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Machine Learning Techniques for Dimensionality Reduction in Big Data

Jijo Varghese[1]&Dr.P.TamilSelvan[2]
[1]Research Scholar,Department of Computer Science,Karpagam Academy of Higher Education, Coimbatore, Tamilnadu, India. Email: jijo.22@gmail.com
[2]Research Supervisor,Department of Computer Science,Karpagam Academy of Higher Education, Coimbatore, Tamilnadu, India. Email: tmselvanin@gmail.com

Abstract: The incredible growth in information assortment and data-storing abilities during the previous years had prompted data over-burden in many areas. Scientists works in different areas such as scientific laboratory, construction field, cosmic science, geographical information system, share markets, and spatial fields due to this the volume of data are increasing periodically. Because of its elaborating datastructure, it leads to huge difficulties in the analysis of data engineering. Higher dimension data leads to numerous numerical difficulties with certain chances that provide us to propose innovative methods/solutions to overcome these issues. The major issue in higher dimension data are is to distinguish the relationship between useful and non-useful data. Meanwhile, some models were proposed by various researchers to handle the dimensionality problem by providing better accuracy in terms of reduction in unwanted data, but it still faces a lot of deviation. In this survey article, we had analyzed various methods for the data reduction process. We had found that dimensionality reduction methods are providing a good solution to reducing the unwanted volumes in big data. The role of a machine learning algorithm and some feature techniques are very much supportive in this task. Thus this article will be very useful for researchers in the data analytical field to make their work efficient.
Keywords: BigData, Data analysis, Higher-dimension, Machine Learning.

1. Introduction

There is no formal description for "Bigdata" it was commonly represented as a huge quantity of data that is gathered as a dataset in which it was not suitable to process by any traditional data mining algorithms. The traditional methods generate data in a large amount for a given query which leads to insufficient exactness. Working on a large level of datasets creates more complexity in processing. But in the current era, we had to work only in this big data with no option due to advances in the digital world, this leads researchers to open solutions for these issues. Thus there is a need for some methods for the reduction of data in different levels of architecture. The common structure of the big data system is shown in figure 1.

