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The Role of Internet of Things, Machine Learning, Artificial Neural Networks and Industry 5.0 in Business Research: Trends and Future Insights

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Abstract: The globalization of the business world, the rapid advancement of the Internet, and the increased flexibility of information flow have led to rapid digitalization. In this context, this study aims to better understand the trends and developments in the field of business research on the topics of the Internet of Things (IoT), machine learning, artificial neural networks, and Industry 5.0. Study types, keywords, authors, author collaborations, citations, and countries were analyzed for articles published on the above-mentioned topics in the Web of Science (WoS) database between 2007-2023 (limited to September 27th, 2023). Within the scope of the study, 545 articles were identified in the WoS database and for the purposes of the research, this database was limited to the open access articles published in English, under the Business category and indexed in Social Sciences Citation Index (SSCI), Science Citation Index (SCI), and Emerging Sources Citation Index (ESCI). A bibliometric analysis was conducted by employing the VOSviewer tool to analyze network visualization of keywords and layered and density visualizations of subject areas. Results of the analysis demonstrate that studies in this field have continued to increase since 2018. The top five most frequently used keywords with the highest connection power are machine learning, Internet of Things, artificial intelligence, big data, and natural language processing, respectively. This research has revealed that the journals with the highest number of articles in this field and the highest number of citations were Technological Forecasting and Societal Change, Journal of Business Research, Electronic Markets, and Marketing Science. In terms of the number of articles and citations by country in these fields, England, the USA, Germany, Italy, and Australia ranked the highest. This research provides information on latest technologies, identifies gaps and research opportunities in the field, and contributes to shaping future research paths in the field.

Keywords: Internet of things, Machine learning, Neural networks, Industry 5.0

Introduction

Nowadays, the rapidly changing world of technology and industry is shaped by a variety of important concepts. These concepts are at the center of scientific research as well as technological advances. Terms such as the internet of things (IoT), machine learning, artificial neural networks and Industry 5.0 are important topics that drive innovation and revolutionize different sectors (Chander et al., 2022).

IoT is a technology and concept that enables physical objects to communicate with each other and with people over the internet. These objects can include all kinds of devices, sensors, household appliances and industrial equipment. IoT allows these objects to collect, process and share their data. This data can be used for many different purposes, such as making better decisions, improving efficiency, ensuring security and developing new services.

Machine learning is a branch of artificial intelligence that enables computers to recognize patterns and predict future events by analyzing data. Algorithms learn by processing large amounts of data and draw conclusions from that data. Machine learning is used in many application areas such as classification, regression, clustering, natural language processing and prediction.

Artificial neural networks are a model of artificial intelligence that mimics the functioning of the human brain. These networks consist of many connected nodes and layers. Each node performs complex calculations by processing inputs and passing the results to other nodes. Deep learning is based on neural networks, which are very successful on large and complex datasets. It is used in applications such as image recognition, natural language processing and autonomous vehicles.

Industry 5.0 is considered a new era in the manufacturing industry. It is characterized by the fact that industrial production involves smart factories where people work collaboratively. Industry 5.0 represents an approach in which humans and robots work collaboratively, the use of data analytics and artificial intelligence increases, and production processes become more flexible and customizable. This aims to increase productivity as well as develop more sustainable and competitive production methods.

Bibliometric analysis is an important method used to study various aspects of academic research, scientific publications and the scientific world (Donthu et al., 2021). These analyses are used to track scientific developments, understand interdisciplinary relationships, and assess the evolution of specific topics or fields. Bibliometric analysis measures and compares various data points using scientific metrics and statistical methods.

In this study, four important technology and industry concepts, IoT, Machine Learning, Artificial Neural Networks and Industry 5.0 are discussed from a bibliometric perspective. While addressing these four key topics, we explain the definition and importance of each of them and emphasize that these concepts have become the focus of scientific research in recent years. Assessing the development and impact of these topics in the literature will provide a scientific perspective to trace this transformation.

Literature Review

Internet of Things

The term Internet of Things (IoT) was first used by a British technologist named Kevin Ashton. Ashton coined the term in 1999. Kevin Ashton had a vision of connecting the physical world of things to the internet and ensuring them to have interaction with each other. Ashton's work, and the term itself, has subsequently led to IoT becoming a concept with a wide range of applications. From smart homes to healthcare, transportation to industrial automation, IoT is used in many different fields and has become a fundamental component of the modern digital world (Madakam et al., 2015).

In IoT, connected devices collect information, exchange operational details and perform specified activities (Sahni et al. 2017). The IoT involves web-enabled smart devices that compile, transmit and act on the data they receive through integrated systems, including processors, sensors and communication hardware (Medhat et al., 2019). IoT devices make the sensor data they collect visible through the use of an IoT sink or other edge device. These devices occasionally interact with other connected devices and take action based on the data they exchange. While humans can contact with devices to understand, manage or retrieve data, devices perform most of the work without human involvement (Wei et al. 2019). IoT is also capable of machine learning, commonly known as artificial intelligence, which can lead to more utilized and dynamic data processes (Piccialli et al., 2019).

