Assigned: Due:
May 3, 2025 Homework 4.0 May 9, 2025

Please complete the assigned problems to the best of your abilities. Ensure that your work is entirely your own, external resources are only used as permitted by the instructor, and all allowed sources are given proper credit for non-original content.

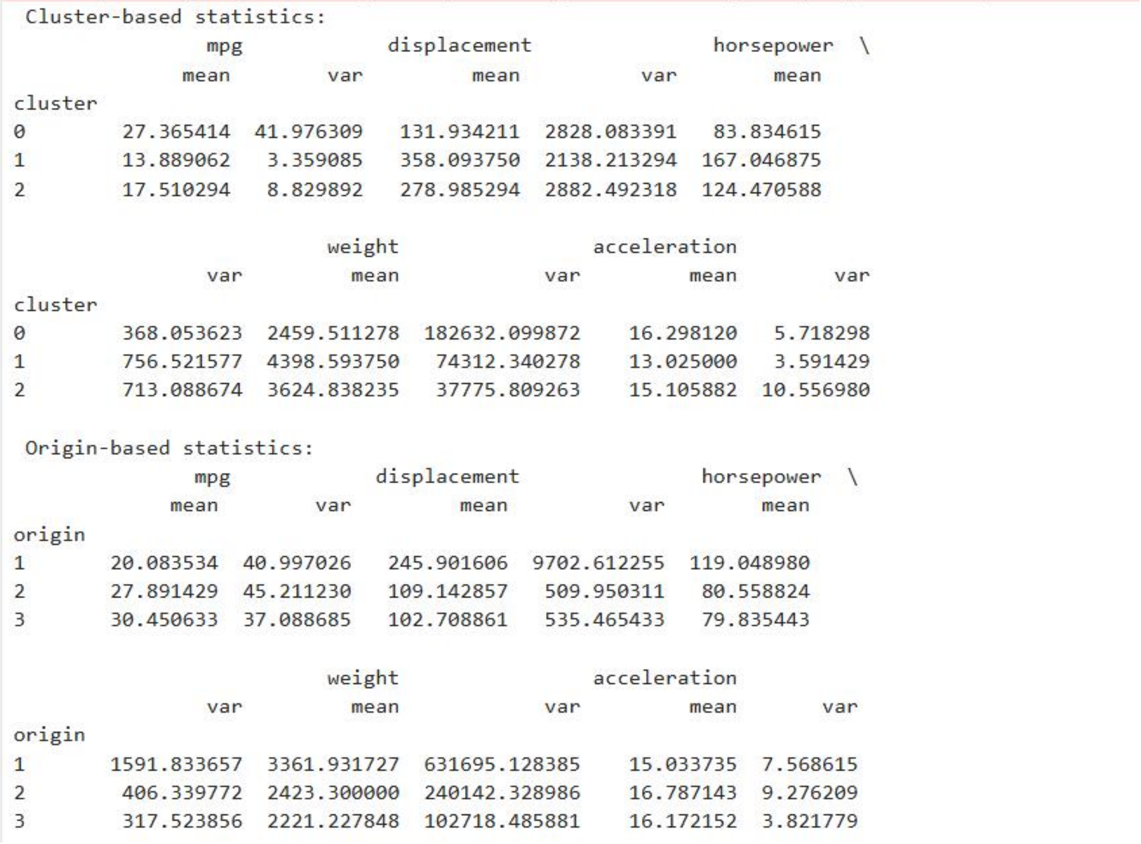
1. Practicum Problems

These problems will primarily reference the lecture materials and the examples given in class using Python. It is suggested that a Jupyter/IPython notebook be used for programmatic components.

1.1 Problem 1

Load the auto-mpg sample dataset from the UCI Machine Learning Repository (auto-mpg.data) into Python using a Pandas dataframe. Using only the continuous fields as features, impute any missing values with the mean, and perform Hierarchical Clustering (Use sklearn.cluster.AgglomerativeClustering) with linkage set to average and the default affinity set to a euclidean. Set the remaining parameters to obtain a shallow tree with 3 clusters as the target. Obtain the mean and variance values for each cluster and compare these values to the values obtained for each class if we used origin as a class label. Is there a Clear relationship between cluster assignment and class label?