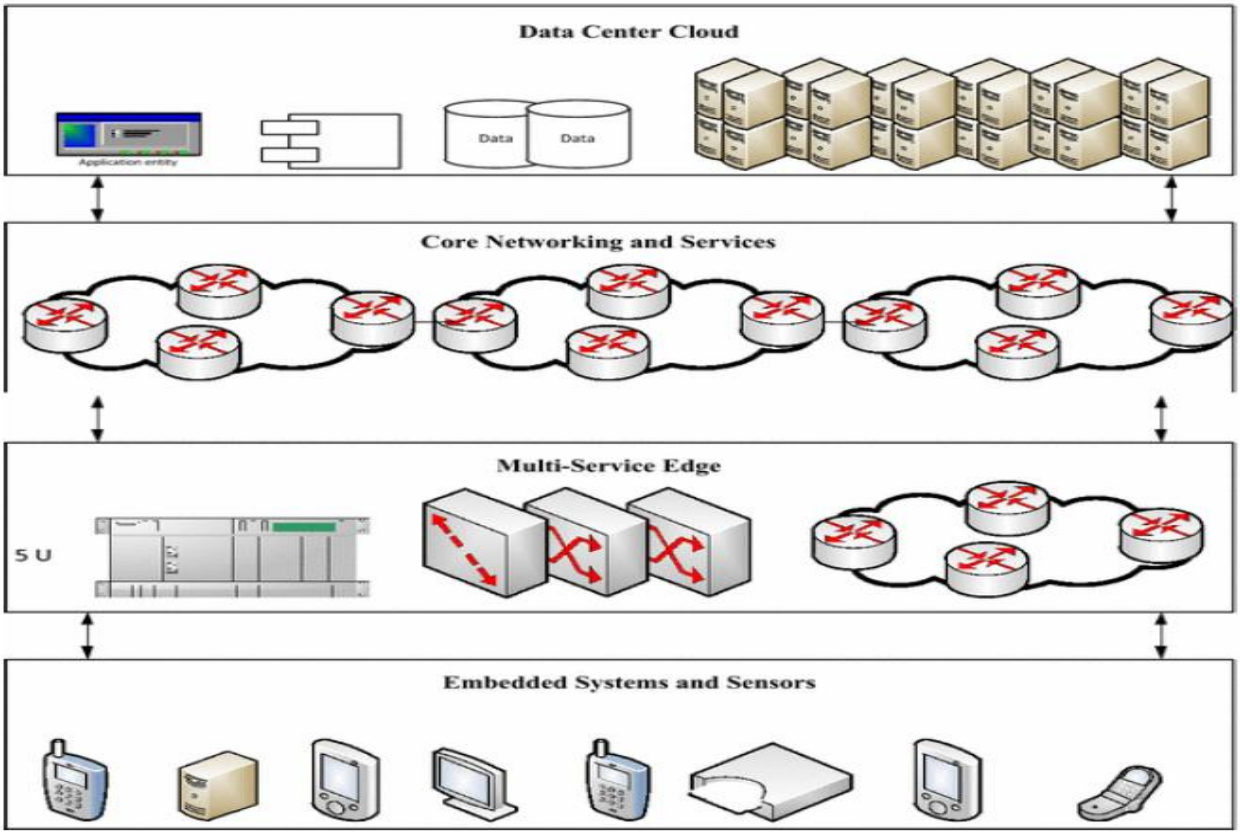

Figure 1.Big Data System Structure

The database which holds data with higher complexity and information with contemporary are the sources that are included in BigData. This was commonly classified as the "V" category. They are Variance in data, high level of Valuable data, Velocity of the data in extreme, large Varieties of data, Veracity in minimum level, and Volume of data with a huge number [1].

Some significant stages that are followed by the applications for BigData are (i) Application based on data, (ii) Analytics processed on data, (iii) Management over the data, and (iv) Generation of the data. In these stages, the Analytics processed on the data plays a major role since it was able to generate data patterns from the database.

While comparing with the analytics of data in a lower dimension it makes extreme complexity in higher dimensional data [2]. Due to various areas that working in welfare for social such as medicinal field, secure domains, environmental monitoring, financial operations and research societies.

The methods of Machine Learning (ML) were utilized since the main issue in the analytics of the data was "Learning". An ultimate goal for ML's is to elaborate on the learning capacity from the experience it had taken on the data structure. The learning methods that can boost their efficiency depend on the collection of data analysis. The issues in mining the data can be overcome by any number of techniques that are given by ML. While the issues are on a larger level it leads to a lack of efficiency and reliability these are the major drawbacks in BigData and it was termed as "Curse of Dimensionality". Thus the methods of ML play a significant role in obtaining reliable, scalable, flexible, and easy computation. Hence many researchers are focussing on the ML methods to overcome these issues faced by BigData.

The conventional strategies utilized for data analytics was not able to adequately manage the gigantic database, since looking for innovative as well as efficient methods and system that opt to mine huge level of data is a tempting topic for researchers. While concerning the crucial scenario and analyzing present technologies of ML evolution it can be possible to overcome the issues of performing and scalable searching terms in data mining. The methods to manage an enormous database were to process parallelly using various methods for attaining high computational speed. The MapReduce method and Hadoop were good examples that provide a better computational speed with multitasking [3].

Period of process and volume of data are the main issues that are faced while coming to execution and versatility. This defined as what is the size of the data set and the amount of time the user gets the answersto their queries. This survey aimed to deal with these issues that are facing in BigData. The following are some well-known methods for investigating the BigData [2]:

(a) Divide-and-conquer: It's a notable methodology that deals to handle the fewer amount of data afterward combining the isolated outcomes accordingly.

(b) Parallelization: This one operates by separating huge issues into fragmented sections that were processed parallelly and then generates the long last conclusive outcome.

(c) Sampling: This was an effective measurable method dependent on the theories of probabilities. This methodology depends on recognizing the connection between the populace and samples. Numerous methods of sampling were proposed due to the advancement in BigData. Some of them are sample by randomness, sample by the proper system, sample-based on clustering, sample-based on maximum-minimum, and sample-based on quotas.

(d) Granular computing: It's a procedure that utilizes granules for generating the proficient structure based on computation for handling the BigData complexities. Some of the granules were groups, intervals, clusters and classes. By analyzing the data with various granules there is a major possibilityofthe reduction of datasize [4].

