ML Final Exam

Tongxiang Lu

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Load the data.

```
fuel_costs.df <- read.csv("fuel_receipts_costs_eia923.csv")
```

Set random four digit seed and split data.

```
library(caret)
```

```
## Loading required package: ggplot2
```

```
## Loading required package: lattice
```

```
set.seed(3272)
fuel_costs.df1<-createDataPartition(fuel_costs.df$fuel_type_code_pudl,p=0.02,
list=F)
```

```
## Warning in createDataPartition(fuel_costs.df$fuel_type_code_pudl, p = 0.02
, :
## Some classes have a single record ( ) and these will be selected for the s
ample
```

```
Sampled_Data = fuel_costs.df[fuel_costs.df1,]

Train_Index=createDataPartition(Sampled_Data$fuel_type_code_pudl, p=0.75, lis
t=F)
```

```
## Warning in createDataPartition(Sampled_Data$fuel_type_code_pudl, p = 0.75,
 :
## Some classes have a single record ( ) and these will be selected for the s
ample
```

```
Train_Data=Sampled_Data[Train_Index,]
Validation_Data=Sampled_Data[-Train_Index,]
```

Remove the missing value.

```
library(dplyr)
```

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag

## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union

sapply(Train_Data,function(x) sum(is.na(x)))

##                                    rowid
##                                        0
##                              plant_id_eia
##                                        0
##                        plant_id_eia_label
##                                        0
##                               report_date
##                                        0
##                        contract_type_code
##                                        0
##                  contract_type_code_label
##                                        0
##                  contract_expiration_date
##                                        0
##                        energy_source_code
##                                        0
##                  energy_source_code_label
##                                        0
##                       fuel_type_code_pudl
##                                        0
##                           fuel_group_code
##                                        0
##                              mine_id_pudl
##                                     5884
##                        mine_id_pudl_label
##                                     5884
##                             supplier_name
##                                        0
##                        fuel_received_units
##                                        0
##                        fuel_mmbtu_per_unit
##                                        0
##                         sulfur_content_pct
##                                        0
##                            ash_content_pct
##                                        0
##                        mercury_content_ppm
##                                     4290
##                        fuel_cost_per_mmbtu
##                                     3084
```

```
##         primary_transportation_mode_code
##                                        0
##   primary_transportation_mode_code_label
##                                        0
##       secondary_transportation_mode_code
##                                        0
## secondary_transportation_mode_code_label
##                                        0
##               natural_gas_transport_code
##                                        0
##  natural_gas_delivery_contract_type_code
##                                        0
##                     moisture_content_pct
##                                     7718
##                     chlorine_content_ppm
##                                     7718
##                            data_maturity
##                                        0
##                      data_maturity_label
##                                        0
```

```
head(Train_Data)
```

```
##     rowid plant_id_eia plant_id_eia_label report_date contract_type_code
## 23     23           26         E C Gaston  2008-01-01                  C
## 81     81           99       Frederickson  2008-01-01                  S
## 126   126          136           Seminole  2008-01-01                  C
## 250   250          535          McClellan  2008-01-01                  S
## 375   375          642             Scholz  2008-01-01                  C
## 397   397          667          Northside  2008-01-01                  C
##     contract_type_code_label contract_expiration_date energy_source_code
## 23                         C               2008-06-01                BIT
## 81                         S                                          NG
## 126                        C               2012-12-01                BIT
## 250                        S                                          NG
## 375                        C               2009-02-01                BIT
## 397                        C               2009-08-01                RFO
##     energy_source_code_label fuel_type_code_pudl fuel_group_code mine_id_p
udl
## 23                       BIT               coal            coal
  9
## 81                        NG                gas     natural_gas
 NA
## 126                      BIT               coal            coal
 26
## 250                       NG                gas     natural_gas
 NA
## 375                      BIT               coal            coal
 88
## 397                      RFO                oil       petroleum
```

