model3

Jay Zhu

2022-12-08

Load the required libraries

```
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
```

```
library(factoextra)
```

```
## Loading required package: ggplot2

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

```
library(cluster)
library(mclust)
```

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

Set seed

```
set.seed(123)
```

Load the data

```
data <- read.csv("radiomics_completedata.csv")
```

Preprocess the data by excluding the binary and categorical data

```
data <- select(data, -c(Institution, Failure.binary))
head(data,5)
```

```
##    Failure Entropy_cooc.W.ADC GLNU_align.H.PET Min_hist.PET Max_hist.PET
## 1 49.30000           12.85352         46.25635     6.249117    17.825541
## 2 12.56667           12.21115         27.45454    11.005214    26.469077
## 3 79.80000           12.75682         90.19570     2.777718     6.877486
## 4 17.86667           13.46730        325.64333     6.296588    22.029843
## 5 39.56667           12.63733         89.57904     3.583846     7.922501
##   Mean_hist.PET Variance_hist.PET Standard_Deviation_hist.PET Skewness_hist.PET
## 1      9.783773          6.814365                    2.612479          0.688533
## 2     15.426640         12.932074                    3.598298          0.789526
## 3      4.295330          0.923425                    0.962163          0.248637
## 4     10.334779          6.649795                    2.580759          0.832011
## 5      4.454175          0.572094                    0.757225          1.574845
##   Kurtosis_hist.PET Energy_hist.PET Entropy_hist.PET AUC_hist.PET H_suv.PET
## 1         -0.339727        0.005095         9.629587     0.506553  1.123930
## 2         -0.319613        0.006297         8.072951     0.507519  1.927281
## 3         -0.944246        0.005015         9.669316     0.503300  0.410573
## 4          0.855861        0.003289        10.574730     0.544274  0.919612
## 5          3.250288        0.008066         7.621834     0.543922  0.306344
##   Volume.PET X3D_surface.PET ratio_3ds_vol.PET ratio_3ds_vol_norm.PET
## 1  13751.970        5622.519          3.214263               15.91400
## 2   9327.705        8356.832          4.848032               21.09429
## 3  26624.003       16832.003          3.163721               19.52154
## 4  51058.073       29100.294          2.027384               20.12864
## 5  29414.553        7769.379          4.815431               21.01721
##   irregularity.PET tumor_length.PET Compactness_v1.PET Compactness_v2.PET
## 1         2.212137         44.04796           0.003366           0.002778
## 2         2.348324         39.39796           0.003078           0.002637
## 3         2.121251         50.91422           0.003145           0.002664
## 4         1.859572         76.23900           0.003118           0.002653
## 5         2.219725         36.93490           0.003081           0.002638
##   Spherical_disproportion.PET Sphericity.PET Asphericity.PET Center_of_mass.PET
## 1                    15.91400       0.065378        14.91400           0.811086
## 2                    21.09429       0.049942        20.09429           0.587732
## 3                    19.52154       0.053762        18.52154           0.393189
## 4                    20.12864       0.052217        19.12864           0.866799
## 5                    21.01721       0.050116        20.01721           0.525997
##   Max_3D_diam.PET Major_axis_length.PET Minor_axis_length.PET
## 1        44.04796              34.60475              25.88546
## 2        39.39796              35.13100              27.30539
## 3        50.91422              48.12896              30.37293
## 4        76.23900              64.12797              54.46594
## 5        36.93490              35.99413              23.84296
##   Least_axis_length.PET Elongation.PET Flatness.PET Max_cooc.L.PET
```

```
## 1              24.98484       0.750543     0.724516       0.005020
## 2              21.15130       0.779759     0.604571       0.008190
## 3              27.52209       0.633585     0.574348       0.005033
## 4              51.56490       0.851856     0.806616       0.005971
## 5              21.38912       0.664919     0.596741       0.007553
##   Average_cooc.L.PET Variance_cooc.L.PET Entropy_cooc.L.PET DAVE_cooc.L.PET
## 1           22.87750            205.6627          10.688721       11.857838
## 2           21.90654            226.6299          10.291026       13.993568
## 3           27.25065            208.9461          10.878250       12.281559
## 4           17.81061            102.6657          10.238635        7.473982
## 5           15.35938            142.2193           9.829042       10.237690
##   DVAR_cooc.L.PET DENT_cooc.L.PET SAVE_cooc.L.PET SVAR_cooc.L.PET
## 1        84.21646        4.997454        45.75246        587.8808
## 2       129.35103        5.205762        43.81055        581.4143
## 3        85.30680        5.004455        54.49878        599.6980
## 4        43.94774        4.379716        35.61869        310.8875
## 5        79.40248        4.799453        30.71623        384.7110
##   SENT_cooc.L.PET ASM_cooc.L.PET Contrast_cooc.L.PET Dissimilarity_cooc.L.PET
## 1        6.530649       0.003302           234.76478                11.857838
## 2        6.489125       0.003596           325.10017                13.993568
## 3        6.587702       0.003198           236.08136                12.281559
## 4        6.108770       0.003680            99.77033                 7.473982
## 5        6.049095       0.004001           184.16098                10.237690
##   Inv_diff_cooc.L.PET Inv_diff_norm_cooc.L.PET IDM_cooc.L.PET
## 1            0.165784                0.858670       0.088949
## 2            0.156018                0.839093       0.085385
## 3            0.154252                0.852986       0.079027
## 4            0.228938                0.904866       0.141631
## 5            0.188717                0.875632       0.108336
##   IDM_norm_cooc.L.PET Inv_var_cooc.L.PET Correlation_cooc.L.PET
## 1            0.953919           0.091308               0.431777
## 2            0.937653           0.087501               0.285278
## 3            0.952616           0.084629               0.437596
## 4            0.980381           0.149832               0.516631
## 5            0.963872           0.114365               0.355073
##   Autocorrelation_cooc.L.PET Tendency_cooc.L.PET Shade_cooc.L.PET
## 1                   611.5456            587.8808        6860.4448
## 2                   543.8667            581.4143        4691.7137
## 3                   833.3669            599.6980         403.0883
## 4                   369.9095            310.8875        3805.6356
## 5                   285.9728            384.7110        9785.4495
##   Prominence_cooc.L.PET IC1_.L.PET IC2_.L.PET Coarseness_vdif_.L.PET
## 1              869822.0  -0.083966   0.789572               0.014320
## 2              803734.5  -0.096731   0.814047               0.014196
## 3              800129.8  -0.072366   0.758160               0.016269
## 4              345452.5  -0.050269   0.655209               0.004936
## 5              743501.3  -0.070677   0.727840               0.017239
##   Contrast_vdif_.L.PET Busyness_vdif_.L.PET Complexity_vdif_.L.PET
## 1             1.021460             0.087378               17053.35
## 2             1.510199             0.080209               21289.19
## 3             1.014169             0.057518               15199.89
## 4             0.306364             0.392674               10762.05
## 5             0.854170             0.081956               16796.63
##   Strength_vdif_.L.PET SRE_align.L.PET LRE_align.L.PET GLNU_align.L.PET
```

```
## 1             27.40494        0.986583        1.070671        10.162131
## 2             35.76496        0.989835        1.057129         8.416510
## 3             24.45341        0.989308        1.057095         9.117958
## 4              5.55092        0.973462        1.129413        94.565775
## 5             57.03783        0.986186        1.069172        10.574675
##   RLNU_align.L.PET RP_align.L.PET LGRE_align.L.PET HGRE_align.L.PET
## 1         383.8912       0.981089         0.063695         590.1484
## 2         263.3486       0.985313         0.065825         560.1103
## 3         394.6779       0.984963         0.039224         781.3663
## 4        2941.3190       0.963661         0.048051         386.6793
## 5         262.4745       0.981101         0.091713         295.6003
##   LGSRE_align.L.PET HGSRE_align.L.PET LGHRE_align.L.PET HGLRE_align.L.PET
## 1          0.062491          580.5855          0.068738          631.5734
## 2          0.064212          554.5346          0.072438          583.5148
## 3          0.038778          768.0350          0.041011          836.1597
## 4          0.046564          376.9558          0.054360          428.3121
## 5          0.090222          292.3243          0.097821          308.7154
##   GLNU_norm_align.L.PET RLNU_norm_align.L.PET GLVAR_align.L.PET
## 1              0.027914              0.961445          201.5094
## 2              0.033437              0.969710          214.6379
## 3              0.024834              0.968128          216.6109
## 4              0.032318              0.928789          107.6866
## 5              0.041113              0.960224          121.3562
##   RLVAR_align.L.PET Entropy_align.L.PET SZSE.L.PET LZSE.L.PET LGLZE.L.PET
## 1          0.025908            5.586143   0.926936   1.384001    0.062262
## 2          0.021453            5.385714   0.961338   1.244838    0.064793
## 3          0.020843            5.702830   0.974475   1.114749    0.040452
## 4          0.046375            5.480351   0.905696   1.617562    0.047964
## 5          0.024509            5.053054   0.966013   1.148597    0.093268
##   HGLZE.L.PET SZLGE.L.PET SZHGE.L.PET LZLGE.L.PET LZHGE.L.PET GLNU_area.L.PET
## 1    592.5775    0.056127    553.5787    0.089951    831.7709        9.166018
## 2    566.7718    0.060570    546.1829    0.086532    650.3679        7.817915
## 3    769.6933    0.040391    735.9377    0.040694    904.7157        8.877842
## 4    393.5484    0.043346    360.6300    0.076789    591.1260       83.352565
## 5    300.9426    0.091138    295.8022    0.101787    321.5044       10.245976
##   ZSNU.L.PET ZSP.L.PET GLNU_norm.L.PET ZSNU_norm.L.PET GLVAR_area.L.PET
## 1   301.1987  0.899841        0.027499        0.823228         201.7881
## 2   233.4102  0.941158        0.032589        0.900252         213.9100
## 3   372.1247  0.966472        0.024663        0.930516         216.4466
## 4  2206.3053  0.860538        0.031941        0.781042         109.9100
## 5   242.2684  0.956101        0.040895        0.909893         123.6639
##   ZSVAR.L.PET Entropy_area.L.PET Max_cooc.H.PET Average_cooc.H.PET
## 1    0.142022           5.886187       0.031232           39.87474
## 2    0.109793           5.546278       0.043568           39.22729
## 3    0.038537           5.775912       0.169447           44.90994
## 4    0.259194           5.901957       0.040212           38.15816
## 5    0.048849           5.156114       0.423535           49.45276
##   Variance_cooc.H.PET Entropy_cooc.H.PET DAVE_cooc.H.PET DVAR_cooc.H.PET
## 1           255.25108           6.344137       13.397288        131.6433
## 2           259.22064           7.168339       14.938851        146.5065
## 3           226.94291           3.662030       11.817845        143.8888
## 4           276.46636           6.205163       12.489582        129.5153
## 5            65.47745           2.835302        6.261891         56.9727
##   DENT_cooc.H.PET SAVE_cooc.H.PET SVAR_cooc.H.PET SENT_cooc.H.PET
```