(e) Feature selection: The reduction of dimension is possible by selecting the opted features in the feature space by using this method [5]. The motivation for selecting the features was to achieve the associated feature subsets in which they are similarly common. Many researchers had worked on these types of methods which produce good results for them.

The methods that are defined above are used by various analysts through ML techniques to obtain better efficiencies in handling BigData scalability issues. To handle the complexities in the BigData we had done detailed research in this survey article to reduce the dimensionality and issues related to BigData, by analyzing various levels of techniques that were handled till now with their pros and cons. By also considering a methodology committed to lessening the data dimension, it implies it is devoted to working with huge datasets, with the end goal of suggesting a proficient ML method with better accuracy for classification and minimal time for computation.

This article was structured as section one deals with the introduction of the BigData issues, the related works for our survey are cited in section 2, the methodologies that are handled in data

reduction were given in section 3, the comparative analysis was discussed in section 4 and finally the conclusion of our survey work given in section 5.

2. Related Works

We had taken some of the reviews of a few papers regarding machine learning for reducing the data dimensional in the Bigdata environment.

In 2016 "A few techniques that were developed based on metaheuristics are cuckoo, BAT and firefly on classifiers such as Artificial Neural Network, fuzzy-based,etc" Thippa Reddy et.al. [6]. For classifying diseases related to heart and diabetics. The rough sets and projection on locality preserving reduction methods for a dimension are utilized by the authors for selecting the features in their work.

In 2017 "The performance of the clustering process using PCA on tumorsthat occurred in the brain was analyzed by the researchers"Irem Ersoez Kaya et.al. [7]. In their work the author initially used PCA techniques for various sizes of images for MRI then implied FCM and K-means clustering. They achieved a good rate of performance by combing K-means with the PCA technique.

In 2018 "For assuring the integrity of medicinal information for the classifier NaiveBayes the researcher"Kalia Orphanou et.al. [8]. They developed a complete encrypted method based on homomorphic using private keys. In their proposed model the owner of data is able for classifying the data in private by not considering the model that is trained. They analyzed and experimented with their algorithm on breast cancer where they observed better efficiency and accuracy.

In 2019 "The identification of the disease-related to heart by utilizing the classifier NaiveBayes was analyzed by the analysts" Zhou Tao et al. [9]. They worked on an experimental performance utilizing the database that is longitudinal for real-time. The period of association rule's temporal average and aid of horizontal to analyze the patient characteristics were compared by the author, in which the outcomes prove better efficiency by utilizing this classification algorithm while comparing with traditional methods.

In 2020 "To detect an initial stage of diabetic, a Firefly with a combination of PCA for deep learning was proposed by the author"Thippa Reddy Gadekallu et al. [10]. The diabetics were classified by ANN while the features that are optimal were chosen by Firefly-PCA. Thus their results show better class in terms of accuracy.

3. Methodologies

In BigData the techniques for reducing the data are presented in this section. Techniques mayenhance its store as well as data movement that is in-network and repetition of information and replication of data. By extension a few techniques merely lessen the size through compress the original data, a few of the techniques lessen the speed of information channels during the initial state earlier getting into on storage of BigData. As an alternative, a few of the techniques extract topological frameworks of ambiguous data and minimize the entire BigData by utilizing the method network theory. The following are the different methods to handle the volumetric data.

3.1. Network Theory

It performs a role that is primary for reducing data with higherdimensionality in ambiguous to data with lowerdimensionality in an organized manner [11]. Although, BigData network topological framework extraction is complicated because of its heterogeneousness and data frameworks that are

complex. Few researchers [12] developed a method that depends on network theory for extracting properties from the network also its topological framework from BigData. Networks are topologically created by developing and assessing connections amongst various points of data. The analysis of nodes that are statistical in networks was done to optimize and reduction of BigData. A fine-tuned network is depicted as a smaller globe network, afreely scalable network, and arbitrary networks they were rated as a factor of statistical variables, specifically Standard Deviation, Mean, and Variance.

3.2. Compression

The datasets with the limit in size were simple to manage concerning the view of its running time and data that were in-network movement within the Bigdata storing process. Compressing type techniques were best-suited prospects regarding data reducing concern view of dimension by protecting the data channels that were whole. Also, the lack of efficiency in computation with the critical task of decompressing at the same time protects the actual structure of the whole database.

