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Development of Artificial Intelligence (AI): A Bibliometric Analysis Approach

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Keywords

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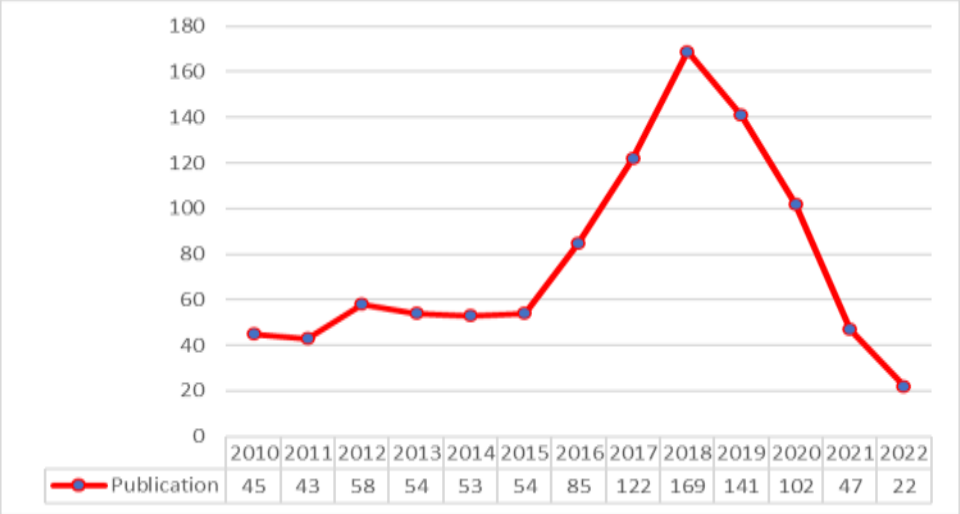
Abstract. The whole world is competing to develop artificial intelligence for the benefit of groups and individuals, and this condition results in significant changes in the style or way of human activity; the development of artificial intelligence in the world of technology is very rapid and inevitable. This research aims to systematically analyze the development of artificial intelligence in human technological civilization within the last three years, namely from 2010 to 2022. This research uses a bibliometric analysis approach assisted by the VOSviewer application. The data used is scientific article data published on Google Scholar during 2010-2022 using the Publish or Perish application on the keyword "Artificial Intelligence" to obtain 999 scientific articles on artificial intelligence, which are used in this bibliometric analysis research. The results of bibliometric analysis obtained 6 clusters with 141 items, the results of mapping network visualization, overlay visualization, and density visualization, and the relationship of the most popular items with other clusters so that a relevant mapping is formed on each item with other clusters.

1. INTRODUCTION

Digital technology is now a very important part of human life. Technological developments facilitate work and meet human needs [1]. Artificial intelligence in the development of information technology is utilized in all fields, the ability to connect devices to an adequate internet network and install various software for activities. [2] Explains that artificial intelligence (AI) is the oldest and broadest field of computer science, dealing with all aspects of imitating cognitive functions for real-world problem-solving and building systems that learn and think like humans. Therefore, AI is often called machine intelligence to distinguish it from human intelligence [3]. The field revolves around the intersection of cognitive science and computer science, and AI is now generating enormous interest due to practical successes in machine learning [4]. Within AI, there is always a strong connection to explainability.

VOSviewer is used to display bibliometric map visualizations. Bibliometric map displays are visualized with VOSviewer based on the name of the author or journal with co-citation data or based on keywords with co-occurrence data in the form of label, sketch, and density map displays and clusters [5]. The clusters in the map from VOSviewer are presented with different colors. Each parameter is operated by a clustering algorithm that can be changed to produce more or fewer clusters [6]. [7] explained that the research mapping process is carried out with the stages of the object selection process, calculating interacting objects, normalization process, creating maps, displaying maps, and evaluating maps. This research aims to identify developments, gaps, and opportunities for artificial intelligence research with Vosviewer. Therefore, it is hoped that the results of this study can be a reference for other researchers in determining research themes, especially those related to artificial intelligence research.



Source: Publish or Perish (2023)

Figure 1. Artificial Intelligence Publications for the Period 2010-2022

Figure 1 above is information on publication data related to artificial intelligence from 2010 to 2022 from the publish or perish application data search. The trend of the publications fluctuates from year to year. The lowest number of publications occurred in 2022, with 22 articles published in books, research articles, reviews, and conferences, the most in 2018, with as many as 169 articles published in the Google Scholar database during the research period. From 2010 to 2018, the trend of research related to artificial intelligence was very significant, indicating that it had begun to prepare for conditions such as today's use of artificial intelligence in daily activities. If observed in 2019 to 2022 in the research period, publications related to artificial intelligence are decreasing every year. According to [8], this condition is based on implementing any research that has been realized in the form of artificial intelligence in the real world. Publications related to artificial intelligence are already at the development stage and are even sustainable.

Research conducted by [9] 2019 with the title "The practical implementation of artificial intelligence technologies in medicine" the study reviews the development of artificial intelligence-based technology in medicine. In reality, the implementation of these technological developments has not yet become a reality, so the purpose of the study was to describe the implementation of artificial intelligence in clinical workflows in medicine, such as data and privacy, data standardization, algorithm transparency, interoperability across platforms, and concern for patient safety. The International Medical Device Regulators Forum (IMDRF) is one of the organizations leading the way in implementing artificial intelligence in medicine. The organization is a volunteer medical device regulator with the aim of harmonizing international medical device regulations.

