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A Quantitative Review on Deep Learning and Smart Factory from 2010 to 2023

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Abstract

The convergence of deep learning and smart factory is drawing a lot of attentions from not only industrial but also academic circles. The objective of this article is to quantitatively review on deep learning and smart factory from 2010 to 2023. This research analyzed the 138 articles, extracted from the Core Collection of Web of Science, in terms of four dimensions such as the main trend in article publications, the main trend in article citations, the distribution of article publications by research area, and the keywords representing the main contents of published articles. The quantitative review results reveal the following four points: First, the article publications drastically grew from 2019 to 2022 in its annual trend. Second, the article citations have rapidly grown since 2018. Third, Engineering, Computer Science, and Telecommunications are the top 3 research areas composing the 138 articles. Fourth, it is the top 10 keywords such as 'deep', 'learning', 'smart', 'detection', factory', 'data', 'system', 'manufacturing', 'neural', and 'network' that represent the main contents of the 138 articles published from 2010 to 2023 in deep learning and smart factory. These findings revealed by this quantitative review will be significantly useful for deepening and widening relevant future research on deep learning and smart factory.

Keywords: Deep Learning; Smart Factory; Artificial Neural Network; Quantitative Review; Artificial Intelligence; AI

1. Introduction

The goal of this research is to quantitatively review the main features in the research trend in the convergence of deep learning and smart factory. With the increasing importance of artificial intelligence [1, 2] and smart factory [3, 4], the convergence of deep learning and smart factor is drawing a lot of attentions from not only industrial but also academic circles. Deep learning is a branch of artificial intelligence [5] and the applications of it are becoming more and more important in various domains including production operations management [6, 7]. The importance of smart factory is also becoming more and more important because they can significantly increase the productivities of production systems [8]. Therefore, the quantitative review on the main features in the research trend in the convergence of deep learning and smart factory will be significantly useful for deepening and widening relevant future research.

This article attempted to quantitatively answer the following research questions (RQs) related to the convergence of deep learning and smart factory from 2010 to 2023:

    (1) RQ 1: What is the main trend in article publications?

    (2) RQ 2: What is the main trend in article citations?

    (3) RQ 3: How are article publications distributed by research areas?

    (4) RQ 4: What are the keywords which represent the main contents of published articles?

2. Research Methods

This article analyzed the 138 data from the Core Collection of Web of Science. It is a well-known database which is globally used for quantitative reviews in specific areas [9, 10]. They have resulted from the advanced search query using the combinations of the relevant key phrases such as 'deep learning' and 'smart factory' including 'smart factories'. The timespan for the advanced search query was from 2010 to 2023.

This study analyzed the 138 data in the four dimensions to answer the abovementioned four RQs relate to the trend in article publications, the trend in article citations, the distributions of article publications by research area, and keywords in the published articles. Especially, the bibliometrix (biblioshiny) [11] which is a package of R program [12] were used to perform the keywords-related analyses such as the word cloud analysis and the annual cumulative occurrence analysis of the top 10 keywords in the titles of 138 article published in deep learning and smart factory from 2010 to 2023.

3. Results

3.1. The Main Trend in Article Publications

Four features have been found out to be salient in article publications as follow: First, the article publications started in 2017 and the number of article publications amounted to 3 in 2017. Second, they show the up and down trend from 2017 to 2019. The number of article publications in 2018 were 7 but it decreased to 6 in 2019. Third, there are a drastic growth in the trend after 2019 through 2022. The number of article publications in 2020 was 18, and it drastically increased to 35 and 43, respectively in 2021 and 2022. Fourth, after 2022, they were revealed to decrease. The number of article publications amounted to 26 in 2023. Figure 1 shows the annual trend in article publications in deep learning and smart factory from 2010 to 2023.
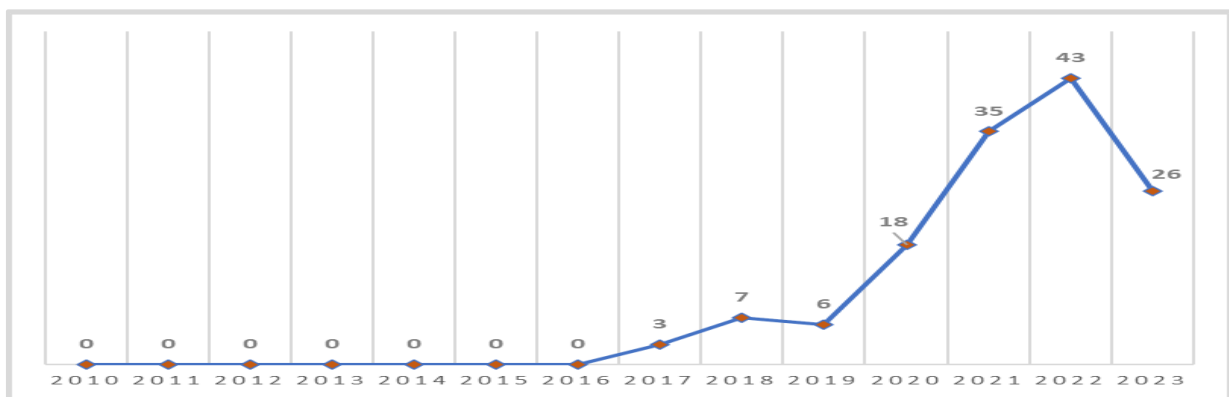

