

# CSC 466 Lab 4 Report

A Comparison of K-Means, Hierarchical Agglomerative Clustering,  
and DBSCAN Clustering Algorithms in Various Datasets

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# Abstract

The following pages outline the evaluation study that we conducted by our clustering algorithm on several provided datasets. For our datasets, we attempt to find the best clusters in the data, then compare and contrast the results we get from our clustering algorithms. For a couple datasets, we can easily visualize the results of the algorithms. Following these results, we will discuss the various benefits/drawbacks of the algorithms themselves.

# Introduction

We wrote 3 algorithms to cluster data: K-Means clustering, Hierarchical Agglomerative Clustering, and DBSCAN. No single algorithm has a clear superiority in every possible dataset, but this report shall try to compare and contrast the differences between the three and hopefully determine the shortcomings of the algorithms. One aspect we will pay particular close attention to is how the algorithms react to outliers. We were provided with 6 datasets in 6 files: 4clusters.csv, mammal\_milk.csv, iris.csv, many\_clusters.csv, AccidentsSet01.csv, and AccidentsSet03.csv. For the datasets with relevant data in 2 or 3 dimensions. We will provide a graph to visually look at the data to help make our analysis of the algorithms as correct as possible.

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## K-Means

### Implementation

The implementation for the k-means algorithm can be found in kmeans.java. K-means is an algorithm that requires the number of clusters to be set before running the algorithm, so it takes a bit of fine tuning to discover a good number of clusters. It is also very sensitive to outliers, which can skew the assignment of centroids towards the outliers. The choosing of initial centroids is not random, but uses the k-means ++ approach of finding the points farthest from each other as the starting points.

## Agglomerative Hierarchical Clustering

### Implementation

A naive implementation of the Agglomerative Hierarchical Clustering algorithm can be found in hclustering.java. In this algorithm, the dendrogram is created from node objects who's relevant code can be found in Node.java. Each data point starts off as its own cluster, represented by a Node. The algorithm then identifies the two closest clusters (determined using average link with distances between points calculated using Manhattan distance) by calculating the distance for each pair of clusters in the current list. It takes the two closest clusters and removes them from the set of clusters. A new node is then inserted to the set of clusters where its two children are the old clusters and the new value is the distance between the children. This process is

repeated until there is 1 “cluster” or node remaining. The naive implementation runs in reasonable time with the smaller datasets given, but will perform slower if given larger datasets.

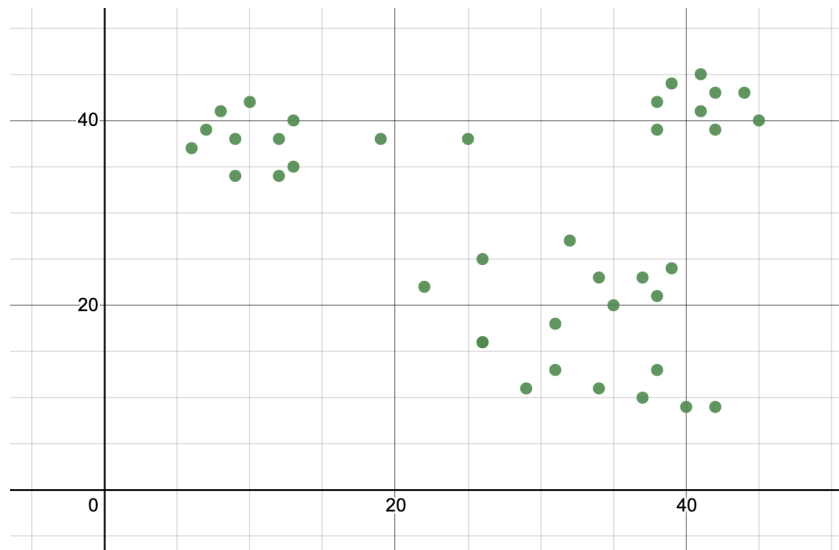
## DBSCAN

### Implementation

The implementation for the DBSCAN algorithm can be found in `dbscan.java`. DBSCAN identifies each point in the dataset as either a core point, boundary point, or noise. A point in the dataset is considered core if there are greater than `minPoints` points within a specified radius (`epsilon`) from that point. Both of these parameters are specified by the user as arguments for the program. Each core point becomes the center of its own cluster. The algorithm then identifies all of the boundary points, and assigns each one to its corresponding cluster. All points still not assigned to a cluster at this point are noise (or outliers). Distances between points are calculated using Manhattan distance.

### 4clusters.csv

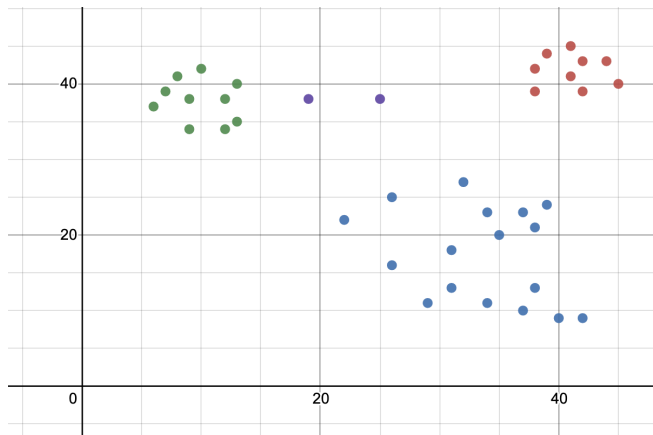
The data for this dataset is very simple, as it is contained in a 2D space. We are told by the title that there are four distinct clusters. We can easily show this data graphically:



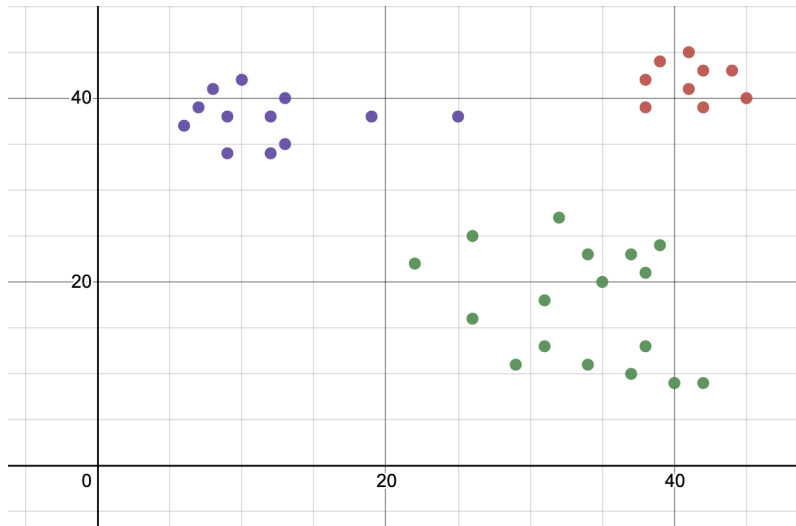
As we can see, it would seem that there are 2 tighter clusters, 1 less dense cluster, and a couple outliers.

## K-means

Running 4clusters.csv through kmeans.java with the k (# of clusters) set to 4, we get an image that looks like this:



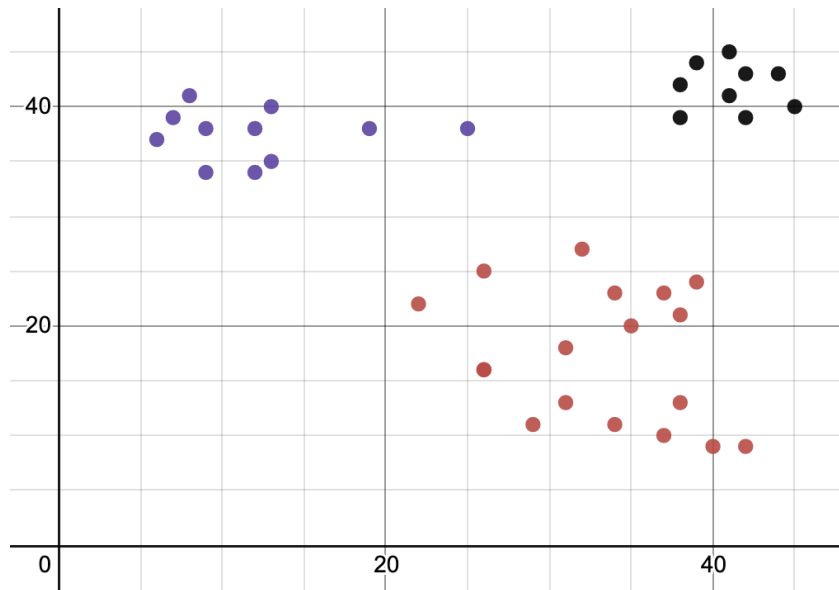
This does not look too bad except the two points in the purple seem to be a bit more like outliers. Recomputing for only 3 clusters reveals a different clustering:



This new configuration for 3 clusters groups those two awkward points in with the upper left cluster, which doesn't feel quite right, and it would be difficult to make the argument that those points belong in that cluster. Thus, the 4 clusters with those 2 points making up their own separate cluster would seem preferable. This cluster could be deemed an "outlier cluster" with only those two points, as the other 3 clusters seem far more legitimate as real clusters.

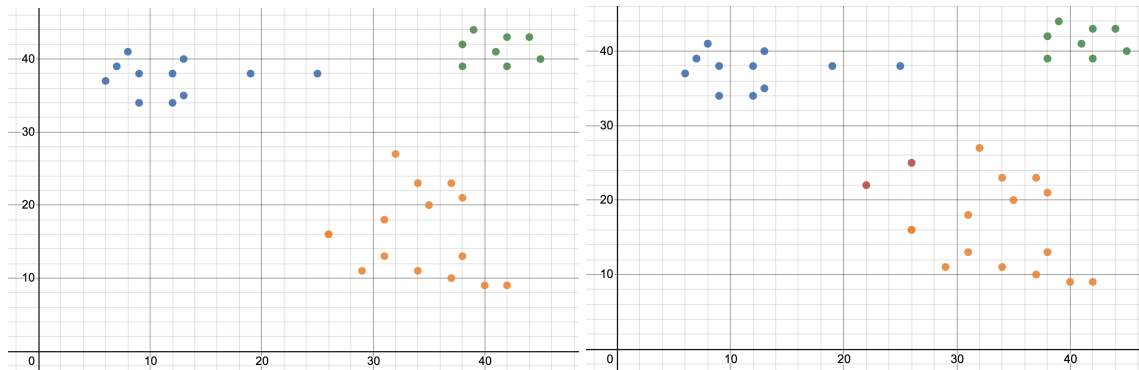
## Agglomerative Hierarchical

Although this dataset provides the amount of clusters desired, this algorithm could only manage to output 3 clusters, when given our desired threshold of 30. Tweaking the threshold never resulted in exactly 4 clusters and this clustering of 3 visually makes the most sense out of everything that we tried, with a relatively low SSE for each cluster.

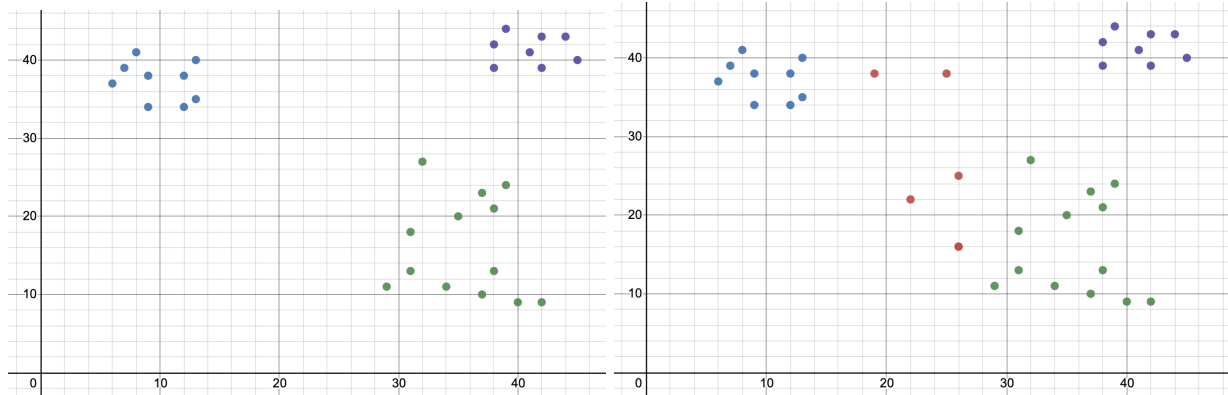


## DBSCAN

DBSCAN has an effective way of determining outliers, so that will be very useful for this dataset. However, those 2 points discussed earlier at (19, 38) and (25, 38) are not the first points to be classified as outliers. That honor goes to (26, 25) and (22, 22), located a bit outside of the bottom loose cluster. The configuration that defines these two points as outliers is epsilon of 8 and a numPoints of 5. Displayed below are the output of this configuration. The image on the left are the 3 clusters the algorithm found, and the image on the right includes the two outliers in red.



Another useful configuration is an epsilon of 7 and a numPoints again at 5. This configuration returns 3 clusters and 6 outliers (5 unique outliers, [26, 16] occurs twice). The output is displayed below again with the left image leaving out the outliers and the image on the right including them in red.