```
 NA
##     mine_id_pudl_label supplier_name fuel_received_units fuel_mmbtu_per_un
it
## 23                   9     t c sales               27907              24.0
62
## 81                  NA        conoco                 229               1.0
30
## 126                 26 alliance coal               34199              24.4
34
## 250                 NA       powerex                  95               1.0
00
## 375                 88    alpha coal               10177              22.0
40
## 397                 NA            bp                6430               6.4
85
##     sulfur_content_pct ash_content_pct mercury_content_ppm fuel_cost_per_m
mbtu
## 23                1.86            15.0                  NA               2
.496
## 81                0.00             0.0                  NA               9
.494
## 126               2.98             8.5                  NA               2
.201
## 250               0.00             0.0                  NA               8
.836
## 375               0.80             9.7                  NA               3
.126
## 397               1.44             0.0                  NA               6
.993
##     primary_transportation_mode_code primary_transportation_mode_code_labe
l
## 23                               RR                                     R
R
## 81

## 126                              RR                                     R
R
## 250

## 375                              RR                                     R
R
## 397                              WT                                     W
T
##     secondary_transportation_mode_code secondary_transportation_mode_code_
label
## 23

## 81
```

```
## 126                                 RR
   RR
## 250

## 375

## 397

##     natural_gas_transport_code natural_gas_delivery_contract_type_code
## 23                        firm
## 81                        firm
## 126
## 250                       firm
## 375                       firm
## 397
##     moisture_content_pct chlorine_content_ppm data_maturity data_maturity_
label
## 23                   NA                   NA         final
final
## 81                   NA                   NA         final
final
## 126                  NA                   NA         final
final
## 250                  NA                   NA         final
final
## 375                  NA                   NA         final
final
## 397                  NA                   NA         final
final
```

Set only numerical variable for my train data analysis.

```
fuel_costs.df1 <- Train_Data[c(2,15,16,17,18,20)]
head(fuel_costs.df1)

##     plant_id_eia fuel_received_units fuel_mmbtu_per_unit sulfur_content_pc
t
## 23            26               27907              24.062                1.8
6
## 81            99                 229               1.030                0.0
0
## 126          136               34199              24.434                2.9
8
## 250          535                  95               1.000                0.0
0
## 375          642               10177              22.040                0.8
0
## 397          667                6430               6.485                1.4
4
```

```
##     ash_content_pct fuel_cost_per_mmbtu
## 23             15.0               2.496
## 81              0.0               9.494
## 126             8.5               2.201
## 250             0.0               8.836
## 375             9.7               3.126
## 397             0.0               6.993
```

```
summary(fuel_costs.df1)
```

```
##   plant_id_eia   fuel_received_units fuel_mmbtu_per_unit sulfur_content_pc
t
##  Min.   :    3   Min.   :       1    Min.   : 0.082      Min.   :0.000

##  1st Qu.: 2721   1st Qu.:    3427    1st Qu.: 1.025      1st Qu.:0.000

##  Median : 6181   Median :   20980    Median : 1.062      Median :0.000

##  Mean   :18636   Mean   :  233464    Mean   : 8.845      Mean   :0.521

##  3rd Qu.:50776   3rd Qu.:   98826    3rd Qu.:17.800      3rd Qu.:0.500

##  Max.   :63688   Max.   :12597588    Max.   :30.000      Max.   :7.980

##

##  ash_content_pct fuel_cost_per_mmbtu
##  Min.   : 0.00   Min.   :    0.188
##  1st Qu.: 0.00   1st Qu.:    2.258
##  Median : 0.00   Median :    3.256
##  Mean   : 3.63   Mean   :    9.702
##  3rd Qu.: 5.80   3rd Qu.:    4.743
##  Max.   :61.40   Max.   :13464.320
##                  NA's   :3084
```

Drop column 6 as it has significant number of missing data.