```
## 1        4.528843        79.74696        769.9364        5.285948
## 2        2.880112        75.45206        667.2773        5.693972
## 3        4.354173        89.81735        824.2760        3.057425
## 4        4.257568        76.31379        820.4186        5.186241
## 5        3.891832        98.90299        765.7524        2.360339
##   ASM_cooc.H.PET Contrast_cooc.H.PET Dissimilarity_cooc.H.PET
## 1       0.017558            311.0628                13.397288
## 2       0.012079            369.6002                14.938851
## 3       0.096088            283.4905                11.817845
## 4       0.020168            285.4418                12.489582
## 5       0.233933             96.1523                 6.261891
##   Inv_diff_cooc.H.PET Inv_diff_norm_cooc.H.PET IDM_cooc.H.PET
## 1            0.240428                0.846191       0.181276
## 2            0.198536                0.831014       0.137656
## 3            0.439712                0.866805       0.405377
## 4            0.279879                0.856139       0.224079
## 5            0.576561                0.923498       0.543300
##   IDM_norm_cooc.H.PET Inv_var_cooc_.H.PET Correlation_cooc.H.PET
## 1            0.940222            0.030684               0.393202
## 2            0.929828            0.032006               0.289621
## 3            0.944553            0.011773               0.377943
## 4            0.945253            0.032706               0.486297
## 5            0.980482            0.021087               0.268281
##   Autocorrelation_cooc.H.PET Tendency_cooc.H.PET Shade_cooc.H.PET
## 1                   1689.514            709.9364        -2209.927
## 2                   1613.004            667.2773        -4195.799
## 3                   2101.874            624.2760        -4303.802
## 4                   1589.599            820.4186        -5395.462
## 5                   2462.728            165.7524         1099.232
##   Prominence_cooc.H.PET IC1_d.H.PET IC2_d.H.PET Coarseness_vdif.H.PET
## 1            1028531.31   -0.043805    0.512217              0.004319
## 2             957339.84   -0.023569    0.418010              0.005180
## 3             729696.02   -0.063791    0.473698              0.003375
## 4            1434052.83   -0.069422    0.611279              0.002825
## 5              55971.88   -0.044636    0.360145              0.003902
##   Contrast_vdif.H.PET Busyness_vdif.H.PET Complexity_vdif.H.PET
## 1            49.10863            0.141647              25517.13
## 2            28.26579            0.103194              28339.01
## 3           220.66779            0.236919              24028.42
## 4            40.72831            0.833266              23437.94
## 5            32.04753            0.124684              15279.35
##   Strength_vdif.H.PET SRE_align.H.PET LRE_align.H.PET RLNU_align.H.PET
## 1            19.64713        0.917833        1.449477        291.82356
## 2            25.47241        0.953059        1.241419        227.49063
## 3            22.15293        0.774121        2.674531        165.69391
## 4             2.79079        0.880393        1.732322       2033.70698
## 5            53.29819        0.741090        2.918639         99.23077
##   RP_align.H.PET LGRE_align.H.PET HGRE_align.H.PET LGSRE_align.H.PET
## 1       0.888556         0.004341         1569.763          0.004198
## 2       0.935326         0.004349         1536.186          0.004223
## 3       0.710370         0.003527         1821.062          0.003336
## 4       0.839415         0.005339         1588.246          0.005019
## 5       0.684948         0.002975         2476.679          0.002849
##   HGSRE_align.H.PET LGHRE_align.H.PET HGLRE_align.H.PET GLNU_norm_align.H.PET
```

```
## 1          1433.081          0.005120          2278.993              0.130158
## 2          1472.727          0.004991          1836.812              0.108781
## 3          1318.500          0.004849          5694.966              0.309012
## 4          1388.818          0.007300          2734.362              0.120339
## 5          1889.628          0.003929          6544.325              0.470904
##   RLNU_norm_align.H.PET GLVAR_align.H.PET RLVAR_align.H.PET Entropy_align.H.PET
## 1              0.805658         271.94120          0.166759            3.665844
## 2              0.881876         263.05257          0.089416            3.807145
## 3              0.559747         231.23849          0.633026            2.962910
## 4              0.733600         302.00409          0.279758            3.963763
## 5              0.516961          63.36076          0.708711            2.615080
##   SZSE.H.PET LZSE.H.PET LGLZE.H.PET HGLZE.H.PET SZLGE.H.PET SZHGE.H.PET
## 1   0.729896   6.346008    0.004206    1945.242    0.003751   1205.4141
## 2   0.889774   1.945761    0.004294    1541.326    0.004071   1371.5287
## 3   0.543152  38.343615    0.003595    1869.824    0.003145    833.9286
## 4   0.686000  28.192087    0.005281    2614.722    0.004412   1088.6316
## 5   0.494282  85.120177    0.002930    2778.032    0.002719   1427.6154
##   LZLGE.H.PET LZHGE.H.PET GLNU_area.H.PET ZSNU.H.PET ZSP.H.PET GLNU_norm.H.PET
## 1    0.014967    9278.763        28.21123  112.61992  0.564877        0.125177
## 2    0.007054    2730.177        23.91083  171.00253  0.829245        0.106933
## 3    0.027806   99597.669        42.33586   36.25834  0.312626        0.330695
## 4    0.066848   39940.885       160.59767  604.01684  0.425782        0.117405
## 5    0.047180  166256.576        23.73782   17.00253  0.245387        0.351578
##   ZSNU_norm.H.PET GLVAR_area.H.PET ZSVAR_H.PET Entropy_area.H.PET
## 1        0.492171        263.01858    3.183797           4.580974
## 2        0.749255        257.55868    0.482612           4.158935
## 3        0.283583        218.15517   27.944240           4.080320
## 4        0.434586        309.53854   22.609920           5.086907
## 5        0.252530         70.97225   68.165160           3.954518
##   Max_cooc.W.PET Average_cooc.W.PET Variance_cooc.W.PET Entropy_cooc.W.PET
## 1       0.013277           8.741717           27.724284           8.310617
## 2       0.015738          10.946398           54.254568           8.954940
## 3       0.046074           4.019422            3.648015           5.580950
## 4       0.013915           9.152454           25.597213           8.286935
## 5       0.116685           2.577872            2.729045           4.706665
##   DAVE_cooc.W.PET DVAR_cooc.W.PET DENT_cooc.W.PET SAVE_cooc.W.PET
## 1        4.361115       12.870015        3.611785       17.480905
## 2        6.845926       31.128005        4.224171       21.890266
## 3        1.595373        1.629296        2.279633        8.036314
## 4        3.728549       11.060383        3.431589       18.302378
## 5        1.376959        1.728999        2.205393        5.153215
##   SVAR_cooc.W.PET SENT_cooc.W.PET ASM_cooc.W.PET Contrast_cooc.W.PET
## 1       79.024802        5.099087       0.006555           31.867274
## 2      139.053134        5.483416       0.005298           77.960077
## 3       10.420558        3.676978       0.027061            4.166444
## 4       77.440194        5.106053       0.007012           24.943599
## 5        7.293066        3.190894       0.061557            3.618055
##   Dissimilarity_cooc.W.PET Inv_diff_cooc.W.PET Inv_diff_norm_cooc.W.PET
## 1                 4.361115           0.306285                 0.861048
## 2                 6.845926           0.244001                 0.837985
## 3                 1.595373           0.503481                 0.863798
## 4                 3.728549           0.343449                 0.905179
## 5                 1.376959           0.558453                 0.882471
##   IDM_cooc.W.PET IDM_norm_cooc.W.PET Inv_var_cooc.W.PET Correlation_cooc.W.PET
```