The above configuration looks to be a very good choice for clustering. The two top clusters are very obvious and cohesive, and the bottom cluster is less so, and might benefit from being split into 2 clusters, but no DBSCAN configuration splits that cluster in 2 even with a numPoints of 2, so we must be content with this output.

## Mammal-milk.csv

This dataset contains a listing of 25 different mammals along with various info such as the percentage of protein, fat, water, lactose, and ash in their milk. This data cannot be shown graphically as it has 5 dimensions.

### K-means

Given that we cannot view the clusters visually, narrowing down a good number of clusters is harder to do than in 4clusters for example. We must instead rely on looking at the printed data such as the average, minimum, and maximum distance to centroids and also the sum of squared errors. Given some time to ponder the output from various numbers of centroid, it would appear from the data that the correct number of centroids is 4.

### Agglomerative Hierarchical

Running this algorithm on this dataset with a wide variety of values for threshold always produces the same 4 clusters, with 10 data points being left out of the clusters. This remains true from threshold = 7 all the way to 25. Decreasing to 6 produces no clusters, and increasing significantly beyond 25 causes all data points to be grouped into 1 big cluster. Thus, it would appear that the 4 clusters created are the optimal clustering using this algorithm.

### DBSCAN

DBSCAN appears to have a bit of difficulty finding clusters for this dataset. Assuming we would like a cluster to have at least 3 points, an epsilon of 3 produces no valid clusters, an epsilon of 4 produces 3 clusters with 12 outliers, an epsilon of 5-9 produces just 2 clusters and 9 or 10 outliers, and any epsilon 10 and above produces a single cluster. If we lower the numPoints to

make a cluster to 2, then we get 4 clusters with an epsilon of 4, but defining a cluster as only 2 points and having the number of outliers remain at 9 out of 25 does not seem right, so it would seem that the proper configuration is 3 points for a cluster and an epsilon of 4 despite its many outliers (almost half the data).

## Iris.csv

This dataset contains information about various iris plants. Relevant information for clustering includes sepal length and width and petal length and width. This dataset has 4 dimensions and cannot be shown graphically.

### K-means

For this dataset, as with the other datasets we could not see visually, it is hard to land on a singular k value. We are inclined to go with 5 clusters since the avg, min and max distances for the clusters all seemed fairly small. It feels like 5 clusters for a larger dataset such as this would be deemed rational, but with no outlier detection we feel like we are flying relatively blind and do not trust this output fully.

### Agglomerative Hierarchical

This dataset's dendrogram split at a threshold of 6 results in 4 clusters. One cluster predominantly Iris-setosa, another predominantly Iris-versicolor, and 2 clusters completely consisting of datapoints of the class Iris-virginica. The first cluster includes data points of all 3 class labels, and unsurprisingly has the highest average distance out of all the clusters, but all other clusters have an average distance of about 2 or less. Lowering the threshold will create smaller clusters, but that first cluster persists as a widely varying group and average distance from center hardly decreases so 4 clusters will suffice.

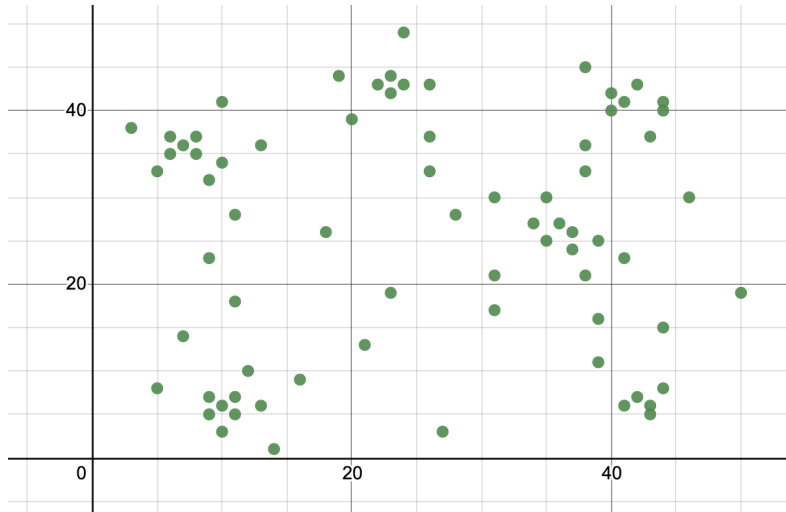
### DBSCAN

This dataset contains 148 entries, so it makes sense for this dataset to hold a higher standard for what defines the number of points required to be a cluster. As it turns out, numPoints plays far less a role in defining clusters in this dataset than epsilon does. An epsilon of 0.5 results in only a single cluster and 111 outliers, which does not seem very useful. On the other hand, an epsilon of 1.5 results in every point being split into 1 of 2 clusters with no outliers. This does not seem too bad, but if we can shave off some of the more "outlier-type" points maybe our clusters will become more defined. The output does not really stray from 2 clusters unless we bring numPoints down to 3, and for a dataset of 148 points, 3 does not really seem appropriate for a cluster. An epsilon of 1 produces 9 outliers, but an epsilon of 0.75 produces 16 outliers and 0.7 produces 26 outliers. These values seem a bit more appropriate than 9 outliers, so choosing an epsilon of 0.7 or 0.75 seems to be the best choice, depending on the percentage of data points we want to define as outliers.



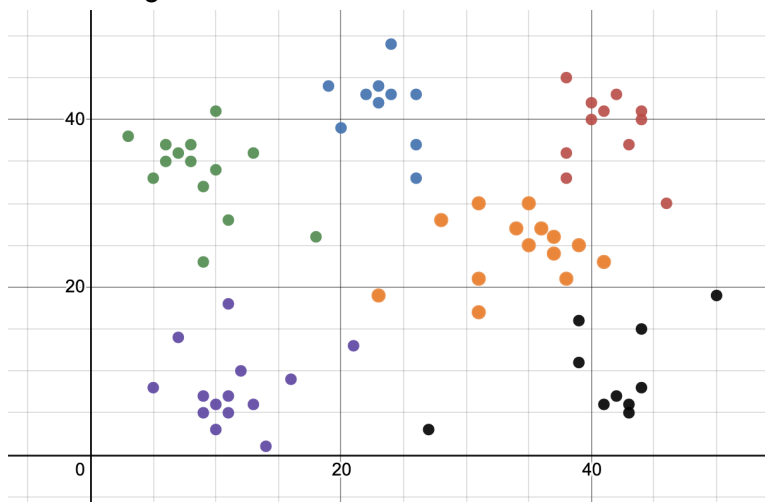
# Many\_clusters.csv

This dataset can be shown graphically.



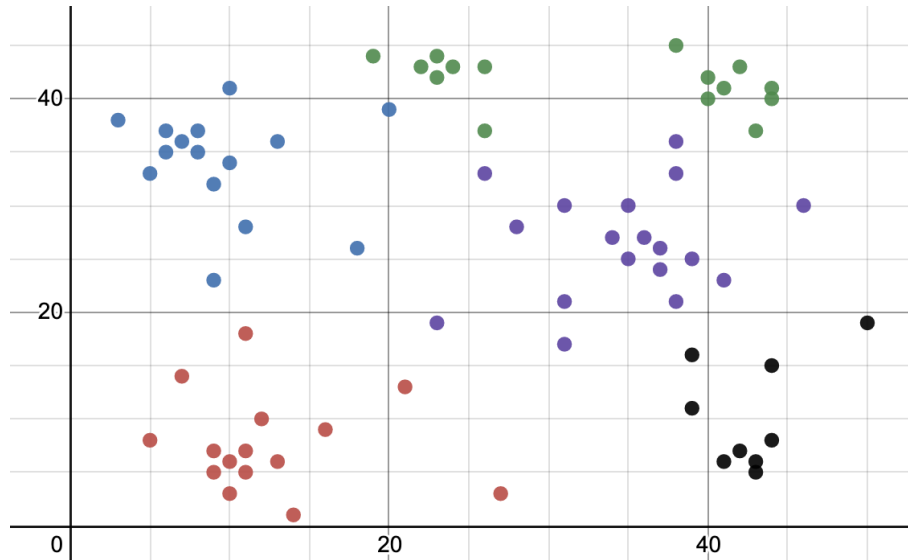
## K-means

Luckily, we are able to visually look at this dataset before running k-means on it so that we have a rough idea of how many clusters to look for. We tried running k-means for 6 clusters, and the output displayed below was very satisfactory (as far as k-means can be) for our clusters. The major clusters we can see visually are all given separate clusters as they should be, and the outliers are grouped in with their closest clusters, resulting in a grouping that is about as good as we can get with k-means.



## Agglomerative Hierarchical

Our chosen optimal output for this dataset with hierarchical clustering is created on threshold of 20. It creates 1 less cluster than the other algorithms, but this cut of the dendrogram seemed the most reasonable out of all the ones we tried based on distance measures and sizes of the clusters.

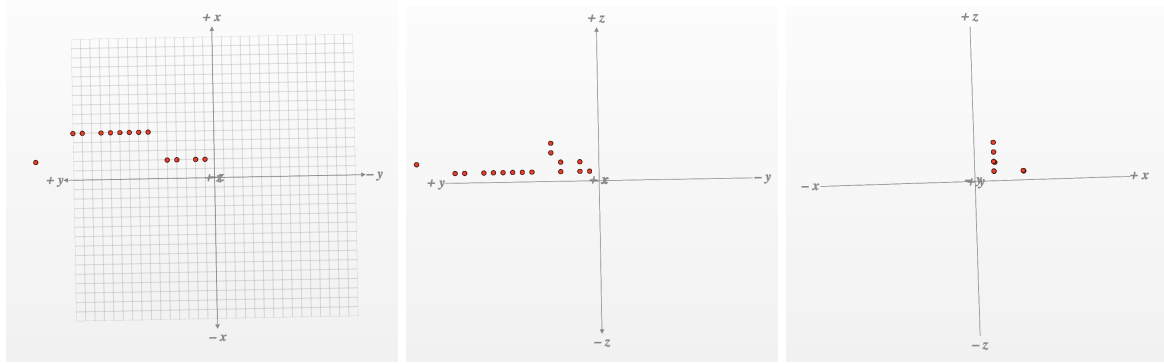


## DBSCAN

Simply looking at the data visually, we can either define 5 or 6 datasets, but 6 datasets would appear to be more probable with there being 6 areas on the graph where points are tightly clustered together. Armed with this information, we configured our DBSCAN until it outputted 6 clusters. The configuration that allowed for such an output was an epsilon of 5.5 and numPoints of 4. Interestingly, increasing numPoints to 5 did not output any more than 5 clusters. This can be attributed to the 4 points in a small, squashed diamond shape in the upper middle part of the graph. However, we wanted to make these points a cluster since they were so close together, so we set numPoints to 4.

## AccidentsSet01.csv

This dataset is 3-D, so we can attempt to display the data as 3 cross-sections of the same graph. It appears by looking at the cross sections above that there are two clusters and one outlier.



## K-means

K-means, as it does not have outlier detection and is therefore very sensitive to outliers, does a fairly decent job at recognizing the two clusters and the outlier if  $k$  is set to 3. For  $k=3$ , k-means gives the outlier point (2, 19, 2) its very own cluster, so it is a “cluster” of just one point. We can therefore call this cluster an “outlier cluster” and define the other two clusters of 7 and 8 points to be the 2 legitimate clusters. With a  $k$  of 2, the outlier point gets grouped in with another cluster, and actually shifts the center of one of the clusters so much that other points that were previously in a nice well-defined cluster are now more confusingly assigned to a cluster that may or may not be the same cluster as its true neighbors.

## Agglomerative Hierarchical

Running this algorithm with a threshold of 12 results in 4 clusters. Increasing the threshold to 13 places all of the data points into 1 big cluster, and there is clearly no need to split into more than 4 clusters, so the attached output in the appendix must be the optimal output when using Agglomerative Hierarchical Clustering on this dataset.

## DBSCAN

DBSCAN does a comparatively excellent job on this dataset. For an epsilon of 4 and a numPoints of 5, it gives basically the same two clusters as k-means but also recognizes the outlier point, and does not consider it with the other two clusters. As seen in the graphs at the start, the points are visually clustered into two fairly obvious clusters, and DBSCAN recognizes this well.

## AccidentsSet03.csv

This 4 dimensional dataset cannot be graphed visually, so we must again rely on our algorithms’ outputs to determine the best clusters.

## K-means

K-means struggled to paint a clear picture of this data. The best we could do with no outlier detection was a k of 3 which gave us clusters of sizes 11, 17, and 11. The average distances to the center did not seem too bad though, so we can take some solace in that and say that at least the clusters should be reasonable enough as an output, but it is hard to be confident in this assessment.

## Agglomerative Hierarchical

This algorithm struggled on the dataset, only capable of presenting either 1 or 2 clusters. When running with a threshold of 6, it is possible to get 2 clusters, but 1 cluster only has 2 data points.

