. R., *Operator-n layer construction for optimizing capsule network methods in image classification problems*, Journal of Information Hiding and Multimedia Signal Processing, 14.3 (2023), 90-101.

[10] Haq M. U., Sethi M. A. J., Rehman A. U., *Capsule network with its limitation, modification, and applications—a survey*, Machine Learning and Knowledge Extraction, 5.3 (2023), 891-921.

[11] Gu J., Tresp V., Hu H., *Capsule network is not more robust than convolutional network*, in Proceedings of the IEEE/CVF conference on computer vision and pattern recognition, 2021, 14309-14317.

[12] Wang Y., Sun A., Han J., Liu Y., Zhu X., *Sentiment analysis by capsules*, in Proceedings of the 2018 world wide web conference, 2018, 1165-1174.

[13] Kim M., Chi S., *Detection of centerline crossing in abnormal driving using capsnet*, The Journal of Supercomputing, 75.1 (2019), 189-196.

[14] Li Y., Lu H., Wang Y., Gao R., Zhao C., *Vit-cap: a novel vision transformer-based capsule network model for finger vein recognition*, Applied Sciences, 12.20 (2022), 10364.

[15] Nguyen H. P., Ribeiro B., *Advanced capsule networks via context awareness*, in Artificial Neural Networks and Machine Learning-ICANN 2019: Theoretical Neural Computation: 28th International Conference on Artificial Neural Networks, Munich, Germany, September 17-19, 2019, Proceedings, Part I 28, 166-177.

[16] Chao H., Dong L., Liu Y., Lu B., *Emotion recognition from multiband eeg signals using capsnet*, Sensors, 19.9 (2019), 2212.

[17] Ding X., Wang N., Gao X., Li J.,. Wang X, Liu T., *Group feedback capsule network*,IEEE Transactions on Image Processing, 29 (2020), 6789-6799.

[18] Sun K., Wen X., Yuan L., Xu H., *Dense capsule networks with fewer parameters*, Soft Computing, 25.10 (2021), 6927-6945.

[19] Tao J., Zhang X., Luo X., Wang Y., Song C., Sun Y., *Adaptive capsule network*, Computer Vision and Image Understanding, 218 (2022), 103405.

[20] Zeng R., Song Y., *A fast routing capsule network with improved dense blocks*, IEEE Transactions on Industrial Informatics, 18.7 (2021), 4383-4392.

[21] Wang W., Lee F., Yang S., Chen Q., *An improved capsule network based on capsule filter routing*, IEEE Access, 9 (2021), 109374-109383.

[22] Mazzia V., Salvetti F., Chiaberge M., *Efficient-capsnet: Capsule network with self-attention routing*, Scientific reports, 11.1 (2021), 14634.

[23] Paoletti M. E., Haut J. M., Fernandez-Beltran R., Plaza J., Plaza A., Li J., Pla F., *Capsule networks for hyperspectral image classification*, IEEE Transactions on Geoscience and Remote Sensing, 57.4 (2018), 2145-2160.

[24] Zhu Z., Peng G., Chen Y., Gao H., *A convolutional neural network based on a capsule network with strong generalization for bearing fault diagnosis*, Neurocomputing, 323 (2019), 62-75.

[25] Toraman S., Alakus T. B., Turkoglu I., *Convolutional capsnet: A novel artificial neural network approach to detect covid-19 disease from x-ray images using capsule networks*, Chaos, Solitons & Fractals, 140 (2020), 110122.

[26] Xiang C., Zhang L., Tang Y., Zou W., Xu C., *Ms-capsnet: A novel multi-scale capsule network*, IEEE Signal Processing Letters, 25.12 (2018), 1850-1854.

[27] Liu Y., Ding Y., Li C., Cheng J., Song R., Wan F., Chen X., *Multi-channel eeg-based emotion recognition via a multi-level features guided capsule network*, Computers in Biology and Medicine, 123 (2020), 103927.

[28] Nguyen H. H., Yamagishi J., Echizen I., *Capsule-forensics: Using capsule networks to detect forged images and videos*, in ICASSP 2019-2019 IEEE international conference on acoustics, speech and signal processing (ICASSP), 2307-2311.

[29] Afshar P., Mohammadi A., Plataniotis K. N., *Brain tumor type classification via capsule networks*, in *2018 25th IEEE international conference on image processing (ICIP)*, 3129-3133.

[30] Zhao Y.,Birdal T., Deng H., Tombari F., *3d point capsule networks*, in Proceedings of the IEEE/CVF conference on computer vision and pattern recognition, 2019, 1009-1018.

[31] Afshar P., Plataniotis K. N., Mohammadi A., *Capsule networks for brain tumor classification based on mri images and coarse tumor boundaries*, in ICASSP 2019-2019 IEEE international conference on acoustics, speech and signal processing (ICASSP), 1368–1372.

[32] Zhao W., Ye J., Yang M., Lei Z., Zhang S., Zhao Z., *Investigating capsule networks with dynamic routing for text classification*, arXiv preprint arXiv:1804.00538, 2018.

[33] Afshar P., Heidarian S., Naderkhani F., Oikonomou A., Plataniotis K. N., Mohammadi A., *Covid-caps: A capsule network-based framework for identification of covid-19 cases from x-ray images*, Pattern Recognition Letters, 138 (2020), 638-643.

[34] Patrick M. K., Adekoya A. F., Mighty A. A., Edward B. Y., *Capsule networks – a survey*, Journal of King Saud University-computer and information sciences, 34.1 (2022),1295-1310.

[35] Akinyelu A. A., Zaccagna F., Grist J. T., Castelli M., Rundo L., *Brain tumor diagnosis using machine learning, convolutional neural networks, capsule neural networks and vision transformers, applied to mri: a survey*, Journal of imaging, 8.8 (2022), 205.

[36] Huang R., Li J., Liao Y., Chen J., Wang Z.,Li W. , *Deep adversarial capsule network for compound fault diagnosis of machinery toward multidomain generalization task*, IEEE Transactions on Instrumentation and Measurement, 70 (2020), 1-11.

[37] Zhang B., Li X., Xu X., Leung K.-C., Chen Z., Ye Y., *Knowledge guided capsule attention network for aspect-based sentiment analysis*, IEEE/ACM Transactions on Audio, Speech, and Language Processing, 28 (2020), 2538-2551.

[38] Liu Z., Shen P.-X., Li W., Duan L.-M., Deng D.-L., *Quantum capsule networks*, Quantum Science and Technology, 8.1 (2022), 015016.

[39] Khan S., Naseer M., Hayat M., Zamir S. W., Khan F. S., Shah M., *Transformers in vision: A survey*, ACM computing surveys (CSUR), 54.10s (1011), 1-41.

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