Research conducted by [10] 2022 with the title "Artificial intelligence and life in 2030: the one hundred year study on artificial intelligence" explained that Artificial intelligence (AI) is a science and computing technology inspired by the way humans use the human body and nervous system in learning, feeling, taking action, and reasoning. While the development of AI is unpredictable and uneven, the progress in the field of AI is very significant. At first, AI was an academic field of study. Then, in the twenty-first century, AI-enabled a constellation of technologies that impacted everyday life. The deep form of machine learning based on variable layered representations with other terms neural networks that make speech articulation practical on today's technological devices, with these algorithms can be widely applied to information technology applications and computer networks so that in the coming 2030 artificial intelligence is both a convenience and a threat to humans themselves.

Research conducted by [11] 2020 with the title "Artificial Intelligence (AI) applications for COVID-19 pandemic" The purpose of the research is to prevent, analyze, and fight Covid-19 and other pandemics by reviewing the function of AI as a technology that can prepare new technology

support such as Artificial Intelligence (AI). The study found significant Artificial Intelligence (AI) applications for the Covid-19 pandemic. The resulting technology can detect clusters of cases and predict where the virus will have an impact in the future from previous data. So that health nurses can use this technology for decision-making in dealing with the virus and help get real-time information.

2. METHOD

This research uses bibliometric analysis of scientific publications as a tool to develop Artificial Intelligence (AI) in technology. The benefits of bibliometric analysis as a research mapping tool from research that has been done and will be done as well as opportunities or opportunities in the future. Research data is traced from Google Scholar sources with the search keyword "Artificial Intelligence," with a thirteen-year observation period from 2010 to 2022. Several previous studies have explained This bibliometric analysis method with detailed information from the reference manager stage and research sample data collection [7], and [12]. The author uses the Publish or Perish reference manager application to retrieve the data needed in the research. The Publish or Perish, reference manager application can search for data and literature according to the theme sought and then produce the desired database. Mapping this research data using the VOSviewer application, VOSviewer is a bibliometric analysis method carried out by many previous studies. VOSviewer can create maps of researchers and journals from search sources with keywords on research topics. The stages for creating an overview and mapping of research are reference data from the data collection results using the Publish or Perish application. Then, the data is sorted based on the topic or theme needed. Then, the next stage is mapped with bibliometric analysis using VOSviewer.

3. RESULTS AND DISCUSSION

The observation period in the study is 2010 to 2022, with bibliometric analysis obtained 999 articles with the keyword "Artificial Intelligence" indexed by Google Scholar. The publication trend obtained in 2010 was 45 publications. In 2011, there were 43 publications. In 2012, there were 58 publications. In 2013, there were 54 publications. In 2014, there were 53 publications. In 2015, there were 54 publications. In 2016, there were 85 publications. In 2017, there were 122 publications. In 2018, there were 169 publications. In 2019, there were 141 publications. In 2020, there were 102 publications. In 2021 there were 47 publications, and in 2022 there were 22.

4. Table 1. Most citations related to Artificial Intelligence (AI)

No	Citation	Title	Publisher	Year	Author
1	63.460	Reinforcement learning: An introduction	The MIT Press	2018	[1]
2	56.370	Artificial intelligence a modern approach	Pearson Education, Inc	2010	[13]
3	54.636	Deep learning	The MIT Press	2016	[14]
4	42.459	C4. 5: programs for machine learning	Elsevier	2014	[15]
5	27.260	Tensorflow: Large-scale machine learning on heterogeneous distributed systems	*arXiv preprint arXiv*	2016	[16]
6	21.914	Scripts, plans, goals, and understanding: An inquiry into human knowledge structures	Psychology Press	2013	[8]
7	21.709	Understanding the difficulty of training deep feedforward neural networks	JMLR Workshop and Conference Proceedings.	2010	[17]
8	20.680	Distributed optimization and statistical learning via the	*Foundations and Trends® in*	2011	[18]

		alternating direction method of multipliers	*Machine learning*		
9	17.703	The fourth industrial revolution	Currency.	2017	[19]
10	17.256	Life on the Screen	Simon and Schuster	2011	[20]

Source: Publish or Perish (2023)

Table 1 is the result of mapping based on the most citations in Artificial Intelligence-related publication articles, which are arranged in the top ten most cited rankings. Most citations are occupied by [1], with the title of the article "Reinforcement learning: An introduction" published by The MIT Press with 63,460 citations. The last of the top ten most cited articles was published [20] titled "Life on the Screen" and published by Simon and Schuster with 17,256 citations.

