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Bibiliometric Analysis of the Scientific Production of Deep Learning and Big Data

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Abstract*:* This article presents a bibliometric analysis of the scientific production on deep learning and big data worldwide. Using the R package and the associated biblioshiny, the study analyzed 456 research articles published in Scopus between 2003 and 2023. The study applied performance analysis, keyword analysis, and thematic analysis. China is the country with the highest production (536 publications) followed by India (260 publications), likewise, most of these collaborations occur from China to the United States, Hong Kong, Sweden, Australia, Pakistan, Saudi Arabia and other countries. The rapid growth of the keywords Deep learning, big data, learning systems and data analytics; It demonstrated the interest of researchers, industry professionals, governments, investors and all other key players in the need to optimize information processing with artificial intelligence features. Finally, the thematic analysis shows that the predictive improvements through Big Data will be applied to traffic management, medical care and the forecasting of economic trends. As future work, Data Masking should be considered as a security measure, incorporation of multi-cloud architecture, Data Fabric and Data Mesh, to manage and improve the exchange of data from different sources.

Keywords: *Artificial intelligence, bibliometric analysis, big data, deep learning*

1. Introduction

Undoubtedly, the era of Big Data has marked a before and after in the way in which contemporary societies generate, store and process information. It is estimated that close to 90% of global data was produced in the last few years alone, illustrating the dizzying pace with which humanity is creating and sharing information. This explosion of data, while offering unprecedented opportunities, also poses significant challenges. The vastness of these data sets brings with it an inherent complexity, making their analysis and understanding require advanced techniques and specialized tools. Faced with such a scenario, an inescapable question arises: how can we efficiently navigate this ocean of data and extract valuable information from it? This is where Data Science is positioned as an essential discipline in the 21st century. As the challenges of Big Data grow, Data Science evolves to develop tools and methodologies that allow not only to analyze, but also to interpret and take advantage of this information in an optimal way. The ramifications of this phenomenon are vast. From industrial and technology sectors to medicine, education and government, the ability to manage and analyze large data sets is essential to drive innovation, improve decision making and anticipate future trends. However, the rise of Big Data also raises ethical and privacy concerns that need to be approached with caution [1].

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The characteristics of Big Data are focused on the 4VS, volume, speed, variety and veracity. Where Volume implies that the data needed to solve the problem must be very large in size, and behave in an increasing way. Speed implies that decision making based on big data analysis has to happen in real time, so the data and models needed to make that decision have to be processed very quickly. On the other hand, Variety implies that the data comes from various formats and that they must be processed jointly for decision making. Finally, Veracity implies that there is no uncertainty in the data necessary for decision making, however, it is necessary to take into account that more available data sources do not necessarily guarantee their fidelity [2].

Deep Learning, a subcategory of machine learning, has revolutionized our ability to understand and classify complex data. It is based on the use of artificial neural networks, which emulate the structure of the human brain through interconnected nodes, known as neurons. These neurons not only receive and process information, but also transmit it to other neurons for further analysis. A distinctive feature of these neural networks is their multilayer structure. Each layer specializes in decoding specific features of the data. During the training process, the model parameters are updated to minimize a value called "loss", which is a metric that quantifies the discrepancy between the network prediction and the actual data. In simple terms, a lower loss value indicates that the neural network is performing its task efficiently [3].

Based on what was detailed in previous lines, the main objective of this paper is to carry out a bibliometric analysis of the current state of deep learning and Big Data research worldwide.

2. Methodology

2.1. Search strategy

The research has an approach with bibliometric methodology. Data for this review were extracted from the SCOPUS database on 9 August 2023 using the following search terms, (TITLE ("deep learning" AND "big data")). SCOPUS was chosen in this study because it covers a wide range of journals and is more comprehensive than other databases. Web of Science was not included because 99% of the journals indexed in this database are already indexed in SCOPUS. Meanwhile, Google Scholar was not considered for the study because it does not provide the detailed information that network analysis, such as the bibliometric approach, demands.

The process followed is based on the PRISMA methodology (Prevention and Recovery Information System for Monitoring and Analysis) that is part of the studies based on systematic reviews [4], as represented in the following flowchart (Fig. 1).