The Cluster 2 clearly corresponds to a lightweight, high-mpg vehicle, possibly coinciding with origin=3.
Cluster 0 has a high weight, low mpg, and probably more origin=1.
But instead of a one-to-one mapping correspondence, there is an intersection.



```
 Cluster-based statistics:
               mpg           displacement              horsepower  \
              mean        var          mean          var         mean
cluster
0        27.365414  41.976309    131.934211  2828.083391   83.834615
1        13.889062   3.359085    358.093750  2138.213294  167.046875
2        17.510294   8.829892    278.985294  2882.492318  124.470588

                       weight                  acceleration
               var         mean            var         mean        var
cluster
0        368.053623  2459.511278  182632.099872    16.298120   5.718298
1        756.521577  4398.593750   74312.340278    13.025000   3.591429
2        713.088674  3624.838235   37775.809263    15.105882  10.556980

 Origin-based statistics:
              mpg           displacement              horsepower  \
             mean        var          mean          var         mean
origin
1       20.083534  40.997026    245.901606  9702.612255  119.048980
2       27.891429  45.211230    109.142857   509.950311   80.558824
3       30.450633  37.088685    102.708861   535.465433   79.835443

                       weight                  acceleration
               var         mean            var         mean       var
origin
1       1591.833657  3361.931727  631695.128385    15.033735  7.568615
2        406.339772  2423.300000  240142.328986    16.787143  9.276209
3        317.523856  2221.227848  102718.485881    16.172152  3.821779
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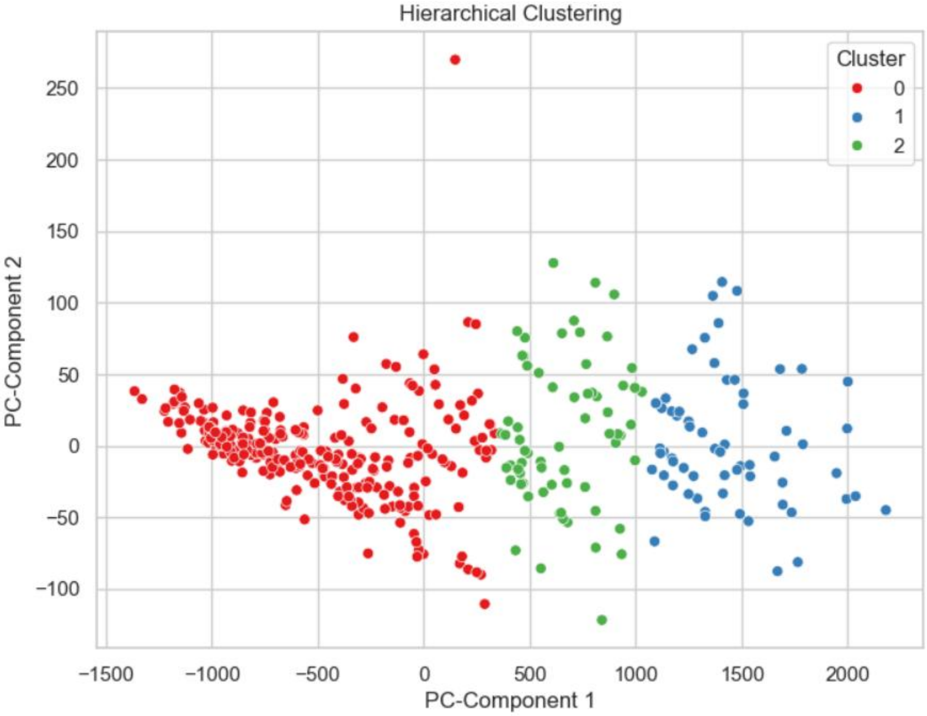
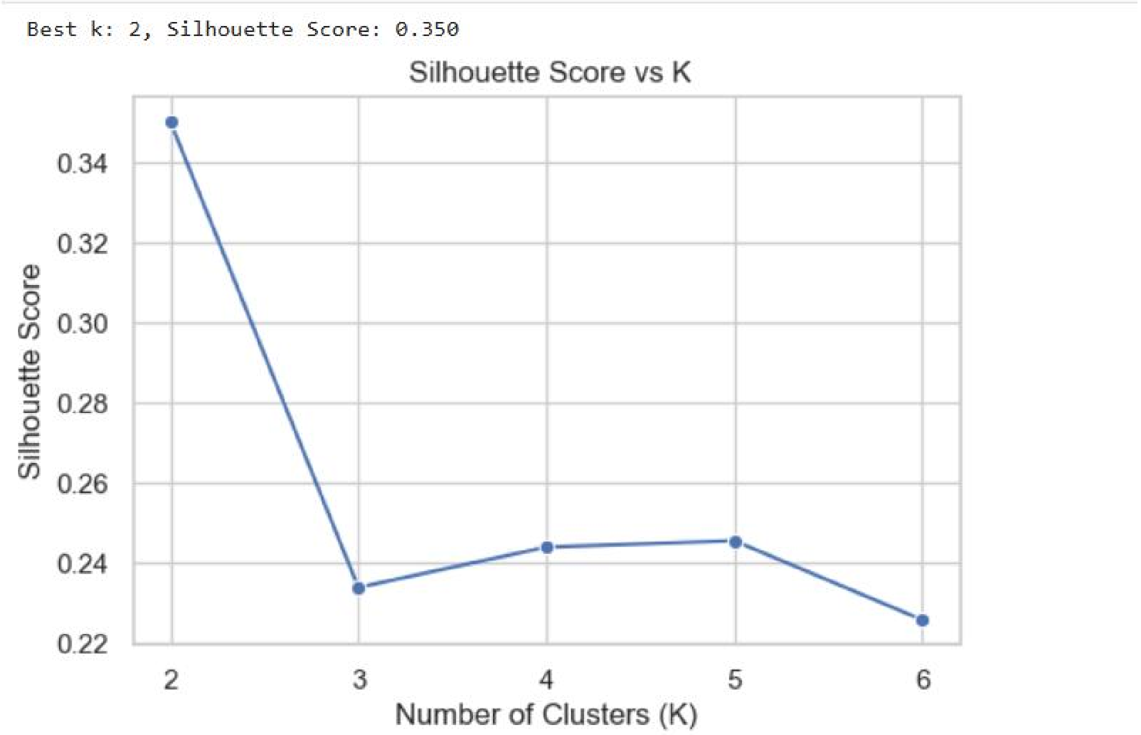


1.2 Problem 2

Load the Boston dataset (sklearn.datasets.load ~~bos~~ton()) into Python using a Pandas dataframe. Perform a K-Means analysis on scaled data, with the number of clusters ranging from 2 to 6. Provide the Silhouette score to justify which value of k is optimal. Calculate the mean values for all features in each cluster for the optimal clustering - how do these values differ from the centroid coordinates?

The highest profile score was k=2 (0.35).



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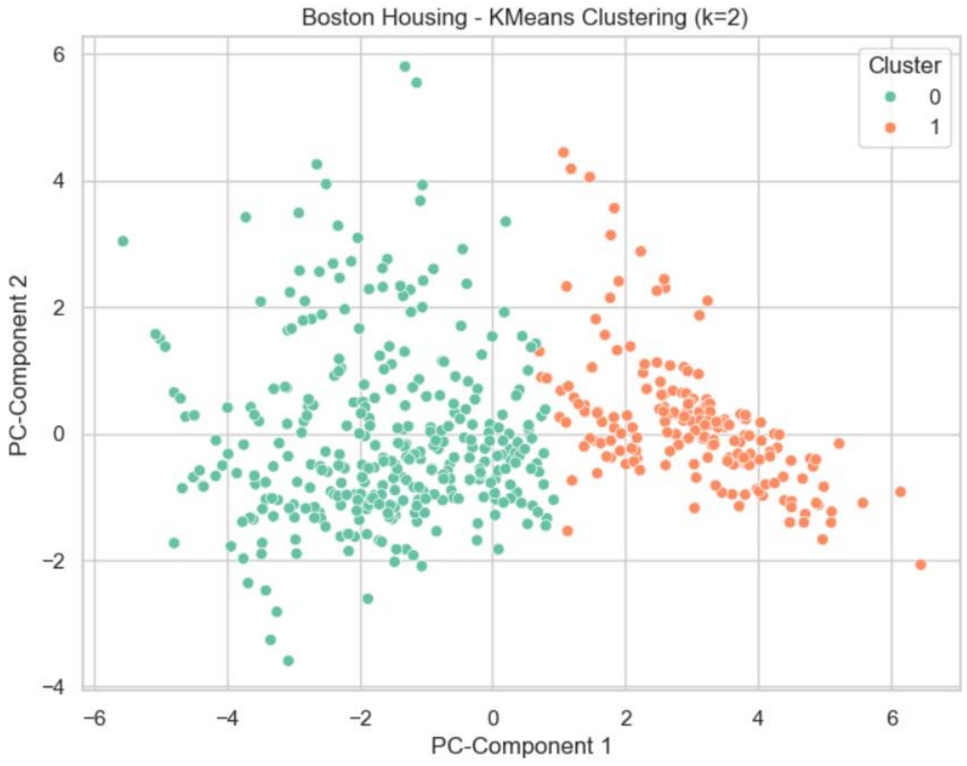
Best k: 2, Silhouette Score: 0.350
```

