

Application of Artificial Intelligence and Machine Learning in Manufacturing Industry : A Bibliometric Study

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Abstract:

Purpose: The use of machine learning (ML) and artificial intelligence (AI) in the manufacturing industries is covered in-depth in this paper's bibliometric examination of the literature.

Methodology: The authors of this study analyzed a dataset of 3,597 papers published between 2003 and 2023 using bibliometric techniques. Using Vosviewer, they primarily focused on performance analysis and scientific mapping of articles. In order to narrow down the scope of the study, authors performed a keyword search on the official publisher websites and in academic databases like Scopus, ACM etc.

Findings: This study gave a quick overview of AI and ML in the manufacturing industry and the trends in publications over the last twenty years. It revealed that "Artificial Intelligence" was the highly used keyword amongst all the papers, with a total occurrence of 2342 and a total link strength of "19448". The analysis observed that country "China" has done the most publications in the field and stood at first rank with 594 publications to its credit. Research results also concluded that the National Natural Science Foundation of China has sponsored maximum publications. Additionally, the analysis revealed that highest number of publications, i.e., 2290, are undertaken in engineering domain.

Practical implications: A new type of intelligent manufacturing and sustainable manufacturing will be powered by artificial intelligence and machine learning, or AI/ML. Sustainable manufacturing encompasses all aspects of a sustainable process, from supply chain management to quality control, predictive maintenance, and energy consumption. This study will help scientists and researchers in the field of AI and ML with future research.

Originality/value: AI and ML have been used to make a lot of different things happen, like optimizing processes, making things in factories, and predicting how things will turn out. This analysis would provide a comprehensive overview of the major developments in AI and ML over the years. It is a more comprehensive and thorough process due to the techniques employed.

Keywords: Machine Learning (ML), Artificial Intelligence (AI), Bibliometric analysis, manufacturing industries, Scopus

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Introduction:

The application of machine learning (ML) and artificial intelligence (AI) in manufacturing processes is growing in frequency. Manufacturing Process Planning, Control Predictive Maintenance, Quality Control, Process Control, and Optimization are some of the machine learning approaches utilized in factories. Learning Systems and Logistics Robotics Assistance for Shop Floor Workers, etc. (Fahle, Prinz & Kuhlenkötter, 2020; Sircar et al., 2021). The popularity of AI and ML continues to grow and is further supported by the increasing trend of digitalization. Recent competitions on the web demonstrate that companies see tremendous opportunities in data-driven technologies and are ready to offer substantial prizes to solve specific challenges (Rai, Tiwari, Ivanov & Dolgui, 2021; Cioffi et al., 2020).

The implementation of smart production systems necessitates the development of novel solutions to enhance the efficacy and sustainability of production operations while simultaneously decreasing expenses. Artificial Intelligence (AI)-based technologies, such as the Internet of Thing (IoT), advanced embedded systems (embedded systems), cloud computing (cloud computing), big data (big data), cognitive systems (VR and AR), and other AI-driven technologies, are available to create new industrial possibilities (Moore, 2017; Gupta, 2017; Balamurugan et al., 2019). Processes and systems design in engineering and manufacturing are full of challenges, like dynamics, chaotic behaviour, and intricacy. Recently, big data, super-fast computing, cloud computing, and AI have changed the way engineers and manufacturing professionals do their jobs. These new technologies offer exciting new ways to solve real-world problems with the help of AI and machine learning (Badesa et al., 2014; Akshatha & Shreedhara, 2018; Nti et al., 2022). Thus, keeping in view the importance of machine learning and AL in manufacturing industries, the following objectives have been made:

- 1) This paper provides a comprehensive overview of how AI and ML techniques are currently being used in the manufacturing Industry.
- 2) It is also aimed at to predicting how the field will change in the future. It's a journey that could keep changing as new generations of scientists join the conversation and get involved. It not only provides a foundation for future comparisons, but it also raises a lot of questions for future research.
- 3) Authors also look at the work of famous authors, famous countries, and famous universities, as well as the most popular terms and research topics.
- 4) In addition, it will also look at the leading countries and how they contribute to research and explore opportunities for future cooperation and goals.

Research Methodology

The literature that is currently available in the domains of artificial intelligence, machine learning, and the manufacturing industry is examined in this work through bibliometric analysis carried out with Vosviewer software. The data used for the execution of bibliometric analysis is collected using the database extracted from Scopus. Multiple level filterations have been performed to extract the data for analysis for the time period 2003-2023. The keywords used for extracting the data was Artificial Intelligence and Manufacturing for the time period 2003-2023. The paper attempted to the bibliometric data and figured out a comprehensive structure of measurement to classify the different periodicals, articles, authors, and organizations. For understanding different research themes, detailed content analysis of the articles was done.