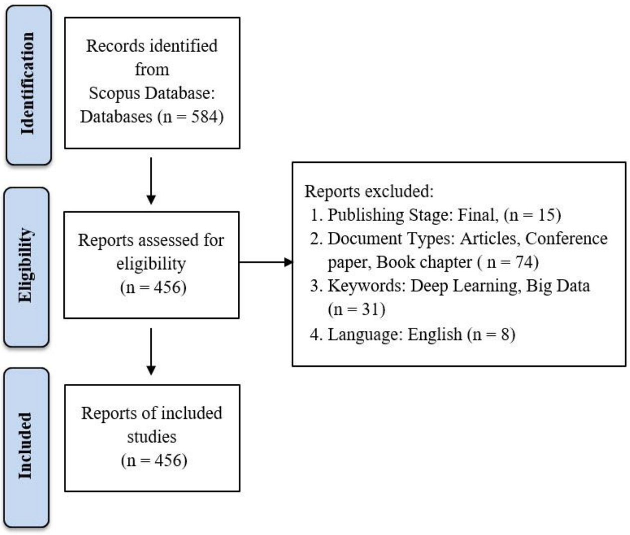

Fig. 1. Flowchart until final records are obtained according to the PRISMA model

We have located 456 research articles in the Scopus database that meet the criteria of publication stage, document type, keyword, and language. These logs have been reduced using the features mentioned above. Articles, conference articles and book chapters are considered. Only full manuscripts that have been published were considered, while 15 studies that are in the communication stage or are being prepared for publication were discarded. Eliminated 74 publications referring to review, onference review, book and other documents. We excluded 31 articles due to the keyword other than "deep learning" or "big data". Since they were only interested in articles written in English at this level, we had to remove 8 reports based on the language they were written in.

2.2. Analysis of data

Data analysis was performed based on the methods of Arifah et al. [5]. Selected articles were retrieved and systematically ordered using Microsoft Excel in comma-separated values (CSV) format.

To perform the bibliometric analysis, the "bibliometrix R-package" software was used. The R package is open source software created by Aria and Cuccurullo that provides a set of tools for conducting quantitative research in bibliometrics [6]. All the data (CSV) were imported into the web interface application (Biblioshiny for bibliometrix) from which the reports for the bibliometric analysis were generated.

3. Results

3.1. Evolution of scientific production

In Fig. 2, the production of 456 research papers distributed over ten years (2014 to 2023) is shown. In 2014, the publication of 1 article began; from 2016 to 2019 there was a boom in the publication of articles, going from 10 to 83 publications respectively; during the years 2020 and 2021, the production of articles decreased to 68; and by the year 2022 there was an increase to 111 published articles because there were many technological advances that changed the way companies and all other industries work because everyone wanted to take advantage of this advance and work in a simpler and more sophisticated way.

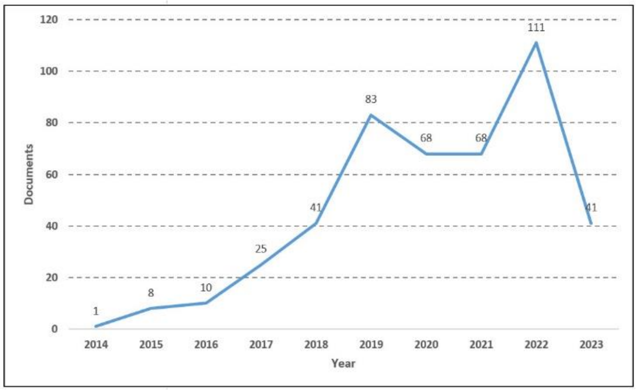

Fig. 2. Evolution of the annual number of publications

3.2. More productive journal

The top 20 journals collectively published 35.44% of all publications, demonstrating a sparse distribution. Having IEEE access (15) and Lecture notes in computer science (including subseries lecture notes in artificial intelligence and lecture notes in bioinformatics) (11) the sources with the largest number of articles available, followed by Lecture notes in networks and systems (9) , Computational intelligence and neuroscience (8), Lecture notes in electrical engineering (8), Lecture notes on data engineering and communications technologies (8), Advances in intelligent systems and computing (6), Communications in computer and information science (5), Applied sciences (Switzerland) (4), Computers and electrical engineering (4), International journal of innovative technology and exploring engineering (4), Journal of advanced research in dynamical and control systems (4), Proceedings of spie - the international society for optical engineering (4), Scientific programming (3), Concurrency and computation: practice and experience (3), Economics, management, and financial markets (3), Future generation computer systems (3), International journal of environmental research and public health (3), Journal of big data (3) and Journal of intelligent and fuzzy systems (3).

