ML Assignment 4

R Markdown

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When you click the **Knit** button a document will be generated that includes both content as well as the output of any embedded R code chunks within the document. You can embed an R code chunk like this:

Note that the `echo = FALSE` parameter was added to the code chunk to prevent printing of the R code that generated the plot.

Loading the Data

```
rm(list = ls())

library(tidyverse)

## -- Attaching packages --------------------------------------- tidyverse
1.3.0 --

## v ggplot2 3.3.2     v purrr   0.3.4
## v tibble  3.0.4     v dplyr   1.0.2
## v tidyr   1.1.2     v stringr 1.4.0
## v readr   1.4.0     v forcats 0.5.0

## Warning: package 'tibble' was built under R version 4.0.3

## Warning: package 'tidyr' was built under R version 4.0.3

## Warning: package 'readr' was built under R version 4.0.3

## Warning: package 'dplyr' was built under R version 4.0.3

## -- Conflicts ------------------------------------------
tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()

#install.packages("factoextra")
library(factoextra)

## Warning: package 'factoextra' was built under R version 4.0.3

## Welcome! Want to learn more? See two factoextra-related books at
https://goo.gl/ve3WBa
```

```r
library(ISLR)
set.seed(123)

DFUniver<-read.csv("Universities.csv")
colnames(DFUniver)
```

```
##  [1] "College.Name"               "State"
##  [3] "Public..1...Private..2."    "X..appli..rec.d"
##  [5] "X..appl..accepted"          "X..new.stud..enrolled"
##  [7] "X..new.stud..from.top.10."  "X..new.stud..from.top.25."
##  [9] "X..FT.undergrad"            "X..PT.undergrad"
## [11] "in.state.tuition"           "out.of.state.tuition"
## [13] "room"                       "board"
## [15] "add..fees"                  "estim..book.costs"
## [17] "estim..personal.."          "X..fac..w.PHD"
## [19] "stud..fac..ratio"           "Graduation.rate"
```

```r
#summary(DFUniver)

#Changing the column names to suitable ones.
DFUniver<-DFUniver%>%rename(
  Pub.Private=Public..1...Private..2.,
  ApplRec=X..appli..rec.d,
  ApplAccept=X..appl..accepted,
  NewStdEnr=X..new.stud..enrolled,
  Top10=X..new.stud..from.top.10.,
  Top25=X..new.stud..from.top.25.,
  FTUnderG=X..FT.undergrad,
  PTUnderG=X..PT.undergrad,
  InStateFee=in.state.tuition,
  OutStateFee=out.of.state.tuition,
  BookCost=estim..book.costs,
  PerCost=estim..personal..,
  PHD=X..fac..w.PHD,
  StFactRatio=stud..fac..ratio
)

colnames(DFUniver)
```

```
##  [1] "College.Name"    "State"           "Pub.Private"     "ApplRec"
##  [5] "ApplAccept"      "NewStdEnr"       "Top10"           "Top25"
##  [9] "FTUnderG"        "PTUnderG"        "InStateFee"      "OutStateFee"
## [13] "room"            "board"           "add..fees"       "BookCost"
## [17] "PerCost"         "PHD"             "StFactRatio"
"Graduation.rate"
```

Removing missing records from the Dataset (Measurements)

```r
#Total NULL fields in the data frame
count(DFUniver[!complete.cases(DFUniver),])
```

```
##     n
## 1 831
```

```
#Ipute the NULL values
DFUniver1<-na.omit(DFUniver)
count(DFUniver1)
```

```
##     n
## 1 471
```

Finding the Data Summary and Measure of Dependence

```
#Summary Data
summary(DFUniver1)
```