```
## 1       0.213874            0.955388           0.224294               0.427805
## 2       0.158456            0.936467           0.164222               0.284054
## 3       0.439777            0.957440           0.421156               0.431424
## 4       0.254836            0.980367           0.261941               0.515299
## 5       0.509374            0.964322           0.439330               0.339500
##   Autocorrelation_cooc.W.PET Tendency_cooc.W.PET Shade_cooc.W.PET
## 1                  88.165309           79.024802       341.143402
## 2                 135.044039          139.053134       552.913441
## 3                  17.701479           10.420558         2.361775
## 4                  96.847788           77.440194       471.374078
## 5                   7.553672            7.293066        26.823935
##   Prominence_cooc.W.PET IC1_d.W.PET IC2_d.W.PET Coarseness_vdif.W.PET
## 1            15813.1737   -0.042283    0.565302              0.015034
## 2            45767.4163   -0.044029    0.591913              0.015811
## 3              242.8423   -0.052987    0.524822              0.017811
## 4            21312.7505   -0.056187    0.630354              0.004934
## 5              276.1447   -0.033151    0.398878              0.018221
##   Contrast_vdif.W.PET Busyness_vdif.W.PET Complexity_vdif.W.PET
## 1            0.294464            0.717283             869.48613
## 2            0.599158            0.420854            2313.88985
## 3            0.112568            2.860859              40.08855
## 4            0.133588            1.549091            1346.28621
## 5            0.078944            3.650188              44.97271
##   Strength_vdif.W.PET SRE_align.W.PET LRE_align.W.PET GLNU_align.W.PET
## 1            3.919855        0.961787        1.191350         24.97624
## 2            8.341981        0.977438        1.116168         14.88136
## 3            0.511453        0.889821        1.618702         53.72505
## 4            1.384522        0.943354        1.291573        179.17215
## 5            1.109636        0.876250        1.674603         59.72108
##   RLNU_align.W.PET RP_align.W.PET LGRE_align.W.PET HGRE_align.W.PET
## 1         347.5995       0.947236         0.150278        85.345885
## 2         250.6373       0.968373         0.127690       139.175484
## 3         265.0196       0.853307         0.272808        15.983362
## 4        2609.2747       0.922696         0.092857       101.288786
## 5         170.2453       0.840992         0.466475         7.937118
##   LGSRE_align.W.PET HGSRE_align.W.PET LGHRE_align.W.PET HGLRE_align.W.PET
## 1          0.144360         82.365395          0.178628          98.96776
## 2          0.122525        136.722689          0.150485         150.71592
## 3          0.245883         13.790048          0.414898          28.12741
## 4          0.087782         95.978334          0.117784         126.22675
## 5          0.401364          7.231352          0.833918          11.22377
##   GLNU_norm_align.W.PET RLNU_norm_align.W.PET GLVAR_align.W.PET
## 1              0.067162              0.901536         27.361255
## 2              0.058138              0.938874         51.482886
## 3              0.154351              0.749487          3.691659
## 4              0.061479              0.859819         27.190856
## 5              0.256845              0.724823          2.405984
##   RLVAR_align.W.PET Entropy_align.W.PET SZSE.W.PET LZSE.W.PET LGLZE.W.PET
## 1          0.069370            4.413771   0.862196   2.111226    0.136626
## 2          0.043126            4.601911   0.939019   1.436265    0.126898
## 3          0.229632            3.470022   0.737823   5.821460    0.309701
## 4          0.107059            4.683410   0.816094   3.396694    0.091699
## 5          0.239812            2.974484   0.688181   6.186741    0.438075
##   HGLZE.W.PET SZLGE.W.PET SZHGE.W.PET LZLGE.W.PET LZHGE.W.PET GLNU_area.W.PET
```

```
## 1   88.918679    0.112325   79.094274    0.392257   161.03980        20.13918
## 2  138.464377    0.116457  128.987889    0.195656   189.79771        13.47643
## 3   14.973723    0.247502   10.310508    1.043890   117.40582        38.33586
## 4  106.496868    0.073436   88.831921    0.286957   297.89713       131.17762
## 5    9.015688    0.284427    6.692377    3.360406    31.91043        35.02885
##   ZSNU.W.PET ZSP.W.PET GLNU_norm.W.PET ZSNU_norm.W.PET GLVAR_area.W.PET
## 1  224.38141  0.789816        0.065066        0.699359        27.622423
## 2  211.55675  0.901447        0.056642        0.852145        50.978030
## 3  121.85027  0.586665        0.160280        0.503961         3.807675
## 4 1419.26821  0.697656        0.059662        0.620677        29.116647
## 5   66.31832  0.545387        0.232966        0.438818         2.699725
##   ZSVAR.W.PET Entropy_area.W.PET Min_hist.ADC Max_hist.ADC Mean_hist.ADC
## 1    0.497852           4.937916    549.00253     2268.003      1238.232
## 2    0.198720           4.834988      0.00253     2211.003      1158.946
## 3    2.890741           4.143192    634.00253     2860.003      1252.476
## 4    1.327156           5.449999      0.00253     2869.003      1195.303
## 5    2.793389           3.991207      0.00253     2389.003      1022.390
##   Variance_hist.ADC Standard_Deviation_hist.ADC Skewness_hist.ADC
## 1         113473.17                    336.8603           1.05752
## 2          83953.26                    289.7494          -0.49105
## 3         193194.07                    439.5410           1.53649
## 4         132561.08                    364.0919           0.24067
## 5         110268.35                    332.0693           0.31916
##   Kurtosis_hist.ADC Energy_hist.ADC Entropy_hist.ADC AUC_hist.ADC Volume.ADC
## 1           0.39978         0.00757          7.72697      0.52307   14702.81
## 2           1.41215         0.00503          8.82392      0.49147   11850.17
## 3           2.15473         0.00426          9.42564      0.56722   26067.89
## 4           0.23359         0.00365         10.02927      0.52148   51577.90
## 5           0.50069         0.00454          9.12787      0.50458   27419.14
##   X3D_surface.ADC ratio_3ds_vol.ADC ratio_3ds_vol_norm.ADC irregularity.ADC
## 1        2621.908           0.39370                1.52762          1.93975
## 2        3814.097           0.27791                1.37006          1.76130
## 3        5638.645           0.21884                1.32876          1.57930
## 4       11033.100           0.21644                1.64907          1.63673
## 5        5670.769           0.22562                1.35892          1.61457
##   Compactness_v1.ADC Compactness_v2.ADC Spherical_disproportion.ADC
## 1            0.03070            0.28444                     1.52762
## 2            0.03570            0.39354                     1.37006
## 3            0.03727            0.43122                     1.32876
## 4            0.02764            0.22655                     1.64907
## 5            0.03611            0.40326                     1.35892
##   Sphericity.ADC Asphericity.ADC Center_of_mass.ADC Max_3D_diam.ADC
## 1        0.65823         0.52762            0.97407        46.80855
## 2        0.73378         0.37006            1.00173        57.64178
## 3        0.75655         0.32876            1.48789        64.07496
## 4        0.60987         0.64907            1.32794        85.02235
## 5        0.73978         0.35892            0.57983        59.88998
##   Major_axis_length.ADC Minor_axis_length.ADC Least_axis_length.ADC
## 1              45.53640              20.24517              13.58989
## 2              35.07877              28.70241              23.63536
## 3              42.14714              36.72698              25.93458
## 4              58.00549              42.98623              35.06326
## 5              39.28351              35.40209              31.13508
##   Elongation.ADC Flatness.ADC Max_cooc.L.ADC Average_cooc.L.ADC
```

```
## 1        0.44709      0.30093        0.01362           24.26969
## 2        0.82074      0.67629        0.00769           34.15443
## 3        0.87392      0.61784        0.00984           17.40595
## 4        0.74359      0.60699        0.00893           26.20041
## 5        0.90372      0.79509        0.00863           27.03123
##   Variance_cooc.L.ADC Entropy_cooc.L.ADC DAVE_cooc.L.ADC DVAR_cooc.L.ADC
## 1           135.95808            9.35172         9.33833        95.10941
## 2            60.59539            9.52569         6.58341        31.97649
## 3           159.14565            9.93157         8.05607        81.58702
## 4            57.02199            9.50974         5.46198        23.67951
## 5            65.76514            9.76494         6.96837        33.58727
##   DENT_cooc.L.ADC SAVE_cooc.L.ADC SVAR_cooc.L.ADC SENT_cooc.L.ADC
## 1         4.68745        48.53685        361.5607         4.49616
## 2         4.18551        68.30632        167.0920         2.32433
## 3         4.48343        34.80936        490.1310         5.16708
## 4         3.95039        52.39829        174.5978         4.55938
## 5         4.26293        54.05993        180.9453         4.48500
##   ASM_cooc.L.ADC Contrast_cooc.L.ADC Dissimilarity_cooc.L.ADC
## 1        0.00535           182.26652                 9.33833
## 2        0.00448            75.28447                 6.58341
## 3        0.00458           146.44656                 8.05607
## 4        0.00454            53.48506                 5.46198
## 5        0.00414            82.11021                 6.96837
##   Inv_diff_cooc.L.ADC Inv_diff_norm_cooc.L.ADC IDM_cooc.L.ADC
## 1             0.23569                 0.88844        0.15619
## 2             0.24103                 0.91456        0.15044
## 3             0.24921                 0.90225        0.16496
## 4             0.27847                 0.92805        0.18834
## 5             0.23450                 0.90993        0.14567
##   IDM_norm_cooc.L.ADC Inv_var_cooc.L.ADC Correlation_cooc.L.ADC
## 1             0.96528            0.15633                0.33222
## 2             0.98542            0.15887                0.38132
## 3             0.97276            0.17144                0.54243
## 4             0.99019            0.19368                0.53355
## 5             0.98376            0.15283                0.37826
##   Autocorrelation_.L.ADC Tendency_cooc.L.ADC Shade_.L.ADC Prominence_cooc.L.ADC
## 1               633.7211            361.5607    7639.8939             517154.08
## 2              1189.3065            167.0920   -1156.8109             112937.29
## 3               388.8025            490.1310   17093.4493            1296059.93
## 4               716.6097            174.5978     616.3283              88605.95
## 5               755.2618            180.9453     592.0947             113320.37
##   IC1_.L.ADC IC2_.L.ADC Coarseness_vdif_.L.ADC Contrast_vdif_.L.ADC
## 1   -0.11842    0.83912                0.02135               0.71307
## 2   -0.05061    0.63924                0.01258               0.23808
## 3   -0.07274    0.73740                0.00784               0.40394
## 4   -0.06200    0.68774                0.00556               0.15512
## 5   -0.04812    0.63329                0.01085               0.27967
##   Busyness_vdif_.L.ADC Complexity_vdif_.L.ADC Strength_vdif_.L.ADC
## 1              0.04811               8748.919              30.44366
## 2              0.05243               5213.433              10.85376
## 3              0.21602               9811.189              12.83805
## 4              0.20181               4912.319               3.52728
## 5              0.08515               5705.778               8.31391
##   SRE_align.L.ADC LRE_align.L.ADC GLNU_align.L.ADC RLNU_align.L.ADC
```

