1. Linear Regression:

**Data set Used**: White Wines

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1a )**Do linear regression to learn the single-feature regression models, one model for each of the 11 features. Find the R2 and AIC values for each of these models. Report these values for the models.**

Functions Used from the **statsmodels.regression.linear\_model ::**

%%Generating the linear regression Model:

*lmwhite\_i = smf.ols(formula='quality~'+ i,data=df).fit()*

%% Calculating the R2 value:

*r2\_value\_i=(lmwhite\_i.rsquared)*

%% Calculating the AIC value:

*Aic\_value\_i=(lmwhite.aic)*

***Output Values:***

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Hence the best model obtained:

Best Feature with highest r2 value: **alcohol** R2\_Value : 0.1897 AIC\_Value: 11682.782414

1b) Select the model with the highest R2 value, combine with its feature other features, one at a time, and thus generate all bivariate regression models (models containing two features). One of these two features is from the selected single-feature model and the other is from one of the remaining 10 features. Report the R2 and AIC values for all the bivariate regression models.

* Combining all the features one at a time with the Alcohol (best feature) from the single feature regression model to obtain the bivariate regression model.

%%Generating the linear regression Model:

*lmwhite\_i = smf.ols(formula='quality~'+alcohol+i ,data=df).fit()*

Output Values:

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Hence the best model in the Bivariate regression model obtained is:

Best Feature with highest r2 value: **alcohol+volatile\_acidity** R2\_Value: 0.2402 AIC\_Value: 11369.551596

1c) Select the bivariate model with the highest R2 value as the Best model at this stage. Combine a third feature from the remaining nine features with this selected bivariate model to build (and then select the best) 3-feature regression models. Report the R2 and AIC values of all these models.

* Combining all the remaining features one at a time with the Alcohol + Volatile\_acidity (best feature) from the single feature regression model to obtain the 3-feature regression model.

%%Generating the linear regression Model:

*lmwhite\_i = smf.ols(formula='quality~'+alcohol+* volatile\_acidity+i *,data=df).fit()*

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Hence the best model in the 3-Feature regression model obtained is:

Best Feature with highest r2 value:**alcohol+volatile\_acidity+residual\_sugar** R2\_Value : 0.2585 AIC\_Value: 11252.166211

1d) Repeat the steps above to generate (k+1)-feature models from the k-feature models until the following situation arises: all the (k+1)-feature models have an AIC value higher than the AIC value of the k-feature model from which they are being generated. Stop the process and report the k-feature model found as being the best regression model for this data. Report the features included, their coefficients, and p-values for the coefficients. Comment on the magnitudes of the p-values.

# Iterating through the combination of features

while(Flag=’False’):

print(count+1,"- feature Regression Models","\n")

count=count+1

counter=0

i\_vector=[]

aic\_value=[]

lmwhite=[]

for i in df.columns:

if i=="quality" or feature.find(i)>0:

continue;

# Building the model and calculating the R2 and AIC value

if feature=="":

lmwhite\_dummy=smf.ols(formula='quality~'+ i,data=df).fit()

else :

lmwhite\_dummy=smf.ols(formula='quality~ '+feature+"+"+ i ,data=df).fit()

i\_vector.append(feature+ "+"+i)

lmwhite.append(lmwhite\_dummy)

r2\_value\_dummy=(lmwhite\_dummy.rsquared)

r2\_value.append(r2\_value\_dummy)

aic\_value\_dummy=(lmwhite\_dummy.aic)

aic\_value.append(aic\_value\_dummy)

print("Model::","Feature:",(feature+"+"+i).strip("+"),"R2\_Value:", round(r2\_value\_dummy,4),"AIC\_Value:",round(aic\_value\_dummy,6),"\n")

# Finding the Best model in the iteration

i\_vec.append(i\_vector)

aic.append(aic\_value)

r2.append(r2\_value)

feature\_num = r2\_value.index(max(r2\_value))

feature=i\_vector[feature\_num]

r2\_value=[]

best\_aic.append(aic\_value[feature\_num])

bestlm.append(lmwhite[feature\_num])

# Stopping Condition

for j in aic\_value:

if j>=best\_aic[-2]:

counter=counter+1

if counter==len(aic\_value)-1:

flag = ‘True’

Results Obtained:

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In this Iteration the AIC values obtained are 11108.26,11108.09,11107.71 which are all greater than the best combination from 8feature regression model 11106.28. Hence, we stop the iterations and get the best model as:

8- Feature Regression model best fitting to the data with optimal R2 and AIC value is:

Best Feature with highest r2 value: **alcohol+volatile\_acidity+residual\_sugar+free\_sulfur\_dioxide+density+pH+sulphates+fixed\_acidity** R2\_Value: 0.2818 AIC\_Value: 11106.287754

|  |  |  |
| --- | --- | --- |
| **Feature** | **Co-efficient** | **P Value** |
| Intercept | 154.1062 | 2.2E-17 |
| Alcohol | 0.1932 | 1.31E-15 |
| volatile\_acidity | -1.8881 | 1.02E-64 |
| residual\_sugar | 0.0828 | 1.39E-29 |
| free\_sulfur\_dioxide | 0.0033 | 7.67E-07 |
| Density | -154.2913 | 5.28E-17 |
| pH | 0.6942 | 2.07E-11 |
| sulphates | 0.6285 | 3.52E-10 |
| fixed\_acidity | 0.0681 | 8.64E-04 |

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P\_Value:  The p-values for the coefficients indicate whether these relationships are statistically significant. **Along with the coefficients, p values provide enough evidence to reject the otherwise taken null hypothesis instead of the regression line obtained**.

A higher Pvalue indicate that the variable is not significant for the regression model, whereas a lower magnitude provides enough evidence that the inclusion of the variable is significant for the regression model and that the target value is dependent on the variable.

**In our model all the pvalues are almost equal to 0.00 which means that they are all very much significant in regression model and contribute in the prediction**.

1e) Find the five wines that have the largest magnitudes of difference between the predicted and the actual wine-quality values. Look at the regression model, the rest of the data, and comment on why you think these wines are outliers.

#Fitting the obtained Regression line on the data to predict the value:

pred=bestlm[7].predict(X\_Val)

error=abs(pred)

**Top 5 wines with largest magnitude of error: (Index started from 0)**



The quality groups of 3,9 are only 25 among the 4898. The very little proportion of these stay as the outliers providing very little learning data for the regression models. If the model is fitted to include these as well, it would lead to overfitting of the data.

1. **Clustering**:

**Data set Used**: White Wines

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2a) Plot the data on a 2-D scatter plot and mark by hand the boundaries of the ideal clusters that you would like discovered in this dataset.

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2b) Run the k-means algorithm for k = 3, 5, 7, 9, 11, 13, 15, 17 and 19. Plot the total SSE and BIC values for the above values of k. What is the best number of clusters for this dataset? How did you find the best number of clusters, briefly explain.

Function used : k=KMeans(n\_clusters=n, random\_state=0).fit(X\_set)

sse\_1=k.inertia\_

**SSE and BIC values plotted:**

**SSE – Sum of Squares Error**

**BIC = n\*log(SSE/n) + log(n)\*c\*(d+1)**

**SSE :** [2197916.389830343, 1226034.9648687756, 715958.7767559565, 452886.12803022546, 288182.23747907684, 252374.8302387761, 220838.09934794006, 191738.1678454749, 163550.34196059694]

**BIC :** [55418.59571144362, 49936.62508592988, 44890.813398306156, 40606.13696001127, 36377.96469481235, 35190.765884857836, 33995.874346819684, 32726.58369880081, 31288.6548795303]

A picture containing object

Description automatically generated

As the above two plots infer, the knee point is obtained at the k =11 ie., the change in SSE or BIC is not very significant or almost remains same when compared to the other k values earlier in the curve.

Though the errors of the higher k value is low it is deceptive in the sense that it breaks the original clusters into smaller clusters and so the error decreases.

Hence k =11 is chosen as the best number of clusters.

2c) For the best number of clusters selected above, plot the scatter plot of the data showing the points of each cluster with a different color/symbol. Mark the points on the scatter plot that belong to clusters other than what your intuition says. Why did k-means algorithm place them in these different clusters – explain very briefly.

**Scatter Plot of the Clusters Formed:**

A close up of a map

Description automatically generated

Kmeans differed from my intuition for the marked points:

A close up of a map

Description automatically generated

K means clustering is **a center based clustering technique**. Hence, to a greater extent depends on the initial centroids chosen. Now once the centroids are chosen initially, iteratively the distances are calculated from all the other data points to the centroid and all the data points nearest to the centroid are made into a cluster.