Several methods [13] regarding BigData compressing were suggested concerning the literary works, incorporating compressing based on spatiotemporal, compressing by parallel, sketching, and gzip. In the environment based on the cloud, the reduction of data was complicated because of its various stages of virtualization and heterogeneousness concerning the cloud infrastructure that is underlying. Methods of spatiotemporal for compressing data in the cloud's big graph data produce datasets with reduced size. The method works for clustering the data that is online by correlating similarities in its time series towards shared workloads on the clusters. By extension, this works compression that is temporal in every node of the network to minimize entire data. The suggested method efficiently fulfills the processing standard of data fidelity that is acceptable for many software needs. Concerning other networks, wireless sensor networks (WSNs) were producing a huge amount of data channels in significant sizes. The compressing of data based on spatiotemporal protocol guarantees communication that is efficient as well as storage and transmission feasibility. This suggested method minimizes the dimension of transported data although it guarantees an extended lifespan of the network. The correlation is measured by the protocol in the level of data that is sensed, which decides the contents of the data to be transported.

3.3. Data Duplication (Redundancy Elimination)

In the environment of BigData, the analysis of data faces a major problem in Data redundancy [14]. Some of the common factors for redundancy of data were: (i) Replication of data (ii) data sets scalability (iii) Node aggregation. Redundancy level increase to 98% merely due to the one virtual machine (VM) aggregation it also leads to a redundant level of 49% growth in huge datasets. In the clustering stage, the process of storage availabilities leads to redundancy at 99% which was termed data replication. Due to redundancy, it facesa major lack in its energy level and throughput which leads to major degradation in its performance. Hence better methods for eliminating redundant and efficient deduplication are in need.

3.4. Dimension Reduction/Minimization

The minimization in BigData was primarily regarded as minimizing the dimensionality of data, it faces lots of issues due to collect an extreme amount of data which was termed as 'Curse of Dimensionality' among the number of featuresthat leads to the capacity of storing and increasing

complexity in computation [15]. The broad scope of reducing the dimension techniques was suggested in the literature which was used presently. The minimization of dimensionality was achieved dependent on both extractions of features and the selection of features.

The extraction of features looks at the entire facts of contents and routes the valuable facts of contents to a feature space in low dimensionality. The selection of features depended on avoiding the features from measurements that are available that do doesn't play a role in class separability. Also, was termed as features with repetitive and unwanted were dismissed. It could be possible to distinguish the methods utilized to minimize the dimension of a method of non-linearity or linearity. The methods might be characterized dependent on the point of view for selecting or extracting the features.

