

# HUDM6122 Homework\_06

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## 0.1 Github Address

All my latest homework can be found on Github: [https://github.com/cgpan/hudm6122\\_homeworks](https://github.com/cgpan/hudm6122_homeworks) . Thanks for checking if interested.

## 0.2 Ex 6.1

*Apply k-means to the crime rate data after standardising each variable by its standard deviation. Compare the results with those given in the text found by standardising by a variable's range.*

### MY SOLUTION:

I began this assignment at Mar 27th, at that time there was no `crime` dataset available. Therefore, for this homework, I first extracted the data information from the `MVA` package and created the dataset in a csv format for reading convenience. For space-saving concern, the R syntax to create dataset was in a separated file called "HW06\_test.R", which can be found it in my Github repo.

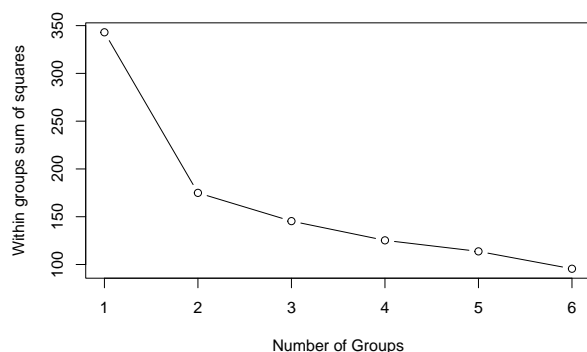
As discussed on page.179 of the textbook, one need to remove the outlier (i.e., DC) first.

```
> # import the dataset
> crime <- read.csv("crime.csv",row.names = 1)
> dim(crime)
[1] 51 7
>
> # drop the outlier DC and check the dimension of the dataset
> df <- crime[-which(row.names(crime) == "DC"),]
> dim(df)
[1] 50 7
>
> # standardized the variable by its SD
> df_s <- sweep(df,2,apply(df, 2, sd), FUN = "/")
> sapply(df_s, var)
Murder Rape Robbery Assault Burglary Theft Vehicle
1 1 1 1 1 1 1 1
>
> # similar to textbook, I use the within group variance to
> # investigate the appropriate number of cluster
> n <- nrow(df_s)
> # make an empty vector to load the wss for each # of cluster
> wss <- rep(0,6)
> # write the only one cluster(ie, the sum square of the total data)
> # for the one-group condition, I use the variance times the sample size minus 1
```

```

> # to get the withingroup sum of squares
> wss[1] <- (n-1) * sum(sapply(df_s, var))
> # for the following conditions, can use the kmeans to get the wss directly
> for (i in 2:6) {
+   wss[i] <- sum(kmeans(df_s,
+                         centers = i)$withinss)
+ }
> plot(1:6,wss, type = "b",
+       xlab = "Number of Groups",
+       ylab = "Within groups sum of squares")

```



From the plot of within-group sum of squares for one- to six-cluster solutions is similar to the textbook's result. The elbow occurs at the two-group solution. Thus, I run the k-means method for this solutions.

```

> kmeans(df_s, centers=2)
K-means clustering with 2 clusters of sizes 22, 28

Cluster means:
  Murder      Rape  Robbery  Assault  Burglary   Theft  Vehicle
1 2.711724 3.132781 2.1001609 2.836238 3.680055 4.479685 2.642471
2 1.371839 1.712574 0.6770169 1.308089 2.203667 3.411210 1.177732

Clustering vector:
ME NH VT MA RI CT NY NJ PA OH IN IL MI WI MN IA MO ND SD NE KS DE MD VA WV NC
 2  2  2  1  2  2  1  1  2  2  2  1  1  2  2  2  1  2  2  2  2  2  1  2  2  2
SC GA FL KY TN AL MS AR LA OK TX MT ID WY CO NM AZ UT NV WA OR CA AK HI
 1  1  1  2  1  2  2  2  1  1  1  2  2  2  1  1  1  2  1  1  1  1  1  1  2

Within cluster sum of squares by cluster:
[1] 102.3351 72.6241
(between_SS / total_SS = 49.0 %)

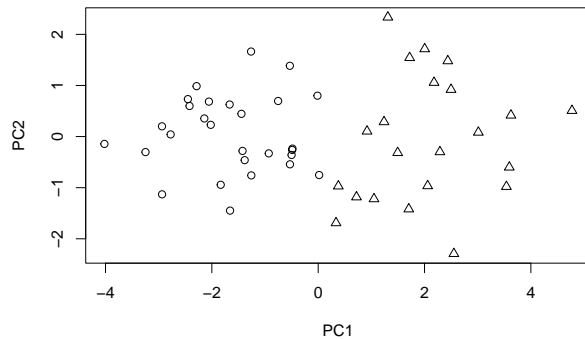
Available components:

[1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss"
[6] "betweenss"    "size"         "iter"         "ifault"

