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Artificial intelligence in malnutrition research: a bibliometric analysis

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ABSTRACT

Malnutrition is a nutritional imbalance in a child's body. Currently, there have been many reviews done on malnutrition in children. However, reviews on artificial intelligence linked with malnutrition are yet to be done. Thus, this study aims to identify the implementation of artificial intelligence in predicting malnutrition using bibliometric analysis. The bibliometric analysis consists of four stages: determining the purpose and scope, selecting the analytical technique, collecting data, and presenting the findings. Data used for this analysis is sourced from the Scopus database. The investigation was conducted using VOSviewer and "Publish or Perish" software. Based on five searched words: malnutrition, artificial intelligence, machine learning, neural networks, and deep learning, it was found that machine learning is the most widely used artificial intelligence approach for malnutrition research. Deep learning techniques are reported to grow as it is introduced as a new method in artificial intelligence. Malnutrition prediction tasks are the most studied problem. The use of deep learning, reinforcement learning, and transfer learning methods are used tremendously in malnutrition prediction research. This analysis's results help improve the quality of the review by showing the mapping areas for malnutrition research.

1. Introduction

Malnutrition refers to deficiency or excess intake of nutrients, imbalance of essential nutrients, or impaired utilization of nutrients [1]. Malnutrition manifests in wasting disease, stunting, underweight, and micronutrient deficiencies. Artificial intelligence (AI) can be interpreted as intelligence integrated into a system that can be arranged in the context of the intelligence of scientific entities [2]. Based on the taxonomy, AI is implemented into several techniques: machine learning (ML), neural networks (NN), and deep learning (DL). The ML algorithms enable software applications to predict outcomes accurately without being explicitly programmed. The ML algorithm is based on the idea that machines should be able to learn and adapt through experience, whereas AI refers to broader ideas and machines can perform tasks "smartly." Based on the method, this ML algorithm is implemented using reinforcement learning, unsupervised learning, and supervised learning [3]. An ML algorithm examined in a research domain can be discussed in another field, and this method is called transfer learning [4], [5].

Furthermore, the NN works by imitating how the nerves of the human brain work. With this mechanism, NN allows computer programs to recognize patterns and solve problems. Meanwhile,

The DL is an algorithm inspired by the structure of the human brain. These structures are called artificial neural networks or abbreviated as ANN. The DL can learn and adapt to large amounts of data and solve complex problems with other ML algorithms.

Bibliometric analysis is a method for examining, analyzing, and summarizing the relationships between studies on specific topics that are widespread and increasing in number for better and more accurate understanding [6]. This article aims to investigate the bibliometric analysis of the scientific literature on using AI to study malnutrition. The analysis is conducted to reveal the topic areas that are the subject of most publications and identify research opportunities for these topics. The main contribution of this article is to identify performance analysis and science mapping so that research trends are known regarding the use of AI in malnutrition research.

The remainder of this research is structured by defining the research methods carried out in Section 2, presenting the results of the bibliometric analysis in Section 3, and discussing the results of the bibliometric analysis in Section 4. This research is concluded with the results of the bibliometric analysis in Section 5.

2. Method

This research is a bibliometric analysis based on data from the Scopus database accessed on November 10, 2022. Vosviewer and "Publish or Perish" software were used for the bibliometric analysis. It is because the software provides visualization of bibliometric maps and metric calculations. Examination, analysis, summarization of literature linkages, and identification of relationships between studies are made possible by using these two software.

The stages in this study were conducted by following the guidelines proposed by Donthu et al. [6], which consisted of four steps:

- Determining the purpose and scope of the bibliometric analysis
- Selecting the bibliometric analysis technique
- Collecting data for the bibliometric analysis
- Conducting the bibliometric analysis and presenting the findings

This bibliometric analysis aims to investigate the relationship between the application of an AI approach to the topic of malnutrition research. The scope of bibliometric analysis is implemented by compiling keyword strings for search queries that retrieve studies based on the Scopus database. Based on a widely known theoretical framework, ten search queries were determined for bibliometric analysis, as shown in Table 1.

