

Research Article

Deep Learning Algorithms and Multicriteria Decision-Making Used in Big Data: A Systematic Literature Review

Mei Yang ¹, Shah Nazir ², Qingshan Xu,³ and Shaukat Ali⁴

¹School of Politics and Public Administration, Collaborative Innovation Center of National Security Research, Xinjiang University, Urumuqi 830046, China

²Department of Computer Science, University of Swabi, Khyber Pakhtunkhwa, Pakistan

³School of Management and Economics, Beijing Institute of Technology, Beijing 100081, China

⁴Department of Computer Science, Islamia College University, Peshawar, Pakistan

Correspondence should be addressed to Mei Yang; yangmei@xju.edu.cn

Received 28 June 2020; Accepted 20 July 2020; Published 17 August 2020

Guest Editor: M. Irfan Uddin

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The data are ever increasing with the increase in population, communication of different devices in networks, Internet of Things, sensors, actuators, and so on. This increase goes into different shapes such as volume, velocity, variety, veracity, and value extracting meaningful information and insights, all are challenging tasks and burning issues. Decision-making based on multicriteria is one of the most critical issues solving ways to select the most suitable decision among a number of alternatives. Deep learning algorithms and multicriteria-based decision-making have effective applications in big data. Derivations are made based on the use of deep algorithms and multicriteria. Due to its effectiveness and potentiality, it is exploited in several domains such as computer science and information technology, agriculture, and business sector. The aim of the proposed study is to present a systematic literature study in order to show the applications of deep learning algorithms and multicriteria decision approaches for the problems of big data. The research finds novel means to make the decision support system for the problems of big data using multiple criteria in integration with machine learning and artificial intelligence approaches.

1. Introduction

With the increase in population, communication of different devices in networks, Internet of Things, sensors, actuators, and so on, the size of data is increasing. This increase goes into different shapes such as volume, velocity, variety, veracity, and value extracting meaningful information and insights which are challenging tasks and burning issues. According to IDC [1], in late 2011, about 1.8 ZB of data was created. Globally, per year about 1.2 ZB (10^{21}) is generated by different sources as electronic data [2]. By 2020, data are expected to 40 ZB [3]. Tools and techniques should be available to handle big data in an easy and effective way. The tools should have the capability to process the data, apply different filtering process to extract meaningful insights, cooperate, and communicate with other tools during data exchange.

Decision-making on big data based on multicriteria is one of the challenging issues for researchers and practitioners. To make decision based on appropriate numbers of choices, effectiveness, and potentiality, researchers are finding novel means to make the decision support system for the problems of various application domains of big data by using multiple criteria in integration with machine learning and artificial intelligence. Several decision support systems are available which have the potential to support decision-making activities [4–7]. Decision-making plays an important role in the success of a business or an organization. Based on multiple criteria, the decision-making is difficult as there are several available criteria for the decision to take action.

In the recent approaches for solving problems of big data, the decision support systems are facilitated with the integration of deep learning algorithms to provide a more intelligent decision support system [8–10]. The decision support system has several applications in diverse areas such

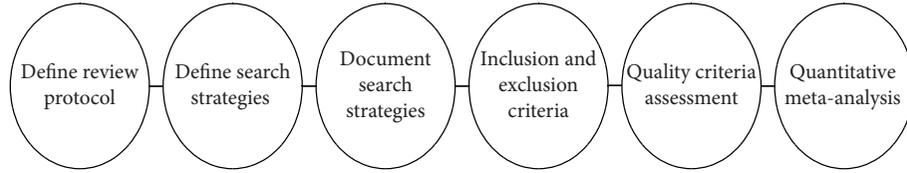


FIGURE 1: Generic process of SLR.

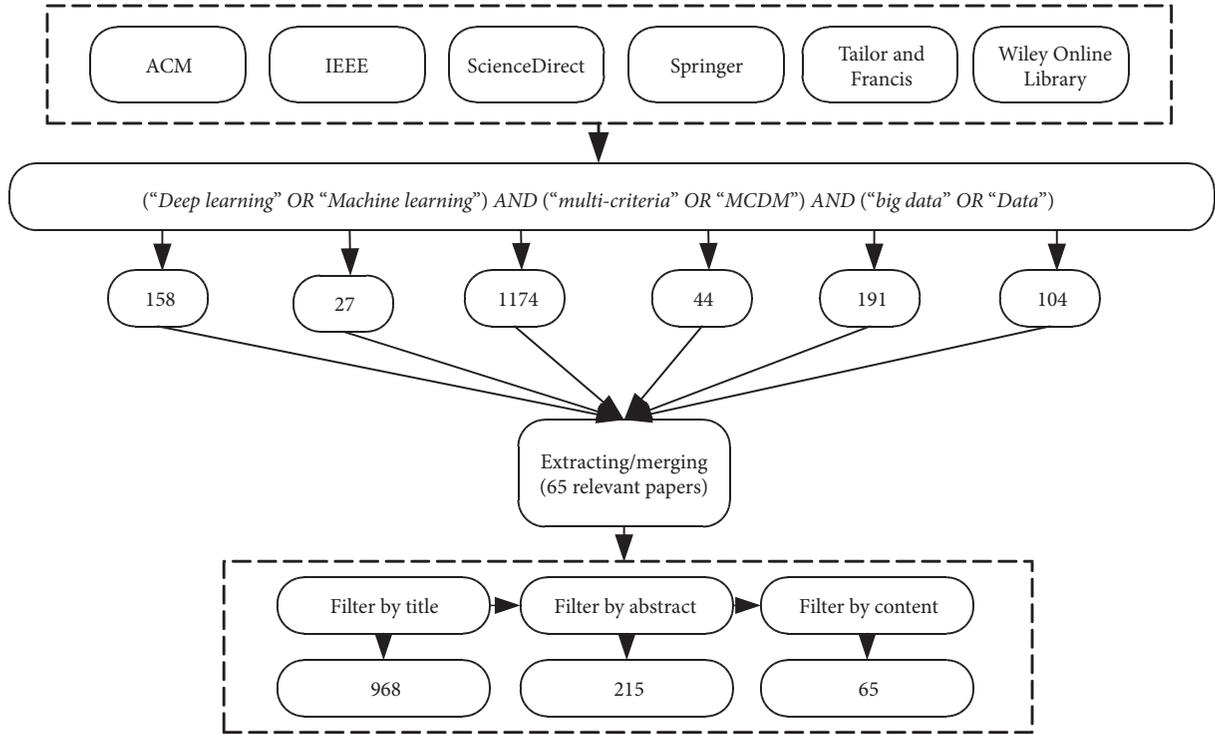


FIGURE 2: Search and filtering process of the proposed study.

