Review of K-Means Clustering Algorithm

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Abstract- *Data mining is the process of extracting useful information from the large amount of data and converting it into understandable form for further use. Clustering is the process of grouping object attributes and features such that the data objects in one group are more similar than data objects in another group. But it is now very challenging due to the sharply increase in the large volume of data generated by number of applications. K means is a simple and widely used algorithm for clustering data. But, the traditional k-means is computationally expensive; sensitive to outlier's .Algorithm result in optimal number of cluster Second algorithm reduce computational complexity and remove dead unit problem. It select the most populated area as cluster center. Third algorithm use simple data structure that can be used to store information in each iteration and that information can be used in next iteration. It increase the speed of clustering and reduce time complexity. Solving these Issues is the subject of many recent research works. In this paper, we will do a review on k-means clustering algorithms.*

Keywords- Clustering, K-means clustering ,Computational complexity

I. INTRODUCTION

Clustering is a process of grouping data objects into disjointed clusters so that the data in the same cluster are similar, but data belonging to different cluster differ. A cluster is a collection of data object that are similar to one another are in same cluster and dissimilar to the objects are in other clusters. The demand for organizing the sharp increasing data and learning valuable information from data, which makes clustering techniques are widely applied in many application areas such as artificial intelligence, biology, customer relationship management, data compression, data mining, information retrieval, image processing, machine learning, marketing, medicine, pattern recognition, psychology, statistics and so on. Big Data is evolving term that describes any voluminous amount of structured, semi-structured and unstructured data. It is characterized by "5Vs", volume (size of data set), variety (range of data type and source), velocity (speed of data in and out), value (how useful the data is), and veracity (quality of data). It creates challenges in their collection, processing, management and analysis. As new data and updates are constantly arriving, there is need of data mining to tackle challenges.

The purpose of the data mining technique is to mine information from a bulky data set and make over it into a reasonable form for supplementary purpose. Data mining is also known as the knowledge discovery in databases (KDD). Technically, data mining is the process of finding patterns among number of fields in large relational database. It is the best process to differentiate between data and information. Data mining consists of extract, transform, and load transaction data onto the data warehouse system, Store and manage the data in a multidimensional database system, Provide data access to business analysts and information technology professionals, analyze the data by application software, Present the data in a useful format, such as a graph Or table

II. CLUSTERING

Clustering is a process of unsupervised learning. Highly superior clusters have high intra-class similarity and low inter-class similarity. Several algorithms have been designed to perform clustering, each one uses different principle. They are divided into hierarchical, partitioning, density-based, model based algorithms and grid-based.It makes an important role in data analysis and data mining applications. Data divides into similar object groups based on their features, each data group will consist of collection of similar objects in clusters.

There are two types of Clustering Partitioning and Hierarchical Clustering.

1. Hierarchical Clustering-A set of nested clusters organized in the form of tree.
2. Partitioning Clustering - A division of data objects into subsets (clusters) such that each data object is in exactly one subset.

III. K-MEANS CLUSTERING

K-means clustering technique is widely used clustering algorithm, which is most popular clustering algorithm that is used in scientific and industrial applications.

It is a method of cluster analysis which is used to partition N objects into k clusters in such a way that each object belongs to the cluster with the nearest mean [3].

The Traditional K Means algorithm is very simple [3]:

Select the value of K i.e. Initial centroids.

Repeat step 3 and 4 for all data points in dataset.

Find the nearest point from that centroids in the Dataset.

Form K cluster by assigning each point to its closest centroid.

Calculate the new global centroid for each cluster.

Properties of k-means algorithm [3]:

Efficient while processing large data set.

It works only on numeric values.

The shapes of clusters are convex.

K-means is the most commonly used partitioning algorithm in cluster analysis because of its simplicity and performance. But it has some restrictions when dealing with very large datasets because of high computational complexity, sensitive to outliers and its results depends on initial centroids, which are selected randomly. Many solutions have been proposed to improve the performance of K-Means. But no one provide a global solution. Some of proposed algorithms are fast but they fail to maintain the quality of clusters. Some generate clusters of good quality but they are very expensive in term of computational complexity. The outliers are major problem that will effect on quality of clusters. Some algorithm only works on only numerical datasets.

K-mean Algorithm

Input

K : number of desired cluster
D : {d1, d2,…..dn} a data set containing n objects.
Output
A set of k cluster as specified in input Method
Arbitrarily choose k data item from D dataset as initial cluster centriod;

Repeat

Assign each data item di to the cluster to which object is most similar based on the mean value of the object in cluster;

Calculate the new mean value of the data items for each cluster and update the mean value;
Until no change.