3.3. Most relevant authors

In Fig. 3, the 20 most relevant authors are shown according to the number of publications in Scopus. The authors with the most research articles are Wang Y, Wang Z, Wang J, Zhang Y, Khoshgoftaar Tm, Li X, Wang W, Chen J, Li L, Li Y, Lu X, Tamura Y, Yamada S, Zhang J, Bedi P, Chen X, Goyal Sb, Guo J, Johnson Jm, and Kumar A. Future researchers gain good insight by reviewing the works of these prominent authors. It helps them better understand the topic and think about the methodology of their study.

In Fig. 4, a three-field diagram of top authors and countries based on popular research keywords is shown, based on Sankey diagrams [6]. China arguably has the most publications and its researchers write the most on deep learning, big data, and machine learning, and this topic is very popular among scholars in Japan, the United States, and India.

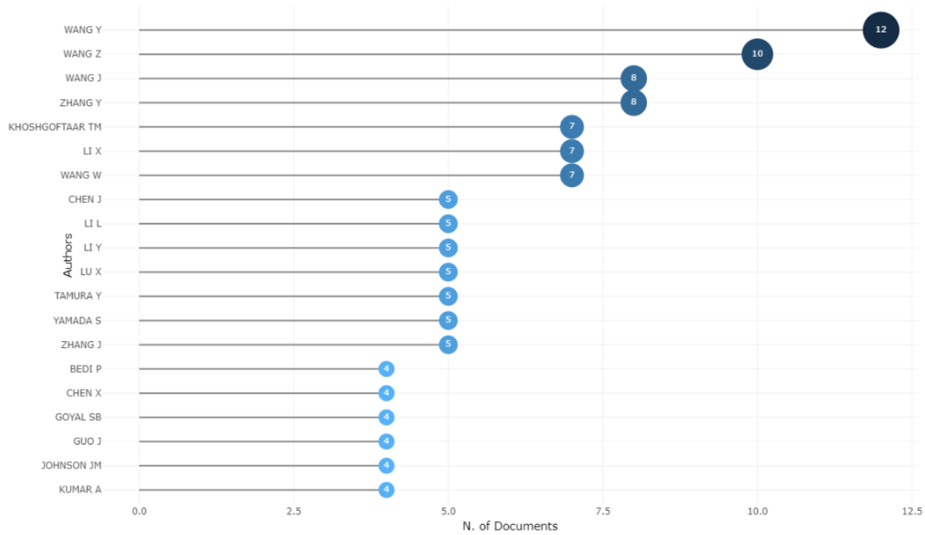

Fig. 3. Most relevant authors according to the number of publications in Scopus

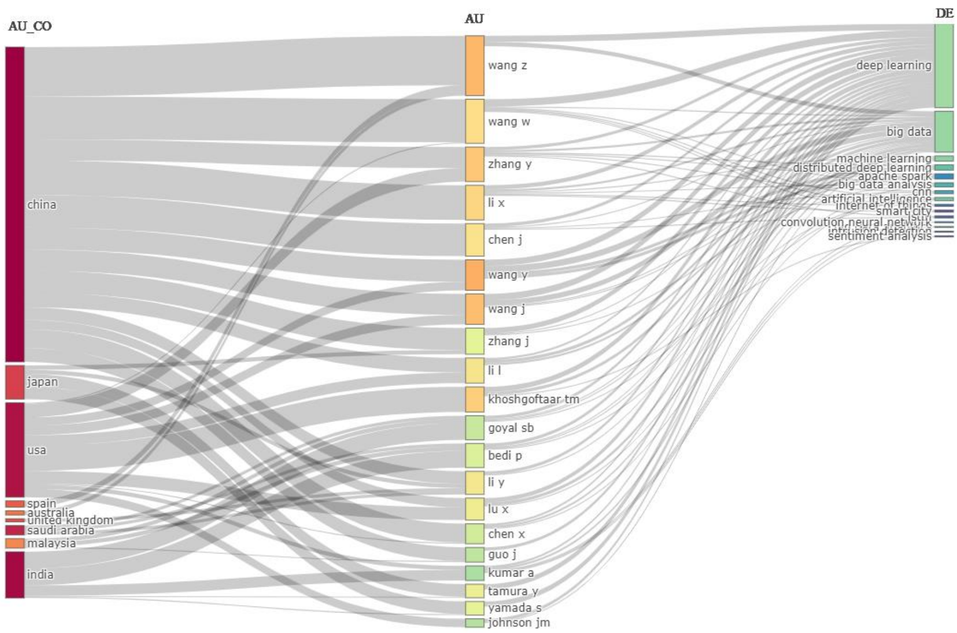

Fig. 4. Three fields graph (countries, authors and keywords)

3.4. Scientific production by countries

Regarding the global production of "deep learning and big data" publications, China has a very high interest in research (536 publications), followed by India (260 publications), the United States (209), South Korea (67), Saudi Saudi Arabia (53), Pakistan (46), Italy (39), Japan (37), Canada (27) and the United Kingdom (27) among the 10 countries with the highest scientific production.