TABLE 1: Summary statistics of query execution in the given libraries.

Libraries	Keyword query	Total	Included	Span of time
ACM	("Deep learning" OR "Machine learning") AND ("multi-criteria" OR "MCDM") AND ("big data" OR "Data")	158	8	2016–2020
IEEE Xplore	("Deep learning" OR "Machine learning") AND ("multi-criteria" OR "MCDM") AND ("big data" OR "Data")	27	12	2016–2020
ScienceDirect	("Deep learning" OR "Machine learning") AND ("multi-criteria" OR "MCDM") AND ("big data" OR "Data")	1174	28	2016–2020
Springer	("Deep learning" OR "Machine learning") AND ("multi-criteria" OR "MCDM") AND ("big data" OR "Data")	44	7	2016–2020
Taylor and Francis	("Deep learning" OR "Machine learning") AND ("multi-criteria" OR "MCDM") AND ("big data" OR "Data")	191	5	2016–2020
Wiley Online	("Deep learning" OR "Machine learning") AND ("multi-criteria" OR "MCDM") AND ("big data" OR "Data")	104	5	2016–2020

as business [11], energy sector [12], and agriculture [13]. Various domains explain the theories and methods which come from simple to more advanced and intelligent models for decision making [14, 15].

Keeping in view the effectiveness and importance of adopting the decision support system (DSS) along with the use of deep learning algorithms, the proposed study presents a

systematic literature review of the last five (05) years from 2016 to 2020. The aim of the proposed study is to identify the trends, scope, and methods from the existing literature in order to present an improved decision support system with integration of deep learning solutions to tackle big data. Keywords were defined based on the research questions for conducting the survey, and the papers were included based on the criteria of

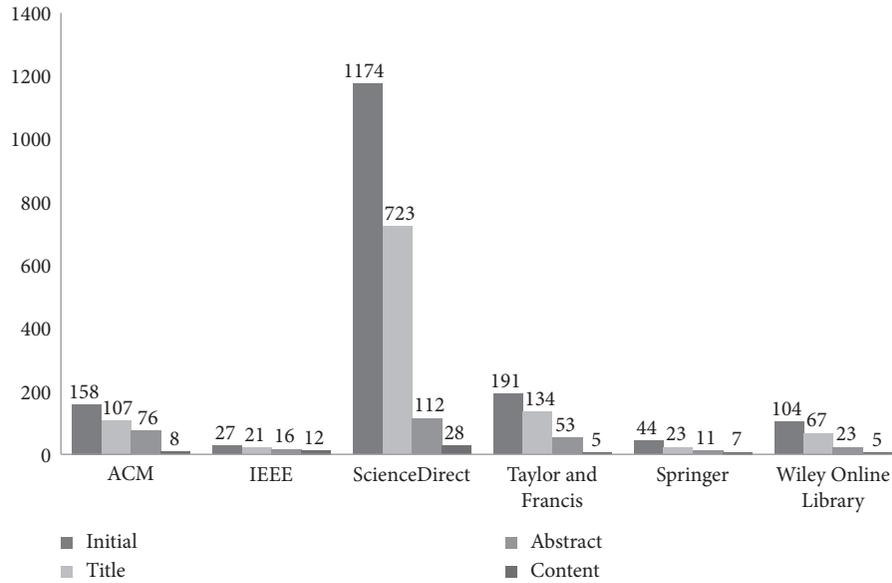


FIGURE 3: Search and filtering results.

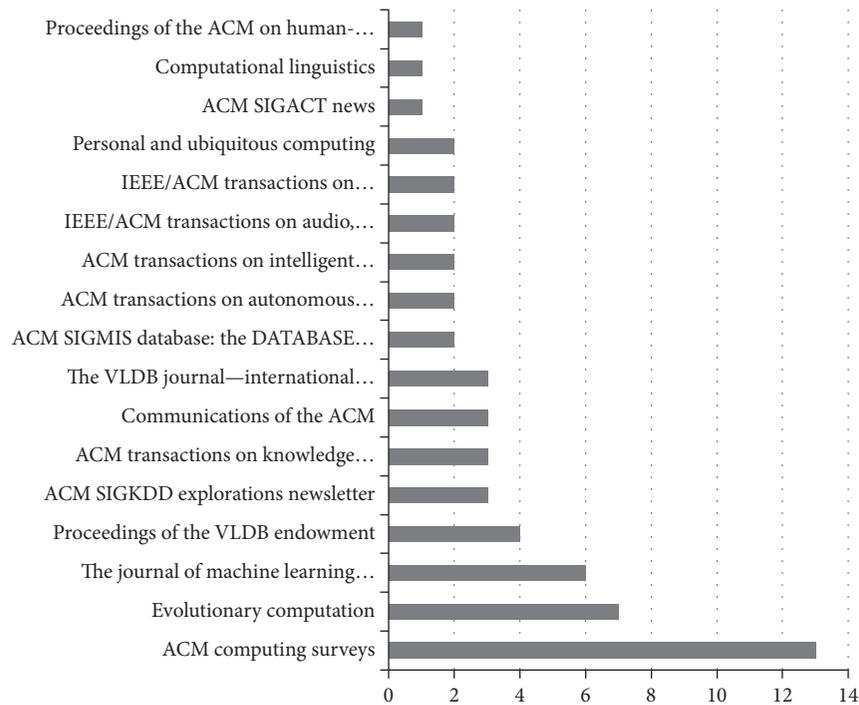


FIGURE 4: Initial results of the journal/magazine names along with the total number of publications.

quality assessment. The selected papers from the literature were further analysed to answer the research questions of the study.

Experimental results of the proposed study show that deep learning algorithms and decision support systems are exploited in a useful way. The research integrated power machine learning as well as artificial intelligence and multicriteria decision-making models to provide effective solutions to problems which are more complex.

The organization of the paper is as follows: next section represents the research method with the details of the protocol followed for conducting the proposed research. Section

3 represents the results and discussion section of the paper with the analysis of answering the research questions. The paper concludes in Section 4.