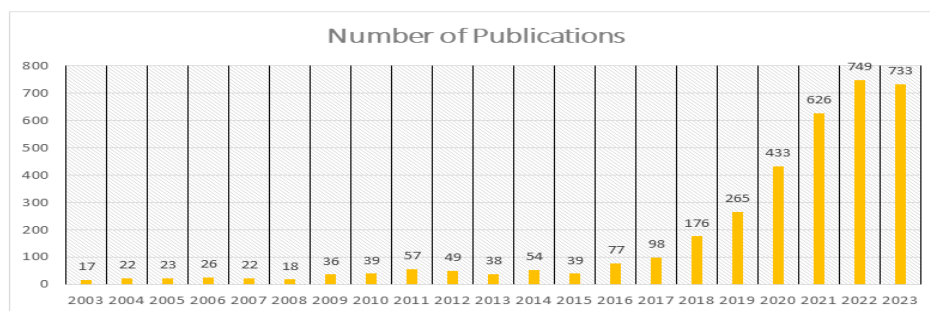
Data Analysis and Data Interpretation

Analyzing Publication Trend:

1. Twenty Years Publication Trend: Year on Year Basis

In the realm of artificial intelligence, machine learning, and manufacturing industry examination of previous literature, a twenty-year trend has been found, spanning from 2003 to 2023. Figure 1 shows this tendency, and Table 1 presents year-by-year publishing statistics. There are seven hundred thirty-three (733) papers published in 2023, while the papers published in 2022 is nearly seven hundred forty-nine (749). Nearly six hundred twenty-six (626) papers were published in the year 2021. Hence, it is usually predictable to see an surge in publication statistics in the forthcoming years. Though academicians don't have access to entire publications, only a few papers are available in open access while others are usually charges a fee.

Fig 1: Year Wise Publication Graph



(Source; Researcher's Output)

Table 1: Year Wise Publication Statistics

Year	Number of Publications
2003	17
2004	22
2005	23
2006	26
2007	22
2008	18
2009	36
2010	39
2011	57
2012	49
2013	38
2014	54
2015	39
2016	77
2017	98
2018	176
2019	265
2020	433
2021	626
2022	749
2023	733

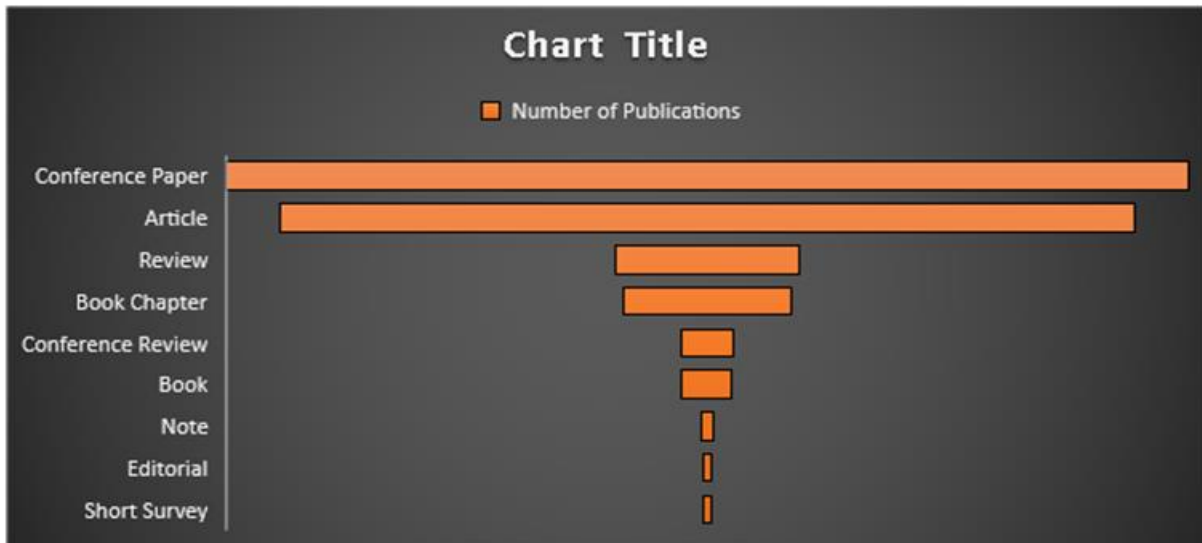
(Source; Researcher's Output)

2. Document Type and Subject -Wise Analysis

In this section, an attempt is made to analyze the publications over the last decade as per their document type, like conference papers, articles, reviews, surveys etc. Figure 2 demonstrates the document type statistics. Nearly 1621 publications are in the form of conference papers, 1439 are in the form of articles and 310 are published as reviews. Nearly 283 publications are published as book chapters and approximately 84 as books. An