Figure 1. Annual trend in the article publications in deep learning and smart factory

3.2. The Main Trend in Article Citations

The article citations began in 2018, and have grown rapidly to 2023. The number of citations amounted to 12 in 2018 but it increased to 34 in 2019. The number of citations amounted to 132 and 474, respectively, in 2020 and 2021. It increased to 712 and 918, respectively, in 2022 and 2023. Figure 2 visualizes the annual trend in article citations in deep learning and smart factory from 2010 to 2023.
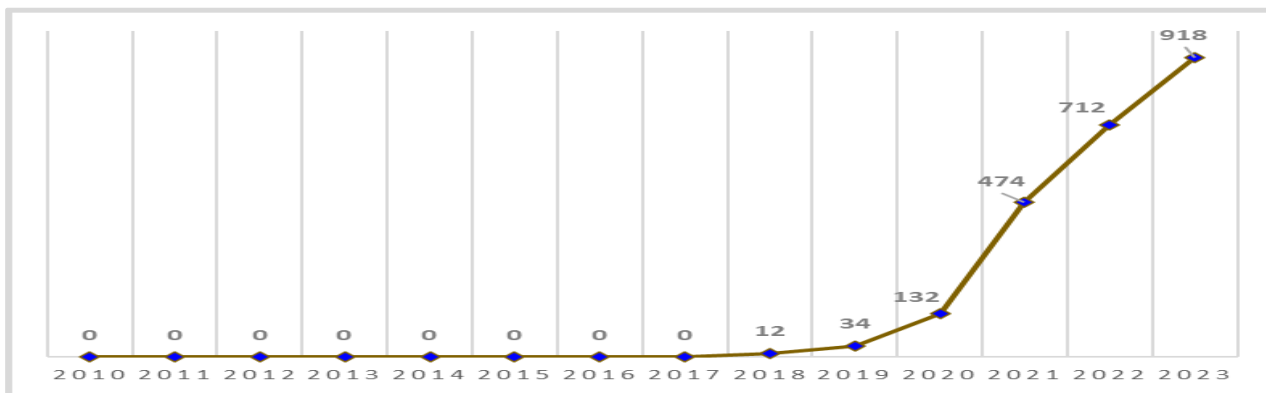

Figure 2. Annual trend in the article citations in deep learning and smart factory

3.3. Distribution of Article Publications by Research Area

Engineering was ranked as the top 1 research area with 87 article publications (63.0%), Computer Science as the top 2 research area with 72 article publications (52.2%), and Telecommunications as the top 3 research area with 29 article publications (21.0%). Chemistry was ranked as the top 4 research area with 25 article publications (18.1%), Physics as the top 5 research area with 20 article publications (14.5%), both Instruments Instrumentation and Material Science as the top 6 research area with 17 article publications (12.3%), Automation Control Systems as the top 8 research area with 15 article publications (10.9%), Science Technology Other Topics as the top 9 research area with 7 article publications (5.1%), and both Environmental Sciences Ecology and Robotics as the top 10 research area with 4 article publications (2.9%). Figure 3 shows the distribution of article publications by research area in deep learning and smart factory from 2010 to 2023.
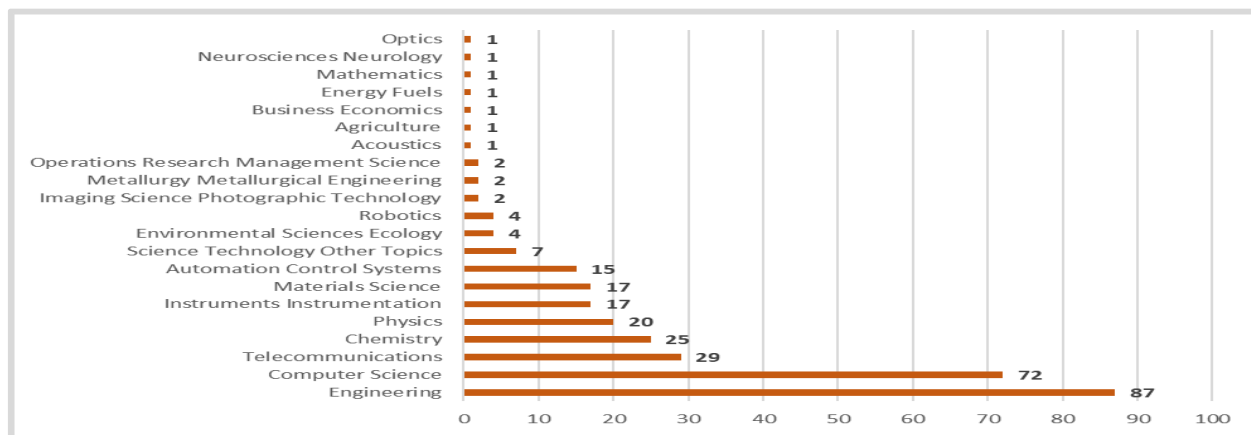