```

Next, to visualize the result, I plot the two-group solution in the space of the first two principal components of the correlation matrix of the data.

```
> crime_pca <- prcomp(df_s)
> plot(crime_pca$x[,1:2],
+      pch = kmeans(df_s, centers = 2)$cluster)
```



The result is similar to the plot found in the textbook. It suggests that the cluster analysis here is dividing into two parts a homogeneous set of data.

### 0.3 Ex 6.2

*Calculate the first five principal components scores for the Romano- British pottery data, and then construct the scatterplot matrix of the scores, displaying the contours of the estimated bivariate density for each panel of the plot and a boxplot of each score in the appropriate place on the diagonal. Label the points in the scatterplot matrix with their kiln numbers.*

#### MY SOLUTION:

Since the chemical elements are different scales, it is necessary to standardize them first.

```
> # import the data
> data("pottery", package = "HSAUR2")
> dim(pottery)
[1] 45 10
> # run PCA for five-components solution;
> # since the chemical elements are at different scales, standardization is necessary.
>
> pca <- prcomp(pottery[, -10], center = TRUE)
> scores <- pca$x[, 1:5]
```

Next, I use the scores of the first five principal components scores to construct the scatterplot matrix of the scores.

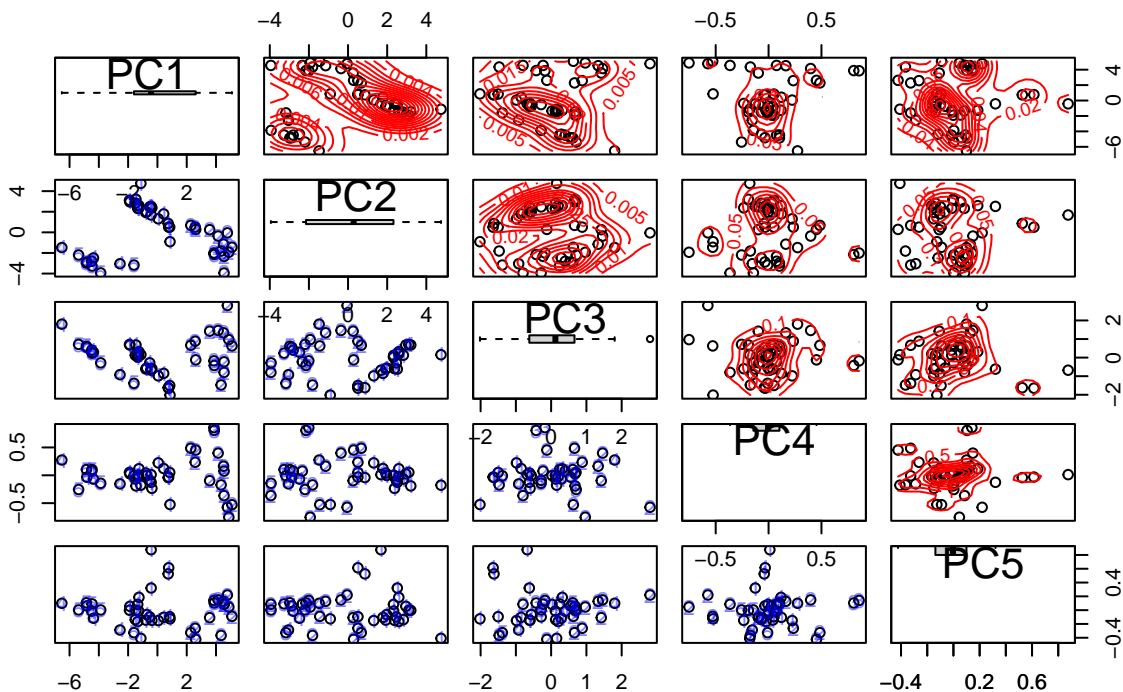
```
> # create a scatterplot matrix with density contours
> pairs(scores,
+       main = "Scatterplot Matrix of Pottery Data Principal Component Scores",
+       upper.panel = function(x, y) {
+         points(x, y)
+         den <- MASS::kde2d(x, y)
+         contour(den, add = TRUE, col = "red", lwd = 1)
+       },
```

```

+   diag.panel = function(x) {
+     boxplot(x, horizontal = T, add = TRUE)
+   },
+   lower.panel = function(x, y) {
+     points(x, y)
+     text(x, y, pottery$kiln, pch = 16, col = adjustcolor("blue", .5))})
> # Add kiln number labels to the scatterplot matrix
> text(scores, labels = pottery$kiln, pos = 1, cex = 0.1)