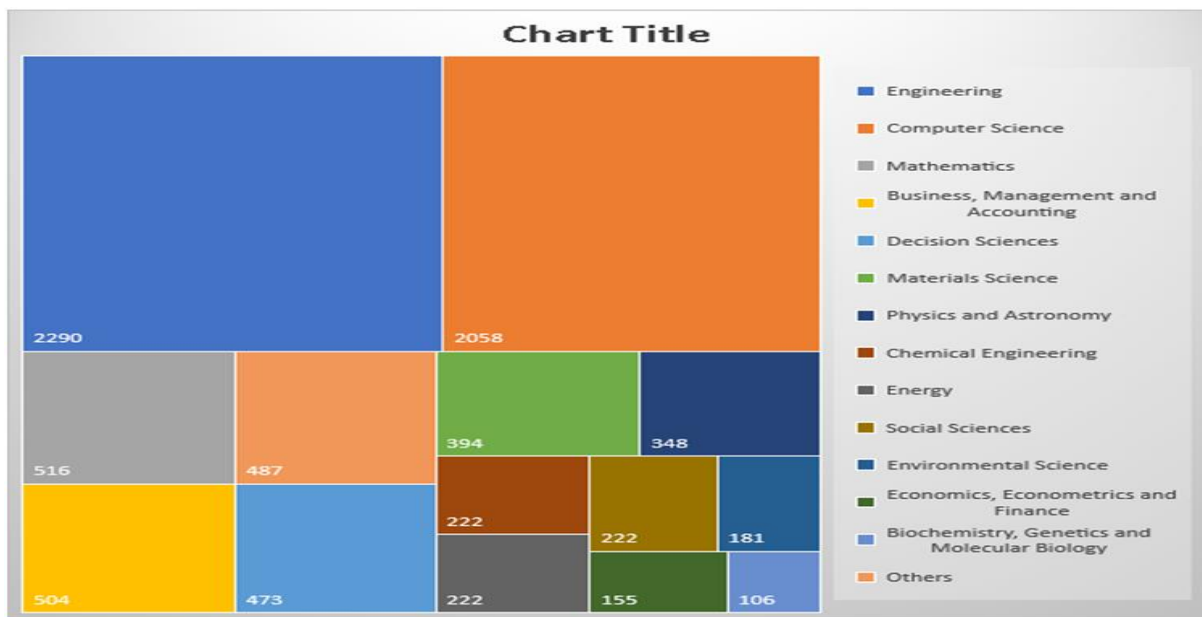
analysis is also done to investigate the plentiful subjects under which “ Artificial Intelligence , Machine Learning and Manufacturing Industry” are studied. The highest number of publications i.e. 2290, are undertaken in the engineering domain, whereas 2058 are in the subject of computer science. Approximately 504 papers are published in business, management and accounting, whereas 516 are published in the field of mathematics. Figure 3 elaborates on the subject-wise publication trend.

Fig 2: Publication statistics Document Type



(Source; Researcher's Output)

Fig 3: Subject Wise Publication



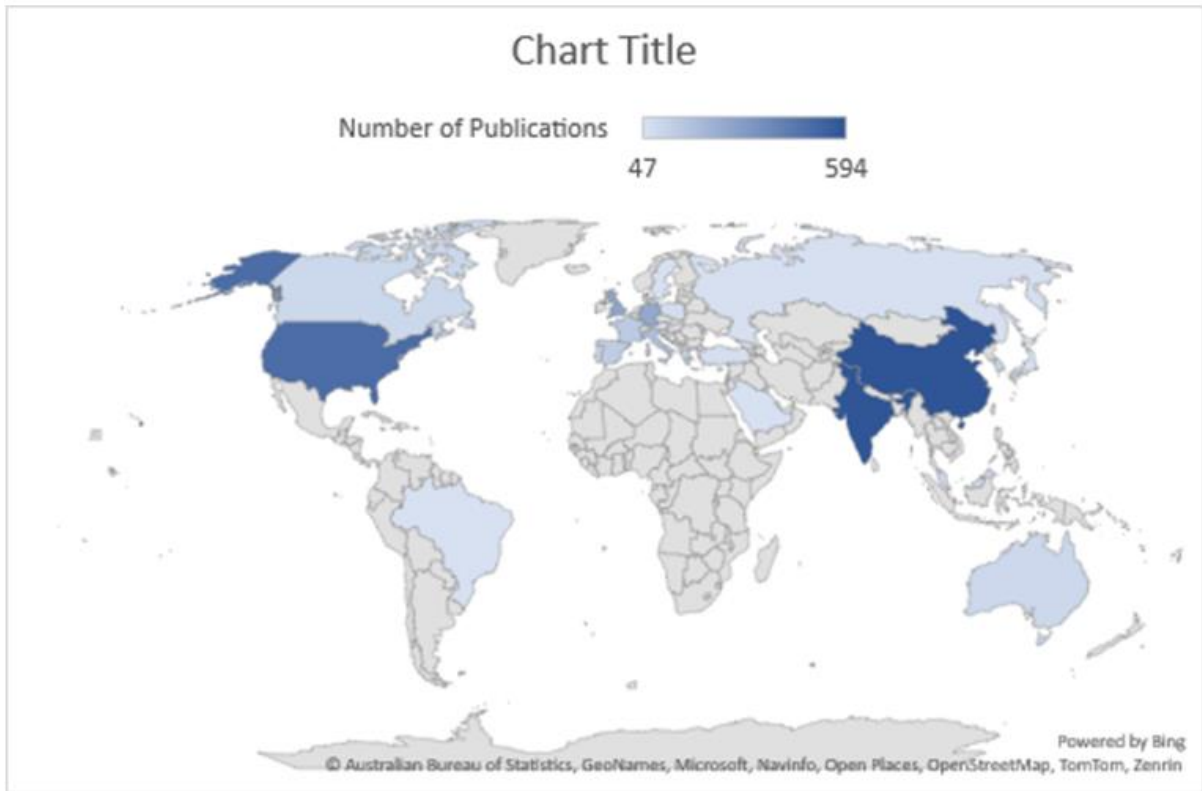
(Source; Researcher's Output)

3. Country Wise Analysis

The goal of this part is to look into the publishing trend by nation in order to determine which nation has the greatest sway over the field of "Artificial Intelligence, Machine Learning, and Manufacturing Industry." The thorough country wise data is showcased in the Table 2. The Country "China" has done the most publications in the field and stood at

first rank with 594 publications to its credit, followed by India with 591 publications. With 500 publications, the United States of America (USA) held the third place. The network map created by Vos viewer software also emphasized the significant results. Figure 4 represents the country-wise publication trend.