```
## 1         0.97677         1.11587          9.40856         232.7602
## 2         0.97564         1.11803         26.43616         645.9593
## 3         0.96919         1.14834         43.70925        1177.5699
## 4         0.96126         1.18592        102.31243        2562.1046
## 5         0.97703         1.11715         28.40221         788.2562
##   RP_align.L.ADC LGRE_align.L.ADC HGRE_align.L.ADC LGSRE_align.L.ADC
## 1        0.96871          0.00908         831.5410           0.00900
## 2        0.96669          0.00605        1191.1595           0.00602
## 3        0.95823          0.01361         487.9258           0.01321
## 4        0.94795          0.00810         786.0107           0.00784
## 5        0.96795          0.00721         833.8975           0.00716
##   HGSRE_align.L.ADC LGHRE_align.L.ADC HGLRE_align.L.ADC GLNU_norm_align.L.ADC
## 1          820.9252           0.00946          876.2823               0.04038
## 2         1157.5280           0.00615         1335.5219               0.04066
## 3          478.4817           0.01531          528.1310               0.03656
## 4          757.7992           0.00954          909.4492               0.03841
## 5          815.1979           0.00741          917.7657               0.03626
##   RLNU_norm_align.L.ADC GLVAR_align.L.ADC RLVAR_align.L.ADC Entropy_align.L.ADC
## 1               0.93826         154.93296           0.04141              5.29371
## 2               0.93411          69.45486           0.04188              5.17751
## 3               0.91877         156.30297           0.05240              5.47452
## 4               0.90022          64.98946           0.06534              5.31012
## 5               0.93819          78.05347           0.04295              5.30441
##   SZSE.L.ADC LZSE.L.ADC LGLZE.L.ADC HGLZE.L.ADC SZLGE.L.ADC SZHGE.L.ADC
## 1    0.93703    1.33159     0.00927    858.5837     0.00905    831.8537
## 2    0.92448    1.39444     0.00624   1184.8610     0.00617   1086.4222
## 3    0.87706    1.82170     0.01338    514.4899     0.01189    468.7768
## 4    0.90217    1.59820     0.00767    792.5723     0.00686    720.2240
## 5    0.91279    1.55603     0.00757    833.3315     0.00743    760.6074
##   LZLGE.L.ADC LZHGE.L.ADC GLNU_area.L.ADC ZSNU.L.ADC ZSP.L.ADC GLNU_norm.L.ADC
## 1     0.01042    981.8102         8.25894   197.1051   0.91304         0.03781
## 2     0.00662   1681.2171        24.10984   524.4053   0.89683         0.04002
## 3     0.02376    734.9103        34.98083   798.7819   0.82545         0.03416
## 4     0.01300   1204.1618        90.93063  1994.0215   0.86029         0.03768
## 5     0.00840   1283.7978        24.73040   600.5032   0.87065         0.03520
##   ZSNU_norm.L.ADC GLVAR_area.L.ADC ZSVAR.L.ADC Entropy_area.L.ADC
## 1         0.84485        158.37071     0.12535            5.53926
## 2         0.81809         71.19097     0.14408            5.46224
## 3         0.72475        157.77185     0.34501            6.00431
## 4         0.77331         66.76247     0.23904            5.67242
## 5         0.79579         82.41219     0.22912            5.69671
##   Max_cooc.H.ADC Average_cooc.H.ADC Variance_cooc.H.ADC Entropy_cooc.H.ADC
## 1        0.00464           29.95976            310.9790           11.72265
## 2        0.00420           33.61846            312.8265           11.35537
## 3        0.00622           30.58315            335.7248           11.53210
## 4        0.00461           30.75681            310.6464           11.60919
## 5        0.00393           31.26939            305.7453           11.56749
##   DAVE_cooc.H.ADC DVAR_cooc.H.ADC DENT_cooc.H.ADC SAVE_cooc.H.ADC
## 1        15.71847        162.7022         5.37436        59.91700
## 2        15.39980        148.1637         5.34697        67.23440
## 3        13.82367        148.1751         5.24052        61.16377
## 4        12.67796        118.4962         5.12061        61.51110
## 5        15.22805        152.9835         5.34969        62.53624
##   SVAR_cooc.H.ADC SENT_cooc.H.ADC ASM_cooc.H.ADC Contrast_cooc.H.ADC
```

```
## 1        834.2180         3.87272        0.00312            409.6931
## 2        866.0614         3.21841        0.00292            385.2396
## 3       1003.6953         3.81762        0.00296            339.1990
## 4        963.4178         3.73436        0.00290            279.1628
## 5        838.1762         3.61892        0.00291            384.8001
##   Dissimilarity_cooc.H.ADC Inv_diff_cooc.H.ADC Inv_diff_norm_cooc.H.ADC
## 1                 15.71847             0.14449                  0.82408
## 2                 15.39980             0.13871                  0.82594
## 3                 13.82367             0.16711                  0.84276
## 4                 12.67796             0.16941                  0.85215
## 5                 15.22805             0.14798                  0.82834
##   IDM_cooc.H.ADC IDM_norm_cooc.H.ADC Inv_var_cooc.H.ADC Correlation_cooc.H.ADC
## 1        0.07807             0.92422            0.08536                0.34381
## 2        0.06993             0.92757            0.07472                0.38679
## 3        0.09608             0.93697            0.09823                0.49736
## 4        0.09588             0.94673            0.09742                0.55321
## 5        0.07991             0.92793            0.08208                0.37325
##   Autocorrelation_cooc.H.ADC Tendency_cooc.H.ADC Shade_cooc.H.ADC
## 1                   1003.570            834.2180       4888.58538
## 2                   1250.239            866.0614      -4080.74039
## 3                   1101.301           1003.6953       7361.25628
## 4                   1116.892            963.4178       2723.56893
## 5                   1090.963            838.1762        -98.86912
##   Prominence_cooc.H.ADC IC1_d.H.ADC IC2_d.H.ADC Coarseness_vdif.H.ADC
## 1               1518300    -0.15943     0.92667                0.02421
## 2               1589114    -0.05988     0.72703                0.01048
## 3               2077405    -0.06514     0.74687                0.00767
## 4               1824192    -0.05338     0.70043                0.00496
## 5               1538643    -0.05818     0.72034                0.00898
##   Contrast_vdif.H.ADC Busyness_vdif.H.ADC Complexity_vdif.H.ADC
## 1             1.85757             0.03586              16806.66
## 2             1.80534             0.09301              16186.56
## 3             1.49359             0.14284              13464.93
## 4             1.41213             0.29907              12641.54
## 5             1.83534             0.11398              16384.39
##   Strength_vdif.H.ADC SRE_align.H.ADC LRE_align.H.ADC GLNU_align.H.ADC
## 1            29.66079         0.99220         1.04664          4.07230
## 2            10.90410         0.99123         1.04949         11.31108
## 3             7.03589         0.98442         1.08787         20.88959
## 4             3.31909         0.98263         1.08821         46.68109
## 5             8.83863         0.98826         1.06328         13.66324
##   RLNU_align.H.ADC RP_align.H.ADC LGRE_align.H.ADC HGRE_align.H.ADC
## 1         246.9236        0.98876          0.02752         1363.457
## 2         687.6470        0.98755          0.02717         1357.005
## 3        1249.7235        0.97718          0.02776         1343.165
## 4        2786.7832        0.97588          0.02638         1359.587
## 5         824.1350        0.98339          0.02668         1358.525
##   LGSRE_align.H.ADC HGSRE_align.H.ADC LGHRE_align.H.ADC HGLRE_align.H.ADC
## 1           0.02695          1349.190           0.02979          1430.871
## 2           0.02648          1340.025           0.02994          1430.336
## 3           0.02707          1310.372           0.03080          1516.790
## 4           0.02500          1334.267           0.03403          1466.691
## 5           0.02577          1338.937           0.03083          1444.863
##   GLNU_norm_align.H.ADC RLNU_norm_align.H.ADC GLVAR_align.H.ADC
```