```
fuel_costs.df2 <- fuel_costs.df1[,-6]
summary(fuel_costs.df2)
```

```
##   plant_id_eia   fuel_received_units fuel_mmbtu_per_unit sulfur_content_pc
t
##  Min.   :    3   Min.   :       1    Min.   : 0.082      Min.   :0.000

##  1st Qu.: 2721   1st Qu.:    3427    1st Qu.: 1.025      1st Qu.:0.000

##  Median : 6181   Median :   20980    Median : 1.062      Median :0.000

##  Mean   :18636   Mean   :  233464    Mean   : 8.845      Mean   :0.521
```

```
##  3rd Qu.:50776   3rd Qu.:   98826    3rd Qu.:17.800      3rd Qu.:0.500

##  Max.   :63688   Max.   :12597588    Max.   :30.000      Max.   :7.980

##  ash_content_pct
##  Min.   : 0.00
##  1st Qu.: 0.00
##  Median : 0.00
##  Mean   : 3.63
##  3rd Qu.: 5.80
##  Max.   :61.40
```

Set only numerical variable for my test data analysis.

```
fuel_costs.df1_valid <- Validation_Data[c(2,15,16,17,18,20)]
summary(fuel_costs.df1_valid)

##   plant_id_eia   fuel_received_units fuel_mmbtu_per_unit sulfur_content_pc
t
##  Min.   :    3   Min.   :       1    Min.   : 0.283      Min.   :0.0000

##  1st Qu.: 2721   1st Qu.:    3742    1st Qu.: 1.025      1st Qu.:0.0000

##  Median : 6139   Median :   20798    Median : 1.061      Median :0.0000

##  Mean   :18274   Mean   :  238712    Mean   : 8.862      Mean   :0.5138

##  3rd Qu.:50498   3rd Qu.:  107664    3rd Qu.:17.773      3rd Qu.:0.4700

##  Max.   :63688   Max.   :11237212    Max.   :29.220      Max.   :7.2400

##

##  ash_content_pct  fuel_cost_per_mmbtu
##  Min.   : 0.000   Min.   :  -6.310
##  1st Qu.: 0.000   1st Qu.:   2.272
##  Median : 0.000   Median :   3.245
##  Mean   : 3.601   Mean   :   6.609
##  3rd Qu.: 5.800   3rd Qu.:   4.829
##  Max.   :60.700   Max.   :1939.507
##                   NA's   :1040
```

Drop column 6 as it has significant number of missing data.

```
fuel_costs.df2_valid <- fuel_costs.df1_valid[,-6]
summary(fuel_costs.df2_valid)
```

```
##   plant_id_eia   fuel_received_units fuel_mmbtu_per_unit sulfur_content_pc
t
##  Min.   :    3   Min.   :       1    Min.   : 0.283      Min.   :0.0000

##  1st Qu.: 2721   1st Qu.:    3742    1st Qu.: 1.025      1st Qu.:0.0000

##  Median : 6139   Median :   20798    Median : 1.061      Median :0.0000

##  Mean   :18274   Mean   :  238712    Mean   : 8.862      Mean   :0.5138

##  3rd Qu.:50498   3rd Qu.:  107664    3rd Qu.:17.773      3rd Qu.:0.4700

##  Max.   :63688   Max.   :11237212    Max.   :29.220      Max.   :7.2400

##  ash_content_pct
##  Min.   : 0.000
##  1st Qu.: 0.000
##  Median : 0.000
##  Mean   : 3.601
##  3rd Qu.: 5.800
##  Max.   :60.700
```

Normalize data.

```
library(tidyverse)

## ── Attaching packages ─────────────────────────────────────── tidyverse 1.
3.2 ──
## ✓ tibble  3.1.7     ✓ purrr   0.3.4
## ✓ tidyr   1.2.1     ✓ stringr 1.4.0
## ✓ readr   2.1.2     ✓ forcats 0.5.2
## ── Conflicts ────────────────────────────────────────── tidyverse_conflict
s() ──
## ✖ dplyr::filter() masks stats::filter()
## ✖ dplyr::lag()    masks stats::lag()
## ✖ purrr::lift()   masks caret::lift()

fuel_costs.df3 <- scale(fuel_costs.df2[,1:5])
head(fuel_costs.df3)

