Artificial Intelligence and Smart Machine Learning: Progress, Trends and Directions

[1]Ajanta Priyadarshinee, [2]Rakesh Roshan Swain, [3]Rakesh Kumar Patnaik, [4]Ritika Behera

[1]Assistant Professor, Department of Electrical Engineering, GIET, Ghangapatana, Bhubaneswar
[2]Assistant Professor, Department of Electrical Engineering, GIET, Ghangapatana, Bhubaneswar
[3]Assistant Professor, Department of Electrical Engineering, GIET, Ghangapatana, Bhubaneswar
[4]Assistant Professor, Department of Electrical Engineering, GIET, Ghangapatana, Bhubaneswar
Email: ajantapriyadarshinee@gietbbsr.edu.in, rakeshroshan@gietbbsr.edu.in, rakeshpatnaik@gietbbsr.edu.in, ritikabehera@gietbbsr.edu.in

Abstract: Adaptation and innovation stand as critical pillars for the manufacturing industry's evolution, particularly in achieving sustainable practices through the integration of new technologies. To advance sustainability goals, the implementation of smart production necessitates a global perspective on the application of smart production technologies. In this context, the extensive research endeavors in artificial intelligence (AI) have yielded various AI-based techniques, notably machine learning, which have found traction in the industry, facilitating sustainable manufacturing practices. Consequently, the primary objective of this research was to systematically analyze the scientific literature concerning the utilization of artificial intelligence and machine learning (ML) within the industrial domain. Indeed, with the advent of Industry 4.0, artificial intelligence and machine learning emerge as pivotal drivers of the smart factory revolution. This review aims to categorize the literature based on publication year, authors, scientific sector, country, institution, and keywords. The analysis was conducted utilizing data from the Web of Science and SCOPUS databases.

Keywords: artificial intelligence; machine learning; systematic literature review; applications; Industry 4.0; smart production; sustainability

1. Introduction

Smart production systems require innovative solutions to increase the quality and sustainability of manufacturing activities while reducing costs. In this context, artificial intelligence (AI)-driven technologies, leveraged by I4.0 Key Enabling Technologies (e.g., Internet of Thing, advanced embedded systems, cloud computing, big data, cognitive systems, virtual and augmented reality), are ready to generate new industrial paradigms [1].

In this regard, it is interesting to remember that the father of artificial intelligence, John McCarthy [2], in the 1990s, defined artificial intelligence as "artificial intelligence is the science and engineering of making intelligent machines, especially intelligent computer programs". Generally, the term "AI" is used when a machine simulates functions that humans associate with other human minds, such as learning and problem solving [3]. On a very broad account, the areas of artificial intelligence are classified into 16 categories [4–8]. These are reasoning, programming, artificial life, belief revision, data mining, distributed AI, expert systems, genetic algorithms, systems, knowledge representation, machine learning, natural language understanding, neural networks, theorem proving, constraint satisfaction, and theory of computation [9–11].

In the 21st century, AI has become an important area of research in all fields: Engineering, science, education, medicine, business, accounting, finance, marketing, economics, stock market, and law, among others [12–17]. The range of AI has grown enormously since the intelligence of machines with machine learning capabilities has created profound impacts on business, governments, and society.

They also influence the larger trends in global sustainability. Artificial intelligence can be useful to solve critical issue for sustainable manufacturing (e.g., optimization of energy resources, logistics, supply chain management, waste management, etc.). In this context, in smart production, there is a trend to incorporate AI into green manufacturing processes for stricter environmental policies. In fact, as said in March 2019 by Hendrik Fink, head of Sustainability Services at Price water house Coopers, “If we properly incorporate artificial intelligence, we can achieve a revolution with regard to sustainability. AI will be the driving force of the fourth industrial revolution”.

A number of impressive documentations of established research methods and philosophy have been discussed for several years. Unfortunately, little comparison and integration across studies exists. In this article, a common understanding of AI and ML research and its variations was created. This paper is not attempting to provide an all-encompassing framework on the literature on AI and ML research. Rather, it attempts to provide a starting point for integrating knowledge across research in this domain and suggests paths for future research. It explores studies in certain novel disciplines: Environmental pollution, medicine, maintenance, manufacturing, etc.

