Homework6

2022-11-18

(1)Cluster these data using Gaussian mixtures, t-mixtures, skew-normal mixtures, and skew-t mixtures, and decide which clustering you find most convincing, with reasons.

```
library(fpc)
library(smacof)
```

```
## Caricamento del pacchetto richiesto: plotrix
```

```
## Caricamento del pacchetto richiesto: colorspace
```

```
## Caricamento del pacchetto richiesto: e1071
```

```
##
## Caricamento pacchetto: 'smacof'
```

```
## Il seguente oggetto è mascherato da 'package:base':
##
##     transform
```

```
library(cluster)
library(pdfCluster)
```

```
## pdfCluster 1.0-3
```

```
data <- read.table("C:/Users/Utente/OneDrive/Desktop/bigData/datasets/stars5000.dat", quote="\"", comment.char="",header = T
RUE)
data<-as.matrix(data)

library(mclust)
```

```
## Warning: il pacchetto 'mclust' è stato creato con R versione 4.2.2
```

```
## Package 'mclust' version 6.0.0
## Type 'citation("mclust")' for citing this R package in publications.
```

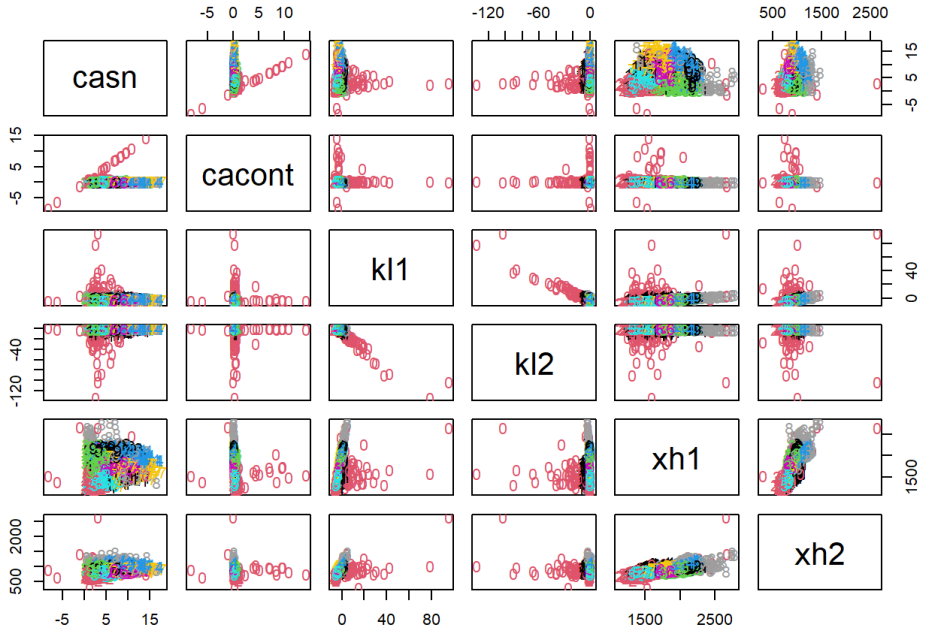
```
set.seed(1234)
mdata<-Mclust(data,G=1:10, scale=TRUE)
mdata$G
```

```
## [1] 10
```

```
summary(mdata)
```

```
## ----------------------------------------------------
## Gaussian finite mixture model fitted by EM algorithm
## ----------------------------------------------------
##
## Mclust VVV (ellipsoidal, varying volume, shape, and orientation) model with 10
## components:
##
##  log-likelihood    n  df       BIC       ICL
##       -67806.74 5000 279 -137989.8 -139581.5
##
## Clustering table:
##   1   2   3   4   5   6   7   8   9  10
## 313 448 802 886 481 518 648 237 602  65
```

```
#summary(mdata$BIC)
pairs(data,col=mdata$classification ,pch=clusym[mdata$classification])
```



The best models are the last 3 and are both VVV, so fully flexible models.

```
library(teigen)
set.seed(1234)
tdata<-teigen(data,Gs=1:10)
```

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## Warning: I passi della fase Quick-TRANSfer hanno superato il massimo (= 250000)
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6.3 secs  |    89% complete
| Approx. remaining:  35.1 secs  |    89% complet
```

```
Time taken: 267.5 secs  |  Approx. remaining:
                           Time taken: 267.5 secs

Time taken: 268.3 secs  |  Approx. remaining:
                           Time taken:   269 secs

