Object Oriented K-Means clustering using Eigen Decomposition for Student Data

N.Sree Ram
LBRCE, Mylavaram
JNTUK Kakinada
Andhra Pradesh, India

Dr. K. Satya Prasad
Professor, Dept of ECE
JNTUK, Kakinada
Andhra Pradesh, India

Dr. J. V. R. Murthy
Professor, Dept of CSE
JNTUK, Kakinada
Andhra Pradesh, India

Abstract: Data clustering [1] is the process of forming classes or groups of similar data objects. The real time data objects are either multi-dimensional [4] or high dimensional [3]. Grouping these high dimensional data objects requires a lot of computational effort, time and space. To remove these hurdles from clustering of high dimensional data, the proposed work uses Eigen decomposition for dimensionality reduction, and then k-means is implemented through object oriented [2] programming on student’s marks data. The experimental results show how Eigen value decomposition and object oriented implementation brings novelty to clustering process.

Keywords: Eigen decomposition; k-means; object oriented implementation; clustering; high dimensional data

I. INTRODUCTION

Clustering [1] high dimensional data is a challenging issue in data and knowledge engineering. Generally the real time data objects are high dimensional. Typical clustering techniques are available to process these high dimensional data, but implementation of these techniques don’t provide modularity, data security, code reusability and require much more computational effort. In order to bring novelty to k-means, this proposed work uses Eigen decomposition for dimensionality reduction, and then k-means is implemented as object oriented system. Dimensionality reduction [10] is one of the important tasks in data pre-processing and uses different kinds of matrix decomposition techniques such as cholesky decomposition, LU decomposition, QR decomposition, single valued decomposition, and Eigen Decomposition. In this paper, Eigen decomposition is used for dimensionality reduction, which will be explained in the second section of this paper. In order to incorporate modularity, reusability, and data security, k-means was implemented with object oriented paradigm, which will be clearly discussed in section 3 of this paper. In Object Oriented implementation [11], the entire system is implemented as a set of objects, classes and methods section 4 provides information about object oriented k-means using Eigen decomposition. Section 5 of this paper shows implementation details of the system in object oriented paradigm and experimental results of proposed algorithm whereas section 6 provides conclusion.

II. RELATED WORK

A. Eigen Decomposition

Clustering of high dimensional data [3] requires dimensionality reduction as pre-processing of data. Typical dimensionality reduction techniques are available, which can project data from high dimensional space to low dimensional space. This proposed work uses Eigen Decomposition based dimensionality reduction technique known as Principal Component Analysis [11] (PCA). The Eigen decomposition is also known as spectral decomposition and it can be applied to a square matrix with distinct Eigen vectors i.e.

\[ A = V D V^{-1} \]  

(1)

Where D is diagonal matrix forms from Eigen values of A, and the columns of V are the corresponding to Eigen vectors of A. The classical Dimensionality reduction method Principal Component Analysis works based on Eigen decomposition. PCA [4][5] was invented in 1901 by Karal Pearson and is the simplest of the true Eigen vector based multivariate analysis. When a multivariate data set is represented as a set of coordinates in a high dimensional data space, PCA can generate the low dimensional data. In PCA first the given high dimensional data is represented as a set of coordinates in a high dimensional data space, PCA can generate the low dimensional data. In PCA firstly the given high dimensional data is represented as a set of coordinates called as data matrix. Secondy calculation is made on the mean of the each dimension to generate mean variant matrix and generate the covariance matrix of the data matrix by using the following formula

\[ \text{Cov}(X, Y) = \Sigma( X_i - \bar{X})( Y_i - \bar{Y}) / \sqrt{N} = \Sigma x_{ij} / N \]  

(2)

Where N is the number of scores in each set of data, \( \bar{X} \) is the mean of the N scores in the first data set \( X_i \) is the ith
raw score in the first set of scores, $x_i$ is the $i$th deviation score in the first set of scores, $Y$ is the mean of the $N$ scores in the second data set, $Y_i$ is the $i$th raw score in the second set of scores and $\text{Cov}(X,Y)$ is the covariance of corresponding scores in the two sets of data. Covariance matrix is always square matrix. Now, calculate the Eigen values from the covariance matrix using formula

$$ (A - \lambda I)\mathbf{v} = 0, \quad (3) $$

Where $I$ is an identity square matrix. Now generate the Eigen vectors of each Eigen value and arrange the vectors as per the order of Eigen values. Finally transpose the Eigen vector matrix, extract highest significant dimensions and multiply this with mean variant matrix of data matrix to get feature vector. These dimensions are called Principal Components of the data matrix.