The final aim was to anticipate the transformation of the discipline in the future age. This would be a journey that may experience change in its course as new generations of scholars contribute to the dialogue and to the action. As noted earlier, this work presents a review, hence it lays a foundation for future inquiry. It not only others a basis for future comparisons but prompts a number of new questions for investigations as well. While topics that might be considered as results of this work are numerous, some are of particularly broad interest or impact.

2. Methodology

The methodological approach used mixes bibliometric, content analysis, and social network techniques. In this study, a state-of-the-art research was conducted through the SCOPUS and Web of Science databases. For the publication time span, the time from 1999 to 2019 was considered with the intent to understand how the level of attention towards the topic has changed before and after the introduction of Industry 4.0. The research methodology chosen for this study was a systematic literature review. The main phases of the study were as follows:

1. Phase 1: Research and Classification. The present phase was divided into three steps:

_ Step 1: Identification;

_ Step 2: Screening; and

_ Step 3: Inclusion.

In phase 1, bibliometric data was collected (step 1). Then, a screening of the overall result was carried out to identify which documents can be taken into consideration, in line with the research areas deemed interesting and relevant (step 2). At the end of this step, the last step (step 3) aimed to select the documents to be analyzed in detail.

2. Phase 2: Analysis. Once phase 1 was completed, the next phase was phase 2, which was the analysis of the results. The approach used for the bibliometric analysis included:

_ The use of indicators for the parameters studied; and

_ SNA (social network analysis) for the keywords.

The indicators chosen to perform the analysis were total papers (TPs), which are the total number of publications, and total citations (TCs), which is the total number of citations.

SNA finds application in various social sciences, and has lately been employed in the study of various phenomena, such as international trade, information dissemination, the study of institutions, and the functioning of organizations. The analysis of the use of the term SNA in the scientific literature has undergone exponential growth in the use of this mode of computable representation of complex and interdependent phenomena. For the purpose of the study, UCINET, NetDraw software was used, which was expressly designed for the creation and graphic processing of networks, and was used to represent the keywords in the network, and Excel for data input.

3. Phase 3: Discussion. At the end of the second phase, a third and final one followed, where the results were discussed, and conclusions were drawn.

3. Research Areas Analysis

The total research area analysis collected from the 82 papers was 164 because each paper can be considered as more than one research area analysis. Given the small number of documents identified in the period before I4.0, the ranking refers mostly to the current industrial revolution. Also, in this case, the result is consistent with the introduction of paradigm 4.0, which has intensified research and the adoption of technology.

The first thematic areas and disciplines that are at the top of the ranking are computer science, engineering and biochemistry, genetics, and molecular Biology, respectively, with 29%, 23%, and 6% of publications. Furthermore, the other disciplines identified for which applicative findings are found are considered transversal to the first three disciplines and this is a consequence of I4.0. In terms of the percentage contribution, the first three areas cover about 60% of the papers considered.

Considering the top 20 research areas, given the frequency of the research areas' distribution, Figure 5 shows a higher level of concentration in the disciplines indicated above. The total research area analysis collected from the 82 papers was 164 because each paper can be considered as more than one research area analysis. Given the small number of documents identified in the period before I4.0, the ranking refers mostly to the current industrial revolution. Also, in this case, the result is consistent with the introduction of paradigm 4.0, which has intensified research and the adoption of technology.

The first thematic areas and disciplines that are at the top of the ranking are computer science, engineering and biochemistry, genetics, and molecular Biology, respectively, with 29%, 23%, and 6% of publications. Furthermore, the other disciplines identified for which applicative findings are found are considered transversal to the first three disciplines and this is a consequence of I4.0. In terms of the percentage contribution, the first three areas cover about 60% of the papers considered.

Considering the top 20 research areas, given the frequency of the research areas' distribution, Figure 5 shows a higher level of concentration in the disciplines indicated above. In fact, in terms of the percentage contribution, the first five areas cover about 70% of the papers considered. Regardless, by only counting research areas found once, there is a total of 27.

This means two things:

- The large number of fields in which this kind of research is involved; and
- Most papers have a transversal approach, that is, the object of each research crosses more than one field of application, thus involving more research areas. This confirms the wide interest in these subjects from several fields.

In this section, the top 20 sources or journals that were published most frequently were extracted. A journal is a time-bound publication with the objective of promoting and monitoring the progress of the discipline it represents. In this specific case, the total source journals detected from the documents is 74, but, considering the top 20, given the frequency of the source journals' distribution, only the first 13 sources have more than one paper published, with a total percentage contribution of 43% of the total. After analyzing the sources separately, the results obtained in the two databases were found to not be the same. In WoS, the top source journal was IEEE Access with two publications while in Scopus, the top source journals are Procedia Computer Science, Matec Web of Conferences, and Machine Learning with four publications, which contribute 5% of the total.