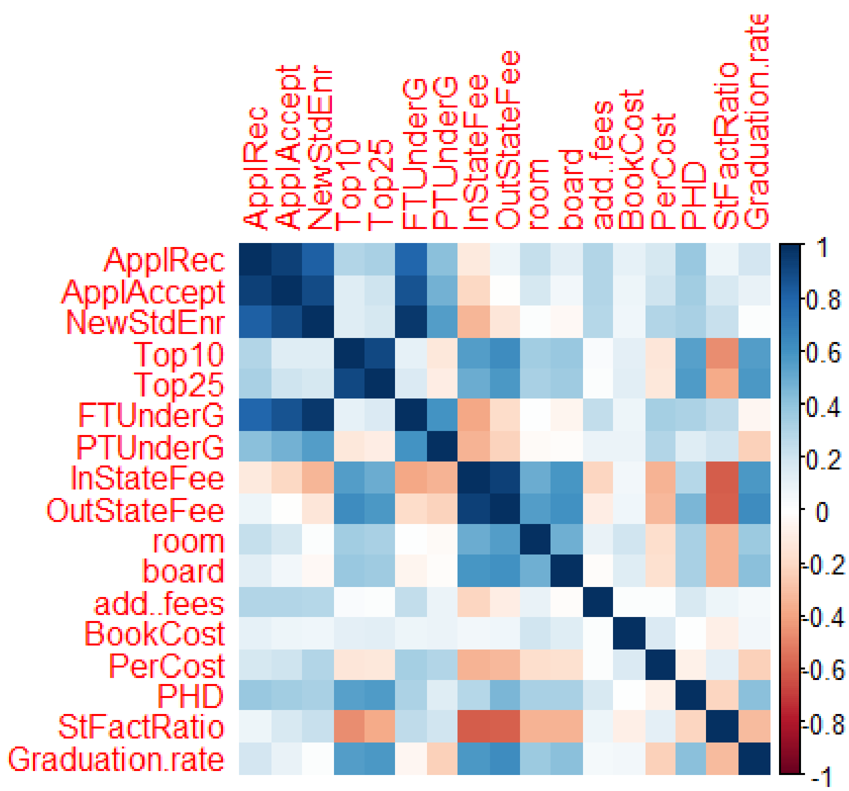
```
##  College.Name          State              Pub.Private        ApplRec
##  Length:471         Length:471         Min.   :1.000   Min.   :   77
##  Class :character   Class :character   1st Qu.:1.000   1st Qu.:  802
##  Mode  :character   Mode  :character   Median :2.000   Median : 1646
##                                        Mean   :1.728   Mean   : 3147
##                                        3rd Qu.:2.000   3rd Qu.: 3862
##                                        Max.   :2.000   Max.   :48094
##    ApplAccept        NewStdEnr          Top10           Top25
##  Min.   :   61.0   Min.   :  27.0   Min.   : 1.00   Min.   :  9.00
##  1st Qu.:  635.5   1st Qu.: 264.0   1st Qu.:15.00   1st Qu.: 40.00
##  Median : 1227.0   Median : 443.0   Median :23.00   Median : 54.00
##  Mean   : 2063.0   Mean   : 780.7   Mean   :28.01   Mean   : 55.65
##  3rd Qu.: 2456.0   3rd Qu.: 896.5   3rd Qu.:36.00   3rd Qu.: 69.00
##  Max.   :26330.0   Max.   :6392.0   Max.   :96.00   Max.   :100.00
##     FTUnderG        PTUnderG          InStateFee     OutStateFee
##  Min.   :  249   Min.   :    1.0   Min.   :  608   Min.   : 1044
##  1st Qu.: 1018   1st Qu.:   81.5   1st Qu.: 3650   1st Qu.: 7290
##  Median : 1715   Median :  299.0   Median : 9858   Median :10100
##  Mean   : 3563   Mean   :  797.5   Mean   : 9407   Mean   :10575
##  3rd Qu.: 4056   3rd Qu.:  869.0   3rd Qu.:13246   3rd Qu.:13286
##  Max.   :31643   Max.   :21836.0   Max.   :20100   Max.   :20100
##       room           board         add..fees         BookCost
PerCost
##  Min.   : 640   Min.   : 531   Min.   :  10.0   Min.   :  90.0   Min.   :
250
##  1st Qu.:1740   1st Qu.:1750   1st Qu.: 137.5   1st Qu.: 500.0   1st Qu.:
850
##  Median :2090   Median :2082   Median : 280.0   Median : 500.0   Median
:1200
##  Mean   :2221   Mean   :2122   Mean   : 379.0   Mean   : 548.8   Mean
:1312
##  3rd Qu.:2663   3rd Qu.:2420   3rd Qu.: 486.0   3rd Qu.: 600.0   3rd
Qu.:1600
##  Max.   :4816   Max.   :4541   Max.   :3247.0   Max.   :2340.0   Max.
:6800
##       PHD          StFactRatio    Graduation.rate
```

```
## Min. : 8.00 Min. : 2.90 Min. : 15.00
## 1st Qu.: 63.00 1st Qu.:11.30 1st Qu.: 53.00
## Median : 76.00 Median :13.40 Median : 66.00
## Mean : 73.21 Mean :13.96 Mean : 65.56
## 3rd Qu.: 87.00 3rd Qu.:16.45 3rd Qu.: 79.00
## Max. :103.00 Max. :28.80 Max. :118.00
```

```r
#Subsetting the data

DFNumerical<-subset(DFUniver1, select = -c(1,2,3))

#Finding the correlation between the data set
library(corrplot)
```

```
## Warning: package 'corrplot' was built under R version 4.0.3

## corrplot 0.84 loaded
```

```r
corrplot(cor(DFNumerical), method = "color")
```