## DBSCAN

This is one of the datasets where despite not being able to look at the dataset visually, DBSCAN makes it quite simple to grasp the general layout of the points. After some fine tuning, we decided that an epsilon of 2 and a numPoints of 4 revealed the best clustering. For this configuration, there were 3 clusters of sizes 26, 8, and 21 as well as 4 outliers. The SSE for each of these clusters was quite small even for the datasets of size 21 or 26, so we are confident that these clusters exist. Simply looking at the terminal output for this configuration showed how similar some points were to each other and different from points in another cluster.

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## Discussion/Analysis

After reviewing our results from all the given datasets, we have concluded that generally DBSCAN has the best performance out of all the algorithms implemented in this lab. Its ability to handle outliers gives it a capacity to cluster more accurately than the other 2 algorithms, where the outliers must always be considered in the distance measures for clusters. The ability to see the dendrogram as represented by a json object is helpful in hclustering, but ultimately did not help enough to give an advantage over DBSCAN, who's clusters seem to more accurately represent the data.

# Appendix

4clusters.csv

K-means

PARAMETERS: k=3

finrawson@Finians-Air CSC466-Lab4 % java kmeans data/4clusters.csv 4

Cluster 0

Center: [41.111111111111114, 41.77777777777778]

9 points

[44, 43]

[42, 43]

[39, 44]

[45, 40]

[41, 41]

[38, 39]

[41, 45]

[42, 39]

[38, 42]

Avg Dist To Center: 2.9117006199139848

Max Dist To Center: 4.275973645531965

Min Dist To Center: 0.7856742013183874

SSE: 14501.0

Cluster 1

Center: [22.0, 38.0]

2 points

[25, 38]

[19, 38]

Avg Dist To Center: 3.0

Max Dist To Center: 3.0

Min Dist To Center: 3.0

SSE: 14501.0

Cluster 2

Center: [9.9, 37.8]

10 points

[10, 42]

[13, 35]

[8, 41]

[9, 34]

[9, 38]

[7, 39]

[13, 40]

[12, 34]

[12, 38]

[6, 37]

Avg Dist To Center: 3.4299301473944332

Max Dist To Center: 4.3416586692184795

Min Dist To Center: 0.9219544457292896

SSE: 14501.0

Cluster 3

Center: [33.588235294117645, 17.352941176470587]

17 points

[26, 25]

[34, 23]

[22, 22]

[31, 13]

[32, 27]

[31, 18]

[39, 24]

[35, 20]

[37, 23]

[38, 13]

[34, 11]

[26, 16]

[29, 11]

[38, 21]

[37, 10]

[42, 9]

[40, 9]

Avg Dist To Center: 7.583628833925927

Max Dist To Center: 12.485285456935953

Min Dist To Center: 2.6678918753996608

SSE: 14501.0

PARAMETERS: k=3

finrawson@Finians-Air CSC466-Lab4 % java kmeans data/4clusters.csv 3

Cluster 0

Center: [41.111111111111114, 41.77777777777778]

9 points

[44, 43]

[42, 43]

[39, 44]

[45, 40]

[41, 41]

[38, 39]

[41, 45]

[42, 39]

[38, 42]

Avg Dist To Center: 2.9117006199139848

Max Dist To Center: 4.275973645531965

Min Dist To Center: 0.7856742013183874

SSE: 15582.0

Cluster 1

Center: [33.588235294117645, 17.352941176470587]

17 points

[26, 25]

[34, 23]

[22, 22]

[31, 13]

[32, 27]

[31, 18]

[39, 24]

[35, 20]

[37, 23]

[38, 13]

[34, 11]

[26, 16]

[29, 11]

[38, 21]

[37, 10]

[42, 9]

[40, 9]

Avg Dist To Center: 7.583628833925927

Max Dist To Center: 12.485285456935953

Min Dist To Center: 2.6678918753996608

SSE: 15582.0

Cluster 2

Center: [11.916666666666666, 37.833333333333336]

12 points

[10, 42]

[13, 35]

[25, 38]

[8, 41]

[9, 34]

[9, 38]

[7, 39]

[13, 40]

[12, 34]

[12, 38]

[6, 37]

[19, 38]

Avg Dist To Center: 4.83629553923822

Max Dist To Center: 13.08439486139458

Min Dist To Center: 0.18633899812498061

SSE: 15582.0

### Agglomerative Hierarchical

PARAMETERS: threshold=30

finrawson@Finians-Air CSC466-Lab4 % java -cp "../lib/org.json.jar" hclustering  
data/4clusters.csv 30

Cluster 0:

[1, 1]

Center: [39, 24]

Max Dist. to Center: 23.000000

Min Dist. to Center: 3.000000

Avg Dist. to Center: 14.235294

SSE: 4054.000000

18 Points:

[32, 27]

[26, 25]

[39, 24]

[34, 23]

[37, 23]

[22, 22]

[38, 21]

[35, 20]

[31, 18]

[31, 13]

[38, 13]

[29, 11]

[34, 11]

[37, 10]

[26, 16]

[26, 16]

[42, 9]

[40, 9]

Cluster 1:

[1, 1]

Center: [44, 43]

Max Dist. to Center: 10.000000

Min Dist. to Center: 2.000000

Avg Dist. to Center: 5.625000

SSE: 291.000000



9 Points:

[38, 42]

[41, 41]

[45, 40]

[38, 39]

[42, 39]

[39, 44]

[41, 45]

[44, 43]

[42, 43]

Cluster 2:

$[1, 1]$

Center: [25, 38]

Max Dist. to Center: 20.000000

Min Dist. to Center: 6.000000

Avg Dist. to Center: 16.000000

SSE: 2732.000000

11 Points:

[8, 41]

[13, 40]

[7, 39]

[9, 38]

[12, 38]

[19, 38]

[25, 38]

[6, 37]

[9, 34]

[12, 34]

[13, 35]

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      }  
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            "height": 0  
          }  
        ],  
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      }  
    ],  
    "type": "node",  
    "height": 3  
  }  
],  
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"height": 3
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      "height": 28
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      "value": 36,
      "height": 0
    }
  ],
  "type": "node",
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  "height": 0
}
],
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  "type": "leaf",
  "value": 34,
  "height": 0
}
],
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},
{
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  "value": 33,
  "height": 0
}
],
"type": "node",
"height": 28
},
{
```



```
        "type": "leaf",
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      ],
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    {
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      "height": 0
    }
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}
],
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},
{
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}
],
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},
{
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}
],
"type": "node",
"height": 28
},
```

```
        {
          "type": "leaf",
          "value": 25,
          "height": 0
        }
      ],
      "type": "node",
      "height": 28
    },
    {
      "type": "leaf",
      "value": 24,
      "height": 0
    }
  ],
  "type": "node",
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},
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  "height": 0
}
],
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},
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  "height": 0
}
],
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"height": 28
},
{
  "type": "leaf",
  "value": 21,
  "height": 0
}
],
"type": "node",
"height": 28
```

```

    }
  ],
  "type": "node",
  "height": 47.888888888888886
},
{
  "type": "leaf",
  "value": 4,
  "height": 0
}
],
"type": "root",
"height": 32.973684210526315
}

```

## DBSCAN

PARAMETERS: epsilon=8 numPoints=5

finrawson@Finians-Air CSC466-Lab4 % java dbscan data/4clusters.csv 8 5

Cluster: 0

Center: [41, 45]

Max Dist. to Center: 9.000000

Min Dist. to Center: 3.000000

Avg Dist. to Center: 5.750000

SSE: 306.000000

8 Points:

[39, 44]

[42, 43]

[44, 43]

[38, 42]

[41, 41]

[42, 39]

[38, 39]

[45, 40]

Cluster: 1

Center: [10, 42]

Max Dist. to Center: 19.000000

Min Dist. to Center: 3.000000

Avg Dist. to Center: 8.636364

SSE: 1023.000000

11 Points:

[8, 41]

[13, 40]

[7, 39]

[9, 38]  
[12, 38]  
[6, 37]  
[13, 35]  
[12, 34]  
[9, 34]  
[19, 38]  
[25, 38]

Cluster: 2  
Center: [34, 23]  
Max Dist. to Center: 22.000000  
Min Dist. to Center: 3.000000  
Avg Dist. to Center: 11.800000  
SSE: 2585.000000  
15 Points:

[32, 27]  
[39, 24]  
[37, 23]  
[38, 21]  
[35, 20]  
[31, 18]  
[26, 16]  
[31, 13]  
[26, 16]  
[38, 13]  
[29, 11]  
[34, 11]  
[37, 10]  
[40, 9]  
[42, 9]

Percent Outliers in Data: 0.052632  
# of Outliers: 2  
[26, 25]  
[22, 22]

PARAMETERS: epsilon=7 numPoints=5  
finrawson@Finians-Air CSC466-Lab4 % java dbscan data/4clusters.csv 7 5  
Cluster: 0  
Center: [41, 45]  
Max Dist. to Center: 9.000000  
Min Dist. to Center: 3.000000  
Avg Dist. to Center: 5.750000

SSE: 306.000000

8 Points:

[39, 44]

[42, 43]

[44, 43]

[38, 42]

[41, 41]

[38, 39]

[45, 40]

[42, 39]

Cluster: 1

Center: [10, 42]

Max Dist. to Center: 10.000000

Min Dist. to Center: 3.000000

Avg Dist. to Center: 7.000000

SSE: 493.000000

9 Points:

[8, 41]

[13, 40]

[7, 39]

[9, 38]

[12, 38]

[6, 37]

[13, 35]

[9, 34]

[12, 34]

Cluster: 2

Center: [34, 23]

Max Dist. to Center: 22.000000

Min Dist. to Center: 3.000000

Avg Dist. to Center: 11.307692

SSE: 2135.000000

13 Points:

[32, 27]

[39, 24]

[37, 23]

[38, 21]

[35, 20]

[31, 18]

[31, 13]

[29, 11]

[34, 11]

[38, 13]  
[37, 10]  
[40, 9]  
[42, 9]

Percent Outliers in Data: 0.157895

# of Outliers: 6

[19, 38]  
[25, 38]  
[26, 25]  
[22, 22]  
[26, 16]  
[26, 16]

Mammal\_milk.csv

K-means

PARAMETERS: k=4

finrawson@Finians-Air CSC466-Lab4 % java kmeans data/mammal\_milk.csv 4

Cluster 0

Center: [88.5, 2.57, 2.8, 5.68, 0.485]

10 points

[90.3, 1.7, 1.4, 6.2, 0.4]  
[86.9, 4.8, 1.7, 5.7, 0.9]  
[90.4, 0.6, 4.5, 4.4, 0.1]  
[86.5, 3.9, 3.2, 5.6, 0.8]  
[86.2, 3, 4.8, 5.3, 0.7]  
[88.5, 1.4, 3.5, 6, 0.24]  
[87.7, 3.5, 3.4, 4.8, 0.71]  
[90, 2, 1.8, 5.5, 0.47]  
[88.4, 2.2, 2.7, 6.4, 0.18]  
[90.1, 2.6, 1, 6.9, 0.35]

Avg Dist To Center: 2.307742412099644

Max Dist To Center: 3.4881979588320413

Min Dist To Center: 0.8765414993027995

SSE: 10694.22

Cluster 1

Center: [81.18571428571428, 7.428571428571429, 6.8999999999999995,  
4.014285714285714, 0.9314285714285715]

7 points

[82.8, 7.1, 5.1, 3.7, 1.1]  
[81.9, 7.4, 7.2, 2.7, 0.85]  
[81.6, 10.1, 6.3, 4.4, 0.75]

[82.1, 5.9, 7.9, 4.7, 0.78]

[82, 5.6, 6.4, 4.7, 0.91]

[81.6, 6.6, 5.9, 4.9, 0.93]

[76.3, 9.3, 9.5, 3, 1.2]

Avg Dist To Center: 2.6702085191443983

Max Dist To Center: 5.935769124725189

Min Dist To Center: 1.5280700112179693

SSE: 10694.22

Cluster 2

Center: [68.33333333333333, 9.550000000000002, 17.416666666666664, 2.9166666666666665, 1.33]

6 points

[65.9, 10.4, 19.7, 2.6, 1.4]

[71.3, 12.3, 13.1, 1.9, 2.3]

[64.8, 11.1, 21.2, 1.6, 0.85]

[70.7, 3.6, 17.6, 5.6, 0.63]

[72.5, 9.2, 12.6, 3.3, 1.4]

[64.8, 10.7, 20.3, 2.5, 1.4]

Avg Dist To Center: 5.535768966213837

Max Dist To Center: 6.980508577460533

Min Dist To Center: 3.458670264711563

SSE: 10694.22

Cluster 3

Center: [45.65, 10.149999999999999, 38.45, 0.45, 0.69]

2 points

[44.9, 10.6, 34.9, 0.9, 0.53]

[46.4, 9.7, 42, 0, 0.85]

Avg Dist To Center: 3.6872211758992712

Max Dist To Center: 3.6872211758992752

Min Dist To Center: 3.6872211758992677

SSE: 10694.22

## Agglomerative Hierarchical

PARAMETERS: threshold=6

finrawson@Finians-Air CSC466-Lab4 % java -cp " ../lib/org.json.jar" hclustering  
data/mammal\_milk.csv 7

Cluster 0:

[0, 1, 1, 1, 1, 1]

Center: [Cat, 81.6, 10.1, 6.3, 4.4, 0.75]

Max Dist. to Center: 6.630000

Min Dist. to Center: 4.580000

Avg Dist. to Center: 5.764000

SSE: 168.837400

6 Points:

[Buffalo, 82.1, 5.9, 7.9, 4.7, 0.78]  
[Guinea Pig, 81.9, 7.4, 7.2, 2.7, 0.85]  
[Cat, 81.6, 10.1, 6.3, 4.4, 0.75]  
[Fox, 81.6, 6.6, 5.9, 4.9, 0.93]  
[Sheep, 82, 5.6, 6.4, 4.7, 0.91]  
[Pig, 82.8, 7.1, 5.1, 3.7, 1.1]

Cluster 1:

[0, 1, 1, 1, 1, 1]  
Center: [Deer, 65.9, 10.4, 19.7, 2.6, 1.4]  
Max Dist. to Center: 4.850000  
Min Dist. to Center: 2.100000  
Avg Dist. to Center: 3.475000  
SSE: 27.932500  
3 Points:  
[Deer, 65.9, 10.4, 19.7, 2.6, 1.4]  
[Whale, 64.8, 11.1, 21.2, 1.6, 0.85]  
[Reindeer, 64.8, 10.7, 20.3, 2.5, 1.4]

Cluster 2:

[0, 1, 1, 1, 1, 1]  
Center: [Donkey, 90.3, 1.7, 1.4, 6.2, 0.4]  
Max Dist. to Center: 6.400000  
Min Dist. to Center: 1.770000  
Avg Dist. to Center: 4.212500  
SSE: 81.860900  
5 Points:  
[Orangutan, 88.5, 1.4, 3.5, 6, 0.24]  
[Monkey, 88.4, 2.2, 2.7, 6.4, 0.18]  
[Donkey, 90.3, 1.7, 1.4, 6.2, 0.4]  
[Mule, 90, 2, 1.8, 5.5, 0.47]  
[Hippo, 90.4, 0.6, 4.5, 4.4, 0.1]

Cluster 3:

[0, 1, 1, 1, 1, 1]  
Center: [Camel, 87.7, 3.5, 3.4, 4.8, 0.71]  
Max Dist. to Center: 4.890000  
Min Dist. to Center: 2.690000  
Avg Dist. to Center: 3.830000  
SSE: 46.436300  
4 Points:  
[Camel, 87.7, 3.5, 3.4, 4.8, 0.71]  
[Bison, 86.9, 4.8, 1.7, 5.7, 0.9]  
[Zebra, 86.2, 3, 4.8, 5.3, 0.7]



[Llama, 86.5, 3.9, 3.2, 5.6, 0.8]