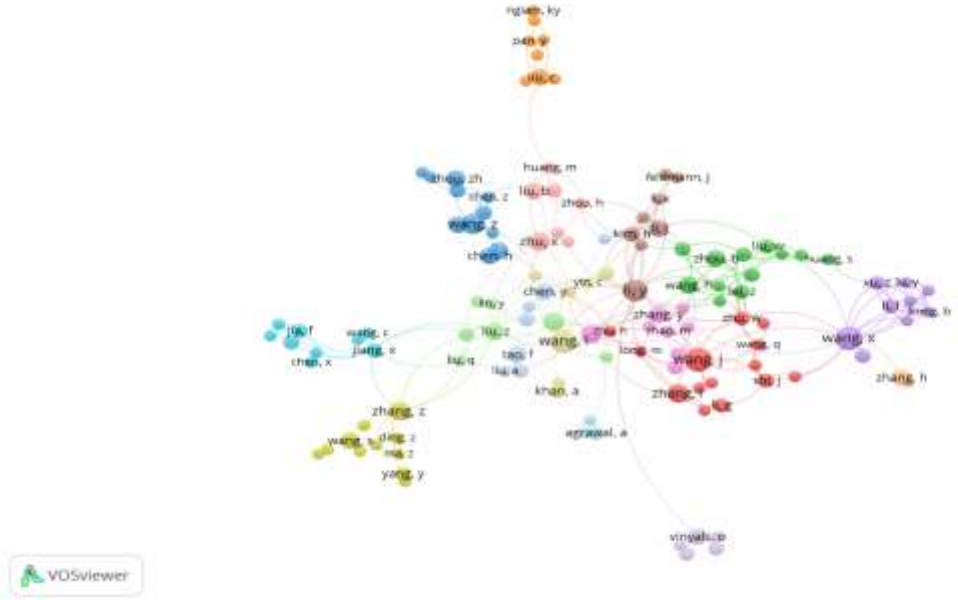


Figure 2. Co-Authorship in Artificial Intelligence (AI)

Figure 2 is Co-Authorship information on publication articles related to Artificial Intelligence with a minimum of 2 authorships on each article. The results obtained as many as 16 Co-Authorship clusters with 128 items (Authorship) by forming author networks on each publication article related to publications related to Artificial Intelligence.

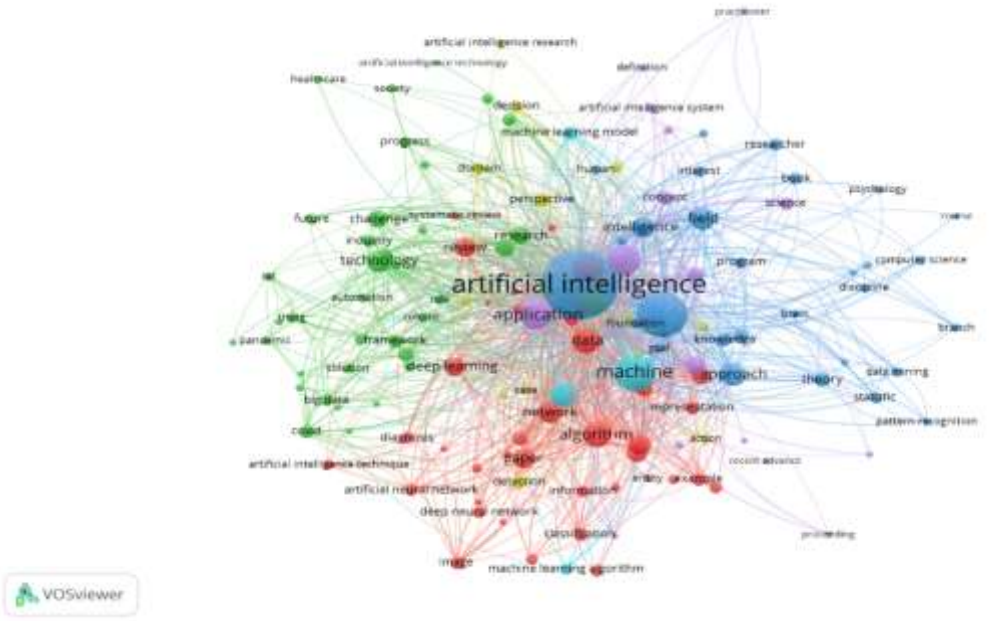


Figure 3. Network Visualization of Artificial Intelligence (AI)

Figure 3 is a network visualization between keywords. The results of network visualization with VOSviewer obtained six interconnected clusters with 141 items (keywords). The mapping results obtained the first cluster with 38 keyword items, the second cluster with 36 keyword items, the third cluster with 30 keyword items, the fourth cluster with 17 keyword items, the fifth cluster with 16 keyword items, and the sixth cluster with four keyword items. The items formed are keyword item-level relationships often used in articles related to Artificial Intelligence. Keyword item data for each cluster can be seen in Table 2 below:

Table 2. Keyword Term Clusters

Cluster	Keyword Terms
Kluster 1 (38 item)	Model, algorithm, data, network, task, paper, review, learning, deep learning, study, prediction, neural network, performance, example, image, classification, representation, diagnosis, architecture, artificial neural network, deep neural network, feature, information, ability, artificial intelligence technique, convolutional neural network, computer vision, graph, form, natural language processing, recent year, artificial intelligence application, emergence, entity, systematic review, vision, art, artificial intelligence method.
Kluster 2 (36 item)	Technology, development, research, challenge, tool, framework, covid, advance, big data, industry, impact, program, future, internet, medicine, Role, world, solution, thing, automation, practice, robotic, opportunity, society, iot, overview, breakthrough, pandemic, fourth industrial, revolution, healthcare, artificial intelligence technology, combination, integration, blockchain, natural language, possibility.
Kluster 3 (30 item)	Artificial intelligence, machine learning, approach, field, intelligence, theory, knowledge, computer, book, researcher, program, interest, statistic, data mining, goal, human, discipline, computer science, foundation, psychology, brain, branch, education, human intelligence, pattern recognition, idea, subfield, cognitive science, course, articial intelligence.
Kluster 4 (17 item)	Problem, work, perspective, detection, domain, decision, reinforcement, learning, intelligent system, action, article, case, planning, evolution,

	platform, user, intelligent agent, artificial intelligence research.
Kluster 5 (16 item)	System, application, survey, analysis, concept, science, artificial, intelligence system, explainable artificial intelligence, evolution, definition, recent advance, security, uncertainty, computational, intelligence, practitioner, proceeding.
Kluster 6 (4 item)	Machine, technique, machine learning model, machine learning algorithm.