Figure 3. Distribution of article publications by research area

3.4. Keywords in the published articles

The keywords such as 'deep' and 'learning' were ranked the top 1 and 2, respectively, with the frequency of 57 and 51. 'Smart', 'detection', factory' were ranked as the top 3, 4 and 5, respectively, with the frequency of 45, 34, and 22. 'Data' and 'system' were ranked as the top 6 and 7, respectively, with the frequency of 16 and 15. 'Manufacturing' and 'neural' were ranked as the 8 with the same frequency of 14. 'Network' was ranked as the top 10 with the frequency of 13. Figure 4 provides the world cloud of the 138 articles.

Figure 4. Word cloud of the articles published in deep learning and smart factory

Figure 5 shows the cumulative occurrence of the top 10 keywords in the titles of the 138 published articles in deep learning and smart factory. In 2017, 'smart' and 'factory' were the most frequently occurring words with the same number of cumulative occurrence of 2. In 2018, 'deep' and 'learning' were the most frequently occurring words with the same number of cumulative occurrence of 6. In 2019, 'deep' and 'smart' were the most frequently occurring words with the same number of cumulative occurrence of 8. From 2020 to 2023, 'deep' was revealed to be the most frequently occurring word in terms of the number of cumulative occurrence as seen in Figure 5.
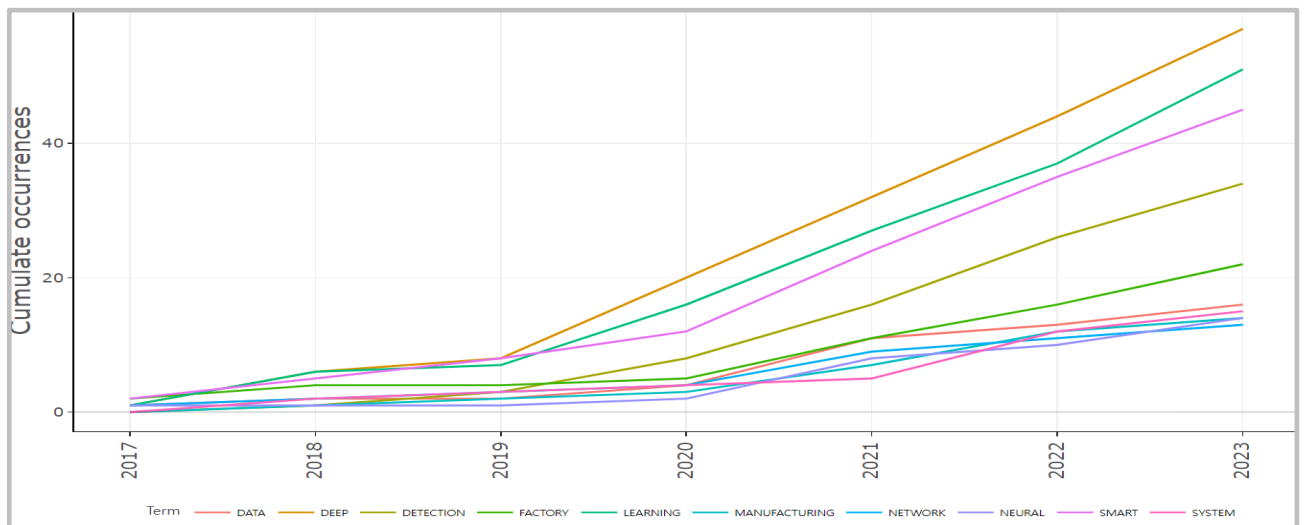