Fig 4: Country Wise Publications



Source: Researcher's Output)

Table 2: Country Wise Publication Data

<i>Country/Territory</i>	<i>Number of Publications</i>
<i>China</i>	594
<i>India</i>	591
<i>United States</i>	500
<i>United Kingdom</i>	287
<i>Germany</i>	271
<i>Italy</i>	183
<i>France</i>	142
<i>Spain</i>	131
<i>South Korea</i>	108
<i>Taiwan</i>	105
<i>Canada</i>	91
<i>Australia</i>	89
<i>Malaysia</i>	83
<i>Greece</i>	81
<i>Portugal</i>	75

Poland	65
Turkey	64
Russian Federation	60
Sweden	56
Saudi Arabia	55
Brazil	54
Japan	48
Singapore	48
Austria	47
Hong Kong	47

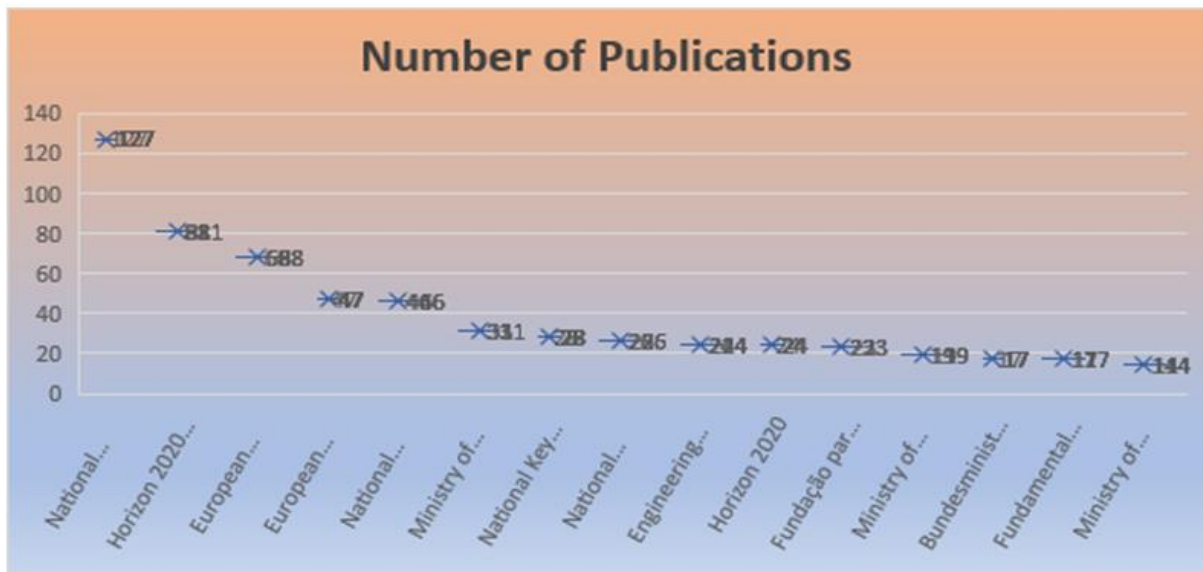
(Source; Researcher's Output)

4. Sponsor Wise Publication Analysis

In this section, influential sponsors are investigated in the field of “Artificial Intelligence , Machine Learning and Manufacturing Industry.” The National Natural Science Foundation of China has

sponsored the most publications, followed by the Horizon 2020 Framework Programme and the European Commission with 127 ,81 and 68 publications, respectively. A detailed analysis of major sponsors is presented in figure 5 and table 3.

Fig 5: Sponsors wise Publications



(Source; Researcher's Output)

Table 3: Sponsor Wise Publication Statistics

Funding / Sponsor	Number Of Publications
National Natural Science Foundation of China	127
Horizon 2020 Framework Programme	81
European Commission	68
European Regional Development Fund	47
National Science Foundation	46
Ministry Of Science and Technology, Taiwan	31

National Key Research and Development Program of China	28
National Research Foundation of Korea	26
Engineering And Physical Sciences Research Council	24
Horizon 2020	24
Fundação Para A Ciência E a Tecnologia	23
Ministry Of Science, Ict and Future Planning	19
Bundesministerium Für Bildung Und Forschung	17
Fundamental Research Funds for The Central Universities	17
Ministry Of Trade, Industry and Energy	14