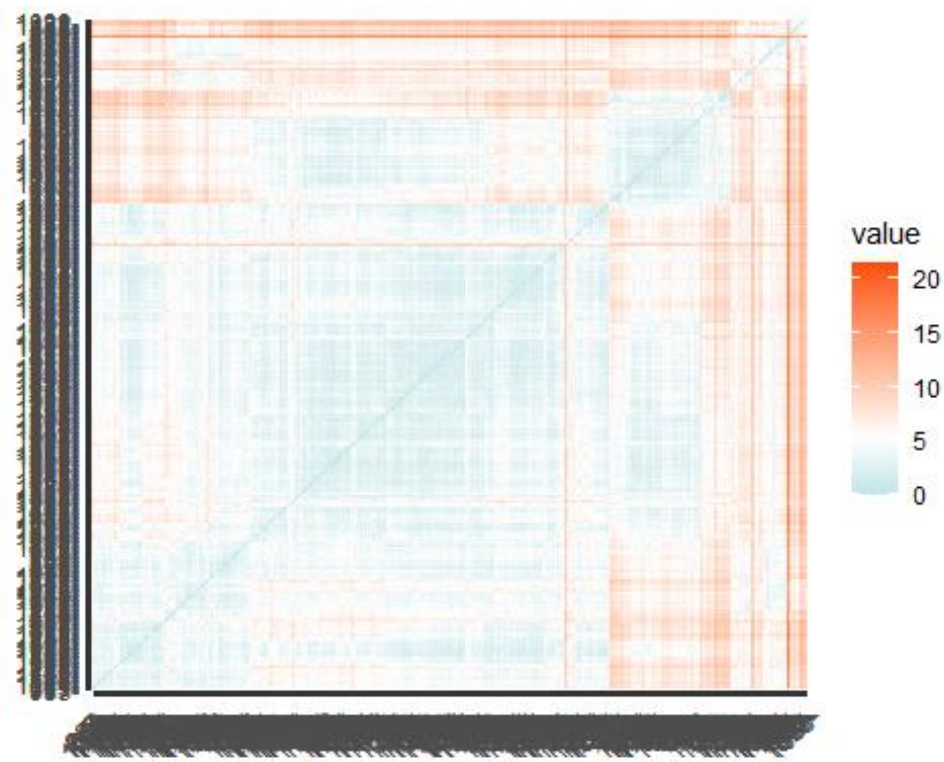


In the correlation graph, Darker Blue(+1) and Dark Orange(-1) shows the higher correlated data. Using this data to understand any correlation among the column data.

Applying K-means clustering for Numeric Data

```r
#Scaling the Data
DFNumerical<-scale(DFNumerical)
```

```
#Distance Between Observations
distance <- get_dist(DFNumerical)

fviz_dist(distance, gradient = list(low = "#00AFBB", mid = "white", high =
"#FC4E07"))
```