Time taken: 271.1 secs  |  Approx. remaining:
                           Time taken: 271.1 secs

Time taken: 271.1 secs  |  Approx. remaining:
                           Time taken: 271.1 secs

Time taken: 271.1 secs  |  Approx. remaining:
                           Time taken: 271.1 secs

Time taken: 271.1 secs  |  Approx. remaining:
                           Time taken: 271.1 secs

Time taken: 271.7 secs  |  Approx. remaining:
                           Time taken: 272.3 secs

Time taken: 273.1 secs  |  Approx. remaining:
                           Time taken: 273.1 secs

Time taken: 273.1 secs  |  Approx. remaining:
                           Time taken: 273.1 secs

Time taken: 273.1 secs  |  Approx. remaining:
                           Time taken: 273.1 secs

Time taken: 273.1 secs  |  Approx. remaining:
                           Time taken: 273.1 secs

Time taken: 273.4 secs  |  Approx. remaining:
                           Time taken:   274 secs

Time taken: 275.6 secs  |  Approx. remaining:
                           Time taken: 275.6 secs

Time taken: 275.7 secs  |  Approx. remaining:
                           Time taken: 275.7 secs

Time taken: 275.7 secs  |  Approx. remaining:
                         Time taken: 275.7 secs

Time taken: 275.7 secs  |  Approx. remaining:  5
                           Time taken: 275.7 secs

Time taken:   276 secs  |  Approx. remaining:  5
                           Time taken: 276.5 secs

Time taken:   278 secs  |  Approx. remaining:  5
                           Time taken: 278.1 secs

Time taken: 278.1 secs  |  Approx. remaining:  5
                           Time taken: 278.1 secs

Time taken: 278.1 secs  |  Approx. remaining:  4
                           Time taken: 278.1 secs

Time taken: 278.1 secs  |  Approx. remaining:  4
                           Time taken: 278.1 secs

Time taken: 278.5 secs  |  Approx. remaining:  4
                           Time taken: 279.5 secs

Time taken: 281.7 secs  |  Approx. remaining:  4
                           Time taken: 281.7 secs

Time taken: 281.7 secs  |  Approx. remaining:  3
                           Time taken: 281.7 secs

Time taken: 281.7 secs  |  Approx. remaining:  3
                           Time taken: 281.7 secs
```

```
e                                                                         Time taken: 281.7 secs  |  Approx. remaining:  3
3.8 secs  |    89% complete                                                                      Time taken: 281.7 secs
|  Approx. remaining:  32.5 secs  |    90% complet
e                                                                         Time taken: 282.1 secs  |  Approx. remaining:  3
1.3 secs  |    90% complete                                                                      Time taken: 282.8 secs
|  Approx. remaining:  30.2 secs  |    90% complet
e                                                                         Time taken: 284.8 secs  |  Approx. remaining:  2
9.2 secs  |    91% complete                                                                      Time taken: 284.8 secs
|  Approx. remaining:  27.9 secs  |    91% complet
e                                                                         Time taken: 284.8 secs  |  Approx. remaining:  2
6.7 secs  |    91% complete                                                                      Time taken: 284.9 secs
|  Approx. remaining:  25.5 secs  |    92% complet
e                                                                         Time taken: 284.9 secs  |  Approx. remaining:  2
4.3 secs  |    92% complete                                                                      Time taken: 284.9 secs
|  Approx. remaining:  23.1 secs  |    92% complet
e                                                                         Time taken: 284.9 secs  |  Approx. remaining:  2
1.9 secs  |    93% complete                                                                      Time taken: 284.9 secs
|  Approx. remaining:  20.7 secs  |    93% complet
e                                                                         Time taken: 285.3 secs  |  Approx. remaining:  1
9.6 secs  |    94% complete                                                                      Time taken: 285.9 secs
|  Approx. remaining:  18.5 secs  |    94% complet
e                                                                         Time taken: 287.3 secs  |  Approx. remaining:  1
7.4 secs  |    94% complete                                                                      Time taken: 287.4 secs
|  Approx. remaining:  16.3 secs  |    95% complet
e                                                                         Time taken: 287.4 secs  |  Approx. remaining:  1
5.1 secs  |    95% complete                                                                      Time taken: 287.4 secs
|  Approx. remaining:    14 secs  |    95% complet
e                                                                         Time taken: 287.4 secs  |  Approx. remaining:  1
2.9 secs  |    96% complete                                                                      Time taken: 287.4 secs
|  Approx. remaining:  11.8 secs  |    96% complet
e                                                                         Time taken: 287.4 secs  |  Approx. remaining:  1
0.6 secs  |    96% complete                                                                      Time taken: 287.4 secs
|  Approx. remaining:   9.5 secs  |    97% complet
e                                                                         Time taken:   288 secs  |  Approx. remaining:
8.5 secs  |    97% complete                                                                      Time taken: 288.5 secs
|  Approx. remaining:   7.4 secs  |    98% complet
e                                                                         Time taken: 289.8 secs  |  Approx. remaining:
6.3 secs  |    98% complete                                                                      Time taken: 289.8 secs
|  Approx. remaining:   5.3 secs  |    98% complet
e                                                                         Time taken: 289.8 secs  |  Approx. remaining:
4.2 secs  |    99% complete                                                                      Time taken: 289.8 secs
|  Approx. remaining:   3.1 secs  |    99% complet
e                                                                         Time taken: 289.8 secs  |  Approx. remaining:
2.1 secs  |    99% complete                                                                      Time taken: 289.9 secs
|  Approx. remaining:     1 secs  |   100% complet
e                                                                         Time taken: 289.9 secs  |  Approx. remaining:
0 secs  |   100% complete
```