Source: VOSviewer (2023)

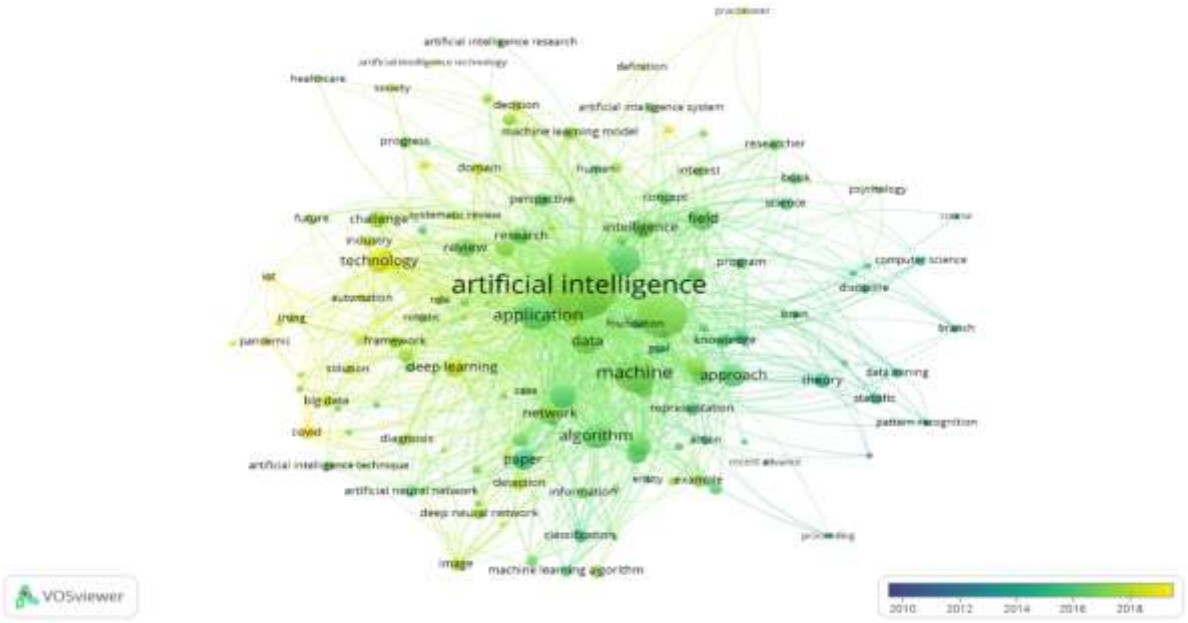


Figure 4. Overlay Visualization of Artificial Intelligence (AI)

Figure 4 is a visualization of the research overlay related to Artificial Intelligence in the research year, namely 2010 to 2022. The blue to dark blue indicates that the keywords are items in previous research, such as artificial intelligence, application, data, machine, program, and others. Recent keyword items are identified in bright yellow as keyword items that are newly used or researched and related to previous research keyword items, such as pandemic keyword items, technology, deep learning, big data, IoT, and others.

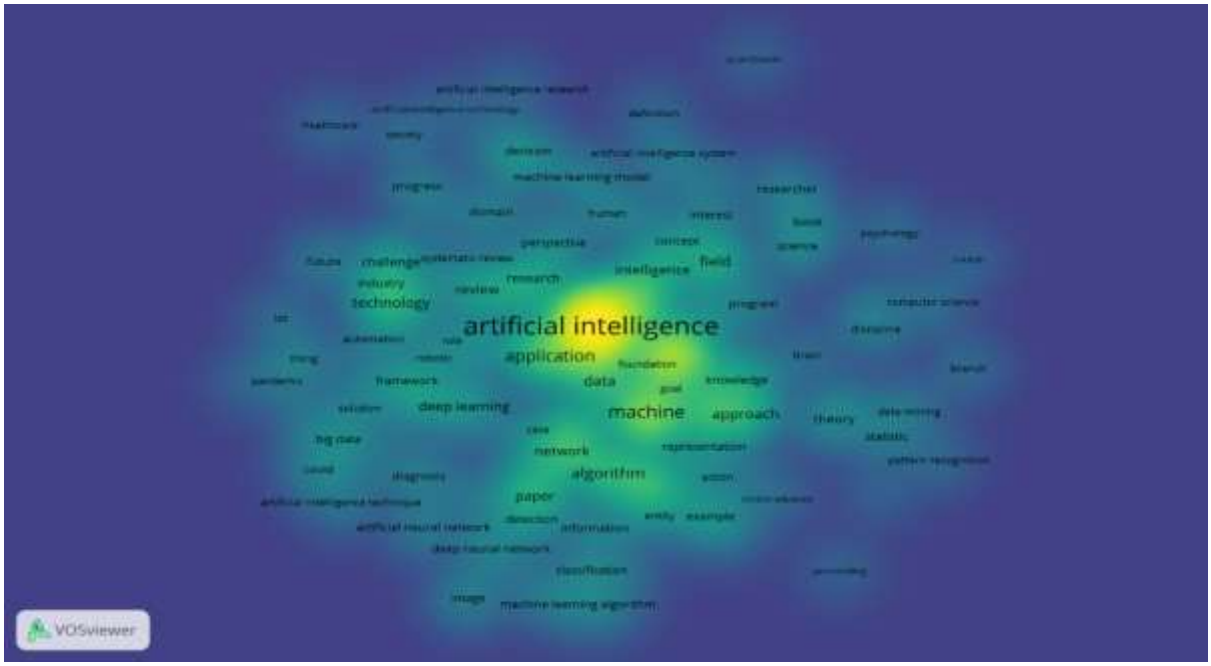


Figure 5. Density Visualization of Artificial Intelligence (AI)