A journal is a time-bound publication with the objective of promoting and monitoring the progress of the discipline it represents. In this specific case, the total source journals detected from the documents is 74, but, considering the top 20, given the frequency of the source journals' distribution, only the first 13 sources have more than one paper published, with a total percentage contribution of 43% of the total. After analyzing the sources separately, the results obtained in the two databases were found to not be the same. InWoS, the top source journal was IEEE Access with two publications while in Scopus, the top source journals are Procedia Computer Science, Matec Web of Conferences, and Machine Learning with four publications, which contribute 5% of the total.

Aggregating the data collected from the two databases, the ranking moves to that obtained by Scopus, making sure that IEEE Access is no longer first in the standings, but only eighth, and that the former are precisely those of Scopus: Procedia Computer Science, Matec Web Of Conferences, and Machine Learning, with the same number of publications. Next, the 10 source journals have a 3% publication contribution while the rest have a one-to-one relationship (1%) with the corresponding source journal.

The low level of concentration of the sources suggests that there is a great deal of interest in these topics from several scientific journals. As a matter of fact, it is foreseeable that specialized sector sources (AI Magazine and Machine Learning) are among the first 13; however, it is interesting to note that other sources are involved, such as Sustainability Switzerland or BMC Bioinformatics and Nuclear.

Phase 3: Discussion

3.3.1. Benefits of Artificial Intelligence and Machine Learning in Industrial Contexts From the analysis of the research carried out, the first information that emerged is that there is a growing importance of innovation and digitalization in products, services, and processes. Consequently, it means that the adoption of advanced manufacturing technologies, such AI and ML, is an emerging issue. In other words, AI/ML algorithms represent an opportunity to handle high dimensional problems and data. The interest in the subject is extended to all scientific sectors, but with a focus on computer science and engineering. The most significant benefits of using AI and ML in industrial sectors include: 1) Greater innovation, 2) process optimization, 3) resources optimization, and 4) improved quality. After all, AI with ML is one of the most important technologies today and is transforming the economy and society, as demonstrated by the over 340,000 patent applications filed since the 1950s.

From the analysis of the research carried out, the first information that emerged is that there is a growing importance of innovation and digitalization in products, services, and processes. Consequently, it means that the adoption of advanced manufacturing technologies, such AI and ML, is an emerging issue. In other words, AI/ML algorithms represent an opportunity to handle high dimensional problems and data. The interest in the subject is extended to all scientific sectors, but with a focus on computer science and engineering.

The most significant benefits of using AI and ML in industrial sectors include: (1) Greater innovation, (2) process optimization, (3) resources optimization, and (4) improved quality. After all, AI with ML is one of the most important technologies today and is transforming the economy and society, as demonstrated by the over 340,000 patent applications filed since the 1950s. Other information that emerged is about the authors and affiliation. Many of these are in a 1:1 ratio compared to the selected documents and this supports the fact that there is no interest in technological applications in one direction, but that, once again, the interest is very wide in the scientific community. Furthermore, it can be said that the countries most interested in scientific research are the USA, China and European countries. This result is not a surprise.

In terms of investment, the effort currently being deployed by the United States and China to acquire dominance in the AI sector is far superior to that of other countries. More specifically, China has clearly stated its ambition to become a world leader in AI by 2030 Among the Chinese plans, of absolute interest is the "Made in China 2025" plan, dedicated to the manufacturing sector; the "Internet +" plan is also dedicated to smart manufacturing and innovation. A direct consequence of the above considerations could be having new generations of researchers who will contribute to future comparisons, accompanied by new questions for investigations.

3.2. Emerging Trends of Artificial Intelligence and Machine Learning

From the perspective of sustainability, the analysis highlighted that the new paradigm of smart manufacturing has the potential to bring fundamental improvements in the industry by addressing the issue of scarce resources and improving productivity.

In fact, the survey pointed out a growing interest on applications related to green manufacturing and sustainable development, proving that AI/ML play an important role in increasing sustainability through the intelligent utilization of materials and energy consumption (i.e., reduction of energy consumption and pollutant emissions, environmental footprint monitoring and evaluation, etc.).