Firstly we arbitrarily select the value of k from data set D which specify the desired number of cluster. Each value of k initially represent the center of cluster or mean of cluster. For each of the remaining data item in D, data item is assigned to the cluster to which it is the most similar, based on distance between data item and cluster mean. Then compute the new mean for each cluster and update the mean value. Repeat this process until centroid tends to be unchangeable or we can say that until the criterion function converges.

In k-mean algorithm the intercluster distance i.e the minimum distance between cluster center is measured as Inter =min { mk – mkk } for all k = 1,2……k-1 and kk = k+1……..k …………………………..(1)

Drawback of K-mean Algorithm

Sensitive to the selection of initial cluster center.

There is no rule for the decision of value of k and sensitive to initial value ,for different initial value there will be different result.

This algorithm is easy to be effected by abnormal points.

It may contain dead unit problem.

IV. LITERATURE REVIEW

Amira Boukhdhir, Oussama Lachiheb,Mohamed Salah Gouider[1] proposed algorithm an improved KMeans with Map Reduce design for very large dataset. The algorithm takes less execution time as compared to traditional KMeans, PKMeans and Fast KMeans. It removes the outlier from numerical datasets also Map Reduce technique used to select initial centroids and forming the clusters. But it has limitations like the value of numbers of centroids required as input by user. It works on numerical datasets only. Also numbers of clusters are not determined automatically.

Duong Van Hieu, Phayung Meesad [2] proposed algorithm for reducing executing time of the k-means .They implemented this by cutting off a number of last iterations. In this experiment method 30% of iterations are reduced, so 30%

of executing time is reduced, and accuracy is high. However, the choosing randomly the initial centroids produces the instable clusters. Clustering result may be affected by noise points, so it produces inaccurate result.

Li Ma and al [3] developed a solution for improving the quality of traditional k-means clusters. They used the technique of selecting systematically the value of k i.e number of clusters as well as the initial centroids. Also they reduced the number of noise points so the outlier's problem solved. This algorithm produces good quality clusters but it takes more computation time. Xiaoli Cui and al [4] proposed an algorithm i. e. an improved k-means. This algorithm works on only representative points instead of the whole dataset, using a sampling technique. The result of this the I/O cost and the network cost reduced because of Parallel K-means. Experimental results shows that the algorithm is efficient and it has better performance as compared with k-means but, there is no high accuracy.

Yugal Kumar, G. Sahoo [5] focused on K-Means initialization problems. The K-Means initialization problem of algorithm is formulated by two ways; first, how many numbers of clusters required for clustering and second, how to initialize initial centers for clusters of K-Means algorithm. This paper covers the solution for of the initialization problem of initial cluster centers. For that, a binary search initialization method is used to initialize the initial cluster points i.e. initial centroid for K-Means algorithm Performance of algorithm evaluated using UCI repository datasets.

Huang Xiuchang, SU Wei [6] focused on problem of user behavior pattern analysis, which has the insensitivity of numerical value, uneven spatial and temporal distribution characteristics strong noise. The traditional clustering algorithm not works properly. This paper analyses the existing clustering methods, trajectory analysis methods, and behavior pattern analysis methods, and combines clustering algorithm into the trajectory analysis. After modifying thetraditional K-MEANS clustering algorithm, the new improved algorithm designed which is suitable to solve the problem of user behavior pattern analysis compared with traditional clustering methods on the basis of the test of the simulation data and actual data, the results shows that the improved algorithm more suitable for solving the trajectory pattern of user behavior problems.

Nidhi Singh, Divakar Singh [7] K-means is widely used for clustering algorithm. This paper proves that the accuracy of k-means for iris dataset is much than the hierarchical clustering and for diabetes dataset accuracy of hierarchal clustering is more than the k-means algorithm. The time taken to cluster the data sets is less in case of k-means. A good clustering method produces high-quality clusters to ensure that objects of a same cluster are more similar than members of different cluster. Kmeans algorithm in this paper works well for large datasets.