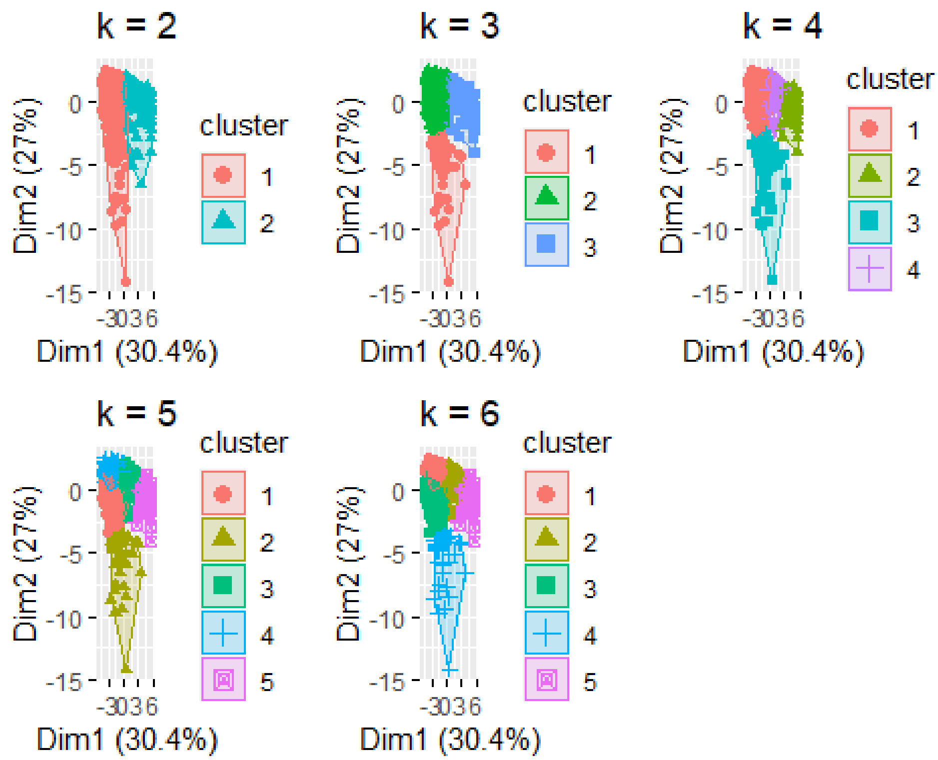


Comparison different cluster values

```
k2 <- kmeans(DFNumerical, centers = 2, nstart = 25)
k3 <- kmeans(DFNumerical, centers = 3, nstart = 25)
k4 <- kmeans(DFNumerical, centers = 4, nstart = 25)
k5 <- kmeans(DFNumerical, centers = 5, nstart = 25)
k6 <- kmeans(DFNumerical, centers = 5, nstart = 25)

# plots to compare
p2 <- fviz_cluster(k2, geom = "point", data = DFNumerical) + ggtitle("k = 2")
p3 <- fviz_cluster(k3, geom = "point",  data = DFNumerical) + ggtitle("k =
3")
p4 <- fviz_cluster(k4, geom = "point",  data = DFNumerical) + ggtitle("k =
4")
p5 <- fviz_cluster(k5, geom = "point",  data = DFNumerical) + ggtitle("k =
5")
p6 <- fviz_cluster(k6, geom = "point",  data = DFNumerical) + ggtitle("k =
6")

library(gridExtra)
```

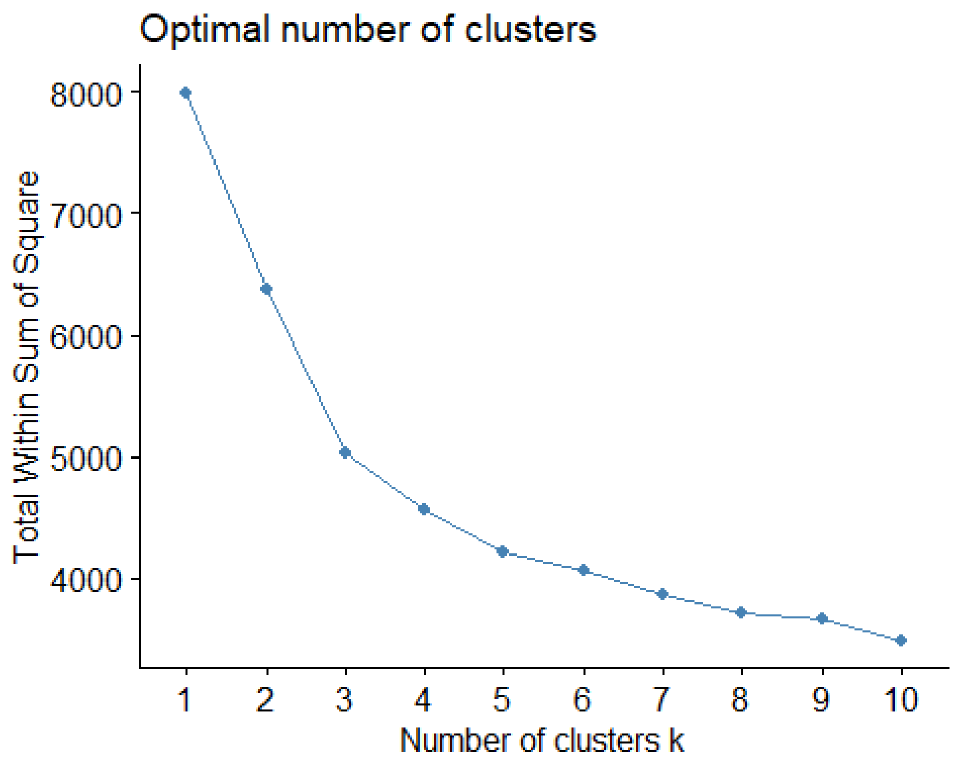
```
##
## Attaching package: 'gridExtra'

## The following object is masked from 'package:dplyr':
##
##     combine
```

```
grid.arrange(p2, p3, p4, p5, p6, nrow = 2)
```