##     plant_id_eia fuel_received_units fuel_mmbtu_per_unit sulfur_content_pc
t
## 23    -0.8133595          -0.2906048           1.5500835          1.321304
6
## 81    -0.8101690          -0.3297344          -0.7961466         -0.514051
5
## 126   -0.8085519          -0.2817096           1.5879785          2.426465
3
## 250   -0.7911134          -0.3299238          -0.7992027         -0.514051
```

```
5
## 375   -0.7864369          -0.3156705           1.3441059          0.275349
0
## 397   -0.7853443          -0.3209678          -0.2404552          0.906869
4
##     ash_content_pct
## 23        1.7094611
## 81       -0.5458617
## 126       0.7321545
## 250      -0.5458617
## 375       0.9125804
## 397      -0.5458617
```

```
fuel_costs.df3_valid<-scale(fuel_costs.df2_valid[,1:5])
head(fuel_costs.df3_valid)
```

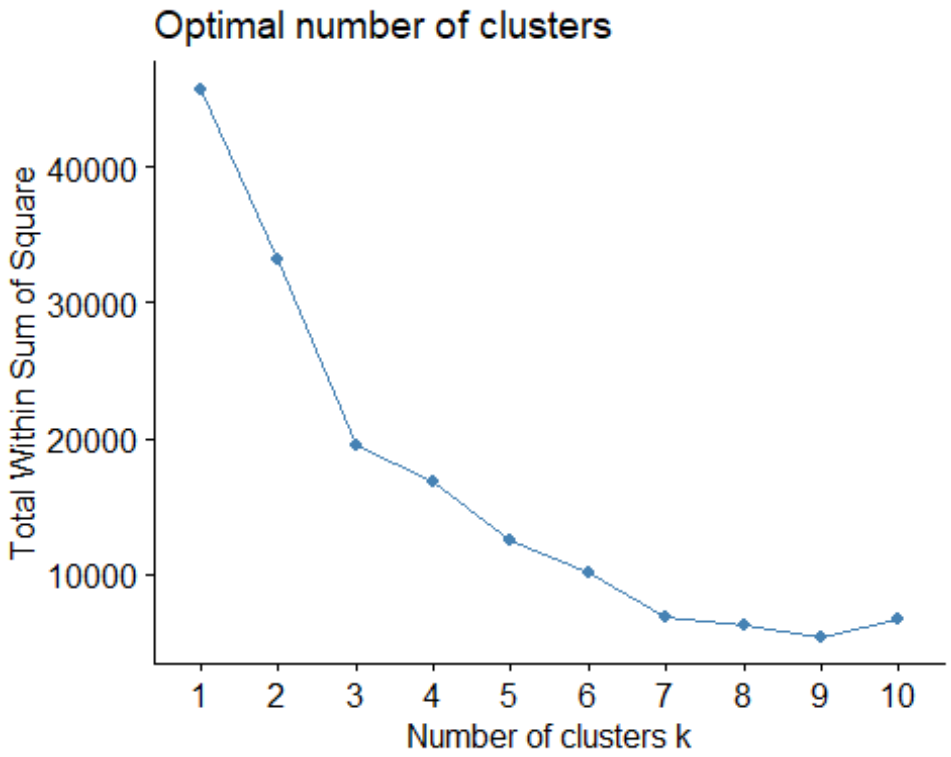
```
##      plant_id_eia fuel_received_units fuel_mmbtu_per_unit sulfur_content_p
ct
## 37     -0.8025552          -0.3479648           1.5627664         -0.11409
33
## 155    -0.7945856          -0.3508313          -0.7960437         -0.51517
02
## 310    -0.7797911          -0.2741325           1.6471149          0.54768
35
## 422    -0.7736708          -0.2865769           1.6908135          0.41733
35
## 1750   -0.6741604          -0.3499650          -0.7980762         -0.51517
02
## 2072   -0.6584853          -0.3343688           1.6196762          0.29701
05
##      ash_content_pct
## 37         0.7278437
## 155       -0.5461576
## 310        1.0766774
## 422        0.6368436
## 1750      -0.5461576
## 2072       1.1676775
```

Trying to find the optimal k