Kedar B. Sawan [8] existing K-means clustering algorithm has a number of drawbacks. The selection of initial starting point will have effect on the results of number of clusters formed and their new centroids. Overview of the existing methods of choosing the value of K i.e. the number of clusters along with new method to select the initial centroid points for the K-means algorithm has been proposed in the paper along with the modified K-Means algorithm to overcome the deficiency of the classical K-means clustering algorithm. The new method is closely related to the approach of K-means clustering because it takes into account information reflecting the performance of the algorithm. The improved version of the algorithm uses a systematic way to find initial centroid points which reduces the number of dataset scans and will produce better accuracy in less number of iteration with the traditional algorithm. The method could be computationally expensive if used with large data sets because it requires calculating the distance of every point with the first point of the given dataset as a very first step of the algorithm and sort it based on this distance. However this drawback could be taken care by using multi-threading technique while implementing it within the program. However further research is required to verify the capability of this method when applied to data sets with more complex object distributions.

Bapusaheb B. Bhusare, S. M. Bansode [9] the K means clustering algorithm which mainly based on initial cluster centers. In this paper K means clustering algorithm by designed in such way that the initial centroids selected using Pillar algorithm. Pillar algorithm effectively chooses the initial centroids and improves accuracy of clusters. However, proposed algorithm has outlier problem leads to reduced performance. So there is need to choose the appropriate parameter in data set for outlier detection mechanism. An improvement in pillar algorithm is done and the number of distance calculation reduced for the previous initial centroids neighbors and used for next step of iterations which causes to increase in the computational time. The experimental results show that the use of pillar algorithm with change improved solution.

Kamaljit Kaur, Dr. Dalvinder Singh Dhaliwal, Dr. Ravinder Kumar Vohra [10] found that the K-Means algorithm has two major limitations 1. Several distance calculations of each data point from all the centroids in each iteration. 2. The final clusters depend upon the selection of initial centroids. This work improves k-Means clustering algorithm designed in MATLAB and the datasets from UCI machine learning repository used. The initial centroids initial centroids not selected randomly. By using new approach good clustering results obtained. The new method of selection of initial centroid is better than selecting the initial centroids randomly.

Abhijit Kane's [11] paper includes the automatically find the number of clusters in a dataset. Here every step requires re-clustering of the dataset, total O (n) operations computed. This method works well for clusters that are distinctlyseparated. This method is also density-independent, making it useful for clustering algorithms like the Expectation-maximization algorithm.

Omar Kettani, Faical Ramdani, Benaissa Tadili [12] work covers an algorithm designed for automatic clustering. Thismethod computes the correct number of clusters on tested data sets. This method was compared with G-means. The comparison of algorithm shows that the proposed approach much better than G-means in terms of clustering accuracy.
Avni Godara, Varun Sharm [13] covers the prime algorithm. The KMeans clustering is a powerful algorithm used most of the application in daily life dataset, but problem of initial centroid selection. In past years number of papers presented to improve classical k means algorithm. To remove problem of initial centroid selection need to define data points for centroid before next iteration. The use of prim's algorithm gives better results for selection of initial centroid and choose easily data points for future iterations. Experimental result also shows that the prime algorithm gives better and optimal performance for initial centroids, accuracy of result not adjusted.

D. Sharmila Rani, V. T. Shenbagamuthu [14] K-means is a typical clustering algorithm and it is used for clustering largesets of data. This work includes K-means algorithm and analyses the standard K-means clustering algorithm. The standard K-means algorithm is computationally complex and need to reassign the data points, a number of times during every iteration, which makes effect on the efficiency of standard K-means clustering. This paper work covers a simple and efficient way for assigning data points to clusters. This work ensures that the entire process of clustering in O (nk) time without sacrificing the accuracy of clusters.

Effat Naaz, Divya Sharma, D Sirisha, Venkatesan M. [15] Paper build a system to know the accuracy of medication associated with each symptom. To do this K-means Clustering on the clinical note corpus applied. The document clustering results in improving the medication recommendation. An experimental result shows that pre-processing before clustering results in efficient process of clustering. For experimental work different tools used like, section annotator, symptom annotator, negation annotator and medication annotator to get different views of clinical notes which improves the visibility of clinical note. The result of this is increase of the accuracy of medications associated with the symptoms.

V. DYNAMIC CLUSTERING OF DATA WITH MODIFIED K-MEAN

This paper propose a new algorithm which can increase the cluster quality and fix the number of cluster. In standard kmean algorithm we have to give the value of k i.e the number of cluster in advance . Practically it is very difficult to give the value of k in advance or fixing the value of k in advance will lead to a poor quality cluster. If the value of k is very small then there will be a chance of putting dissimilar objects into same group and if the value of k is large then the more similar objects will be put into different groups. In this algorithm we have to give the value of k as input and we also have to mention either the value of k is fixed or not fixed. This algorithm work for two cases

When the value of k is fixed.
When the value of k is not fixed.