Table.1 Query String

#	Search Strings
QS1	TITLE-ABS-KEY("malnutrition")
QS2	(TITLE-ABS-KEY("malnutrition") AND TITLE-ABS-KEY("artificial intelligence"))
QS3	(TITLE-ABS-KEY("malnutrition") AND TITLE-ABS-KEY("machine learning"))
QS4	(TITLE-ABS-KEY("malnutrition") AND TITLE-ABS-KEY("reinforcement learning"))
QS5	(TITLE-ABS-KEY("malnutrition") AND TITLE-ABS-KEY("unsupervised learning"))
QS6	(TITLE-ABS-KEY("malnutrition") AND TITLE-ABS-KEY("supervised learning"))
QS7	(TITLE-ABS-KEY("malnutrition") AND TITLE-ABS-KEY("transfer learning"))
QS8	(TITLE-ABS-KEY("malnutrition") AND TITLE-ABS-KEY("neural network*"))
QS9	(TITLE-ABS-KEY("malnutrition") AND TITLE-ABS-KEY("deep learning"))
QS10	(TITLE-ABS-KEY("malnutrition") AND TITLE-ABS-KEY("artificial intelligence" OR "machine learning" OR "reinforcement learning" OR "unsupervised learning" OR "supervised learning" OR "transfer learning" OR "neural network*" OR "deep learning"))

The results of this search query are stored in CSV and RIS formats. CSV files are used for performance analysis and science mapping using VOSviewer software, while RIS files are used to

calculate citation metrics using "Publish or Perish" software. According to Naveen Donthu et al. [6], there are two bibliometric analysis techniques: main and enrichment. The main technique is divided into performance analysis and science mapping. This study is limited to only using main techniques for bibliometric analysis.

3. Results and Discussion

This section presents the results from two analyses: performance analysis and science mapping. Performance analysis identifies the contribution of a significant part of the research to the field under study, while science mapping identifies the relationships between essential elements of the investigation.

3.1. Performance Analysis

Performance analysis is conducted by investigating publication-related metrics and citation-related metrics.

- The search query resulted in 98,809 documents for the keyword 'malnutrition'. From the number, it is proven that this topic is widely intriguing to researchers. This research investigates the implementation of an AI approach to malnutrition research using search queries (QS2 to QS10). The result of this search indicates that no studies link unsupervised learning methods to malnutrition research. The result also shows that the data used for malnutrition research is data that has been labeled or classified. While the reinforcement learning method is relatively new, the trends are growing. The working mechanism of reinforcement learning differs from supervised learning, which has been labeled as a fixed value for the studied data. The reinforcement learning method was developed to receive orders based on the conditions encountered. Machines can learn from past data to avoid mistakes. The mechanism of learning is simple. The machine is rewarded for correct learning and vice versa. Fig. 1 shows the number of publications per query string.

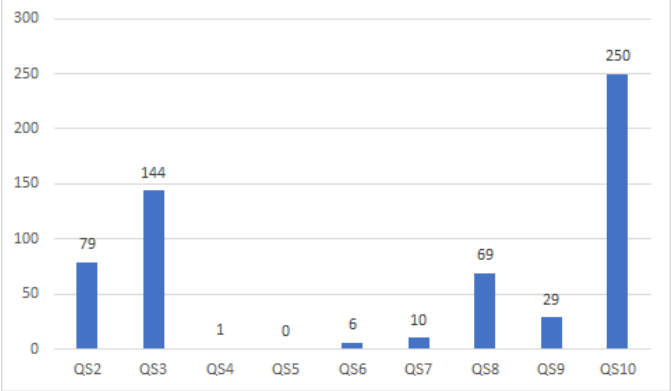

Fig. 1. Number of publications per query string

The combination of the term AI, ML, NN, and DL in malnutrition research has a more dominant number of publications, with ML [7]–[11] being the most popular method widely combined. DL [12]–[14] is the least combined method. The number of publications is extracted based on time series data per year to find out from research trends.