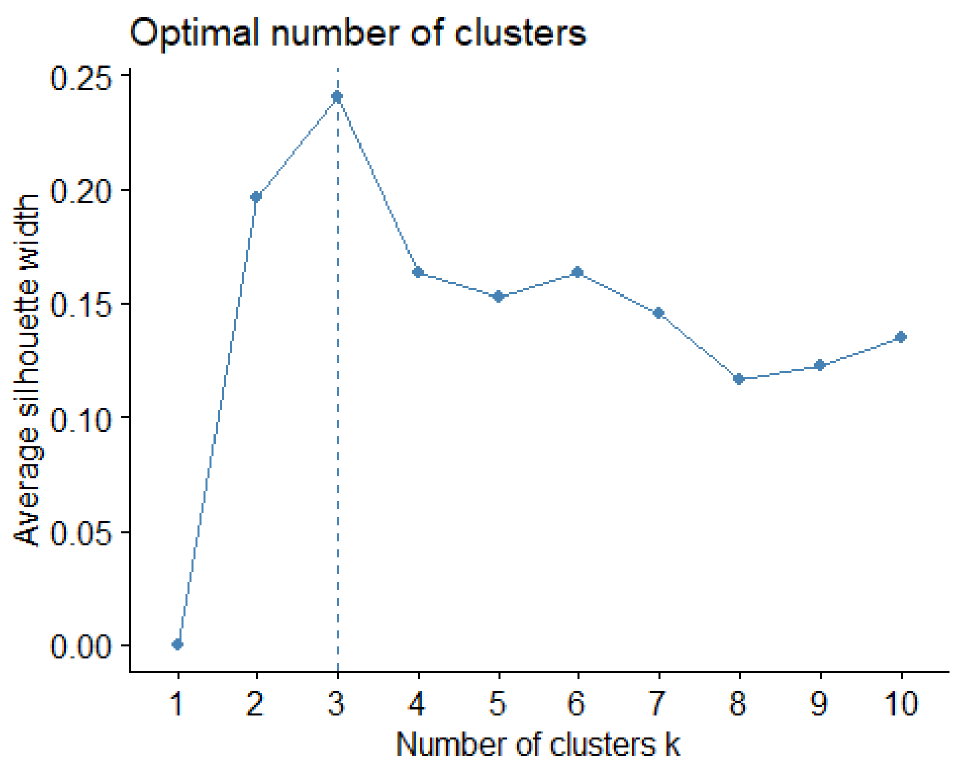


From the above comparison it seems that 3 clusters would be good. Determining Optimal Cluster using Elbow and Silhouette method.

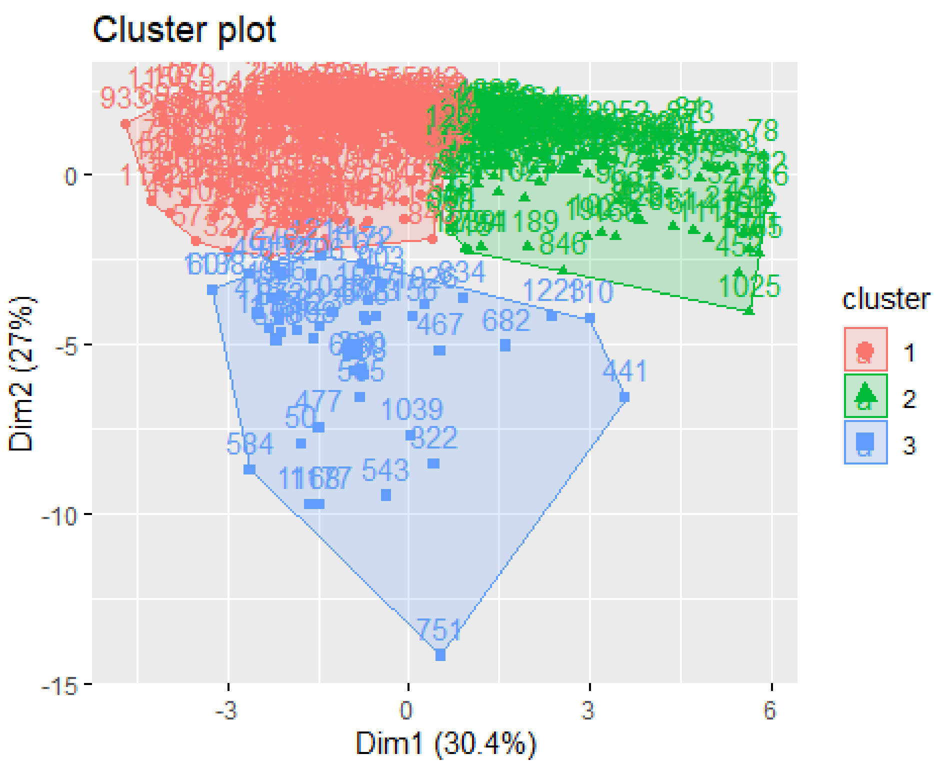
```
set.seed(123)
#Finding optimal number of clusters - Elbow Method
fviz_nbclust(DFNumerical, kmeans, method = "wss")
```




```
#Determining Optimal Cluster by Average Silhouette Method
fviz_nbclust(DFNumerical, kmeans, method = "silhouette")
```



```
#Silhouette method shows that 3 numbers of clusters would be optimum. From previous cluster plotting we have seen that optimal cluster size would be 3.

#3 clusters are the reasonable for this data and the optimal K is 3.
k3 <- kmeans(DFNumerical, centers = 3, nstart = 25)
# Optimal Visualization
fviz_cluster(k3,data = DFNumerical)
```