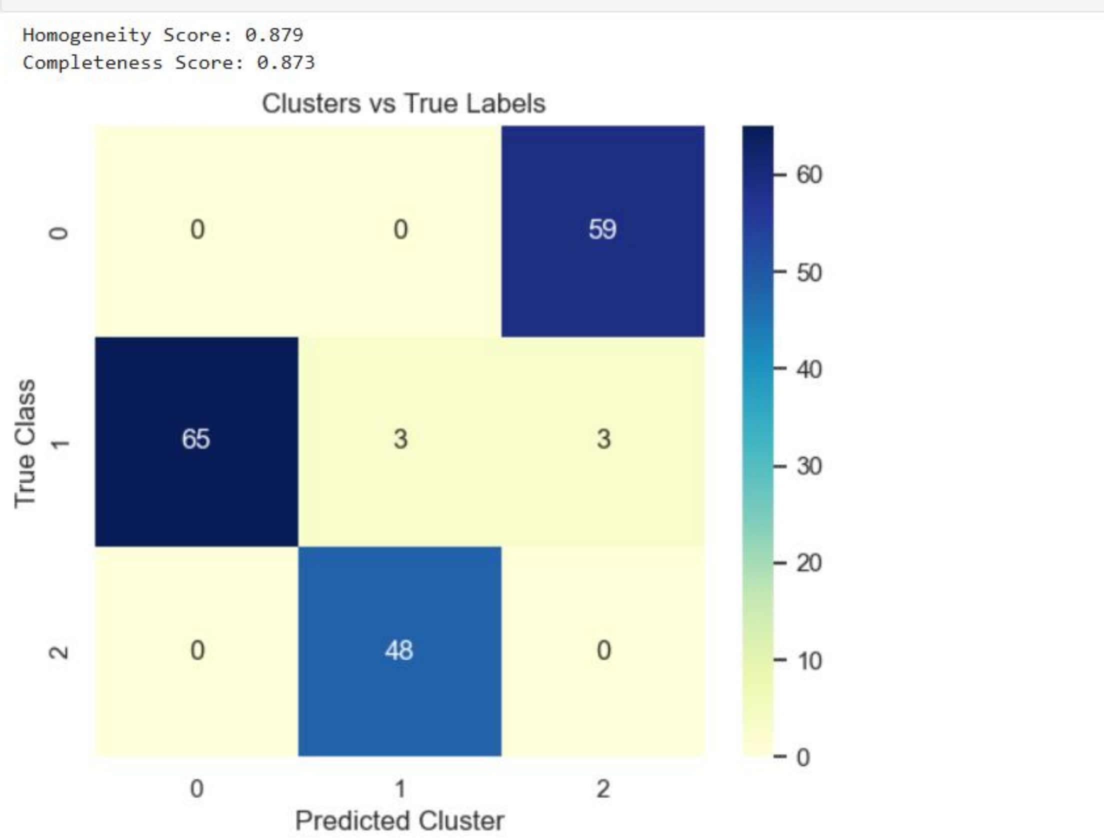
Clusters 0 and 1 are clearly separated in the PCA space, and each cluster is significantly different, very close to the centroid of KMeans.
The cluster mean is the true average of all samples within the cluster.
The centroid is the "geometric center" calculated by the model's algorithm.
They are close on most features, but may be slightly biased on high variance features