Previous bibliometric studies on IoT have been analyzed in relation to concepts or fields such as marketing (Miskiewicz, 2020), supply chain management and logistics (Rejeb et al., 2020), food safety (Bouzembrak et al., 2019), blockchain (Kamran et al., 2020), agriculture (Rejeb et al., 2022) and tourism (Suneel et al., 2022). In general, it has been observed that interest in IoT has increased rapidly, especially since 2010.

Machine Learning

Machine learning, recognized as a pivotal discipline within the field of artificial intelligence, empowers computer systems to acquire knowledge through the analysis of data. Its fundamental objective is to equip these systems with the capability to forecast future events by discerning patterns inherent in data. The potency of machine learning in handling copious datasets endows it with a broad spectrum of applications, spanning across diverse sectors such as business, science, healthcare, finance, and numerous others.

Machine learning can be categorized into two principal domains: supervised and unsupervised learning. Supervised learning entails the training of models using labeled data, whereas unsupervised learning is instrumental in extracting patterns and relationships from unlabeled data. Furthermore, advanced methodologies like deep learning have attained remarkable success, particularly in tasks demanding higher complexity.

Machine learning is poised to continue its transformative impact on the realms of science and industry, providing valuable tools for diverse applications including data mining, recommendation systems, automation, and the anticipation of future trends (Freeman et al., 2019). This technology harnesses algorithms to elucidate patterns and relationships embedded within datasets, making it indispensable for decision-making processes across various domains. Its significance is exemplified in applications encompassing natural language processing, robotics, image analysis, object recognition, and notably, the healthcare sector, where machine learning plays a pivotal role (Tzanakou et al., 2017). The overarching objective of machine learning is to facilitate automatic inference from data without human intervention (Dietterich, 1990).

Artificial Neural Networks (ANNs)

ANNs, often referred to simply as neural networks, represent a class of machine learning algorithms inspired by the structural and functional principles of the human brain. These networks are composed of interconnected computational units termed neurons, which collaboratively process and analyze data. ANNs' rising prominence in recent years is attributed to their capacity for continuous learning and improvement, rendering them particularly suited for tasks characterized by extensive data volumes.

The architecture of a neural network is often likened to that of the human brain. Analogous to the brain's neural networks, artificial neural networks consist of layers of interconnected neurons. The input layer serves to receive information from the external environment, while the output layer delivers the final result. Hidden layers situated in between execute the requisite computations to transform the input into the desired output. Each neuron within a neural network receives input from neurons in the preceding layer and applies a mathematical function, referred to as the activation function, to this input to generate an output. Subsequently, this output is propagated to the following layer of neurons until it reaches the output layer. The activation function is pivotal in determining the neuron's output based on its input.

The connections between neurons in a neural network are represented by numerical values known as weights, which specify the strength of the connection between two neurons. Over the course of training, these weights are iteratively adjusted to minimize the disparity between the output generated by the neural network and the desired output.

One of the most compelling attributes of ANNs is their ability to learn from extensive datasets. By fine-tuning the neuron weights, neural networks are capable of recognizing patterns and correlations in data, thus enabling precise predictions and classifications. This makes ANNs exceptionally valuable in applications such as image and speech recognition, natural language processing, and financial forecasting.

Several distinct types of ANNs exist, each characterized by its unique architecture and application. Feed-forward neural networks, the most elementary type, feature data flow from the input layer to the output layer without feedback loops. Convolutional neural networks, frequently employed in image recognition, involve multiple layers of convolution and pooling operations. Recurrent neural networks, on the other hand, are tailored for processing sequential data, including time series data and text.

Industry 5.0

The advent of intelligent manufacturing systems, as catalyzed by Industry 4.0, has underscored the pivotal role of human capabilities. Industry 5.0 seeks to build upon this foundational premise, placing its emphasis on a human-centric, sustainable, and adaptable approach to the realm of production. At its core, Industry 5.0 is dedicated to the amplification of productivity and efficiency, achieved through the synergistic utilization of human, robotic, and artificial intelligence technologies. Concurrently, it endeavors to rekindle awareness of societal sensitivities that were at times marginalized during the Industry 4.0 era. The essential competencies inherent in Industry 5.0 orbit the nurturing of inventive products and cutting-edge technologies. This conceptual framework has risen to paramount importance for both individual enterprises and the broader national economies, fortifying their competitive prowess (Balog & Demirova, 2021). In a more expansive context, Industry 5.0 embodies a concept that has matured to harness human ingenuity in harmonious coaction with potent, intelligent, and precision-driven machinery (Maddikunta et al., 2022).

Methodology

In the literature, there is no study in which the trends and development of research on the Internet of Things, machine learning, artificial neural networks and industry 5.0 are evaluated together with bibliometric analysis. In this context, in this study, the types of studies, keywords, authors, author collaborations, author collaborations, citations, and countries related to the research conducted in these fields were analyzed using bibliometric analysis method. Software programs such as VOSviewer, CiteSpace, RStudio's bibliometrics package, BibExcel, Gephi and Histcite are frequently used for bibliometric analysis, which is a statistical method used to reveal the publication trends of research in a healthier way (Rashmi & Kataria, 2021). In this study, VOSviewer (1.6.19) (Van Eck & Waltman, 2010) was used to visualize the clusters and interdisciplinary mapping of the field so that researchers from different disciplines can easily understand the findings obtained.