In Fig.5, the collaborative relationships between continents that are increasingly frequent are shown; Most of these collaborations occur from China to the United States (9), Hong Kong (4), Sweden (3), Australia (2), Pakistan (2), Saudi Arabia (2) and other countries. In addition, the second largest partner (India) collaborated with the United States (6), Malaysia (5), Saudi Arabia (3), Peru (2), Korea (2), Bangladesh (2), Australia (2) and others; Likewise, the third main collaborator (United States) collaborated with Korea (2), Pakistan (2), Romania (2), Saudi Arabia (2) and other countries.

3.5. Most Cited Documents Worldwide

Table 1 shows the results of the 15 most cited documents worldwide on Deep Learning and Big Data [7-21], in which LV Y, 2015, IEEE TRANS INTELL TRANSP SYST leads with 2245 citations in total (249.44 per year), NAJAFABADI MM, 2015, J BIG DATA with 1462 citations in total (162.44 per year); HOSSAIN MS, 2019, INF FUSION with 255 total citations (51 per year); WANG J, 2017, IEEE INFOCOM PROC with 215 total citations (30.71 per year); WAHEED H, 2020, COMPUT HUM BEHAV with 203 total citations (33.33 per year); Since these articles are the most referenced in research, it can be said that it is a good indicator to show that researchers are producing a large number of works on Deep Learning and Big Data, however, it would be more optimal if the citations are from more recent documents.

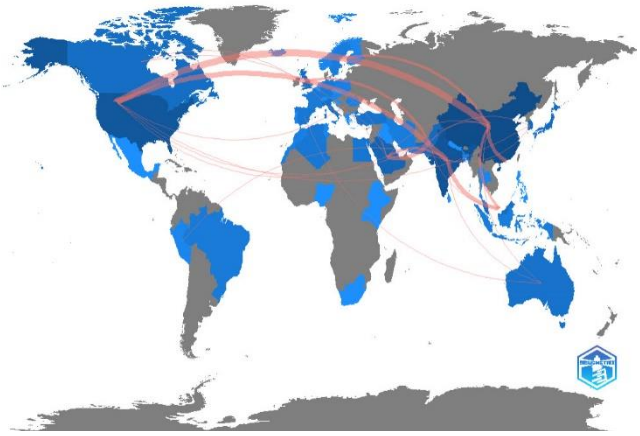

Fig. 5. Country Collaboration Map

Table 1. Top 20 of the most cited articles worldwide

Paper	DOI	Total Citations	TC per Year
LV Y, 2015, IEEE TRANS INTELL TRANSP SYST	10.1109/TITS.2014.2345663	2245	249.44
NAJAFABADI MM, 2015, J BIG DATA	10.1186/s40537-014-0007-7	1462	162.44
HOSSAIN MS, 2019, INF FUSION	10.1016/j.inffus.2018.09.008	255	51.00
WANG J, 2017, PROC IEEE INFOCOM	10.1109/INFOCOM.2017.8057090	215	30.71
WAHEED H, 2020, COMPUT HUM BEHAV	10.1016/j.chb.2019.106189	203	50.75
CHAE S, 2018, INT J ENVIRON RES PUBLIC HEALTH	10.3390/ijerph15081596	200	33.33
LI Y, 2019, METHODS	10.1016/j.ymeth.2019.04.008	196	39.20
CHATTERJEE A, 2019, COMPUT HUM BEHAV	10.1016/j.chb.2018.12.029	194	38.80
SOHANGIR S, 2018, J BIG DATA	10.1186/s40537-017-0111-6	191	31.83
NING C, 2019, COMPUT CHEM ENG	10.1016/j.compchemeng.2019.03.034	182	36.40

HASSAN MM, 2020, INF SCI	10.1016/j.ins.2019.10.069	159	39.75
LIU J, 2020, INF FUSION	10.1016/j.inffus.2019.06.016	132	33.00
FRANCIS J, 2019, MANUF LET	10.1016/j.mfglet.2019.02.001	129	25.80
JAN B, 2019, COMPUT ELECTR ENG	10.1016/j.compeleceng.2017.12.009	117	23.40
FAKER O, 2019, ACMSE - PROC ACM SOUTHEAST CONF	10.1145/3299815.3314439	112	22.40

3.6. Keyword analysis

It is necessary to analyze the keywords because it provides an idea about the main topics that are being discussed in the research area [22]. The Word Cloud (Fig. 6) shows the words that have been used frequently in the research area. The most representative trends are "deep learning" and "big data" respectively, growing rapidly in the last 10 years.