1.3 Problem 3

Load the wine dataset (sklearn.datasets.load wine()) into Python using a Pandas dataframe. Perform a K-Means analysis on scaled data, with the number of clusters set to 3. Given the actual class labels, calculate the Homogeneity/Completeness for the optimal k - what information does each of these metrics provide?

The 3 clusters are almost diagonally distributed with the real wine labels.
cluster 0 is almost entirely class 2;
cluster 1 includes most class 0s;
Cluster 2 is primarily Class 1.



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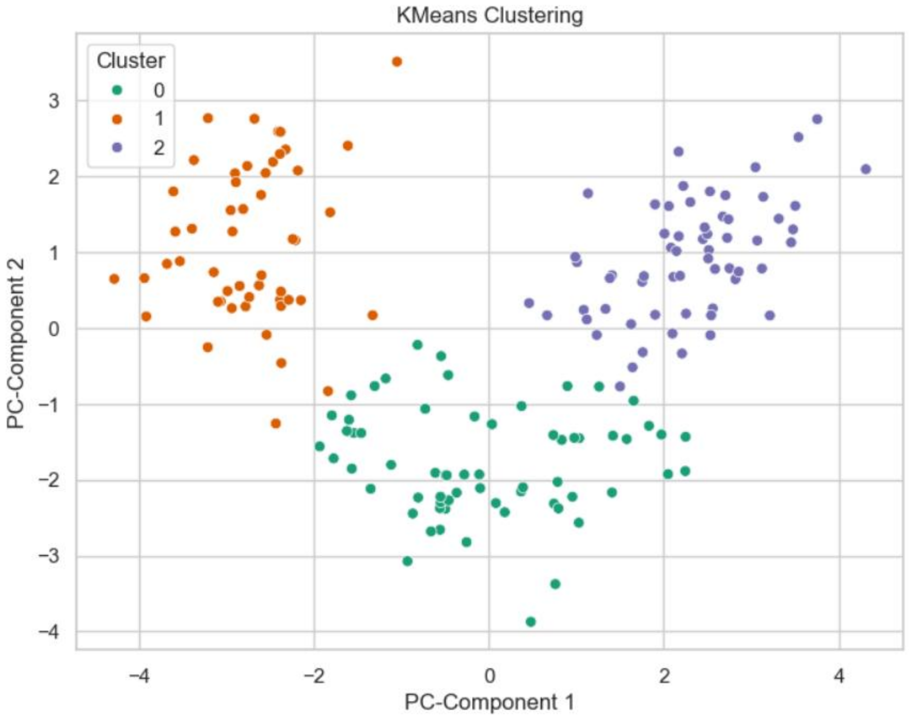
Homogeneity Score: 0.879
Completeness Score: 0.873
```

Homogeneity = 0.873: Inside each cluster, the predominantly same class.
Completeness = 0.873: Each class is mainly clustered in one cluster.
Both of these metrics are close to 1, indicating that the clustering almost completely maps the original category labels.


KMeans Clustering
Cluster
● 0
● 1
● 2
PC-Component 2
3
2
1
0
−1
−2
−3
−4
−4
−2
0
2
4
PC-Component 1

END