```
tdata$G
```

```
## [1] 4
```

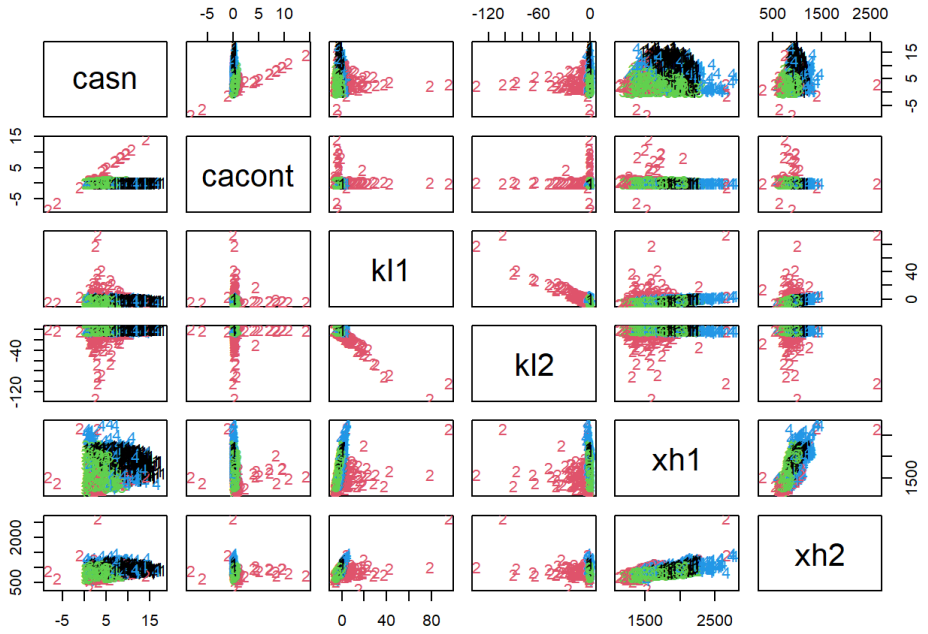
```
summary(tdata)
```

```
## ------------- Summary for teigen -------------
##             ------   RESULTS   ------
##             Loglik:         -6630.344
##             BIC:            -14240.16
##             ICL:            -15242.74
##             Model:          UUUU
##             # Groups:       4
##
##
## Clustering Table:
##
##    1    2    3    4
## 2466  277 1787  470
```