In the first case the algorithm work as standard k-mean algorithm. In the second case the user give the minimum value of k. The algorithm calculate the new cluster center by increasing the value of cluster counter by one in each iteration until it reaches the cluster quality threshold .

The dynamic algorithm is as follows:

Input

K : number of cluster (for dynamic clustering
initialize the value of k by two)
Fixed number of cluster = yes or no (Boolean).
D : {d1, d2,…..dn} a data set containing n objects.

Output

A set of k clusters.

Method

Randomly choose k data item from D dataset as the initial cluster centers.

Repeat

Assign each data item di to the cluster to which object is most similar based on the mean value of the object in cluster;
Calculate the new mean value of the data items for each cluster and update the mean value;

Until no change.

If fixed number of cluster = yes
Compute the intra-cluster distance
If new intra-cluster distance<old intra –cluster and
new inter-cluster distance > old inter-cluster distance
k=k+1
Stop

This algorithm give optimal number of cluster for unknown data set. The time taken by this algorithm for small dataset is almost same as standard k-mean algorithm but the time taken by dynamic clustering algorithm for large data set is more as compare to standard k-mean algorithm.

VI. DATA CLUSTERING WITH MODIFIED K-MEANS ALGORITHM

This paper propose a new approach of data clustering based on the improvement of sensitivity of initial center of clusters. This algorithm will decrease the complexity and effort of numerical calculation and maintain the simplicity and easiness of implementing the k-mean algorithm. This algorithm can reduce the two limitation of standard k-mean algorithm . First is in standard k-mean result directly depends on initial centroid of cluster chosen by algorithm. Second limitation is it may contain dead unit problem. The proposed algorithm is based on density of different region which reduce the first problem. It will also solve the dead point problem because the center of cluster located in first iteration pertaining to the maximum density of data point. In this algorithm the number of desired cluster(k) is provided by user in same way as in standard k mean algorithm .

They divide this approach in two phases:

Phase 1:

In first phase we take the data set and desired number of cluster(k) as input. The whole space is divided in to k*k segment. For example if value of k entered by user is 3(k=3) then the space will be partitioned in to 3*3 segment (3 segment horizontally and 3 segment vertically).Distribute the whole dataset in space and then calculate the frequency of data point in each segment. The segment which have the maximum probability of data point will have the maximum probability to contain center of cluster. If highest frequency of data point is same in two segment and upper bound of segment crosses the threshold then these two segment must be merged and then take the highest k segment for calculating the seed point of cluster. For example if value of k entered by user is 3(k=3) then the space will be partitioned in to 3*3 segment (3 segment horizontally and 3 segment vertically).

Phase 2:

Assign the data point to appropriate cluster center

Step1 : Calculate the distance between each cluster's center by using equation
|Ci, Cj|={d(mi, mj) : (i, j) ϵ [1,k] & i≠j}…………(A)
Where |Ci,Cj| is the distance between cluster Ci and Cj.
Ci : is the ith cluster.
K : number of cluster centroid.
Step2 : Calculate the half of minimum distance between a centroid to the remaining centroid.
dc(i) = ½(min{|Ci,Cj|}………………..(B)
where
dc(i) : is the half of minimum distance from ith center to any other remaining cluster.
Step3 : select any data point to calculate its distance from ith center and called this distance as d and compare it with dc(i).
If (d<=dc(i)) then
Assign data point to ith cluster.
else
calculate the distance from other centroid.
Repeat this process until that data point is assigned to remaining cluster.
If data point is not assigned to any cluster then the center which show minimum distance with the data point becomes the cluster for that data point. Repeat the process for each data point
Step4 : calculate the mean of each cluster and update it .
Repeat 2nd phase until termination condition is reached.

MODIFIED ALGORITHM

Input data set and value of k
If(k=1) then exit
Else
/* divide data point space in k*k segments*/
For each dimension{
Calculate the minimum and maximum data points in each segment
Calculate range of group (RG)=((min+max)/k)
Divide the data point space in k group with width RG

}
Calculate the frequency of data point in each segment.
Choose k highest frequency group
Calculate mean of the selected group /* this will be initial center of cluster*/
Calculate distance between each cluster using eq. A