Based on Fig. 2, it can be seen that in 2023, there is only 1 study that combines malnutrition with ML (QS3). By ignoring the number in 2023, the graph shows that the development trend of malnutrition research using ML algorithms has an exponential trend, and it decreases in 2023. An exciting trend is shown in the study with NN and DL. The DL is a sub-field of ML where the difference is in the feature selection and classification tasks. In ML, the feature selection task is conducted separately from classification. It cannot even be shown if it does not require selection. The feature selection task is achieved using a separate algorithm, and the classification task is also accomplished using various available algorithm options. DL performs these two tasks simultaneously by algorithm-based. In DL, several algorithms originated from NN. These algorithms are Convolutional Neural Network (CNN) [15], [16], Recurrent Neural Networks (RNN) [17], Long Short-Term Memory (LTSM) Networks, and Self Organizing Maps (SOM). Fig. 2 also shows the trend between two

learning types which are NN and DL, shown by line QS8+QS9. This line portrayed an upward movement. Meaning that implementing NN and DL is future work in malnutrition research.

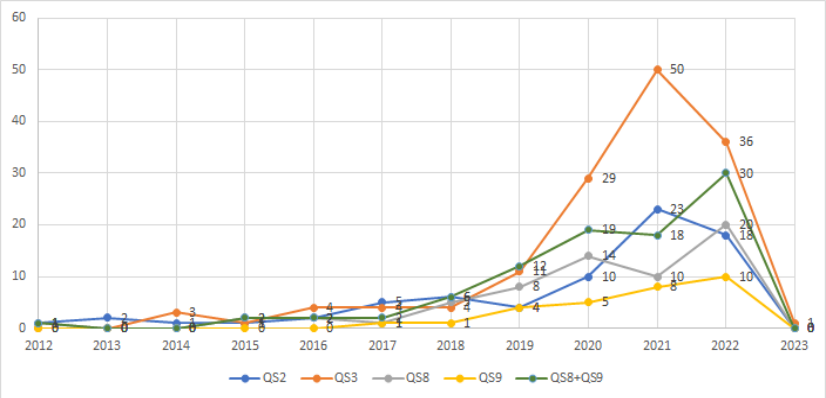

Fig. 2. Number of publications per query string

The third publication-related metrics data extraction is identification by document type, as shown in Fig. 3. There are eight types of documents found in this study. Articles, conference papers, and reviews are the most common type of publications discussing AI in malnutrition.

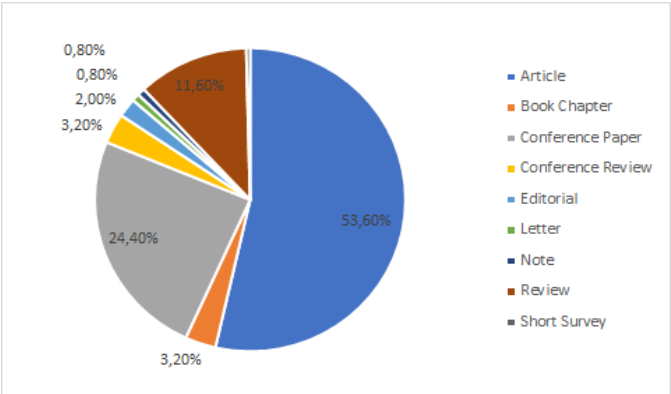

Fig. 3. Publication according to document type

- Citation-related Metrics

The citation data collected from publications used in this analysis are shown in Table 2, where two papers significantly have a high citation impact of 731. One of the papers has 721 citations using ML to determine the healthy gut microbiota postnatally in the first two years [18]. Additionally, throughout 2020-2022, there were six papers found to have a citation impact of above 20 that are [7], [19]–[23]. For [19], [20], ML was introduced to identify various forms of malnutrition with the Global Leadership Initiative on Malnutrition (GLIM) criteria. Other than that, a study conducted by [21] used ML algorithms to determine the relationship between transmission and death during COVID-19, which found that malnutrition was the prevalence associated with COVID-19 mortality.