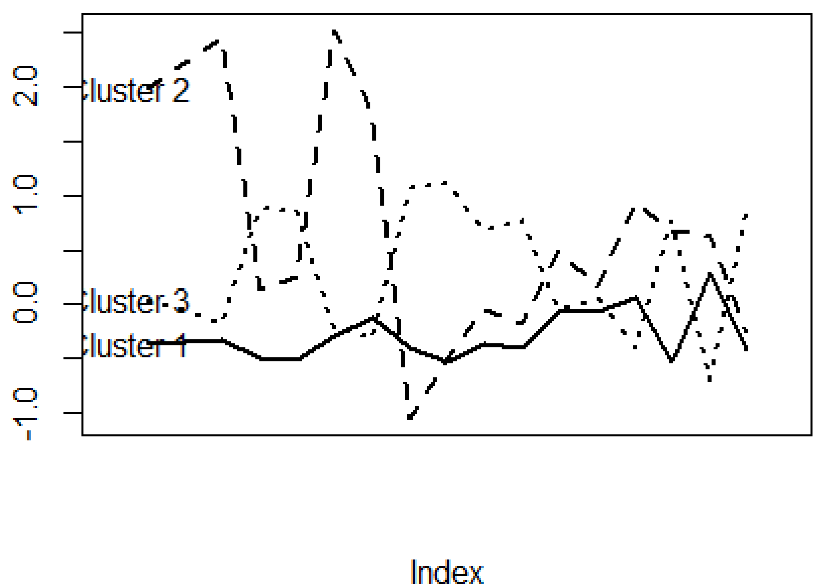


Compare the summary statistics for each cluster and describe each cluster i n this context (e.g., “Universities with high tuition, l ow acceptance rate…”).

```
# 3 is the Optimal Cluster
k3 <- kmeans(DFNumerical,centers = 3 ,nstart = 25)
#print(k3)
k3$centers # Description of the centers

##       ApplRec  ApplAccept  NewStdEnr      Top10      Top25   FTUnderG
## 1 -0.35953828 -0.34918455 -0.3171053 -0.5020886 -0.5128195 -0.2952142
## 2  1.98179657  2.22992267  2.4447222  0.1334215  0.2545856  2.5228452
## 3  0.05140256 -0.04367128 -0.1683551  0.8795798  0.8620961 -0.2324464
##     PTUnderG InStateFee OutStateFee       room      board   add..fees
## 1 -0.1217682 -0.4036544  -0.5263964 -0.3588740 -0.3938990 -0.05832646
## 2  1.7486849 -1.0500277  -0.4918168 -0.0388330 -0.1745795  0.49531762
## 3 -0.3130216  1.0620416   1.1158839  0.6698444  0.7756859 -0.04496556
##      BookCost     PerCost        PHD StFactRatio Graduation.rate
## 1 -0.06621454  0.05935933 -0.5322257   0.2810858      -0.4171456
```

```
## 2  0.16358567  0.93858632  0.6840794   0.6139980      -0.2538234
## 3  0.07122705 -0.39665857  0.7659627  -0.7036167       0.8426062
```

```
plot(c(0), xaxt = 'n', ylab = "", type = "l",
     ylim = c(min(k3$centers), max(k3$centers)), xlim = c(0, 18))
# plot centroids
for (i in c(1:3))
  lines(k3$centers[i,], lty = i, lwd = 2)
# name clusters
text(x = 0.5, y = k3$centers[, 1], labels = paste("Cluster", c(1:3))) #
Cluster Names
```




```
k3$size # Count of Clusters

## [1] 275  46 150

#Merging the clusters to the original Data frame
Clusters<-data.frame(k3$cluster)

Clusters<-Clusters%>%rename(clusters=k3.cluster)

UnivAnalysis<-cbind(DFUniver1, Clusters)
head(UnivAnalysis)

##                               College.Name State Pub.Private ApplRec
ApplAccept
## 1             Alaska Pacific University    AK            2     193
```

```
146
## 3       University of Alaska Southeast    AK            1     146
117
## 10         Birmingham-Southern College    AL            2     805
588
## 12                  Huntingdon College    AL            2     608
520
## 22                   Talladega College    AL            2    4414
1500
## 26 University of Alabama at Birmingham    AL            1    1797
1260
##    NewStdEnr Top10 Top25 FTUnderG PTUnderG InStateFee OutStateFee room
board
## 1         55    16    44      249      869       7560        7560 1620
2500
## 3         89     4    24      492     1849       1742        5226 2514
2250
## 10       287    67    88     1376      207      11660       11660 2050
2430
## 12       127    26    47      538      126       8080        8080 1380
2540
## 22       335    30    60      908      119       5666        5666 1424
1540
## 26       938    24    35     6960     4698       2220        4440 1935
3240
##    add..fees BookCost PerCost PHD StFactRatio Graduation.rate clusters
## 1        130      800    1500  76        11.9              15        1
## 3         34      500    1162  39         9.5              39        1
## 10       120      400     900  74        14.0              72        3
## 12       100      500    1100  63        11.4              44        1
## 22       418     1000    1400  56        15.5              46        1
## 26       291      750    2200  96         6.7              33        1
```