```

## Scatterplot Matrix of Pottery Data Principal Component Scores



### 0.4 Ex 6.3

Return to the air pollution data given in Chapter 1 and use finite mixtures to cluster the data on the basis of the six climate and ecology variables (i.e., excluding the sulphur dioxide concentration). Investigate how sulphur dioxide concentration varies in the clusters you find both graphically and by formal significance testing.

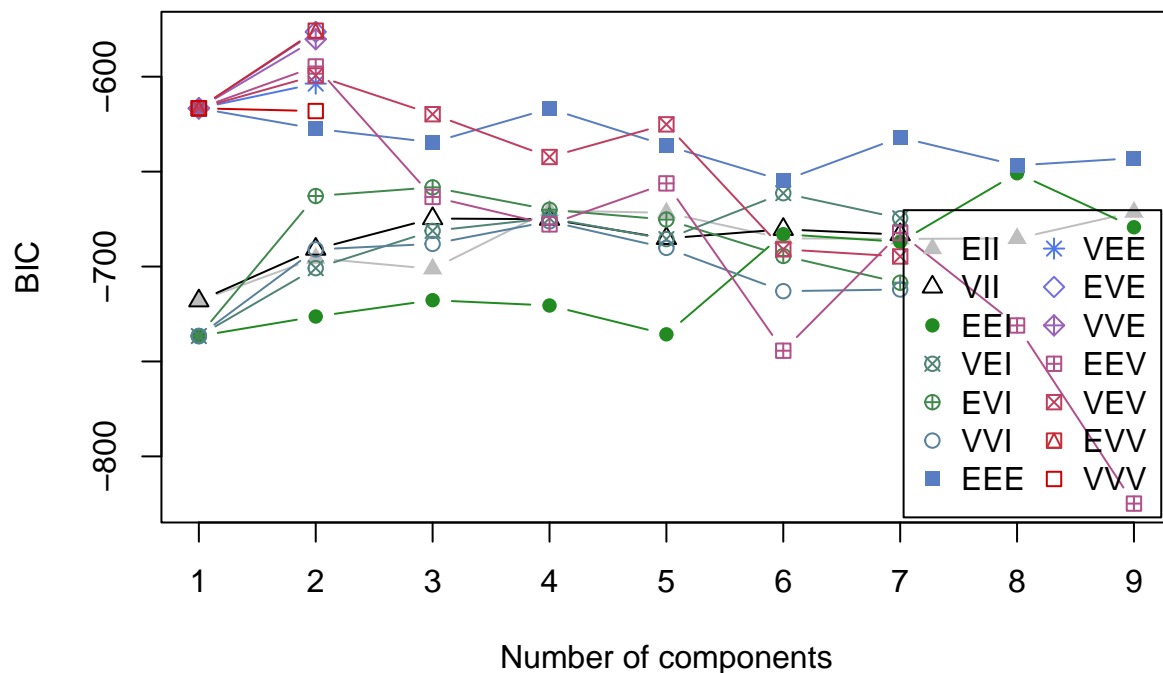
#### MY SOLUTION:

One thing that is quite tricky here is how to rely on BIC to choose the best model. It seems to be conflicting to our normal understanding about AIC and BIC. I'd like to write down some understanding here for my future reference.

AIC and BIC are commonly used to compare the fit of different models, and to select the best model among a set of candidate models. The basic idea behind AIC and BIC is that they attempt to balance the goodness-of-fit of the model with the complexity of the model. AIC and BIC both penalize models that are too complex, but BIC applies a stronger penalty for model complexity than AIC. The model with the lowest AIC or BIC is generally considered the best model among the set of candidate models.