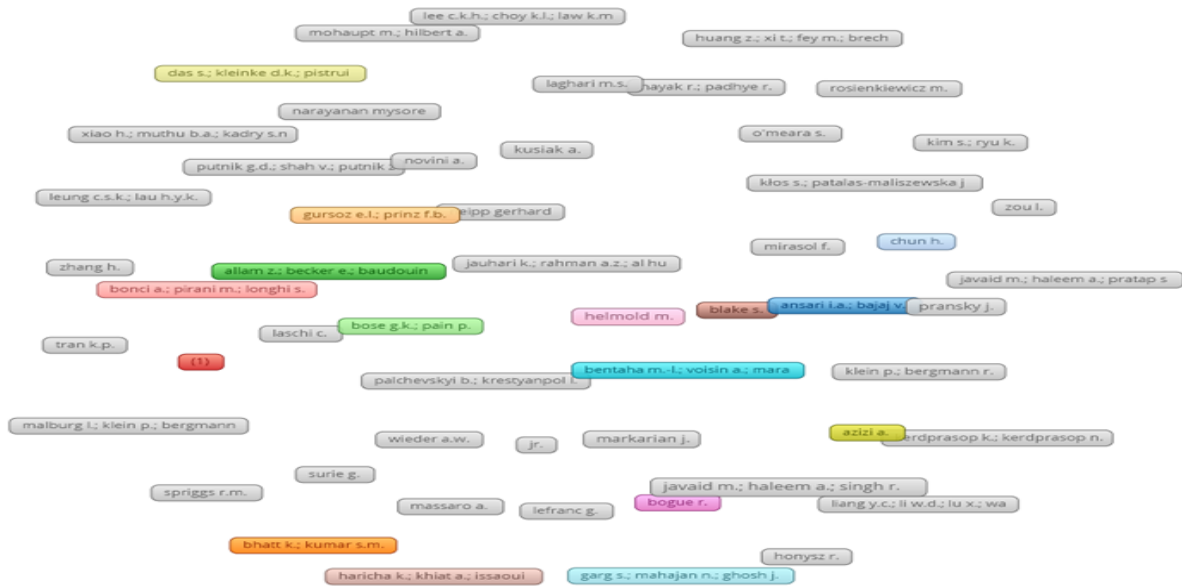
(Source; Researcher's Output)

2. Author Wise Publication Analysis

In this portion of the paper, an examination is made keeping in mind the authors of the publication. Figure 6 showcases the author-wise publication, like Haleem who has sixteen publications to his credit, followed by Javaid, who has fifteen publications to his credit and Anon, who has fourteen publications to his credit, respectively.

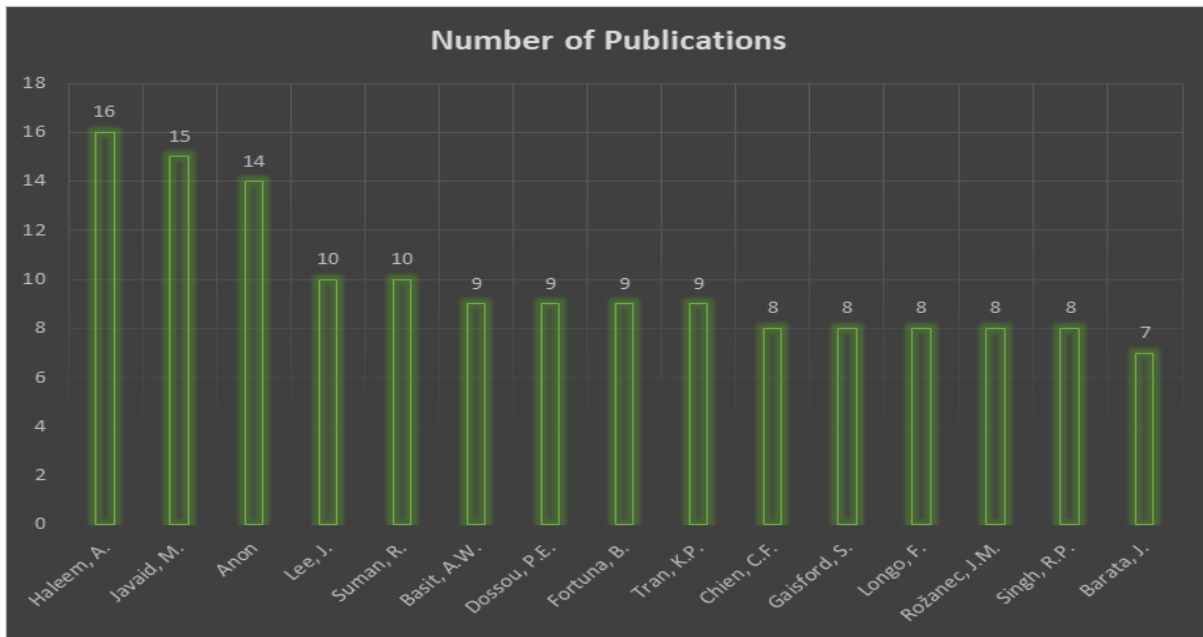
Figure 7 presents the substantial authors in the field of “Artificial Intelligence , Machine Learning, and Manufacturing Industry,” along with the publication quantity by individual authors. This examination will recommend promising academicians in the field of “Artificial Intelligence and manufacturing” about momentous authors in their area.

Fig 6: Authors Densities



(Source; Researcher's Output)