Figure 5 shows the density of publication keyword items related to Artificial Intelligence. In the density visualization results, it can be seen that lighter colours are keyword items that are widely published and researched, such as artificial intelligence, application, machine, foundation, data, deep learning, network, robotic, review, research, goal, algorithm, knowledge, and others, keyword items with faint colours can be recommended for further research because there are still limited discussions related to these keyword items.

Table 3. Keyword Items with the Most Occurrences

Item	Occurrences	Relevance score
Artificial Intelligence	567	0.1228
Machine Learning	271	0.1131
System	127	0.0803
Application	123	0.1009
Data	88	0.1965
Problem	85	0.2203
Technology	71	0.588
Network	65	0.4036

Source: VOSviewer (2023)

Table 3 is the cluster analysis stage, and cluster analysis is the relationship between two or more keyword items in each cluster [21]. Mapping on VOSviewer analysis based on Occurrences, the eight most keyword items were selected so that the keyword items will be analyzed for the relationship of each item with keyword items from other clusters, following the mapping:

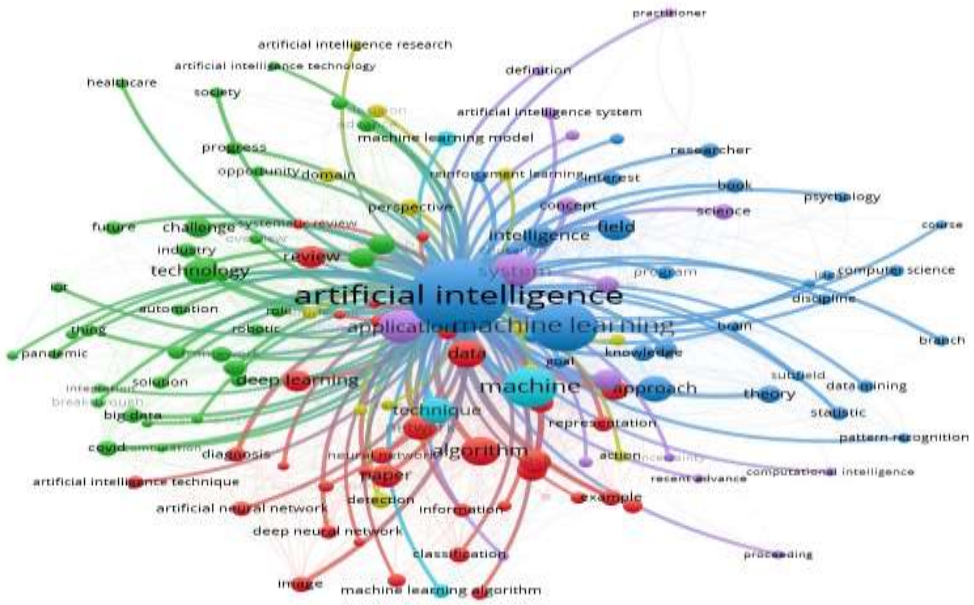


Figure 6. "Artificial Intelligence" Visualization Network

Figure 6 is a visualization network of items with the keyword "Artificial Intelligence" and dark blue clusters corresponding to five clusters. The first cluster keyword items are algorithm, deep neural, review, information, and others in red. The second cluster keyword items are machine, technique, learning, machine learning model, and others in light blue. The third cluster keyword items are detection, perspective, domain, and others in yellow. The fourth cluster keyword items are computational intelligence, recent advances, artificial intelligence system, concept, science, and others in purple. The fifth cluster keyword items are health care, society, progress, opportunity, solution, and others in green.