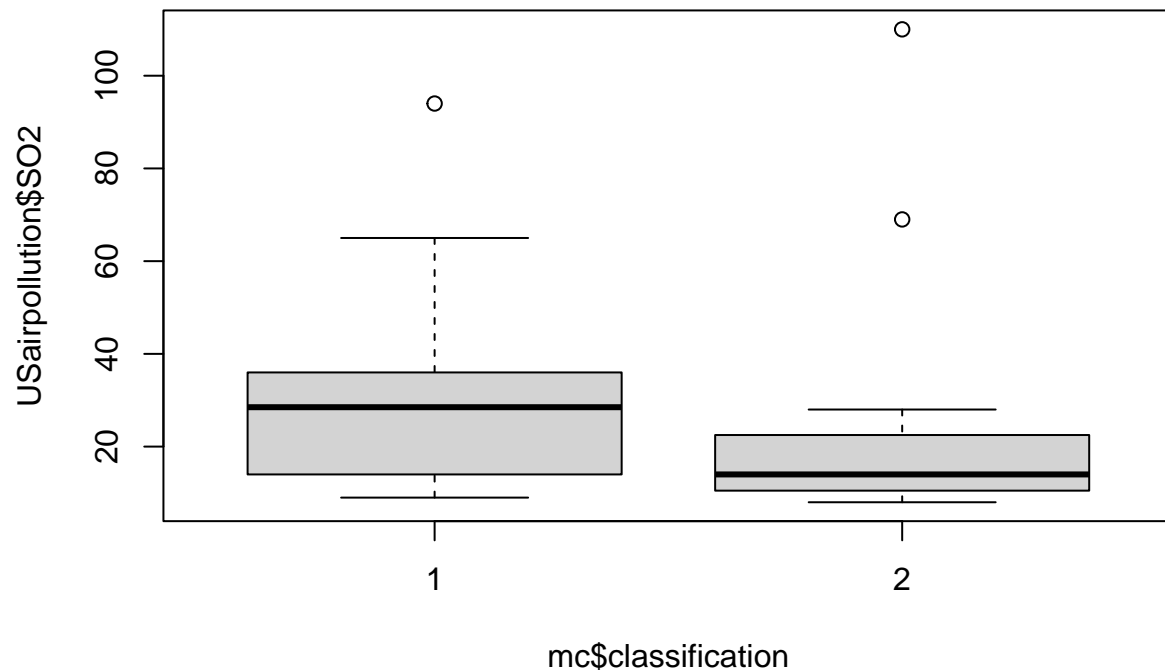
However, in finite mixture approach, the larger the value of the BIC, the stronger the evidence for the model and number of clusters. But why? I did some literature review and did not find any clues. I will continue to figure out this issue.

```
> # import the data
> data("USairpollution", package = "HSAUR2")
> dim(USairpollution)
[1] 41 7
> colnames(USairpollution)
[1] "SO2" "temp" "manu" "popul" "wind" "precip" "predays"
>
> # before running the finite mixture approach, standardize the data first;
> # air_sdz <- sweep(USairpollution, 2, apply(USairpollution[, -1], 2, sd), FUN = "/")
> air_s <- scale(USairpollution)
>
> # run the finite mixtures to the cluster the data
> # install.packages("mclust")
> library(mclust)
> mc <- Mclust(air_s[, -1])
> plot(mc$BIC)
```



The BIC criterion selects model EVV and two clusters as the optimal solution.

```
> # For the following method, I referred to Xue Yu's idea. Thanks for her help.
> boxplot(USairpollution$SO2~ mc$classification)
```



The boxplot shows that there seems no significant difference between the two clusters in SO2 concentration. Next, I will run a two sample t test to figure out the relation.

```
> t.test(USairpollution$SO2~mc$classification)

Welch Two Sample t-test

data:  USairpollution$SO2 by mc$classification
t = 0.30473, df = 12.88, p-value = 0.7654
alternative hypothesis: true difference in means between group 1 and group 2 is not equal to 0
95 percent confidence interval:
 -19.34158  25.68703
sample estimates:
mean in group 1 mean in group 2
    30.90000     27.72727
```

The test result also indicates that there is no significant difference in SO2 concentration in the two clusters,  $t = .305$ ,  $p = .765$ .