```
library(factoextra)
```

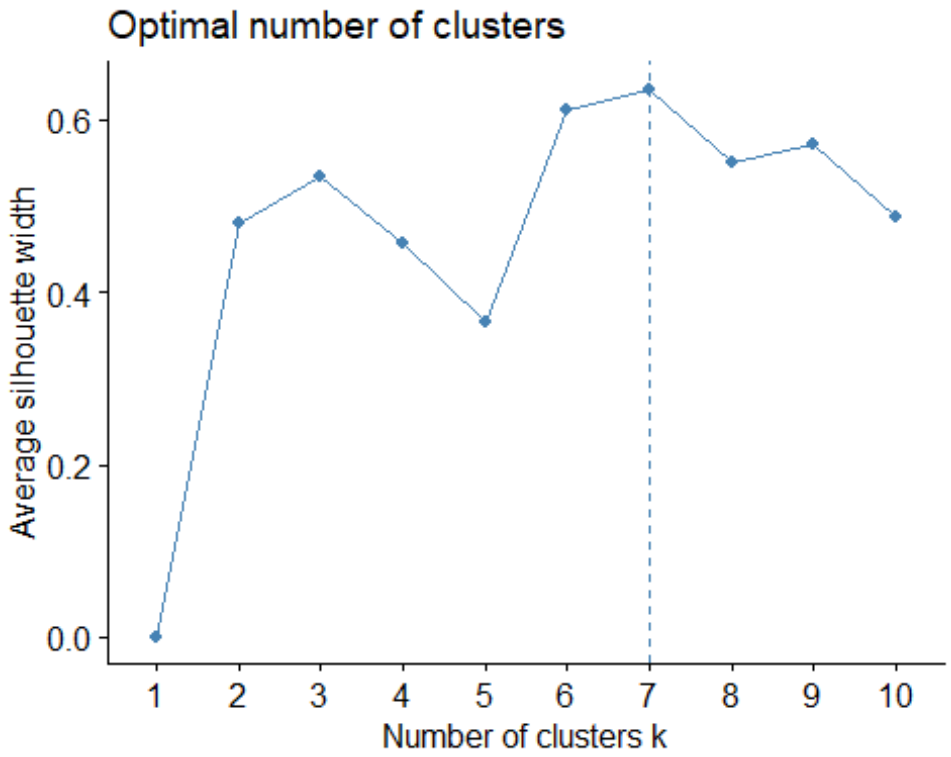
```
## Welcome! Want to learn more? See two factoextra-related books at https://g
oo.gl/ve3WBa
```

```
wss <- fviz_nbclust(fuel_costs.df3,kmeans,method="wss")
wss
```




```
# It is very ambiguous to find the optimal K.

silhouete <- fviz_nbclust(fuel_costs.df3,kmeans,method="silhouette")
silhouete
```

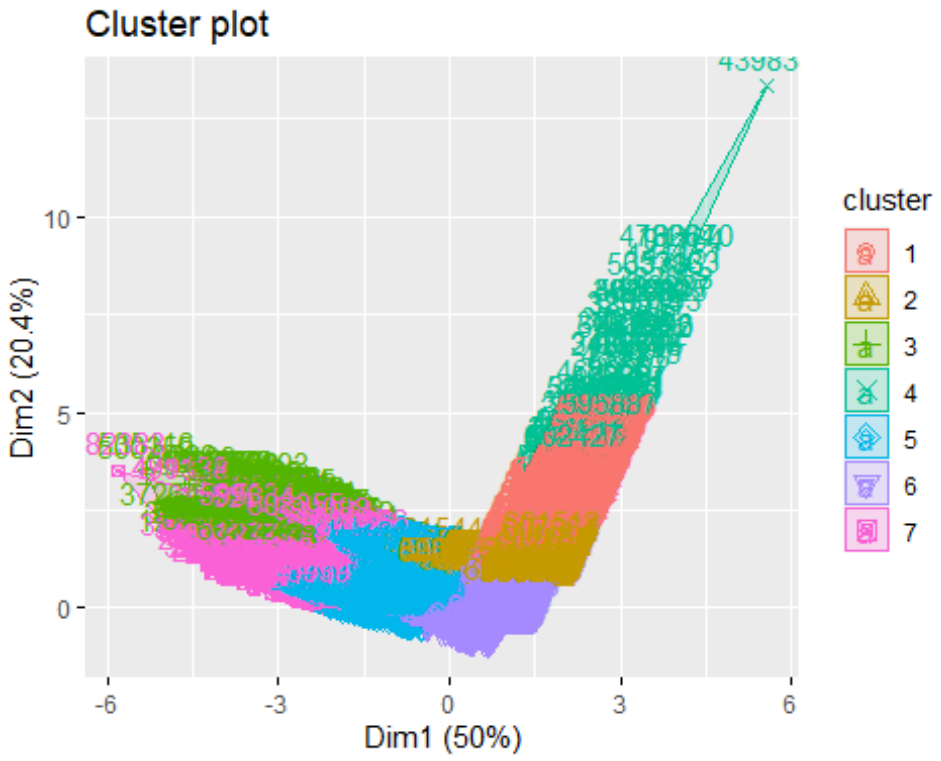