The study [22] states that climate change has an impact on reducing crop production and potentially affects global malnutrition. Hence, predictions with ML algorithms offer a solution to match food needs with climate change. The study [7] identified malnutrition by analyzing body weight and body mass index (BMI) based on facial images using the CNNs method. Several studies also studied the prediction of malnutrition in children under the age of five by comparing several ML algorithms: linear discriminant analysis (LDA) [24], k-nearest neighbors (k-NN) [25], support vector machines (SVM) [23], random forest (RF) [26], and logistic regression (LR) [27]. From the studies, it can be concluded that the RF outperforms other algorithms [23] in predicting malnutrition.

Table 2 and Table 3 show the citation data extraction based on the highest number of citations and the published papers in Nature and PLoS ONE, respectively. These two journals are Quartile 1 journals which are based on SCImago Journal Rank (SJR) and Journal Impact Factor (JIF) from Clarivate. Both tables show complete citation data.

Table.2 Citation From Publication

Journals	Citation	Papers	SJR 2021	2021 JIF
Nature (1476-4687)	731	2	Q1 17.9	Q1 69.504
Journal of Physiology (1469-7793)	171	1	Q1 1.51	Q1 6.228
Reproduction (1741-7899)	88	1	Q1 0.94	Q1 3.923
Clinical Infectious Diseases (1537-6591)	84	2	Q1 4.39	Q1 20.999
International Journal of Medical Informatics (1386-5056)	81	3	Q1 1.14	Q1 4.73
Clinical Nutrition (0261-5614)	70	5	Q1 1.15	Q1 7.643
Journal of Parenteral and Enteral Nutrition (1941-2444)	54	2	Q2 0.82	Q3 3.896
Journal of Neuroendocrinology (1365-2826)	50	1	Q2 0.97	Q2 3.870
Science of the Total Environment (0048-9697)	45	1	Q1 1.81	Q1 10.753
PLoS ONE (1932-6203)	43	7	Q1 0.75	Q1 3.752
Nutrition (0899-9007)	41	3	Q1 0.89	Q2 4.893
Procedia Computer Science (1877-0509)	34	2	0.57	-
Nutrients (2072-6643)	31	5	Q1 1.29	Q1 6.703
Genes (2073-4425)	30	1	Q2 1.03	Q2 4.141
Computers and Electronics in Agriculture (0168-1699)	28	1	Q1 1.6	Q1 6.757
IET Image Processing (1751-9659)	28	1	Q2 0.54	Q3 1.773
Journal of Clinical Nursing (1365-2702)	24	1	Q1 0.83	Q1 4.423
JMIR Medical Informatics (2291-9694)	23	2	Q2 0.81	Q3 3.228
AAAI Spring Symposium - Technical Report (-)	23	1	-	-
Journal of Clinical Medicine (2077-0383)	21	1	Q1 1.04	Q2 4.964