Furthermore, it emerged that AI/ML algorithms present a wide array of applications that provide an opportunity for sustainable development, which will involve several stakeholders from different countries and sectors, including inventory and supply chain management, predictive maintenance, and production.

4. Conclusions

This research delves into the examination of the current state-of-the-art applications of Artificial Intelligence (AI) and Machine Learning (ML), focusing on a topic that has garnered significant attention in scientific research. Given the vast expanse of literature available on any subject, achieving comprehensive coverage of all published documents related to a particular topic can be arduous or even unfeasible. Consequently, a systematic approach was adopted to select the most pertinent literature for analysis. This document offers a systematic review of ML applications across various scientific domains.

In the selection process, objective and transparent investigation methods were employed, independent of the researchers' expertise. The objectives of this document encompass not only furnishing a comprehensive framework for the literature concerning AI and ML research but also serving as a starting point for synthesizing knowledge through further research in this domain and suggesting potential avenues for future research endeavors.

It is noteworthy that this document solely utilized two databases, namely WoS and Scopus, with inclusion criteria limited to documents with open access. Consequently, numerous other documents with restricted access and alternative indexing databases, such as Google Scholar, remain untapped resources that could be incorporated in future research efforts.

References

[1] Gupta, N.A. Literature Survey on Artificial Intelligence. 2017. Available online: https://www.ijert.org/research/a-literature-survey-on-artificial-intelligence-IJERTCONV5IS19015.pdf (accessed on 7 January 2020).

[2] McCarthy, J.; Minsky, M.L.; Rochester, N.; Shannon, C.E. A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence. AI Mag. 2006, 27, 12.

[3] Moore, A. Carnegie Mellon Dean of Computer Science on the Future of AI. Available online:https://www.forbes.com/sites/peterhigh/2017/10/30/carnegie-mellon-dean-of-computer-science-onthe-future-of-ai/#3a283c652197 (accessed on 7 January 2020).

[4] Becker, A.; Bar-Yehuda, R.; Geiger, D. Randomised algorithms for the loop cutset problem. J. Artif. Intell. Res.2000, 12, 219–234.

[5] Singer, J.; Gent, I.P.; Smaill, A. Backbone fragility and the local search cost peak. J. Artif. Intell. Res. 2000,12, 235–270.

[6] Chen, X.; Van Beek, P. Conflict-directed backjumping revisited. J. Artif. Intell. Res. 2001, 14, 53–81.

[7] Hong, J. Goal recognition through goal graph analysis. J. Artif. Intell. Res. 2001, 15, 1–30.

[8] Stone, P.; Littman, M.L.; Singh, S.; Kearns, M. ATTAC-2000: An adaptive autonomous bidding agent. J. Artif. Intell. Res. 2000, 15, 189–206.

[9] Peng, Y.; Zhang, X. Integrative data mining in systems biology: from text to network mining. Artif. Intell. Med.2007, 41, 83–86.

[10] Zhou, X.; Liu, B.;Wu, Z.; Feng, Y. Integrative mining of traditional Chines medicine literature and MEDLINE for functional gene networks. Artif. Intell. Med. 2007, 41, 87–104.

[11] Wang, S.; Wang, Y.; Du, W.; Sun, F.; Wang, X.; Zhou, C.; Liang, Y. A multi- approaches-guided genetic algorithm with application to operon prediction. Artif. Intell. Med. 2007, 41, 151–159.

[12] Halal, W.E. Artificial intelligence is almost here. Horizon 2003, 11, 37–38. Available online: https://www.emerald.com/insight/content/doi/10.1108/10748120310486771/full/html (accessed on 7 January 2020).

[13] Masnikosa, V.P. The fundamental problem of an artificial intelligence realization. Kybernetes 1998, 27, 71–80.

[14] Metaxiotis, K.; Ergazakis, K.; Samouilidis, E.; Psarras, J. Decision support through knowledge management: The role of the artificial intelligence. Inf. Manag. Comput. Secur. 2003, 11, 216–221.

[15] Raynor,W.J. The international dictionary of artificial intelligence. Ref. Rev. 2000, 14, 1–380.

[16] Stefanuk, V.L.; Zhozhikashvili, A.V. Productions and rules in artificial intelligence. Kybernetes 2002, 31, ty817–826.

[17] Tay, D.P.H.; Ho, D.K.H. Artificial intelligence and the mass appraisal of residential apartments. J. Prop. Valuat. Invest. 1992, 10, 525–540.