Fig. 7 shows the growth of the top keywords over the years. The top ten (10) keywords are deep learning, big data, learning systems, learning algorithms, data mining, data analytics, deep neural networks, data handling, and forecasting classification (of information).

Fig. 6. Word cloud

The rapid growth of the words demonstrated the interest of researchers, industry professionals, governments, investors and all other key players in the need to optimize information processing with artificial intelligence features.

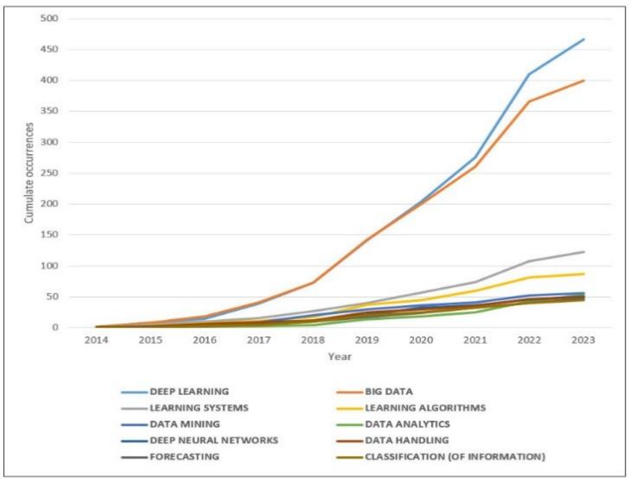

Fig. 7. Word growth

3.7. Thematic analysis

The thematic map provides information on patterns, trends, seasonality, and outliers for the study topics. Thematic maps are presented in a more understandable way as the themes are divided into four quadrants according to their centrality (on the X axis) and density (on the Y axis). The level of connectivity between topics is measured by centrality, which is significant in a given domain. Density, on the other hand, measures how much a cluster has progressed in terms of cohesion within the cluster [23]. As categorized in Fig. 8, there are four main topic classifications (Motive Topics, Core Topics, Niche Topics, and Emerging Topics).

Motor themes are themes that can influence the field of study and are well established. The five themes (big data, deep learning, learning systems, learning algorithms and data mining) are fundamental to “deep learning and big data”. Research on one topic has a direct impact on the other. For example, in the field of medical diagnostics, computational deep learning methods, combined with the abundance of medical data, present unprecedented opportunities for accurate and efficient electronic diagnosis; Thus, in order to forecast the spread of the COVID-19 pandemic in one or several countries in advance, statistical and deep learning models were used, which included the autoregressive integrated moving average (ARIMA) model with a seasonal perspective, memory long-term (LSTM) and Prophet models [24].

The basic topics (convolutional neural network, machine learning, algorithm, prediction) are interdisciplinary topics, involving many fields of study, including medicine, education, construction, finance, robotics, materials science, agribusiness , biology, cybersecurity, astronomy among others. Basic topics cannot be investigated without considering more than one field of study. This prompted the need for research collaborations between various experts to carry out a comprehensive investigation as shown in Fig. 5.

Niche topics (humans, controlled study, and data analysis) refer to specialized topics among researchers or institutions. For example, MIT has created the online course Data Science and Big Data: Decisions based on data; with the purpose of applying data science techniques for business decision making with artificial intelligence, based on recommender systems, regressions, network models and graphs, anomaly detection, machine learning and Big Data analysis. Data.

Emerging themes, or obsolete themes, are themes that have the potential for further development. In the current study the open source software, open systems and bug tracking system could be considered obsolete topics.