Figure 5. Cumulative occurrences of the top 10 Keywords

4. Conclusion

The goal of this study is to quantitatively review the main features in the research trend in deep learning and smart factory from 2010 to 2023. The quantitative analysis results, by using the data of 138 articles from the Core Collection of Web of Science, provides the four answers to the four RQs in terms of the main trend article publications, the main trend in article citations, the distribution of article publications by research area, and the keywords concerning the main contents of published articles as follows:

First, the article publications were found out to drastically grow from 2019 to 2022 in its annual trend, which answers the RQ 1. They show the up and down trend from 2017 to 2019 and the down trend after 2022, as seen in Figure 1.

Second, the article citations were revealed to rapidly grow since 2018. In 2018, the number of article citations were only 12 but it has increased to 918 by 2023 as illustrated in Figure 2, answering the RQ 2.

Third, the 138 published article were found out to be distributed in various research areas as seen in Figure 3, answering the RQ 3. More specifically, Engineering, Computer Science, and Telecommunications were the top 3 research areas.

Fourth, it is the top 10 keywords such as 'deep', 'learning', 'smart', 'detection', factory', 'data', 'system', 'manufacturing', 'neural', and 'network' that represent the main contents of the 138 published articles in deep learning and smart factory, answering the RQ 4.

References

[1] P. P. Shinde and S. Shah, "A review of machine learning and deep learning applications," *Fourth international conference on computing communication control and automation (ICCUBEA), IEEE*, pp. 1-6, 2018.
DOI: https//doi.org 10.1109/ICCUBEA.2018.8697857

[2] S. Makridakis, "The forthcoming Artificial Intelligence (AI) revolution: Its impact on society and firms." *Futures*, Vol. 90, pp. 46-60. 2017.
DOI: https://doi.org/10.1016/j.futures.2017.03.006

[3] P. Osterrieder, L. Budde, and T. Friedli, "The smart factory as a key construct of industry 4.0: A systematic literature review," *International Journal of Production Economics,* Vol. 221, 2020.
DOI: https://doi.org/10.1016/j.ijpe.2019.08.011

[4] B. Chen, J. Wan, L. Shu, P. Li, M. Mukherjee, and B. Yin, "Smart factory of industry 4.0: Key technologies, application case, and challenges," *IEEE Access*, Vol. 6, pp. 6505-6519, 2017.
DOI: https://doi.org/10.1109/access.2017.2783682

[5] N.E. Benti, M. D. Chaka, and A.G. Semie, "Forecasting Renewable Energy Generation with Machine learning and Deep Learning: Current Advances and Future Prospects," *Sustainability*, Vol. 15, 2023.
DOI: https://doi.org/10.3390/su15097087

[6] S. Weng and H. Chen, "Exploring the role of deep learning technology in the sustainable development of the music production industry," *Sustainability,* Vol. 12, 2020.
DOI: https://doi.org/10.3390/su12020625

[7] L. Li, K. Ota, and M. Dong, "Deep learning for smart industry: Efficient manufacture inspection system with fog computing," *IEEE Transactions on Industrial Informatics*, Vol. 14, pp. 4665-4673. 2018.
DOI: https://doi.org/10.1109/tii.2018.2842821

[8] H. Hwang , "Design of Remote Management System for Smart Factory," *International Journal of Internet, Broadcasting and Communication*, Vol. 12, No. 4 pp. 109-121. 2020.
DOI: https://doi.org/10.7236/IJIBC.2020.12.4.109

[9]   L. Zhang, J. Ling, and M. Lin, "Artificial intelligence in renewable energy: A comprehensive bibliometric analysis." *Energy Reports*, Vol. 8, pp. 14072-14088. 2022.
      DOI: https://doi.org/10.1016/j.egyr.2022.10.347

[10] K. Zhang and Q. Liang, "Recent progress of cooperation on climate mitigation: A bibliometric analysis." *Journal of Cleaner Production*, Vol. 277, 2020.
      DOI: https://doi.org/10.1016/j.jclepro.2020.123495

[11] M. Aria and C. Cuccurullo, "bibliometrix: An R-tool for comprehensive science mapping analysis," *Journal of Informetrics*, Vol. 11, No. 4, pp. 959-975, 2017.
      DOI: https://doi.org/10.1016/j.joi.2017.08.007

[12] bibliometrix.org, BIBLIOMETRIX, *https://www.bibliometrix.org/home*.