```
{
  "nodes": [
    {
      "nodes": [
        {
          "nodes": [
            {
              "nodes": [
                {
                  "nodes": [
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                      "value": 22,
                      "height": 0
                    },
                    {
                      "type": "leaf",
                      "value": 21,
                      "height": 0
                    }
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                  "height": 6.309999999999995
                },
                {
                  "type": "leaf",
                  "value": 20,
                  "height": 0
                }
              ],
              "type": "node",
              "height": 6.309999999999995
            },
            {
              "type": "leaf",
              "value": 18,
```

```

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],
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},
{
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  "value": 17,
  "height": 0
}
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  "height": 33.75
},
{
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  "value": 16,
  "height": 0
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},
{
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    {
      "nodes": [
        {
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            {
              "nodes": [
                {
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                      "value": 12,
                      "height": 0
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                    {

```

```
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    "type": "node",
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  },
  {
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    "value": 3,
    "height": 0
  }
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},
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},
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  "height": 0
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},
{
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      "nodes": [
        {
          "nodes": [
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              "value": 14,
```

```

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      {
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        "value": 11,
        "height": 0
      }
    ],
    "type": "node",
    "height": 6.309999999999995
  },
  {
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    "value": 6,
    "height": 0
  }
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},
{
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  "value": 5,
  "height": 0
}
],
"type": "node",
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},
{
  "nodes": [
    {
      "nodes": [
        {
          "nodes": [
            {
              "nodes": [
                {

```

```
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        "value": 15,
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      {
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        "height": 0
      }
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    "type": "node",
    "height": 6.309999999999995
  },
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    "value": 10,
    "height": 0
  }
],
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},
{
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  "value": 9,
  "height": 0
}
],
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},
{
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  "value": 8,
  "height": 0
}
],
"type": "node",
"height": 6.309999999999995
},
{
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  "value": 7,
  "height": 0
}
```

```
    }
  ],
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}
],
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},
{
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}
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],
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"height": 96.24000000000001
},
{
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    },
    {
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    }
  ],
  "type": "node",
  "height": 33.75
}
],
"type": "node",
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},
{
  "type": "leaf",
```