2. Research Method

Systematic literature review is a protocol of conducting literature review of a specific research and systematically collects the research papers based on the defined research questions and keywords, analyzing the selected studies in order to assess the applications and impact of the study.

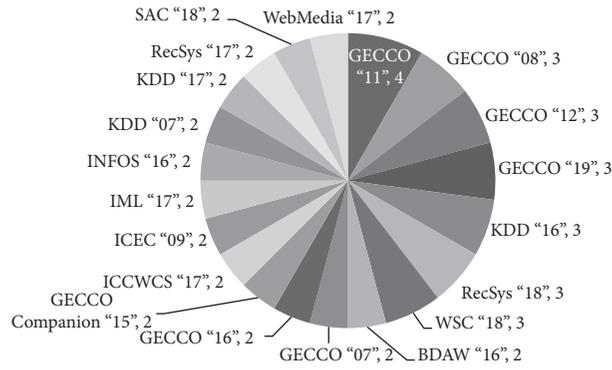


FIGURE 5: Proceeding names with the number of papers.

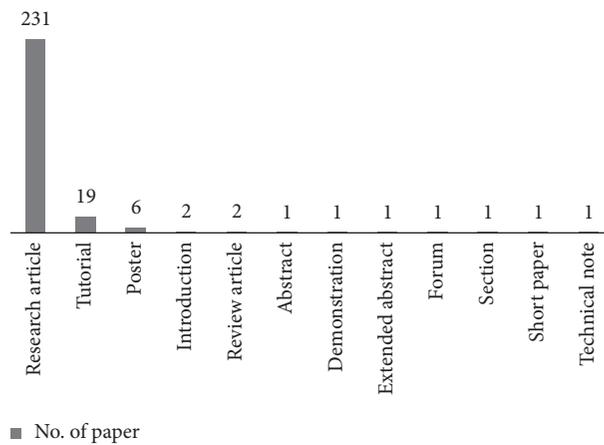


FIGURE 6: Content types with the number of papers.

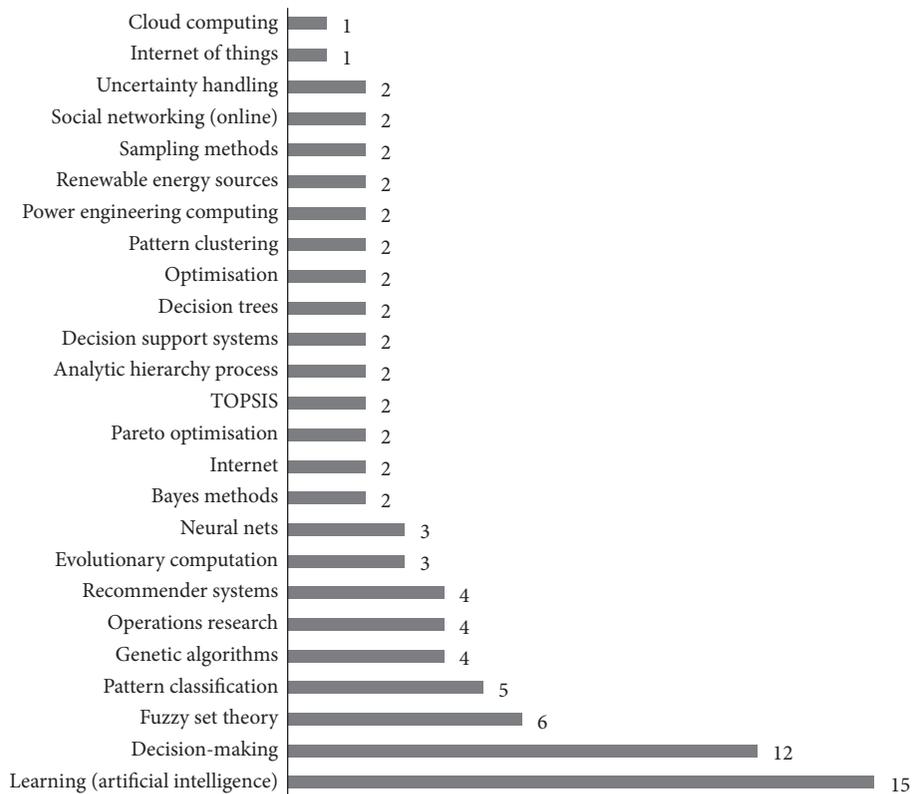


FIGURE 7: Publication topics with the number of papers.

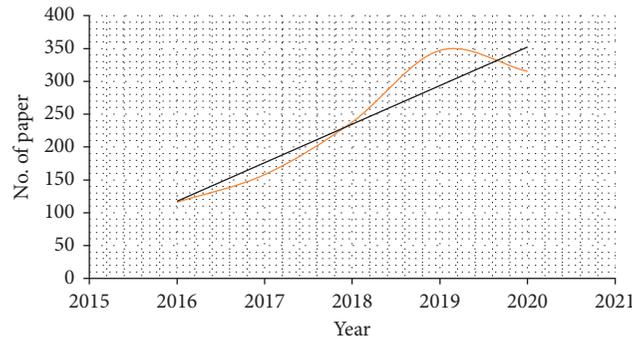


FIGURE 8: Number of publications in the given years.

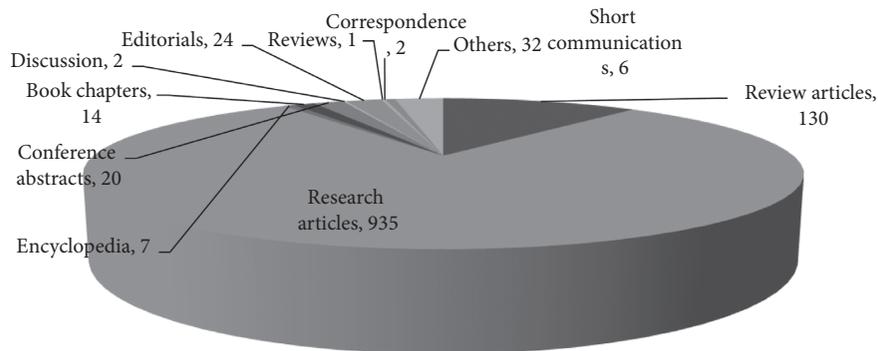


FIGURE 9: Article types with the number of papers.