Data Selection and Data Collection

Studies on the Internet of Things, machine learning, artificial neural networks and industry 5.0 between 2007-2023 (limited to 27.09.2023) in the Web of Science (WoS) database were evaluated. Within the scope of the study, 545 articles identified in the WoS database, which is among the most comprehensive databases in terms of articles in multidisciplinary fields, scanned in SSCI, SCI and ESCI, covering business categories, open access and published in English, open access, were evaluated.

Search Criteria

Firstly, articles published in WoS indexed journals with the keywords "Internet of Things" "Machine Learning" "Artificial Neural Network" and "Industry 5.0" in their titles and/or abstracts were searched in Web of Science Categories business. 545 English articles in SSCI, SCI (SCI-E) and ESCI, which are considered as the most prestigious indexes, were recorded to be included in the analysis.

Results and Discussion

Number of Publications by Year

The total number of studies in the WoS database with the keywords "Internet of Things" "Machine Learning" "Artificial Neural Network" and "Industry 5.0" is 545 as shown in Table 1 and Figure 1. It is seen that the first study record belongs to 2007. It can be stated that the studies on the field have continued to increase since 2016.

Keyword Analysis

Figure 2 shows all subject areas related to the keywords Internet of Things, machine learning, artificial neural networks and industry 5.0. In the bibliometric analysis with VOSviewer, 3 different mapping visualizations were analyzed: network visualization Figure 2, layered visualization Figure 3 and density visualization Figure 4.

Table 1. Distribution of studies by years

Year	Frequency	Percentage %
2007	1	0,0018
2010	1	0,0018
2012	3	0,0055
2013	3	0,0055
2014	4	0,0073
2015	7	0,0128
2016	11	0,0202
2017	20	0,0367
2018	34	0,0624
2019	43	0,0789
2020	80	0,1468
2021	116	0,2128
2022	128	0,2349
2023	94	0,1725
Total	545	1,0000