3.4.1. Different Methods for Extracting the Features

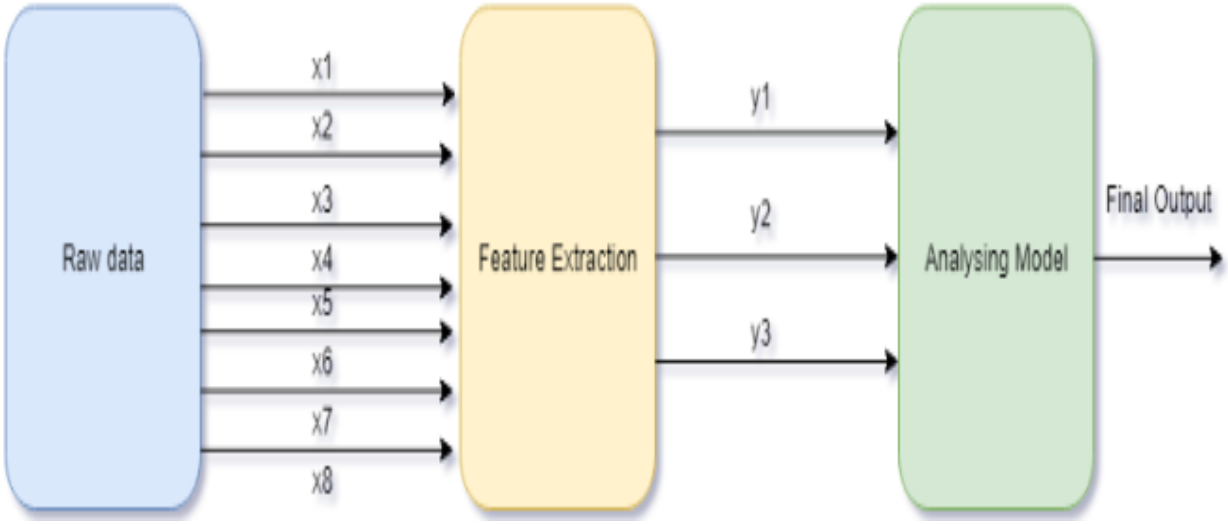

Figure 2. Model for Feature Extraction

The extraction of features is actually for generating a unique, compact collection of features that even encapsulates almost all of the valuable insight. It probably appeared as organized and unorganized techniques. For example,the LDA method acts as organized and the PCA method acts as unorganized. The overview model for feature extraction was shown in figure 2.

3.4.1.1. Linear Discriminant Analysis (LDA)

It utilizes the information through several features to generate a unique axis and projects the information onto the new axis in a way as to reduce the variance and enhance the exact distance amongst the means of the classes. It's an organized/supervised technique simply be used in combination with labeled data. This is composed of statistical properties of one's data, computed for every single class. For an individual input variable (x) here is the mean together with variance regarding the variable for every single class. For several variables, theseare the equivalent properties computed throughout the multivariate Gaussian, specifically the means together with the covariance matrix. It can also be influenced by scale, therefore the user can normalize their dataset first. It's supervised, therefore which needs labeled data. It provides variations (for example. quadratic LDA)

to handle particular roadblocks. However, the fresh features which can be created are difficult to interpret utilizing LDA.

3.4.1.2. Principal Component Analysis (PCA)

It's a dimensionality reduction that detects significant connections within the given data and transforms the prevailing data according to these connections. Next, it quantifies the necessity of these connections therefore it can keep the main connections. By considering this description, it follows these given procedures:

(i)It discovers the connection amongst features by utilizing a Covariance Matrix.

(ii) By using the linear transformation or eigendecomposition associated with CovarianceMatrix, it finds eigenvectors and eigenvalues.

(iii)Next, it transformsthe data utilizing Eigenvectors into principal components.

(iv)Finally, it quantifies the necessity of these connections utilizing Eigenvalues and maintains the significant principal components.

These fresh features which are produced by PCA are orthogonal, in terms these are generally uncorrelated. Subsequently, they've been ranked in order of these "explained variance." The very first principal component (PC1) represents the essential variance in the dataset, PC2 represents the second-most variance, and such like. It is possible to minimize the dimensionality by preventing the number of principal components to maintain according to the cumulative explained variance. This method can be influenced by scale, therefore it should normalize the dataset first. It was able to find a linear correlation among the given features. This implies as long as it got a few of the variables in the dataset which can be linearly correlated, it would very useful.