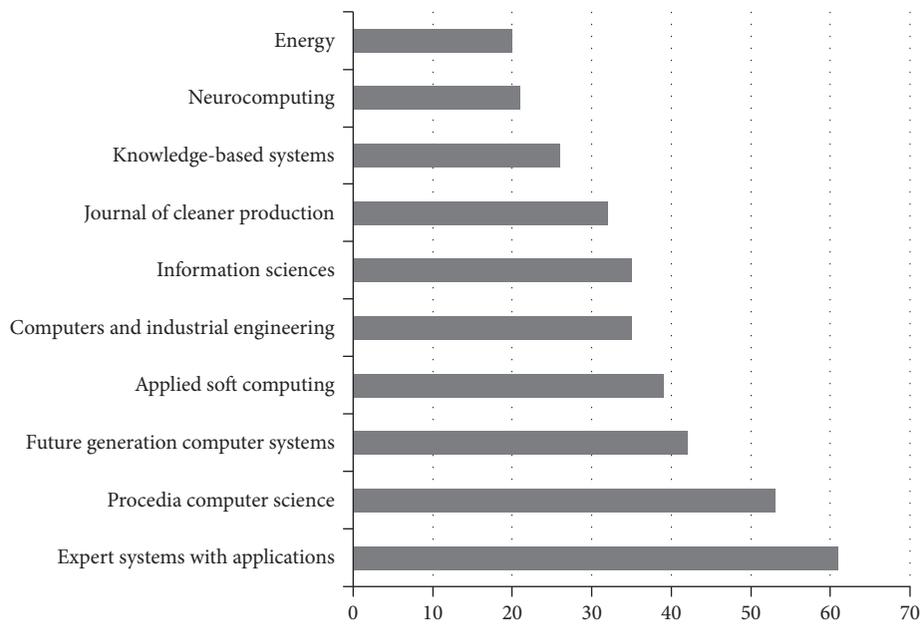


FIGURE 10: Publication title along with the number of papers.

Several guidelines are suggested by the researcher for conducting a systematic literature review. The guidelines are followed in the proposed system literature survey [16, 17]. The following sections briefly show the research method and protocol followed for conducting the proposed study. Figure 1 shows the generic process of conducting the SLR.

2.1. Research Plan and Method. For conducting an efficient and successful search process, the following famous libraries were searched in order to get most relevant materials:

- (i) ACM
- (ii) IEEE Xplore

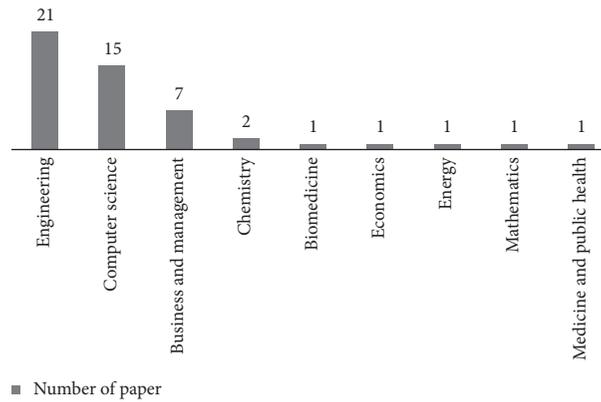


FIGURE 11: Disciplines of publications with their number of papers.

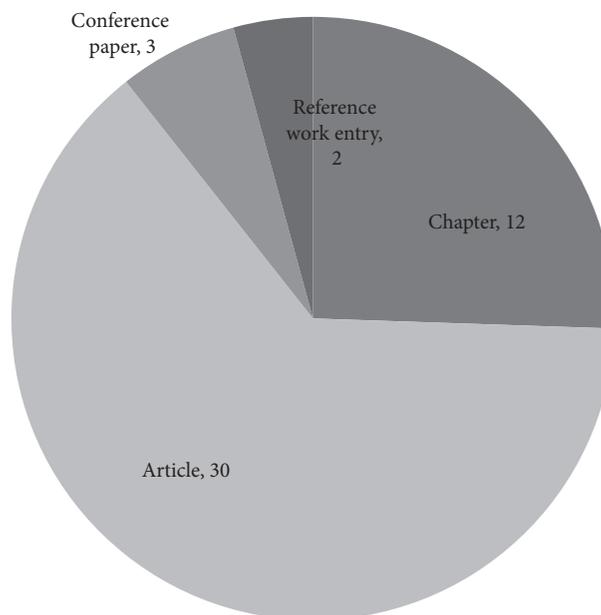


FIGURE 12: Publication type with their number of papers.

- (iii) ScienceDirect
- (iv) Springer
- (v) Taylor and Francis
- (vi) Wiley Online

2.2. *Research Questions.* The following are the research questions (RQs) of the proposed study:

- (i) RQ1: what are the techniques and applications of multicriteria decision in big data?
- (ii) RQ2: what are the applications of deep learning algorithms in big data?
- (iii) RQ3: how to analyze the existing literature for the applications of multicriteria and deep learning algorithms in big data?

2.3. *Search Process.* The search process is very tricky due to the reason that a paper should not be missed. Six popular libraries that are ACM, IEEE, ScienceDirect, Springer, Taylor and Francis, and Wiley Online were considered for the search process. Initially, research questions were defined. The reason behind the selection of these libraries is that these libraries are dominant in the field and publishing quality research work which are mostly peer reviewed. After that, the following keywords were defined with different Boolean operators to search the query:

("Deep learning" OR "Machine learning") AND ("multi-criteria" OR "MCDM") AND ("big data" OR "Data")

Searching the libraries by the individual keywords is not an effective way to select appropriate materials. So, for this, the keywords were combined by logical