```
ClusterStat<-
UnivAnalysis%>%group_by(clusters)%>%summarise(Acceptance_rate=sum(ApplAccept)
/sum(ApplRec),
AvgOutStateTution=mean(OutStateFee),AvgInStateTution=mean(InStateFee),
AvgGradRate=mean(Graduation.rate))
```

```
## `summarise()` ungrouping output (override with `.groups` argument)
```

```
ClusterStat
```

```
## # A tibble: 3 x 5
##   clusters Acceptance_rate AvgOutStateTution AvgInStateTution AvgGradRate
##      <int>           <dbl>             <dbl>            <dbl>       <dbl>
## 1        1           0.706             8306.            7180.        58.0
## 2        2           0.682             8455.            3614.        61.0
## 3        3           0.582            15386.           15266.        80.9
```

```
#Cluster 1 - Universities with highest acceptance rate, Lowest Out State fee but average In state fees but the graduation rate is also low.

#Cluster 3- Universities with Lowest acceptance rate but having highest Out of state fees. But the graduation rate is significantly higher.

#Cluster 2 - Universities with lowest in state tuition fees and have around 60% graduation rate.

#We can perform all comparision analysis in similar ways.
```

Using the categorical measurements that were not used i n the analysis (State and Private/Public) to characterize the different clusters.

```
#State wise values present in the cluster
table(DFUniver1$State, k3$cluster)

##
##       1  2  3
##   AK  2  0  0
##   AL  3  0  1
##   AR  4  0  0
##   AZ  0  2  0
##   CA  3  2 10
##   CO  5  0  1
##   CT  3  1  6
##   DC  0  0  4
##   DE  1  1  0
##   FL  3  1  4
##   GA  4  1  2
##   HI  1  0  0
##   IA 16  0  2
##   ID  2  0  0
##   IL  7  2  6
##   IN  8  0  7
##   KS  7  0  0
##   KY  4  0  2
##   LA  2  1  2
##   MA  7  3 12
##   MD  1  1  1
##   ME  4  0  2
##   MI  7  2  4
##   MN  6  1  4
##   MO 12  1  2
##   MS  5  0  0
##   MT  2  0  0
##   NC 16  4  3
##   ND  5  0  0
##   NE  5  1  1
##   NH  4  1  1
```

```
##   NJ  9  1  3
##   NM  2  0  0
##   NY 18  2 18
##   OH 13  4  7
##   OK  5  1  0
##   OR  1  0  4
##   PA 19  3 20
##   RI  1  1  2
##   SC  7  0  2
##   SD  4  0  0
##   TN 11  1  3
##   TX 14  4  2
##   UT  1  1  0
##   VA  8  3  4
##   VT  5  0  2
##   WA  0  0  2
##   WI  5  0  4
##   WV  2  0  0
##   WY  1  0  0

#View(UnivAnalysis)
Cluster1 <- UnivAnalysis[UnivAnalysis$clusters == 1,]
#View(Cluster1[,c(1,2,3,21)])

Cluster2 <- UnivAnalysis[UnivAnalysis$clusters == 2,]
#View(Cluster2[,c(1,2,3,21)])

Cluster3 <- UnivAnalysis[UnivAnalysis$clusters == 3,]
#View(Cluster3[,c(1,2,3,21)])

library(ggplot2)
legend <- factor(UnivAnalysis$clusters,levels = c(1,2,3),labels = c("Cluster 1","Cluster 2","Cluster 3"))
ggplot(UnivAnalysis,aes(x=State,y=factor(Pub.Private,levels = c(1,2),labels = c("Public","Private")),
        color=legend))+
         geom_point()+ylab("Public/Private")+xlab("state")+ggtitle("Cluster Plot")
```


```r
#Plotted the graph which represents all the public and private colleges along
with its cluster. Each state has colleges a maximum of 2 out of the 3
clusters. Yes, there is a relationship between clusters and categorical
information.
```