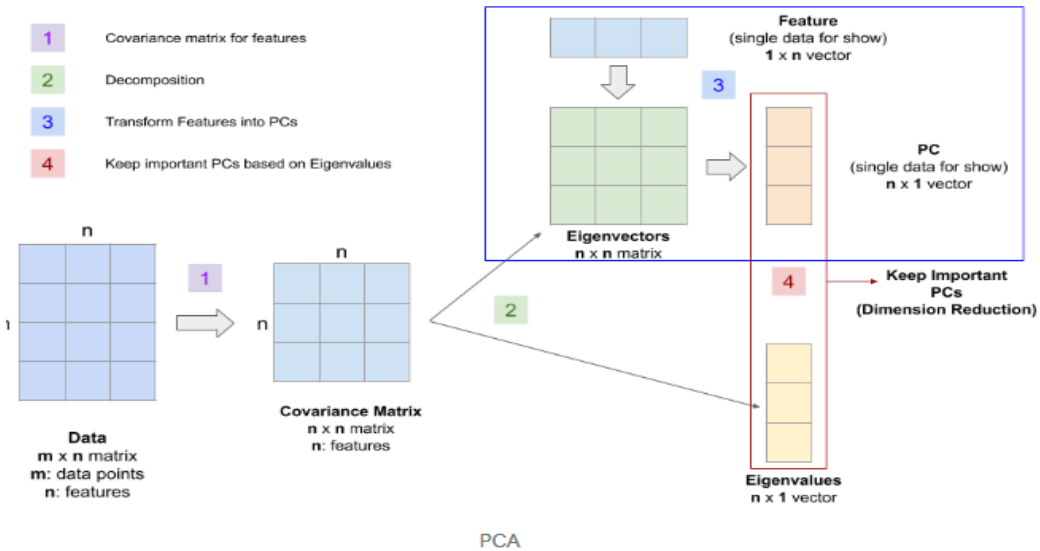

Figure 3. Structure of PCA

3.4.1.3. Autoencoders

This method is a family of ML methods that could be utilized as the dimensionality reduction method. It is well in utilizing the non-linear transformations for showing data at the higher dimensionality into the low dimensionality. It's a neural network that is trained to reconstruct its original inputs. Commonly it comprises 2 segments.

(i) Encoder: It processes the compression for data which it gets as an input, for the purpose to eliminate every available noise then useless data. The result of this step is commonly known as a bottleneck or latentspace.

(ii) Decoder: The latent space which is encoded is given as input to this stage and then attempts to recreate the original input of Autoencoder utilizing simply its compressed form (the encoded latent space).

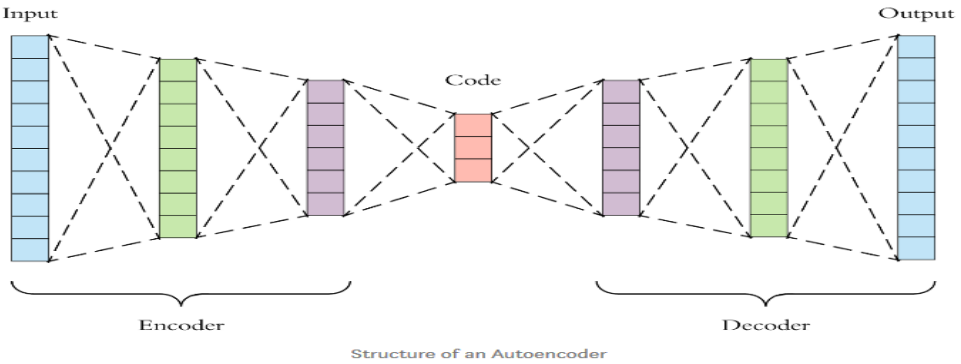

Figure 4. Structure of an Autoencoder

The figure shows the layer in the middle handles the maximum amount of input features among a small number of neurons, therefore, providing the thick then small input representations. Hence it was based on a neural network method to extract the features it may require a huge number of data to train.

3.4.2. Different Methods for Feature Selection

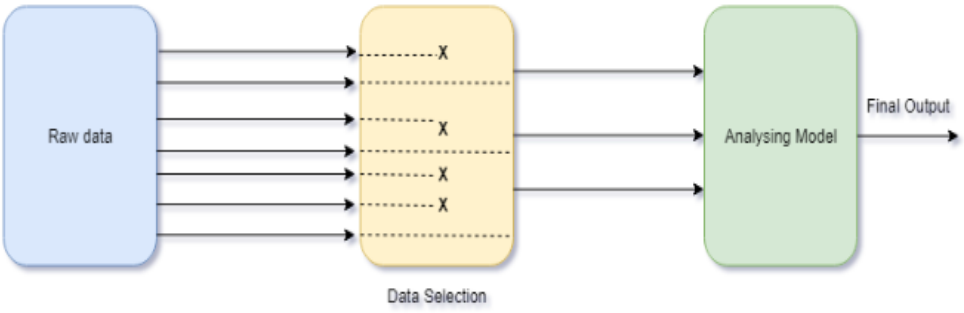

Figure 5. Model for Feature Selection

It's a specific process, the selection of features may be supervised/organized else unsupervised/unorganized. For example, the method of Genetic acts as supervised and Variance Thresholds act as unsupervised. It is possible to collaborate with various techniques together based on the requirements. The overview model for feature selection was shown in figure 3.4.