```
        "value": 0,  
        "height": 0  
    },  
    ],  
    "type": "root",  
    "height": 29.764166666666668  
}
```

## DBSCAN

PARAMETERS: epsilon=4 numPoints=3

finrawson@Finians-Air CSC466-Lab4 % java dbscan data/mammal\_milk.csv 4 3

Cluster: 0

Center: [Fox, 81.6, 6.6, 5.9, 4.9, 0.93]

Max Dist. to Center: 3.870000

Min Dist. to Center: 2.120000

Avg Dist. to Center: 3.180000

SSE: 32.073800

3 Points:

[Buffalo, 82.1, 5.9, 7.9, 4.7, 0.78]

[Pig, 82.8, 7.1, 5.1, 3.7, 1.1]

[Sheep, 82, 5.6, 6.4, 4.7, 0.91]

Cluster: 1

Center: [Llama, 86.5, 3.9, 3.2, 5.6, 0.8]

Max Dist. to Center: 3.200000

Min Dist. to Center: 2.690000

Avg Dist. to Center: 2.963333

SSE: 26.476100

3 Points:

[Camel, 87.7, 3.5, 3.4, 4.8, 0.71]

[Bison, 86.9, 4.8, 1.7, 5.7, 0.9]

[Zebra, 86.2, 3, 4.8, 5.3, 0.7]

Cluster: 2

Center: [Mule, 90, 2, 1.8, 5.5, 0.47]

Max Dist. to Center: 4.530000

Min Dist. to Center: 1.770000

Avg Dist. to Center: 3.302500

SSE: 47.906300

4 Points:

[Horse, 90.1, 2.6, 1, 6.9, 0.35]

[Monkey, 88.4, 2.2, 2.7, 6.4, 0.18]

[Donkey, 90.3, 1.7, 1.4, 6.2, 0.4]

[Orangutan, 88.5, 1.4, 3.5, 6, 0.24]

Percent Outliers in Data: 0.500000

# of Outliers: 12

[Hippo, 90.4, 0.6, 4.5, 4.4, 0.1]

[Guinea Pig, 81.9, 7.4, 7.2, 2.7, 0.85]

[Cat, 81.6, 10.1, 6.3, 4.4, 0.75]

[Dog, 76.3, 9.3, 9.5, 3, 1.2]

[Elephant, 70.7, 3.6, 17.6, 5.6, 0.63]

[Rabbit, 71.3, 12.3, 13.1, 1.9, 2.3]

[Rat, 72.5, 9.2, 12.6, 3.3, 1.4]

[Deer, 65.9, 10.4, 19.7, 2.6, 1.4]

[Reindeer, 64.8, 10.7, 20.3, 2.5, 1.4]

[Whale, 64.8, 11.1, 21.2, 1.6, 0.85]

[Seal, 46.4, 9.7, 42, 0, 0.85]

[Dolphin, 44.9, 10.6, 34.9, 0.9, 0.53]

## Iris.csv

### K-means

PARAMETERS: k=5

finrawson@Finians-Air CSC466-Lab4 % java kmeans data/iris.csv 5

Cluster 0

Center: [5.532142857142857, 2.635714285714286, 3.960714285714285,  
1.2285714285714284]

28 points

[5.2, 2.7, 3.9, 1.4]

[5.7, 2.8, 4.1, 1.3]

[5.6, 2.7, 4.2, 1.3]

[5.6, 2.5, 3.9, 1.1]

[4.9, 2.5, 4.5, 1.7]

[5.6, 3.0, 4.1, 1.3]

[5.1, 2.5, 3.0, 1.1]

[5.5, 2.6, 4.4, 1.2]

[4.9, 2.4, 3.3, 1.0]

[5.8, 2.7, 3.9, 1.2]

[5.9, 3.0, 4.2, 1.5]

[5.5, 2.3, 4.0, 1.3]

[5.7, 2.8, 4.5, 1.3]

[5.0, 2.3, 3.3, 1.0]

[5.0, 2.0, 3.5, 1.0]

[6.1, 2.8, 4.0, 1.3]

[5.7, 3.0, 4.2, 1.2]

[5.8, 2.7, 4.1, 1.0]



[5.6, 3.0, 4.5, 1.5]

[5.6, 2.9, 3.6, 1.3]

[5.7, 2.6, 3.5, 1.0]

[5.5, 2.4, 3.7, 1.0]

[6.0, 2.2, 4.0, 1.0]

[5.8, 2.6, 4.0, 1.2]

[5.5, 2.4, 3.8, 1.1]

[5.4, 3.0, 4.5, 1.5]

[5.5, 2.5, 4.0, 1.3]

[5.7, 2.9, 4.2, 1.3]

Avg Dist To Center: 0.5317707503609307

Max Dist To Center: 1.0698917549672664

Min Dist To Center: 0.1615454696842668

SSE: 33418.0000000000015

Cluster 1

Center: [6.264102564102564, 2.8589743589743595, 4.8076923076923075,  
1.6179487179487175]

39 points

[6.2, 2.8, 4.8, 1.8]

[6.0, 2.7, 5.1, 1.6]

[6.2, 2.2, 4.5, 1.5]

[6.3, 2.3, 4.4, 1.3]

[6.0, 2.2, 5.0, 1.5]

[6.2, 2.9, 4.3, 1.3]

[5.8, 2.7, 5.1, 1.9]

[6.8, 2.8, 4.8, 1.4]

[6.1, 3.0, 4.9, 1.8]

[6.3, 2.5, 4.9, 1.5]

[6.1, 2.9, 4.7, 1.4]

[6.1, 2.6, 5.6, 1.4]

[6.4, 2.7, 5.3, 1.9]

[6.1, 3.0, 4.6, 1.4]

[6.4, 2.9, 4.3, 1.3]

[6.5, 2.8, 4.6, 1.5]

[6.7, 3.1, 4.7, 1.5]

[6.3, 2.8, 5.1, 1.5]

[6.5, 3.0, 5.2, 2.0]

[6.3, 3.3, 4.7, 1.6]

[6.6, 2.9, 4.6, 1.3]

[5.6, 2.8, 4.9, 2.0]

[6.9, 3.1, 4.9, 1.5]

[6.7, 3.1, 4.4, 1.4]

[6.3, 2.5, 5.0, 1.9]

[5.8, 2.8, 5.1, 2.4]

[6.0, 2.9, 4.5, 1.5]

[5.9, 3.0, 5.1, 1.8]

[6.7, 3.0, 5.0, 1.7]

[5.9, 3.2, 4.8, 1.8]

[6.0, 3.0, 4.8, 1.8]

[6.3, 2.7, 4.9, 1.8]

[6.5, 3.2, 5.1, 2.0]

[6.4, 3.2, 4.5, 1.5]

[5.7, 2.5, 5.0, 2.0]

[6.6, 3.0, 4.4, 1.4]

[6.0, 3.4, 4.5, 1.6]

[7.0, 3.2, 4.7, 1.4]

[6.1, 2.8, 4.7, 1.2]

Avg Dist To Center: 0.5540125547324894

Max Dist To Center: 0.957035610499063

Min Dist To Center: 0.20196275556425916

SSE: 33418.000000000015

Cluster 2

Center: [4.812903225806451, 3.229032258064517, 1.432258064516129,  
0.23548387096774198]

31 points

[4.5, 2.3, 1.3, 0.3]

[4.8, 3.4, 1.9, 0.2]

[5.0, 3.6, 1.4, 0.2]

[5.2, 3.4, 1.4, 0.2]

[5.0, 3.5, 1.3, 0.3]

[4.6, 3.6, 1.0, 0.2]

[4.7, 3.2, 1.6, 0.2]

[4.9, 3.0, 1.4, 0.2]

[4.4, 3.0, 1.3, 0.2]

[5.1, 3.3, 1.7, 0.5]

[4.8, 3.4, 1.6, 0.2]

[4.6, 3.4, 1.4, 0.3]

[4.9, 3.1, 1.5, 0.1]

[5.0, 3.4, 1.5, 0.2]

[4.6, 3.1, 1.5, 0.2]

[5.0, 3.5, 1.6, 0.6]

[5.0, 3.0, 1.6, 0.2]

[5.0, 3.3, 1.4, 0.2]

[4.8, 3.0, 1.4, 0.3]

[4.8, 3.0, 1.4, 0.1]

[4.8, 3.1, 1.6, 0.2]

[5.1, 3.5, 1.4, 0.3]

[5.1, 3.5, 1.4, 0.2]

[4.7, 3.2, 1.3, 0.2]

[5.0, 3.4, 1.6, 0.4]

[5.0, 3.2, 1.2, 0.2]

[4.4, 3.2, 1.3, 0.2]

[5.1, 3.4, 1.5, 0.2]

[4.4, 2.9, 1.4, 0.2]

[4.3, 3.0, 1.1, 0.1]

[4.6, 3.2, 1.4, 0.2]

Avg Dist To Center: 0.37456458515209473

Max Dist To Center: 0.9912940490991551

Min Dist To Center: 0.17983690148085585

SSE: 33418.0000000000015

Cluster 3

Center: [5.370588235294118, 3.8, 1.5176470588235293, 0.27647058823529413]

17 points

[5.2, 3.5, 1.5, 0.2]

[5.4, 3.4, 1.5, 0.4]

[5.1, 3.8, 1.5, 0.3]

[5.1, 3.8, 1.6, 0.2]

[5.4, 3.9, 1.7, 0.4]

[5.4, 3.4, 1.7, 0.2]

[5.4, 3.7, 1.5, 0.2]

[5.1, 3.7, 1.5, 0.4]

[5.7, 3.8, 1.7, 0.3]

[5.5, 4.2, 1.4, 0.2]

[5.7, 4.4, 1.5, 0.4]

[5.1, 3.8, 1.9, 0.4]

[5.8, 4.0, 1.2, 0.2]

[5.2, 4.1, 1.5, 0.1]

[5.4, 3.9, 1.3, 0.4]

[5.3, 3.7, 1.5, 0.2]

[5.5, 3.5, 1.3, 0.2]

Avg Dist To Center: 0.3679616370444892

Max Dist To Center: 0.6957607670619976

Min Dist To Center: 0.1304769000754046

SSE: 33418.0000000000015

Cluster 4

Center: [6.912500000000001, 3.0999999999999996, 5.846875000000001, 2.13125]

32 points

[6.9, 3.1, 5.1, 2.3]

[7.6, 3.0, 6.6, 2.1]

[6.2, 3.4, 5.4, 2.3]

[6.4, 3.2, 5.3, 2.3]

[7.7, 2.6, 6.9, 2.3]

[7.1, 3.0, 5.9, 2.1]  
[6.7, 3.1, 5.6, 2.4]  
[6.4, 3.1, 5.5, 1.8]  
[6.7, 2.5, 5.8, 1.8]  
[7.4, 2.8, 6.1, 1.9]  
[6.9, 3.2, 5.7, 2.3]  
[6.7, 3.3, 5.7, 2.1]  
[7.2, 3.6, 6.1, 2.5]  
[6.7, 3.3, 5.7, 2.5]  
[6.5, 3.0, 5.5, 1.8]  
[6.3, 3.3, 6.0, 2.5]  
[6.4, 2.8, 5.6, 2.2]  
[6.4, 2.8, 5.6, 2.1]  
[7.7, 3.8, 6.7, 2.2]  
[6.5, 3.0, 5.8, 2.2]  
[7.2, 3.2, 6.0, 1.8]  
[6.7, 3.0, 5.2, 2.3]  
[6.3, 3.4, 5.6, 2.4]  
[7.2, 3.0, 5.8, 1.6]  
[6.3, 2.9, 5.6, 1.8]  
[7.3, 2.9, 6.3, 1.8]  
[7.7, 3.0, 6.1, 2.3]  
[6.9, 3.1, 5.4, 2.1]  
[7.7, 2.8, 6.7, 2.0]  
[6.8, 3.0, 5.5, 2.1]  
[6.8, 3.2, 5.9, 2.3]  
[7.9, 3.8, 6.4, 2.0]  
Avg Dist To Center: 0.699982408848203  
Max Dist To Center: 1.4169351001810198  
Min Dist To Center: 0.22125794477260974  
SSE: 33418.000000000015

### Agglomerative Hierarchical

PARAMETERS: threshold = 6

OUTPUT

Cluster 0:

[1, 1, 1, 1, 0]

Center: [5.9, 3.0, 4.2, 1.5, Iris-versicolor]

Max Dist. to Center: 6.400000

Min Dist. to Center: 0.800000

Avg Dist. to Center: 4.549231

SSE: 1493.870000

66 Points:

[4.6, 3.4, 1.4, 0.3, Iris-setosa]

[5.8, 4.0, 1.2, 0.2, Iris-setosa]  
[5.2, 2.7, 3.9, 1.4, Iris-versicolor]  
[5.7, 4.4, 1.5, 0.4, Iris-setosa]  
[5.9, 3.0, 4.2, 1.5, Iris-versicolor]  
[5.7, 3.8, 1.7, 0.3, Iris-setosa]  
[6.0, 2.2, 4.0, 1.0, Iris-versicolor]  
[4.6, 3.6, 1.0, 0.2, Iris-setosa]  
[5.6, 2.9, 3.6, 1.3, Iris-versicolor]  
[5.1, 3.3, 1.7, 0.5, Iris-setosa]  
[6.1, 2.8, 4.0, 1.3, Iris-versicolor]  
[4.8, 3.4, 1.9, 0.2, Iris-setosa]  
[5.7, 2.6, 3.5, 1.0, Iris-versicolor]  
[4.5, 2.3, 1.3, 0.3, Iris-setosa]  
[5.5, 2.6, 4.4, 1.2, Iris-versicolor]  
[5.1, 2.5, 3.0, 1.1, Iris-versicolor]  
[5.2, 4.1, 1.5, 0.1, Iris-setosa]  
[4.9, 2.5, 4.5, 1.7, Iris-virginica]  
[4.3, 3.0, 1.1, 0.1, Iris-setosa]  
[4.4, 2.9, 1.4, 0.2, Iris-setosa]  
[5.3, 3.7, 1.5, 0.2, Iris-setosa]  
[5.1, 3.8, 1.6, 0.2, Iris-setosa]  
[5.1, 3.8, 1.9, 0.4, Iris-setosa]  
[5.4, 3.9, 1.7, 0.4, Iris-setosa]  
[5.5, 2.3, 4.0, 1.3, Iris-versicolor]  
[4.9, 2.4, 3.3, 1.0, Iris-versicolor]  
[4.9, 3.0, 1.4, 0.2, Iris-setosa]  
[5.6, 2.5, 3.9, 1.1, Iris-versicolor]  
[5.0, 2.3, 3.3, 1.0, Iris-versicolor]  
[5.0, 2.0, 3.5, 1.0, Iris-versicolor]  
[5.1, 3.5, 1.4, 0.2, Iris-setosa]  
[5.5, 4.2, 1.4, 0.2, Iris-setosa]  
[5.4, 3.9, 1.3, 0.4, Iris-setosa]  
[4.7, 3.2, 1.3, 0.2, Iris-setosa]  
[5.5, 2.4, 3.7, 1.0, Iris-versicolor]  
[5.5, 2.4, 3.8, 1.1, Iris-versicolor]  
[5.0, 3.6, 1.4, 0.2, Iris-setosa]  
[4.6, 3.1, 1.5, 0.2, Iris-setosa]  
[5.4, 3.7, 1.5, 0.2, Iris-setosa]  
[5.0, 3.4, 1.5, 0.2, Iris-setosa]  
[5.1, 3.5, 1.4, 0.3, Iris-setosa]  
[4.9, 3.1, 1.5, 0.1, Iris-setosa]  
[5.1, 3.8, 1.5, 0.3, Iris-setosa]  
[4.8, 3.4, 1.6, 0.2, Iris-setosa]  
[5.4, 3.4, 1.7, 0.2, Iris-setosa]

[4.8, 3.0, 1.4, 0.1, Iris-setosa]  
[5.1, 3.7, 1.5, 0.4, Iris-setosa]  
[5.0, 3.0, 1.6, 0.2, Iris-setosa]  
[5.0, 3.4, 1.6, 0.4, Iris-setosa]  
[4.7, 3.2, 1.6, 0.2, Iris-setosa]  
[5.2, 3.5, 1.5, 0.2, Iris-setosa]  
[4.8, 3.1, 1.6, 0.2, Iris-setosa]  
[4.9, 3.1, 1.5, 0.1, Iris-setosa]  
[5.2, 3.4, 1.4, 0.2, Iris-setosa]  
[5.1, 3.4, 1.5, 0.2, Iris-setosa]  
[5.0, 3.2, 1.2, 0.2, Iris-setosa]  
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[4.4, 3.0, 1.3, 0.2, Iris-setosa]  
[4.4, 3.2, 1.3, 0.2, Iris-setosa]  
[4.8, 3.0, 1.4, 0.3, Iris-setosa]  
[5.0, 3.3, 1.4, 0.2, Iris-setosa]  
[4.6, 3.2, 1.4, 0.2, Iris-setosa]

Cluster 1:

[1, 1, 1, 1, 0]

Center: [6.4, 2.8, 5.6, 2.2, Iris-virginica]

Max Dist. to Center: 3.700000

Min Dist. to Center: 0.100000

Avg Dist. to Center: 2.116667

SSE: 277.290000

55 Points:

[6.5, 3.2, 5.1, 2.0, Iris-virginica]  
[5.8, 2.8, 5.1, 2.4, Iris-virginica]  
[6.0, 2.2, 5.0, 1.5, Iris-virginica]  
[6.1, 2.6, 5.6, 1.4, Iris-virginica]  
[5.8, 2.7, 5.1, 1.9, Iris-virginica]  
[6.3, 2.9, 5.6, 1.8, Iris-virginica]  
[6.4, 3.1, 5.5, 1.8, Iris-virginica]  
[6.5, 3.0, 5.5, 1.8, Iris-virginica]  
[6.3, 2.5, 4.9, 1.5, Iris-versicolor]  
[5.6, 2.8, 4.9, 2.0, Iris-virginica]  
[5.7, 2.5, 5.0, 2.0, Iris-virginica]  
[6.4, 2.7, 5.3, 1.9, Iris-virginica]  
[5.9, 3.2, 4.8, 1.8, Iris-versicolor]  
[6.3, 2.8, 5.1, 1.5, Iris-virginica]

[6.0, 2.7, 5.1, 1.6, Iris-versicolor]  
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[6.2, 2.8, 4.8, 1.8, Iris-virginica]  
[6.1, 2.8, 4.7, 1.2, Iris-versicolor]  
[5.8, 2.7, 3.9, 1.2, Iris-versicolor]  
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[5.6, 3.0, 4.1, 1.3, Iris-versicolor]  
[6.0, 3.0, 4.8, 1.8, Iris-virginica]  
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[5.5, 2.5, 4.0, 1.3, Iris-versicolor]  
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[5.7, 2.9, 4.2, 1.3, Iris-versicolor]

Cluster 2:

[1, 1, 1, 1, 0]

Center: [7.7, 3.0, 6.1, 2.3, Iris-virginica]

Max Dist. to Center: 3.400000

Min Dist. to Center: 1.000000

Avg Dist. to Center: 1.915000

SSE: 79.030000

21 Points:

[6.3, 3.3, 6.0, 2.5, Iris-virginica]

[7.1, 3.0, 5.9, 2.1, Iris-virginica]

[6.5, 3.0, 5.8, 2.2, Iris-virginica]

[6.7, 2.5, 5.8, 1.8, Iris-virginica]

[7.7, 3.0, 6.1, 2.3, Iris-virginica]

[6.3, 2.5, 5.0, 1.9, Iris-virginica]

[7.2, 3.0, 5.8, 1.6, Iris-virginica]

[7.2, 3.2, 6.0, 1.8, Iris-virginica]

[6.9, 3.2, 5.7, 2.3, Iris-virginica]

[6.8, 3.0, 5.5, 2.1, Iris-virginica]

[6.4, 3.2, 5.3, 2.3, Iris-virginica]

[6.7, 3.3, 5.7, 2.1, Iris-virginica]

[6.9, 3.1, 5.4, 2.1, Iris-virginica]

[6.2, 3.4, 5.4, 2.3, Iris-virginica]

[6.3, 3.4, 5.6, 2.4, Iris-virginica]

[6.7, 3.1, 5.6, 2.4, Iris-virginica]

[6.9, 3.1, 5.1, 2.3, Iris-virginica]

[6.7, 3.3, 5.7, 2.5, Iris-virginica]

[6.8, 3.2, 5.9, 2.3, Iris-virginica]

[6.5, 3.0, 5.2, 2.0, Iris-virginica]

[6.7, 3.0, 5.2, 2.3, Iris-virginica]

Cluster 3:

[1, 1, 1, 1, 0]

Center: [7.7, 3.8, 6.7, 2.2, Iris-virginica]

Max Dist. to Center: 2.200000

Min Dist. to Center: 0.700000

Avg Dist. to Center: 1.485714

SSE: 17.200000

8 Points:

[7.2, 3.6, 6.1, 2.5, Iris-virginica]

[7.7, 3.8, 6.7, 2.2, Iris-virginica]

[7.7, 2.6, 6.9, 2.3, Iris-virginica]

[7.9, 3.8, 6.4, 2.0, Iris-virginica]

[7.7, 2.8, 6.7, 2.0, Iris-virginica]

[7.6, 3.0, 6.6, 2.1, Iris-virginica]

[7.4, 2.8, 6.1, 1.9, Iris-virginica]

[7.3, 2.9, 6.3, 1.8, Iris-virginica]



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  "height": 0
}
],
"type": "node",
"height": 0.6999999999999993
```