Feature vector = Mean adjusted data* Row feature vectors.

The entire process is explained as an algorithm as follows

Algorithm 1: PCA or Eigen Decomposition

Input: Data matrix
Output: Feature vector
Method:
Step 1: Represent the given data set as coordinates matrix
Step 2: Calculate the mean of each dimension in the data set using $\sum x_i/m$
Step 3: Generate mean adjusted matrix for data matrix
Step 4: Generate the covariance of data matrix using $\sum (X - \text{mean}(X))(Y - \text{mean}(Y))/n$
Step 5: Find out the Eigen value of covariance matrix i.e. $(A - \lambda I)\mathbf{v} = 0$, where $I$ is identity matrix
Step 6: Generate the Eigen vectors of respective Eigen values of covariance matrix.
Step 7: Arrange the Eigen vectors from high significant Eigen value to low significant Eigen value.
Step 8: Transpose the Eigen vector matrix
Step 9: Extract the high significant dimensions and multiply with mean adjusted data matrix i.e. Feature Vector = Eigen vector matrix*Mean adjusted matrix.
Step 10: The product of two matrices in above step is the feature vectors and also known as Principal Components.

Thus Eigen decomposition projects data from high dimensional space to low dimensional space.

B. K-Means

K-means [1][7] is one of the most well-known partitioning clustering techniques, which assigns each object to exactly one cluster. The objects in one cluster are similar to each other and the objects in one cluster are dissimilar to objects in other cluster. It uses proximity measures to identify the similarity and dissimilarity between the objects. The most popular proximity measure is Euclidian Distance, which measures the geometric distance between the objects. in this first any $k$ of the objects need to pick up as centroids of $k$ clusters. Now calculate distance between each centroid and other objects in data set. Based on the distance the objects are allocated to clusters respectively and then calculate mean of each cluster. Now replace centroid of each cluster with this mean. Repeat this process until no change in further clusters. The entire process is represented as an algorithm.

Algorithm 2: K-Means

Input: $k$ specifies number of clusters, $D$ data set and $N$ specifies number of objects in data set.
Output: $K$ clusters
Method:
Step 1: Randomly pickup $k$ centroids from data set $D$
Step 2: Calculate the distance from each centroid to remaining all other objects and construct distance matrix with size $K*N$
Step 3: Assign each object to exactly one cluster which is having minimum distance.
Step 4: Calculate the mean of each cluster
Step 5: Replace centroids with this mean. Now mean of cluster will act as centroid
Step 6: Repeat the steps from step 2 until no change in clusters.

C. Object Oriented Paradigm

Object Oriented Paradigm is fashion of implementing system by following Object Oriented Principles and concepts. In this the entire system is implemented as a collection of objects. An object is a real time entity which is having some set of characteristics and specific behaviour. The characteristics of an object specify the state of an object and the behaviour of an object change the state of an object. In this one object can interact with other objects in the system by using message passing technique. The three basic object oriented principles are encapsulation, inheritance and polymorphism. Encapsulation is the process of combining both characteristics and behaviour of object as single object. Inheritance is a process of defining a new object by inheriting features and behaviour from an existing object. Polymorphism is a process of defining different behaviours with the same name. There are variety of programming languages with object oriented Paradigm [1] such as smalltalk, C++ and Java. The object oriented programming languages provide a basic construct to define an object called as class. The class can be
used to combine both behaviour and characteristics of an object. The characteristics of an object is defines as member data and behaviour can define through methods. Data abstraction is one of the important features available in this paradigm which provides security to data by means of methods. Inheritance and polymorphism provide modularity and reusability respectively.