```
## 1               0.01859               0.97614          329.5023
## 2               0.01850               0.97320          329.3505
## 3               0.01848               0.95625          325.6524
## 4               0.01843               0.95150          327.9251
## 5               0.01850               0.96576          329.3047
##   RLVAR_align.H.ADC Entropy_align.H.ADC SZSE.H.ADC LZSE.H.ADC LGLZE.H.ADC
## 1           0.01753             6.01510    0.96829    1.15763     0.02871
## 2           0.01839             6.04615    0.96505    1.15896     0.02661
## 3           0.03446             6.10308    0.93628    1.65499     0.02502
## 4           0.03209             6.13418    0.95168    1.26414     0.02388
## 5           0.02330             6.06848    0.95866    1.24670     0.02517
##   HGLZE.H.ADC SZLGE.H.ADC SZHGE.H.ADC LZLGE.H.ADC LZHGE.H.ADC GLNU_area.H.ADC
## 1    1353.052     0.02838    1303.023     0.03004    1618.472         3.99028
## 2    1355.552     0.02483    1302.738     0.03376    1584.380        10.95282
## 3    1293.549     0.02152    1196.086     0.04888    2953.476        19.42358
## 4    1353.634     0.02049    1283.290     0.04521    1725.853        44.63370
## 5    1328.345     0.02373    1252.666     0.04477    1783.557        13.08842
##   ZSNU.H.ADC ZSP.H.ADC GLNU_norm.H.ADC ZSNU_norm.H.ADC GLVAR_area.H.ADC
## 1   223.9086   0.95584         0.01881         0.91643         324.0822
## 2   619.2862   0.95385         0.01854         0.90792         327.6186
## 3  1007.9399   0.89316         0.01876         0.84458         305.6363
## 4  2450.9039   0.93025         0.01848         0.87848         321.4979
## 5   727.4123   0.93716         0.01859         0.89506         324.1160
##   ZSVAR.H.ADC Entropy_area.H.ADC Max_cooc.W.ADC Average_cooc.W.ADC
## 1     0.05727            6.06723        0.00675           65.37977
## 2     0.05401            6.18594        0.00382          118.60405
## 3     0.39430            6.37088        0.00376           60.27417
## 4     0.10225            6.32299        0.00302          117.52784
## 5     0.10193            6.21756        0.00355          101.18139
##   Variance_cooc.W.ADC DAVE_cooc.W.ADC DVAR_cooc.W.ADC DENT_cooc.W.ADC
## 1           1010.0875        25.43812         706.5272         6.06338
## 2            746.1691        23.15154         390.8192         5.94785
## 3           1991.6618        28.49457        1018.7085         6.25261
## 4           1181.5174        24.91785         487.4797         6.07963
## 5            945.7911        26.38488         481.6157         6.14012
##   SAVE_cooc.W.ADC SVAR_cooc.W.ADC SENT_cooc.W.ADC ASM_cooc.W.ADC
## 1        130.7570        2686.849         5.54316        0.00323
## 2        237.2056        2057.975         2.77584        0.00280
## 3        120.5458        6136.137         6.76239        0.00275
## 4        235.0531        3617.812         6.13864        0.00265
## 5        202.3602        2605.515         5.80987        0.00273
##   Contrast_cooc.W.ADC Dissimilarity_cooc.W.ADC Inv_diff_cooc.W.ADC
## 1            1353.496                25.43812             0.12826
## 2             926.696                23.15154             0.10420
## 3            1830.505                28.49457             0.10990
## 4            1108.253                24.91785             0.10456
## 5            1177.644                26.38488             0.09861
##   Inv_diff_norm_cooc.W.ADC IDM_cooc.W.ADC IDM_norm_cooc.W.ADC
## 1                  0.88720        0.06987             0.96438
## 2                  0.91342        0.04700             0.98505
## 3                  0.90097        0.05282             0.97202
## 4                  0.92684        0.04905             0.98983
## 5                  0.90880        0.04557             0.98327
##   Inv_var_cooc.W.ADC Correlation_cooc.W.ADC Autocorrelation_cooc.W.ADC
```

```
## 1            0.07218               0.33254                  4607.525
## 2            0.04790               0.38156                 14349.142
## 3            0.05640               0.54299                  4709.081
## 4            0.04962               0.53354                 14439.590
## 5            0.04452               0.37996                 10594.131
##   Tendency_cooc.W.ADC Shade_cooc.W.ADC Prominence_cooc.W.ADC IC1_d.W.ADC
## 1            2686.849        154504.57              28492973    -0.20561
## 2            2057.975        -49857.50              17100002    -0.13210
## 3            6136.137        755229.72             202604689    -0.13981
## 4            3617.812         57995.75              38091821    -0.08828
## 5            2605.515         31890.26              23457384    -0.13836
##   IC2_d.W.ADC Coarseness_vdif.W.ADC Contrast_vdif.W.ADC Busyness_vdif.W.ADC
## 1     0.96152               0.01818             4.78265             0.01774
## 2     0.91270               0.01162             1.49489             0.00979
## 3     0.92904               0.00742             1.99390             0.02744
## 4     0.85241               0.00544             1.11708             0.01846
## 5     0.92596               0.01002             1.72379             0.01257
##   Complexity_vdif.W.ADC Strength_vdif.W.ADC SRE_align.W.ADC LRE_align.W.ADC
## 1              94483.95           120.21874         0.99193         1.04495
## 2             123984.35            70.45906         0.99469         1.03484
## 3             322896.60           118.12334         0.99389         1.03917
## 4             270786.27            41.10745         0.99307         1.04143
## 5             183481.75            68.98942         0.99446         1.03681
##   GLNU_align.W.ADC RLNU_align.W.ADC RP_align.W.ADC LGRE_align.W.ADC
## 1          4.26622         246.5777        0.98876          0.00683
## 2          8.60033         696.8829        0.99205          0.00418
## 3         13.91071        1298.3291        0.99080          0.00430
## 4         24.38419        2904.1988        0.98991          0.00579
## 5          8.43212         844.4260        0.99159          0.00400
##   HGRE_align.W.ADC LGSRE_align.W.ADC HGSRE_align.W.ADC LGHRE_align.W.ADC
## 1         5992.756           0.00683          5952.927           0.00685
## 2        14395.425           0.00418         14281.115           0.00418
## 3         5853.808           0.00429          5824.143           0.00434
## 4        15776.936           0.00562         15649.652           0.00681
## 5        11683.555           0.00400         11599.962           0.00400
##   HGLRE_align.W.ADC GLNU_norm_align.W.ADC RLNU_norm_align.W.ADC
## 1          6152.074               0.01935               0.97502
## 2         14868.922               0.01462               0.98198
## 3          5983.117               0.01300               0.97996
## 4         16293.667               0.01072               0.97773
## 5         12044.998               0.01230               0.98150
##   GLVAR_align.W.ADC RLVAR_align.W.ADC Entropy_align.W.ADC SZSE.W.ADC LZSE.W.ADC
## 1         1139.4041           0.01629             6.94511    0.98460    1.07424
## 2          842.8456           0.01345             6.67452    0.96527    1.11797
## 3         1938.7178           0.01519             6.79621    0.98765    1.17872
## 4         1327.6869           0.01562             7.20649    0.98060    1.10239
## 5         1109.3728           0.01437             6.95074    0.97667    1.13245
##   LGLZE.W.ADC HGLZE.W.ADC SZLGE.W.ADC SZHGE.W.ADC LZLGE.W.ADC LZHGE.W.ADC
## 1     0.00686    6055.150     0.00686    6018.454     0.00690    6201.935
## 2     0.00422   14407.506     0.00422   14026.413     0.00423   16054.013
## 3     0.00433    5883.686     0.00430    5711.245     0.00453    6674.638
## 4     0.00511   15809.845     0.00455   15506.485     0.00888   17172.910
## 5     0.00403   11663.603     0.00403   11366.888     0.00405   13231.943
##   GLNU_area.W.ADC ZSNU.W.ADC ZSP.W.ADC GLNU_norm.W.ADC ZSNU_norm.W.ADC
```

```
## 1         4.13400   239.2894   0.97918         0.01899         0.95586
## 2         8.37627   644.7370   0.95637         0.01461         0.93288
## 3        13.11686  1165.7026   0.97268         0.02501         0.91537
## 4        23.84726  2760.4129   0.97203         0.01069         0.94658
## 5         8.14437   784.5973   0.96469         0.02526         0.93769
##   GLVAR_area.W.ADC ZSVAR.W.ADC Entropy_area.W.ADC
## 1        1145.1050     0.02586            6.28632
## 2         847.5254     0.04153            6.77853
## 3        1923.8571     0.07104            7.15685
## 4        1329.9529     0.03848            7.29521
## 5        1116.3867     0.05223            7.05149
```

Run the K-Means algorithm with k = 20 clusters

```
clusters <- kmeans(data, 20, nstart=26)
# between_ss/total_ss = 0.99
```

View the cluster assignments