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},
{
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}
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    {
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      "height": 0
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}
],
"type": "node",
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},
{
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      {
        "nodes": [
          {
            "nodes": [
              {
                "nodes": [
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                  },
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                    "type": "leaf",
                    "value": 142,
                    "height": 0
                  }
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                "type": "node",
                "height": 0.69999999999999993
              },
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                "value": 138,
                "height": 0
              }
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            "height": 0.69999999999999993
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      {

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    "height": 0.6999999999999993
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    "value": 123,
    "height": 0
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        },
        {
          "type": "leaf",
          "value": 83,
          "height": 0
        }
      ]
    }
  ]
}
```

```

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}
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},
{
  "nodes": [
    {
      "nodes": [
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          "value": 121,
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        },
        {
          "type": "leaf",
          "value": 113,
          "height": 0
        }
      ],
      "type": "node",
      "height": 0.6999999999999993
    },
    {
      "type": "leaf",
      "value": 101,
      "height": 0
    }
  ],
  "type": "node",
  "height": 0.6999999999999993
}

```

```

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"type": "node",
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{
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              "value": 132,
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              "value": 128,
              "height": 0
            }
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          "height": 0.6999999999999993
        },
        {
          "type": "leaf",
          "value": 111,
          "height": 0
        }
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      "type": "node",
      "height": 0.6999999999999993
    },
    {
      "type": "leaf",
      "value": 103,
      "height": 0
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  "type": "node",
  "height": 0.6999999999999993
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```

```

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      "nodes": [
        {
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          "value": 137,
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          "type": "leaf",
          "value": 116,
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},
{
  "type": "leaf",

```

```

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},
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],
    "type": "root",
    "height": 6.251875901875914
}

```

## DBSCAN

PARAMETERS: epsilon=0.7 numPoints=5

finrawson@Finians-Air CSC466-Lab4 % java dbscan data/iris.csv 0.7 5

Cluster: 0

Center: [5.1, 3.5, 1.4, 0.2, Iris-setosa]

Max Dist. to Center: 1.700000

Min Dist. to Center: 0.100000

Avg Dist. to Center: 0.737778

SSE: 29.740000

45 Points:

[4.9, 3.0, 1.4, 0.2, Iris-setosa]

[5.0, 3.6, 1.4, 0.2, Iris-setosa]

[5.0, 3.4, 1.5, 0.2, Iris-setosa]

[5.4, 3.7, 1.5, 0.2, Iris-setosa]

[4.8, 3.4, 1.6, 0.2, Iris-setosa]

[5.1, 3.5, 1.4, 0.3, Iris-setosa]

[5.1, 3.8, 1.5, 0.3, Iris-setosa]  
[5.1, 3.7, 1.5, 0.4, Iris-setosa]  
[5.0, 3.4, 1.6, 0.4, Iris-setosa]  
[5.2, 3.5, 1.5, 0.2, Iris-setosa]  
[5.2, 3.4, 1.4, 0.2, Iris-setosa]  
[5.0, 3.2, 1.2, 0.2, Iris-setosa]  
[5.5, 3.5, 1.3, 0.2, Iris-setosa]  
[5.1, 3.4, 1.5, 0.2, Iris-setosa]  
[5.0, 3.5, 1.3, 0.3, Iris-setosa]  
[5.0, 3.5, 1.6, 0.6, Iris-setosa]  
[5.1, 3.8, 1.6, 0.2, Iris-setosa]  
[5.3, 3.7, 1.5, 0.2, Iris-setosa]  
[5.0, 3.3, 1.4, 0.2, Iris-setosa]  
[4.7, 3.2, 1.3, 0.2, Iris-setosa]  
[4.6, 3.1, 1.5, 0.2, Iris-setosa]  
[4.4, 2.9, 1.4, 0.2, Iris-setosa]  
[4.9, 3.1, 1.5, 0.1, Iris-setosa]  
[4.8, 3.0, 1.4, 0.1, Iris-setosa]  
[5.0, 3.0, 1.6, 0.2, Iris-setosa]  
[4.7, 3.2, 1.6, 0.2, Iris-setosa]  
[4.8, 3.1, 1.6, 0.2, Iris-setosa]  
[4.9, 3.1, 1.5, 0.1, Iris-setosa]  
[4.9, 3.1, 1.5, 0.1, Iris-setosa]  
[4.4, 3.0, 1.3, 0.2, Iris-setosa]  
[4.8, 3.0, 1.4, 0.3, Iris-setosa]  
[4.6, 3.2, 1.4, 0.2, Iris-setosa]  
[4.6, 3.4, 1.4, 0.3, Iris-setosa]  
[5.4, 3.4, 1.7, 0.2, Iris-setosa]  
[5.1, 3.3, 1.7, 0.5, Iris-setosa]  
[4.8, 3.4, 1.9, 0.2, Iris-setosa]  
[5.4, 3.4, 1.5, 0.4, Iris-setosa]  
[5.4, 3.9, 1.7, 0.4, Iris-setosa]  
[5.4, 3.9, 1.3, 0.4, Iris-setosa]  
[5.7, 3.8, 1.7, 0.3, Iris-setosa]  
[5.2, 4.1, 1.5, 0.1, Iris-setosa]  
[5.5, 4.2, 1.4, 0.2, Iris-setosa]  
[5.1, 3.8, 1.9, 0.4, Iris-setosa]  
[4.4, 3.2, 1.3, 0.2, Iris-setosa]  
[4.3, 3.0, 1.1, 0.1, Iris-setosa]

Cluster: 1

Center: [6.4, 3.2, 4.5, 1.5, Iris-versicolor]

Max Dist. to Center: 3.000000

Min Dist. to Center: 0.500000

Avg Dist. to Center: 1.663636

SSE: 246.430000

77 Points:

[6.5, 2.8, 4.6, 1.5, Iris-versicolor]  
[6.3, 3.3, 4.7, 1.6, Iris-versicolor]  
[6.7, 3.1, 4.4, 1.4, Iris-versicolor]  
[6.6, 3.0, 4.4, 1.4, Iris-versicolor]  
[6.7, 3.1, 4.7, 1.5, Iris-versicolor]  
[6.6, 2.9, 4.6, 1.3, Iris-versicolor]  
[6.4, 2.9, 4.3, 1.3, Iris-versicolor]  
[6.8, 2.8, 4.8, 1.4, Iris-versicolor]  
[6.0, 2.9, 4.5, 1.5, Iris-versicolor]  
[6.0, 3.4, 4.5, 1.6, Iris-versicolor]  
[7.0, 3.2, 4.7, 1.4, Iris-versicolor]  
[6.1, 3.0, 4.6, 1.4, Iris-versicolor]  
[6.9, 3.1, 4.9, 1.5, Iris-versicolor]  
[6.7, 3.0, 5.0, 1.7, Iris-versicolor]  
[6.2, 2.9, 4.3, 1.3, Iris-versicolor]  
[5.7, 2.8, 4.5, 1.3, Iris-versicolor]  
[5.9, 3.0, 4.2, 1.5, Iris-versicolor]  
[6.1, 2.9, 4.7, 1.4, Iris-versicolor]  
[5.6, 3.0, 4.5, 1.5, Iris-versicolor]  
[5.4, 3.0, 4.5, 1.5, Iris-versicolor]  
[6.1, 2.8, 4.7, 1.2, Iris-versicolor]  
[6.1, 2.8, 4.0, 1.3, Iris-versicolor]  
[5.7, 2.9, 4.2, 1.3, Iris-versicolor]  
[5.5, 2.6, 4.4, 1.2, Iris-versicolor]  
[5.6, 2.7, 4.2, 1.3, Iris-versicolor]  
[5.7, 3.0, 4.2, 1.2, Iris-versicolor]  
[5.7, 2.8, 4.1, 1.3, Iris-versicolor]  
[5.6, 3.0, 4.1, 1.3, Iris-versicolor]  
[6.0, 3.0, 4.8, 1.8, Iris-virginica]  
[5.8, 2.7, 3.9, 1.2, Iris-versicolor]  
[5.8, 2.6, 4.0, 1.2, Iris-versicolor]  
[5.5, 2.5, 4.0, 1.3, Iris-versicolor]  
[5.8, 2.7, 4.1, 1.0, Iris-versicolor]  
[5.6, 2.9, 3.6, 1.3, Iris-versicolor]  
[5.9, 3.2, 4.8, 1.8, Iris-versicolor]  
[6.2, 2.8, 4.8, 1.8, Iris-virginica]  
[6.1, 3.0, 4.9, 1.8, Iris-virginica]  
[5.9, 3.0, 5.1, 1.8, Iris-virginica]  
[5.6, 2.5, 3.9, 1.1, Iris-versicolor]  
[5.5, 2.3, 4.0, 1.3, Iris-versicolor]  
[5.5, 2.4, 3.8, 1.1, Iris-versicolor]



[6.3, 2.7, 4.9, 1.8, Iris-virginica]  
[6.3, 2.8, 5.1, 1.5, Iris-virginica]  
[6.3, 2.5, 5.0, 1.9, Iris-virginica]  
[6.0, 2.7, 5.1, 1.6, Iris-versicolor]  
[5.8, 2.7, 5.1, 1.9, Iris-virginica]  
[5.8, 2.7, 5.1, 1.9, Iris-virginica]  
[5.5, 2.4, 3.7, 1.0, Iris-versicolor]  
[6.3, 2.5, 4.9, 1.5, Iris-versicolor]  
[6.4, 2.7, 5.3, 1.9, Iris-virginica]  
[5.7, 2.5, 5.0, 2.0, Iris-virginica]  
[6.0, 2.2, 5.0, 1.5, Iris-virginica]  
[5.8, 2.8, 5.1, 2.4, Iris-virginica]  
[5.6, 2.8, 4.9, 2.0, Iris-virginica]  
[5.7, 2.6, 3.5, 1.0, Iris-versicolor]  
[6.5, 3.0, 5.5, 1.8, Iris-virginica]  
[6.4, 2.8, 5.6, 2.1, Iris-virginica]  
[6.4, 2.8, 5.6, 2.2, Iris-virginica]  
[6.5, 3.0, 5.2, 2.0, Iris-virginica]  
[6.3, 2.9, 5.6, 1.8, Iris-virginica]  
[6.8, 3.0, 5.5, 2.1, Iris-virginica]  
[6.4, 3.1, 5.5, 1.8, Iris-virginica]  
[6.5, 3.0, 5.8, 2.2, Iris-virginica]  
[6.5, 3.2, 5.1, 2.0, Iris-virginica]  
[6.4, 3.2, 5.3, 2.3, Iris-virginica]  
[6.7, 3.0, 5.2, 2.3, Iris-virginica]  
[6.7, 3.3, 5.7, 2.1, Iris-virginica]  
[6.9, 3.1, 5.4, 2.1, Iris-virginica]  
[6.7, 3.1, 5.6, 2.4, Iris-virginica]  
[6.2, 3.4, 5.4, 2.3, Iris-virginica]  
[6.9, 3.1, 5.1, 2.3, Iris-virginica]  
[6.9, 3.2, 5.7, 2.3, Iris-virginica]  
[6.8, 3.2, 5.9, 2.3, Iris-virginica]  
[6.7, 3.3, 5.7, 2.5, Iris-virginica]  
[6.3, 3.4, 5.6, 2.4, Iris-virginica]  
[7.1, 3.0, 5.9, 2.1, Iris-virginica]  
[6.3, 3.3, 6.0, 2.5, Iris-virginica]

Percent Outliers in Data: 0.174497

# of Outliers: 26

[5.8, 4.0, 1.2, 0.2, Iris-setosa]  
[5.7, 4.4, 1.5, 0.4, Iris-setosa]  
[4.6, 3.6, 1.0, 0.2, Iris-setosa]  
[4.5, 2.3, 1.3, 0.3, Iris-setosa]  
[4.9, 2.4, 3.3, 1.0, Iris-versicolor]

[5.2, 2.7, 3.9, 1.4, Iris-versicolor]  
[5.0, 2.0, 3.5, 1.0, Iris-versicolor]  
[6.0, 2.2, 4.0, 1.0, Iris-versicolor]  
[6.2, 2.2, 4.5, 1.5, Iris-versicolor]  
[6.3, 2.3, 4.4, 1.3, Iris-versicolor]  
[5.0, 2.3, 3.3, 1.0, Iris-versicolor]  
[5.1, 2.5, 3.0, 1.1, Iris-versicolor]  
[7.6, 3.0, 6.6, 2.1, Iris-virginica]  
[4.9, 2.5, 4.5, 1.7, Iris-virginica]  
[7.3, 2.9, 6.3, 1.8, Iris-virginica]  
[6.7, 2.5, 5.8, 1.8, Iris-virginica]  
[7.2, 3.6, 6.1, 2.5, Iris-virginica]  
[7.7, 3.8, 6.7, 2.2, Iris-virginica]  
[7.7, 2.6, 6.9, 2.3, Iris-virginica]  
[7.7, 2.8, 6.7, 2.0, Iris-virginica]  
[7.2, 3.2, 6.0, 1.8, Iris-virginica]  
[7.2, 3.0, 5.8, 1.6, Iris-virginica]  
[7.4, 2.8, 6.1, 1.9, Iris-virginica]  
[7.9, 3.8, 6.4, 2.0, Iris-virginica]  
[6.1, 2.6, 5.6, 1.4, Iris-virginica]  
[7.7, 3.0, 6.1, 2.3, Iris-virginica]