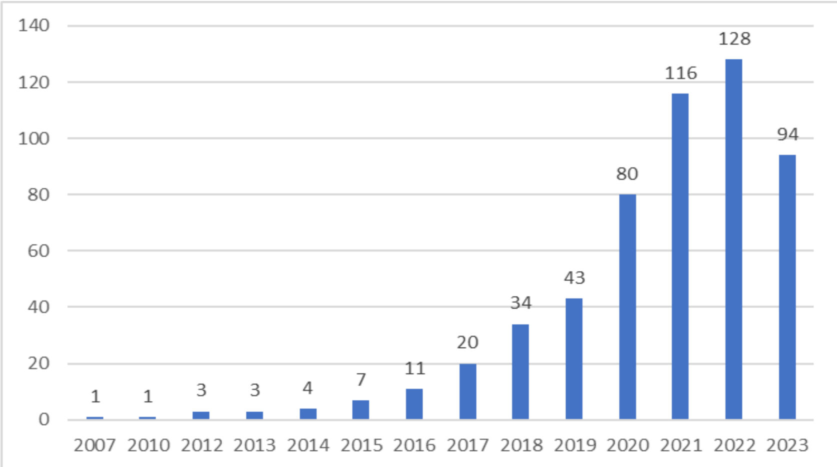

Figure 1. Number of studies by year

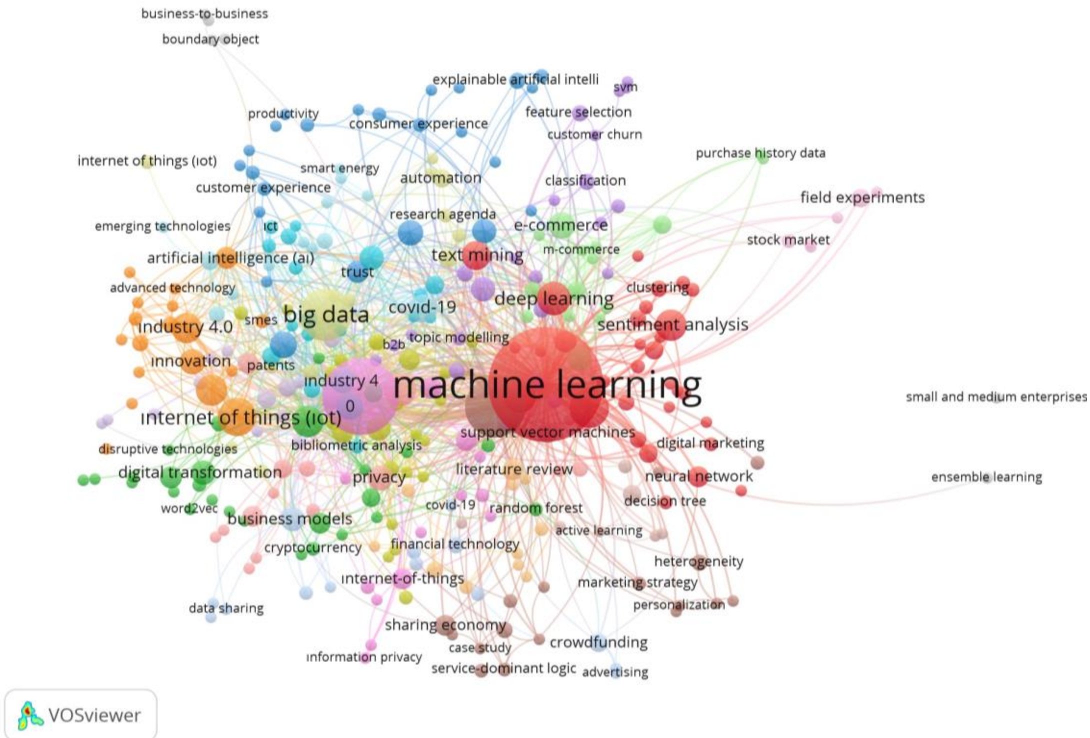

Figure 2. Network visualization map of keywords

Keywords used 2 times or more in 545 articles scanned in the WoS database were analyzed. According to these criteria; 314 keywords were reached from 2108 keywords; 21 clusters were evaluated as 1693 links and total link strength was 2144. Figure 2 shows that the most frequently used keywords in the 21 clusters are machine learning (178), internet of things (80), artificial intelligence (50), big data (38), natural language processing (21). Figure 3 indicates that machine learning and internet of things clusters are more frequently analyzed in recent years when compared to industry 4.0 and big data.