```
tdata$allbic
```

```
##            G=1       G=2       G=3       G=4       G=5       G=6       G=7
## UUUU -26588.60 -20972.63 -15341.74 -14240.16      -Inf      -Inf      -Inf
## UUUC      -Inf -22205.54 -15768.76 -14646.01      -Inf      -Inf      -Inf
## CUCU      -Inf -21161.71 -17931.52 -16281.38      -Inf      -Inf      -Inf
## CUCC      -Inf -21984.04 -18880.28 -17494.83      -Inf      -Inf      -Inf
## CUUU      -Inf -21005.49 -15830.93 -14968.89      -Inf      -Inf      -Inf
## CUUC      -Inf -22213.36 -16863.26 -16009.63      -Inf      -Inf      -Inf
## CCCU      -Inf -23710.59 -23290.40 -22205.19 -22104.07 -21458.17 -19694.98
## CCCC      -Inf -25036.30 -24865.41 -23593.03 -23483.48 -22950.87 -22456.89
## CIUU -46548.96 -36092.73 -33500.94 -28845.31      -Inf      -Inf      -Inf
## CIUC      -Inf -36045.33 -33829.35 -29370.02      -Inf      -Inf      -Inf
## CICU      -Inf -36701.26 -36325.47 -32479.24 -32377.22 -29377.98 -27586.10
## CICC      -Inf -37045.37 -36923.72 -32943.25 -32834.24 -30253.62 -28478.49
## UIIU -67751.57 -56843.51 -56410.94 -50345.04      -Inf      -Inf      -Inf
## UIIC      -Inf -56829.88 -56517.47 -50473.22      -Inf      -Inf      -Inf
## CIIU      -Inf -56861.40 -56584.01 -50491.70      -Inf      -Inf      -Inf
## CIIC      -Inf -56930.65 -56816.41 -50763.35      -Inf      -Inf      -Inf
## UIUU      -Inf -35993.73 -33265.10 -28563.52      -Inf      -Inf      -Inf
## UIUC      -Inf -35896.32 -33474.84 -28848.32      -Inf      -Inf      -Inf
## UCCU      -Inf -23558.21 -21579.38 -20395.51      -Inf      -Inf      -Inf
## UCCC      -Inf -24988.28 -22807.89 -21535.22      -Inf      -Inf      -Inf
## UUCU      -Inf      -Inf      -Inf -20358.60      -Inf      -Inf      -Inf
## UUCC      -Inf      -Inf      -Inf      -Inf      -Inf      -Inf      -Inf
## UICU      -Inf -36974.10 -35618.93 -31498.10      -Inf      -Inf      -Inf
## UICC      -Inf -36999.85 -35929.77 -31897.86      -Inf      -Inf      -Inf
## UCUU      -Inf -36121.51 -33392.86 -28691.28      -Inf      -Inf      -Inf
## UCUC      -Inf -36024.09 -33602.61 -28976.08      -Inf      -Inf      -Inf
## CCUU      -Inf -36220.50 -33628.69 -28973.08      -Inf      -Inf      -Inf
## CCUC      -Inf -36173.07 -33957.12 -29497.78      -Inf      -Inf      -Inf
##            G=8       G=9      G=10
## UUUU      -Inf      -Inf      -Inf
## UUUC      -Inf      -Inf      -Inf
## CUCU      -Inf      -Inf      -Inf
## CUCC      -Inf      -Inf      -Inf
## CUUU      -Inf      -Inf      -Inf
## CUUC      -Inf      -Inf      -Inf
## CCCU -21004.69 -20495.35 -20021.61
## CCCC -22068.85 -19324.87 -18951.78
## CIUU      -Inf      -Inf      -Inf
## CIUC      -Inf      -Inf      -Inf
## CICU -27460.56 -27923.77 -27540.98
## CICC -28163.29 -27270.31 -27112.37
## UIIU      -Inf      -Inf      -Inf
## UIIC      -Inf      -Inf      -Inf
## CIIU      -Inf      -Inf      -Inf
## CIIC      -Inf      -Inf      -Inf
## UIUU      -Inf      -Inf      -Inf
## UIUC      -Inf      -Inf      -Inf
## UCCU      -Inf      -Inf      -Inf
## UCCC      -Inf      -Inf      -Inf
## UUCU      -Inf      -Inf      -Inf
## UUCC      -Inf      -Inf      -Inf
## UICU      -Inf      -Inf      -Inf
## UICC      -Inf      -Inf      -Inf
## UCUU      -Inf      -Inf      -Inf
## UCUC      -Inf      -Inf      -Inf
## CCUU      -Inf      -Inf      -Inf
## CCUC      -Inf      -Inf      -Inf
```

```
#plot(tdata, what='contour')
pairs(data,col=tdata$classification ,pch=clusym[tdata$classification])
```


casn
cacont
kl1
kl2
xh1
xh2
-5 0 5 10
-120 -60 0
500 1500 2500
-5 5 15
0 40
-120 -40
1500
500 2000
-5 5 15
0 40 80
1500 2500