Fig 7: Author Wise Publication Statistics



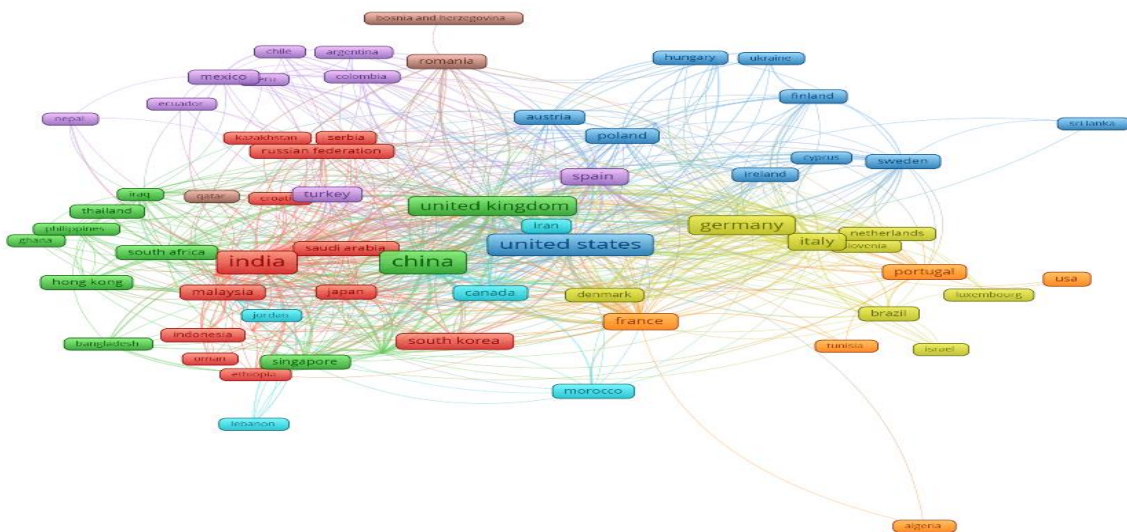
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Co-Occurrence : Co-Authorship Analysis (Countries)

In performing the co- authorship for nations analysis, all 176 countries are taken into consideration. The distribution of countries for documents and citations has been showcased in Figure 8 and table 4. Within VOSviewer, the interconnection and association amongst any two countries will be determined with the aid of the gap among nations. The stronger the connection between nations, the closer they are. Nations with

greater clout seem to be China, the United States, India, the United Kingdom, and Germany. With 763 connections overall and 1960 total link strength, there are eight clusters among the nations. The United States has the maximum citations of 22,133, with 301 as the total link strength, as mentioned in table 4. United Kingdom has the second-largest citations at 9,272, followed by China and India with 8,829 and 6093, respectively. Figure 9 represents the cluster for the developing country of India.

Fig 8: Country Wise Co-Occurrence Analysis



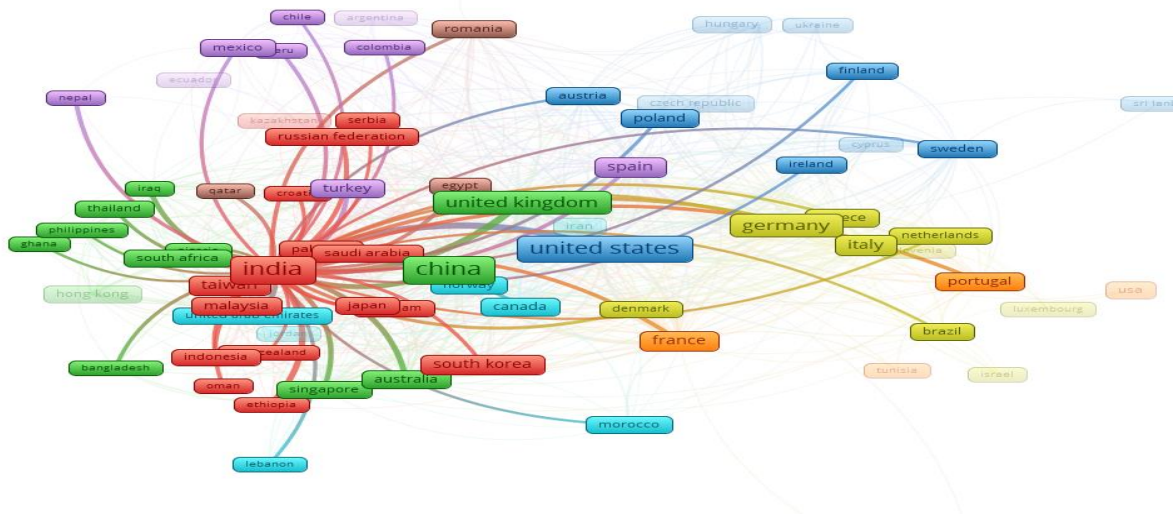
(Source; Researcher's Output)

Table 4: Country Wise Citation Statistics

Country	Documents	Citations	Total Link Strength
United States	502	22133	301
United Kingdom	287	9272	326
China	600	8829	245
India	591	6093	294
Germany	272	4021	163
France	142	3754	156
Italy	183	3020	148
Australia	91	2694	93
Singapore	48	2615	69
Sweden	55	2219	55
Spain	132	2182	143
Portugal	76	2044	50
Turkey	65	1979	61
Canada	93	1840	77
Greece	81	1644	80
Denmark	24	1574	37
Taiwan	106	1491	58
Brazil	54	1334	27
Netherlands	26	1285	34
South Korea	108	1277	31
Malaysia	83	1267	82
New Zealand	11	1138	17
Austria	47	1129	46
South Africa	39	1115	39
Saudi Arabia	56	869	94

(Source; Researcher's Output)

Fig 8: India's Co-Occurrence Analysis



(Source; Researcher's Output)

Keyword Analysis:

This segment of the research paper permitted the inspection of the topic-related essence of the data by considering the examination of keywords by the academicians. Such an inspection necessitates measurement of complete excellence along with the relative content of the paper, Strozzi et al., (2017). The existing research work inspects the research design amongst “Artificial Intelligence , Machine Learning, and Manufacturing Industry.” To inspect and analyse the trend amongst keywords, all 20,845 keywords were considered from a pool of 3887 papers, and with the support of Vosviewer software , a network of all keywords was created. The examination showed “ Artificial Intelligence ” as the most used keyword amongst all the papers, with a total occurrence of 2342 and a total link strength of “19448”. “ Industry 4.0” comes out as the second most commonly used keyword with a frequency of 933, followed by manufacturing with

a frequency of 630. The other important keywords highlighted in the analysis included machine learning , manufacturing industries , industrial research, followed by smart manufacturing, etc. A thorough demonstration of the keywords is shown in the table 5 wherein occurrences and total link strength of the keywords are also stated.