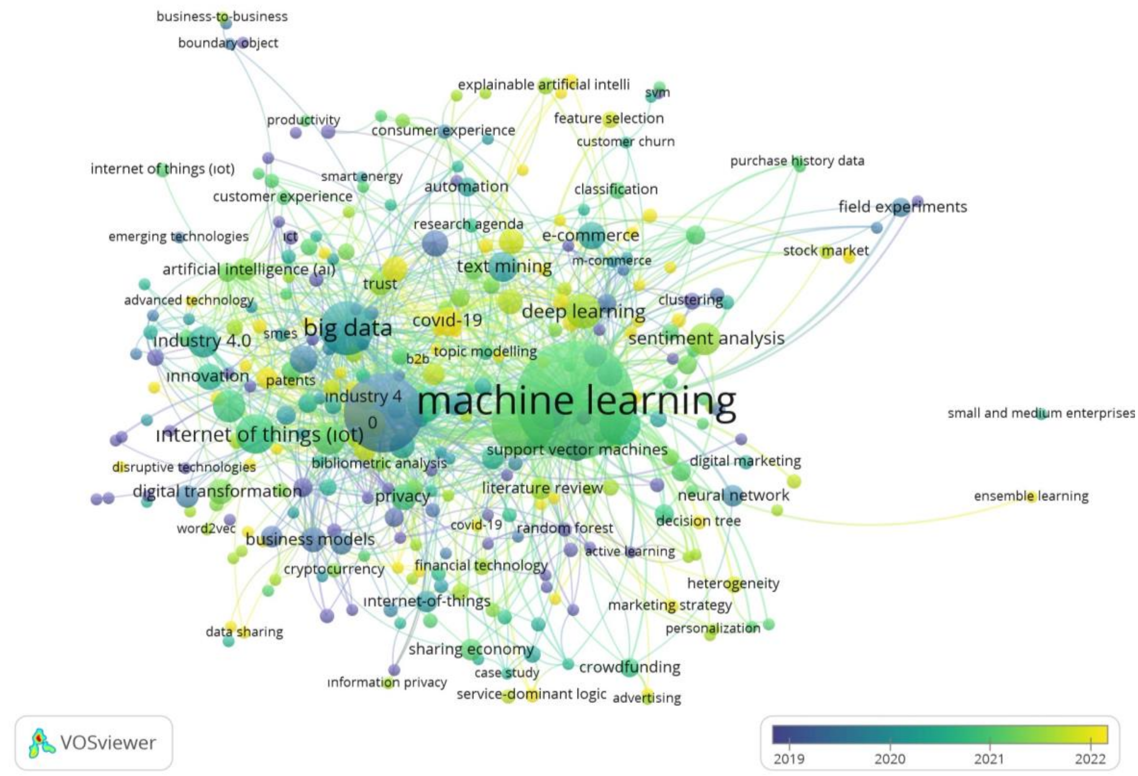

Figure 3. Layered visualization of keywords

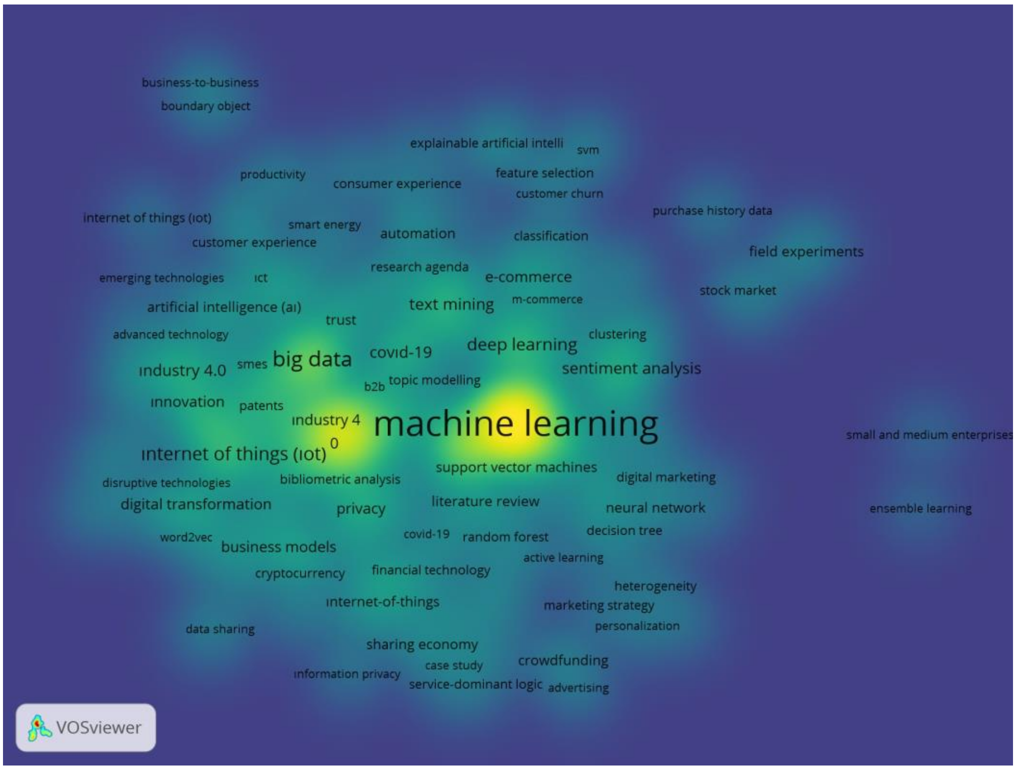

Figure 4. Density visualization map of keywords

According to Figure 4, the keywords with the highest linking power are machine learning (395), internet of things (188), artificial intelligence (151), big data (135), natural language processing (70). Clusters that are interconnected with each other constitute the connection foci of related clusters. While the proximity of the elements to each other expresses the strength of the relationship, the distance means that there is not enough relationship or similarity. There is no relationship between elements consisting of keywords that are not connected to each other by link strength (Dogan et al., 2021).

Co-Author Analysis

Within the scope of the co-author analysis, 1355 out of 1644 authors were evaluated, provided that the author has at least 1 article and at least 1 citation (Figure 5). In this context, the co-authors with the highest total link strength are Dwivedi and Yogesh (22); Rana and Nripendra (p.17); Hauser and John (15).

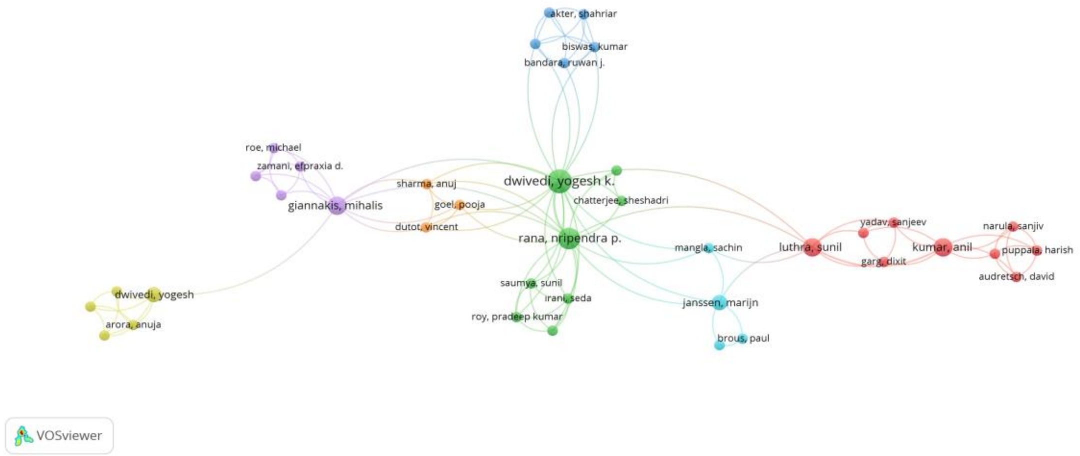

Figure 5. Co-author analysis map

Author Citation Analysis

When the author citation analysis was evaluated with at least 1 study and at least 2 citations, 568 authors were evaluated. In this context; Gretzel, Ulrike 672 is seen as the most cited author (Figure 6).