```
clusters$cluster
```

```
##   [1]  7  4  2 17  1 15  7  1  4 15  1  7  7 13 20  1 16  1 17 12  5  4 11  7  6
##  [26]  7 20  4  1 11  6  8 14  1  4 17 18 20  8  6  8  6 14  6  6  5 15 16 11  1
##  [51]  4 20 18 11 11 16 13 12  6 12 17  4  3 11 16 16 16 18 16 13 11 15  6 11 11
##  [76]  6 11 11 16  7 16  8 16  5 11 16  4 11  6 11  6  6 11 13  3 20  4 20  4 16
## [101] 11  6  6 13  6  3  5  6  6  4  1  1  6 11  6 11 16  1  5 11  6  6 11 13  3
## [126] 20  4 20  4 16 11  6  6 13  6  3  5  6  6  4  1  1  6 11 11 16  1 19 17 17
## [151] 12  2 19 11 13  8 15 16 15 14 20  2 19  1  4  4  2  1  8 11  9 16 11 19 16
## [176] 19 19  1  8  1 10  4 12 19  4  7 19 16 19  4 16 19  8  2 12 17 12
```

View the cluster centers

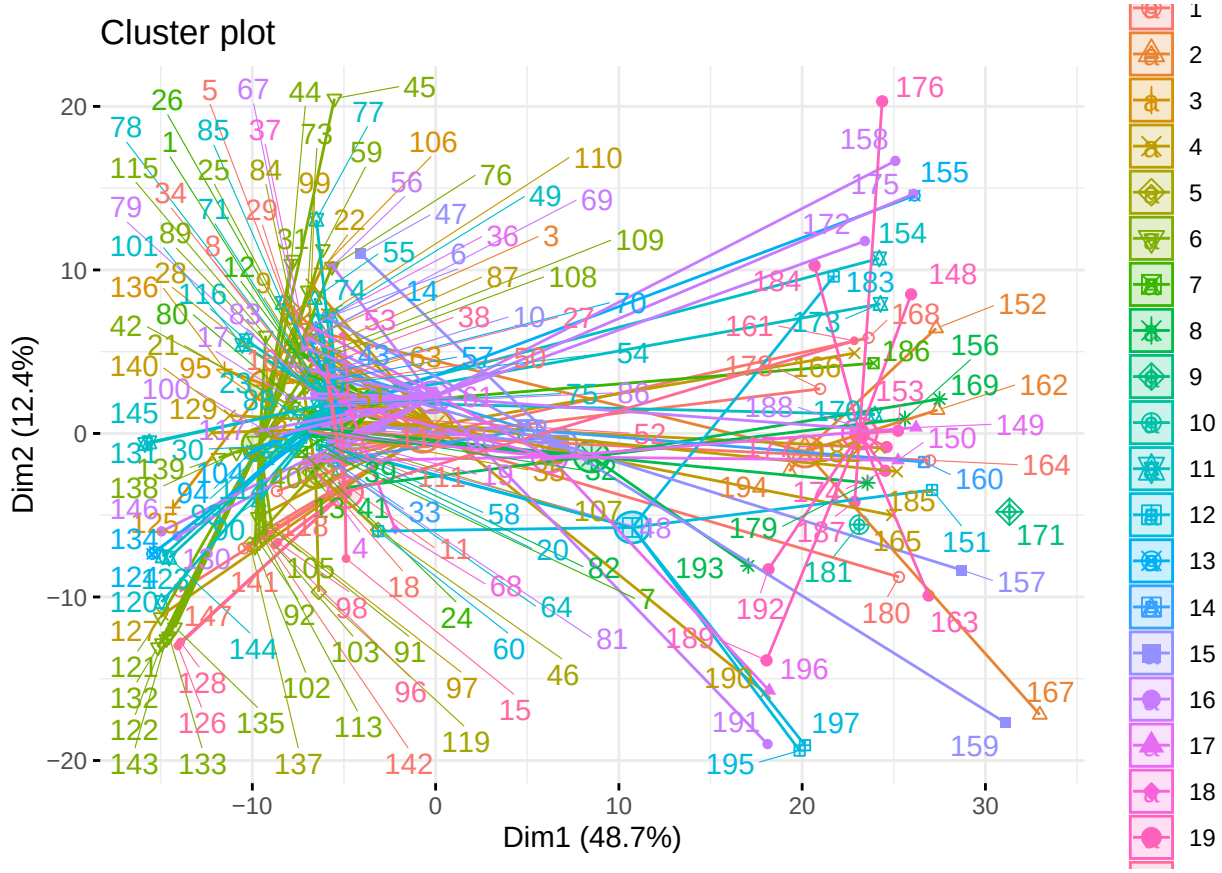
```
centers <- clusters$centers
```

Visualize the clusters using a scatterplot

```
options(ggrepel.max.overlaps = Inf)

fviz_cluster(clusters, data = data,
             ellipse.type = "euclid",
             star.plot = TRUE,
             repel = TRUE,
             ggtheme = theme_minimal(),
)
```

```
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
```

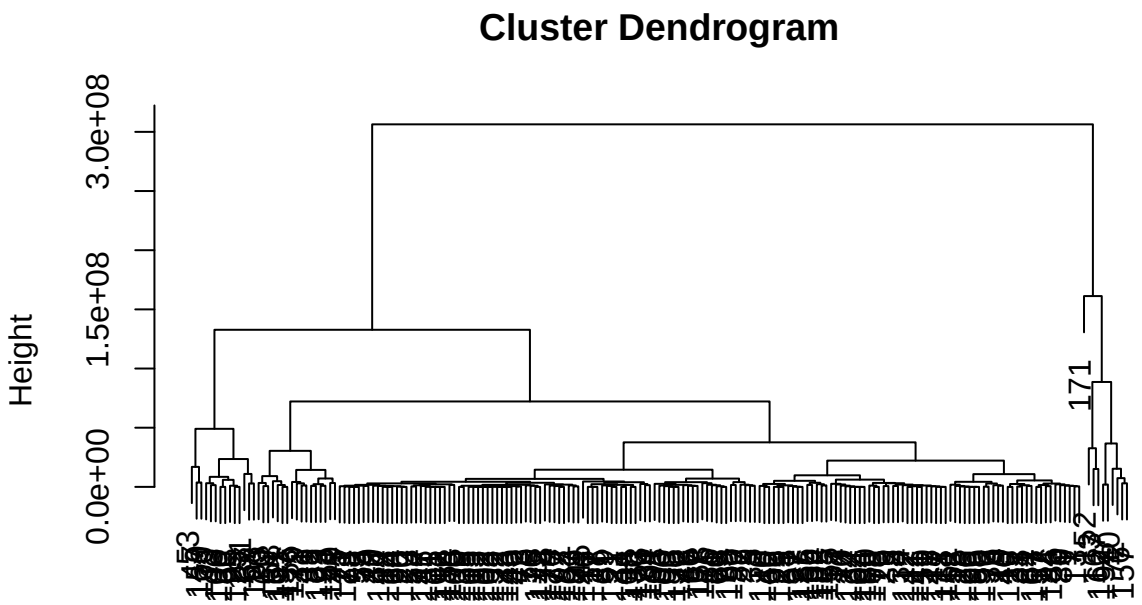


Hierarchical Model

```
d <- dist(data)
hcl <- hclust(d)
```

The Dendrogram

```
plot(hcl)
```




```
cutree(hcl, k=20)
```

```
##   [1]  1  2  3  4  2  5  1  2  6  7  2  1  1  2  4  2  8  2  4  9  1  6  8  1  8
##  [26]  1  1  2  2  8  8 10 11  2  6  4 12  1 13  8 10  8 11  8  8  1 14  6  8  2
##  [51]  2  4 15  8  8  6  2  9  8  9 13  2 11  8  6  6  6 12  6  2  8  5  8  8  8
##  [76]  8  8  8  6  1  6 13  6  1  8  6  6  8  8  8  8  8  8  2 11  4  2  4  2  6
## [101]  8  8  8  2  8 11  1  8  8  2  2  2  8  8  8  8  8  2  1  8  8  8  8  2 11
## [126]  4  2  4  2  6  8  8  8  2  8 11  1  8  8  2  2  2  8  8  8  8  2  8 13  4
## [151]  9 16  8  8  2 10  5  6 14 11  4 17  8  2  2  2 18  2 13  8 19  6  8  8  6
## [176]  8  8  2 10  2 20  2  9  8  2  1  8  6  8  6  6  8 13 17  9  4  9
```

Model Based

```
mcl <- Mclust(data[-1], G=5)
summary(mcl)
```

```
## ----------------------------------------------------
## Gaussian finite mixture model fitted by EM algorithm
## ----------------------------------------------------
##
## Mclust VVI (diagonal, varying volume and shape) model with 5 components:
##
```

```
##  log-likelihood   n   df       BIC       ICL
##         -180431 197 4284 -383495.2 -383495.2
##
## Clustering table:
##  1  2  3  4  5
## 94 50  3  6 44
```

```
# Detail of mcl: using VVI model in 5 groups
mcl
```

```
## 'Mclust' model object: (VVI,5)
##
## Available components:
##  [1] "call"           "data"           "modelName"      "n"
##  [5] "d"              "G"              "BIC"            "loglik"
##  [9] "df"             "bic"            "icl"            "hypvol"
## [13] "parameters"     "z"              "classification" "uncertainty"
```