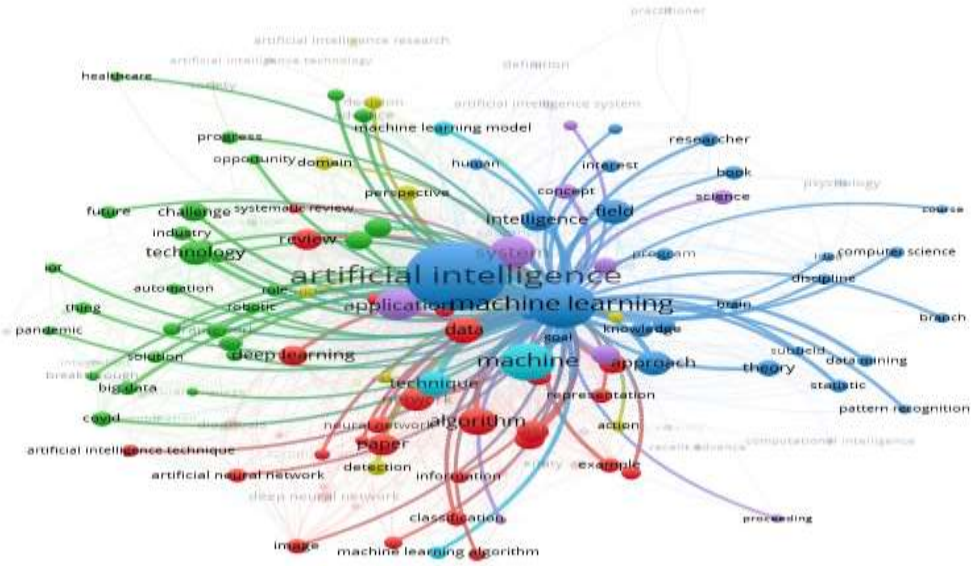


Figure 7. "Machine Learning" Visualization Network

Figure 7 is a visualization network of items with the keyword "Machine Learning" with dark blue clusters connected to five clusters. The first cluster keywords are algorithm, information, classification, paper, artificial neural network, and others in red. The second cluster keywords are detection, action, perspective, domain, and others in yellow. The third cluster keyword items such as machine learning, technique, human, machine learning model, and others are in Tosca blue. The

fourth cluster is keywords such as science, concept, system, application, and others in purple. The fifth keyword items are technology, industry, think, pandemic, big data, and others in green colour.

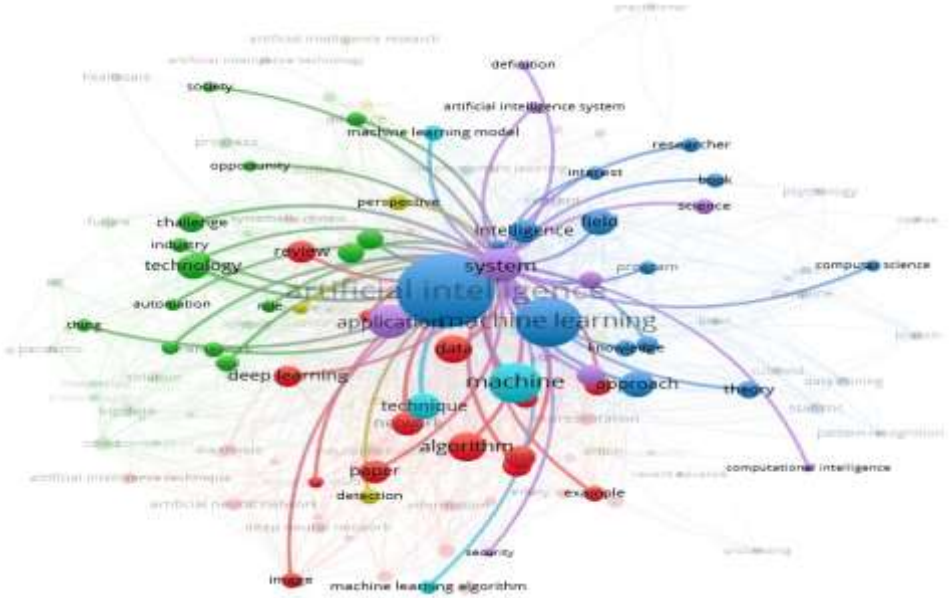


Figure 8. "System" Visualization Network

Figure 8 is a visualization network with the keyword item "System" with a purple cluster connected to five clusters. The first clusters keywords items such as paper, example, image, review, and others in red. The second cluster keyword items are detection, perspective, and others in yellow. The third cluster keyword items are machine learning algorithm, intelligence, problem, machine learning model, and others in Tosca blue. The fourth cluster of keyword items is theory, book, researcher, interest, knowledge, and others in dark blue. The fifth keyword items are role, automation, technology, and others in green.

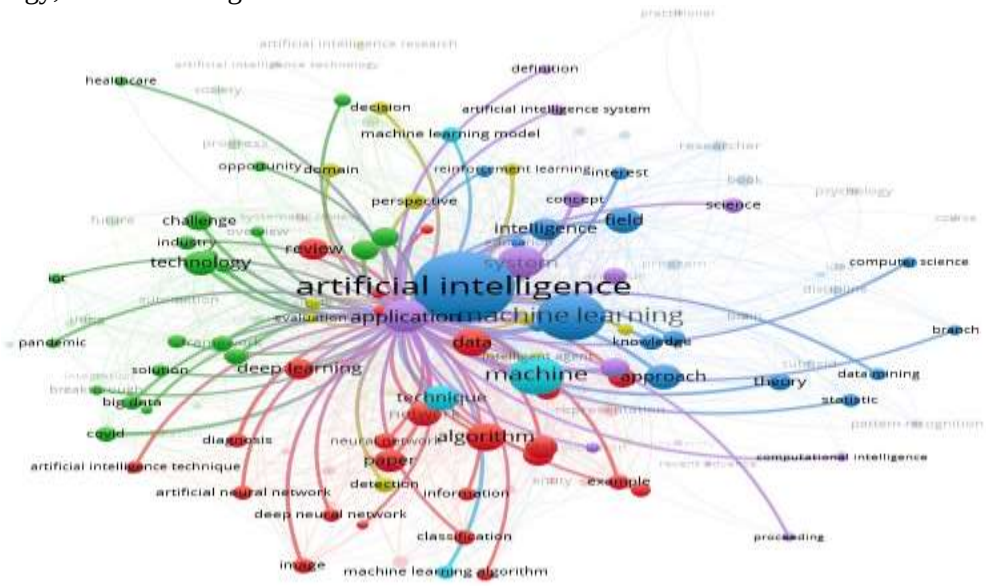


Figure 9. "Aplication" Visualization Network

Figure 9 is a visualization network with the keyword item "Aplication" with a purple cluster connected to five clusters. The first cluster keyword items are review, data, algorithm, paper, deep learning, and others in red. The second cluster keyword items are detection, domain, decision, and others in yellow. The third cluster keyword items are technique, machine, machine learning model,

and others in Tosca blue. The fourth cluster keyword items are theory, statistics, data mining, computer science, and others in blue. The fifth cluster keyword items are the solution, pandemic, opportunity, challenge, and others in green colour.