```
# I find my optimal K=7 by silhouete method.
```

By WSS and silhouette method comparasion, I find silouette method more precise,

so I choose running kmeans k=7.

```
cluster.kmean <- kmeans(fuel_costs.df3,centers=7,nstart=25)
cluster.k1<-kmeans(fuel_costs.df3,centers = 7, nstart = 25)
fviz_cluster(cluster.k1, data = fuel_costs.df3)
```




```
cluster.k1$size

## [1]  398 2015  157   66 2126 3350 1020

cluster.k1$centers

##   plant_id_eia fuel_received_units fuel_mmbtu_per_unit sulfur_content_pct
## 1    1.1545003          2.80208717          -0.7962344        -0.51405145
## 2    1.5873003         -0.07744249          -0.7353519        -0.48028647
## 3    0.5675617         -0.30984285           0.5236354         0.81410226
## 4    0.4233654          7.93294810          -0.8024069        -0.51405145
## 5   -0.5417620         -0.25902963           1.1991241         0.08384699
## 6   -0.6182863         -0.17738288          -0.6995372        -0.48700565
## 7   -0.5410837         -0.28351340           1.5328385         2.48205223
##   ash_content_pct
## 1      -0.5458617
## 2      -0.5328640
## 3       5.2649225
## 4      -0.5458617
## 5       0.6476524
## 6      -0.5458617
## 7       0.9334664
```

Interpretation

Cluster 1

This cluster receives a very high volume of fuel（big positive numbers) with low ash and sulfur(negative numbers), which means this cluster accumulated pure fuel. Thus, I conclude this cluster with surplus inflow of pure fuel. Additionally, the positive number of plant indicates that the plant with larger identification number is relevant to the large volume of fuel.

Cluster 2

This cluster is identified as everything low with low quantity of fuel received, low heat content of the fuel, low sulfur content percentage and low ash content as well. Both the negative and positive things are low here.

Cluster 3

This cluster is basically characterized with the highest ash content in the fuel, in which the most impure energy is located with high heat content of the fuel, high sulfur content and high ash content percentage. So, I recommend US power generation to bring proper policy to curb the impurity in the fuel.

Cluster 4

This is the highest fuel received cluster with low ash content. Such a large volume of relatively purer fuel! Contrary to cluster 3, US power generation can use the incentive policy to further encourage collecting good fuel with less ash content.

Cluster 5

Cluster 5 has a higher heat value of the fuel together with moderately high sulfur content and ash content. My conclusion is cluster 5 has more fuel with more efficiency and releases more energy.

Cluster 6

This is the cluster with everything low. The difference between cluster 2 and cluster 6 is that this cluster has the plant with smaller identification numbers than cluster 2. Contrary to cluster 1, this cluster shows that the plants with lower identification number are associated with low volume of fuel.

Cluster 7

Cluster 7 can be named a larger volume of fuel than average with very high sulfur content in it. From the perspective of emission control and the longevity of automobiles, this is the cluster the US power generation must keep an eye on and formulate policy to reduce the sulfur content.