```
# Classfication details
table(data$Failure, mcl$classification)
```

```
##
##              1 2 3 4 5
##   4.76667    1 0 0 0 0
##   4.9666666  0 0 0 0 1
##   4.966666667 1 0 0 0 0
##   5.03333    1 0 0 0 0
##   5.2        0 0 0 0 1
##   5.4        1 0 0 0 0
##   5.53333333 1 0 0 0 0
##   5.83333    1 0 0 0 0
##   5.86667    0 2 0 0 0
##   6.13333    0 1 0 0 0
##   6.3        1 0 0 0 0
##   6.333      0 0 0 0 1
##   6.46667    1 0 0 0 0
##   6.7333333  1 0 0 0 0
##   6.8666     0 0 0 0 1
##   7.06667    1 0 0 0 0
##   7.133333333 1 0 0 0 0
##   7.33333    1 0 0 0 0
##   7.93333    1 0 0 0 0
##   8          0 1 0 0 0
##   8.0333     0 1 0 0 0
##   8.1        0 2 0 0 0
##   8.133      0 1 0 0 0
##   8.2        0 0 0 0 1
##   8.3        0 1 0 0 0
##   8.36666667 1 0 0 0 0
##   8.433333333 0 1 0 0 0
##   8.5        0 2 0 0 0
##   8.6        0 1 0 0 0
##   8.733333333 0 1 0 0 0
```

```
##   8.9         0 0 1 0 0
##   8.933333333 0 1 0 0 0
##   9.2         1 0 0 0 0
##   9.4         0 1 0 0 0
##   9.43        0 1 0 0 0
##   9.433333333 0 1 0 0 0
##   9.6         0 1 0 0 0
##   9.8         0 1 0 0 0
##   9.866666667 0 1 0 0 0
##   9.9         0 1 0 0 0
##   10.06667    1 0 0 0 0
##   10.1        1 0 0 0 0
##   10.43333333 1 0 0 0 0
##   10.5        0 0 0 0 1
##   10.8666667  0 1 0 0 0
##   11.1666     0 0 0 0 1
##   11.2666     0 1 0 0 0
##   11.36666667 1 0 0 0 0
##   12          0 1 0 0 0
##   12.03333    1 1 0 0 0
##   12.3        1 2 0 0 0
##   12.53       0 0 0 0 1
##   12.56667    1 0 0 0 0
##   12.6        0 0 0 1 0
##   12.7        2 1 0 0 0
##   13          0 0 0 0 1
##   13.26666667 1 0 0 0 0
##   13.4        1 0 0 0 0
##   13.56667    1 0 0 0 0
##   13.83333333 1 0 0 0 0
##   13.86666667 0 1 0 0 0
##   14.13333    0 1 0 0 0
##   14.4        0 0 0 0 1
##   14.93333333 0 0 0 0 1
##   15          0 1 0 0 0
##   15.06666667 0 1 0 0 0
##   15.06667    1 0 0 0 0
##   15.46666    0 1 0 0 0
##   15.5        2 0 0 0 0
##   16.33333333 0 0 1 0 0
##   16.43333333 0 0 0 0 1
##   16.7        0 0 0 0 1
##   17          1 0 0 0 0
##   17.6        1 0 0 0 1
##   17.73333333 0 0 0 0 1
##   17.8        1 0 0 0 1
##   17.86667    1 0 0 0 0
##   18.36666667 1 0 0 0 0
##   18.46666667 0 1 0 0 1
##   18.7        1 0 0 0 0
##   18.9        0 0 0 0 1
##   19.16666    0 0 0 0 1
##   19.23333333 1 0 0 0 0
##   19.4        0 0 0 0 1
```

```
##   20.3        1 0 0 0 0
##   20.36666667 0 1 0 0 0
##   20.5        1 0 0 0 0
##   20.7        0 0 0 0 1
##   20.7666667  1 0 0 0 0
##   20.9333333  1 0 0 0 0
##   21.76666667 0 0 0 0 1
##   22.26666667 1 0 0 0 0
##   22.7        1 0 0 0 0
##   22.9666667  1 0 0 0 0
##   23.23333333 1 0 0 0 0
##   23.4333333  1 0 0 0 0
##   24          0 0 0 0 1
##   24.06666667 1 0 0 0 0
##   24.13333333 1 0 0 0 0
##   24.2        0 1 0 0 0
##   24.26667    1 0 0 0 0
##   24.33333333 1 0 0 0 0
##   24.36666667 0 0 0 0 1
##   25          1 0 0 0 0
##   25.53       0 1 0 0 0
##   26.16666667 1 0 0 0 0
##   26.3        1 0 0 0 0
##   26.3666667  1 0 0 0 0
##   26.6        0 0 0 0 1
##   26.9        1 0 0 0 0
##   27.16666667 0 1 0 0 0
##   27.6333     0 0 0 0 1
##   27.8        1 0 0 0 0
##   28.1        0 1 0 0 0
##   28.56666667 0 0 0 0 1
##   28.7        0 0 0 0 1
##   28.7666     0 0 0 0 1
##   29          1 0 0 0 1
##   30.0666667  1 0 0 0 0
##   30.1        0 0 0 0 1
##   30.6333333  1 0 0 0 0
##   31.2        1 0 0 0 0
##   31.4        1 0 0 0 0
##   32.7333333  1 0 0 0 0
##   32.9        1 0 0 0 0
##   34.53333333 0 0 0 0 1
##   34.83333333 0 0 0 1 0
##   34.9333333  1 0 0 0 0
##   35.33333    1 0 0 0 0
##   35.46666667 0 1 0 0 0
##   35.56666667 0 0 0 0 1
##   35.8        1 0 0 0 0
##   36.06666667 0 0 0 0 1
##   36.4        0 0 0 0 1
##   37.9        0 0 0 0 1
##   38.26666667 0 0 0 0 1
##   38.33333333 0 0 0 0 1
##   38.5        0 0 0 0 1
```

```
##   38.96666667 0 1 0 0 0
##   39.13333    1 0 0 0 0
##   39.16666667 0 0 0 0 1
##   39.5666667  1 0 0 0 0
##   40.1666667  1 0 0 0 0
##   40.7333333  1 0 0 0 0
##   41.6        1 0 0 0 0
##   43.1        1 0 0 0 0
##   43.9666667  1 0 0 0 0
##   45.06666667 0 0 0 1 0
##   45.33333333 0 0 0 1 0
##   45.8        1 0 0 0 0
##   46          0 0 0 0 1
##   46.26666667 0 0 0 0 1
##   46.3        1 0 0 1 0
##   47.56666667 0 0 0 0 1
##   48.06666667 0 0 0 1 0
##   48.1        1 0 0 0 0
##   48.6        1 0 0 0 0
##   48.9666667  1 0 0 0 0
##   49.3        1 0 0 0 0
##   49.66666667 0 0 0 0 1
##   50.4666667  1 0 0 0 0
##   51.0333333  1 0 0 0 0
##   51.1666667  1 0 0 0 0
##   51.8        1 0 0 0 0
##   53.5333333  1 0 0 0 0
##   56.0666667  0 0 1 0 0
##   56.1666667  1 0 0 0 0
##   58.6666667  1 0 0 0 0
##   60.2333333  1 0 0 0 0
##   61.73333333 0 1 0 0 0
##   61.8666     0 1 0 0 0
##   62.6        0 1 0 0 0
##   63.1666667  1 0 0 0 0
##   68.63333333 0 1 0 0 0
##   69.1        0 1 0 0 0
##   71.63333333 0 1 0 0 0
##   73.1333333  1 0 0 0 0
##   74.5666667  1 0 0 0 0
##   74.96666667 0 1 0 0 0
##   79.3        1 0 0 0 0
##   79.8        1 0 0 0 0
##   83.1        1 0 0 0 0
##   97.63333333 0 1 0 0 0
```

```
# Use Rand Index
adjustedRandIndex(data$Failure, mcl$classification)
```

```
## [1] 0.0001716184
```

```
# Not optimal on clustering
```

Mean - Distribution

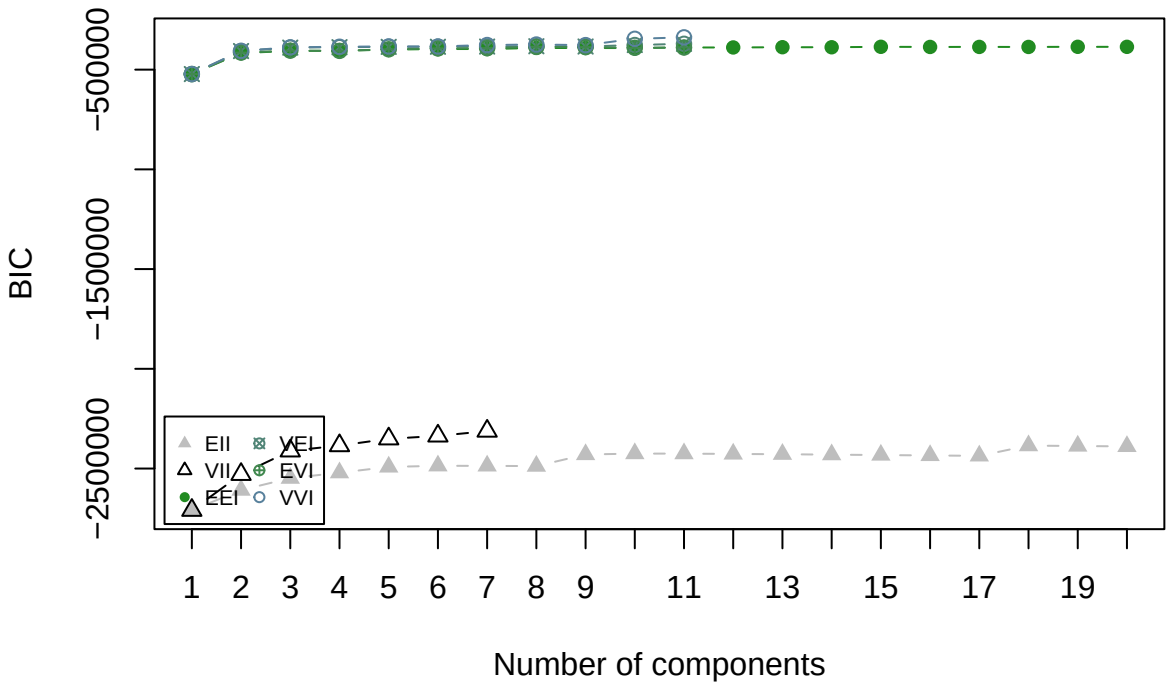
```
mean <- summary(mcl, parameter=TRUE)$mean
head(mean,5)
```