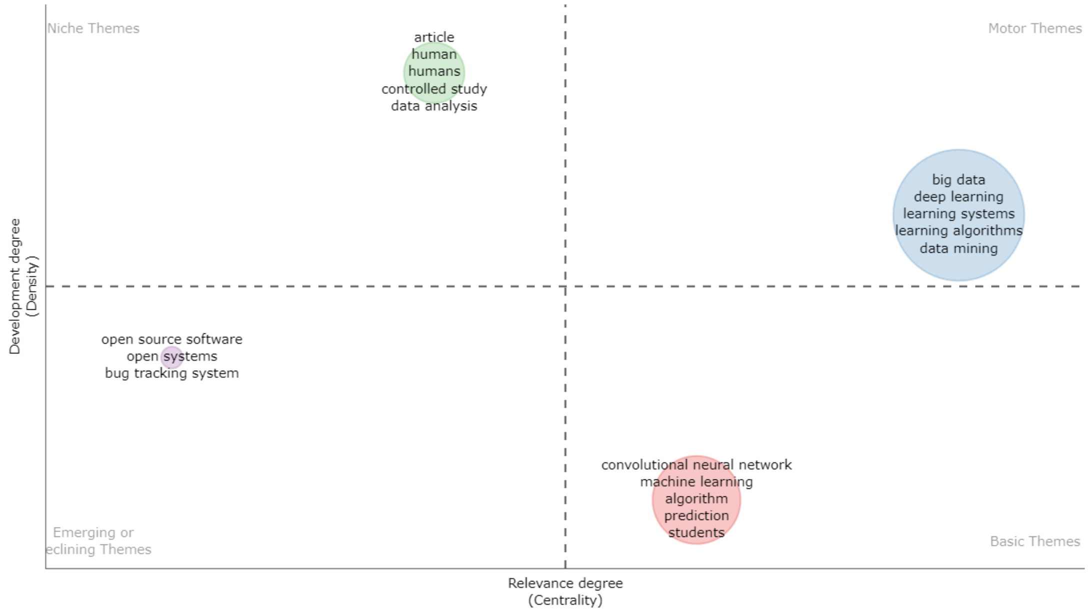

Fig. 8. Thematic map

4. Current challenges and future studies

Deep Learning has shown enormous success in many fields, but it still faces some critical challenges. One of them and one that represents a challenge is the need for large labeled training data sets, which can be difficult to obtain in some domains [25]. On the other hand, non-standardized data, lack of model interpretability, difficulty in estimating uncertainty, large model size, overfitting, and gradient problems such as gradient disappearance/explosion are others. notable challenges. Some solutions have been proposed, such as transfer learning, data augmentation, model compression, dropout regularization, and architectural innovations such as residual connections [26]. Likewise, the volume of network and Internet traffic is expanding daily, and threats to the security of networks, the Internet, websites and organizations are growing, so detecting intrusions in a data environment is much needed [27].

While deep learning has come a long way, the next waves of progress will likely come from improvements such as semi-supervised learning [28] to reduce data dependency, more robust model architectures to improve generalizability [29], leveraging the cloud and specialized hardware for efficient scaling, device deployment with optimizations for edge hardware [30], improved methods for model interpretation and uncertainty quantification [31], new attention and locking mechanisms to increase performance of the model, and techniques to increase the robustness outside the distribution. Testing of methodologies to address model fragility and underspecification will also be critical as deep learning is implemented in more mission-critical real-world applications. The field still has a lot of innovation ahead of it in terms of modeling techniques and evaluation practices to make deep learning more useful, reliable, scalable, and interpretable.

As in Deep Learning, one of the main challenges facing Big Data is dealing with the massive amounts of heterogeneous data that is generated, which is known as the "new data gap" [32]. Different data sources produce different formats, different resolutions, and need different types of storage. There is a need for better methods to efficiently integrate, process, and analyze these large, varied data sets to extract useful information. It is recommended to take advantage of cloud computing platforms and develop specialized techniques such as data fusion, downscaling, and data mining to help process large observational data that have been used [33]. [34] points out that there are several engineering challenges around the sources of large amounts of data that need to be taken into account, especially in terms of sensor integrability, connectivity and metrological performance, in order to obtain reliable measurement systems and precise.

To take advantage of all the benefits offered by Big Data, an interdisciplinary collaboration is required that considers computer science, statistics, and other disciplines related to the research topic. With careful implementation, big data can usher in an era of data-driven and evidence-based personalized care. Data Masking as a security measure [35], incorporation of multi-cloud architecture, Data Fabric and Data Mesh [36, 37], to manage and improve the exchange of data from different sources. Technical, regulatory, and organizational challenges around data quality, privacy, and talent development must be overcome through sustained research and investment [38].

Therefore, companies must adopt these technologies if they consider maintaining themselves over time, educational institutions in the same way, adapt their curricula in order to create skills in future professions, states provide the relevant regulations in order to protect the user. and finally the users who must know the pros and cons of their life in the networks. From the emerging themes, more research is required to break the current technological barriers.

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