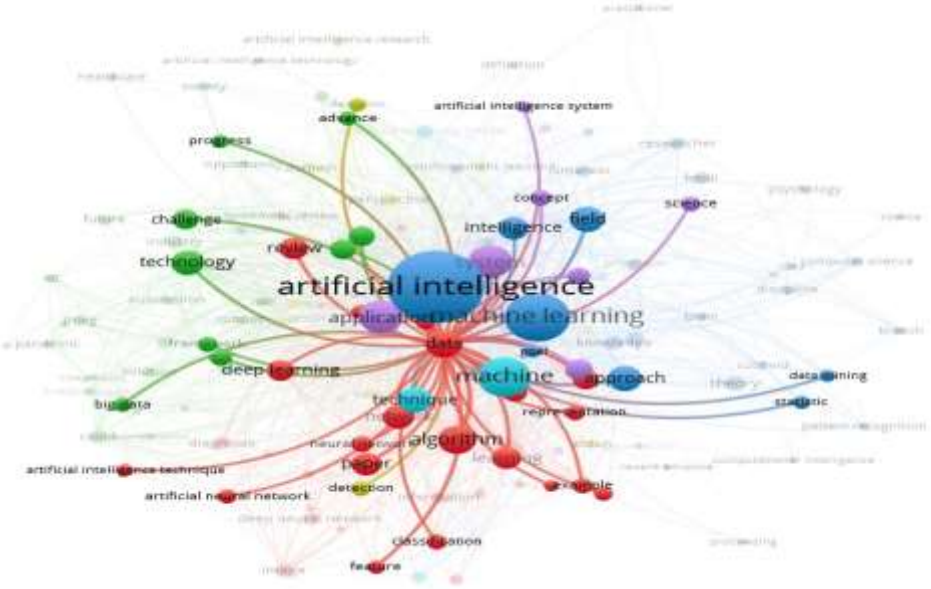


Figure 10. "Data" Visualization Network

Figure 10 is a visualization network with the keyword item "Data" with a red cluster connected to five clusters. The first cluster keyword item is detection, and the decision is in yellow. The second cluster keyword items are technique and machine in Tosca blue. The third cluster keyword items are statistics, data mining, filed, intelligence, and others in dark blue. The fourth cluster keyword items are artificial intelligence system, concept, application, and others in purple. The fifth cluster keyword items are progress, advance, bid data, and others in green.

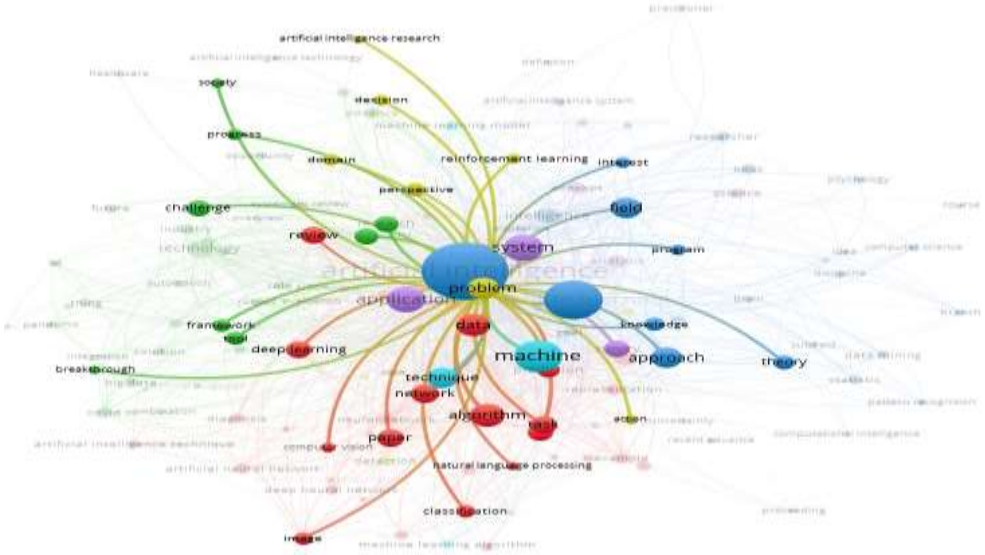


Figure 11: "Problem" Visualization Network

Figure 11 is a visualization network with the keyword "Problem" with a yellow cluster connected to five clusters. The first cluster keyword items are classification, natural language processing, network, deep learning, and others in red. The second cluster keyword items are system and application in Tosca blue. The second cluster keyword items are technique, machine, and interest in Tosca Blue. The third cluster keyword items are theory, field, program, knowledge, and approach

in blue. The fourth cluster keyword items are system, survey, and application in purple. The fifth cluster keyword items are framework, tool, research, progress, society, and others in green colour.