```
##                           [,1]      [,2]       [,3]      [,4]     [,5]
## Entropy_cooc.W.ADC  12.246889 12.274846  12.495067 12.506752 12.30474
## GLNU_align.H.PET   100.304090 92.596252 100.948968 71.425574 90.91919
## Min_hist.PET         6.541052  8.038139   1.744269  8.577207 13.71931
## Max_hist.PET        17.926972 23.388337   4.550298 20.028819 40.75210
## Mean_hist.PET        9.880932 12.448087   2.534460 12.568413 21.09946
```

```
# Again, apply new categories
mcl_opt <- Mclust(data[-1], 1:20)
mcl
```

```
## 'Mclust' model object: (VVI,5)
##
## Available components:
##  [1] "call"           "data"           "modelName"      "n"
##  [5] "d"              "G"              "BIC"            "loglik"
##  [9] "df"             "bic"            "icl"            "hypvol"
## [13] "parameters"     "z"              "classification" "uncertainty"
```

```
# Determine why using VVI
plot.Mclust(mcl_opt, what = "BIC",
     ylim = range(mcl_opt$BIC, na.rm = TRUE),
     legendArgs = list(x = "bottomleft", cex =0.7), ncol=5)
```




```
mcl2 <- Mclust(data, G=11, modelNames = "VVI")
mcl2
```

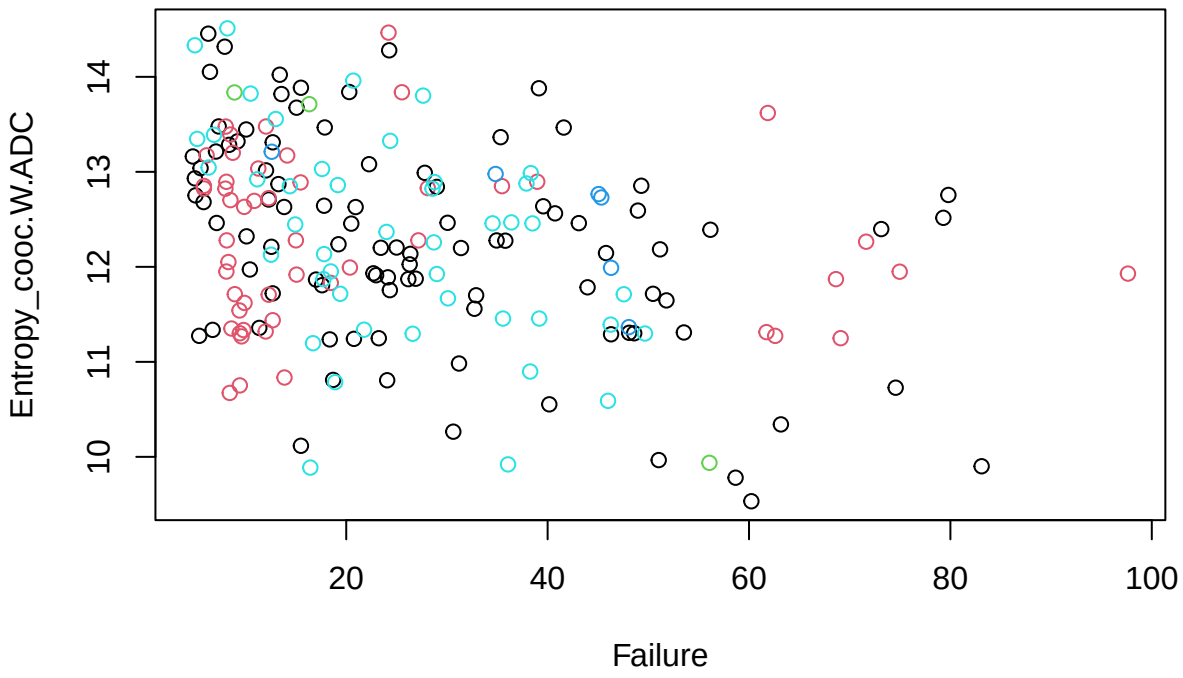
```
## 'Mclust' model object: (VVI,11)
##
## Available components:
##  [1] "call"           "data"           "modelName"      "n"
##  [5] "d"              "G"              "BIC"            "loglik"
##  [9] "df"             "bic"            "icl"            "hypvol"
## [13] "parameters"     "z"              "classification" "uncertainty"
```

Plot mcl2

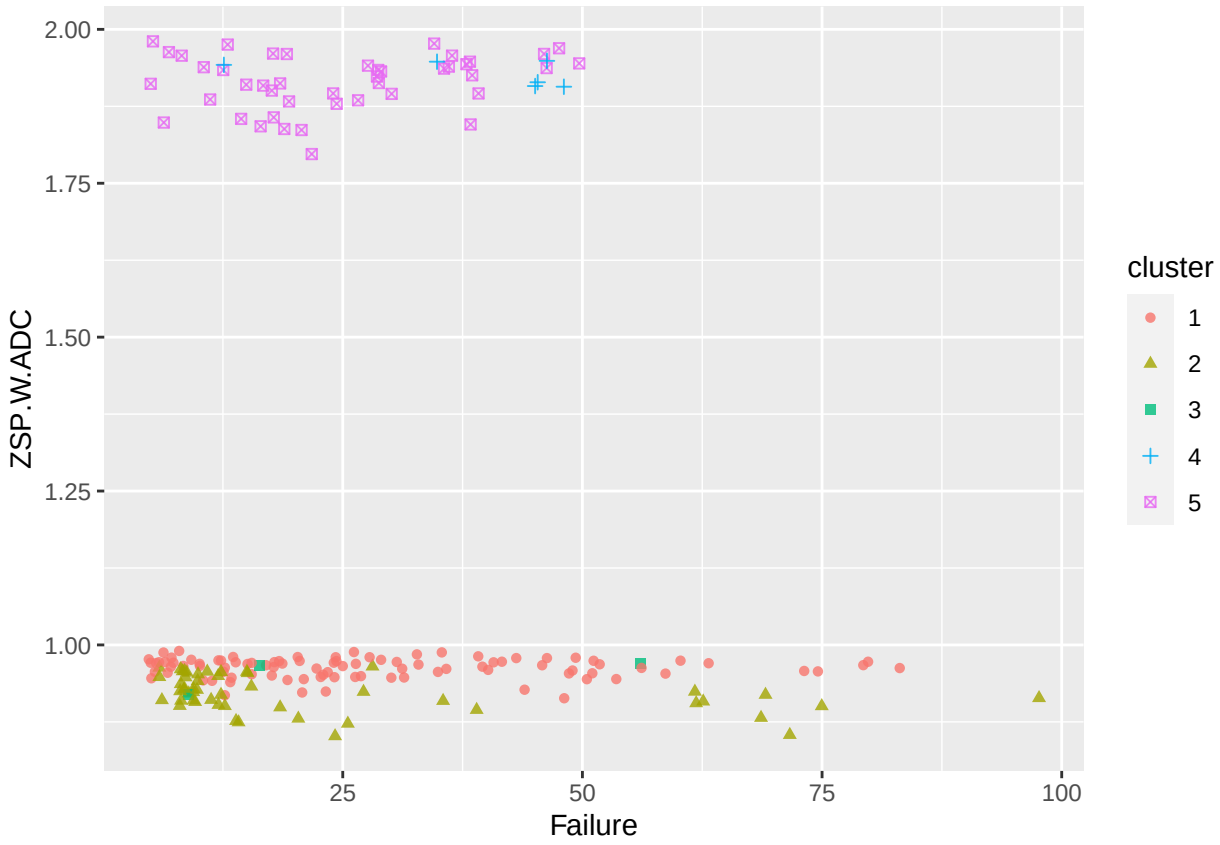
```
# plot(mcl2, what="density")
```

Visualization

```
cluster1 <- mcl$classification
plot(data[,1:2], col=cluster1)
```




```
# Clustering of Failure and ZSP.W.AD
cluster <- factor(predict(mcl)$classification)
ggplot(data=data, aes(x=Failure, y=ZSP.W.ADC, color=cluster, shape=cluster)) +
  geom_point(alpha=.8)
```


2.00
1.75
1.50
1.25
1.00
ZSP.W.ADC
25
50
75
100
Failure
cluster
1
2
3
4
5