Table.3 Number of Publications Per Journal

Journals	Citation	Papers	SJR 2021	2021 JIF
PLoS ONE (1932-6203)	7	43	Q1 0.75	Q1 3.752
Communications in Computer and Information Science (-)	6	7	-	-
ACM International Conference Proceeding Series (-)	6	16	-	-
Lecture Notes in Networks and Systems (-)	5	1	-	-
Lecture Notes in Electrical Engineering (-)	5	0	-	-
Advances in Intelligent Systems and Computing (-)	5	6	-	-
Nutrients (2072-6643)	5	31	Q1 1.29	Q1 6.703
Clinical Nutrition (0261-5614)	5	70	Q1 1.15	Q1 7.643
International Journal of Environmental Research and Public Health (1660-4601)	5	20	Q1 0.81	Q2 4.614
Scientific Reports (2045-2322)	3	3	Q1 1.01	Q2 4.997
Nutrition (0899-9007)	3	41	Q1 0.89	Q2 4.893
World Journal of Gastroenterology (1007-9327)	3	17	Q1 1.23	Q2 5.374
International Journal of Medical Informatics (1386-5056)	3	81	Q1 1.14	Q1 4.73

The analysis used the “Publish or Perish” software to extract citation metric information consisting of several metrics, as shown in Table 4. The study was conducted by comparing five search query data to determine the research progress. This data indicates that the research trend with DL in QS9 began in 2017 with citation impact that is close to AI (QS2) and NN (QS8), which this term was introduced earlier (1988 and 1990). Based on these metrics, it can be seen that research with an ML algorithm is more dominant and provides a greater impact with a more significant number of papers. However, the DL is the future of malnutrition research as it is more recent and closely impacts its predecessor methods.

Table.4 Citation Metric

Citation Metric	QS2	QS3	QS8	QS9	QS10
Publication years	1988-2022	2010-2023	1990-2022	2017-2022	1988-2023
Citation years	34 (1988-2022)	12 (2010-2022)	32 (1990-2022)	5 (2017-2022)	34 (1988-2023)
Papers	79	144	69	29	250
Citations	583	1673	590	85	2517
Cites/year	17.15	139.42	18.44	17.0	74.03
Cites/paper	7.38	11.62	8.55	2.93	10.07
Authors/paper	5.34	5.61	4.57	4.59	5.21
h-index	13	17	11	5	20
g-index	20	38	23	8	44
hI,norm	6	8	6	3	10
hI,annual	0.18	0.67	0.19	0.60	0.29
hA-index	8	12	6	4	12
Papers with ACC >= 1,2,5,10,20	50, 38, 18, 3, 0	88, 71, 37, 14, 6	32, 25, 9, 3, 1	13, 12, 2, 0, 0	142, 108, 50, 17, 6

3.2. Science Mapping

Science mapping is conducted by analyzing the co-word analysis and co-authorship analysis. The software "VOSviewer" is used to investigate the relationship between words and authors [28].

- Co-word analysis was conducted using the Vosviewer software by determining the minimum number of occurrences of a keyword being analyzed by 3. The results obtained are 459 keywords meet the threshold of 3351 keywords. These selected keywords are then grouped into 7 clusters marked with different colors. The word malnutrition is the word with the most occurrences, so the nodes for malnutrition appear more significant than the others. In addition to the word malnutrition, several other words can be seen, such as human, humans, machine learning, artificial intelligence, and Nutrition, as shown in Fig. 4.