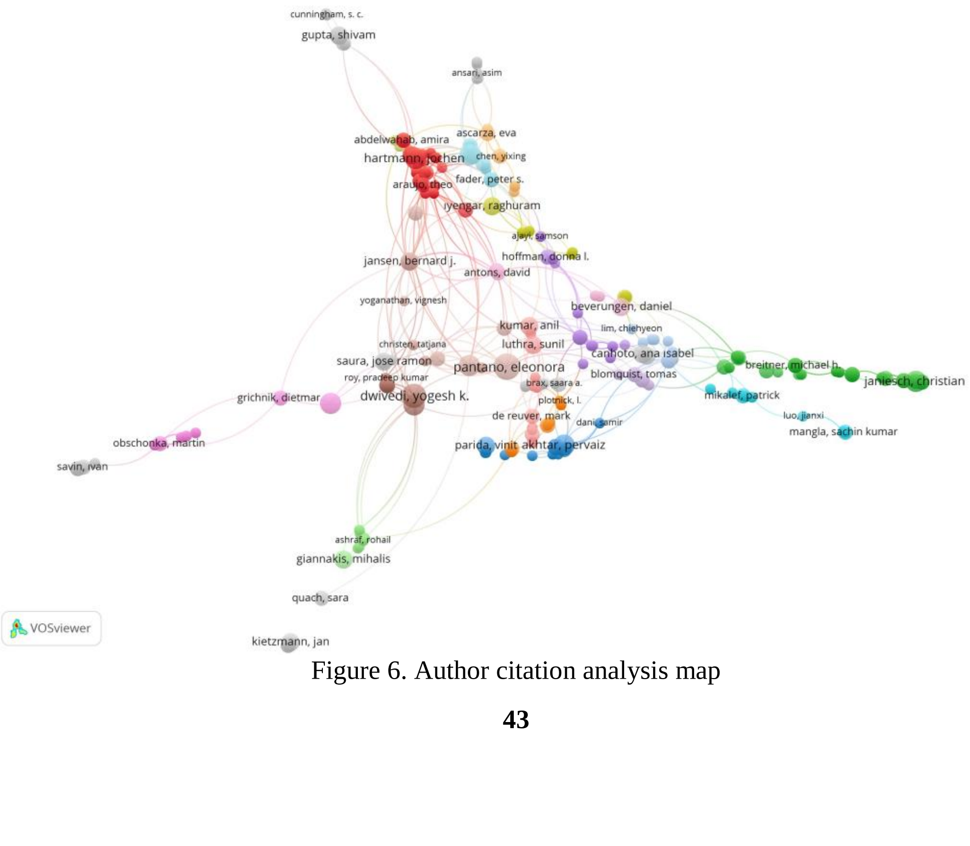

Figure 6. Author citation analysis map

Source Citation Analysis

Regarding the source citation analysis, 69 out of 133 sources were evaluated when limited to at least 2 studies and at least 2 citations (Table 2). Source citation analysis map is shown in Figure 7.

Table 2. Journals in which the Articles are Mostly Published, Number of Articles and Citations

No	Article	F	Citation
1	Technological Forecasting and Social Change	62	2105
2	Journal of Business Research	37	1544
3	Electronic Markets	30	1473
4	Marketing Science	14	776
5	Long Range Planning	2	646
6	Business Horizons	8	517
7	Journal of Retailing and Consumer Services	7	450
8	IEEE Transactions on Engineering Management	24	410
9	Journal of Consumer Research	3	331
10	Journal of Marketing Management	5	285

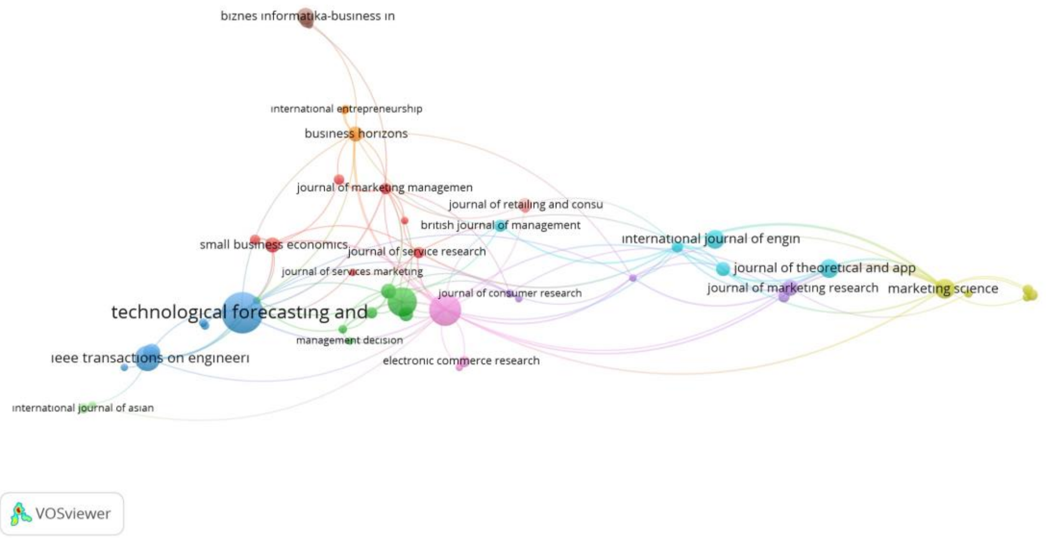

Figure 7. Source Citation Analysis Map

Table 3. Number of studies and citations by country

No	Country	Documents	Citations	Total Link Strength
1	England	117	3927	230
2	USA	105	3834	214
3	Germany	66	2579	147
4	Italy	48	1913	96
5	Australia	31	1311	83
6	India	42	1027	77
7	Peoples R China	42	851	61
8	Netherlands	35	844	103
9	South Korea	16	837	29
10	Finland	28	801	71
11	France	27	792	77
12	Sweden	14	659	25
13	Scotland	7	657	12
14	Wales	9	619	37
15	Austria	11	492	33
16	Norway	8	377	11
17	Spain	24	364	27
18	Canada	21	357	32
19	Cyprus	2	350	10
20	Taiwan	11	332	29

Country Citation Analysis

Regarding the number of country studies and citations, it was analyzed as at least 1 study and at least 1 citation. As a result of the analysis, 51 out of 74 countries that meet the specified criteria were evaluated in this category. The top 20 countries, number of articles and citations are shown in Table 3. The ranking is based on the number of citations.