The most significant and frequently cited term in Figure 9's network route formed by the vosviewer is "Artificial Intelligence." Moreover, Figure 10 creates a network map with Manufacturing as its primary emphasis. This represents cluster 3 in the network path with 861 links, 6,122 as total link strength, and 630 as occurrences. The network diagram represents the important words with which Manufacturing is related, like aartificial intelligence, industrial research, industry 4.0, manufacturing industries, manufacture, production control, digital twin etc.

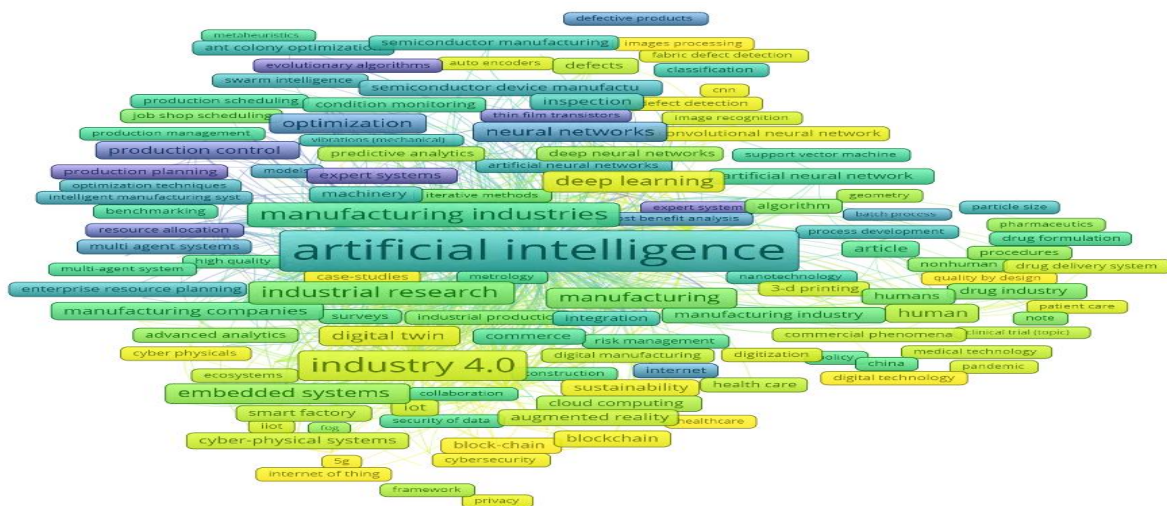
Table 5: Keyword Statistics

Keyword	Occurrences	Total Link Strength
Artificial Intelligence	2342	19448
Industry 4.0	933	8083
Manufacture	630	6122
Machine Learning	539	5324
Manufacturing Industries	434	4090

Internet Of Things	395	4174
Decision Making	331	3716
Industrial Research	331	3376
Learning Systems	295	3336
Decision Support Systems	289	2959
Smart Manufacturing	287	2673
Deep Learning	275	2708
Manufacturing	228	2134
Automation	223	2322
Big Data	220	2367

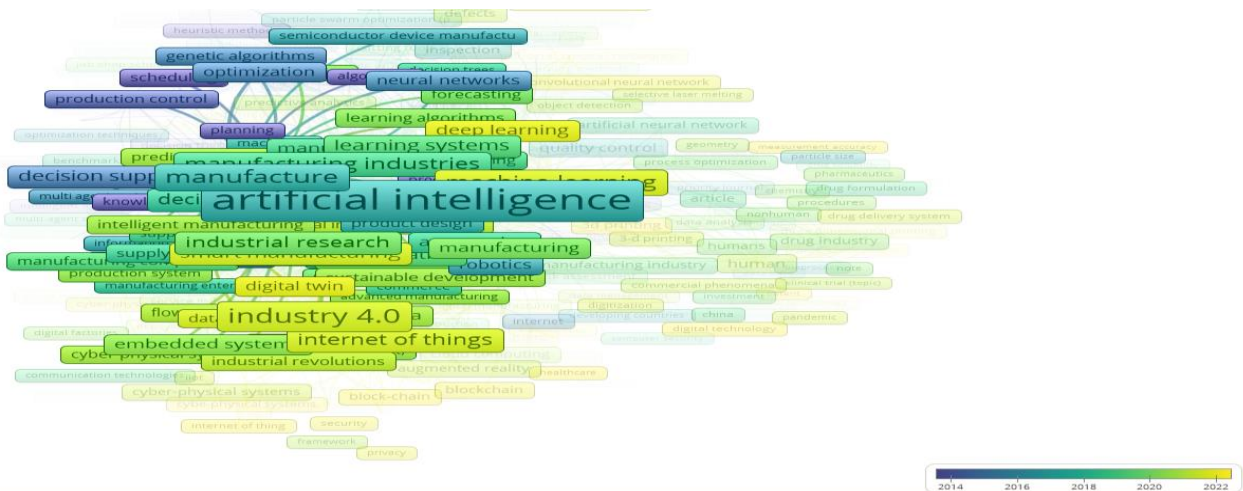
(Source; Researcher's Output)