3.4.2.1. Variance Thresholds

This method actively seeks the variance in a single measurement to a different of a provided features as well as in the event which variance is certainly not various in every single measurement under the provided threshold, feature this is certainly in charge of measurement was taken away. Features that won't modify a lot will not add the most effective information. Making use of variance thresholds is

a simple as well as comparatively secure option to decrease dimensionality at the beginning of the modeling process. However, this itself will never be adequate if it wants to decrease the dimensions since it's highly subjective also it has to alter the variance threshold manually. This type of selection of features could be applied to making use of any programming language such as R and Python.

3.4.2.2. Correlation Thresholds

In this, the features were used by examining whether such features were correlated to every single feature accurately. If they're, then it entirely reflects towards the end outcomes of features which could be similar to the output it gets as soon as it utilizes such types of features. The feature type it wants to omit was achieved by calculating every pair-wise correlation. Then, in the event, in which correlation within a set of features exceeds a provided threshold, it would eliminate the one which contains a higher mean absolute correlation along with other features. Such as the previous method, this could be dependent on prediction therefore the responsibility to tune the thresholds through a particular way in which the useful information will never be neglected, this was entirely based on the preference of the user. Due to such reasons, the method consists of built-in abilities to select features such as PCA were referred over this.

3.4.2.3. Genetic Algorithms

These were generally a method based on a searching pattern that was encouraged through evolutionary biology as well as natural selection, incorporating mutation with cross-over to conveniently navigate huge solution spaces. It was utilized for discovering an optimal binary vector, in which every single bit is connected with an element. If any little bit of this vector equals 1, then the particular feature was permitted to be involved in classification.If the bit is a 0, then its specific related feature will not participate. While selecting the features, "genes" terms a single feature together with "organism" terms as a candidate collection of features. Every single organism within the "population" was ranked in a score of fitness likewise the performance of a model stays in a hold-out set. The Fittest organisms will thrive to reproduce, repeating through to the population converges on a remedy for some generations later. It might conveniently opt for the features from extremely higher dimension datasets, in which exhaustive search is unfeasible. However, the majority of the situation might genuinely believe this is simply not worth the effort which will be quite true concerning the context as making use of PCA or built-in selection could be a lot easier.

4. Results and Discussion

The necessary metrics for analyzing the big datasets from any source using different methods were projected in this section.

(i) Accuracy:

This is the percentage of accurate predictions that a method has made in comparison to the actual value of the label when you look at the testing phase.

Accuracy could be estimated such as:

$$\text{Accuracy} = (TN + TP)/(TN+TP+FN+FP)$$

Where TP holds True Positives,

TN holds True negatives,

FP holds False positives,

FN holds false negatives.

- In the event that the class label of a record in a dataset is positive, therefore the method judges the class label for the record as positive, it is called as true positive.
- In the event that the class label of a record in a dataset is negative, therefore the method judges the class label for the record as negative, it is called a true negative.
- In the event that the class label of a record in a dataset is positive, however, the method judges the class label for the record as negative, it is called a false negative.
- In the event that the class label of a record in a dataset is negative, however, the method judges the class label for the record as positive, it is called as false positive.

(ii) Sensitivity:

This is the percentage of true positives that can be accurately judged by the method while testing. It was estimated as follows:

Sensitivity = TP/(TP + FN)

(iii) Specificity:

This is the percentage of true negatives that can be accurately judged by the method while testing. It was estimated as follows:

Specificity = TN/(TN + FP)

By using the above metrics we had analyzed some of the survey methods from the outcomes of the literature article we were reviewed.

"Cardiotocography dataset is considered from UCI machine learning repository, which has 2126 instances and 23 attributes. The major attributes that are used for contractions of the uterus and the fetal heart are UC (uterine contractions per second) and FM (fetal movements per second). Few other attributes also play a role in recognizing the fetal heart" by Thippa Reddy (2016) [6].The accuracy comparison for genetic algorithm and LDA were given in Table 1 and Figure 6 (X-axis types of methods and Y-axis percentage for accuracy).