When the number of country studies and citations are evaluated; the top countries are England, USA, Germany, Italy, Australia, India, Peoples r China, Netherlands, South Korea, Finland (Figure 8).

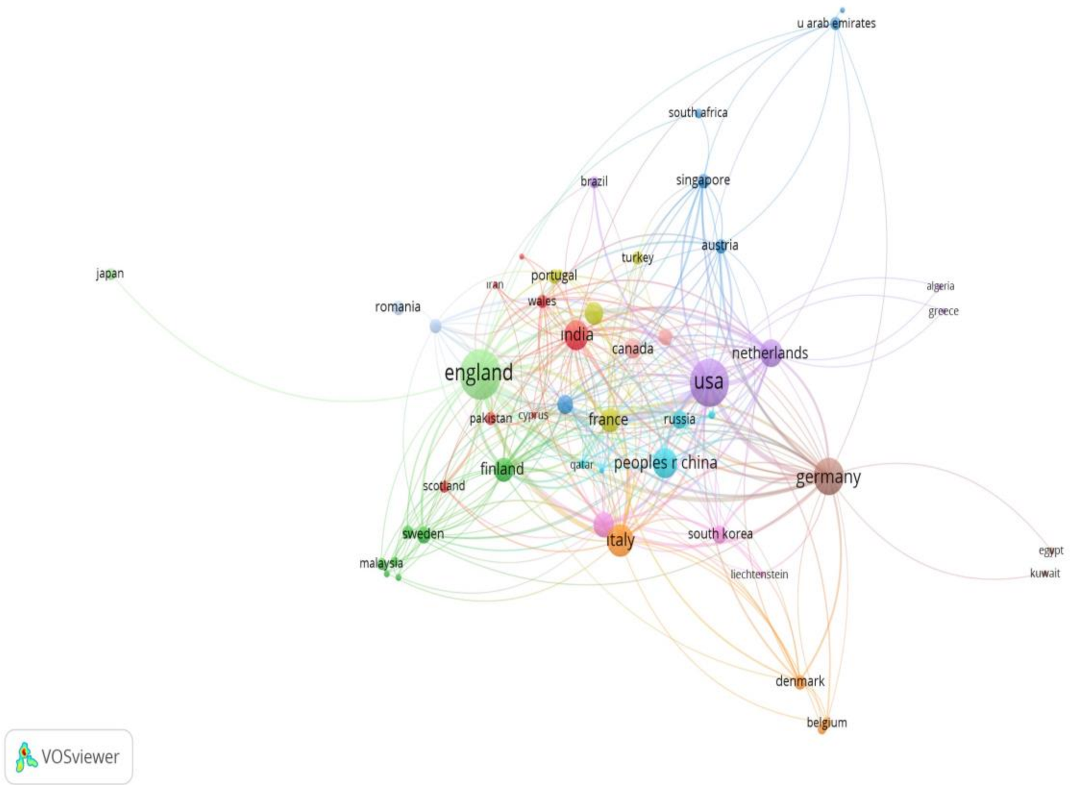

Figure 8. Visualization of studies by country

Institution Citation Analysis

Regarding the number of institutional citations, 176 out of 877 organizations were evaluated when the institution was limited to at least 2 studies and at least 2 citations. The top 10 institutions are as follows; York Univ, Rutgers State Univ, Southwestern Univ Finance & Econ, Swinburne Univ Technol, Univ Southern Calif, Osnabruck Univ, Shanghai Lixin Univ Accounting & Finance, Univ Manchester, Rmit Univ, Charles Sturt University (Table 4). Figure 9 shows the institution citation analysis map.

Table 4. Number of articles, citations and total link strength by institutions

No	Organization	Documents	Citations	Total Link Strength
1	Univ Queensland	4	694	16
2	Virginia Polytech Inst & State Univ	2	679	9
3	Swansea Univ	9	619	34
4	Friedrich Alexander Univ Erlangen Nurnberg	2	478	8
5	Univ Turin	2	443	7
6	Univ Hamburg	5	407	49
7	New York Univ	4	401	21
8	George Washington Univ	2	390	14
9	Lulea Univ Technol	4	362	7
10	Univ Vaasa	6	362	19