```
str(tdata)
```

```
## List of 13
##  $ iter          : num 870
##  $ fuzzy         : num [1:5000, 1:4] 7.29e-04 9.11e-01 9.37e-01 1.37e-05 9.98e-01 ...
##  $ parameters    :List of 9
##   ..$ df     : num [1:4] 173.9 2 27.7 13.4
##   ..$ mean   : num [1:4, 1:6] 0.583 -0.816 -0.683 0.12 -0.169 ...
##   ..$ lambda : num [1:4] 0.0432 0.1907 0.0611 0.1555
##   ..$ d      : num [1:6, 1:6, 1:4] 0.7385 0.0693 -0.2819 0.0145 -0.4661 ...
##   ..$ a      : num [1:6, 1:6, 1:4] 22.9 0 0 0 0 ...
##   ..$ weights: num [1:5000, 1:4] 0.925 0.996 1.007 0.879 1.015 ...
##   ..$ sigma  : num [1:6, 1:6, 1:4] 0.87336 0.00864 -0.08227 0.00344 -0.15509 ...
##   ..$ pig    : num [1:4] 0.4787 0.0572 0.3623 0.1018
##   ..$ conv   : logi TRUE
##  $ allbic        : num [1:28, 1:10] -26589 -Inf -Inf -Inf -Inf ...
##   ..- attr(*, "dimnames")=List of 2
##   .. ..$ : chr [1:28] "UUUU" "UUUC" "CUCU" "CUCC" ...
##   .. ..$ : chr [1:10] "G=1" "G=2" "G=3" "G=4" ...
##  $ bic           : num -14240
##  $ bestmodel     : chr "The best model (BIC of -14240.16) is UUUU with G=4"
##  $ modelname     : chr "UUUU"
##  $ classification: int [1:5000] 3 1 1 3 1 1 1 3 3 1 ...
##  $ G             : int 4
##  $ x             : num [1:5000, 1:6] -0.0331 0.122 0.3941 -0.7674 0.9563 ...
##   ..- attr(*, "dimnames")=List of 2
##   .. ..$ : NULL
##   .. ..$ : chr [1:6] "casn" "cacont" "kl1" "kl2" ...
##   ..- attr(*, "scaled:center")= Named num [1:6] 5.956 0.297 -1.52 -0.611 1814.508 ...
##   .. ..- attr(*, "names")= chr [1:6] "casn" "cacont" "kl1" "kl2" ...
##   ..- attr(*, "scaled:scale")= Named num [1:6] 3.316 0.445 2.918 3.965 256.562 ...
##   .. ..- attr(*, "names")= chr [1:6] "casn" "cacont" "kl1" "kl2" ...
##  $ logl          : num -6630
##  $ iclresults    :List of 10
##   ..$ iter          : num 870
##   ..$ fuzzy         : num [1:5000, 1:4] 7.29e-04 9.11e-01 9.37e-01 1.37e-05 9.98e-01 ...
##   ..$ allicl        : num [1:28, 1:10] -26589 -Inf -Inf -Inf -Inf ...
##   .. ..- attr(*, "dimnames")=List of 2
##   .. .. ..$ : chr [1:28] "UUUU" "UUUC" "CUCU" "CUCC" ...
##   .. .. ..$ : chr [1:10] "G=1" "G=2" "G=3" "G=4" ...
##   ..$ parameters    :List of 9
##   .. ..$ df     : num [1:4] 173.9 2 27.7 13.4
##   .. ..$ mean   : num [1:4, 1:6] 0.583 -0.816 -0.683 0.12 -0.169 ...
##   .. ..$ lambda : num Inf
##   .. ..$ d      : num Inf
##   .. ..$ a      : num Inf
##   .. ..$ weights: num [1:5000, 1:4] 0.925 0.996 1.007 0.879 1.015 ...
##   .. ..$ sigma  : num [1:6, 1:6, 1:4] 0.87336 0.00864 -0.08227 0.00344 -0.15509 ...
##   .. ..$ pig    : num [1:4] 0.4787 0.0572 0.3623 0.1018
##   .. ..$ conv   : logi TRUE
##   ..$ icl           : num -15243
##   ..$ bestmodel     : chr "The best model (ICL of -15242.74) is UUUU with G=4"
##   ..$ classification: int [1:5000] 3 1 1 3 1 1 1 3 3 1 ...
##   ..$ modelname     : chr "UUUU"
##   ..$ G             : int 4
##   ..$ logl          : num -6630
##  $ info          :List of 5
##   ..$ univar    : logi FALSE
##   ..$ gauss     : logi FALSE
##   ..$ scalelogic: logi TRUE
##   ..$ scalemeans: Named num [1:6] 5.956 0.297 -1.52 -0.611 1814.508 ...
##   .. ..- attr(*, "names")= chr [1:6] "casn" "cacont" "kl1" "kl2" ...
##   ..$ scalesd   : Named num [1:6] 3.316 0.445 2.918 3.965 256.562 ...
##   .. ..- attr(*, "names")= chr [1:6] "casn" "cacont" "kl1" "kl2" ...
##  - attr(*, "class")= chr "teigen"
```

The best number of clusters is 4 and the best model is a UUUU.