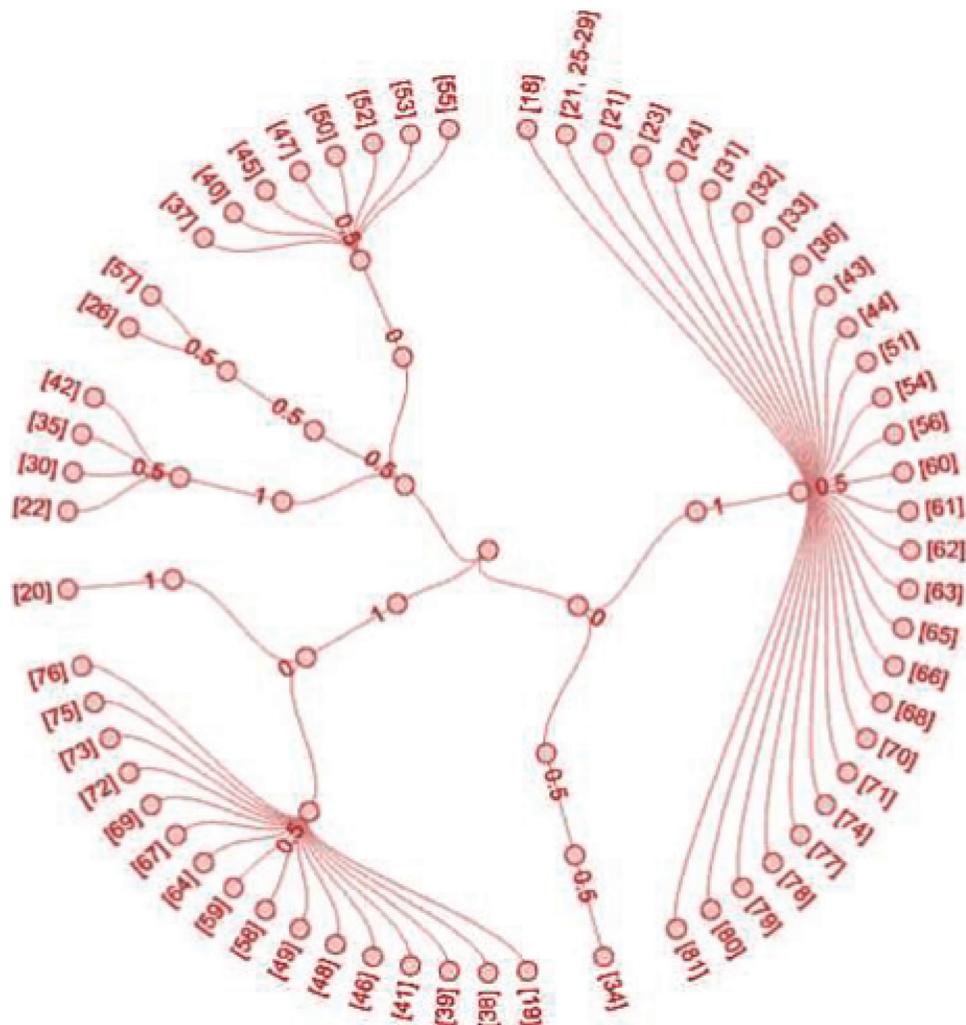


FIGURE 15: Quality evaluation of the selected papers.

Figure 2 shows the process of conducting the search and filtering process.

2.4. Study Selection. The designed query was searched in the specified libraries in order to obtain the relevant associated materials for the proposed study. Among these libraries, the filtering process was performed for the year range from 2016 to 2020. Using this procedure, query is applied and search results are obtained, which is shown in detail in Table 1.

From each of the libraries, the papers were filtered by title, abstract, and content. All the papers are then analysed based on its contents, and the most final set of relevant papers is selected. The final selected papers are analysed to answer the research questions and to achieve the objectives of the study. Figure 3 shows the search and filtering results in the given libraries.

Figure 4 shows the initial results of the journal/magazine names along with the total number of publications in the ACM library.

Figure 5 shows the proceeding names with the number of publications.

Figure 6 shows the content types along with the number of publications.

Figure 7 shows the publication topics along with the number of papers in the IEEE library.

Figure 8 shows the number of publications in the given year in the ScienceDirect library.

Figure 9 shows the article type along with the number of papers.

Figure 10 shows the publication title with the number of papers.

Figure 11 shows the publication disciplines in the Springer library.

Figure 12 shows the publication type with their number of papers.

Figure 13 shows the number of selected papers in all the given libraries including ACM, IEEE, ScienceDirect, Springer, Taylor and Francis, and Wiley Online Library.

The final list of the selected papers is given in Figure 14.

2.5. Quality Assessment. The quality of the selected papers was aimed to check for showing the relevancy of the

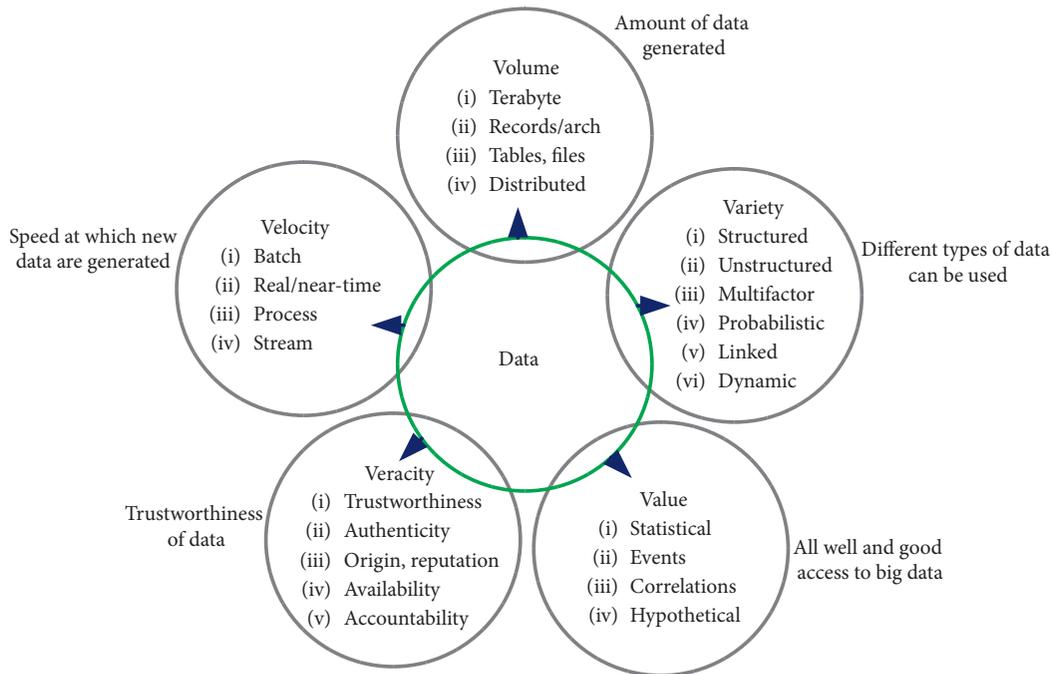


FIGURE 16: 5 Vs of data.