Table 1.Accuracy Comparison

Datasets	LDA	Genetic Algorithm
Type 1	89	96
Type 2	87	95

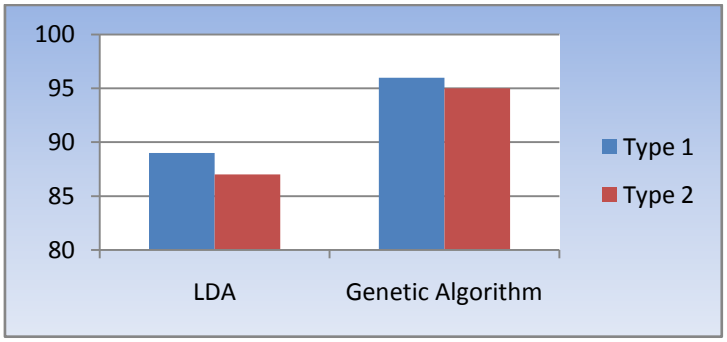

Figure 6.Graphical Form for Accuracy Comparison

The specificity comparison for genetic algorithm and LDA were given in Table 2 and Figure 7(X-axis types of methods and Y-axis percentage for specificity).

Table 2. Specificity Comparison

Datasets	LDA	Genetic Algorithm
Type 1	92	97
Type 2	90	96

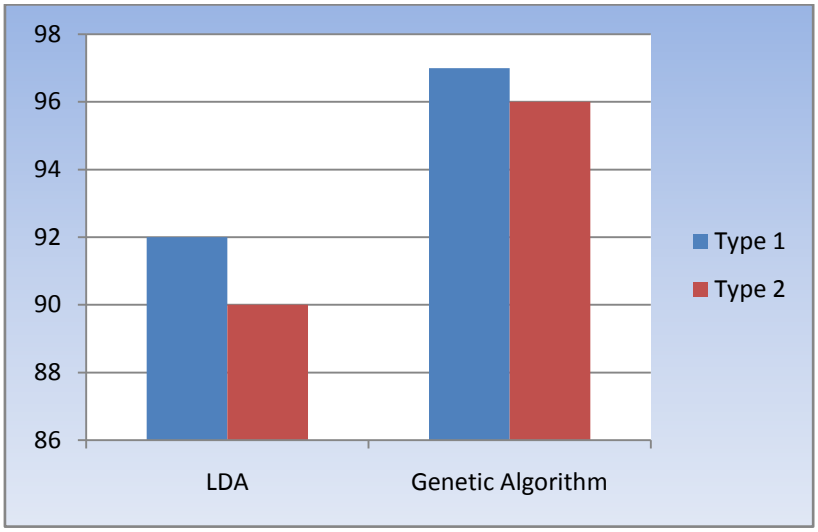

Figure 7.Graphical Form for Specificity Comparison

5. Conclusion

In Big data, the complexness of handling the large level of dataefficiently is a vital problem this is certainly must be lessened. The techniques reviewed in this specific article were an attempt to deal with handling problems. These reviews of literature, reveal that there surely no pre-existing techniques are available to manage the problem of big data complexness solitary-handedly by taking into consideration all "V's" of big data. The research reviewed in this specific article is mainly dedicated to data reduction regards to its volume by minimizing its size and diverseness (minimizing a wide range of features or dimensions). Although, even more attempts have to deal with to decrease big data streams concerningtheir velocity and veracity. In extension, the latest techniques were needed to decrease big data streams in the earlier stage soon after the production of the data and its particular entrance into the big data systems.

As a whole, compression-dependent data reduction techniques were appropriate for minimizing volume. Although, the burden of decompressing wants to be looked at to boost efficiency. Likewise, network theory-dependent techniques work well for extracting frameworks from unstructured data furthermore to effectively manage the diverseness in big data. The data deduplication techniques were helpful to enhance information persistence.

Hence, the above-mentioned techniques were an appropriate option to handle the variability problems in big data. Similarly, data pre-processing, dimension reduction, data mining, and machine learning techniques were very much useful for data reduction at various stages in big data systems.

Retaining in point of view of the outcomes for this survey, we conclude that big data reduction techniques were a growing analysis area that needs much attention for researchers.

In the Future the upcoming analysis will most likely focus on trying to find more efficient local search procedures used by the optimization agents. It was furthermore envisaged to analyze various learners and various strategies concerning the decision-making in the classification ensemble. Finally, it might be furthermore worthwhile to identify experimentally scaling up obstacles when it comes to recommended techniques.

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