Take the minimum distance for each cluster and make it half using eq. B
For each data point P=1 to N0{
For each cluster j=1 to k {
Calculate $d(zp,mj)=\sqrt{\sum k\text{-}l(Zp,k\text{-}Mj,k)}$
Where
Zp is the pth data point Mj is the centroid of jth cluster.
If (d(Zp, Mj) $\leq$ dcj){
Then Zp assign to cluster Cj
Break
}
Else
Continue;
}
If Zp does not belong to any cluster then
Zpϵ min(d(Zp, Mj)) where i ϵ [1, Nc]
}
Check termination condition of algorithm if satisfied
Exit
else
Calculate centroid of cluster
$Mj = 1/nj(\Sigma Zp)$
Δ Zp ϵ Cj

Where nj is the number of data point in cluster j.In this algorithm step is one time execution step it reduce the problem of dead unit and optimize the selection of initial centroid of cluster by using most populated area as center of cluster. As in modified algorithm threshold distance will ensure minimum execution time during the allocation of data point to cluster.

Computational Complexity:

This paper propose a new algorithm which increase the speed and accuracy of clustering and reduce the computational complexity of standard k-mean algorithm. As in k-mean algorithm in each iteration we have to calculate the distance between each data item and all cluster centers and then find the nearest cluster center and assign data item to that center. It reduce the efficiency of k-mean algorithm especially for large capacity data-bases. The basic idea of this algorithm is two keep two simple data structure to store the information of each iteration and that information can be used in next iteration. First data structure can be used to store the label of cluster. Second data structure can be used to store the distance of each data item to the nearest cluster center in each iteration this information can be used in next iteration. In second iteration we calculate the distance between data item and the new cluster center. After that we compare the distance between data item and new cluster with distance stored in previous iteration. If the new distance is smaller than or equal to older center then data item stay in its cluster that was assigned in previous iteration. Now there is no need to calculate distance between data item and remaining k-1cluster center. Some data item will remain in original cluster in each iteration so there is no need to calculate the distance and it will reduce the computational complexity.

VII. ALGORITHM

Input

K : number of desired cluster
D : {d1, d2,…..dn} a data set containing n objects.

Output

A set of k cluster as specified in input

Method

Arbitrarily choose k data item from D dataset as initial cluster

centriod;

Calculate d(di, cj) = the distance between each data item and all k cluster center. Assign data item to nearest cluster.
Where di : is data item in data set D
(1<=i<= n)
Cj : is the cluster center
(1<=j<= k)

For each data object di find the closest center cj assign di to cluster j.

Store the label of cluster center in which data object di is in array cluster[]. Store distance of data object di to the nearest cluster in array dist[].
Set Cluster[i] = j, j is the label of nearest cluster.
Set Dist[i] = d(di, cj), d(di, cj) is the nearest Euclidean distance to the closest center.
For each cluster j(1<=j<=k) calculate cluster center;
Repeat
For each data object di compute its distance to the center
of present nearest cluster
a. If this distance<=Dist[i] then

Data object stay in initial cluster;
b. else
for every cluster center cj compute distance d(di, cj) of each data object to all the center assign data object di to nearest cluster center cj.
set cluster[i]=j;
set Dist[i]=d(di, cj);
For each cluster center j recalculate the centers;
Until convergence criteria met
Output the clustering results;

Total time required by improved algorithm is o(nk) while total time required by standard k-mean algorithm is o(nkt). So the improved algorithm improve clustering speed and reducethe time complexity.

VIII. CONCLUSION

This paper analyze the shortcomings of k-mean algorithm and also discuss three dissimilar algorithms that remove the limitations of k-mean algorithm and improve the speed and efficiency of k-mean algorithm and result in optimal number of cluster. The first algorithm remove the limitation of specifying the value of k in advance which is very difficult practically. It also gives the optimal number of cluster. The second algorithm reduce computational complexity and also remove dead unit problem. It select the most populated area as center of cluster. In k-mean algorithm result will depends on initial centroid second algorithm also reduce this problem. Third algorithm reduce the time complexity by using two simple data structure to store the information of each iteration which can be used in next iteration. As in first algorithm time complexity is greater as compared to standard k-mean algorithm for large data set as compared to standard k-mean algorithm for large data set .

In this review work most widely used k-means clustering techniques of data mining is analyzed. This work shows that there are several methods to improve the clustering with different approaches. Various clustering techniques are reviewed which improve the existing algorithm with different perspective. Some limitations of existing algorithm will be eliminated in future work. This technique will be useful in extraction of useful information using cluster from huge database. It removes the limitation of K-means clustering algorithm and gives accurate result in less time so we can say it's very efficient than standard K-means clustering algorithm and quality of cluster also improved. From Our analysis of different K-means approaches, we conclude that it's better than traditional K-means clustering algorithm.

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