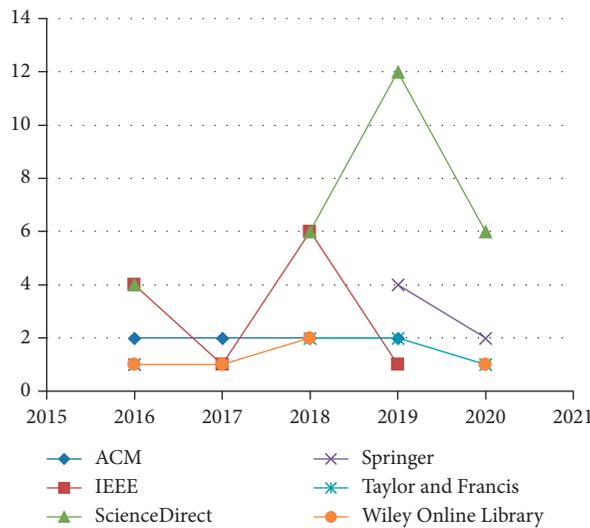


FIGURE 17: Number of publications in given years and libraries.

selected papers to the proposed research. Scores of 0, 0.5, and 1 were adopted to give a score to the research questions based on the specific research paper. The score 0 was given to the paper which do not satisfy the research question, 0.5 for the paper which partially satisfies the research question, and 1 for paper which fully satisfies the research questions. The quality evaluation of selected papers is depicted in Figure 15.

3. Results and Discussion

Big data contains a huge amount of information which needs to be extracted for a specific purpose of the user.

Such kind of data is very difficult to manage, organize, and structure. Various tools are used for extracting meaningful information and insights. The applications of machine learning algorithms play an important role in real life. The machine learning has been used mostly for classification purposes [18]. Figure 16 shows the 5 Vs of big data.

Several types of analysis were done to show the impact, number of publications, and the increase in research activities in the popular libraries. In this analysis, maybe some relevant papers are missed due to the search query and some other reasons. Figure 17 shows the number of publications in the given libraries.

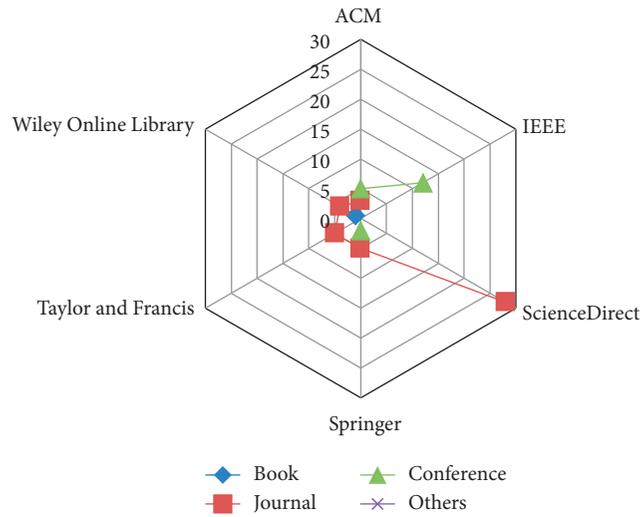


FIGURE 18: Type of publications along with the number of papers in the given libraries.

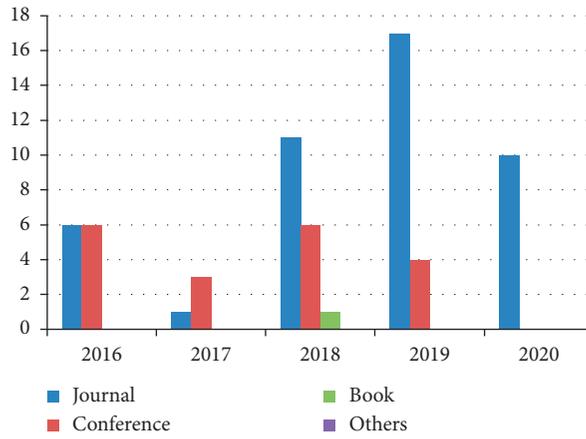


FIGURE 19: Year and article type.

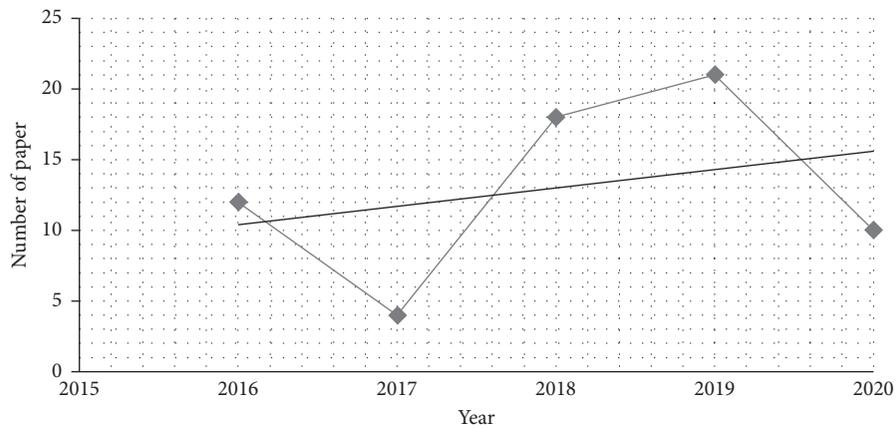


FIGURE 20: Number of papers in the given years.

Figure 18 shows the type of publications along with the number of papers in the given libraries.

Figure 19 shows the year and type of publication.

Figure 20 shows the number of papers in the given year. Table 2 shows the details of the answers to the research questions with the method used along with the description.

TABLE 2: Details of the answers to the research question defined for the proposed research.