## Many\_clusters.csv

### K-means

PARAMETERS: k=6

finrawson@Finians-Air CSC466-Lab4 % java kmeans data/many\_clusters.csv 6

Cluster 0

Center: [23.3, 41.7]

10 points

[22, 43]

[19, 44]

[23, 42]

[23, 44]

[20, 39]

[24, 43]

[24, 49]

[26, 33]

[26, 37]

[26, 43]

Avg Dist To Center: 4.005879958716357

Max Dist To Center: 9.109335870413389

Min Dist To Center: 0.424264068711927

SSE: 24470.0

Cluster 1

Center: [41.27272727272727, 38.90909090909091]

11 points

[42, 43]

[43, 37]

[44, 40]

[44, 41]

[40, 40]

[40, 42]

[38, 33]

[46, 30]

[38, 36]

[41, 41]

[38, 45]

Avg Dist To Center: 4.396794888519616

Max Dist To Center: 10.08558418062448

Min Dist To Center: 1.676280810416891

SSE: 24470.0

Cluster 2

Center: [41.2, 9.6]

10 points

[41, 6]

[50, 19]

[42, 7]

[39, 11]

[39, 16]

[27, 3]

[43, 5]

[43, 6]

[44, 15]

[44, 8]

Avg Dist To Center: 6.250851785588284

Max Dist To Center: 15.658863304850708

Min Dist To Center: 2.607680962081062

SSE: 24470.0

Cluster 3

Center: [11.357142857142858, 8.0]

14 points

[21, 13]

[7, 14]

[13, 6]

[14, 1]

[10, 3]

[10, 6]

[11, 18]

[11, 5]

[11, 7]

[9, 5]

[12, 10]

[9, 7]

[5, 8]

[16, 9]

Avg Dist To Center: 4.97272032239714

Max Dist To Center: 10.862075946961106

Min Dist To Center: 1.0618620533798935

SSE: 24470.0

Cluster 4

Center: [8.785714285714286, 33.642857142857146]

14 points

[9, 32]

[5, 33]

[6, 35]

[6, 37]

[18, 26]

[13, 36]

[7, 36]

[3, 38]

[10, 34]

[11, 28]

[9, 23]

[8, 35]

[8, 37]

[10, 41]

Avg Dist To Center: 5.028802899674038

Max Dist To Center: 11.971479713494581

Min Dist To Center: 1.2657175104763807

SSE: 24470.0

Cluster 5

Center: [34.0, 24.5]

14 points

[31, 30]

[28, 28]

[36, 27]

[37, 24]

[37, 26]

[41, 23]

[38, 21]

[34, 27]

[23, 19]

[31, 17]

[39, 25]

[35, 25]

[31, 21]

[35, 30]

Avg Dist To Center: 5.32151913461238

Max Dist To Center: 12.298373876248844

Min Dist To Center: 1.118033988749895

SSE: 24470.0

### Agglomerative Hierarchical

PARAMETERS: threshold=20

finrawson@Finians-Air CSC466-Lab4 % java -cp "../lib/org.json.jar" hclustering  
data/many\_clusters.csv 20

Cluster 0:

[1, 1]

Center: [21, 13]

Max Dist. to Center: 21.000000

Min Dist. to Center: 9.000000

Avg Dist. to Center: 16.642857

SSE: 4027.000000

15 Points:

[11, 18]

[7, 14]

[21, 13]

[12, 10]

[16, 9]

[5, 8]

[9, 7]

[11, 7]

[10, 6]

[13, 6]

[9, 5]

[11, 5]

[10, 3]

[14, 1]

[27, 3]

Cluster 1:

[1, 1]

Center: [50, 19]

Max Dist. to Center: 22.000000

Min Dist. to Center: 10.000000  
Avg Dist. to Center: 17.875000  
SSE: 2671.000000

9 Points:

[50, 19]  
[39, 16]  
[44, 15]  
[39, 11]  
[44, 8]  
[42, 7]  
[41, 6]  
[43, 5]  
[43, 6]

Cluster 2:

[1, 1]

Center: [46, 30]

Max Dist. to Center: 34.000000

Min Dist. to Center: 11.000000

Avg Dist. to Center: 17.235294

SSE: 5729.000000

18 Points:

[38, 36]  
[26, 33]  
[38, 33]  
[31, 30]  
[46, 30]  
[35, 30]  
[28, 28]  
[34, 27]  
[36, 27]  
[37, 26]  
[35, 25]  
[39, 25]  
[37, 24]  
[41, 23]  
[31, 21]  
[38, 21]  
[31, 17]  
[23, 19]

Cluster 3:

[1, 1]

Center: [42, 43]

Max Dist. to Center: 24.000000

Min Dist. to Center: 3.000000

Avg Dist. to Center: 12.357143

SSE: 3009.000000

15 Points:

[38, 45]

[19, 44]

[23, 44]

[22, 43]

[24, 43]

[23, 42]

[26, 43]

[42, 43]

[40, 42]

[41, 41]

[44, 41]

[40, 40]

[44, 40]

[43, 37]

[26, 37]

Cluster 4:

[1, 1]

Center: [20, 39]

Max Dist. to Center: 27.000000

Min Dist. to Center: 10.000000

Avg Dist. to Center: 16.857143

SSE: 4200.000000

15 Points:

[10, 41]

[20, 39]

[3, 38]

[6, 37]

[8, 37]

[7, 36]

[13, 36]

[6, 35]

[8, 35]

[10, 34]

[5, 33]

[9, 32]

[11, 28]

[9, 23]

[18, 26]

[illegible]



```
        {
          "type": "leaf",
          "value": 19,
          "height": 0
        }
      ],
      "type": "node",
      "height": 18
    },
    {
      "type": "leaf",
      "value": 14,
      "height": 0
    }
  ],
  "type": "node",
  "height": 18
},
{
  "type": "leaf",
  "value": 13,
  "height": 0
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],
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```
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```
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  }
}
```

## DBSCAN

PARAMETERS: epsilon=5.5 numPoints=4

finrawson@Finians-Air CSC466-Lab4 % java dbscan data/many\_clusters.csv 5.5 4

Cluster: 0

Center: [23, 44]

Max Dist. to Center: 4.000000

Min Dist. to Center: 2.000000

Avg Dist. to Center: 2.800000

SSE: 44.000000

5 Points:

[19, 44]

[22, 43]

[24, 43]

[26, 43]

[23, 42]

Cluster: 1

Center: [42, 43]

Max Dist. to Center: 7.000000

Min Dist. to Center: 3.000000

Avg Dist. to Center: 4.714286

SSE: 169.000000

7 Points:

[40, 42]

[41, 41]

[44, 41]

[40, 40]

[44, 40]

[38, 45]

[43, 37]

Cluster: 2

Center: [6, 37]

Max Dist. to Center: 8.000000

Min Dist. to Center: 2.000000

Avg Dist. to Center: 4.666667

SSE: 246.000000

9 Points:

[3, 38]

[8, 37]

[7, 36]

[6, 35]

[8, 35]

[5, 33]

[10, 34]

[9, 32]

[13, 36]

Cluster: 3

Center: [35, 30]

Max Dist. to Center: 13.000000

Min Dist. to Center: 4.000000

Avg Dist. to Center: 7.400000

SSE: 648.000000

10 Points:

[31, 30]

[34, 27]

[36, 27]

[35, 25]

[28, 28]

[37, 26]

[39, 25]

[37, 24]

[41, 23]

[38, 21]

Cluster: 4

Center: [44, 8]

Max Dist. to Center: 5.000000

Min Dist. to Center: 3.000000

Avg Dist. to Center: 3.750000

SSE: 59.000000

4 Points:

[42, 7]

[41, 6]

[43, 6]

[43, 5]

Cluster: 5

Center: [9, 7]

Max Dist. to Center: 9.000000

Min Dist. to Center: 2.000000

Avg Dist. to Center: 4.444444

SSE: 220.000000

9 Points:

[5, 8]

[11, 7]

[10, 6]

[13, 6]

[9, 5]

[11, 5]

[10, 3]

[12, 10]

[16, 9]

Percent Outliers in Data: 0.319444

# of Outliers: 23

[24, 49]

[10, 41]

[20, 39]

[26, 37]

[38, 36]

[26, 33]

[38, 33]

[46, 30]

[11, 28]

[18, 26]

[9, 23]

[31, 21]

[23, 19]

[50, 19]

[11, 18]

[31, 17]

[39, 16]

[44, 15]

[7, 14]

[21, 13]

[39, 11]

[27, 3]

[14, 1]

## AccidentsSet01.csv

### K-means

PARAMETERS: k=3

finrawson@Finians-Air CSC466-Lab4 % java kmeans data/AccidentsSet01.csv 3

Cluster 0

Center: [5.0, 11.285714285714286, 1.0]

7 points

[5, 15, 1]

[5, 14, 1]

[5, 11, 1]

[5, 12, 1]

[5, 10, 1]

[5, 8, 1]

[5, 9, 1]

Avg Dist To Center: 2.0408163265306123

Max Dist To Center: 3.7142857142857135

Min Dist To Center: 0.2857142857142865

SSE: 840.0

Cluster 1

Center: [2.375, 3.75, 1.875]

8 points

[2, 4, 2]

[2, 5, 3]

[5, 7, 1]

[2, 4, 1]

[2, 1, 1]

[2, 2, 2]

[2, 2, 1]

[2, 5, 4]

Avg Dist To Center: 2.07917757050978

Max Dist To Center: 4.268342769740968

Min Dist To Center: 0.46770717334674267

SSE: 840.0

Cluster 2

Center: [2.0, 19.0, 2.0]

1 points

[2, 19, 2]

Avg Dist To Center: 0.0

Max Dist To Center: 0.0

Min Dist To Center: 0.0

SSE: 840.0

PARAMETERS: k=2

finrawson@Finians-Air CSC466-Lab4 % java kmeans data/AccidentsSet01.csv 2

Cluster 0

Center: [2.6666666666666665, 4.222222222222222, 1.7777777777777777]

9 points

[5, 8, 1]

[2, 4, 2]

[2, 5, 3]

[5, 7, 1]

[2, 4, 1]

[2, 1, 1]

[2, 2, 2]

[2, 2, 1]

[2, 5, 4]

Avg Dist To Center: 2.4670904720420213

Max Dist To Center: 4.507880616689065

Min Dist To Center: 0.7370277311900888

SSE: 953.0

Cluster 1

Center: [4.571428571428571, 12.857142857142858, 1.1428571428571428]

7 points

[5, 15, 1]

[5, 14, 1]

[5, 11, 1]

[5, 12, 1]

[5, 10, 1]

[5, 9, 1]

[2, 19, 2]

Avg Dist To Center: 2.827070699931355

Max Dist To Center: 6.7142857142857135

Min Dist To Center: 0.9689042833036102

SSE: 953.0

### Agglomerative Hierarchical

PARAMETERS: threshold = 12

OUTPUT

Cluster 0:

[1, 1, 1]

Center: [5, 15, 1]

Max Dist. to Center: 1.000000

Min Dist. to Center: 1.000000

Avg Dist. to Center: 1.000000

SSE: 1.000000

2 Points:

[5, 14, 1]  
[5, 15, 1]

Cluster 1:

[1, 1, 1]

Center: [2, 5, 4]

Max Dist. to Center: 4.000000

Min Dist. to Center: 1.000000

Avg Dist. to Center: 2.666667

SSE: 26.000000

4 Points:

[2, 4, 1]

[2, 4, 2]

[2, 5, 4]

[2, 5, 3]

Cluster 2:

[1, 1, 1]

Center: [5, 12, 1]

Max Dist. to Center: 5.000000

Min Dist. to Center: 1.000000

Avg Dist. to Center: 3.333333

SSE: 76.000000

7 Points:

[5, 7, 1]

[5, 8, 1]

[5, 8, 1]

[5, 11, 1]

[5, 12, 1]

[5, 9, 1]

[5, 9, 1]

Cluster 3:

[1, 1, 1]

Center: [2, 2, 2]

Max Dist. to Center: 2.000000

Min Dist. to Center: 0.000000

Avg Dist. to Center: 1.000000

SSE: 5.000000

4 Points:

[2, 1, 1]

[2, 2, 1]

[2, 2, 2]

[2, 2, 2]

```
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      "nodes": [
        {
          "nodes": [
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  ]
}
```



```
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        {
          "nodes": [
```

```

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        {
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```