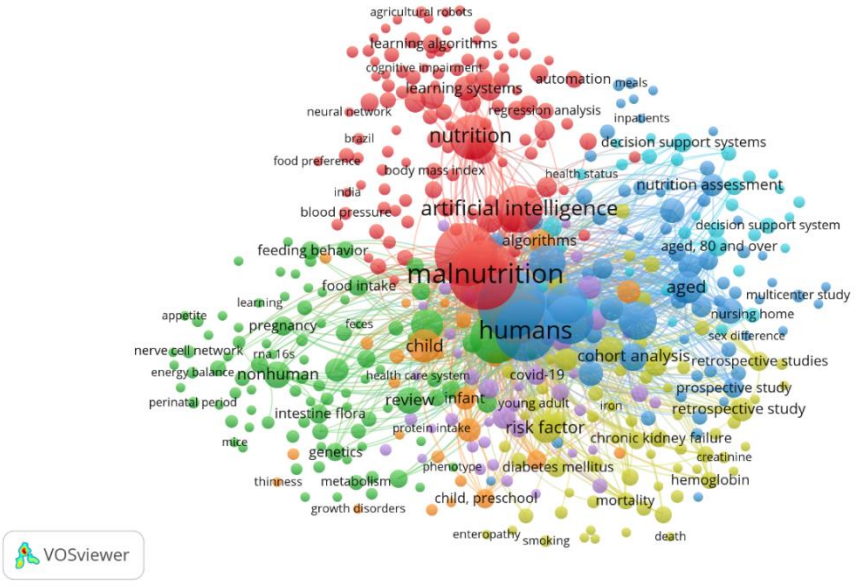

Fig. 4. Network Visualization

Fig. 5 shows that some terms related to algorithms in AI are k-NN, CNN, RF, LR, and SVM. These algorithms perform decision-making, decision support system, and predictive analysis. Apart from these tasks, these algorithms are also used in image processing, image analysis, and signal processing.

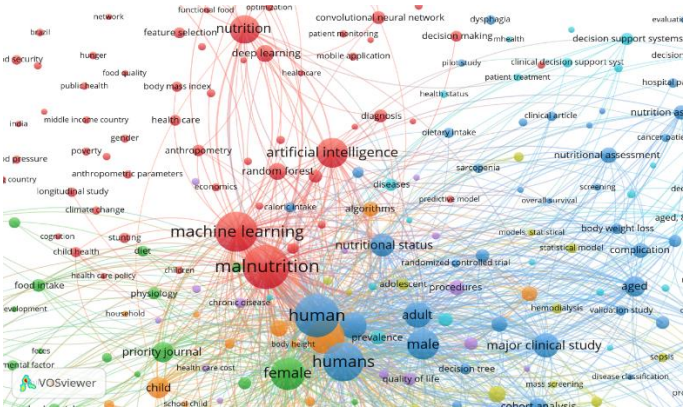

Fig. 5. Detailed Network Visualization

VOSviewer presents three types of visualization: network visualization (Fig. 4), overlay visualization, and density visualization (Fig. 6). Density visualization is a visualization of the depth of research related to the topic being studied. More highlighted colors mean more researchers are studying the word. These colors accentuate the words' highlights in the network visualization.

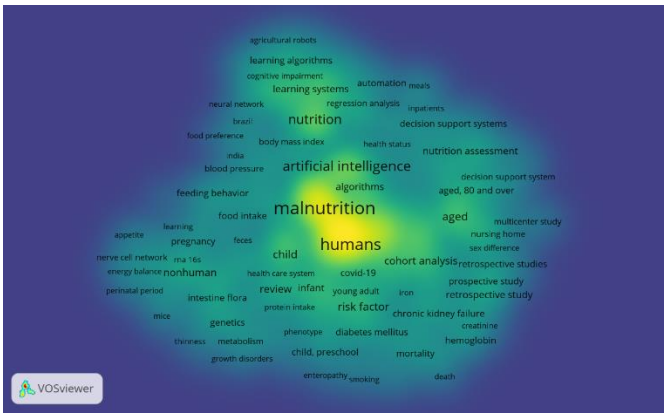

Fig. 6. Density visualization

- Author affiliations were conducted to determine the relationship between researchers and countries and which countries have impacted research on AI and malnutrition. VOSviewer software is used for this investigation with parameter setting with a minimum of 1 document for an author. From the analysis, 80 countries were found to be involved in this research. Table 5 presents the top 10 countries based on the studied paper that contribute to 12.5% of the entire countries based on total link strength. It was found that The United States published the most papers based on the number of documents, followed by India, China, the United Kingdom, and Brazil. From the number of citations, the highest country cited is the United States, followed by Bangladesh, Australia, the United Kingdom, and Sweden.