Citation	Method	Description	RQ1	RQ2	RQ3
[19]	Support vector machine for classifications of biomedical signal on the platform of IoT	The authors proposed an approach for observing the signal using the digital signal processor and then measured the heart rate, blood oxygen saturation, and blood pressure. SVM is used for classification purpose, and it showed the data into unhealthy, healthy, and very unhealthy and described the accuracy of prediction classification.	√		√
[20]	Treatments of hypertension based on big data using machine learning (ML)	Application of ML algorithms for big data in achieving insights into the management of hypertension disease. The decision tree and neural networks are used as ML techniques to identify the factors to contribute in hypertension drug treatment.	√		√
[21]	Big data analytics and data mining for predicting the heart disease	Various technologies related to data mining for the disease of heart are discussed. These techniques can help in early prediction of heart disease. Some of these techniques are classification involving decision tree, Naïve Bayes, genetic algorithm, neural network, AI, and clustering algorithms such as support vector machine and KNN. The proposed review presents details of the available prediction models from the year 2004 to 2016 which uses data mining.	√		√
[22]	Applications of the ML algorithm in cardiovascular medicine	The basic and potentiality of ML algorithms are described. The issues and assessments of the needs of ML algorithms in cardiovascular medicine are discussed.	√		√
[23]	Study on comparisons of different ML classifiers on data of medical	Comparative study of different classifiers such KNN, Naïve Bayes, SVM, NN, Gaussian mixture model, and decision tree has been done in order to achieve good performance in critical prediction of cardiac arrest. This comparison was done behind the reason as a specific classifiers may or may not work very well in a particular case (dataset).	√	√	√
[24]	ML for bioinformatics	Bioinformatics is classified into voluminous, incremental database, and techniques of composite data analytics. These datasets such as DNA and RNA contain huge information which is termed as big data. Techniques of ML are used for extracting information from these datasets.	√		√
[25]	Techniques of unsupervised machine learning	The data of Facebook walls of 153 different organizations were analysed to extract information about the performances and engagement of the user based on unsupervised techniques of ML	√		√
[22, 26–30]	Deep learning and machine learning	The two-fold model of big data is presented for healthcare. Firstly, they presented the issues in the existing mobile healthcare system, while in the second phase mHealth 2.0, they proposed techniques of ML and deep neural networks for the processing of big data and information retrieving purpose that ensure the efficiency, time saving, data integrity, and manageable solution for making the healthcare green. The techniques have applications in the intensive care unit for essential health monitoring of the patients.	√		√
[27]	Apache Spark	The authors presented the Apache Spark deployed in cloud primarily focuses on applying technique of ML for predicting health status of the patients based on the tweets	√	√	√

TABLE 2: Continued.

Citation	Method	Description	RQ1	RQ2	RQ3
[31]	Healthcare big data security through machine learning	The study proposed an integrated technique based on masking encryption, granular access control, activity monitoring, dynamic data encryption, and models of endpoint validation. The proposed system results by providing an efficient diagnostic system for disease in the healthcare-based big data system.	✓	✓	✓
[32]	Application of the deep learning network in left ventricular volume prediction in cardiac MRI	The authors developed left ventricular volume prediction approach without segmentation by deep learning technology and the data set form large-scale cardiac MRI from the second annual data science bowl in 2016.		✓	✓
[33]	Applications of machine learning and analytical hierarchy process for risk assessment	The authors presented multicriteria decision methods and machine learning algorithms for assessment of risk of oil and gas pipeline defects		✓	✓
[34]	A metaheuristic approach for developing PROAFTN with the decision tree	The authors presented an MCDA-based method called PROAFTN as a fuzzy classification method. The method used data preprocessing and genetic algorithm for extracting parameters from the data.		✓	✓
[35]	Fuzzy set theory for active learning	The concept of fuzzy set theory is presented for learning		✓	✓
[36]	Deep learning networks for limited data	Deep networks for limited data to calculate the uncertainty are presented	✓	✓	✓
[37]	MCDS for evaluation of RES	The authors presented an approach to cover methodology developed and the tools for processing resource data		✓	✓
[38]	Leveraging ensemble pruning for imbalanced data classification	Integrated pruning algorithm is presented for imbalanced data	✓		✓
[39]	MCDM approach-based framework for analytics of social media	A framework based on MCDM approach is proposed for social media analytics applied on the Twitter dataset	✓		✓
[40]	Selecting dig data reference architecture through decision support	Methodology of design science research is used. Literature review and application of comparison of the software architecture analysis method and existing big data reference architecture are found and compared. The AHP was used, and the experiment was done through the real-world use case.	✓		✓
[41]	Big data and visual analytics	Analytics of big data is used for solving the damages caused with alarms. The method integrates technique of interdisciplinary and accomplishing analytics with evidential inference.	✓		✓
[42]	Video trajectory analysis using unsupervised clustering and multicriteria ranking	The unsupervised trajectory method of cluster (t-cluster) is proposed. The method creates object indexes by fusing high-level interpretable features, then the clusters are fused through MCDM, and trajectories are ranked accordingly.	✓		✓
[43]	Visual analytics and machine learning	The authors reported the existing literature by highlighting and integrating the advances in the machine learning and visual analytics	✓	✓	✓
[44]	Applications of machine learning for early detection and treatment outcome prediction	The author presented a novel model of classification for general purpose and for launching reliable predictive rules for the applications of biology and medical		✓	✓
[45]	Resource provisioning for applications of deep learning in smart healthcare	The authors presented a technique of proximity-based provisioning of resources for avoiding delay in achieving inference results with the mobile cloud system		✓	✓

TABLE 2: Continued.

Citation	Method	Description	RQ1	RQ2	RQ3
[46]	Outlier reduction in web mining framework	The study presented reducing outlier framework in the analysis of regression with support of ordered weighted operators as MCDM	✓		✓
[47]	Flood susceptibility mapping of arid areas based on GIS-based MCDM, southeastern Tunisia	With the help of MCDM approach (AHP), an attempt is made to prepare flood hazard susceptibility map of the Gabes regions	✓		✓
[48]	Healthcare management and analytics of big data	The existing literature is examined for the purpose of reviewing the existing research and to derive new agenda.	✓		✓
[49]	The multicriteria quadratic programming model for imbalanced data	The paper presented a model of multiple criteria quadratic programming by launching the cost of misclassification to the multiple criteria quadratic programming model	✓		✓
[50]	Clustering MCDM approach for analysis of big data for evaluation of marketing strategies	The strategy of digital bank has been recommended applying big data for the banking industry of Iran. The strategy would help the banks of Iran to distinguish and analyze the needs of the customers to offer services proportionate to their manner.	✓		✓
[51]	Subgroup discovery in MOOCs	The paper aims to describe and categorize diverse types of learners in massive open online course by the help of the subgroup discovery method based on MapReduce	✓		✓
[52]	Applications of machine learning algorithms in treatment of oncology big data	The study presented a decision-making systems which is a part of user-centered healthcare based on predicting cancer distribution		✓	✓
[53]	Wireless networks and analytics of big data	A survey of the literature is presented for the analytics of big data approaches in wireless networks	✓		✓
[54]	Open-source big data cognitive computing platform	The research has developed a platform for meeting the need of user requirement analytics for the data that are structured and unstructured	✓		✓
[55]	Floating car data and machine learning for traffic prediction	The presented approach detects the traffics in the road networks of urban area through supervised learning approach		✓	✓
[56]	Using clustering techniques for selection of ideal cloud services	By using the approach, the user can enter the values of his/her best service and the technique of clustering; the nearest best service is selected and returned to the user.	✓		✓
[57]	Integrating deep learning and argumentative reasoning to analyze textual content of social media	With the help of deep learning for relation-based augment mining to derive augmentative relations of support and attack		✓	✓
[58]	EXEHDA-RR	The paper presented machine learning in preclassification of the middleware resources of EXEHDA to reduce cost of computation by MCDA algorithms	✓	✓	✓
[59]	Social AHP	The paper presented an approach for the services of citizen-to-citizen interaction through AHP by using the identified attributes and model of decision to considering the social attributes	✓		✓
[60]	Approaches of MCDM for big data analytics capabilities and firm performance	With the help of MCDM methodology, the abilities of big data analytics and the impact of these abilities on performance of firm are explored	✓		✓
[61]	Profitability performance in project tendering with big data and deep learning for benchmarking	The study developed a benchmark system for the evaluation of tender using big data		✓	✓