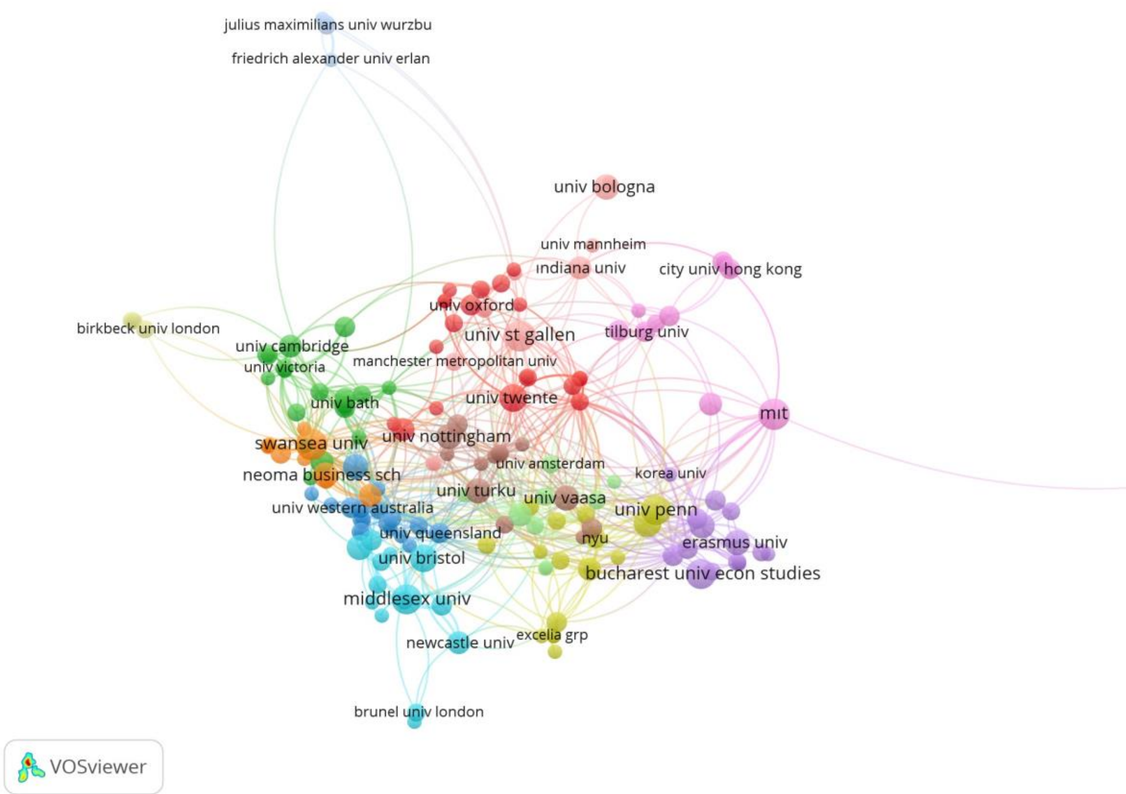

Figure 9. Institution citation analysis map

As analyses demonstrate, the concepts of Internet of Things (IoT), Machine Learning, Artificial Neural Networks and Industry 5.0 has been studied by various researchers in a broad range of countries, publishing their works in a variety of journals. The main purpose of these analyses is to provide future researchers with inspiration to produce their own research and guide them in this endeavor.

Conclusion

In conclusion, the convergence of Internet of Things (IoT), Machine Learning, Artificial Neural Networks, and the emergence of Industry 5.0 is ushering in a new era of possibilities in business research. These technologies have already transformed the way we collect, analyze, and utilize data, offering businesses unprecedented insights and efficiencies. As we move forward, it is essential for researchers, businesses, and professionals to stay at the forefront of these trends and adapt to the ever-evolving landscape. The integration of IoT devices with ML and ANNs is enhancing our ability to process vast amounts of data, extract meaningful patterns, and make real-time decisions. This synergy empowers businesses to optimize their operations, enhance customer experiences, and drive innovation. The advent of Industry 5.0, which emphasizes human-technology collaboration and the reintegration of physical and digital worlds, will further revolutionize industries and open up new avenues for research.

In this study, a bibliometric analysis was conducted to provide insight into the prevalence of the concepts of Internet of Things (IoT), Machine Learning, Artificial Neural Networks, and Industry 5.0 in the field of business research. A total of 545 articles were identified in the WoS database and for the purposes of the research, study types, keywords, authors, author collaborations, citations, and countries of articles published on these topics in the Web of Science (WoS) database between 2007-2023 (limited to September 27th, 2023) were analyzed based on the criteria that the articles were open access, in English, categorized under “business” and indexed in Social Sciences Citation Index (SSCI), Science Citation Index (SCI), and Emerging Sources Citation Index (ESCI). A bibliometric analysis was conducted by employing the VOSviewer tool and the results of the analysis demonstrated that studies in this field have continued to increase since 2018. The top five most frequently used keywords with the highest connection power were machine learning, Internet of Things, artificial intelligence, big data, and natural language processing, respectively. The journals with the highest number of articles and citations were Technological Forecasting and Societal Change, Journal of Business Research, Electronic Markets, and Marketing Science. In terms of the number of articles and citations by country in these fields, England, the USA, Germany, Italy, and Australia ranked the highest. This research provides information on latest technologies, identifies gaps and research opportunities in the field, and contributes to shaping future research paths in the field.

The future of business research lies in harnessing the transformative power of IoT, Machine Learning, Artificial Neural Networks, and Industry 5.0. By embracing these trends, businesses can gain competitive advantage, foster innovation, and contribute to the ongoing evolution of their own industries. As the digital and physical realms become more interconnected, researchers and businesses will play a pivotal role in shaping the way people work, produce, and interact in the years to come. Therefore, staying informed, adaptable, and ethically responsible in this technological journey will be key to unlocking the full potential of these cutting-edge tools in business research.

Recommendations

Authors of this study recommend future business researchers in the fields of IoT, Machine Learning, Artificial Neural Networks, and Industry 5.0 to examine the analyses and acquire guidance and insight into the topics they may focus on in their own studies and also find journals, countries and other authors that may be interested in their work.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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