What other external i nformation can explain the contents of some or all of these clusters?

```r
k3$withinss # within cluster sum of squares with high ratio as possible

## [1] 2562.342 1044.680 1424.892

k3$betweenss # mean of distances between cluster centers with ration lower as
possible

## [1] 2958.086

k3$size # number of points in each cluster

## [1] 275  46 150

k3$centers # CLuster Centers

##       ApplRec  ApplAccept  NewStdEnr      Top10      Top25   FTUnderG
## 1 -0.35953828 -0.34918455 -0.3171053 -0.5020886 -0.5128195 -0.2952142
## 2  1.98179657  2.22992267  2.4447222  0.1334215  0.2545856  2.5228452
## 3  0.05140256 -0.04367128 -0.1683551  0.8795798  0.8620961 -0.2324464
##     PTUnderG InStateFee OutStateFee       room      board   add..fees
## 1 -0.1217682 -0.4036544  -0.5263964 -0.3588740 -0.3938990 -0.05832646
## 2  1.7486849 -1.0500277  -0.4918168 -0.0388330 -0.1745795  0.49531762
```

```
## 3 -0.3130216  1.0620416   1.1158839  0.6698444  0.7756859 -0.04496556
##      BookCost     PerCost        PHD StFactRatio Graduation.rate
## 1 -0.06621454  0.05935933 -0.5322257   0.2810858      -0.4171456
## 2  0.16358567  0.93858632  0.6840794   0.6139980      -0.2538234
## 3  0.07122705 -0.39665857  0.7659627  -0.7036167       0.8426062

#•  Within cluster sum of squares with high ratio as possible
#•  Mean of distances between cluster centers with ration lower as possible
#•  Number of points in each cluster
#•  Cluster Centers
#•  The k value which the highest $withinss is the best choice, because we
expect the within sum of squares ratio to be as lower as possible.
```

Consider Tufts University, which is missing some information. Compute the Euclidean distance of this record from each of the clusters that you found above (using only the measurements that you have). Which cluster is it closest to? Impute the missing values for Tufts by taking the average of the cluster on those measurements.

```
library(cluster)

#Finding the Tufts University Data
Tufts<-DFUniver[DFUniver$College.Name =="Tufts University",]
Tufts<-data.frame(Tufts)

#Finding the  NULL fields from the Tufts University   data frame
Tufts[!complete.cases(Tufts)]

##         College.Name State Pub.Private ApplRec ApplAccept NewStdEnr Top10
Top25
## 476 Tufts University    MA           2    7614       3605      1205    60
90
##     FTUnderG PTUnderG InStateFee OutStateFee room board add..fees BookCost
## 476     4598       NA      19701       19701 3038  2930       503      600
##     PerCost PHD StFactRatio Graduation.rate
## 476     928  99        10.3              92

#PTUnderG field has NULL value

#Euclidean Distance
dist(rbind(Tufts, k3$centers[1,]))

## Warning in dist(rbind(Tufts, k3$centers[1, ])): NAs introduced by coercion

##        476
## 2 32343.31

dist(rbind(Tufts, k3$centers[2,]))

## Warning in dist(rbind(Tufts, k3$centers[2, ])): NAs introduced by coercion
```

```
##        476
## 2 32342.17
```

```r
dist(rbind(Tufts, k3$centers[3,]))
```

```
## Warning in dist(rbind(Tufts, k3$centers[3, ])): NAs introduced by coercion
```

```
##       476
## 2 32341.6
```

```r
#Cluster 3 has shortest distance

Avg_PTUnderG <- mean(Cluster3$PTUnderG)

#Update the value 609.22 for the Tuft University
Tufts[,c(10)]<-Avg_PTUnderG
Tufts[,c(10)]
```

```
## [1] 313.5867
```