**Hence, K means tend to give the globular shaped structures and may not be very effective for others.**

In our example as well, the points marked are all points that are marked are nearer to the centroids that the k means chose and so are placed in that way, which is different from the intuition.

This is one of those situations where we can see that the K means may fail with the non-globular structures.

2d) Plot the silhouette diagram for the best clustering you have selected. Comment on the characteristics of the silhouette diagram that you think are informative about this clustering. Comment using the cluster numbers and their plots on the silhouette diagram.

A close up of a map

Description automatically generated

The silhouette value is a measure of how similar an object is to its own cluster (cohesion) compared to other clusters (separation).

So in the above figure, the clusters (8)yellow,(4) and (3)blue are having data points with higher values which means that they are closely packed and are nearer to their centroids and far away from other centroids. And the width of the clusters depict the number of data points.

However, the clusters (5) green,(9) orange,(10)red are loosely packed as they have points that are away from the centroid of its own cluster.

The cluster (4) is a good cluster with greater number of points closely bounded followed by (8).

On the whole the coefficient is very much nearer to 0.6 which means the points are well in cohesion and the clusters are well separated to some extent. Though this is not very great, they are not bad as well.

2e) Perform single-linkage hierarchical clustering for this data and cut the dendrogram to obtain 11 clusters. There are options/parameters in most toolboxes to generate a given number of clusters. Plot the 2-D scatter plot of the dataset showing data points of each of the 11 clusters with different color/symbol.

Function Used:

z=sc.cluster.hierarchy.linkage(X\_set,method='single',metric='euclidean)

r=sc.cluster.hierarchy.dendrogram(z,no\_plot=False)

The red line in the below graph shows the vertical distance that would give 11 clusters.

A picture containing sky

Description automatically generated

*%% Cut the dendogram at the 3.2 distance*

fc=fcluster(z,3.2,criterion='distance')

values, counts = np.unique(fc, return\_counts=True)

print("Number of Data points in each cluster ",counts)

print("Cluster Number",values)

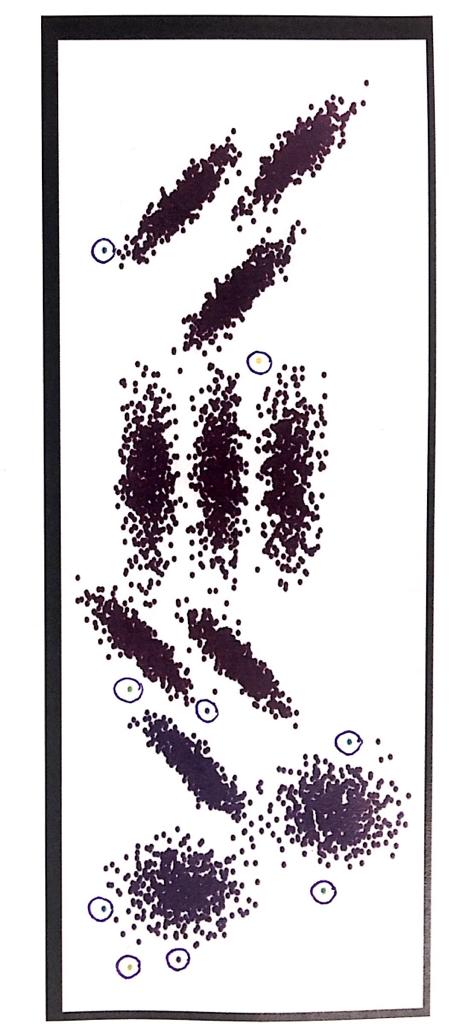


**Scatter Plot**:



2f) Mark any data points on this scatter plot that are clustered differently from your intuitive view of the correct clusters. Explain why Single-linkage clustering may have placed them in counter-intuitive clusters.

Single Linkage clustering is a type of Agglomerative Hierarchical clustering where the clusters are merged when the nearest points between clusters have a minimum distance. The clustering starts from the individual points starting at random and iteratively combines the clusters that have minimum distances between its nearest points.



Except the points that are marked all the other are intuitively placed into separate clusters but the single linkage placed them into 2 clusters. This happened because it forms contingency clusters which is one of the major drawbacks of single linkage clusters.

Single linkage cannot identify the clusters that have data points between them, even if they are scarce it combines them.

All the clusters here have at least few data points between them , hence they are formed as one cluster.