```
adjustedRandIndex(mdata$classification,tdata$classification)
```

```
## [1] 0.2375457
```

The two clustering are very different, in fact the adjusted Rand index is very low = 0.2375.

```
library(mixsmsn)
```

```
## Caricamento del pacchetto richiesto: mvtnorm
```

```
##
## Caricamento pacchetto: 'mvtnorm'
```

```
## Il seguente oggetto è mascherato da 'package:mclust':
##
##     dmvnorm
```

```
set.seed(1234)
#scdata<-smsn.search(data,nu=1,g.min=1,g.max=5,family="Skew.normal",uni.Gama=TRUE, iter.max=50)

sn_bic<-NULL
for(i in 2:6){
  sndata<-smsn.mmix(data, nu=1, g=i, family = "Skew.normal",iter.max=30)
  sn_bic[i]<-sndata$bic
}
which.min(sn_bic)
```

```
## [1] 5
```

```
str(sndata)
```

```
## List of 13
##  $ mu      :List of 6
##   ..$ : num [1:6] 7.25 0.21 -2.67 1.78 1792.79 ...
##   ..$ : num [1:6] 8.06 0.195 -0.82 -0.242 1989.495 ...
##   ..$ : num [1:6] 7.0034 0.3211 -3.1316 -0.0412 1642.9705 ...
##   ..$ : num [1:6] 4.64 4.18 -5.06 3.9 1637.28 ...
##   ..$ : num [1:6] 2.473 0.357 -2.943 -0.174 1727.013 ...
##   ..$ : num [1:6] 3.375 0.505 -4.395 2.373 1470.033 ...
##  $ Sigma   :List of 6
##   ..$ : num [1:6, 1:6] 3.12318 0.00331 -0.31185 0.52284 -1.05058 ...
##   ..$ : num [1:6, 1:6] 2.79969 0.00091 0.01492 -0.06037 -0.56882 ...
##   ..$ : num [1:6, 1:6] 3.1412 -0.0125 0.0191 0.0201 -0.1033 ...
##   ..$ : num [1:6, 1:6] 3.6826 3.0557 -0.1245 0.1463 0.0603 ...
##   ..$ : num [1:6, 1:6] 1.5359 0.0573 0.1927 -0.0425 -0.1536 ...
##   ..$ : num [1:6, 1:6] 1.4318 0.0573 0.1098 -0.0833 0.2301 ...
##  $ shape   :List of 6
##   ..$ : num [1:6, 1] -0.5732 -0.0677 5.1866 -5.8389 0.467 ...
##   ..$ : num [1:6, 1] -0.454 0.533 1.066 0.873 1.274 ...
##   ..$ : num [1:6, 1] -0.1008 -0.0271 0.9583 -0.9964 1.6537 ...
##   ..$ : num [1:6, 1] -1.394 1.155 4.439 -9.095 -0.974 ...
##   ..$ : num [1:6, 1] 1.762 -0.475 2.567 -1.862 -1.978 ...
##   ..$ : num [1:6, 1] -0.00995 0.89073 4.68784 -8.98992 0.45893 ...
##  $ pii     : num [1:6] 0.07047 0.31107 0.28754 0.00483 0.29365 ...
##  $ nu      : num 1
##  $ logLik  : num -71117
##  $ aic     : num 142641
##  $ bic     : num 143964
##  $ edc     : num 145105
##  $ icl     : num 145444
##  $ iter    : num 31
##  $ n       : int 5000
##  $ uni.Gama: logi FALSE
##  - attr(*, "class")= chr "Skew.normal"
```

The number of groups for which the BIC is lower is 5.