Table.5 Citation From Publication

Country	Document	Citation	Total link strength
United States	59	1339	85
United Kingdom	23	323	51
Canada	14	192	36
China	25	185	33
Germany	11	168	32
Brazil	15	156	31
Sweden	9	226	25
Italy	12	166	24
Netherlands	11	148	24
India	42	185	22

The country analysis based on total link strength is visualized in Fig. 7. There are several outlier countries in this visualization where this country still needs to join the large network community, with the top country being the United States. These outlier countries are Indonesia, Turkey, the Philippines, the Czech Republic, Japan, Thailand, Sri Lanka, Romania, and Lithuania. On the other hand, Fig. 8 shows a more detailed country analysis for a group of interrelated countries. The United States is the center of relations that is connected with other significant nodes: the United Kingdom, India, China, Brazil, and others. Several small nodes are also connected to this large node, including Somalia, Kenya, Ghana, Malawi, Iran, Zambia, Peru, Nigeria, Faro Islands, Cuba, and others. This result shows that research focusing on AI in malnutrition collaborates between countries.

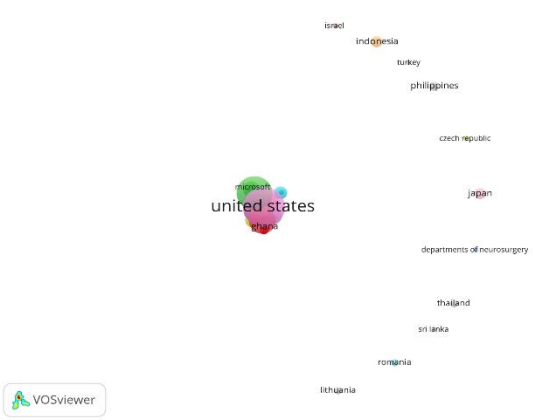

Fig. 7. Country analysis

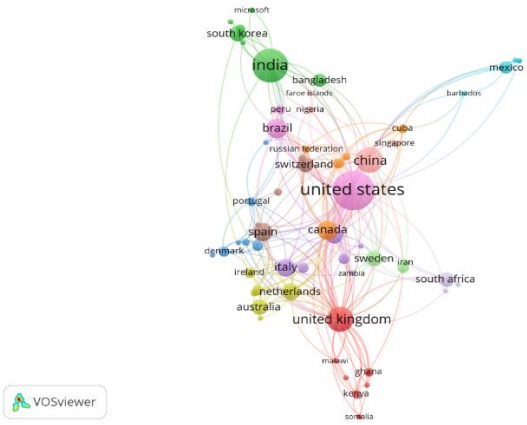

Fig. 8. Detailed country analysis

This section discusses the keywords of this research which are malnutrition, AI, ML, and DL. As the main focus of this research is from a public health perspective, the word malnutrition is connected with more words than other investigated words, as seen in Fig. 9. Some of the words that can be highlighted in Fig. 9 are malnutrition, related to mortality [29], children or preschool [30], as well as the cause factor of feeding behavior [31] and food intake [32]. Thus, it can be concluded that nutrition assessment is very much needed. Thus, solutions from AI are related to learning systems and decision support systems.

Co-word analysis with AI is this study's focus, shown in Fig. 10. This co-word analysis shows that apart from being related to the words that appear in the word Nutrition, this AI is related to hospitals [33] and functions as a diagnostic tool. The network formed in Fig. 10 is no more significant than the network formed for ML algorithms, as shown in Fig. 11. The new words that appear and can be highlighted in Fig. 11 are classification and body mass index. The ML algorithms have been used to predict malnutrition based on body mass index.