```

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"type": "root",
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}

```

## DBSCAN

PARAMETERS: epsilon=4 numPoints=5

finrawson@Finians-Air CSC466-Lab4 % java dbscan data/AccidentsSet01.csv 4 5

Cluster: 0

Center: [5, 12, 1]

Max Dist. to Center: 5.000000

Min Dist. to Center: 1.000000

Avg Dist. to Center: 3.000000

SSE: 93.000000

9 Points:

[5, 15, 1]

[5, 14, 1]

[5, 11, 1]

[5, 10, 1]  
[5, 9, 1]  
[5, 9, 1]  
[5, 8, 1]  
[5, 8, 1]  
[5, 7, 1]

Cluster: 1

Center: [2, 2, 2]

Max Dist. to Center: 5.000000

Min Dist. to Center: 0.000000

Avg Dist. to Center: 2.428571

SSE: 59.000000

7 Points:

[2, 1, 1]  
[2, 2, 2]  
[2, 2, 1]  
[2, 4, 2]  
[2, 4, 1]  
[2, 5, 3]  
[2, 5, 4]

Percent Outliers in Data: 0.055556

# of Outliers: 1

[2, 19, 2]

## AccidentsSet03.csv

### K-means

PARAMETERS: k=3

finrawson@Finians-Air CSC466-Lab4 % java kmeans data/AccidentsSet03.csv 3

Cluster 0

Center: [1.2352941176470589, 0.5294117647058824, 2.9411764705882355,  
1.3529411764705883, 1.0]

17 points

[2.00, 0.00, 2.00, 1.00, 0.00]  
[1.00, 0.00, 2.00, 1.00, 0.00]  
[1.00, 1.00, 2.00, 1.00, 1.00]  
[1.00, 2.00, 4.00, 1.00, 2.00]  
[1.00, 0.00, 4.00, 2.00, 0.00]  
[2.00, 0.00, 4.00, 2.00, 0.00]  
[1.00, 1.00, 4.00, 1.00, 1.00]  
[1.00, 0.00, 4.00, 3.00, 3.00]

[2.00, 1.00, 2.00, 1.00, 2.00]

[1.00, 0.00, 2.00, 2.00, 1.00]

[1.00, 0.00, 2.00, 1.00, 1.00]

[1.00, 1.00, 2.00, 1.00, 0.00]

[1.00, 1.00, 4.00, 1.00, 2.00]

[1.00, 0.00, 2.00, 2.00, 2.00]

[1.00, 1.00, 4.00, 1.00, 0.00]

[2.00, 1.00, 2.00, 1.00, 1.00]

[1.00, 0.00, 4.00, 1.00, 1.00]

Avg Dist To Center: 1.596815364991895

Max Dist To Center: 2.858242497236786

Min Dist To Center: 1.1345471483521126

SSE: 1615.0

Cluster 1

Center: [10.0, 0.0, 4.0, 1.0, 1.0]

1 points

[10.00, 0.00, 4.00, 1.00, 1.00]

Avg Dist To Center: 0.0

Max Dist To Center: 0.0

Min Dist To Center: 0.0

SSE: 1615.0

Cluster 2

Center: [3.5454545454545454, 0.18181818181818182, 3.090909090909091, 1.0, 0.5454545454545454]

11 points

[3.00, 0.00, 2.00, 1.00, 0.00]

[4.00, 0.00, 2.00, 1.00, 0.00]

[4.00, 0.00, 4.00, 1.00, 0.00]

[5.00, 0.00, 4.00, 1.00, 0.00]

[3.00, 0.00, 4.00, 1.00, 0.00]

[3.00, 0.00, 4.00, 1.00, 2.00]

[3.00, 1.00, 2.00, 1.00, 0.00]

[3.00, 0.00, 2.00, 1.00, 1.00]

[5.00, 0.00, 4.00, 1.00, 1.00]

[3.00, 0.00, 4.00, 1.00, 1.00]

[3.00, 1.00, 2.00, 1.00, 1.00]

Avg Dist To Center: 1.4567699396864489

Max Dist To Center: 1.8090680674665818

Min Dist To Center: 1.1677484162422844

SSE: 1615.0

## Agglomerative Hierarchical

PARAMETERS: threshold = 6

### OUTPUT

Cluster 0:

[1, 1, 1]

Center: [5, 15, 1]

Max Dist. to Center: 1.000000

Min Dist. to Center: 1.000000

Avg Dist. to Center: 1.000000

SSE: 1.000000

2 Points:

[5, 14, 1]

[5, 15, 1]

Cluster 1:

[1, 1, 1]

Center: [2, 5, 4]

Max Dist. to Center: 4.000000

Min Dist. to Center: 1.000000

Avg Dist. to Center: 2.666667

SSE: 26.000000

4 Points:

[2, 4, 1]

[2, 4, 2]

[2, 5, 4]

[2, 5, 3]

Cluster 2:

[1, 1, 1]

Center: [5, 12, 1]

Max Dist. to Center: 5.000000

Min Dist. to Center: 1.000000

Avg Dist. to Center: 3.333333

SSE: 76.000000

7 Points:

[5, 7, 1]

[5, 8, 1]

[5, 8, 1]

[5, 11, 1]

[5, 12, 1]

[5, 9, 1]

[5, 9, 1]

Cluster 3:

[1, 1, 1]

Center: [2, 2, 2]

Max Dist. to Center: 2.000000

Min Dist. to Center: 0.000000

Avg Dist. to Center: 1.000000

SSE: 5.000000

4 Points:

[2, 1, 1]

[2, 2, 1]

[2, 2, 2]

[2, 2, 2]

```
{
  "nodes": [
    {
      "nodes": [
        {
          "nodes": [
            {
              "nodes": [
                {
                  "nodes": [
                    {
                      "nodes": [
                        {
                          "nodes": [
                            {
                              "nodes": [
                                {
                                  "type": "leaf",
                                  "value": 3,
                                  "height": 0
                                },
                                {
                                  "type": "leaf",
                                  "value": 2,
                                  "height": 0
                                }
                              ]
                            },
                            "type": "node",
                            "height": 1
                          ],
                        },
                      ],
                    },
                    "type": "node",
                    "height": 1
                  ],
                },
                "type": "node",
                "height": 1
              ],
            },
            "type": "node",
            "height": 1
          ],
        },
        "type": "node",
        "height": 1
      ],
    },
    "type": "node",
    "height": 1
  ],
  "type": "node",
  "height": 1
}
```



```
{
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      "value": 6,
      "height": 0
    },
    {
      "type": "leaf",
      "value": 5,
      "height": 0
    }
  ],
  "type": "node",
  "height": 1
},
{
  "nodes": [
    {
      "type": "leaf",
      "value": 8,
      "height": 0
    },
    {
      "type": "leaf",
      "value": 7,
      "height": 0
    }
  ],
  "type": "node",
  "height": 1
},
{
  "nodes": [
    {
      "type": "leaf",
      "value": 9,
      "height": 0
    }
  ],
  "type": "node",
  "height": 3
},
{
  "type": "leaf",
  "value": 9,
  "height": 0
}
```

```
    }
  ],
  "type": "node",
  "height": 3
},
{
  "nodes": [
    {
      "nodes": [
        {
          "nodes": [
            {
              "type": "leaf",
              "value": 13,
              "height": 0
            },
            {
              "type": "leaf",
              "value": 12,
              "height": 0
            }
          ],
          "type": "node",
          "height": 1
        },
        {
          "type": "leaf",
          "value": 14,
          "height": 0
        }
      ],
      "type": "node",
      "height": 3
    },
    {
      "type": "leaf",
      "value": 11,
      "height": 0
    }
  ],
  "type": "node",
  "height": 3
},
]
```

```
"type": "node",
"height": 13
},
{
  "nodes": [
    {
      "nodes": [
        {
          "nodes": [
            {
              "type": "leaf",
              "value": 18,
              "height": 0
            },
            {
              "type": "leaf",
              "value": 17,
              "height": 0
            }
          ],
          "type": "node",
          "height": 3
        },
        {
          "type": "leaf",
          "value": 15,
          "height": 0
        }
      ],
      "type": "node",
      "height": 3
    },
    {
      "type": "leaf",
      "value": 16,
      "height": 0
    }
  ],
  "type": "node",
  "height": 3
},
{
  "type": "node",
  "height": 13
}
```

```

    },
    {
      "nodes": [
        {
          "type": "leaf",
          "value": 1,
          "height": 0
        },
        {
          "type": "leaf",
          "value": 0,
          "height": 0
        }
      ],
      "type": "node",
      "height": 1
    }
  ],
  "type": "node",
  "height": 13
},
{
  "type": "leaf",
  "value": 4,
  "height": 0
}
],
"type": "node",
"height": 13
},
{
  "type": "leaf",
  "value": 10,
  "height": 0
}
],
"type": "root",
"height": 14.444444444444445
}

```

## DBSCAN

PARAMETERS: epsilon=2 numPoints=4

finrawson@Finians-Air CSC466-Lab4 % java dbscan data/AccidentsSet03.csv 2 4

Cluster: 0

Center: [3.00, 0.00, 2.00, 1.00, 0.00]

Max Dist. to Center: 5.000000

Min Dist. to Center: 1.000000

Avg Dist. to Center: 2.692308

SSE: 220.000000

26 Points:

[2.00, 0.00, 2.00, 1.00, 0.00]  
[3.00, 0.00, 2.00, 1.00, 1.00]  
[4.00, 0.00, 2.00, 1.00, 0.00]  
[2.00, 0.00, 2.00, 1.00, 0.00]  
[3.00, 1.00, 2.00, 1.00, 0.00]  
[4.00, 0.00, 2.00, 1.00, 0.00]  
[1.00, 0.00, 2.00, 1.00, 0.00]  
[3.00, 1.00, 2.00, 1.00, 1.00]  
[1.00, 0.00, 2.00, 1.00, 1.00]  
[1.00, 0.00, 2.00, 1.00, 1.00]  
[1.00, 0.00, 2.00, 1.00, 1.00]  
[1.00, 0.00, 2.00, 1.00, 1.00]  
[1.00, 0.00, 2.00, 1.00, 1.00]  
[1.00, 0.00, 2.00, 1.00, 1.00]  
[1.00, 0.00, 2.00, 1.00, 1.00]  
[1.00, 0.00, 2.00, 1.00, 1.00]  
[1.00, 0.00, 2.00, 1.00, 1.00]  
[1.00, 1.00, 2.00, 1.00, 0.00]  
[1.00, 1.00, 2.00, 1.00, 0.00]  
[1.00, 1.00, 2.00, 1.00, 0.00]  
[2.00, 1.00, 2.00, 1.00, 1.00]  
[1.00, 1.00, 2.00, 1.00, 1.00]  
[1.00, 0.00, 2.00, 2.00, 1.00]  
[1.00, 1.00, 2.00, 1.00, 1.00]  
[2.00, 1.00, 2.00, 1.00, 2.00]  
[1.00, 0.00, 2.00, 2.00, 2.00]

Cluster: 1

Center: [4.00, 0.00, 4.00, 1.00, 0.00]

Max Dist. to Center: 3.000000

Min Dist. to Center: 1.000000

Avg Dist. to Center: 1.625000

SSE: 25.000000

8 Points:

[5.00, 0.00, 4.00, 1.00, 0.00]  
[3.00, 0.00, 4.00, 1.00, 0.00]  
[3.00, 0.00, 4.00, 1.00, 0.00]

[3.00, 0.00, 4.00, 1.00, 0.00]  
[5.00, 0.00, 4.00, 1.00, 1.00]  
[3.00, 0.00, 4.00, 1.00, 1.00]  
[3.00, 0.00, 4.00, 1.00, 1.00]  
[3.00, 0.00, 4.00, 1.00, 2.00]

Cluster: 2

Center: [1.00, 0.00, 4.00, 1.00, 1.00]

Max Dist. to Center: 3.000000

Min Dist. to Center: 1.000000

Avg Dist. to Center: 1.619048

SSE: 62.000000

21 Points:

[1.00, 1.00, 4.00, 1.00, 1.00]  
[1.00, 1.00, 4.00, 1.00, 1.00]  
[1.00, 1.00, 4.00, 1.00, 1.00]  
[1.00, 1.00, 4.00, 1.00, 1.00]  
[1.00, 1.00, 4.00, 1.00, 1.00]  
[1.00, 1.00, 4.00, 1.00, 1.00]  
[1.00, 1.00, 4.00, 1.00, 1.00]  
[1.00, 1.00, 4.00, 1.00, 1.00]  
[1.00, 1.00, 4.00, 1.00, 1.00]  
[1.00, 1.00, 4.00, 1.00, 0.00]  
[1.00, 1.00, 4.00, 1.00, 2.00]  
[1.00, 1.00, 4.00, 1.00, 2.00]  
[1.00, 1.00, 4.00, 1.00, 0.00]  
[1.00, 1.00, 4.00, 1.00, 0.00]  
[1.00, 1.00, 4.00, 1.00, 0.00]  
[1.00, 1.00, 4.00, 1.00, 0.00]  
[1.00, 1.00, 4.00, 1.00, 0.00]  
[1.00, 1.00, 4.00, 1.00, 0.00]  
[1.00, 1.00, 4.00, 1.00, 0.00]  
[1.00, 2.00, 4.00, 1.00, 2.00]

Percent Outliers in Data: 0.065574

# of Outliers: 4

[10.00, 0.00, 4.00, 1.00, 1.00]  
[1.00, 0.00, 4.00, 2.00, 0.00]  
[2.00, 0.00, 4.00, 2.00, 0.00]  
[1.00, 0.00, 4.00, 3.00, 3.00]