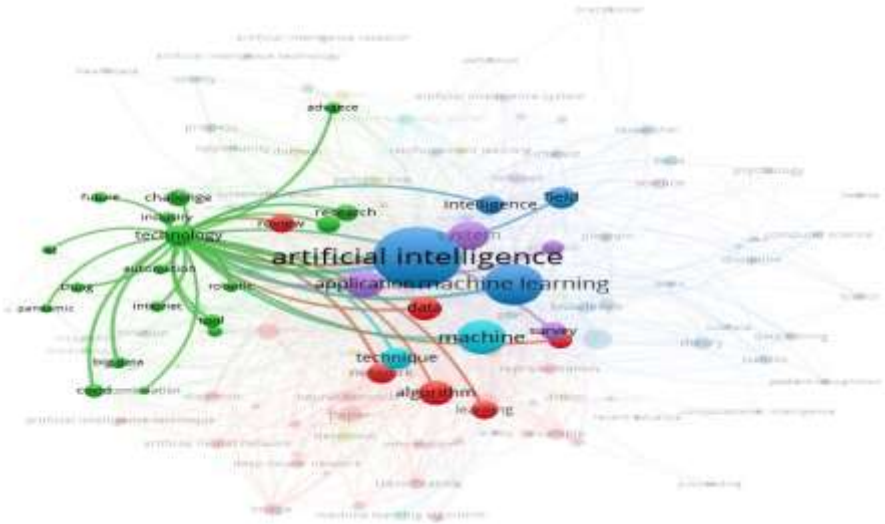


Figure 12. "Technology" Visualization Network

Figure 12 is a visualization network with the keyword "Technology" in the green cluster connected to four clusters. The first cluster keyword items are algorithm, network, learning, data, and review in red. The second cluster keyword items are machine and technique in Tosca blue. The third cluster keyword items are survey, application, system, and analysis in purple. The fourth cluster keywords are intelligence, artificial intelligence, machine learning, and filed in blue.

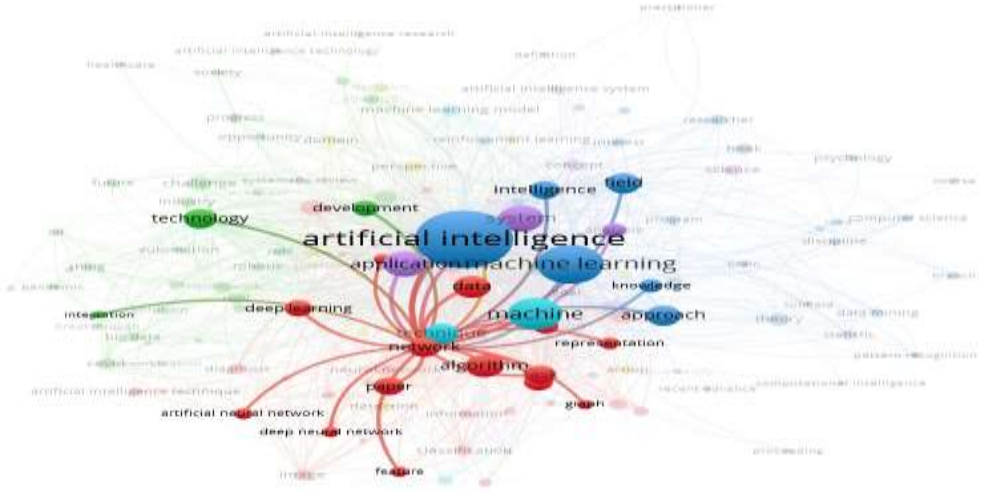


Figure 13: "Network" visualization network

Figure 13 is a visualization network with the keyword item "Network" with red clusters connected to four clusters. The first cluster keyword items are machine and technique in Tosca blue. The second cluster keyword items are integration, technology, and development in green. The third cluster keyword item is the application in purple. The fourth cluster keyword items are artificial intelligence, machine learning, field, intelligence, knowledge, and approach in blue.

4. CONCLUSION

The research aims to trace the database of Artificial Intelligence (AI) research developments indexed on Google Scholar with an observation period of thirteen years, namely from 2010 to 2022, with descriptive analysis techniques and bibliometric analysis. Bibliometric mapping in this study

uses the VOSviewer application and the visualization information needed. The sample article data needed in this study was searched using the Publish or Perish application with the keyword "Artificial Intelligence." The results of the data search show that there are 999 research articles obtained in the Google Scholar database. Research related to Artificial Intelligence during the observation period fluctuated from 2010 to 2018, experiencing a positive trend yearly. However, from 2019 to 2022, research publications on Artificial Intelligence have decreased significantly. From the results of network visualization, the keyword "Artificial Intelligence" is the most widely used. Then, the results of the overlay visualization with dark green color show older previous research, such as application, Machines, Artificial Intelligence, and others, then the latest research with light yellow color such as Pandemic, Deep Learning, Technology, and others. Density visualization results with the keyword "Artificial Intelligence" being a keyword that often appears and is involved in the research period. The mapping results on the most citations are researched from RS Sutton, AG Barto in 2018 with the title "Reinforcement learning: An introduction" with a total of 63,460 citations. The keyword "Artificial Intelligence" is also the most Occurrences of 567 occurrences. The results of bibliometric mapping obtained 6 clusters with 141 interconnected items.

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