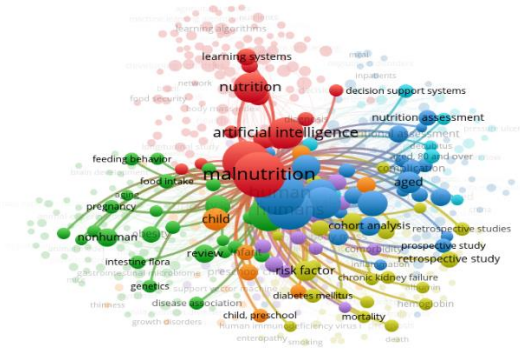

Fig. 9. Co-word analysis for malnutrition words

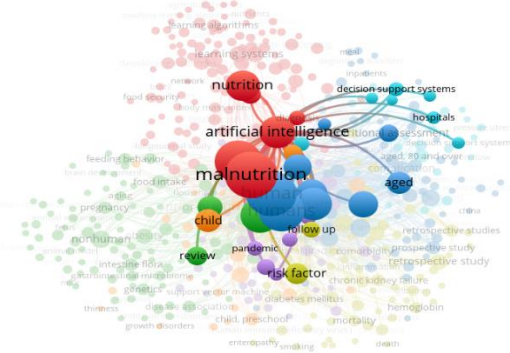

Fig. 10. Co-word analysis for artificial intelligence words

The last co-word analysis is analysis for DL. The network related to this DL is smaller than other networks, as shown in Fig. 12. The new word that appears in this DL network is a convolutional neural network (CNN). CNN is a DL algorithm based on a neural network commonly used in image data.

The prediction task can also use CNN which for this study, is malnutrition data. In general, the relationship between the word AI in malnutrition research proposes predictions with algorithms from ML, NN, and DL to determine malnutrition in children based on the variables examined.

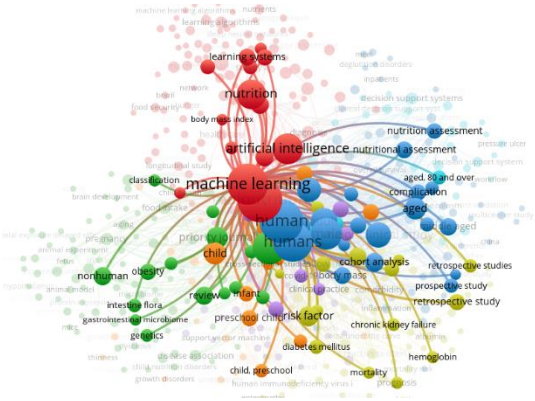

Fig. 11. Co-word analysis for malnutrition words

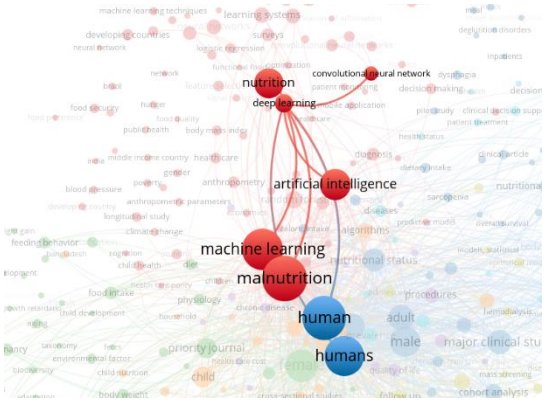

Fig. 12. Co-word analysis for artificial intelligence words

4. Conclusion

The rapid development of research on malnutrition using AI can be seen in the growing number of papers yearly. Based on the Scopus database, this study uses bibliometric analysis for using AI in malnutrition research. Several aspects were reviewed on 250 documents, such as performance analysis and Science mapping using Vosviewer and "Publish or Perish" software. It was found that ML algorithms dominate this research compared to NN and DL. The use of the ML algorithm is related to the task of predicting malnutrition based on body mass index. Nevertheless, in recent years, it has become apparent that DL algorithms are the future for malnutrition research, along with the increasing number of research that utilized DL to improve the research topic being studied. In addition, reinforcement learning and transfer learning are potential methods for further malnutrition research. The weakness of this research is that the data used is still sourced from only one database. Therefore, several data sources, such as the Web of Science, SpringerLink, and IEEE, should be used for future research.

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