TABLE 2: Continued.

Citation	Method	Description	RQ1	RQ2	RQ3
[62]	Big data and machine learning for game-predicting	The research has developed ranking for teams and players and designed a system for the answers of managerial questions regarding the game of hockey. With the help of 18 performance measure, the player rating is done. The game of hockey is predicted using big data and machine learning.		√	√
[63]	Image classification through multicriteria active deep learning	The study proposed multicriteria active deep learning for learning strategy for deep neural networks in the classification of image		√	√
[64]	Classification of multiattribute inventory through an integrated decision analytic framework of machine learning with multicriteria decision-making	Multicriteria inventory classification approach was presented through the integration of machine learning with multicriteria decision-making		√	√
[65]	Decisions for marketing, supplying, and purchasing	With the help of online review, a decision support system is presented for measuring the stratification of the customer	√		√
[66]	Deep learning with GIS data for prediction of automobile maintenance	The research presented an approach of GIS data into modelling of TBF, and it researched the impact on automobile TBF with the help of deep learning		√	√
[67]	Deep learning and data warehouse for depth prediction of urban flood	Deep learning and data warehouse were considered for assessing the flood risk in urban areas		√	√
[68]	Selecting cloud service through a hybrid multicriteria decision	MCDM approach was developed for the selection of cloud services	√		√
[69]	Machine learning-based traffic offloading in fog networks	The study presented an offloading solution and shows different profiles for different proposes such as to get maximum data rate, save battery, and so on		√	√
[70]	Framework of IT for identifying high-quality physicians using big data analytics	With the help of signalling theory, high-quality doctors are identifying based on the four-level model	√		√
[71]	Analysis of microarray leukemia data using an efficient MapReduce-based KNN	The study presented an approach by using framework of Hadoop for classification of microarray data. The KNN classifier was used for the classification purpose of data.		√	√
[72]	Combining CNN streams of RGB-D and skeletal data for recognition of human activity	Convolution neural network-based approach is proposed for the recognition of human activity		√	√
[73]	Applying machine learning to the AHP multicriteria decision-making method to asset prioritization in the context of industrial maintenance 4.0	With the help of machine learning algorithms and relevance analysis of attribute to process the event log failure of components of industrial machine	√		√
[74]	Amended fused TOPSIS-VIKOR for classification	The study presented a novel classification ATOVIC based on fused VIKOR and TOPSIS	√		√
[75]	Machine learning models, epistemic set-valued data, and generalized loss functions	The research aim is to study the problem where the goal is to identify optimal model to specific criteria in supervised and regression classification problems		√	√
[76]	Framework for modelling of drug electrochemical removal from wastewater based on data mining algorithms, scatter interpolation method, and multicriteria decision analysis	The study presented a framework for modelling of removal of drug from wastewater. With the help of data mining algorithms, ciprofloxacin electrochemical removal modelling is done and MCDA is developed for ranking the algorithm of data mining.	√		√
[77]	Feature selection based on multicriteria on cost-sensitive data with missing values	An evaluation system based on multicriteria is proposed for evaluating features from diverse viewpoints	√		√

TABLE 2: Continued.

Citation	Method	Description	RQ1	RQ2	RQ3
[78]	Frameworks of ML and data mining for prediction of drug response in cancer	The study gives an overview of the supervised and unsupervised algorithms used in the prediction of drug response, the strategies applied for designing these algorithms into functional models, data resources for feeding to frameworks, and challenges for maximizing the performance of the models		✓	✓
[79]	Data fusion and machine learning for industrial prognosis	The study overviewed the literature in data fusion and analysis for industrial prognosis		✓	✓
[80]	A supervised machine learning approach to data-driven simulation	With the help of data analytics, the risk profiles of supplier performance based on uncertainty are analysed		✓	✓
[81]	Machine learning model-based favourite data to analyze asymmetric competition	The study presented an approach for analysis of asymmetric competition based on favourite data with the help of machine learning algorithms		✓	✓
[82]	Machine learning powered software for accurate prediction of biogas production	The study presented machine learning approaches for biogas production data from projects of China		✓	✓

4. Conclusion

With the current advancements in technology, the data are ever increasing with the increase in population, communications, IoT, actuators, sensors, and so on. This increase goes into different shapes of data whose decision becomes a challenging issue due to its growth of volume. Deep learning algorithms and multicriteria-based decision-making have effective applications in big data. Due to its effectiveness and potentiality, it is exploited in several domains such as computer science and information technology, agriculture, and business sector. The aim of the proposed study is to present a systematic literature in order to show the applications of deep learning algorithms and multicriteria decision approaches for the problems of big data. The research finds novel means to make the decision support system for the problems of big data using multiple criteria in integration with machine learning and artificial intelligence approaches. The presented study will provide better insights into the research community in the area domain and will help them in the designing of more robust, efficient, and effective multicriteria-based decision support system models, framework, technique, and integrated solutions of machine learning algorithms.

Data Availability

No data are available.

Conflicts of Interest

No conflicts of interest exist regarding this paper.

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