Fig 9: Keywords Network Map



(Source; Researcher's Output)

Figure 10: Manufacturing Co-Related Word Network



(Source; Researcher's Output)

Co-Occurrence Organization Analysis

The Department of Mechanical Engineering, Jamia Millia Islamia, has the most citations (394), followed by the Department of Industrial and

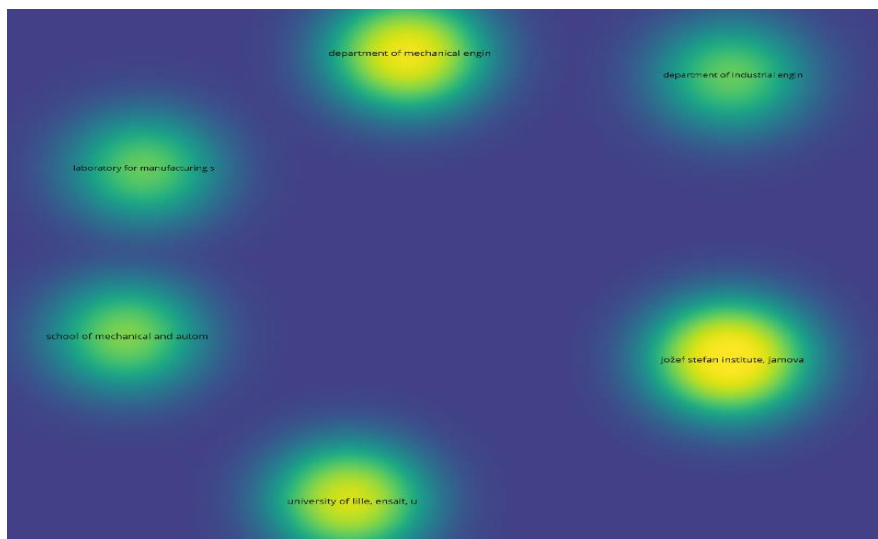
Production Engineering with 201 citations. All the foremost organizations that are connected with Artificial Intelligence, Machine Learning and Manufacturing Industry are shown in the density organization network in Figure 11 and table 6.

Table 6: Statistics Organization Wise

<i>Organization</i>	<i>Documents</i>	<i>Citations</i>	<i>Total Link Strength</i>
Department Of Mechanical Engineering, Jamia Millia Islamia, New Delhi, India	9	394	5
Department Of Industrial and Production Engineering, Dr B R Ambedkar National Institute of Technology, Punjab, Jalandhar, India	5	201	5
School Of Mechanical and Automotive Engineering, South China University of Technology, Guangzhou, 510640, China	6	156	0
Department Of Industrial Engineering and Engineering Management, National Tsing Hua University, Hsinchu, 30013, Taiwan	5	116	0
Laboratory For Manufacturing Systems and Automation, Department of Mechanical Engineering and Aeronautics, University of Patras, Patras, 26504, Greece	5	65	0
Jožef Stefan Institute, Jamova 39, Ljubljana, 1000, Slovenia	6	39	12
Jožef Stefan International Postgraduate School, Jamova 39, Ljubljana, 1000, Slovenia	6	39	12
Qlector D.O.O., Rovšnikova 7, Ljubljana, 1000, Slovenia	6	39	12
International Research Institute for Artificial Intelligence and Data Science, Dong A University, Danang, Viet Nam	5	13	4
University Of Lille, Ensait, Ulr 2461 - Gemtex - Génie Et Matériaux Textiles, Lille, F-59000, France	6	2	4

(Source; Researcher's Output)

Fig 11: Network Map Organization Wise



(Source; Researcher's Output)

Conclusion:

This study provided a concise overview of the application of Machine Learning (ML) and Artificial Intelligence (AI) in manufacturing industries and the evolution of publications over the past twenty years. It revealed that “Artificial Intelligence” was the highly used keyword amongst all the papers with a total occurrence of 2342 and a total link strength of “19448”. The analysis observed that the country “China” has done the most publications in the field and stood at first rank with 594 publications to its credit, followed by India with 591 publications. The USA stood in third place with 500 publications. Research results also concluded that the National Natural Science Foundation of China has sponsored the most publications, followed by the Horizon 2020 Framework Programme and European Commission with 127, 81, and 68 publications, respectively. Additionally, the analysis revealed that the highest number of publications, *i.e.*, 2290, are undertaken in the engineering domain, whereas 2058 are in the subject of computer science. Approximately 504 papers are published in management, whereas 516 are published in the field of mathematics. This study is beneficial for future researchers as it provides a concise summary of the existing research.

Limitations and Future Scope:

The current research work has not encircled all the prevailing literature and publications in the fields of Artificial Intelligence, Machine Learning and Manufacturing Industry of accessible from the Scopus data available as multi-level filtration described in the research methodology. The current study has considered publications from 2003 to 2023, all other previous papers have not been considered. Also, data is extracted from only one database, *i.e.*, Scopus; all other databases like Web of Science, etc., can be considered in the future. The academician has used Vos viewer software for performing data analysis. There is other software that can also be explored. There is an opportunity for forthcoming studies on relative analysis of network maps created from manifold databases such as Scopus and the Web of Sciences. A comparative analysis can be performed using databases from different sources like Scopus, Web of Science, etc.

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