```
set.seed(1234)

#st.search <- smsn.mmix(data, nu=5,g.min=1,g.max=6, family="Skew.t")
#st.search$criteria
#st.search$best.model$bic
#plot(1:6,st_search$criteria,type="l",ylab="BIC",xlab="Number of clusters")
```

The code doesn't work because the dataset has an high number of observations on a lower dimensional hyperplane, and the smsn.search is not suitable.

(2)In a situation with 10 variables and 4 mixture components, what is the number of free parameters.

```
?nMclustParams
```

```
## avvio in corso del server httpd per la guida ... fatto
```

```
VVV<-nMclustParams(modelName = "VVV", d= 10, G=4)
VII<-nMclustParams(modelName = "VII", d= 10, G=4)
EEE<-nMclustParams(modelName = "EEE", d= 10, G=4)
```

VVV = 263 VII = 47 EEE = 98 Other models computed manually.

4. Step 1 Draw a random data subset of ns observations.

```
library(stats)
datas<-scale(data)
set.seed(1234)
ns <- 1000
train <- sample(seq_len(nrow(data)), size = ns)
sample <- datas[train,]
```

Step 2 Compute the mixture ML estimators using the EM-algorithm on that sub-set.

```
time<-system.time(mclust<-Mclust(sample, G=2:15))
summary(time)
```

```
##    utente   sistema trascorso
##     23.22      0.05     23.42
```

```
mclust$G
```

```
## [1] 7
```

It takes 30.75 seconds to define 7 groups.

Step 2 Run Mclust on the all data.

```
time2<-system.time(mclust2<-Mclust(datas, G=2:15))
summary(time2)
```

```
##    utente   sistema trascorso
##    147.22      0.08    147.44
```

```
mclust2$G
```

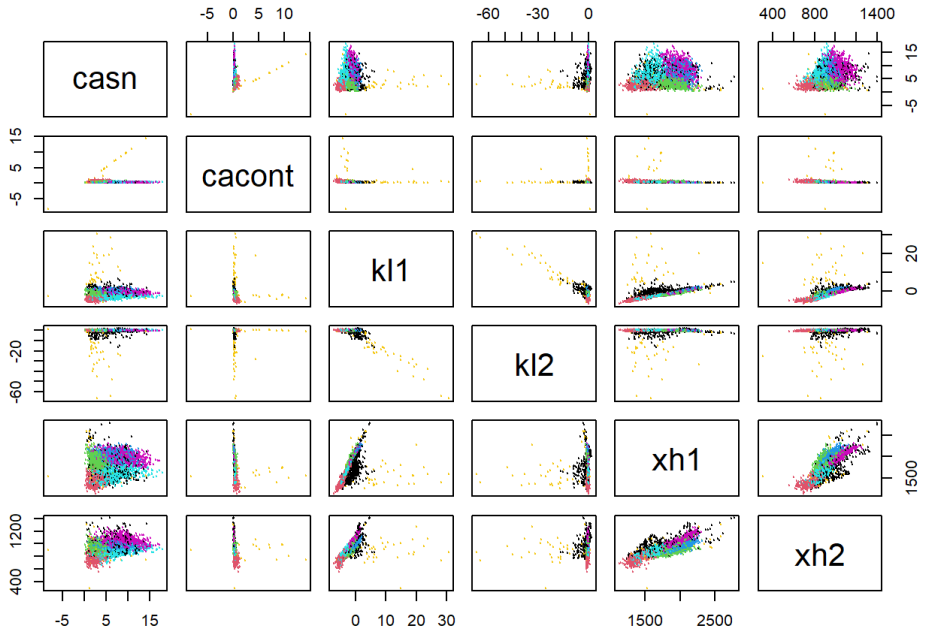
```
## [1] 14
```

It takes 159.83 seconds (5 times the time occured for the mclust on the sample) to define the best number of clusters equal to 14. Here the occurring time is higher because we deal with big data. We can say that for the big data it isn't a good method because it take much more time than the required for the sample, and the results obtained are very different (7groups vs 14 groups)

Step 3 Use function predict.mclust to extend the fitted model to all observations (read the help page for how exactly to do that).

```
posterior<- predict.Mclust(mclust, newdata = datas[-train,])
#summary(mclust)

pairs(data[-train,], pch= 20, cex=0.1, col= posterior$classification)
```


casn
cacont
kl1
kl2
xh1
xh2
-5 0 5 10
-60 -30 0
400 800 1400
-5 5 15
0 20
-60 -20
1500
400 1200
-5 5 15
0 10 20 30
1500 2500