III. OBJECT ORIENTED K-MEANS

Most of the researches implemented k-means algorithm in conventional procedural paradigm, which doesn’t provide data security, modularity and code reusability. In order to incorporate modularity and code reusability the proposed work is implemented K-Means in Object Oriented paradigm. In this work entire k-means is defined as a single object, which consists of dataset, distance matrix, k number of clusters and centroids as member data and distance calculation and cluster forming as methods. The entire process is explained as algorithm as follows.

Algorithm 3: Object Oriented k-Means

Input: Data set, Distance matrix, and K (Number of clusters)
Output: K clusters

Method:
Step 1: create class and named it as k-means
Step 2: Define Data set, Distance matrix and k (number of clusters) as member data i.e. properties of an object
Step 3: Implement the methods distance calculation and cluster forming to define behaviour of object
Step 4: Finally create object to k-means class

The object oriented k-means can be modelled by using class diagram as follows.

IV. OBJECT ORIENTED K-MEANS USING EIGEN DECOMPOSITION

To enable the object oriented k-means to cluster multi-dimensional data objects the proposed work used Eigen decomposition technique for Dimensionality reduction. First Eigen decomposition was applied on dataset which will generate feature vector. This Eigen decomposition is implemented as Eigen object. Now apply Object oriented K-means on feature vector instead of directly applying on original data set. Object oriented k-means is implemented as another object and there exists generalization relationship between Eigen object and k-means object which can be modeled as follow using class diagram.

V. IMPLEMENTATION AND EXPERIMENTAL RESULTS

This proposed work is implemented by using object oriented programming language Java [6] and the student marks data is stored in Oracle data base. It used JDBC Type 4 driver [6] to access data set from database. The data set in data base is five dimensional and is shown as follows

Table I. student data

<table>
<thead>
<tr>
<th>H.T.No</th>
<th>Marks in DBMS</th>
<th>Marks in SE</th>
<th>Marks in Java</th>
<th>Marks in Data Mining</th>
</tr>
</thead>
<tbody>
<tr>
<td>1176050001</td>
<td>75</td>
<td>80</td>
<td>73</td>
<td>69</td>
</tr>
<tr>
<td>1176050002</td>
<td>74</td>
<td>78</td>
<td>69</td>
<td>65</td>
</tr>
<tr>
<td>1176050003</td>
<td>54</td>
<td>58</td>
<td>72</td>
<td>81</td>
</tr>
<tr>
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<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>1176050012</td>
<td>92</td>
<td>81</td>
<td>76</td>
<td>78</td>
</tr>
</tbody>
</table>

The student data objects are clustered based on their marks so the four dimensions of the data representing the marks obtained by the student are taken as task relevant data Eigen decomposition is applied to reduce the dimensions. During this process 4*4 covariance matrix was generated as shown below.
Table II. Covariance matrix

<table>
<thead>
<tr>
<th></th>
<th>231.8792</th>
<th>365.2727</th>
<th>94.4242</th>
<th>65.0606</th>
</tr>
</thead>
<tbody>
<tr>
<td>231.8792</td>
<td>365.2727</td>
<td>94.4242</td>
<td>65.0606</td>
<td></td>
</tr>
<tr>
<td>365.2727</td>
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<td>82.2272</td>
<td>56.91</td>
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</tr>
<tr>
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<td>77.6728</td>
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<tr>
<td>65.0606</td>
<td>56.91</td>
<td>52.4242</td>
<td>66.7880</td>
<td></td>
</tr>
</tbody>
</table>

From this covariance matrix the feature vector was generated by applying Eigen decomposition. The feature vector resulted from this work is shown as follows

Table III. Feature vector

<table>
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<tr>
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<th>-0.2274</th>
<th>5.22015</th>
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<th></th>
</tr>
</thead>
<tbody>
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<td>-25.2179</td>
<td>-14.7251</td>
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<tr>
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<td>15.5242</td>
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</tbody>
</table>

VI. CONCLUSION

In this paper we presented Eigen decomposition as dimensionality reduction and k-means applied on the feature vector resulted from Eigen decomposition. The implementation of entire work is done in object oriented paradigm. So that the data security is provided by restricting the data accessibility except the methods in that object. Due to the usage of object oriented principles it could be possible to bring modularity and reusability. In order to accelerate the performance of the algorithm in future it will implement in multi core environment by using multi-threading.

VII. REFERENCES

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